EVALUATION FRAME FOR COMPARISON OF ALTERNATIVE MANAGEMENT REGIMES USING MPA AND CLOSED SEASONS APPLIED TO BALTIC COD.

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Abstract.

An "Evaluation Frame"(EF) of fisheries management regimes is presented, together with the simulation model behind it. The EF executes two parallel simulations of the reference system and the alternative system. Each system comprises an "operational model" which simulates input data to a "management model". The operational model system simulates the "true world", whereas the management model simulates the advisory process of ICES combined with the management procedures of EU. The simulations may be executed in deterministic modes as well as in stochastic mode. The management regimes are compared by aid of a suite of "measures of performance", which are defined by the various groups of stakeholders. Examples are the traditional measures of ICES, the Spawning Stock biomass and the average fishing mortality. Other measures can be bio-economic measures such as the net present value of cash flow, or employment measured in man-years. The EF is demonstrated for marine protected areas (MPA), closed seasons and restrictions on maximum number of sea day as management tools for the Baltic cod fisheries. The purpose of these MPAs and effort regulations is the recovery of the Baltic cod stock.

DTU Aqua
Charlottenlund Slot
2920 Charlottenlund
Juli 2008

ISBN: 978-87-7481-080-3

DTU Aqua-rapport nr.: 191-08

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1. INTRODUCTION

The software package presented here is named "TEMAS" (Technical Measures) because it was originally developed to assess the effect of mainly technical management measures. A broader descriptive name is Evaluation Frame (EF). (The first version of the package for technical management measures was presented in Ulrich *et al*, 2002 and a more comprehensive version is presented in Ulrich *et al*., 2007, while the present manual represents the latest version). The TEMAS software is implemented in EXCEL with extensive use of macros written in Visual Basic. In the context of the EU-FP6 EFIMAS and PROTECT projects it should be noted that closed seasons and MPAs in the terminology of TEMAS is technical management measures. Therefore, this latest version of TEMAS reported here contains components to evaluate closed seasons and MPAs. The case study of this application is the Baltic fisheries with focus on the cod fisheries and the areas and seasons closed to protect the cod spawners.
An introduction to the Baltic Fisheries is given in Annex F. The report of the "TECTAC" EU project contains a description and discussion TEMAS, (TECTAC, 2005). TECTAC is the acronym for: "Technological developments and tactical adaptations of important EU fleets". TECTAC was EU project no. Q5RS-2002-01291, and it ran from 2002 to 2005[1]. As is the case for EFIMAS and PROTECT, the TECTAC project applied both the ISIS-Model (Mahévas, and Pelletier, 2004) and the TEMAS model (Ulrich *et al,* 2007). TECTAC was the first time TEMAS was applied in its extended form. The TECTAC report also describes a suite of features, which became integrated in TEMAS because the TEMAS group participated in the TECTAC project.

1.1. OVERALL STRUCTURE OF EVALUATION FRAMEWORK

The overall contents of TEMAS are illustrated by the data-flowchart in Figure 1. The system compares two management regimes, A and B, by simulating the fisheries system over a series of years for both regimes, and eventually it compares the performance of the two regimes during the time period. Thus the figure illustrates a dynamic system, where the arrows indicate the processes of one single time period (month, quarter or year).
The "operating system" (Figure 1) is a model simulation of the eco-system and the fisheries system. The boxes "Management regime A" and "Management regime B" indicates two models which can simulate the management processes (which may include simulation of ICES WG, setting of TACs, etc.).
The operating system generates ("fake" or "hypothetical") input data to the management models, and it predicts the effect of the management regulations on the eco-system and the fisheries.
Thus, you may consider TEMAS as a triple, model. Firstly, it executes the simulation of management regime A, using the operational model to produce input to the management simulation. Secondly, it does the same of management regime B, and thirdly it compares the two simulations.

[1] ***Objectives of TECTAC:*** *The fish stocks managed under the European Common Fisheries Policy are considered to be in danger because of excessive fishing mortalities. A common concern of fisheries managers is to be able to reconcile the objectives of maintaining fisheries profit whilst safeguarding the fish resources, especially when these are exploited beyond biological safe limits. In EU waters, the management of fisheries and fish resources has been adversely altered by, (i) the lack of consensus on management targets and strategies and also, (ii) the poor understanding of the links between management tools, fleet developments and the pressure exerted on fishing communities. The overall objective of this project is to address (ii), and more precisely to supply fisheries managers with a modelling tool that will allow them evaluating the impact of regulations (TACs, MAGPs, area and season closures, subsidies) on the dynamics of fleets and fishing mortality. The carrying idea is the investigation of the dynamics of the elements that cause changes in fleet dynamics: the technological advances in both gears and vessel equipment, and also the overall tactical adaptation of fishing vessels. How do they occur? Why do they occur? What are their consequences on the resource and their socio-economics? In order to address these issues, in relation to the overall objective, this study aims to achieve three sub-objectives. Examples will be drawn from a wide selection of demersal fleets operating in the North Sea, the Eastern Channel, the Celtic Sea and the Bay of Biscay.*

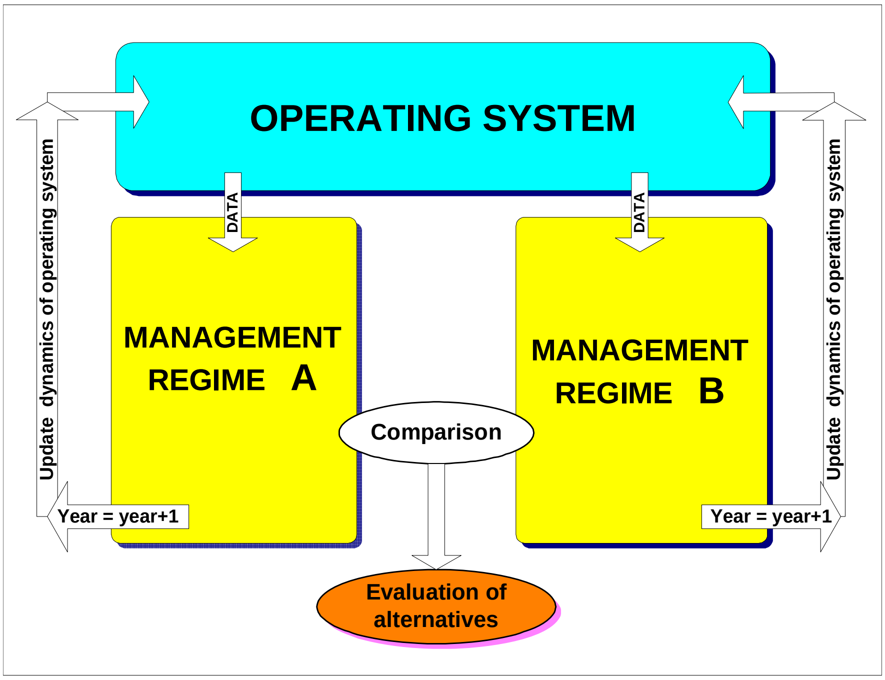


Figure 1.1.1 The principal components of TEMAS for one time period of a dynamic process.

The operating model produces input to the management model for year "y"
The management produces management regulations for year "y+1"
The management regulations for year "y+1" is used as input to the operational model, to produce input to the management model in year y+1, …. Etc.

In the context of evaluation of MPAs and closed seasons, the alternative management regimes could be, the current management regime with no closed seasons and MPAs. (The current regime could be Eg. TAC and maximum number of sea days, mesh size regulations etc.). That would be option 3. Option 3, however, is mainly meant for comparison of gear regulations, such as meshsizes and separation devices mounted on the gear. Option 6 allows for comparison of two alternative definitions of MPAs.

	Regime Comparisons	Regime A	Regime B
1	Scientific advice / No scientific advice	ACFM Advice (TAC based on harvest control rule)	No ACFM Advice (TAC based on last years landings, and selected CPUE trends)
2	TAC regime with No misreporting / With Misreporting	ACFM Advice (TAC based on harvest control rule) No misreporting	Misreporting (Various assumptions, effect of regulations on misreporting)
3	With / without new Technical manage-ment measures. E.g. closed seasons and/or closed areas (MPA).	TAC (With current, Technical management measures, except for closed areas and seasons)	TAC with NEW Technical management measures. E.g. closed seasons and/or closed areas (MPA).
4	TAC / Effort regimes with ACFM's harvest control rule.	TAC (based on the current HCR of ACFM)	Effort, An alternative regime, management by effort regulations. Both regimes based on the current HCR of ACFM"
5	TAC / Effort regimes with NEW harvest control rule.	TAC (based on the current HCR of ACFM)	Effort, An alternative regime, management by effort regulations. Based on an alternative HCR, (mixed fisheries, - fleet based …)
6	Two alternatives for definition of MPAs	TAC, with first option for season/MPA	TAC, with second option for season/MPA

Table 1.1.1. The five pairs of regime comparisons of the current TEMAS program.

The current management regime with closed seasons and MPA

In the standard implementation of TEMAS, five pairs of alternative management regimes are considered Table 1). The five pairs or regime comparisons suggested here may not be the most relevant examples one could think of, and should be considered illustrations of the concepts, rather than the only examples for TEMAS.

The operational model is the same in all regime comparisons. The operational model simulates fish stocks, fishing fleets etc., and from the simulated quantities it simulates input data to the pair of management models.

The TEMAS model can do single deterministic simulations or multiple stochastic simulations. The multiple stochastic simulations executes a number of single deterministic simulations (say 1000 simulations), each of which based on parameters drawn by a random number generator. We shall forget about multiple stochastic simulations for the time being, and concentrate on single deterministic simulations.

In the present context of MPA and closed seasons of Baltic fisheries, focus will be on case study 3, but also the other cases are more or less relevant. Misreporting, for example, is considered a major problem in the Baltic cod fisheries (ICES, 2006).

TEMAS accounts for a number of different types of "errors" in the system. An error means a "deviation from the model", or "something that can go wrong" .

1. Measurement error. Errors in input data, such as catch at age data, caused by data being estimated from samples, and not from complete enumeration.

2. Estimation error. Errors caused by the method used to estimate parameters, or erroneous assumption about the data.
3. Model misspecification error. Errors caused by incomplete or wrong understandings of the mechanism behind the system dynamics. The assumed Stock/recruitment relationships may be candidates for model misspecifications.

4. Implementation error. The errors caused by regulations not being reacted to as assumed. The fishers may find ways to implement regulations, which do not lead to the achievements of the intensions of regulations.

The software will be able to simulate the effect of errors and bias, by stochastic simulations. Stochastic simulation is simple to repeat the same calculations a large number of times, each time with new parameter-values drawn by a random number generator. The stochastic simulation requires specifications of probability distributions of those parameters which are considered stochastic variables.

The stochastic simulation module simply executes TEMAS a large number of times (say, 1000 times), and each time it draws parameters and initial condition variables by random number generators, executes a simulation over a series of years. At the end it retrieves the results of all 1000 simulations and converts them into, for example, frequency diagrams.

Finally it should be noted that the operational model of TEMAS contains many parameters which cannot be estimated by the data currently available. Therefore a large number of parameters will have be assigned "plausible" values, that is, values not estimated by statistical methods and observations but values which are believed to be "reasonable". Likewise, TEMAS will contain a number of sub-models which has not been verified by recognized statistical tests. Therefore, the concept of "prediction power" may not be applicable to TEMAS.

We will simply not be in a position to say anything about the prediction power. The output of the model is in the best case of the nature: "It is likely that management regime A gives a better performance than management regime B" with respect of a selected measure of performance. TEMAS should not be used to quantify, for example, the expected spawning stock biomasses.

There is no alternative to this approach, when it comes to test alternative management regimes, which has not been tested earlier. A real statistical experimental design would require that the two alternative management regimes were test on two identical ecosystems, and such an experiment will never become possible in practice.

1.2. WHAT IS THE NATURE A FISHERIES EVALUATION FRAME?

Figure 1.2.1. Look at a flight simulator from the outside.

Perhaps the best presentation of an evaluation frame is to compare it to a flight-simulator. Figure 1.2.1 shows a flight-simulator from the outside. From the outside you can see that it is not an aeroplane and it cannot fly.

However, stepping inside (Figure 1.2.2) you will get the illusion that you are in the cockpit of an aeroplane. What you see in the windows of the cockpit are produced by a Video film, and what the video film shows depends on how you operate the navigation instruments.
Thus everything is fake and has no relationship to the real world. However, despite its illusion-features, the flight simulator is a very useful tool, because it is almost the same as the real world, and the pilot-trainees achieve experiences in a safer way than in real aeroplanes. They can actually see what happens when they break rules, without making any damage.

Hitting the virtual control tower of the virtual airport is (kind of) ok in a flight simulator. Nobody get killed or anything damaged in a flight simulator.

Figure 1.2.2. Look at a flight simulator from the inside.

The Evaluation Frame is like a flight simulator. The simulated management system, is like the fake cockpit of the flight simulator. The operational model of TEMAS is like the video-film you see on the windows of the flight simulator.

The principles in this comparison are correct, but when it comes to the details you may claim that the operational model cannot mimic the ecosystem to the same degree as the flight simulator can mimic, say, the run-way and the airport.

The simulation of the cockpit is almost perfect in the flight simulator, and although it is easier for us to simulate the management procedure than the eco-system, it is still a lot more difficult than simulation a cockpit.
The physical flight simulator (Figure 1.2.1) may be considered the parallel to the source code of the Evaluation Frame. If you are a designer of the flight simulator or the evaluation frame, you must master the "bricks" from which the thing is build.

But the features that there is no relationship to the real world, and all input and output is created inside the simulator are the same for Evaluation Frame and Flight Simulator.
The idea with the Evaluation Frame is to give the managers the opportunity to test alternative management strategies, which may or may not lead to a catastrophe (Figure 1.2.3). The philosophy is that "one should never test anything for the first time in the real world".
If you cannot simulate it, you should not implement it in the real world!

Figure 1.2.3. Running the Evaluation Frame

2. THE TEMAS OPERATIONAL MODEL APPLIED TO BALTIC FISHERIES

The TEMAS operational model is a multi-species, multi-fleet dynamic software implementation of a bio-economic stochastic simulation model, which focus on the analysis of the effect of technical management measures. Technical management measures, however, cannot be analysed in isolation from other factors influencing the fisheries system. Therefore TEMAS covers all essential components of the fisheries system, seen from the angle of a fisheries manager.

TEMAS focuses on the description of fishing fleets and their technical activities, rather than anything else of the ecosystem/fisheries/fisheries economics complex. The focal point in TEMAS are the vessels of the fleets. The idea is that the basic instrument for fisheries management is the capacity of fishing fleets, which in turn is controlled by controlling the number of vessels in each fleet. The number of vessels determines the upper limit of the effort that can be exerted, and the maximum effort determines the upper limit of the fishing mortalities, the effort can create. This way of thinking is somewhat different from the traditional ICES approach of evaluating fish stocks, where the system starts with the input F, without much consideration on what created the F and what controls the F. In this context, technical management measures become a detail, which can to certain degree modify the overall F created by fishing capacity. An idealized version of the basic mathematical model behind TEMAS can be expressed as the product of four factors

Fishing Mortality = (Number of boats) *
(Number of Sea-Days/period/vessel) * (Technical measures) * (Catchability Coefficient)

where fishing mortality is an age and species specific variable.

The “Number of Days/period” and “Technical measures” are the factors (partly) controlled by managers. The “Number of Days/period” can be the munber of sea day per year, which can be controlled by various management regulations, such as TAC (total allowable catch), maximum number of sea days per year or closed seasons.

The “catchability coefficient”, is a measure for the ability of the gear to catch a certain species.

The “number of sea-days/period/vessel” may be determined by several factors, of which fisheries regulations is one. Other factors determining the activities of fishing fleets are the choices made by the fishers, depending on economics and availability of resources. TEMAS attempts to describe the behaviour of fishing fleets, with respect of effort allocation in time and space.

By a technical management measure is meant a regulation measures which (1) Specify rules for gears (e.g. minimum mesh sizes) (2) specify on minimum landing size (3) specify areas closed for fishery (4) gives specifications for vessels (such as maximum engine power) (5) Specify limits for by-catch percentages and target species percentages (6) specify rules for equipment for handling of catch.

Although TEMAS on the theoretical level is capable of predicting the effects of technical management measures, TEMAS should be seen as a tool for structuring the ideas of the authors rather than as a tool for practical prediction for management purposes. TEMAS should be considered a model for qualitative predictions rather than for quantitative predictions. This precautionary approach of model use is not specific to TEMAS, but appears to be adequate for most models applied in fisheries (see e.g. Schnute and Richards 2001, Sparre and Hart 2001).

Technical measures are an integrated part of the Common Fishery Policy of EU, with the main legislation on technical management measures given in “Council regulation (EC) No 850/98 of March 1998 and subsequent amendments. There are a number of additional council regulations on technical management measures, such as No 259/2001 on the measures for recovery of the cod stock in the North Sea. The text of the council regulation is given in Annex D. The objectives of technical measures are to minimise the catch of juvenile fish and to reduce discards. In addition, technical measures are also used as a tool to protect vulnerable species or reduce undesired effects of fishing on the ecosystem. Therefore, “Marine sanctuaries”, (areas permanently closed for all consumptive usages), are also considered a technical management measure.

The TEMAS model aims at dealing with all the types of technical management measures listed in Council regulation (EC) No 850/98 and related regulations. However, the coverage is not complete, as some regulations are dealt with only indirectly.

2.1. THE ROLE OF TECHNICAL MANAGEMENT REGULATIONS

While limitations in effort or catch quotas aim at limiting the overall fishing mortality, technical measures are used to regulate the selectivity of fisheries within this mortality level. Technical measures are thus used as an adjustment tool within management systems based on other means as the basic management principle. "

It is difficult to predict to which extent a specific technical measure is expected to achieve the objectives for which it was introduced and how it will influence the practical fisheries. These difficulties are partly due to insufficient knowledge about the technical selectivity of fisheries, partly due to uncertainties about the reactions of the practical fishery on specific regulations.

The reaction of the fishing industry to technical measures is determined by technical and economic parameters, such as the relationship between discarding and the price/market of juvenile fish.

Technical measures are implemented to affect the selectivity of the fishery in relation to species or size. An evaluation must be based on an understanding of the processes contributing to the overall selectivity of a fishing fleet, including parameters, which are regulated through technical and economic measures. It is also a condition that tools are available to assess how this selectivity in practice will be affected by specific measures, based on an understanding of the reaction of the fisheries within the institutional framework of management and in a socio-economic context and bio-economic context". To this end, the TEMAS project develops a "Fleet selection model".

The fleet selection model includes:

1. The availability of the resources
2. Mesh selection in classical sense in relation to target and by-catch species
3. The effect of minimum landings size
4. The effect of closed areas
5. The effect of total catch quotas
6. The effect of ITQ (Individual Transferable Quotas)
7. The effect of individual quotas and catch rations
8. Gear selection including the whole gear
9. Decision selection which is the result of the decision process behind the fisher's choice of technology (gear), time and place and the use of the catch.
10. Decision on discard/landing practice as the result of technical/economic parameters, such as processing, costs and earnings.

The fleet selection model will be used to evaluate the efficacy of technical measures with respect to management objectives within the institutional management set-up.

2.2. THE BIOLOGICAL FRAME OF TEMAS

The biological model behind TEMAS, is the traditional model by Thompson and Bell (1934), which has been discussed in many textbooks on dynamics of fish stocks (E.g. Ricker, 1975, Beverton & Holt, 1957, and with emphasis on tropical fisheries: Sparre & Venema, 1992). The major part of the biological model behind TEMAS is the traditional model, or generalizations of the traditional model. TEMAS extends the traditional models with a spatial model, accounting for, e.g. migration using the approach of Quinn et al, 1990). All these models originally were thought of as "fish stock assessment model", where parameters were estimated by (e.g.) VPA or "Cohort analysis" (Virtual Population Analysis, Derzhavin, 1922, Fry, 1949). A resent summary of the contemporary practice of VPA is given in Lassen & Medley, 2001.

The concept of "stock" is rather complicated and there is no consensus among scientists on how to define it. A full discussion of the stock concept in the context of fisheries management is given in Begg et al. (1999). A general definition of a living stock widely accepted is: A group of animals from one species, which share a common gene pool. For the management of fisheries, however, this definition is academic rather than practical. Therefore, we shall try to identify more operational concepts. For management of fisheries, it is the concept of "management unit" rather than stock that is useful. A management unit is a resource for which it is possible to make predictions, or, in other words, something for which we can give answers to "What-if questions".

The separation of species into stocks is often very problematic.

In the case of the Baltic cod, it is generally accepted that there are two separate stocks, the Western Stock in ICES Areas 22-24, and the Eastern stock in ICES Areas 25-32. The definition by the ICES areas, however, is rather problematic, and there is no doubt that mixing of the two stocks takes place. Needless to say the cod do not respect the borders defined by the ICES areas. Needless to say the cod do not respect the sub-divisions of the Baltic as defined by ICES, which are not defined relative to the cod distribution.

According to the agreed international standards (FAO, 1995,1996,1997,1999, ICES, 1998, UN 1995), “reference points” are an important concept in implementing a precautionary approach to fishing. Reference points are closely related to the stock concept (Caddy & Mahon, 1995, Gislason, 1999). Therefore, fishing mortality rates, biomass, or other measures should be regarded as indicators of the status of the stock in relation to predefined reference point limits, that should be avoided, or targets, that should be aimed at, in order to achieve the management objective.

The identification of reference points requires a time series of scientific data, often over many years. A key concept in some reference points is the Spawning Stock Biomass (SSB), which is defined as the number of individuals multiplied by the fraction of mature individuals for each age group, summed over all age groups. Another important concept is the “recruit”, which is a juvenile fish entering the exploited part of the stock.

Biological data for individual species or stocks are usually intended for fish stock assessment. Traditional stock assessment methods, like cohort analysis and VPA, use length distribution or age distribution of the entire catch from the stock as the primary input. Some of the most commonly collected biological (stock specific) data are: (a) Length frequency data, (b) Age frequency data, (c) Length/weight data, (c) Sex distribution, (d) Maturity stage, (e) Condition factor and (f) Data for stock identification (e.g. meristic characters);

In addition to cohort analysis, the traditional stock related analyses are: (a) Estimation of growth parameters (b) Estimation of spawning seasons (c) Maturity ogive (percentage mature as a function of age) (d) Estimation of natural mortality. Combined with spatial data, the above data may also be used for estimation of migration routes, spawning grounds, nursery grounds, distribution by depth zone, etc.

In general, TEMAS has inherited all the unsolved problems of traditional fish stock assessment as implemented by ICES.

With a few rare examples, the identification of the relationship between parent stock (SSB, spawning stock biomass) and subsequent recruitment (R) has remained elusive for marine fishes (Gilbert, 1997, Hilborn, 1997, Myers, 1997). The precautionary approach dictates that unless it is scientifically demonstrated that there is no relationship between the parent stock and subsequent recruitment, such a relationship should be assumed to exist, even if the data are ambiguous. Observations of stock and recruitment show large variation around any SSB/R curve, so scientists are not in a position to predict future recruitment with any accuracy. They are only able to tell the probability distribution of the future recruitment, and only then, if a long time series of SSB/R observations is available.

There is a suite of special theories on the factors that determines the recruitment of East Baltic cod. The spawning success is linket to the Spatial and temporal distribution of the cod spawning. There is an extensive literature on the spawning of Baltic cod. Section 7 of. the 1999 Report of the Baltic Fisheries Assessment Working Group. (ICES, 1999) summarises the knowledge basis. A more comprehensive contribution from ICES is the Report of the Study Group on Closed Spawning

Areas of Eastern Baltic Cod, ICES CM 2004/ACFM:17. The following text is extracted from these reports (See also Annex A). The success of recruitment is considered the key to the recovery of the Baltic cod, and the MPA's are designed to improve the success of recruitment. Therefore, special attention is given to this aspect of the cod biology.

The Bornholm Basin, the Gdansk Deep and the Gotland Basin cod are the principal spawning areas of the eastern Baltic cod stock (Figure 2.2.1.1). The salinity and oxygen conditions mainly define the spawning habitat of this stock as well as the water volume suited for egg and larval development. Salinity levels above 11 PSU are necessary to enable cod eggs to reach neutral buoyancy and an oxygen content above 2 ml/l in the water volume in which the eggs float is further required for successful egg development. These conditions define the so-called "reproductive volume", (RV), which has been shown to be positively related to the recruitment of Central Baltic cod.
The processes affecting the RV are:

i) the magnitude of inflows of saline oxygenated water from the western Baltic,
ii) temperature regimes in the western Baltic during winter affecting the oxygen solubility prior to advection (which normally takes place during winter months)
iii) river runoff and
iv) oxygen consumption by biological processes.

The Baltic Sea is characterised by a series of deep basins separated by shallow sills, and an inflow will usually fill up the first basin (the Bornholm Deep) only, with little or no transport in an eastern direction. Only if the inflow is very large or more likely if the advected water is replaced by an even denser water mass in a subsequent inflow or a subsequent inflow of less dense water glides over the earlier inflow water, the eastern Baltic basins will benefit from the water exchange. Thus, hydrographic monitoring and the unique topography make predictions of RV in a given year possible when conducted after the inflow period in January to March. The largest problem in the prediction is whether the inflow will turn south into the Gdansk Deep or north into the Gotland Deep, a process depending on local forcing conditions.
As a secondary effect of large inflows into the Bornholm Deep is that there is an increased likelihood of a potential inflow the following year will reach the eastern spawning areas.

The conditions for reproduction are potentially met in the Bornholm Basin deeper than 60 m, in the Gdansk Deep deeper than 80 m and in the Gotland Basin deeper than 90 m, where cod spawning takes place. However, the oxygen conditions in the eastern spawning areas are unfavourable for egg survival and development during stagnation periods. The conditions for successful egg development have been very limited in the Gotland Basin and Gdansk Deep since 1986.

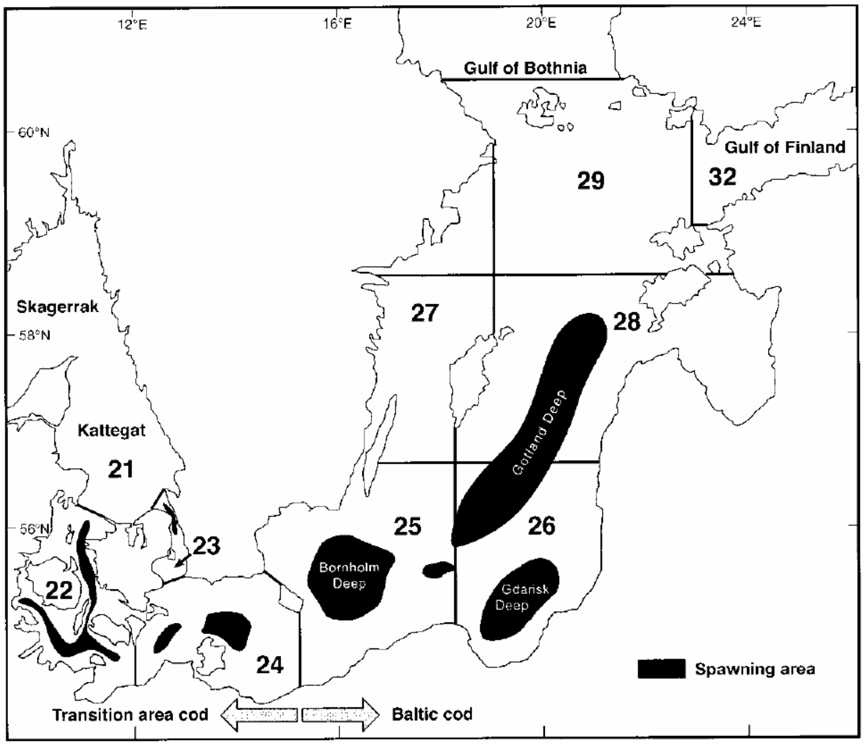


Figure 2.2.1. Historical spawning areas for cod in the Baltic Sea (from Bagge et al. 1994), modified by Aro (2000).

The size and distribution of the spawning stock component and thus the potential egg production in the various areas has also changed over time. The change in spawning stock distribution is evidenced by abundance indices from Baltic International Trawl Survey as well as from SSB estimates based on a spatially dis-aggregated multispecies VPA. Both show a very low spawning stock in Subdivision 28 (central Gotland Basin) at present, while the adult population components in Subdivision 25 (the Bornholm Basin) and 26 (the southern Gotland Basin and the Gdansk Deep) have remained at similar levels. A seasonal shift in the spawning stock distribution between areas seems also to occur. The proportion of the spawning stock increased in the Bornholm Basin during the spawning period while it decreased in the eastern spawning area. This pattern indicates spawning migration into the Bornholm Basin. Cod spawning migrations have previously been described from tagging experiments and from analyses of commercial catch rates with the migration intensity depending on the oxygen conditions in eastern spawning areas.

The hydrographic conditions may not only affect the horizontal distribution of cod spawning aggregation, but also the vertical distribution. Thus, lack of oxygen at the bottom can result in pelagic aggregations of spawning cod in the mid water layer just below the halocline. During the recent stagnation period pelagic aggregations of spawning cod have been abundant in all spawning areas. The combination of decreasing egg production and low egg survival explains the low abundance of egg and larval in the Gdansk Deep and especially the Gotland Basin throughout the 1990s as well as in most recent years. As a result, the Bornholm Basin is at present the main spawning area of the eastern Baltic cod stock.

The spawning time of the eastern Baltic cod stock is very extended, i.e., from March to August – in some years extended into September. The main spawning season lasts approximately 3 months. Peak egg abundance were observed in May / early June in the 1970–80s, while a successive shift to later month was observed in the 1990s with highest egg abundance encountered from late June to late July. The timing of spawning seems to be relatively similar in the three main spawning areas. The females generally started spawning in April and continued at least into August with the majority being in spawning condition in June-July. Males reach generally spawning condition earlier and aggregate also earlier in the spawning areas than females, which means a high fishing intensity on pre-spawning aggregations of cod will result in increased male fishing mortality rates.

A special version of TEMAS applied to the Baltic cod has been developed. This Baltic cod version attempts to account for some of the basic features of the theory for Baltic cod recruitment, but a full account has not been attempted. TEMAS is primarily a model that describes fisheries, it is not the hydrographical model, that would be required to match the theory outlined above.

2.3. THE TECHNICAL FRAME OF TEMAS

The technical units of TEMAS are the "fleets". As for the stocks, the definition of fleet is problematic (e.g. Sparre, 2001). A formal definition is: A "fleet" is a group of uniform vessels, which have approximately the same size and the same construction. The vessels should use the same type of gear and fishing techniques and most often, they share fishing grounds.

The definition is problematic, because, the operations of a vessel may change during the year. A vessel may, for example, do pair trawling for fish during one season and do single trawling for shrimps during another season. Some vessels use a combination of gears during a fishing trip, which may complicate the allocation of vessel to fleets.

Fleets may be defined by a combination of gear, engine horsepower (size of vessel), type of construction and fishing grounds. Horsepower, tonnage and length of vessel are usually correlated within a group of vessels of the same basic construction type. One practical problem is that TEMAS must adequately cover every major fleet. The table below contains an example of categories of fishing vessels according to horsepower class, gear and fishing grounds:

Categories	1	2	3	4
Vessel Length	< 10 M	11-15 M	16-25 M	> 25 M
Gear	Trawl	Danish seine	Gillnet	Purse seine
Fishing grounds	"Central"	"North"	"South"	

Although this division does not appear very narrow, it nevertheless results in potentially 4*4*3 = 48 combinations of categories or different fleets. The example above suggests a low upper limit on the level of details, which it is possible to account for in practice. An example of pragmatic fleet definitions is given in Holland & Sutinen,1999.

When the fleets have been defined, we assume (as an approximation to reality) that all vessels in a fleet are exactly equal and behave in exactly the same way.

All members of a fleet are assumed to have the same "fishing power". Two fishing vessels are said to have the same "fishing power" if they can catch the same amounts and types of fish under similar conditions. For example, two trawlers fishing on the same fishing grounds at the same time must catch the same amounts of fish in terms of species, numbers and sizes to have the same fishing power. One may simplify the concepts of fishing power by making it species-specific. In practice, this ideal definition can rarely be shown to hold. Instead, if the two trawlers catch the same amount of "demersal fish" during a fishing operation on average, they have the same fishing power, and if one vessel catches X % more on average than the other vessel it has X % more fishing power.

A concept closely linked to fishing power is that of a "standard vessel". It is often desirable to express the fishing power relative to some selected vessel type. Usually the most common vessel type is selected as "standard vessel". That may for example be the trawlers of length 15 m with an engine of 60 HP and perhaps some more specific characteristics. Other types of vessels are then expressed in units of standard vessels. If a vessel has 80% of the fishing power of a standard vessel, it counts as a "0.8" standard vessel. It is assumed in TEMAS that a fleet consists of only standard vessels.

Table 2.3.1 shows definitions of 15 gear groups used In the case of the Baltic fisheries. Actually, the database available has 29 specific gears, but many of them are negligible, and are pooled with more significant similar gears.

Mobile gears	***Beam Trawl***			***MobBea***
	Demersal trawl and demersal seine	***Bottom trawl***	***MobDem***	***MobDemBot***
		Danish seiners		***MobDemDan***
		Polyvalent		***MobDemPol***
	Pelagic trawl and seiners	***Pelagic trawl***	***MobPel***	***MobPelTra***
		Pelagic seiners and purse		***MObpelSie***
		Polyvalent		***MobPelPol***
	Dredgers		***MobDre***	***MobDre***
	Polyvalent mobile gears		***MobPom***	***MobPom***
Passive gears	***Gears using hooks***	***Longlines***	***PasHoo***	***PasHooLon***
		Other gears using hooks		***PasHooOth***
	Drift nets and fixed nets		***PasNet***	***PasNet***
	Pots and traps		***PasPot***	***PasPot***
	Polyvalent passive gears		***PasPol***	***PasPol***
Polyvalent gears			***PolPol***	***PolPol***

Table 2.3.1. Detailed definitions of gears applied to the Baltic fisheries.

The average landings of cod Denmark, Germany, Sweden, Poland and Lithurania during the nine years 1995-2003 are shown in Figure 2.3.1. The other Baltic countries, Russia, Estonia, Lithurania and Finland are not in the available data base, as indicated in Figure 2.3.2.

The figure shows that the three gear PasNet, MobDemTra and MobPelSei account for almost 90 % of the cod landings. Figure 2.3.2. shows the landings by Trawl and Gill nets by all Baltic countries in 2005 as given by the ICES working group on Baltic Fisheres (ICES, 2006)
The group "PasNet" is composed of the gears Gill net (84%), Not specified Nets (13%), Trammel nets (3%), Poundnet (1%), Pots (0%), Traps (0%) and Driftnet (0%). The figures in brackets indicates the share of the total cod landings be the group "Pasnet".

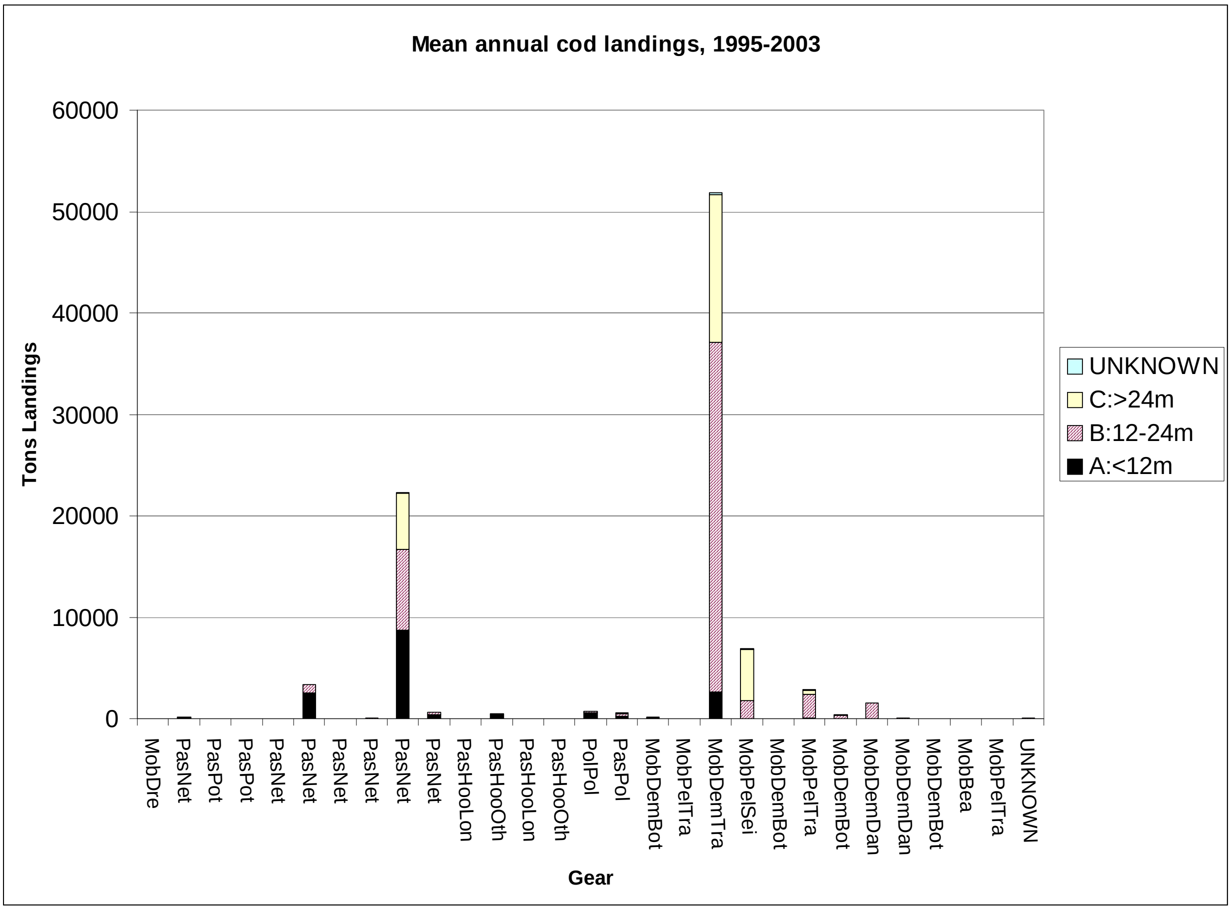


Figure 2.3.1. Average landings of cod by Denmark, Germany, Latvia, Poland and Sweden during the nine years 1995-2003, by gear and vessel size.

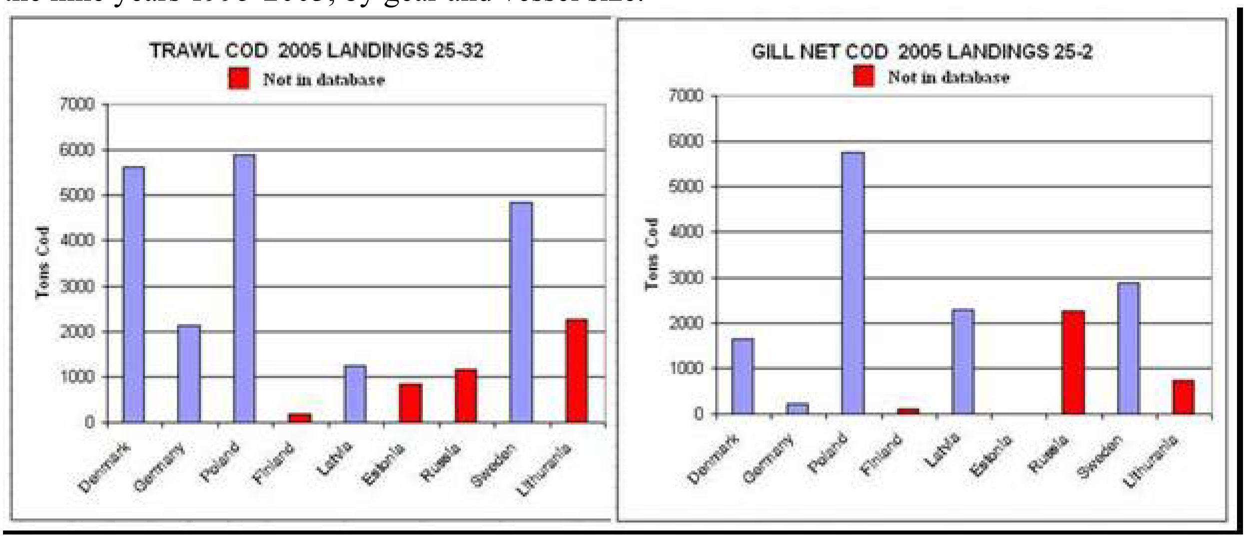


Figure 2.3.2. Landings by Trawl ond gill net in 2005 of all Baltic countries, as given in the ICES Working group on Baltic Fisheries, (ICES, 2006).

The group MobDemTra consists of Bottom Otter board trawl (97%), Danish seine (3%) and Other trawl (0%). The figures in brackets indicate the share of the total cod landings be the group "MobDemTra".

Based on the above data, it was decided to group the Baltic gears into three groups (1) Trawl (2) Gill nets and (3) Other gears.

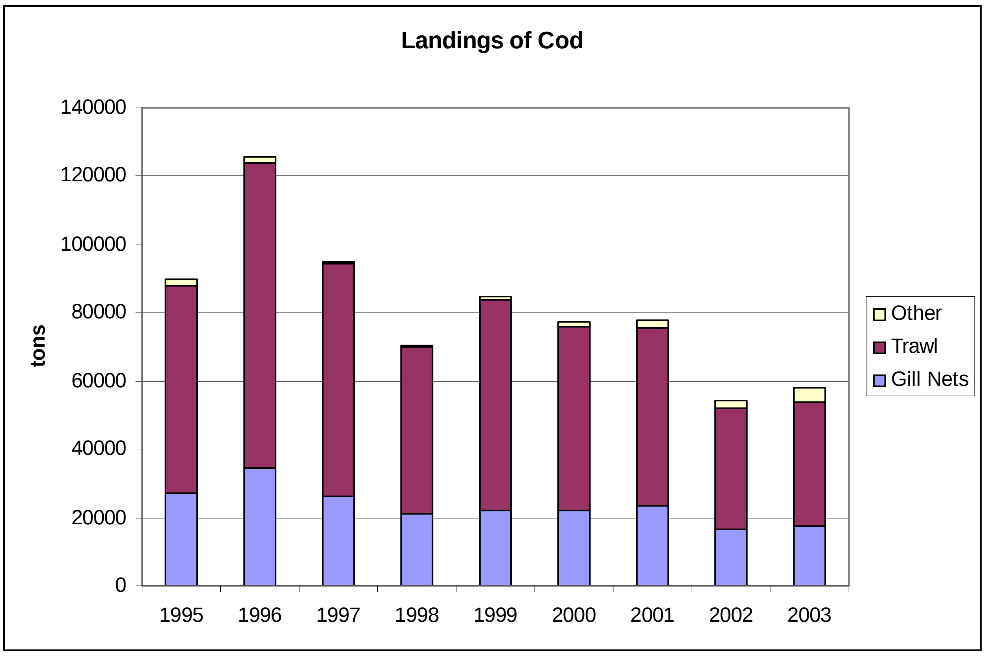


Figure 2.3.2. Landings of Cod by 3 main gear categories by Denmark, Germany, Latvia, Poland and Sweden.

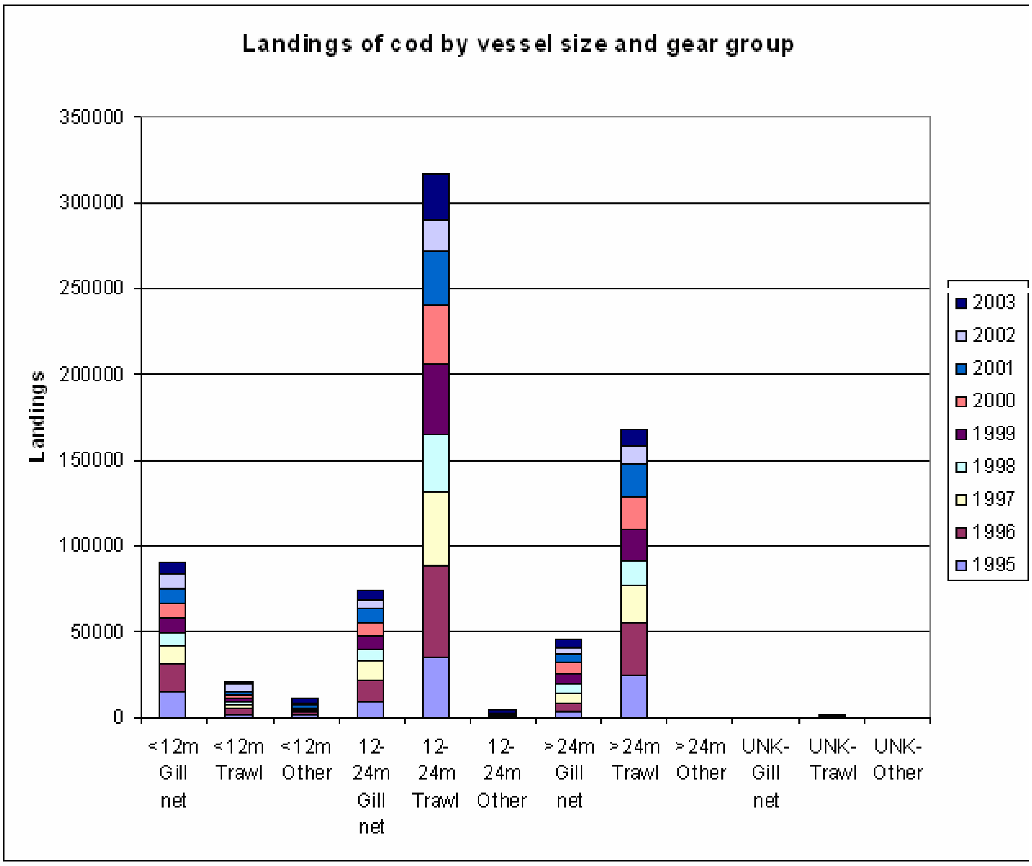


Figure 2.3.3. Landings of cod by vessel size groups and gear groups by Denmark, Germany, Latvia, Poland and Sweden.

2.4. THE SPATIAL FRAME OF TEMAS

TEMAS offers the opportunity to account for spatial aspects, in the sense that fish and fleets can be allocated to a number of areas in a given time period. TEMAS uses a simple "box-model" to handle spatial aspects. However, the inclusion of spatial aspects is optional, and the user may choose to consider the sea one homogenous area. If several areas are considered, this will require a number of additional input parameter, for example “migration coefficients”, the concept of which will be explained below.

The selection of areas or “fishing grounds” is most often constrained by the data. If logbooks are not maintained, precise information on where catches were taken is often absent. Often the practical circumstances dictates that a only few areas are considered, sometimes all fishing areas has to be merged into one single area. A first natural division of the fishing area would to use depths for the definition of areas. That may lead to areas like “in-shore”, (say from 0-20 m depth) and “of-shore” (say, > 20 m depth). Such a division will match both the distributions of vessels (mainly small vessels in the in-shore area, and large vessels in the off-shore area) as well as the distribution of stocks, and size groups with in a stock. Some areas may also be defined as “nursery areas”, that is, areas where juvenile fish are known to be abundant. Such areas may be closed for fishing to protect the juvenile fish and to avoid discarding (see example in Pastoors et al, 2000). Other criteria may be used, which depends on the size and nature of the marine area under study. Sandy, muddy and rocky bottom combined with depth may also form the basis for area definition. In large areas, current and temperature may give natural definitions of areas. An example of pragmatic fleet and area definitions is given in Holland & Sutinen, 1999

TEMAS however, is not suited for handling of a large number of areas. It is not anticipated that TEMAS applications will use more than, say, 10 divisions of the total area. TEMAS is not constructed to deal with a division of the area in small squares (say, 30 by 30 Nm, or smaller). A division of the sea area in TEMAS is relevant only when each division differs conspicuously in terms of distributions of resources and fleets. Furthermore, some knowledge (or at least some opinions) on the distributions and movements of fleets between the selected areas and stocks must be present.

Migration of fish:

For a theoretical discussion of migration in connection with age based fish stock assessment the reader is referred to Quinn II et al. 1990. These authors also discuss the estimation of migration parameters. In principle their model is the approach planned for this version of TEMAS. Chapter 11 in Sparre & Venema, 1992 discusses the assessment of migratory stocks at a somewhat lower mathematical level.

The migration is modelled in a time discrete manner:

a) Migration takes place at the end of each time period and the process of migration takes zero time.
b) During a time period the fish/shrimps are assumed to be homogeneously distributed within the area.

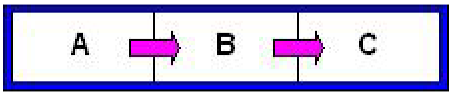
The "Migration Coefficient", MC, from area A to area B is defined as the fraction of the animals in area A which moves to area B. In this definition, the "movements" include the "move" from area A to area A, i.e., the event that the animal does not move.

The migration coefficient depends on (or has the indices):
FAr: Starting area TAr: Destination area
Note that the sum of migration coefficients over destination areas always becomes 1.0, as the starting area is also considered a destination area:

$$1.0 = \sum_{TAr} MC(FAr, TAr, q, a)$$

where a = age group and q = time period (division of year).

To illustrate the concept, an example is considered with three areas, A, B and C and a migration from A to B and from B to C



To simplify the example, the time period index has been left out, so that migration takes place at the end of the year only.

If the migration from A to B takes place gradually over the age groups 2 to 4 and no fish return to area A the migration coefficients for movement out of A could be those shown in Table 2.4.1.

If the migration from B to C takes place gradually over the age groups 6 to 8 and no fish return to area A or B the migration coefficients for movement out of B could be those shown in Table 2.4.1.b. If the fish stay in C the migration coefficients for movement out of C are those shown in Table 2.4.1.c.

MC[a,1,TAr,-]										
From area	Age group									
to area:	0	1	2	3	4	5	6	7	8	9
A (TAr=1)	1	1	0.8	0.5	0.2	0	0	0	0	0
B (TAr =2)	0	0	0.2	0.5	0.8	1	1	1	1	1
C (TAr =3)	0	0	0	0	0	0	0	0	0	0
Total	1	1	1	1	1	1	1	1	1	1

Table 1.4.1.a. Migration coefficients for migration out of area A.

MC[a,2,Tar,-]										
From area	Age group									
to area:	0	1	2	3	4	5	6	7	8	9
A (TAr=1)	0	0	0	0	0	0	0	0	0	0
B (TAr =2)	1	1	1	1	1	1	0.8	0.5	0.2	0
C (TAr =3)	0	0	0	0	0	0	0.2	0.5	0.8	1
Total	1	1	1	1	1	1	1	1	1	1

Table 1.4.1.b. Migration coefficients for migration out of area B.

MC[a,3,Tar,-]										
From area	Age group									
C to area:	0	1	2	3	4	5	6	7	8	9
A (TAr=1)	0	0	0	0	0	0	0	0	0	0
B (TAr =2)	0	0	0	0	0	0	0	0	0	0
C (TAr =3)	1	1	1	1	1	1	1	1	1	1
Total	1	1	1	1	1	1	1	1	1	1

Table 1.4..1.c. Migration coefficients for migration out of area C.

Age	A	B	C	Total
0	1000	0	0	1000
1	1000	0	0	1000
2	800	200	0	1000
3	400	600	0	1000
4	80	920	0	1000
5	0	1000	0	1000
6	0	800	200	1000
7	0	400	600	1000
8	0	80	920	1000
9	0	0	1000	1000

Table 1.4.2. Numbers corresponding to the migration coefficients given in Tables a,b,c,a recruitment of 1000 in area A and zero mortality

To highlight the migration aspect, and de-emphasise other features, which may complicate the picture, an (unrealistic) example where mortality is zero is considered. If 1000 fish in a batch recruit to area A and no fish recruit to areas B and C and mortality is zero the numbers from that batch during its life in each age group become those shown in Table 2.4.2.
This model of migration is general. Using this technique any routes between any configurations of areas can be made. The movements, however, are approximations to reality as they are not continuous processes.

In the case of the Baltic cod, the spatial set-up will be somewhat more complicated, where the MPA will be the spawning areas of cod (for example 1: Bornholm deep, 2: Gotland deep and 3:Gdansk deep, see Figure 2.4.1). TEMAS will be used to simulate the migration of spawners into the MPA, as well as the migration out by juveniles and adults after spawning. For that purpose we will need 4-5 areas. Furthermore the cod resource will be divided into a western stock and an eastern stock, and mixing of the stocks will be simulated. The MPAs may be considered one area (to make calculations simpler) or it may be considered 3 separate areas. The areas shown on Figure are composed of ICES rectangles (Figure 2.4.2) and ICES areas, 22-32 (Figure 2.4.2). ICES statistical rectangles are used here because the basic data (logbook data) are by statistical rectangle.

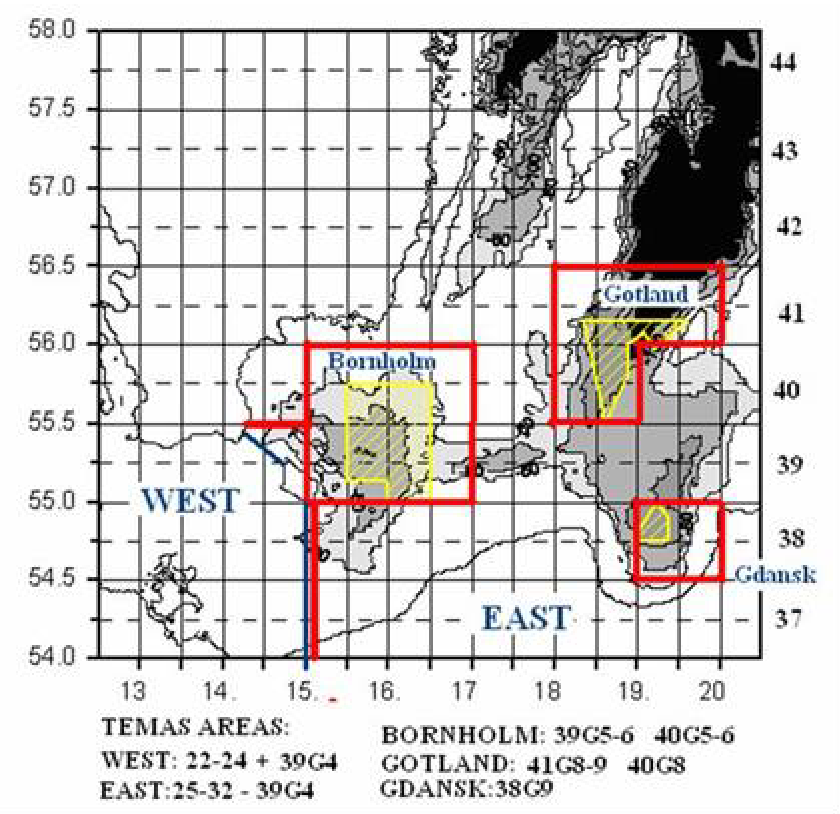


Figure 2.4.1. Tentative definition of Areas of the TEMAS simulation for the Baltic cod. MPR currently in force are the hatched areas.

The selection of areas is always a compromise between conflicting objectives or conditions. As mentioned above, the availability of data (by statistical rectangles) is one condition. The importance of an area in terms of landings is another example. Figure 2.4.3 shows the landings of cod 1993-2003 by areas (composed of ICES rectangles) of Figure 2.4.1. The Gdansk area turns out to be inferior in terms of cod landings, and it should be considered it is worthwhile to include it in the simulation of the Baltic cod. Figure 2.4.3 shows landings in the period 1995-2003 only. Had the time series gone back to the eighties the picture would be different. In those day when the cod stock was a lot bigger than in 2003 (Figure 2.4.4), the cod would have a wider distribution, extending into the northern areas. It is believed that currently it is only the Bornholm deep that contributes to the spawning, whereas the Gotland and Gdansk deeps also contributed substantially in the eighties.

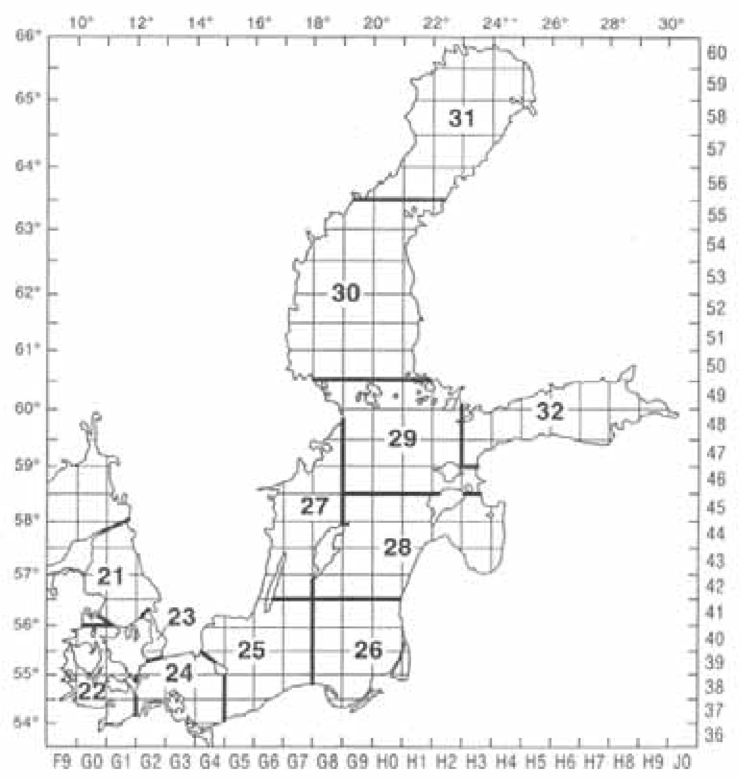


Figure 2.4.2. ICES rectangles and areas (22-32). Area 21 is Kattegat, which is not considered a part of the Baltic Sea. Notice that area 24 and 25 contain two triangles (Rectangle 39G4, Northwest of Bornholm). In Figure 2.4.1. the entire 39G4 is allocated to the western area.

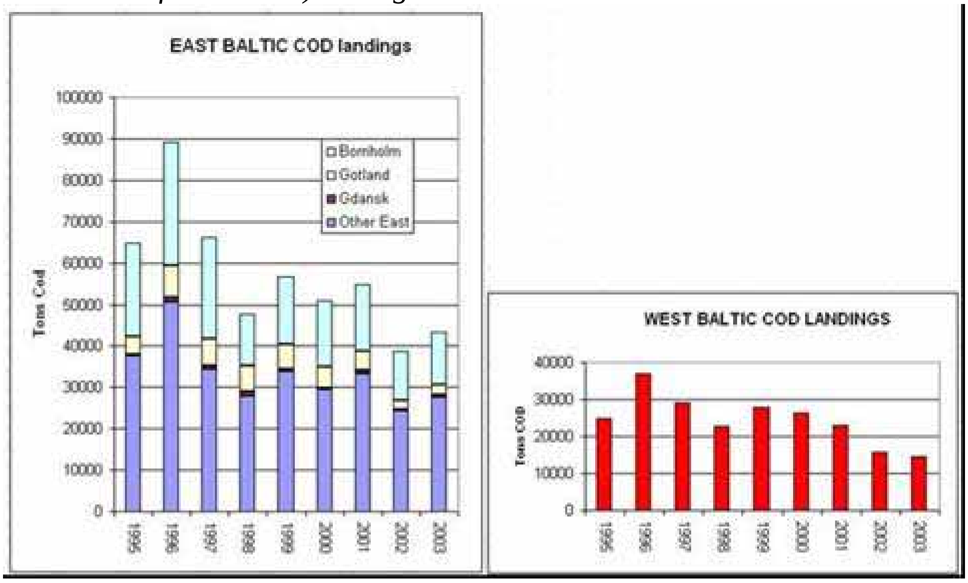


Figure 2.4.3. Landings of cod by areas (composed of ICES rectangles) of Figure 2.4.1, by Denmark, Germany, Latvia, Poland and Sweden.

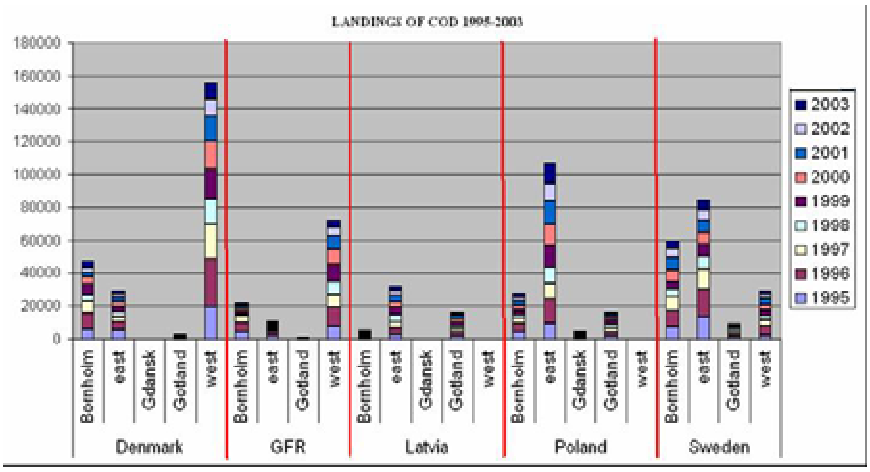


Figure 2.4.4. Landings by country and area of cod 1995-2003 by Denmark, Germany, Latvia, Poland and Sweden

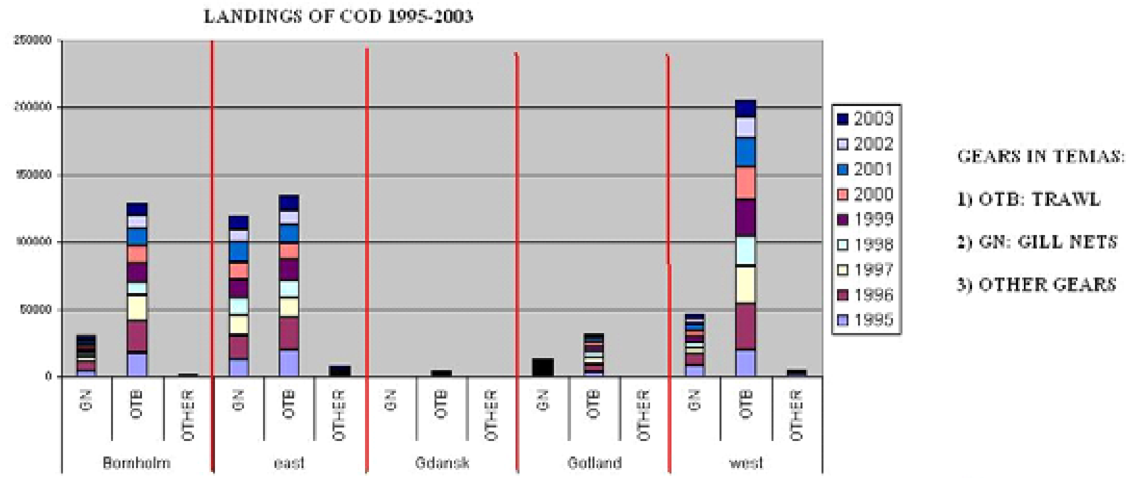


Figure 2.4.5. Landings by area of cod 1995-2003 by Denmark, Germany, Latvia, Poland and Sweden

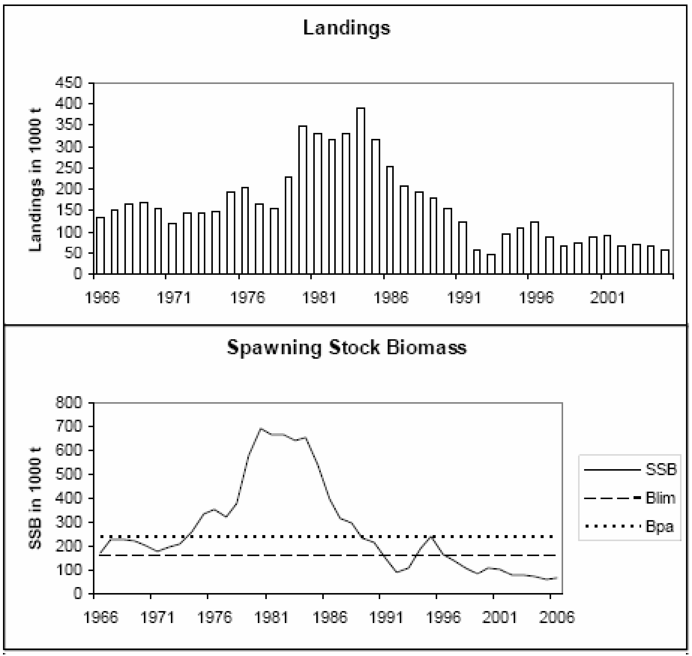


Figure 2.4.4. Historical landings and estimated spawning stock biomasses (SSB).(Source: Report of the Baltic Fisheries Assessment Working Group (WGBFAS), ICES CM 2006/ACFM:24).

2.5. THE ECONOMIC FRAME OF TEMAS

The economic part of TEMAS uses the concepts developed for project analysis to evaluate the financial and economic performance of the fishery during the project horizon (i.e. simulation life span) given different fisheries management measures, government financial transfers, and assumptions about the investment and operational behaviour of fishing firms. The financial performance is assessed from the point of view of both the fishing firms and the government treasury1.

The project horizon is defined as the time span from the initial base year, until the 'end' of the project. The number of project years is determined by the user of TEMAS. In the choice of project years, the user would be guided by various factors and assumptions including the time when management measures are taken and the number of years they take to produce the expected biological and economic results, the chosen value of the discount rate, the lifetime of fishing vessels and other factors as appropriate. A short project horizon of say 5 years may fail to reveal the full benefits of taking management measures such as a reduction of fishing capacity and effort because the population dynamics of the fish stocks have not yet yielded their full recovery to the desirable level. A long project horizon of say 20 years would show very little discernible difference in results to a project horizon of 15 years whenever the discount rate is 15% or higher.

The evaluation of the financial performance is undertaken from the point of view of both the fishing firms and the government while the economic performance is assessed from the standpoint of the economy as a whole. The principal differences between the two financial analyses and the economic analysis are as follows:

The economic analysis includes certain costs that are usually not paid for by the fishing firms and are thus excluded from their financial calculus. These include fisheries management costs such as research, administration and surveillance and enforcement. These costs lead to a cash outflow from the government budget or treasury. This cash outflow, however, might not be equal to their true costs to society to be accounted for in the economic analysis as is further explained below.

The economic analysis uses shadow prices of inputs whenever there is a discrepancy between the prices paid by fishing firms or the government and the economy wide opportunity costs of such inputs. For example, where fuel prices are subsidised, thus lowering fuel expenditures incurred by fishing firms, the economic analysis will be based on fuel prices net of such subsidies.

The financial performance of fishing firms will be affected by the way investments into fishing craft and gear have been financed, i.e. own savings or loans, and by the capital servicing terms of any loans taken in the past or in future years.

The financial performance of the government treasury depends on the cash inflows from the fishery through taxes, licensing fees, fines etc. and cash outflows for fisheries management expenditures, subsidies, etc. during the project horizon.

The economic analysis applies opportunity costs of capital to reflect the real social cost of using capital in fisheries rather than elsewhere in the economy. The opportunity cost concept is only applied to new investments. Past investments are sunk costs to the extent that they have no alternative economic use outside of fisheries.

In the financial analyses, labour costs are based on observed payments made to the fishing crew or government employees.

In the economic analysis, opportunity cost of labour is applied to reflect the real social cost of employing people in fishing or government rather than elsewhere in the economy.

In the financial analysis, payments made to fishing firms to decommission excess fishing capacity increase their net cash flows. Some firms may exit the fishery altogether and may invest decommissioning payments into other economic activities. If so, these firms would not be further considered in the simulation model of the fishery.

Decommissioning payments (i.e. compensations to fishing firms and to displaced fishing crews) are considered as transfer payments, i.e. a cash outflow from the government treasury. These payments are not considered a cost in the economic analysis.

No adjustments are made to fish prices observed in the market which are assumed to accurately reflect social values. However, a simple function has been included to model changes in fish prices as a result of changes in fish landings.

2.6. THE BEHAVIORAL FRAME OF TEMAS

"Behaviour" in the context of TEMAS mainly refers to the behaviour of "fishers" or "fishing vessels", that is the decision making by the skippers. There are in TEMAS, however, also some examples of behaviour algorithms of managers and advisers to managers (such as ICES).

2.6.1. THE GENERAL STRUCTURE OF A BEHAVIOUR RULE

The modelling of "fishers behaviour" is made by "behaviour algorithms" or "behaviour rules", which all have the same general structure. Behaviour in TEMAS is related to fractions of the fleets, that is, "X percent of the vessels in the fleet show behaviour y", (or take decision "y"). You may also say that "the reaction of fleet A" to "condition b" is decision "C".

The general structure of a single rule is:

If (Condition) then (Let x % of the vessels take decision "y")

Most single behaviour rules, however, appear as a link in a chain of rules (also called "nested choices"):

```
If   (Condition A)   then
  If        (condition B)  then
             (Let x % of the vessels take decision "y")
                 else if (condition C) then
            (Let z % of the vessels take decision "q")
         else
  ……..
```

The parameters which determines the percentages taking a certain decision, are defined by the "Discrete choice model" and the "Random Utility Model (RUM)" as will be discussed in Annex A,.

2.6.2. SURVEY OF BEHAVIOUR RULES IN TEMAS

The behavioural aspects of TEMAS includes:

Reaction to technical management measures (mesh size, minimum landing size, closed areas, minimum target species %, maximum by-catch %, vessel restrictions, etc.)
Reaction to non-technical management measures (primarily catch quotas and maximum catch-rates)
Reaction to economic factors (primarily costs and prices)
Reaction to technical factors (primarily the range and equipment of vessels).
Reaction to ecological factors (availability of resources)
Reaction of fisheries advisers (ICES) to catch statistics with respect of quota setting.

The behaviour of fishers will be dealt with at two levels

1) Trip-Related Behaviour (short term).
2) Structure-Related Behaviour (long term).

Within each level, Fishers behaviour has been divided into two parts:

"Technical behaviour" Behaviour triggered by technical management and catch quota regulation.
"Economic behaviour" Behaviour triggered by economic factors, and economic management measures.

However, in principle any behaviour should be explained collectively as a result of all factors influencing the decision-making. It still has to be demonstrated that the above split is a reasonable reflection of real world. That is, that behaviour can be separated according to the phenomena causing the behaviour.

Behaviour will be modelled by so-called "rules" or "behaviour rules". Examples of rules are:

Trip-Related Behaviour	
Fishing Effort Rule	(when to fish)
Fishing Ground Rule	(Where to fish)
Fishing Gear Rule	(which gear to use)
Landing Rule	(where to land)
Discard Rule	(how much to discard)
Compliance Rule	(when to comply with regulation)

Structure-Related Behaviour	
Decommission Rule	(when to accept decommission)
Dis-Investment Rule	(when to withdraw, without decommission)
Investment Rule	(When to invest in a new vessel)
Attrition Rule	(when to pull out due to tear and wear)

2.7. ASSESSING THE EFFECT OF MPAs (MARINE PROTECTED AREAS)

To make a complete assessment the effect of marine protected areas, which have the purpose of improving the production of recruits, it is required to model a long suite underlying relationships, such as.

1) The relationship between spawning stock biomass and recruitment
2) The relationship between environment and recruitment, including the impact of the environment on egg and larvae survival.
3) The temporal and spatial distribution of spawners (distribution of egg production) and juveniles, including spawning migration and migration of juvenile.
4) The relationship between fishery and recruitment.
5) The reallocation of fishing effort after closure of an MPA, including, e.g. the impact of economy on the behaviour of fishers.
6) Predation on cod larvae and juveniles, including cannibalism.
7) Food availability for cod larvae and juveniles.

More fundamental mechanisms could be listed, but even these 7 items makes one almost give up making a model for the effect of MPAs. Some theories and some parameters estimation exists for all the items listed, but none are believed to be fully understood or fully documented with observations and estimations of model parameters.

The word "assessment" is used here conceptually as used by ICES working group. An assessment is composed of two parts (1) Estimation of parameters from historical data (2) Prediction based on the parameters estimated under (1). The main thing to predict is the recruitment, and needless to say to any worker with more than one year of experience in fisheries science, this is "next to impossible". What may possibly be concluded from any model on recruitment are statements like "It is believed that the regulation (e.g. an MPA) is likely to improve the future recruitment". Only the novice in fisheries science can hope to make quantitative prediction of recruitment. This is needless to say to the experienced fish stock assessment worker.

So when a model for the recruitment of Baltic cod, which can be used to assess the effect of MPAs, is presented below, there is no expectation that it can ever be used for quantitative predictions. To underline this fact (which applies any recruitment model for any stock in the world), the model is formulated as a stochastic model, giving output in the form of probability distributions, rather than single figures.

The model presented here will deal with only items 1 to 3 in the list above, although the TEMAS model can handle 4 and 5, whereas TEMAS does not cover items 6 and 7, as it assumes constant natural mortality and growth rates of larvae, juveniles and adults.

ANNEX. A. THE OPERATING MODEL APPLIED TO THE BALTIC

The family of TEMAS operational models is characterized by all members containing the traditional ICES forecast model as a subset. The traditional ICES forecast model can be attributed to e.g. Baranov (1918) or Thompson & Bell (1934). The main characteristic of the Thompson & Bell model is the account of age structures and cohorts in the description of the population dynamics.

A.1. NOTATION OF TEMAS

There are two sets of notations used in TEMAS. The first notation is for mathematical formulas and the second is for code written in VISUAL BASIC. In this Appendix, both notations will be used, but the primary notation is that for mathematical formulas. The style of notation is similar to the traditional one for mathematics.

Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j)=\sum_u X(i,u,j)$. Indices in alphabetical order:

This section introduces some of the symbols used in TEMAS. A Complete list of all variables of the TEMAS model is given in Section A.13.

The symbols used for indices are:

	Index	Explanation	Range
1	a	Age group	a = 0,1,2,…,a_{max}(St)
2	Ar	Area	Ar = 1,2,…,Ar_{max}
3	Ct	Country	Ct = 1,…,Ct_{Max}
4	Fl	Fleet	Fl = 1,2,…,Fl_{max}(Ct)
5	q	Time period (as time)	q = 1,..,q_{max}
6	qa	Time period (as age)	qa = 1,..,q_{max},
7	Rg	Rigging of gear	Rg = 1,…,Rg_{max}(Fl,Ct)
8	Y	Year	y = $y_{firSt, yfirst}$+1,…,y_{last}
9	St	Stock	St = 1,…,St_{max}
10	Va	Vessel age group	Va = 1,…Va_{max}(Fl,Ct)
11	Vs	Vessel size group	Vs = 1,…Vs_{max}(Fl,Ct)

Note that the sequence of indices will be

(Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar)

for all variables.

The indices "q" or "qa" stand for divisions of the year, such as "month", "quarter", "half year" etc. The time period concept may be used to indicate absolute time, and time relative to the birth of a cohort, that is the age of the cohort.
The age of the cohort, however, is given in years and time periods only for the first two years of life, as the from age two and onwards, it is assumed that the difference between (year, period)-cohorts is so small that it can be ignored.
This somewhat complicated age-concept is introduced to enable the model to make a fair approximation for length at age of juvenile fish.
This is necessary for the analysis of gear selection aspects and recruitment, which are most important for juvenile specimens.

In order to reduce the complexity of formulas, the indices Vs, Rg and Ct will be tacitly assumed, when the index Fl occurs.

Time Variables in alphabetical order:

Symbol	Explanation
Dt	Basic time step (fraction of year). dt < 1.0. dt = $1/q_{Max}$
y_{first} ,y_{last}	First year, Last year

A.2. GROWTH, MATURITY AND NATURAL MORTALITY

A.2.1. GROWTH OF INDIVIDUALS

Growth of individuals is most often given in ICES WG by a year specific weight at age arrays. To simplify the model, that is, to reduce the number of parameters, TEMAS uses the von Bertalanffy growth equation, which has only three parameters. If we furthermore assume that some or all growth parameters remain constant from year to year, a considerable reduction in number of parameters has been achieved, relative to the ICES model.

Mean Body length of stock "St", in the middle of time period q of year "y" of age group "a", LGT(St,a,y) is given by the Von Bertalanffy equation (1934):

$$\text{Lgt(St, y,a,q)} = \text{L}_\infty(St)*\left(\ 1-\exp\left[\ -K\ \ (St)*(Age(a,q,qa)-T_0(St))\right]\ \right) \qquad \text{(A.2.1.1)}$$

The age of the fish (or cohort) in units of years is defined (illustrated by Table A.2.1):

$$Age(a,q,qa) = \begin{cases} a+(q-qa+0.5)*dt & if\ a<2 \\ a-da_{Mean}(St)+(q-0.5)*dt & if\ \ a\geq 2 \end{cases} \qquad \text{(A.2.1.2)}$$

$$where \quad da_{Mean}(St) = \sum_{qa=1}^{q_{max}}(qa-1)\ \ *\ \text{RecDistPeriod(St, qa)}$$

RecDistPeriod(St,qa) is the fraction of the annual recruitment which occurs in period qa, from which the mean time at recruitment, da_{Mean}(st), is derived. This is the basis of age allocated to fish at age 2 and older. Thus, after age group 1, the influence of the birth period is assumed to be negligible. This elaborate definition of the age concept is made to accommodate the need from both short lived species, and the need to describe the relationship between age and length for juveniles. In the context of technical management measures, which all have the objective of protecting juveniles, a more detailed description is needed for the juveniles, compared to the ALK approach of ICES WG.

Table A.2.1 illustrates the age concept of TEMAS by showing the number of survivors by age group. In this case the year is divided into 12 months, and recruitment can occur each month. In the present example recruitment occurs only in months 3-7. In the first two years of life, each month-cohort is accounted for, but after age 2, the month-cohort are pooled into a year-cohort. For the year-cohorts, number of survivors is given for each month, as the model in this runs with a time step of one month.

In the case TEMAS is used to evaluate the effect of closed seasons and MPAs, one will often want a short time step, like a month. In other uses of TEMAS the time step may be 2 month, or quarter of the year.
The body length at age can be made a stochastic variable in TEMAS, by introduction of the stochastic factor, ε_K

Age/Time	2006 P1	2006 P2	2006 P3	2006 P4	2006 P5	2006 P6	2006 P7	2006 P8	2006 P9	2006 P10	2006 P11	2006 P12	2007 P1	2007 P2	2007 P3
Age 0 Per. 1	**0**	**0**	**115**	**216**	**348**	**235**	**47**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**665**
Age 0 Per. 2	**0**	**0**	**0**	**113**	**212**	**342**	**232**	**46**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Age 0 Per. 3	**0**	**0**	**0**	**0**	**111**	**209**	**336**	**228**	**45**	**0**	**0**	**0**	**0**	**0**	**0**
Age 0 Per. 4	**0**	**0**	**0**	**0**	**0**	**110**	**205**	**331**	**224**	**45**	**0**	**0**	**0**	**0**	**0**
Age 0 Per. 5	**0**	**0**	**0**	**0**	**0**	**0**	**108**	**202**	**325**	**220**	**44**	**0**	**0**	**0**	**0**
Age 0 Per. 6	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**106**	**198**	**320**	**216**	**43**	**0**	**0**	**0**
Age 0 Per. 7	**35**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**104**	**195**	**314**	**212**	**42**	**0**	**0**
Age 0 Per. 8	**166**	**34**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**102**	**191**	**308**	**209**	**42**	**0**
Age 0 Per. 9	**190**	**162**	**33**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**100**	**188**	**303**	**205**	**41**
Age 0 Per. 10	**122**	**187**	**159**	**33**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**98**	**184**	**297**	**201**
Age 0 Per. 11	**58**	**119**	**183**	**156**	**32**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**96**	**180**	**291**
Age 0 Per. 12	**0**	**57**	**117**	**179**	**153**	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**94**	**177**
Age 1 Per. 1	**0**	**0**	**56**	**114**	**175**	**150**	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**92**
Age 1 Per. 2	**0**	**0**	**0**	**55**	**112**	**172**	**146**	**30**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Age 1 Per. 3	**0**	**0**	**0**	**0**	**53**	**109**	**168**	**143**	**29**	**0**	**0**	**0**	**0**	**0**	**0**
Age 1 Per. 4	**0**	**0**	**0**	**0**	**0**	**52**	**107**	**164**	**140**	**29**	**0**	**0**	**0**	**0**	**0**
Age 1 Per. 5	**0**	**0**	**0**	**0**	**0**	**0**	**51**	**104**	**160**	**136**	**28**	**0**	**0**	**0**	**0**
Age 1 Per. 6	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**50**	**102**	**156**	**133**	**27**	**0**	**0**	**0**
Age 1 Per. 7	**21**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**48**	**99**	**152**	**130**	**27**	**0**	**0**
Age 1 Per. 8	**100**	**20**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**47**	**97**	**148**	**126**	**26**	**0**
Age 1 Per. 9	**115**	**97**	**20**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**46**	**94**	**144**	**123**	**25**
Age 1 Per. 10	**74**	**112**	**95**	**19**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**45**	**92**	**141**	**120**
Age 1 Per. 11	**35**	**72**	**109**	**93**	**19**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**44**	**89**	**137**
Age 1 Per. 12	**0**	**34**	**70**	**106**	**90**	**18**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**43**	**87**
Age 2 Per. 1	**293**	......	......	......	......	......	......	......	......	......	......	......	**311**	......	......
Age 2 Per. 2	......	**285**	......	......	......	......	......	......	......	......	......	......	......	**303**	......
Age 2 Per. 3	......	......	**278**	......	......	......	......	......	......	......	......	......	......	......	**295**
Age 2 Per. 4	......	......	......	**273**	......	......	......	......	......	......	......	......	......	......	......
Age 2 Per. 5	......	......	......	......	**266**	......	......	......	......	......	......	......	......	......	......
Age 2 Per. 6	......	......	......	......	......	**259**	......	......	......	......	......	......	......	......	......
Age 2 Per. 7	......	......	......	......	......	......	**253**	......	......	......	......	......	......	......	......
Age 2 Per. 8	......	......	......	......	......	......	......	**246**	......	......	......	......	......	......	......
Age 2 Per. 9	......	......	......	......	......	......	......	......	**240**	......	......	......	......	......	......
Age 2 Per. 10	......	......	......	......	......	......	......	......	......	**233**	......	......	......	......	......
Age 2 Per. 11	......	......	......	......	......	......	......	......	......	......	**227**	......	......	......	......
Age 2 Per. 12	......	......	......	......	......	......	......	......	......	......	......	**221**	......	......	......
Age 3 Per. 1	**179**	......	......	......	......	......	......	......	......	......	......	......	**216**	......	......
Age 3 Per. 2	......	**174**	......	......	......	......	......	......	......	......	......	......	......	**210**	......
Age 3 Per. 3	......	......	**169**	......	......	......	......	......	......	......	......	......	......	......	**205**
●●															
Age 9 Per. 10	......	......	......	......	......	......	......	......	......	**8**	......	......	......	......	......
Age 9 Per. 11	......	......	......	......	......	......	......	......	......	......	**7**	......	......	......	......
Age 9 Per. 12	......	......	......	......	......	......	......	......	......	......	......	**6**	......	......	......

Table A.2.1. Illustration of the age concept in TEMAS. In this case the time step is one month.

$$\begin{aligned}
&\mathrm{Lgt}\ (\mathrm{St},\ \mathrm{y}, \mathrm{a}, \mathrm{q}) = \\
&\mathrm{L}_{\infty}(St) * \left(1 - \exp\left[-K\ (St) * \varepsilon_K (St, y) * (Age(a,q) - T_0(St)) \right] \right)\ if\ \ a \geq 2 \\
&\mathrm{Lgt}\ (\mathrm{St},\ \mathrm{y}, \mathrm{a}, \mathrm{q}, \mathrm{qa}) = \\
&\mathrm{L}_{\infty}(St) * \left(1 - \exp\left[-K\ (St) * \varepsilon_K (St, y) * (Age(a,q,aq) - T_0(St)) \right] \right)\ if\ \ a \leq 2
\end{aligned} \quad \text{(A.2.1.1.b)}$$

where ε_K(St, y) is a year and stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_K (St).

Body length is assumed to be the same for stock, landings and discards. This is a simplification of the model relative to ICES, which usually operates with separate weight at age keys for landings, stock and discards.

A.2.2. LENGTH/WEIGHT RELATIONSHIP

Mean Body weight is derived from the body length

$$Wgt\ \ (St, y, a, q) = QF\ \ (St, q) * Lgt(St, y, a, q)^{QE\ \ (St)} \quad \text{(A.2.2.1.a)}$$

The condition factors, QF(St,q), is assumed to depend on the time of the year, q. That means that the user has the option to let the condition factor vary over seasons of the year. The condition exponent, QE(St), is assumed to remain constant during the year.

The length/weight relationship can be made stochastic in TEMAS through the stochastic factor, ε_{QF}

$$Wgt\ \ (St, y, a, q) = QF\ \ (St, q) * \varepsilon_{QF}\ (St, y) * Lgt(St, y, a, q)^{QE\ \ (St)} \quad \text{(A.2.2.1.b)}$$

where ε_{QF}(St, y) = (ε_K(St, y) +ε'_{QF}(St, y))/2 and where ε'_{QF}(St, y)) is a year and stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{QF}(St). Body weight is assumed to be the same for stock, landings and discards in the operational model.

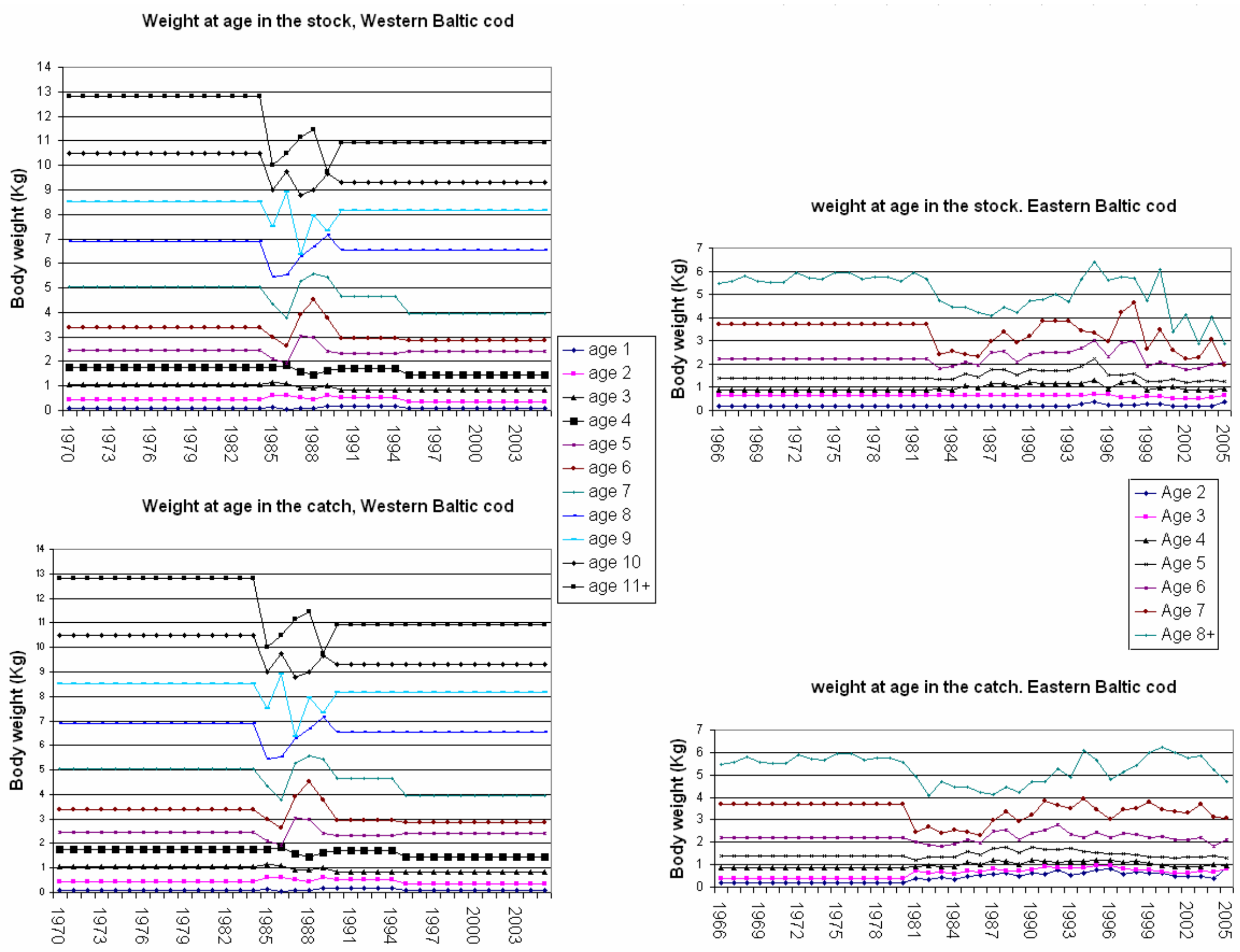


Figure A.2.1. Weight at age as given in the ICES WG report (ICES,2006).

Figure A.2.2. Weight at age as given by the ICES WG (East Stock, East Catch, West Stock, West Catch) and least squares estimate of Von Bertalanffy growth corves (VBEast and VBWest).

Figure A.2.1 shows the weight at age data used by the WGBFAR (ICES,2006). As can be seen, some values remain constant from year to year, whereas rather big variations are observed in other years. We consider these observations somewhat questionable, but hope that they give a reasonable picture of the growth. From these data, estimates of growth parameters for the two stocks were estimated (Table A.2.2). The catch and stock "observations" were pooled as input.

Stock	QF	QE	L∞	K	to
EAST	0.00001	3	131	0.110	0.000
WEST	0.00001	3	148	0.103	-0.384

Table A.2.2. Von Bertalanffy growth parameters of Baltic cod estimated from ICES 2006.

The condition coefficient and condition exponent were allocated the standard (theoretical values), QF = 0.00001 (cm to kg) and QE = 3 for both stocks. Taking into account the way the growth parameters were estimated, it was considered not worthwhile to make a statistical estimation of QF and QE. (the selected values may be as good as any other values).

Using a similar approach for sprat the parameters are shown in Table A.2.3.

CF	CE	Loo	K	To
0.00001	**3.0**	**11.32**	**0.84**	**-0.75**

Table A.2.2. Von Bertalanffy growth parameters of Baltic sprat estimated from ICES 2006.

A.2.3. MATURITY OF INDIVIDUALS

The relationship between age and maturity, is modelled by the logistic curve. The maturity is usually linked to the length of the fish, so that fast growing fish will mature at a younger age than slow-growing specimens. Maturity ogive, that is the fraction of mature fish as a function of body length is

$$\mathrm{Mat(St, y, a, q)} = \frac{1}{1 + \exp(\mathrm{Mat1(St)} - \mathrm{Mat2(St)} * \mathrm{Lgt}(St, a, y, q))} \qquad \text{(A.2.3.1)}$$

where

Mat1(St) = $\ln(3) * LGT_{50\%Mat}(St)/(LGT_{75\%Mat}(St) - LGT_{50\%Mat}(St))$,
Mat2(St) = $\ln(3)/(LGT_{75\%Mat}(St) - LGT_{50\%Mat}(St))$ and
$LGT_{X\%DMat}(St)$ = Length at which X % are mature.

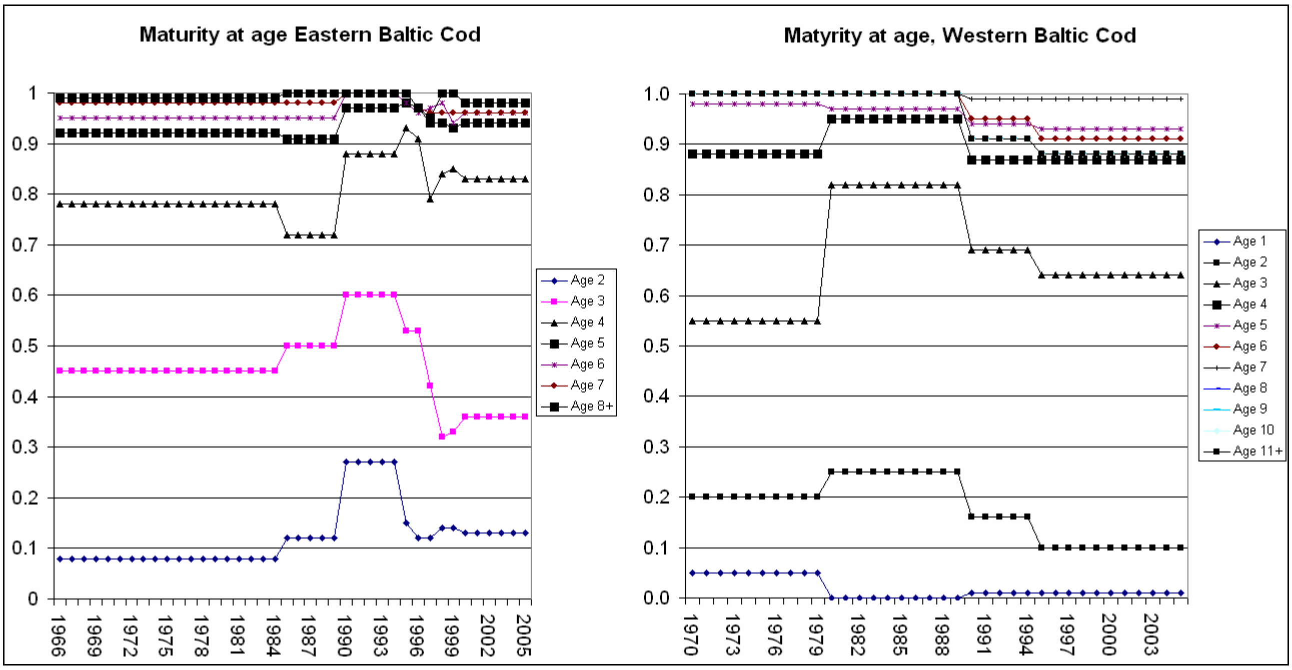


Figure A.2.3. Maturity at age of Baltic cod from ICES (2006)

Figure A.2.3 shows the maturity at age used by the ICES WG (ICES, 2006) in their stock assessment. Using the ICES data for the eastern cod, gave a reasonable fit to the model (Figure A.2.4.A), whereas the western stock did not match to the logistic curve. Therefore the ICES figures were changed for age group 1, 10 and 11, which yielded a better fit (Table A.2.3).

	"Observed" ICES, 2006					Predicted	
Age group	East ICES	Modified West ICES	West ICES	Lgt East	Lgt West	Mat East	Mat West
1	0.000	**0.000**	**0.018**	13.6	19.7	0.021	0.023
2	0.123	0.178	0.178	25.9	32.2	0.128	0.189
3	0.459	0.672	0.672	36.8	43.6	0.454	0.651
4	0.803	0.895	0.895	46.6	53.8	0.798	0.924
5	0.932	0.956	0.956	55.4	63.0	0.941	0.985
6	0.960	0.966	0.966	63.3	71.3	0.982	0.997
7	0.978	0.996	0.996	70.3	78.8	0.994	0.999
8	0.990	0.951	0.951	76.7	85.6	0.998	1.000
9	1.000	0.951	0.951	82.3	91.7	0.999	1.000
10	1.000	**1.000**	**0.951**	87.4	97.2	1.000	1.000
11	1.000	**1.000**	**0.951**	91.9	102.2	1.000	1.000

Table A.2.3. Input for estimation of maturity at age for Baltic cod, from ICES (2006).

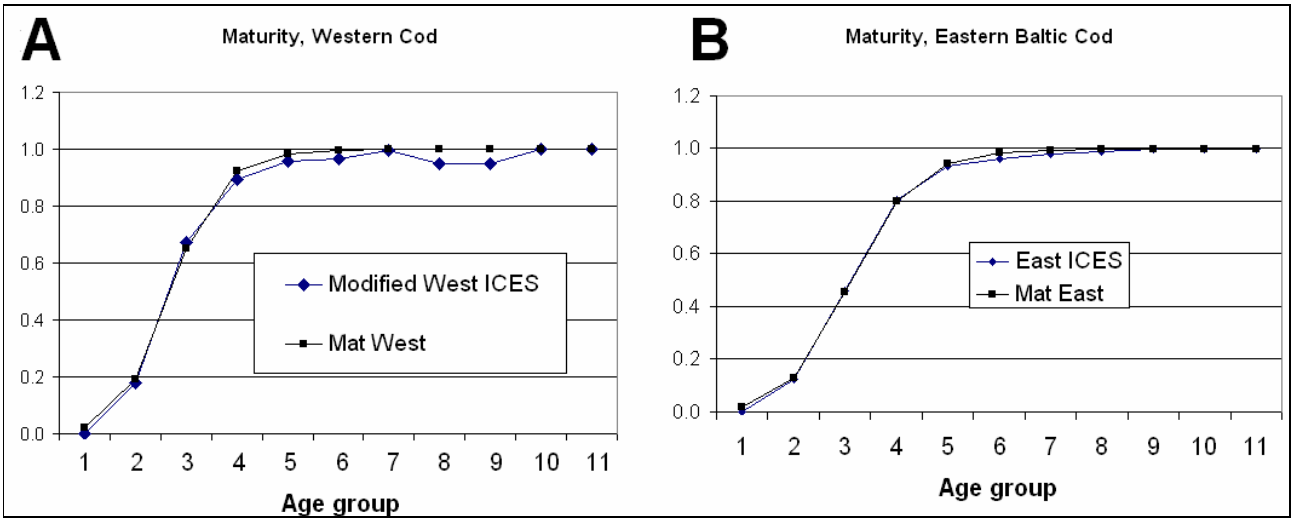


Figure A.2.4. Maturity at age for Baltic cod, estimated from ICES (2006).

Table A.2.4. shows the estimates of maturity at age for Eastern and Western Baltic cod, from ICES (2006) and Table A.2.3.

	Eastern Cod, cm	Western Cod, cm
$LGT_{50\%Mat}$	38.0	40.2
$LGT_{75\%Mat}$	44.9	46.2

Table A.2.4. Estimates of maturity at age for Baltic cod, from ICES (2006).

The results for Baltic sprat (22-32) are shown in Table A.2.5.

	Length cm
$LGT_{50\%Mat}$	8.85
$LGT_{75\%Mat}$	8.94

Table A.2.5. Estimates of maturity at age for Baltic sprat (22-32), from ICES (2006).

A.2.4. NATURAL MORTALITY

The natural mortality is not assumed to remain constant from year to year, and depend only on stock and age group.

M(St, a, y, q) = Natural mortality.

The operational model could be used to test the effect of an increasing trend in natural mortally over suite of years or decades. Table A.2.6 shows the natural mortalities used for the ICES assessments (ICES, 2006). The values are mean values over the years given in the ICES WG report.

Age group	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8+*		
Eastern cod	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20		
Age group	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11+*
Western cod	0.29	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Age group	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8+*			
Sprat	0.64	0.45	0.39	0.36	0.4	0.4	0.47	0.47			

Table A.2.6. Natural mortalities of Baltic stocks derived from ICES 2006.

The expression for predation mortality in multi-species VPA (see e.g. Sparre, 1991), could be used here, and if the TEMAS-approach is further developed, the model of predation mortality might be incorporated, as there are no technical or theoretical problems involved.

A.3. GEAR- AND DISCARD SELECTION OGIVES

A.3.1. DISCARD SELECTION OGIVES

The discard ogive gives the fraction of fish discarded (for any reason) as a function of body length, is modelled by "one minus the logistic curve":

$$DIS(Fl,Vs,Rg,Ct,St,y,a,q) = 1 - \frac{1}{1+\exp(Dis1(Fl,Vs,Rg,Ct,St,y,q) - Dis2(Fl,Vs,Rg,Ct,St,y,q) * Lgt(St,a,q))} \qquad (A.3.1.1)$$

where parameters of the logistic ogive are defined as those of the maturity ogive.
Thus,
$Dis1(Fl,Vs,Rg,Ct,St,y,q) = \ln(3) * LGT_{50\%Discards}(Fl,Vs,Rg,Ct,St,y,q,St)/(LGT_{25\%Discards}(-) - LGT_{50\%Discards}(-))$,
$Dis2(Fl,Vs,Rg,Ct,St,y,q) = \ln(3)/(LGT_{25\%Discards}(Fl,Vs,Rg,Ct,St,y,q,St) - LGT_{50\%Discards}(-))$ and
$LGT_{X\%Discards}(Fl,Vs,Rg,Ct,St,y,q,St)$ = Length at which X % are retained.

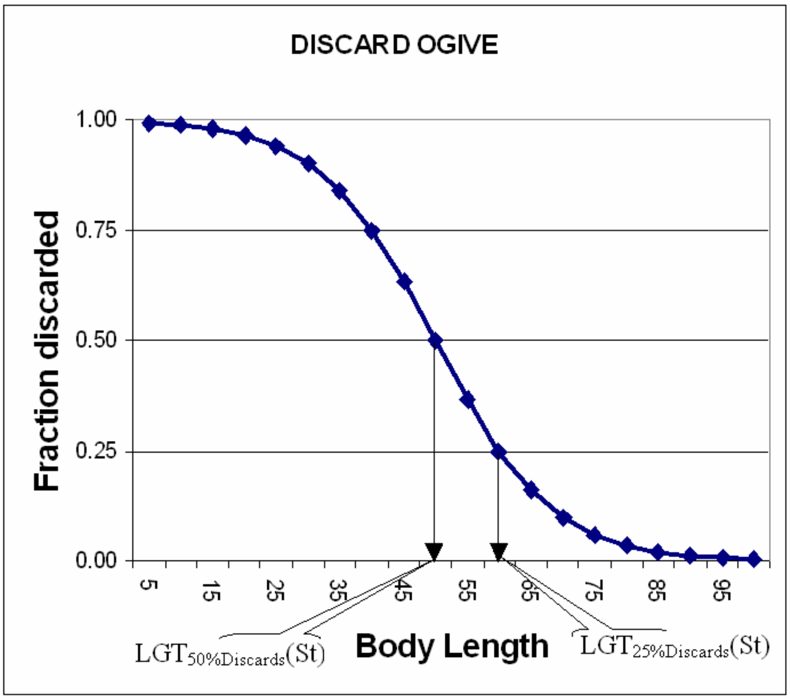


Figure A.3.1. Example of discard Ogive.

The model of discarding illustrates a feature about the TEMAS toolbox. One can think of several ways to extend the model for fishers discard practice (see e.g. Nielsen et al. (in revision)), and the idea with a "toolbox" is that the user should be able to select alternative models for discarding. The discard model might account for high-grading due to quota or ration limitations or due to economic reasons (low commercial value of discards).

Also the influence of minimum legal landing size could be accounted for in the discard-model. The current implementation of TEMAS has the minimum landing size as an input parameter, and the model lets all undersized fish be discarded (see the following section).

Estimation of the discard parameters $LGT_{50\%Discards}$ and $LGT_{50\%Discards}$ can made in many different ways. Here is a very simple method using data from the WGBFAR report. Figure A.3.2 shows a table with discards (D) and landings (L) of all gears combined from the WGBFAR report, together with the two columns "D/(D-L)" and "1-D/(D-L)". The columns L-O have been added to the ICES table. In Figures A.3.2.A and B show how the "1-D/(D-L)"-column is used to estimate $LGT_{50\%Discards}$ and $LGT_{50\%Discards}$ by use of the EXCEL function "Solver"

Table 2.3.6a **Cod in SD 22-24.** Discards and Landings in numbers (thousands) by year and age groups.

Age group	2001 Landing	2001 Discard	2002 Landing	2002 Discard	2003 Landing	2003 Discard	2004 Landing	2004 Discard	2005 Landing	2005 Discard	Total 2001-5 Landing	Total 2001-5 Discard	D/(D+L)	1-D/(D+L)
Age0	0	44	0	0	0	16	0	149	0	47	0	256	1.000	0.000
Age1	2399	4033	1624	2000	2178	1565	368	2666	584	3148	7153	13411	0.652	0.348
Age2	13709	6612	8612	3437	12795	8737	3500	1171	10754	8197	49371	28155	0.363	0.637
Age3	10969	640	8801	1615	6527	489	10009	2252	3026	362	39333	5358	0.120	0.880
Age4	5168	41	2155	19	1898	11	3489	3	3033	65	15742	139	0.009	0.991
Age5	856	0	912	40	333	0	633	0	695	28	3429	68	0.019	0.981
Age6													0.000	1.000
Age7													0.000	1.000
Age8													0.000	1.000

Cod discard curve | Discards_Cod_22-24

Figure A.3.2. Discards (D) and landings (L) numbers of western Baltic cod (all gears combined) from ICES 2006.

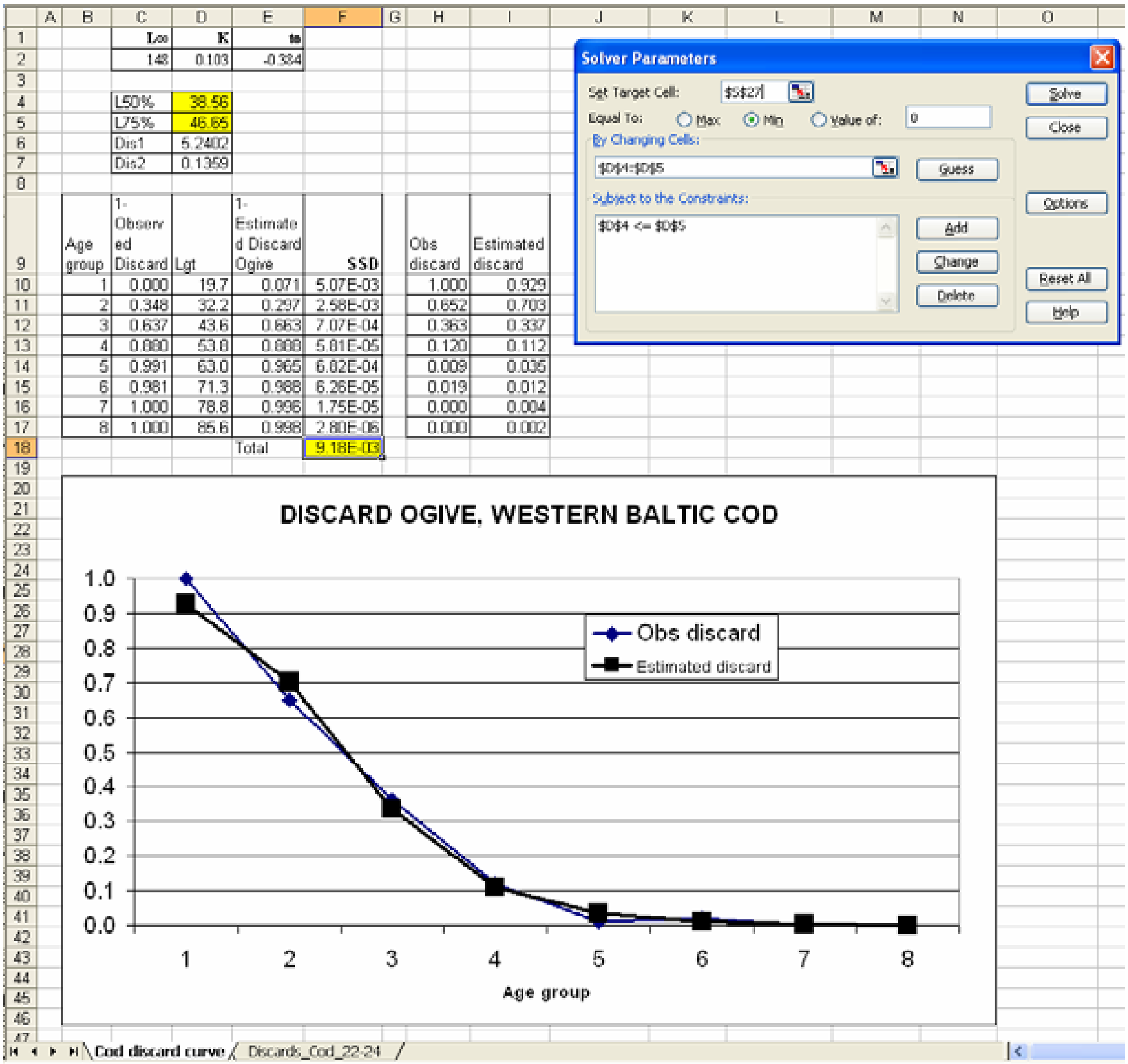


Figure A.3.3.A. Estimation of discards ogive for western Baltic cod (all gears combined) from ICES 2006.

Discards_COD_22-24.xls

	A	B	C	D	E	F
1			**Stock**	**L∞**	**K**	**to**
2			**WEST COD**	148	0.103	-0.384
3						
4			L50%	38.5614		
5			L75%	46.6458		
6			Dis1	=LN(3)*D4/(D5-D4)		
7			Dis2	=LN(3)/(D5-D4)		
8						
9		Age group	Observed Discard	Lgt	Estimated Discard Ogive	**SSD**
10		1	0	=$D$2*(1-EKSP(-$E$2*(B10-$F$2)))	=1/(1+EKSP($D$6-$D$7*D10))	=(C10-E10)^2
11		2	0.3478	=$D$2*(1-EKSP(-$E$2*(B11-$F$2)))	=1/(1+EKSP($D$6-$D$7*D11))	=(C11-E11)^2
12		3	0.6368	=$D$2*(1-EKSP(-$E$2*(B12-$F$2)))	=1/(1+EKSP($D$6-$D$7*D12))	=(C12-E12)^2
13		4	0.8801	=$D$2*(1-EKSP(-$E$2*(B13-$F$2)))	=1/(1+EKSP($D$6-$D$7*D13))	=(C13-E13)^2
14		5	0.9912	=$D$2*(1-EKSP(-$E$2*(B14-$F$2)))	=1/(1+EKSP($D$6-$D$7*D14))	=(C14-E14)^2
15		6	0.9805	=$D$2*(1-EKSP(-$E$2*(B15-$F$2)))	=1/(1+EKSP($D$6-$D$7*D15))	=(C15-E15)^2
16		7	1	=$D$2*(1-EKSP(-$E$2*(B16-$F$2)))	=1/(1+EKSP($D$6-$D$7*D16))	=(C16-E16)^2
17		8	1	=$D$2*(1-EKSP(-$E$2*(B17-$F$2)))	=1/(1+EKSP($D$6-$D$7*D17))	=(C17-E17)^2
18					Total	=SUM(F10:F17)
19				"EKSP" = "EXP" in Danish		

Cod discard curve / Discards_Cod_22-24

Figure A.3.3.B. The EXCEL formulas for estimation of discards ogive for western Baltic cod (all gears combined) from ICES 2006.

A similar approach can be used for individual gear and riggings whenever landings and discard numbers at age are available. When no data are available, the overall estimation above can be used if no better estimate is available.

This estimation could be done with more sophisticated methods and software, but taking the nature (or rather quality) of the input data into account, and combining with the objective of TEMAS, it is not worthwhile to use sophisticated software or methods.

The estimation of growth parameters and maturity ogives in the foregoing sections were also made by aid of the EXCEL solver function.

A.3.2. GEAR- SELECTION OGIVES

The selection ogive SEL gives the fraction of the fish encountered by the gear that are retained. Thus 1-SEL is the fraction that escapes, e.g. through the meshes, a panel or a grid.

The logistic curve is used to model the selection of fishing gears

$$\mathrm{SEL(Fl, Vs, Rg, Ct, St, y, a, q)} = \frac{1}{1+\exp(\mathrm{Sel1\ (Fl, Vs, Rg, Ct, St, y)} - \mathrm{Sel2(Fl, Vs, Rg, Ct, St, y)} * \mathrm{Lgt}\ (St, y, a, q))} \quad \text{(A.3.2.1)}$$

where parameters of the logistic ogive are defined

SEL1(Fl, Vs, Rg, Ct, St, y) = ln(3)* $LGT_{50\%}$(Fl, Vs, Rg, Ct, St, y) /($LGT_{75\%}$(-) - $LGT_{50\%Mat}$(-)),
SEL2(Fl, Vs, Rg, Ct, St, y) = ln(3)/($LGT_{75\%}$(Fl, Vs, Rg, Ct, St, y) - $LGT_{50\%}$(-)) and

$$LGT_{50\%}(Fl,Vs,Rg,Ct,St,y,q) = MS(Fl,Vs,Rg,Ct,y,q) * SF(Fl,Vs,Rg,Ct,St,y,q)$$
$$LGT_{75\%}(Fl,Vs,Rg,Ct,St,y,q) = LGT_{50\%}(Fl,Vs,Rg,Ct,y,q) + SR(Fl,Vs,Rg,Ct,St,y,q)/2$$
$$LGT_{25\%}(Fl,Vs,Rg,Ct,St,y,q) = LGT_{50\%}(Fl,Vs,Rg,Ct,y,q) - SR(Fl,Vs,Rg,Ct,St,y,q)/2$$

MS(Fl, Vs, Rg, Ct, y,q) = Mesh size of fleet Fl in year y,
SF(Fl, Vs, Rg, Ct, St, y,q) = Selection factor and
SR(Fl, Vs, Rg, Ct, St, y,q) = Selection range (=$LGT_{75\%}$-$LGT_{25\%}$)

The term “Mesh size” may mean a real mesh size, for example the size of the meshes in the codend of a trawl, or the mesh size of a gill net. But, “mesh size”, in the context of TEMAS, is a general concept. It should rather be considered a “parameter in the model” for gear selection. Even if, for example, hooks have no meshes, the parameter “mesh size” in TEMAS, can still be used to describe the selection of the gear. Thus, the mesh-size parameter may also cover the effect of, e.g. an “escape window” (e.g. a grid or a panel of squared meshes).

A gear may not catch certain size groups or species either because they escape the gear, or because they are not located where the gear is operated, or for some other reason is not available to the gear. For example, the species may be buried in the sand. The selectivity of a fleet is thus the combined effect of gear selection and availability of the size/species in question. The combined effect is called the “resultant” curve. This curve is derived as the product of the gear selection ogive and the availability ogive (Figure A.3.2.1). In TEMAS, however, these features of selection are not explicitly accounted for in the current version of TEMAS. TEMAS tacitly assumes that the gear selection parameters (selection factor and selection range) are chosen so that they produce the resultant ogive (Hoydahl et al, 1982, McLennan, 1992).

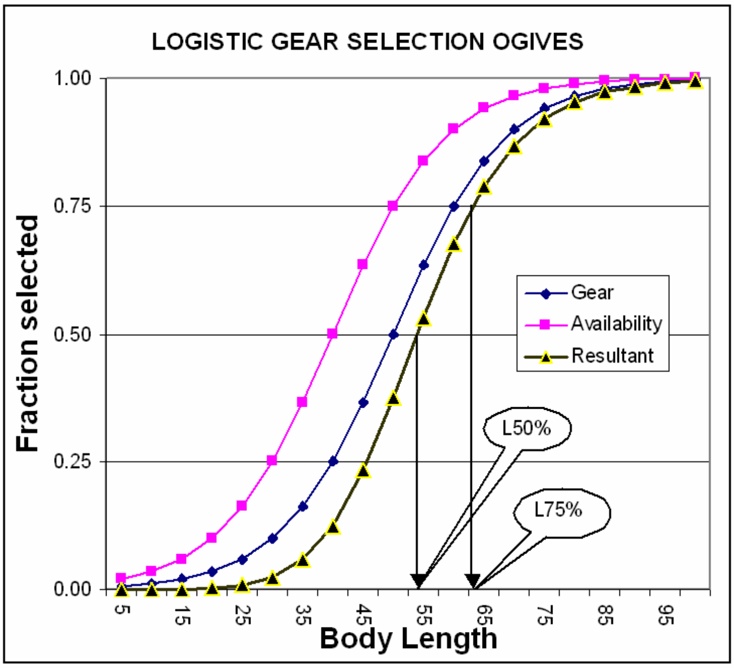


Figure A.3.2.1. Example of "resultant ogive"

The parameters, Sel1 and Sel2, are the parameters in the logistic model, but actually they are not really necessary. Equation (A.3.2.1) can be rewritten:

$$\mathrm{SEL(Fl, St, y, a, q)} = \frac{1}{1 + 3^{\frac{\mathrm{MS}(Fl,y)*SF(Fl,St,y)-Lgt(St,y,a,q)}{\mathrm{MS}(Fl,y)*SF(Fl,St,y)*(SR(Fl,St,y)-1)}}} \qquad \text{(A.3.2.1.b)}$$

Figure A.3.2.2. shows the input to a simple estimation of "overall" LGT50% and LGT50% for western Baltic cod from WGBFAR (ICES, 2006). This approach is based on the assumption that selection has remained constant from 2000 to 2005. The input data is catch and stock numbers from the WGBFAR report (ICES, 2006). Input to the analysis is the average catch and average landings. The selection ogive estimated here is the overall gear selection (the combined selection of all gears). This selection ogive may be used for gears where no better estimate is available.

From WGBFAR (ICES, 2006)

Stock numbers from XSA

YEAR	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean 2000-2005
AGE											Stock
1	41668	98017	127965	57917	63822	45892	67821	34919	66557	23759	50462
2	86104	12737	59297	82494	40414	40452	30377	49271	24097	49563	39029
3	32064	39938	6937	23478	33601	17127	14371	14468	20857	15502	19321
4	5818	7348	7346	2644	6282	7900	3279	3507	5497	5982	5408
5	3988	1462	1334	1821	507	1576	1585	714	1144	1341	1145
6	546	1259	265	458	454	139	471	437	283	364	358
+gp	74	300	172	183	132	142	64	138	159	123	126
TOTAL	170261	161062	203317	168996	145213	113228	117968	103455	118594	96635	

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean 2000-2005 Catch
1	21420	19922	20277	5704	10893	6377	4483	3743	3034	633	4861
2	33772	3859	27707	37509	17640	20720	11497	21532	4671	13912	14995
3	20892	28019	3354	14301	21672	11873	9128	7016	12261	11264	12202
4	3648	5174	4634	1832	3942	5397	2178	1909	3492	3561	3413
5	2217	1030	701	1146	306	906	951	333	633	830	660
6	306	681	123	234	217	76	255	175	165	220	185
7	13	124	66	54	39	60	24	49	66	43	
8	7	34	15	38	8	15	9	5	21	17	
9	0	0	0	3	10	3	1	2	3	1	
10	4	7	0	0	7	1	1	0	4	15	
11+	18	0	0	0	0	0	0	0	0	0	

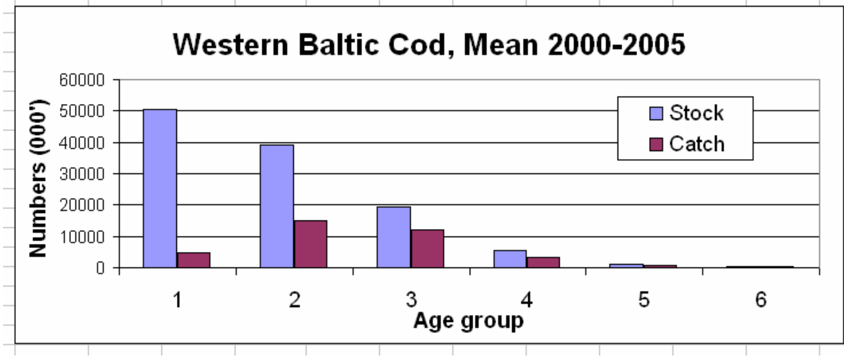
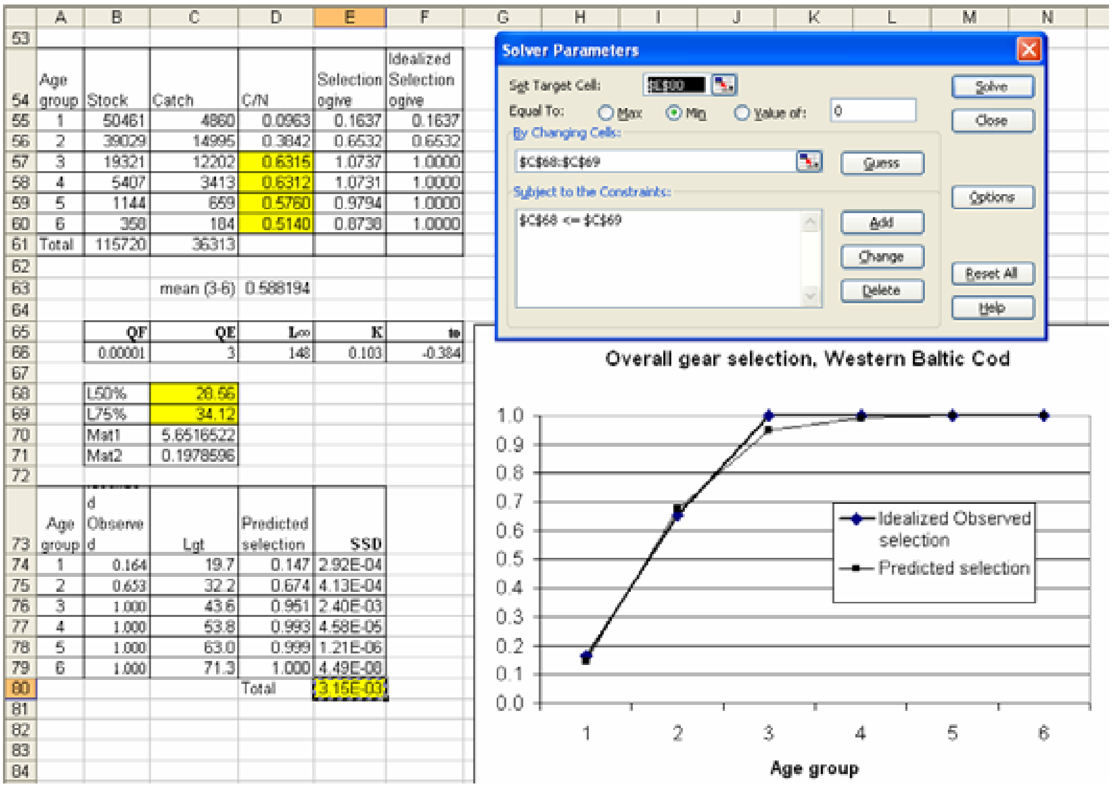


Figure A.3.2.2. Input to estimation of "overall" LGT50% and LGT50% for western Baltic cod from WGBFAR (ICES, 2006)

The idea is then to select an age group believed to be under full exploitation. In the present case we select age 3 (see the graph on Figure A.3.2.3.A). From this age an onwards we allocate the value 1 to the selection. Next step is to estimate the selection parameters $LGT_{50\%}$ and $LGT_{50\%}$ exactly as the parameters for maturity were estimated (Figures A.3.2.3.A and B).

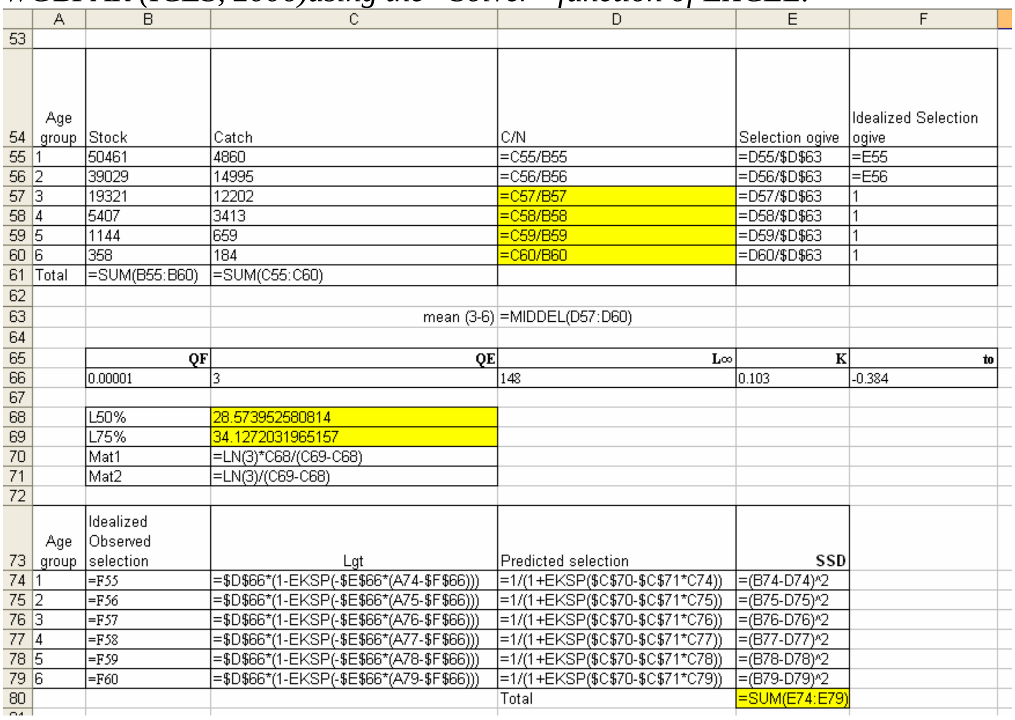
Notice that the same method can be applied to estimate the selection ogive for a fleet, or a combination of a fleet and a gear (a "rigging").



	Age group	Stock	Catch	C/N	Selection ogive	Idealized Selection ogive
55	1	50461	4860	0.0963	0.1637	0.1637
56	2	39029	14995	0.3842	0.6532	0.6532
57	3	19321	12202	0.6315	1.0737	1.0000
58	4	5407	3413	0.6312	1.0731	1.0000
59	5	1144	659	0.5760	0.9794	1.0000
60	6	358	184	0.5140	0.8738	1.0000
61	Total	115720	36313			
63			mean (3-6)	0.588194		
65		QF	QE	L∞	K	t0
66		0.00001	3	148	0.103	-0.384
68		L50%	28.56			
69		L75%	34.12			
70		Mat1	5.6516522			
71		Mat2	0.1978596			

	Age group	Observed	Lgt	Predicted selection	SSD
74	1	0.164	19.7	0.147	2.92E-04
75	2	0.653	32.2	0.674	4.13E-04
76	3	1.000	43.6	0.951	2.40E-03
77	4	1.000	53.8	0.993	4.58E-05
78	5	1.000	63.0	0.999	1.21E-06
79	6	1.000	71.3	1.000	4.49E-08
80				Total	3.15E-03

Figure A.3.2.3.A. Estimation of "overall" LGT50% and LGT50% for western Baltic cod from WGBFAR (ICES, 2006)using the "Solver" function of EXCEL.



	A	B	C	D	E	F
54	Age group	Stock	Catch	C/N	Selection ogive	Idealized Selection ogive
55	1	50461	4860	=C55/B55	=D55/$D$63	=E55
56	2	39029	14995	=C56/B56	=D56/$D$63	=E56
57	3	19321	12202	=C57/B57	=D57/$D$63	1
58	4	5407	3413	=C58/B58	=D58/$D$63	1
59	5	1144	659	=C59/B59	=D59/$D$63	1
60	6	358	184	=C60/B60	=D60/$D$63	1
61	Total	=SUM(B55:B60)	=SUM(C55:C60)			
63			mean (3-6)	=MIDDEL(D57:D60)		
65		QF	QE	L∞	K	t0
66		0.00001	3	148	0.103	-0.384
68		L50%	28.573952580814			
69		L75%	34.1272031965157			
70		Mat1	=LN(3)*C68/(C69-C68)			
71		Mat2	=LN(3)/(C69-C68)			
73	Age group	Idealized Observed selection	Lgt	Predicted selection	SSD	
74	1	=F55	=$D$66*(1-EKSP(-$E$66*(A74-$F$66)))	=1/(1+EKSP($C$70-$C$71*C74))	=(B74-D74)^2	
75	2	=F56	=$D$66*(1-EKSP(-$E$66*(A75-$F$66)))	=1/(1+EKSP($C$70-$C$71*C75))	=(B75-D75)^2	
76	3	=F57	=$D$66*(1-EKSP(-$E$66*(A76-$F$66)))	=1/(1+EKSP($C$70-$C$71*C76))	=(B76-D76)^2	
77	4	=F58	=$D$66*(1-EKSP(-$E$66*(A77-$F$66)))	=1/(1+EKSP($C$70-$C$71*C77))	=(B77-D77)^2	
78	5	=F59	=$D$66*(1-EKSP(-$E$66*(A78-$F$66)))	=1/(1+EKSP($C$70-$C$71*C78))	=(B78-D78)^2	
79	6	=F60	=$D$66*(1-EKSP(-$E$66*(A79-$F$66)))	=1/(1+EKSP($C$70-$C$71*C79))	=(B79-D79)^2	
80				Total	=SUM(E74:E79)	

Figure A.3.2.3.B. EXCEL formulas for Estimation of "overall" LGT50% and LGT50% for western Baltic cod from WGBFAR (ICES, 2006).

Once, $LGT_{50\%}$ and $LGT_{50\%}$ is estimated for a particular gear, the selection factor is given from a division by the mesh size, MS

$$SF(Fl, St, y) = LGT_{50\%}(Fl, St, y) / MS(Fl, y)$$

and the selection range

$$SR(Fl, St, y)=2*(LGT_{75\%}(Fl, St, y) -LGT_{50\%}(Fl, St, y)).$$

As discussed above, what is the physical meaning of the term "mesh size" is not specified in the TEMAS model. One important concept in the case of Baltic cod is the BACOMA trawl, which has a panel of square meshes. The "mesh size" may be linked to the size of the square meshes, but the mesh sizes in the BACOMA panel may not be the only parameter determining the selection. For a description of various parameters of the BACOMA trawl, see for example, Appendix 1 to Annex III in COUNCIL REG. (EC) No 27/2005.

Note that the method assumes that the stock is in equilibrium, an assumption which is more likely to be met, the longer the time series is. This in terms implies the assumption that the selection ogive (e.g. mesh size) has remained constant. The method is indeed questionable, but the next question is then the quality of the input data relative to the sophistication of the estimation method.

A.3.3. MINIMUM LANDIG SIZE

The minimum landing sizes, $Lgt_{Min}^{Land}(St, y, q, Ar)$, of Baltic species in 2006 are shown in Table A.3.3.1. The fish below the minimum allowed landing length is named "undersized fish".

Species	**Geographical area**	**Minimum size**
Cod (*Gadus morhua*)	Subdivisions 22-32	38 cm
Flounder (*Platichthys flesus*)	Subdivisions 22 to 25	23 cm
	Subdivisions 26 to 28	21 cm
	Subdivisions 29 to 32, south of 59° 30'N	18 cm
Plaice (*Pleuronectes platessa*)	Subdivisions 22 to 32	25 cm
Turbot (*Psetta maxima*)	Subdivisions 22 to 32	30 cm
Brill (*Scophthalmus rhombus*)	Subdivisions 22 to 32	30 cm
Eel (*Anguilla anguilla*)	Subdivisions 22 to 32	35 cm
Salmon (*Salmo salar*)	Subdivisions 22 to 30 and 32	60 cm
	Subdivision 31	50 cm
Sea trout (*Salmo trutta*)	Subdivisions 22 to 25 and 29 to 32	40 cm
	Subdivision 26 to 28	50 cm

Table A.3.3.1. Minimum landing sizes of Baltic species in 2006. (Source Annex IV of COUNCIL REG. (EC) No 2187/2005.)

The influence of minimum legal landing $Lgt_{Min}^{Land}(St, y, q, Ar)$ size is accounted for in TEMAS in two ways

1) The choice of mesh size and thereby the choice of gear selection parameters,
2) The discard-model practice.

If the minimum landing size is smaller than

$$LGT_{25\%}(Fl,Vs,Rg,Ct,St,y,q) = LGT_{50\%}(Fl,Vs,Rg,Ct,y,q) - SR(Fl,Vs,Rg,Ct,St,y,q)/2$$

where $LGT_{50\%}$ is defined as the product of mesh size (MS) and selection factor (SF).

$$LGT_{50\%}(Fl,Vs,Rg,Ct,St,y,q) = MS(Fl,Vs,Rg,Ct,y,q) * SF(Fl,Vs,Rg,Ct,St,y,q)$$

and the selection range is defined as $SR = L_{75\%} - L_{25\%}$. (Section A.3.2)
Then there is less than 25%probability that undersize fish are caught, if they encounter the gear. Thus, we can choose the mesh size so that

$$Lgt_{Min}^{Land}(St,y,q,Ar) \geq LGT_{25\%}(Fl,Vs,Rg,St,Ct,y,q) \qquad \text{(A.3.1.1.a)}$$

Which when isolating the mesh size becomes the mesh size condition

$$(Lgt_{Min}^{Land}(St,y,q,Ar) + SR(-)/2)/SF(-) \geq MS(Fl,Vs,Rg,St,Ct,y,q) \qquad \text{(A.3.1.1.b)}$$

The discard practice in TEMAS can be determined in two ways

1) Using the behaviour model (RUM) for discard practice
2) Not using the behaviour model for discard practice, i.e. use a fixed assumption for discard practice.

The current implementation of TEMAS has the minimum landing size as an input parameter, and the model lets all undersized fish be discarded, in case the behaviour model for discard practice is turned off. One of the choices available for discard practice is to let all undersized fish be discarded.

$$\mathrm{DIS}(\mathrm{St,Fl,Vs,Rg,y,a,q,Ar}) = \begin{cases} 1 - \dfrac{1}{1 + \exp(\mathrm{Dis1}(\mathrm{Fl,Vs,Rg,St,y}) - \mathrm{Dis2}(\mathrm{Fl,Vs,Rg,St,y}) * \mathrm{Lgt}(St,a,q))} \\ \qquad if \quad Lgt(St,a,.q) > Lgt_{Min}^{Land}(St,y,q,Ar) \\ 1 \quad if \quad Lgt(St,a,q) \leq Lgt_{Min}^{Land}(St,y,q,Ar) \end{cases} \qquad \text{(A.3.3.2)}$$

where
Dis1(St) = ln(3)* $LGT_{50\%Discards}$(St)/($LGT_{25\%Discards}$(St) - $LGT_{50\%Discards}$(St)),
Dis2(St) = ln(3)/($LGT_{25\%Discards}$(St) - $LGT_{50\%Discards}$(St)) and
$LGT_{X\%Discards}$(St) = Length at which X % are retained.

Figure A.3.3.1 shows a (hypothetical example of a) conventional discard curve (curve A) together with a discard curve with account of minimum landing length (curve B).

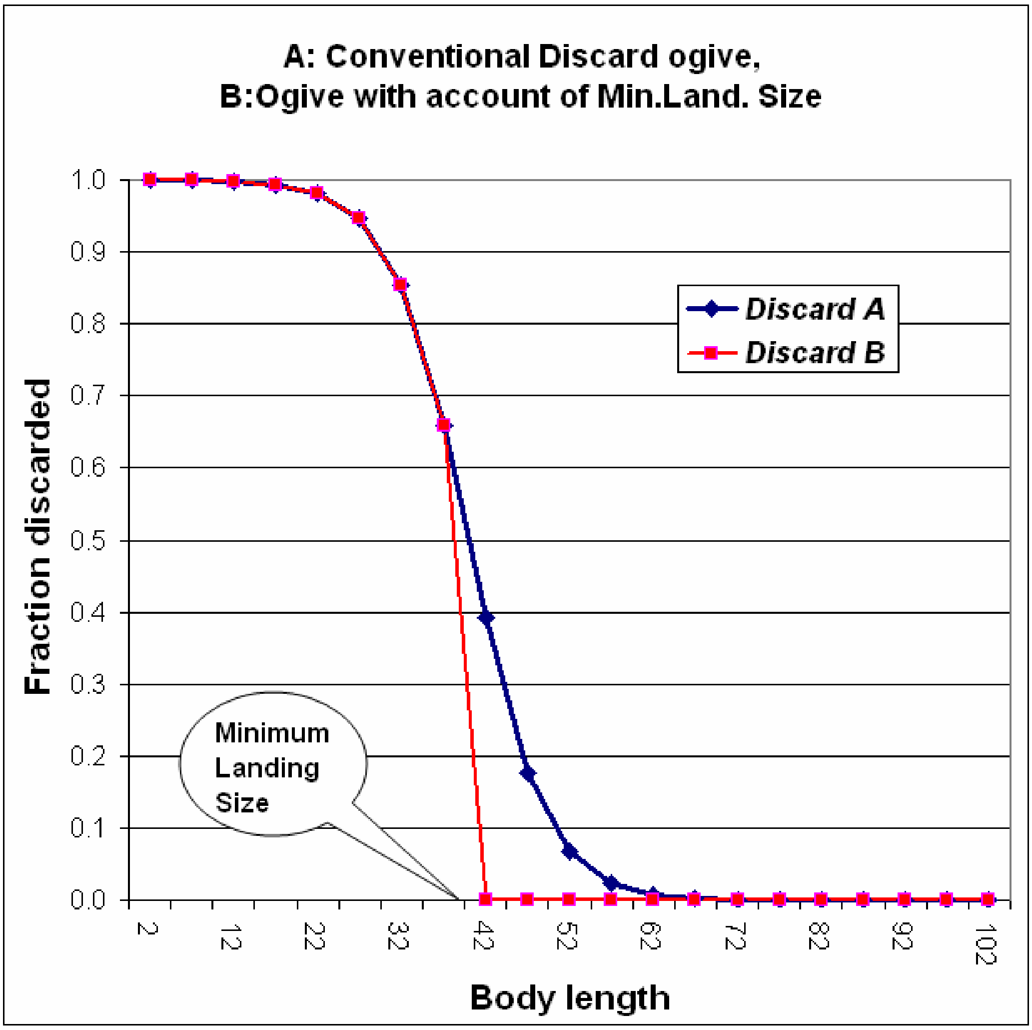


Figure A.3.3.1. Conventional discard curve (A) and discard curve with account of minimum landing length (B).

A.4. NUMBER OF VESSELS, EFFORT AND CAPACITY

The tradition of ICES WGs is to give F, the fishing mortality as input to the catch prediction. Usually, ICES WGs will operate with the total fishing mortality (the combined effect of all fishing fleets). The ICES WG will not use, say, the number of vessels or the number of vessel days at sea or any other data behind the "F". Information on fishing days (or days at sea) has been available for more than a decade, from the logbook databases of EU member states and also from several other states (see for example, the reports of the STECF WG on mixed fisheries, and effort based management, 2006, which presents examples of fleet-based data). The basic idea presented here is not new in general, but is new relative to ICES WGs. The model does the very obvious thing, namely, relates fishing mortality to fishing effort, and in turns the model relates fishing effort to the number of vessels.

The TEMAS model keeps track of the age distributions of vessels in a fleet as the ICES model keeps track of the age distributions of fish. The information on age distributions of vessels (and many other vessel data) are available from the national vessel registers, so there are no hard data problems with the vessels as there are with the data for fish stocks.

Annex F (Basic features of Baltic Fisheries), gives tables of number of vessels by each Baltic country. It also shows that there are public lists of all vessels holding a permit to catch cod in the Baltic. Thus, it appears to be easy to get information on the number of vessels. However, the problem is which of the vessels in the list that are actively fishing in the Baltic, - at which part of the year they are actively using the license. If it was so that the vessels were doing only fishing activities only in a certain sea area and never moved outside this area, the definition of number of vessels would be easier. If, furthermore, no other vessels ever came from outside this area to fish there, there would be no problems in defining the "number of vessels". This might be the case in an isolated lake. Unfortunately, the Baltic and the countries bordering the Baltic cross the borders, and vessels come from outside to fish in the Baltic for short or long periods. Theoretically, the problem might be solved by including all fishing vessels of the world in the model simulation, but needless to say, this approach also has its practical drawbacks.

The following subsections, however, are not concerned with the definition and estimation of number of vessels at the start year of the simulation. In the following sections we shall assume these problems to be overcome. We shall only look at definitions related to predictions, where the concept of "number of vessels are assumed" to be meaningful. In section A.8 we shall come back to the problems of definition and estimation of "number of vessels".

A.4.1. NUMBER AND AGE DISTRIBUTION OF VESSELS:

The number of vessels (whatever it is), $NU_{Vessel}(Fl, Vs, Ct, y, q, \bullet)$, is in TEMAS composed of "vessel age groups", that is[2]

$$NU_{Vessel}(Fl, Vs, Ct, y, q, \bullet) = \sum_{Va=1}^{Va_{Max}} NU_{Nessel}(Fl, Vs, Ct, y, q, Va) \qquad \text{(A.4.1.1)}$$

where $NU_{Vessel}(Fl, Vs, Ct, y, q, Va)$ = Number of vessels which has age "Va". Like the fish, vessels have a mortality, which can be due to having reached the end of their techno-economic lifetime (attrition), withdrawal because of bad financial performance or decommissioning through a buy-back programme.

The (simulated or predicted) number of vessels is updated once per time period, at the beginning of the time period. In the following only one index of time, "y" is used. To be complete the formulas should also have had the period index, "q".

The number of vessels, $NU_{Vessel}(Fl, Vs, Ct, y, q, Va)$, is defined by iteration:

	q > 1	q = 1
Va = 0	$NU_{Vessel}(Fl, Vs, Ct, y, q, 0) = NU_{New\text{-}Vessel}(Fl, Vs, Ct, y, q)$	$NU_{Vessel}(Fl, Vs, Ct, y, 1, 0) = NU_{New\text{-}Vessel}(Fl, Vs, Ct, y, q)$
Va = 1,2,…,Va_{max}-1	$NU_{Vessel}(Fl, Vs, Ct, y, q, Va) = NU_{vessel}(Fl, y, q-1, Va) - NU_{Decomm}(Fl, Vs, Ct, y, q, Va) - NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va) - NU_{Attrition}(Fl, Vs, Ct, y, q, Va)$	$NU_{Vessel}(Fl, Vs, Ct, y, Va) = NU_{vessel}(Fl, y-1, q_{Max}, Va) - NU_{Decomm}(Fl, Vs, Ct, y, 1, Va) - NU_{Withdrawal}(Fl, Vs, Ct, y, 1, Va) - NU_{Attrition}(Fl, Vs, Ct, y, 1, Va)$
Va = Va_{Max} (plus group)	$NU_{vessel}(Fl, Vs, Ct, y, q, Va) = NU_{vessel}(Fl, Vs, Ct, y, q-1, Va_{Max}) + NU_{Decomm}(Fl, Vs, Ct, y, q, Va_{Max}) - NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va_{Max}) - NU_{Attrition}(Fl, Vs, Ct, y, q, Va_{Max})$	$NU_{vessel}(Fl, Vs, Ct, y, 1, Va) = NU_{vessel}(Fl, y-1, q_{Max}, Va_{Max}) + NU_{vessel}(Fl, y-1, q_{Max}, Va_{Max}-1) - NU_{Decomm}(Fl, Vs, Ct, y, 1, Va_{Max}) - NU_{Withdrawal}(Fl, Vs, Ct, y, 1, Va_{Max}) - NU_{Attrition}(Fl, Vs, Ct, y, 1, Va_{Max})$

Where NU_{Decomm}, $NU_{Attrition}$ and $NU_{Withdrawal}$ are the numbers of vessels withdrawn due to a vessel decommissioning, retired vessels having reached the end of their techno-economic lifetime and withdrawn and due to bad financial performance.

$NU_{New\text{-}Vessel}(Fl, Vs, Ct, y, q)$ is the (simulated or predicted) number of new vessels (number of investments in new vessels).

---

2 2:

	Index	Explanation	Range
1	a	Age group	a = 0,1,2,…,a_{max}(St)
2	Ar	Area	Ar = 1,2,…,Ar_{max}
3	Ct	Country	Ct = 1,…,Ct_{Max}
4	Fl	Fleet	Fl = 1,2,…,Fl_{max}(Ct)
5	q	Time period (as time)	q = 1,..,q_{max}
6	qa	Time period (as age)	qa = 1,..,q_{max},
7	Rg	Rigging of gear	Rg = 1,…,Rg_{max}(Fl,Ct)
8	y	Year	y = $y_{firSt, yfirst}$+1,…,y_{last}
9	St	Stock	St = 1,…,St_{max}
10	Va	Vessel age group	Va = 1,…Va_{max}(Fl,Ct)
11	Vs	Vessel size group	Vs = 1,…Vs_{max}(Fl,Ct)

Note that the sequence of indices will be (Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar) for all variables.

Time variables in alphabetical order
dt: Basic time step (fraction of year). dt < 1.0. dt = $1/q_{Max}$
y_{first} ,y_{last}: First year, Last year

Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j) = \sum_u X(i,u,j)$.

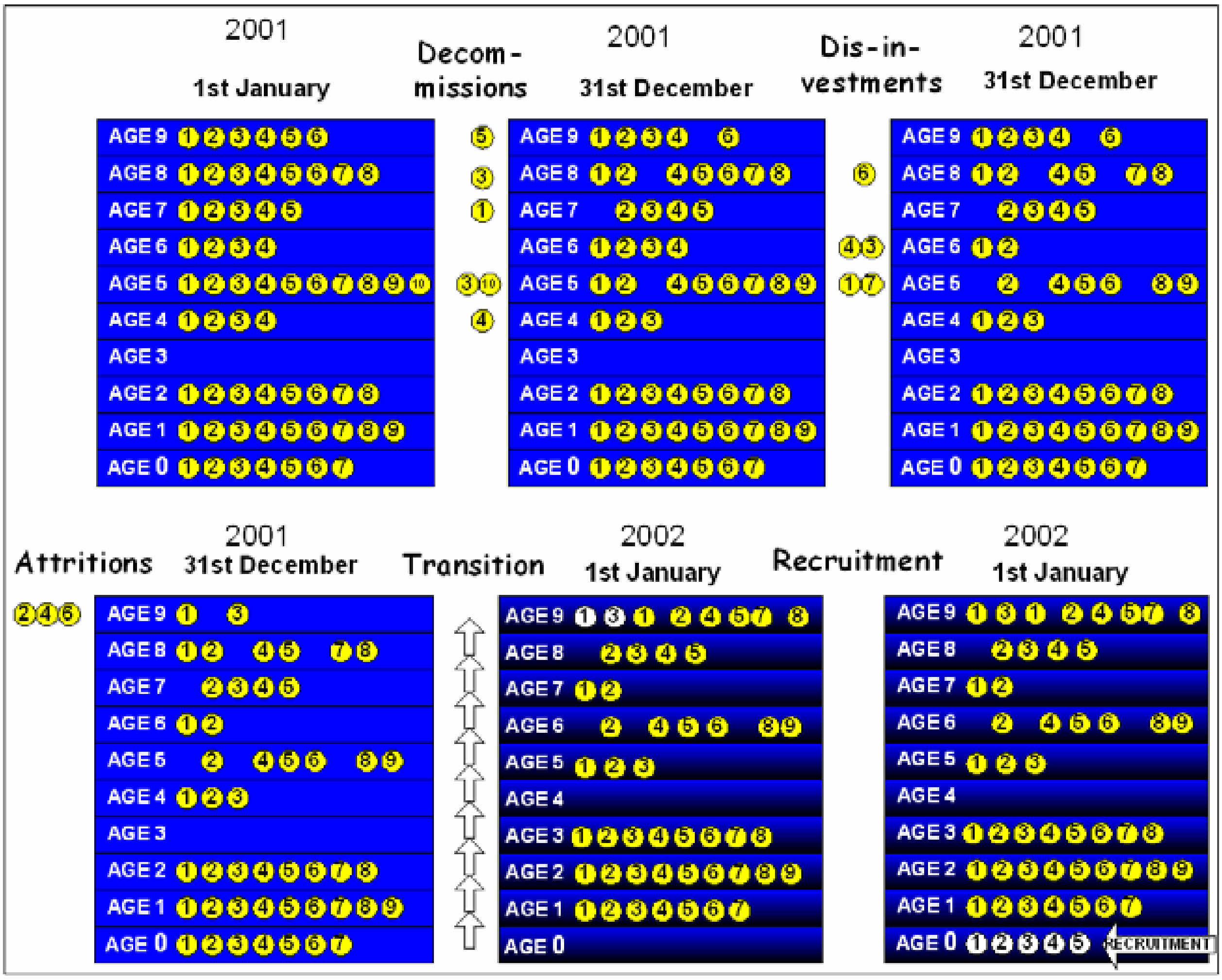


Figure A.4.1.1. Example of vessel number dynamics, where the sequence of events is (1) Decommission (2) Disinvestments (3) Attritions (4) Recruitments (Investments).

The (simulated or predicted) numbers may be either given as input parameters or be determined by the "Structural or long term Fleet behaviour rules". When the number of vessels are computed according to the so-called "structural behaviour rules" of fishing firms, they are computed as a fraction of the existing number of vessels. In that case, it becomes essential in which sequence numbers are computed. For example, the number of decommissions are computed before the number of withdrawals are computed. If a vessel-owner has the choice between decommission and withdrawal without compensation, it is assumed that he will choose the decommission. An example of vessel number dynamics is shown in Figure A.4.1.1, where the sequence of events is (1) Decommission (2) Disinvestments (3) Attritions (4) Recruitments (Investments).

If it is attempted to remove more vessels than there actually are, the input values are changed by the TEMAS program, so that the removals become feasible, as described in the 3-steps algorithm below. (We use the sign " ← " to denote assignment)

Step 1: Decommission

If
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \geq NU_{Decomm}(Fl, Vs, Ct, y, q,Va)$
Then
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \leftarrow NU_{Vessel}(Fl, Vs, Ct, y, q, Va) - NU_{Decomm}(Fl, Vs, Ct, y, q,Va)$
Else
  $NU_{Decomm}(Fl, Vs, Ct, y, q,Va) \leftarrow NU_{Vessel}(Fl, Vs, Ct, y, q, Va)$
  and
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \leftarrow 0$

Step 2: Attrition

If
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \geq NU_{Attrition}(Fl, Vs, Ct, y, q,Va)$
Then
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \leftarrow NU_{Vessel}(Fl, Vs, Ct, y, q, Va) - NU_{Attrition}(Fl, Vs, Ct, y, q,Va)$
Else
  $NU_{Attrition}(Fl, Vs, Ct, y, q,Va) \leftarrow NU_{Vessel}(Fl, Vs, Ct, y, q, Va)$
  and
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \leftarrow 0$

Step 3: Disinvestment (Withdrawal)

If
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \geq NU_{Withdrawal}(Fl, Vs, Ct, y, q,Va)$
Then
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \leftarrow NU_{Vessel}(Fl, Vs, Ct, y, q, Va) - NU_{Withdrawal}(Fl, Vs, Ct, y, q,Va)$
Else
  $NU_{Withdrawal}(Fl, Vs, Ct, y, q,Va) \leftarrow NU_{Vessel}(Fl, Vs, Ct, y, q, Va)$
  and
  $NU_{Vessel}(Fl, Vs, Ct, y, q, Va) \leftarrow 0$

Step 4: Recruitment

$NU_{Vessel}(Fl, Vs, Ct, y, q, 0) = NU_{New-Vessel}(Fl, Vs, Ct, y,q)$

A.4.2. NUMBER OF VESSELS MULTIPLIERS:

The TEMAS model considers the number of vessels by fleet and their capacity to create fishing mortality as key-parameters. The parameters are (in principle) under the control of man, and therefore we have introduced a number of auxiliary variables by which the number of vessels can be manipulated .

The number of new vessels (investments) is created from a “reference number” multiplied by a “Multiplier”:

$$NU_{Vessel}(Fl,Vs,Ct,y,q,0) = X_0^{Vessels} * X_1^{Vessels}(Fl,Vs,Ct,y,q) * NU_{New\ Vessels}^{Reference}(Fl,Vs,Ct,y,q)$$

The multiplier is composed of two factors, where the first factor is independent, and applies to all fleets in all time periods, whereas the second factor depends on fleet and time period.
The multiplier is also applied to the initial number of vessels, that is, the number of vessels in first period of first year. The multiplier applies to all vessel age groups in the initial fleets.

A.4.3. FISHING DAYS OR SEA DAYS:

The variable Effort concepts of TEMAS relates to two purposes:

1) To convert fishing activity into fishing mortality
2) To convert fishing activity into costs of fishing.

Effort of time period q in year y is designated E(Fl, y, q, Ar). TEMAS does not assume a particular type of effort-definition. Effort will usually be measured in sea-days (days away from port) or fishing days (= sea-days – days to steam to and from the fishing grounds).

The definition of Effort might have been more closely related to the fishing operation, such as the "number of kgWat days", "number of trawling hours" or "number of gill net set", but in that case two measures of effort may be required, one for the derivation of fishing mortality and one for the derivation of cost of fishing. However, TEMAS can handle only one effort measure for each fleet. Different fleets can use different effort definitions.

The data that is usually available from logbook databases is the number of sea days. Combining the logbook data with the vessel register that holds information on engine power in KgWat, makes it easy to convert sea days into KgWat-days. KgWat-days is the effort measure used by the EU in many contexts of regulations. The so-called STECF database used to evaluate the effort based management (maximum allowed number of sea days) uses KgWat-days as effort unit (STECF, 2006). On the other hand, this data base does not contain information on vessel sizes, which to a certain degree would reflect the engine power.

In any case it is important to note the unit of effort "Number of effort units exerted during a time period". We will mainly think of effort as "number of sea-days per period", but keep in mind that other definitions can be used, so the general unit of E(Fl, y, q, Ar) becomes "number of effort units per period".

Effort and number of vessels are the control parameters in the fisheries management model. Effort can be controlled in TEMAS in two ways:

(1) Giving effort as input
(2) Let the "Effort-rule" decide the effort (see Section 5).

In the following we shall deal with only the first way of entering effort in the TEMAS model, although the second one may be the most relevant one for practical applications.

$E(Fl, Vs, \bullet, Ct, y, q, \bullet) = \sum_{Ar=1}^{NU_{Area}} \sum_{Rg=1}^{Rg(Fl)} E(Fl, Vs, Rg, Ct.y, q, Ar)$ is the total effort exerted by fleet (Fl,Vs,Ct) during time period q

The input effort in the present version of TEMAS is E(Fl, Vs, Ct, y, q,•), that is the total effort summed over areas, together with the relative distribution of effort over areas:

$$E_{Area-Dist}(Fl, Vs, \bullet, Ct, y, q, Ar) = \frac{E(Fl, Vs, \bullet, Ct, y, q, Ar)}{E(Fl, Vs, \bullet, Ct, y, q, \bullet)} \qquad \text{(A.4.3.1)}$$

The effort distribution can be given as input each period each year, in the case where the behaviour rules (Section 5) are not applied.

Thus, effort is derived from the product of the two input parameters,

$E(Fl, Vs, \bullet, Ct, y, q, \bullet)$ and $E_{Area\text{-}Dist}(Fl, Vs, \bullet, Ct, y, q, Ar)$

Which in turn gives the effort distribution on fleets, vessels sizes and countries:

$$E(Fl, Vs, \bullet, Ct, y, q, Ar) = E(Fl, Vs, \bullet, Ct, y, q, \bullet) * E_{Area\text{-}Dist}(Fl, Vs, \bullet, Ct, y, q, Ar) \quad (A.4.3.2)$$

The next step in the distribution of effort is the distribution on riggings for given area:

$$E(Fl, Vs, Rg, Ct, y, q, Ar) = E(Fl, Vs, \bullet, Ct, y, q, Ar) * E_{Rig\text{-}Dist}(Fl, Vs, Rg, Ct, y, q, Ar) \quad (A.4.3.3)$$

The definition of effort distribution on riggings for given area, Ar is

$$E_{Rig-Dist}(Fl, Vs, Rg, Ct, y, q, Ar) = \frac{E(Fl, Vs, Rg, Ct, y, q, Ar)}{E(Fl, Vs, \bullet, Ct, y, q, Ar)}$$

The nested definition of distribution on areas, and distribution on riggings for given area, are illustrated in Table A.4.3.1.

$E_{Ref}(Fl, Vs, \bullet, Ct, y, q, \bullet)$= **<u>1000</u>**		
Ar	$E_{Area\text{-}Dist}(Fl, Vs, \bullet, Ct, y, q, Ar)$	$E(Fl, Vs, \bullet, Ct, y, q, Ar)$
Area 1	**<u>0.3</u>**	300
Area 2	**<u>0.5</u>**	500
Area 3	**<u>0.2</u>**	200

Ar	$E_{Rig\text{-}Dist}(Fl, Vs, Rg=1, Ct, y, q, Ar)$	$E_{Rig\text{-}Dist}(Fl, Vs, Rg=2, Ct, y, q, Ar)$	$E_{Rig\text{-}Dist}(Fl, Vs, Rg=3, Ct, y, q, Ar)$
Area 1	**<u>0.2</u>**	**<u>0.3</u>**	**<u>0.5</u>**
Area 2	**<u>0.3</u>**	**<u>0.4</u>**	**<u>0.3</u>**
Area 3	**<u>0.5</u>**	**<u>0.3</u>**	**<u>0.2</u>**

Ar	E(Fl, Vs, •, Ct, y, q, Ar)	E(Fl, Vs, Rg=1, Ct, y, q, Ar)	E(Fl,Vs,Rg=2, Ct, y, q, Ar)	E(Fl,Vs,Rg=3, Ct, y, q, Ar)	Total
Area 1	300	60	90	150	300
Area 2	500	150	200	150	500
Area 3	200	100	60	40	200
				Total	1000

Table A.4.3.1. Hypothetical example of effort distributions on areas and riggings. The input parameters are underlined.

The two effort distributions may also be considered the probability that a vessel will choose and area, and then given that area the probability that a it will choose a rigging. Thus, the effort distributions

$E_{Area-Dist}(Fl, Vs, \bullet, Ct, y, q, Ar)$ and

$$E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar)$$

will be linked to the model of fisher's behaviour (Section 5).

To summarize the distribution, the complete model of effort distribution on areas, and on rigs for given area read:

$$E(Fl,Vs,Rg,Ct,y,q,Ar) = E_{\mathrm{Re}\,f}(Fl,Vs,\bullet,Ct,y,q,\bullet)*$$
$$E_{Rig-dist}(Fl,Vs,Rg,y,q,Ar)*E_{Area-dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$$

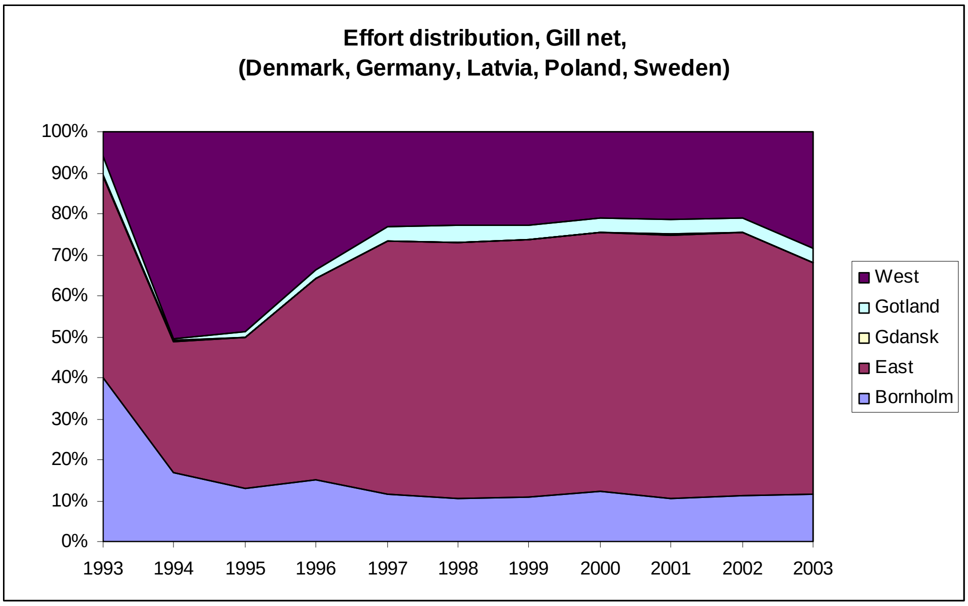


Figure A.4.3.1. Mean (over time periods) effort distribution of gill net effort of the combined fleets from Denmark, Germany, Latvia, Poland and Sweden)

Spatial distribution of Baltic effort, can be aggregated in various ways.

Table A.4.3.2. shows the effort distribution of Danish trawlers, by months, 2003-5, that is

$$E_{Distribution}(Fl,\bullet,\bullet,Ct,y,q,Ar) = \frac{E(Fl,\bullet,\bullet,Ct,y,q,Ar)}{E(Fl,\bullet,\bullet,Ct,y,q,\bullet)}$$

Figure A.4.3.1. shows the mean (over time periods) effort distribution of gill net effort of the combined fleets from Denmark, Germany, Latvia, Poland and Sweden) 1993-2003 on the 5 areas "West","East","Bornholm deep", "Gotland deep" and "GDansk deep", that is

$$E_{Distribution}(Fl,\bullet,\bullet,\bullet,y,\bullet,Ar) = \frac{E(Fl,\bullet,\bullet,\bullet,y,\bullet,Ar)}{E(Fl,\bullet,\bullet,\bullet,y,\bullet,\bullet)}$$ Fl="Gill net", y = 1993, …,2003.

Note that distribution remained almost constant from 1997 to 2002.
Figure A.4.3.2 shows a similar graph for trawl., which show more variation than gill net, but still not very big variations from year to year.
Figure A.4.3.3 shows

$$E_{Distribution}(Fl,\bullet,\bullet,Ct,y,\bullet,Ar) = \frac{E(Fl,\bullet,\bullet,Ct,y,\bullet,Ar)}{E(Fl,\bullet,\bullet,Ct,y,\bullet,\bullet)}$$

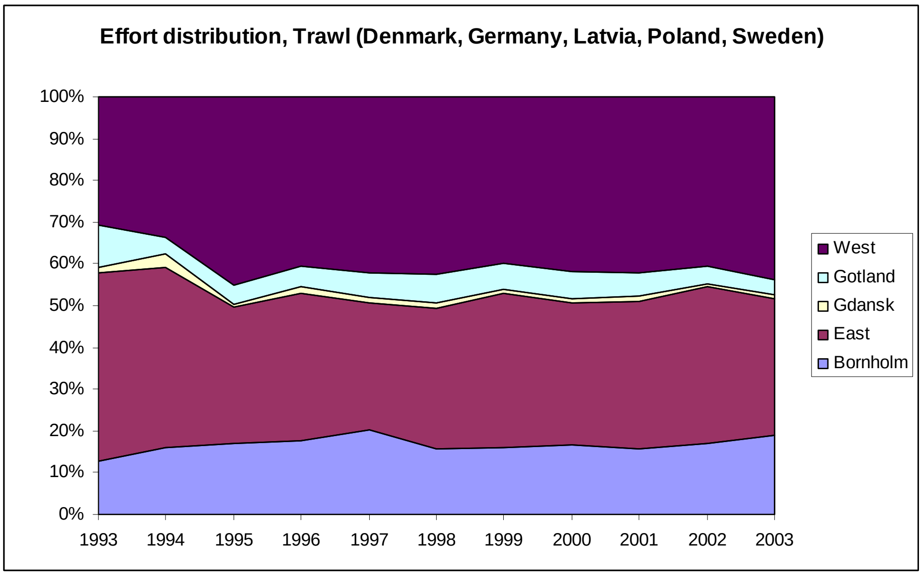


Figure A.4.3.2. Mean (over time periods) effort distribution of trawl effort of the combined fleets from Denmark, Germany, Latvia, Poland and Sweden)

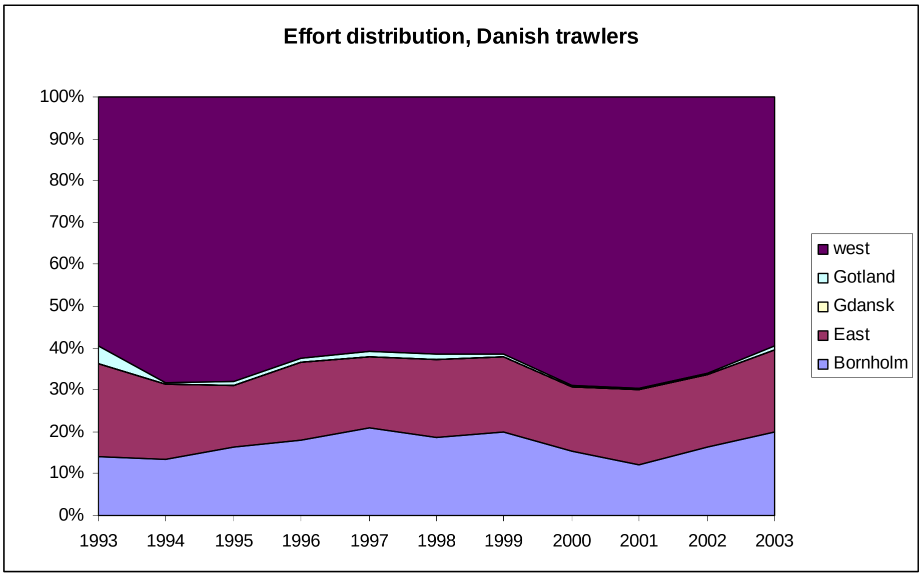


Figure A.4.3.3. Mean (over time periods) effort distribution of Danish trawl.

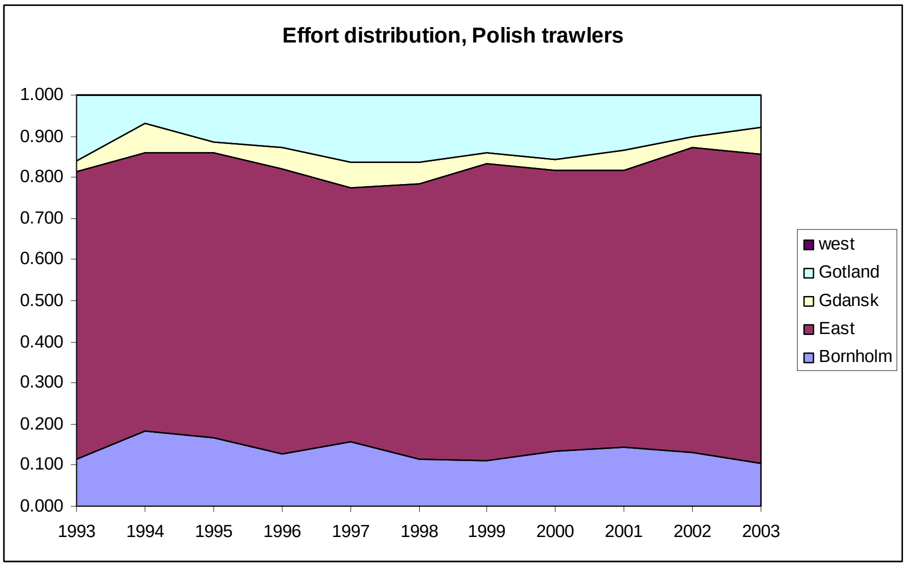


Figure A.4.3.4. Mean (over time periods) effort distribution of Polish trawl.

		Sea days						Distribution					
Year	Month	Born-holm	East	Gdansk	Got-land	west	Total	Born holm	East	Gdansk	Got-land	west	Total
2003	1	473	679			3911	5063	0.093	0.134	0.00000	0.00000	0.772	1.00
	2	832	717		13	2935	4497	0.185	0.159	0.00000	0.00289	0.653	1.00
	3	1198	597			1709	3504	0.342	0.170	0.00000	0.00000	0.488	1.00
	4	530	461		5	452	1448	0.366	0.318	0.00000	0.00345	0.312	1.00
	5	153	68			23	244	0.627	0.279	0.00000	0.00000	0.094	1.00
	6	156	193			443	792	0.197	0.244	0.00000	0.00000	0.559	1.00
	7	113	245			598	956	0.118	0.256	0.00000	0.00000	0.626	1.00
	8	135	219			587	941	0.143	0.233	0.00000	0.00000	0.624	1.00
	9	397	408		9	624	1438	0.276	0.284	0.00000	0.00626	0.434	1.00
	10	314	489		92	966	1861	0.169	0.263	0.00000	0.04944	0.519	1.00
	11	393	507		58	1446	2404	0.163	0.211	0.00000	0.02413	0.601	1.00
	12	305	387		9	1310	2011	0.152	0.192	0.00000	0.00448	0.651	1.00
2003	**Total**	**4999**	**4970**		**186**	**15004**	**25159**	**0.199**	**0.198**	**0.00000**	**0.00739**	**0.596**	**1.00**
2004	1	586	562			3144	4292	0.137	0.131	0.00000	0.00000	0.733	1.00
	2	802	470	1	10	2838	4121	0.195	0.114	0.00024	0.00243	0.689	1.00
	3	918	527		9	2543	3997	0.230	0.132	0.00000	0.00225	0.636	1.00
	4	635	409			524	1568	0.405	0.261	0.00000	0.00000	0.334	1.00
	5	255	170			304	729	0.350	0.233	0.00000	0.00000	0.417	1.00
	6	92	77			219	388	0.237	0.198	0.00000	0.00000	0.564	1.00
	7	8	11			77	96	0.083	0.115	0.00000	0.00000	0.802	1.00
	8	43	53			252	348	0.124	0.152	0.00000	0.00000	0.724	1.00
	9	43	57			293	393	0.109	0.145	0.00000	0.00000	0.746	1.00
	10	81	183			564	828	0.098	0.221	0.00000	0.00000	0.681	1.00
	11	377	365	1	4	935	1682	0.224	0.217	0.00059	0.00238	0.556	1.00
	12	386	359			1302	2047	0.189	0.175	0.00000	0.00000	0.636	1.00
2004	**Total**	**4226**	**3243**	**2**	**23**	**12995**	**20489**	**0.206**	**0.158**	**0.00010**	**0.00112**	**0.634**	**1.00**
2005	1	396	434			2642	3472	0.114	0.125	0.00000	0.00000	0.761	1.00
	2	519	506		16	2619	3660	0.142	0.138	0.00000	0.00437	0.716	1.00
	3	962	588	1		495	2046	0.470	0.287	0.00049	0.00000	0.242	1.00
	4	964	559		4	276	1803	0.535	0.310	0.00000	0.00222	0.153	1.00
	5	155	861			1183	2199	0.070	0.392	0.00000	0.00000	0.538	1.00
	6	25	576			775	1376	0.018	0.419	0.00000	0.00000	0.563	1.00
	7	1	192			539	732	0.001	0.262	0.00000	0.00000	0.736	1.00
	8		228			626	854	0.000	0.267	0.00000	0.00000	0.733	1.00
	9	71	313			506	890	0.080	0.352	0.00000	0.00000	0.569	1.00
	10	120	280			629	1029	0.117	0.272	0.00000	0.00000	0.611	1.00
	11	371	492			925	1788	0.207	0.275	0.00000	0.00000	0.517	1.00
	12	359	552		5	670	1586	0.226	0.348	0.00000	0.00315	0.422	1.00
2005	**Total**	**3943**	**5581**	**1**	**25**	**11885**	**21435**	**0.184**	**0.260**	**0.00005**	**0.00117**	**0.554**	**1.00**

Table A.4.3.2. Effort distribution of Danish trawlers, by months, 2003-5.

A.4.4. FLEET CAPACITY AND EFFORT BASED MANAGEMENT

The capacity is the maximum number of fishing effort units (fishing days or sea days) that a fleet can exert in a time period. It is given by the variable:

EY_{MAX}(Fl, Vs, Ct, y, q, Ar) = The maximum physical number of effort units per vessel per time unit in Area Ar.

This is a technical/social concept. Vessels will need time in harbour for repair and maintenance and crew will need time for holiday. Bad weather may force the vessel to stay in harbour.

EY_{MAX}, however is a concept that is not dependent on fisheries regulations, for example, a legislation that put an upper limit to the number of sea days per time period. Nor does EY_{MAX}, depend on the resource availability or prices of landings. Thus, EY_{MAX}, is dependent only on the physical capability of vessel (with all its machinery and equipment) and the capability of the human resource to work.

$$E(Fl,Vs,\bullet,Ct,y,q,Ar) \leq NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * EY_{Max}(Fl,Vs,Ct,y,q,Ar) \qquad \text{(A.4.4.1)}$$

According to the definition of, EY_{MAX}, it is not dependent on the rigging, as a change from one rigging to another is not assumed to add or remove stress from the vessel and the crew.

Eq. A.4.4.1 secures that the effort level simulated by TEMAS will never exceed a level higher than the physical capacity of the fleets.

We define the "refererence" or the "maximum effort" by

$$E_{REF}(Fl,Vs,Ct,y,q,Ar) = NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * EY_{Max}(Fl,Vs,Ct,y,q,Ar) \qquad \text{(A.4.4.2)}$$

To account for effort based management regulations, such as maximum number of sea days we introduce the concept of "regulation effort", E_{REG}, which is rigging-specific:

$$\begin{aligned} E_{REG}(Fl,Vs,Rg,Ct,y,q,Ar) &= NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * \\ Min\{\ EY_{Max}(Fl,Vs,Ct,y,q,Ar), &ED_{Max}(Fl,Vs,Rg,Ct,y,q,Ar)\ \} \end{aligned} \qquad \text{(A.4.4.3)}$$

where $ED_{Max}(Fl,Vs,Rg,Ct,y,q,Ar)$ is the maximum number of effort units per time period given by legislation, to reduce effort. This leads to the inequality:

$$\sum_{Rg=1}^{Rg_{Max}} E_{REG}(Fl,Vs,Rg,Ct,y,q,Ar) \leq E(Fl,Vs,Ct,y,q,Ar) \qquad \text{(A.4.4.4)}$$

Notice that even when $EY_{Max}(Fl,Vs,Ct,y,q,Ar) \geq ED_{Max}(Fl,Vs,Rg,Ct,y,q,Ar)$ for some riggings but not for other riggings, the equality can be achieved in Eq. A.4.4.4 by reallocation of effort between riggings.

A.4.5. EFFORT MULTIPLIERS, CLOSED PERIODS AND CLOSED AREAS.

Assessing the effect of changing effort by fleet, rigging, area and season is the key-exercise of TEMAS. Therefore, a “multiplier” (“X_E”) to facilitate the manipulation of effort has been introduced. Actual effort used in the simulation is thus defined as the product of a “Reference-effort”, E_{Ref}(Fl , y, q, Ar), and the multipliers (X_E):

$$E(Fl,Vs,Rg,Ct,y,q,Ar) = E_{Re\,f}(Fl,Vs,Rg,Ct,y,q,Ar)* X_E(Fl,Vs,Rg,Ct,y,q,Ar)$$

Using only multipliers less than or equal to one will guarantee that the condition A.4.4.1 is met.

The use multiplier, Area-distribution and rig-distribution is illustrated in Table A.4.5.1.
In this case there are two fleets, two vessel size groups, three areas and two rigs. The year is divided into quarters. We consider only one country and only one year. The resulting effort is the product of four factors:

$$E(Fl,Vs,Rg,Ct,y,q,Ar) = E_{\mathrm{Re}\,f}(Fl,Vs,\bullet,Ct,y,q,\bullet)*$$
$$E_{Rig-dist}(Fl,Vs,Rg,y,q,Ar)*E_{Area-dist}(Fl,Vs,\bullet,Ct,y,q,Ar)*X_E(Fl,Vs,Rg,Ct,y,q,Ar)$$

The reference effort $E_{\mathrm{Re}\,f}(Fl,Vs,\bullet,Ct,y,q,\bullet)$ of four periods, is given in rows 2-5 in Table A.5.4.1 for two fleets each of which is divided into two vessel-size-classes. Rows 7-10 contains the area-distribution $E_{Area-dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$. Rows 12-15 contain the rig-distribution for given area, $E_{Rig-dist}(Fl,Vs,Rg,y,q,Ar)$. Rows 16-19 contain the product of distributions.
$E_{Rig-dist}(Fl,Vs,Rg,y,q,Ar)*E_{Area-dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$.
In the example of Table A.4.5.1. the assumed task is to close the fishery for rig 2 by vessel-size 2 in area 2 in quarters 2 and 3. This can be done by giving $E_{Rig-dist}(Fl,Vs=2,Rg=2,y,q,Ar=2)$ zero value for q =2,3, Fl=1,2. However, this implies a reallocation between rigs, namely that all effort is allocated to rig 2two, $E_{Rig-dist}(Fl,Vs=2,Rg=1,y,q,Ar=2)=1.0$. (the relevant number are indicated by large font in Table A.4.5.1). In case, a complete reallocation is not considered realistic, the multipliers $X\ \ (Fl,Vs=2,Rg=1,Ct,y,q,Ar=2)$ can be applied (see rows 20-23 in the table). $X\ \ (Fl,Vs=2,Rg=2,Ct,y,q,Ar=2)$ has been aalocated the value 1, but the number has been overwritten, because it’s value is irrelevant, - it will be multiplied by zero. $X\ \ (Fl,Vs=2,Rg=1,Ct,y,q,Ar=2)$, q=2,3, has been given the value 0.8 for fleet 1 and 0.7 for fleet 2. This means that for fleet 1 we assume that 20% of the effort is not reallocated.
Most of the multipliers are 1 in this hypothetical example, which mean that we assume that the maximum effort is exerted. However, for quarter 4 (row 23 in the table), the X’es has been given values < 1, implying that only fractions of the maximum effort is being used.

Row	Country = 1															
1			Fleet = 1													
2			**vessel**	**Refe-**	1	**900**				**vessel**	**Refe-**	1	**300**			
3			**size**	**rence**	2	**950**				**size**	**rence**	2	**320**			
4			**1**	**Effort**	3	**900**				**2**	**Effort**	3	**330**			
5					4	**800**						4	**200**			
6		Per	**Area 1**		**Area 2**		**Area3**			**Area 1**		**Area 2**		**Area3**		
7	Area dist	1	**0.30**		**0.30**		0.40			**0.30**		**0.30**		0.40		
8		2	**0.20**		**0.40**		0.40			**0.20**		**0.20**		0.60		
9		3	**0.35**		**0.21**		0.44			**0.35**		**0.24**		0.41		
10		4	**0.22**		**0.51**		0.27			**0.22**		**0.51**		0.27		
11			**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**		**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**	
12	Rig dist given area	1	**0.20**	0.80	**0.20**	0.80	**0.22**	0.78		**0.20**	0.80	**0.20**	0.80	**0.22**	0.78	
13		2	**0.25**	0.75	**0.33**	0.67	**0.27**	0.73		**0.25**	0.75	**1.00**	0.00	**0.27**	0.73	
14		3	**0.26**	0.74	**0.31**	0.69	**0.30**	0.70		**0.26**	0.74	**1.00**	0.00	**0.30**	0.70	
15		4	**0.35**	0.65	**0.32**	0.68	**0.50**	0.50		**0.35**	0.65	**0.32**	0.68	**0.50**	0.50	
16	Area dist * Rig-dist	1	0.060	0.240	0.060	0.240	0.088	0.312		0.060	0.240	0.060	0.240	0.088	0.312	
17		2	0.050	0.150	0.132	0.268	0.108	0.292		0.050	0.150	0.200	0.000	0.162	0.438	
18		3	0.091	0.259	0.065	0.145	0.132	0.308		0.091	0.259	0.240	0.000	0.123	0.287	
19		4	0.077	0.143	0.163	0.347	0.135	0.135		0.077	0.143	0.163	0.347	0.135	0.135	
20	Multiplier	1	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	
21		2	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**0.80**	~~**1.00**~~	**1.00**	**1.00**	
22		3	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**0.80**	~~**1.00**~~	**1.00**	**1.00**	
23		4	**0.70**	**0.70**	**0.60**	**0.60**	**0.65**	**0.65**		**0.80**	**0.80**	**0.75**	**0.75**	**0.70**	**0.70**	
24	Area dist * Rig-dist * Multiplier	1	0.060	0.240	0.060	0.240	0.088	0.312		0.060	0.240	0.060	0.240	0.088	0.312	
25		2	0.050	0.150	0.132	0.268	0.108	0.292		0.050	0.150	0.160	0.000	0.162	0.438	
26		3	0.091	0.259	0.065	0.145	0.132	0.308		0.091	0.259	0.192	0.000	0.123	0.287	
27		4	0.054	0.100	0.098	0.208	0.088	0.088	**Total**	0.062	0.114	0.122	0.260	0.095	0.095	**Total**
28	Effort	1	54.0	216.0	54.0	216.0	79.2	280.8	900	18.0	72.0	18.0	72.0	26.4	93.6	300
29		2	47.5	142.5	125.4	254.6	102.6	277.4	950	16.0	48.0	51.2	0.0	51.8	140.2	307
30		3	81.9	233.1	58.6	130.4	118.8	277.2	900	30.0	85.5	63.4	0.0	40.6	94.7	314
31		4	43.1	80.1	78.3	166.5	70.2	70.2	508	12.3	22.9	24.5	52.0	18.9	18.9	150

Row	Country = 1															
1			Fleet = 2													
2			**vessel**	**Refe-**	1	**500**				**vessel**	**Refe-**	1	**210**			
3			**size**	**rence**	2	**550**				**size**	**rence**	2	**190**			
4			**1**	**Effort**	3	**560**				**2**	**Effort**	3	**180**			
5					4	**530**						4	**170**			
6		Per	**Area 1**		**Area 2**		**Area3**			**Area 1**		**Area 2**		**Area3**		
7	Area dist	1	**0.30**		**0.30**		***0.40***			**0.30**		**0.30**		***0.40***		
8		2	**0.20**		**0.40**		***0.40***			**0.20**		**0.33**		***0.47***		
9		3	**0.35**		**0.21**		***0.44***			**0.35**		**0.21**		***0.44***		
10		4	**0.22**		**0.51**		***0.27***			**0.22**		**0.51**		***0.27***		
11			**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**		**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**	**Rig 1**	**Rig 2**	
12	Rig dist given area	1	**0.20**	0.80	**0.20**	0.80	**0.22**	0.78		**0.20**	0.80	**0.20**	0.80	**0.22**	0.78	
13		2	**0.25**	0.75	**0.33**	0.67	**0.27**	0.73		**0.25**	0.75	**1.00**	0.00	**0.27**	0.73	
14		3	**0.26**	0.74	**0.31**	0.69	**0.30**	0.70		**0.26**	0.74	**1.00**	0.00	**0.30**	0.70	
15		4	**0.35**	0.65	**0.32**	0.68	**0.50**	0.50		**0.35**	0.65	**0.32**	0.68	**0.50**	0.50	
16	Area dist * Rig-dist	1	0.060	0.240	0.060	0.240	0.088	0.312		0.060	0.240	0.060	0.240	0.088	0.312	
17		2	0.050	0.150	0.132	0.268	0.108	0.292		0.050	0.150	0.330	0.000	0.127	0.343	
18		3	0.091	0.259	0.065	0.145	0.132	0.308		0.091	0.259	0.210	0.000	0.132	0.308	
19		4	0.077	0.143	0.163	0.347	0.135	0.135		0.077	0.143	0.163	0.347	0.135	0.135	
20	Multiplier	1	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	
21		2	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**0.70**	~~**1.00**~~	**1.00**	**1.00**	
22		3	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**0.70**	~~**1.00**~~	**1.00**	**1.00**	
23		4	**0.70**	**0.70**	**0.60**	**0.60**	**0.70**	**0.70**		**0.50**	**0.50**	**0.70**	**0.70**	**0.65**	**0.65**	
24	Area dist * Rig-dist * Multiplier	1	0.060	0.240	0.060	0.240	0.088	0.312		0.060	0.240	0.060	0.240	0.088	0.312	
25		2	0.050	0.150	0.132	0.268	0.108	0.292		0.050	0.150	0.231	0.000	0.127	0.343	
26		3	0.091	0.259	0.065	0.145	0.132	0.308		0.091	0.259	0.147	0.000	0.132	0.308	
27		4	0.054	0.100	0.098	0.208	0.095	0.095	**Total**	0.039	0.072	0.114	0.243	0.088	0.088	**Total**
28	Effort	1	30.0	120.0	30.0	120.0	44.0	156.0	500	12.6	50.4	12.6	50.4	18.5	65.5	210
29		2	27.5	82.5	72.6	147.4	59.4	160.6	550	9.5	28.5	43.9	0.0	24.1	65.2	171
30		3	51.0	145.0	36.5	81.1	73.9	172.5	560	16.4	46.6	26.5	0.0	23.8	55.4	169
31		4	28.6	53.1	51.9	110.3	50.1	50.1	344	6.5	12.2	19.4	41.3	14.9	14.9	109

Table A.4.5.1. Illustration of the multiplier (for further explanation, see text)

Rows 24-27 in the table show the product of distributions and multipliers, and these are the factors to multiply to the reference effort. Eventually rows 28-31 contain the resulting effort. Notice that the sums (total) are less than or equal to the reference effort, which it should be as the reference effort is the maximum possible effort.
In case a reallocation of effort by area after an area closure, is required, the area-distribution

$E_{Area-dist}(Fl, Vs, \bullet, Ct, y, q, Ar = 2)$ should be given zero value.

A.4.6. FLEET CHARACTERISTICS

The number of vessels is usually limited. The usual condition for introduction of a new vessel is that a vessel of similar size is removed from fishery. These conditions are often linked to capacity rather than the number of vessels, so that, for example, one big vessel can be replacement three small vessel, if the total fishing capacity of the small vessels equals that of the new big vessel.
Let TON(Fl, Vs, Ct) be the tonnage of an average vessel in vessel size Vs in Fleet Fl country Ct.

If the entry of new vessels is conditions of removal of old vessels with the same tonnage, this would lead to lead to the country specific constraint:

$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{New-Vessel}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct) \leq$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Decomm}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct) +$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Withdrawal}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct) +$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Attrition}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct)$$

If furthermore, decommisioned vessels cannot be replaced the constraint becomes

$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{New-Vessel}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct) \leq$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Withdrawal}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct)$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Attrition}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct)$$

The vessel tonnage is just one example of a “fleet characteristics”. Other examples of fleet characteristics are “Length of vessel” and “KgW of engine”. Several other fleet parameters such as “crew size”, “investment value of new vessel”, “costs per unit of effort” could also have been named “fleet characteristics”, but they are accounted for separately in the TEMAS model. The TEMAS model allow for a user selected number of fleet characteristics to be accounted for. These fleet characteristics may be used in two ways:

1) The definition of fisheries regulations (as in the example with tonnage above)
2) Measures of fleet features used in output tables, as additional information and explanation.

The "maximum regulations" are thought of as an upper limit, MAL (Maximum allowed level) of the characteristics summed over vessels. TEMAS allows for limitations of total characteristics of three levels Country, Fleet and Vessel Size:
Level 1: Country level

$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y,\bullet) * CHARACT(Fl,Vs,Ct) \leq MAL_{Charact}^{Level\ 1}(Ct)$$

Level 2: Fleet level:

$$\sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y,\bullet) * CHARACT(Fl,Vs,Ct) \leq MAL_{Charact}^{Level\ 2}(Fl,Ct)$$

Level 3: Vessel size level:

$$NU_{Vessel}(Fl,Vs,Ct,y,\bullet) * CHARACT(Fl,Vs,Ct) \leq MAL_{Charact}^{Level\ 3}(Fl,Vs,Ct)$$

To indicate a maximum regulation defined by a fleet characteristics, is thus required a specification of the characteristics (tonnage, vessel length, KWat etc.) and the level at which the MAL shall be applied. As illustrated by the example above on investment/replace above, the characteristics may be used for other types of regulations than maximum regulations.
A third example of regulation based on fleet characteristics, could be a restriction that prevents vessels with an engine power exceeding a certain limit to fish in a given area. Suppose vessels were not allowed to fish in a certain MPA (Marine Protected Area) if the engine power exceeded 400 KgWat, then the area distribution of effort could be expressed as

$$E_{Area-dist}^{MPA-\mathrm{Re}g}(Fl,Vs,\bullet,Ct,y,q,Ar) =$$
$$\begin{cases} E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) \ \ if \ \ KgWat(Fl,Vs,Ct) \leq 400 \\ 0 \ \ if \ \ KgWat(Fl,Vs,Ct) \geq 400 \end{cases}$$

A.5. FISHING MORTALITY

The concept of fishing mortality refers to the concept of a stock. The mortality refers to the entire stock. It should therefore be noted that when mortality is assigned to an area smaller than the area occupied by the stock, the conventional fishing mortality concept is no longer applicable. Therefore, we shall use the terminology "Area-mortality" and "Stock-mortality". The fishing mortality is given in the unit "per year" in all cases. The exponential decay-factor becomes "exp(-(F+M)*dt)", as "dt" is the length of a time period. Thus the annual F is computed as

$$F_{Annual} = F_{Period=1} * dt + F_{Period=2} * dt + ... \quad + F_{Last\ \ Period} * dt$$

A.5.1. THE RELATIONSHIP BETWEEN EFFORT AND FISHING MORTALITY:

The simulated area-fishing mortality is derived from the effort and the selection ogive in the case of management based on effort regulation.

$$F(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = E(Fl,Vs,Rg,Ct,q,y,Ar) * \\ Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * SEL(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \quad \text{(A.5.1.1.a)}$$

where E= Effort , SEL= Gear selection and Q = Catchability coefficient.

The units of the model components are: $F: \frac{1}{year}$, $E: \frac{Effort}{period}$, $Q: \frac{period}{Effort * year}$

$SEL: pure\ number$. Thus Q has the unit "per unit of effort".

In the case of stochastic simulation, the relation between effort and area-fishing mortality is assumed to be subject to stochastic variation:

$$F(Fl,Vs,Rg,Ct,y,a,q,Ar) = E(Fl,Vs,Rg,Ct,q,y,Ar) * \\ Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * \varepsilon_Q(Fl,St,y) * \\ SEL(Fl,Vs,Rg,Ct,y.a,q,Ar) \quad \text{(A.5.1.1.b)}$$

where ε_Q (Fl, St, y) = Stochastic factor of catchability, a normally distributed stochastic variable with mean value 1.0 and standard deviation σ_Q .

Eq. (A.5.1.1a) represents the simplest mathematical model for the relationship between effort and fishing mortality (proportionality). TEMAS, however, offers a model, which also accounts for the relationship between catchability and stock abundance, as well as the technical development of efficiency of fishing operation (fishing power). If the fish distribute over the same area irrespectively of the stock size, one should expect the catchability to go down at low stock sizes.

This is reflected by the model:

$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar) = Q_1(Fl,Vs,Rg,Ct,St,y,q,Ar) \\ * B(St,y,q-1,Ar)^{QB\exp(Fl,Vs,Rg,St)} \quad \text{(A.5.1.2)}$$

where B is the biomass and QBexp(Fl,Vs,Rg,St) is a parameter. As Biomass, B, is dependent on fishing mortality, which in turn is dependent on catchability, q, is related to the biomass of last time period "q-1". (Fox, 1974)

TEMAS can furthermore account for the technical development in fishing efficiency of fishing vessels and fishing gears ("technical creeping") by a simple exponential growth of Q:

$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar) = Q_1(Fl,Vs,Rg,Ct,St,y,q,Ar) * \\ B(St,y,q-1,Ar)^{QB\exp(Fl,Vs,Rg,St)} * \exp(y * Q_{Tech-Dev}(Fl,Vs,Rg,St)) \quad \text{(A.5.1.3)}$$

Note that when the parameters, QBexp, and QTech-Dev are given the value zero, we are back to the simple model of Eq. (A.5.1.1) .

As an alternative to the model for technical creeping: $\exp(y * Q_{Tech-Dev}(Fl,Vs,Rg,St))$, TEMAS offers a more general model for catchability as a function of time, by introducing the "relative catchability", $Q_1^{\mathrm{Re}lative}$, which can take only values between 0 and 1, and apply that as a factor to the absolute catchability, $Q_1^{Absolute}$, which is the catchability coefficient in case of no technical creeping:

$$\begin{aligned} &Q_1(Fl,Vs,Rg,Ct,St,y,q,Ar) = \\ &Q_1^{Absolute}(Fl,Vs,Rg,Ct,St,Ar) * Q_1^{\mathrm{Re}lative}(Fl,Vs,Rg,Ct,St,y,q,Ar) \\ &where \quad 0 \le Q_1^{\mathrm{Re}lative} \le 1 \end{aligned} \qquad \text{(A.5.1.4)}$$

Eventually, TEMAS also contains an option for accounting for effect of the rigging on the catchability, by the "rigging factor" exp(RE(Fl, Rg, St)), where "RE" (Rigging Effect), is a rigging specific parameter. (Marchal P., et al, 2007)

$$\begin{aligned} &Q(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = Q_1^{Absolute}(Fl,Vs,Rg,Ct,St,Ar) \\ &Q_1^{\mathrm{Re}lative}(Fl,Vs,Rg,Ct,St,y,q,Ar) * \exp(RE(Fl,Vs,Rg,Ct,St)) \end{aligned} \qquad \text{(A.5.1.5)}$$

The complete model for F as a function of effort, gear selection, stock biomass, technical development, rigging and stochastic variation thus becomes

$$\begin{aligned} &F(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = E(Fl,Vs,Rg,Ct,y,q,Ar) * \\ &Q_1^{Absolute}(Fl,Vs,Rg,Ct,St,Ar) * Q_1^{\mathrm{Re}lative}(Fl,Vs,Rg,Ct,St,y,q,Ar) * \\ &B(St,Ar,y,q-1)^{QB_{Exp}(Fl,Vs,Rg,St)} * \exp(y * Q_{Tech-Dev}(Fl,Vs,Rg,St,y)) * \\ &\exp(RE(Fl,Vs,Rg,St)) * SEL(Fl,Vs,Rg,Ct,St,y,a,q) * \varepsilon_Q(Fl,St,y) \end{aligned} \qquad \text{(A.5.1.6)}$$

The partial Fs, (the Fs not summed over all indices), can be summed over indices (Fl,Vs,Rg,Ct) to give the total "Area-mortality" for period q in year y.

$$\begin{aligned} &F(\bullet,\bullet,\bullet,\bullet,St,y,a,q,Ar) = \\ &\sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} F(Fl,Vs,Rg,St,Ct,y,a,q,Ar) \end{aligned} \qquad \text{(A.5.1.7)}$$

The summation over areas involves weighting with the stock numbers, which will be explained in Section A.6.5.

In the following derivations we need the concept of "Maximum F over age groups"

$$F_{a-Max}(Fl,Vs,Rg,Ct,St,y,q,Ar) = MAX_a\{\ F(Fl,Vs,Rg,Ct,St,y,a,q,Ar)\ \} \qquad \text{(A.5.1.8)}$$

Which expressed by the F/Effort model (A.5.1.1.a) reads

$$\begin{aligned} &F_{a-Max}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = E(Fl,Vs,Rg,Ct,q,y,Ar) * \\ &Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * MAX_a\{\ SEL(Fl,Vs,Rg,Ct,St,y,a,q,Ar)\ \} \end{aligned} \qquad \text{(A.5.1.9.a)}$$

As $MAX_a\{\ SEL(Fl,Vs,Rg,Ct,St,y,a,q,Ar)\ \}$ is (usually) equal to 1 we (usually) get

$$F_{a-Max}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = E(Fl,Vs,Rg,Ct,q,y,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \tag{A.5.1.9.b}$$

$MAX_a\{\ SEL(Fl,Vs,Rg,Ct,St,y,a,q,Ar)\ \}$ be less than one (can't be larger than one, as it stems from the logistic curve)

$$F_{a-Max}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \le E(Fl,Vs,Rg,Ct,q,y,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \tag{A.5.1.9.c}$$

We define the maximum F over ages for all (Fl, Vs, Rg, Ct) combined by

$$F_{a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} F_{a-Max}(Fl,Vs,Rg,Ct,St,y,q,Ar) \tag{A.5.1.10}$$

This in turn leads the the concept of relative Maximum over age groups

$$F_{REL-Max}(Fl,Vs,Rg,Ct,St,y,q,Ar) = F_{a-Max}(Fl,Vs,Rg,Ct,St,y,q,Ar) / F_{a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,a,Ar) \tag{A.5.1.11}$$

Riggings may be combined to give the relative maximum over age for all riggings of a fleet

$$F_{REL-Max}(Fl,Vs,\bullet,Ct,St,y,q,Ar) = F_{a-Max}(Fl,Vs,\bullet,Ct,St,y,q,Ar) / F_{a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,a,Ar) \tag{A.5.1.12}$$

A.5.2. LANDING AND DISCARD AREA-MORTALITY

Area-Fishing mortality is the sum of area-landing mortality and area-discard mortality:

F(Fl, Vs, Rg, Ct, St, y, a, q, Ar) = F_{land}(-) + F_{disc}(-)
Where "(-)" indicates the full set of indices "(Fl, Vs, Rg, Ct, St, y, a, q, Ar)" and
F_{land} (-) = Area-landing mortality,
F_{disc}(-) = Area-discard mortality and F(-) = Area-Fishing mortality.
They are defined by :
F_{land} (-) = F (-) * (1 – DIS(-)) and F_{disc}(-) = F (-) * DIS(-),
where DIS = fraction of fish caught, which are discarded (Eq A.3.1.1).

$$\mathrm{DIS(Fl,Vs,Rg,Ct,St,y,a,q)} = 1 - \frac{1}{1+\exp(\mathrm{Dis1}(-) - \mathrm{Dis2}(-) * \mathrm{Lgt}(St,a,q))} \tag{A.5.2.1}$$

A.6. STOCK NUMBERS, MIGRATION AND STOCK BIOMASS .

<table>
<tr><td colspan="2">Area 1</td><td colspan="4">Y_{first}</td><td>Y_{last}</td></tr>
<tr><td>Age Gr.</td><td>Q \ year</td><td>1995</td><td>1996</td><td>1997</td><td>1998</td><td>1999</td></tr>
<tr><td rowspan="4">0</td><td>Q 1</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td></tr>
<tr><td>Q 2</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td></tr>
<tr><td>Q 3</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td></tr>
<tr><td>Q 4</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td><td>Recruitment</td></tr>
<tr><td rowspan="4">1</td><td>Q 1</td><td>Init. Stock</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q 3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q 4</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">2</td><td>Q 1</td><td>Init. Stock</td><td></td><td colspan="2" rowspan="12">The table indicates the combination of indices, which requires that stock numbers are given as input to TEMAS.

Note: (1): The initial stock may be computed within TEMAS, under the assumption of equilibrium.

Note (2): That recruitment (as an option) may be computed within the model</td><td></td></tr>
<tr><td>Q 2</td><td></td><td></td><td></td></tr>
<tr><td>Q 3</td><td></td><td></td><td></td></tr>
<tr><td>Q 4</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">3</td><td>Q 1</td><td>Init. Stock</td><td></td><td></td></tr>
<tr><td>Q 2</td><td></td><td></td><td></td></tr>
<tr><td>Q 3</td><td></td><td></td><td></td></tr>
<tr><td>Q 4</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">4</td><td>Q 1</td><td>Init. Stock</td><td></td><td></td></tr>
<tr><td>Q 2</td><td></td><td></td><td></td></tr>
<tr><td>Q 3</td><td></td><td></td><td></td></tr>
<tr><td>Q 4</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">5</td><td>Q 1</td><td>Init. Stock</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q 3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q 4</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table A.6.1 Initial values required starting up TEMAS simulation (in one area and dt = 0.25 years). The recruitment is derived from the stock/recruitment model, except for the first year (Compare Figure A.6.2.1, which shows an example with time step of one month)

A.6.1. STOCK NUMBERS AT BEGINNING OF TIME PERIOD (NOT PLUS GROUP)

Stock number of stock “St”, at the beginning of time period “q” of year “y” in area “Ar” is derived as follows:

If $y = y_{first}$ and $q > 1$ and $a > 0$	then	N(St, y_{first}, a, q,Ar) is computed by Eq. (A.6.3.1)
If $y = y_{first}$ and $q = 1$ and $a \geq 0$	then	N(St, $y_{firSt,}$, a, 1,Ar) is an input parameters to TEMAS
If $y > y_{first}$ and $a > 0$	then	N(St, y, a, q,Ar) is computed by Eqs. (A.6.3.1)
If $y > y_{first}$ and $a = 0$ and $q = 1$	then	N(St, y, a=0, q=1, Ar) = Rec(St, y, 1, Ar)
If $y > y_{first}$ and $a = 0$ and $q > 1$	then	N(St, y, a=0, q,Ar) = Rec(St, y, q,Ar) + N(St,y,a=0,q-1,Ar) where N(St,y, a=0, q-1, Ar) is computed by Eq.(A.6.3.1)

The recruitment, Rec(St, y, q, Ar) of stock “St” in Area “Ar” in quarter “q” of year “y is defined by the stock/recruitment model introduced in Section A.9.
The combination of indices where stock numbers are input are illustrated by Table A.6.1.1 (for one area)

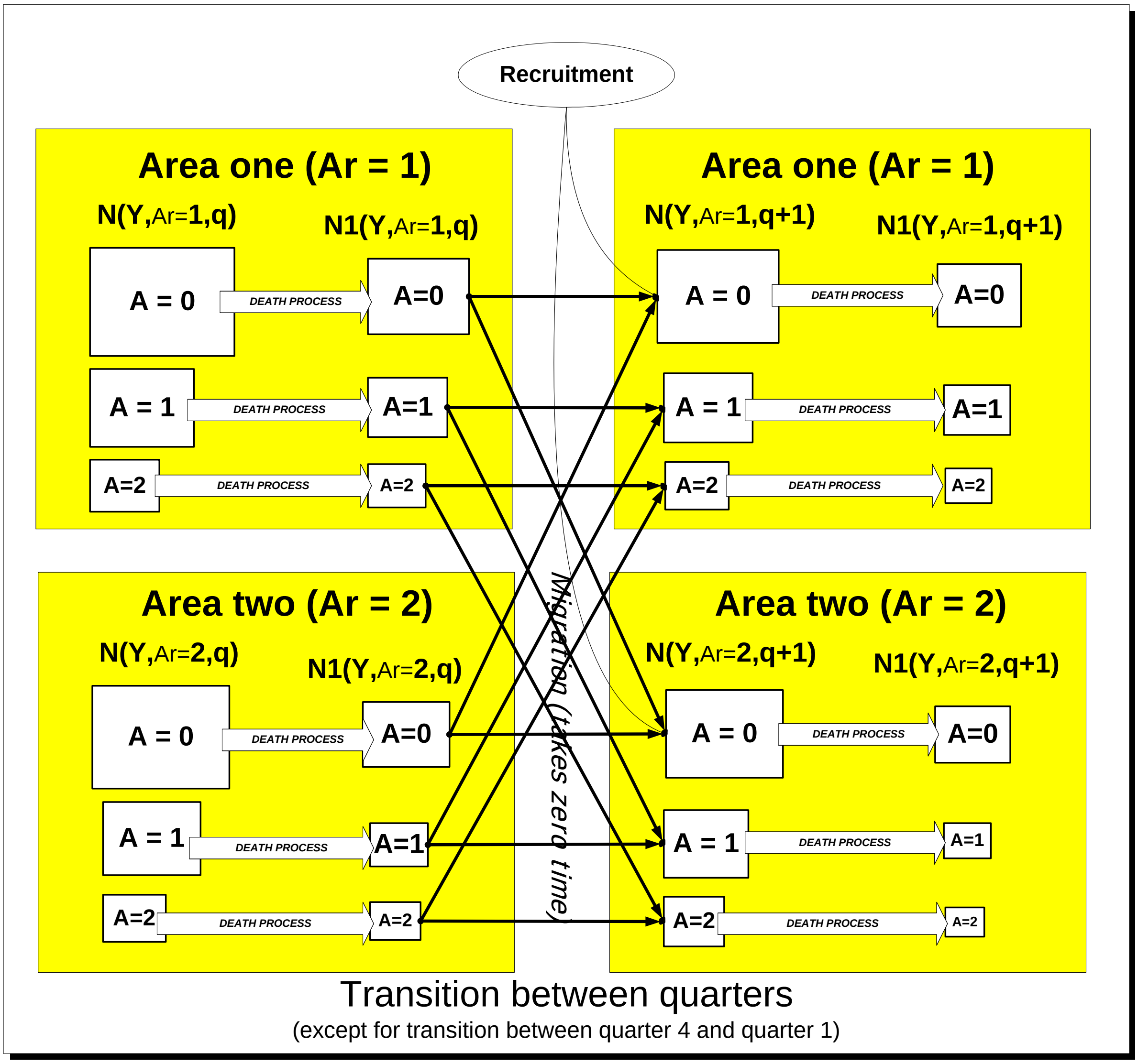


Figure A.6.2.1. Hypothetical example using the quarter as time step (dt = 0.25), with two areas, one stock and 3 age groups. Illustration of the flow of number of survivors between components of TEMAS during quarters 1,2 and 3. Note that the plus group is not treated different from the other age groups in the case q = 1,2,3. Note further that recruitment can take place in any quarter of the year.

A.6.2. STOCK NUMBER AT END OF TIME PERIOD, (BEFORE MIGRATION)

Number of survivors of stock "St", at the end of quarter "q" of year "y" in area "Ar" (before migration):

$$N1\ (St,y,a,q,Ar) = N(St,y,a,q,Ar) * \exp(-Z(St,y,a,q,Ar) * dt) \qquad \text{(A.6.2.1)}$$

Where

Z(St, y, a, q, Ar) = Area specific "Total mortality" of stock "St" in area "Ar" in year "y" during quarter "q" of age group "a".

N(St, y, a, q, Ar) = Stock number of stock "St", at the beginning of quarter "q" of year "y" in area "Ar"

Note that the indices of N and N1 remain unchanged when considering the death process during a time period of the year. The transition between time periods is in the model dealt with "just before migration" and "just after migration". The use of indices in relation to the transition between components of the TEMAS-model is illustrated in Figure A.6.2.1, in the case of dt = 0.25 (the year divided into quarters) Figure A.6.2.1 shows the indices for quarters 1,2 and 3, and Figure A.6.4.1. in the case of quarter four (q = 4).

A.6.3. STOCK NUMBER JUST AFTER MIGRATION – NOT PLUS GROUP

Number of stock "St", at the beginning of time period "q" of year "y" in area "Ar" (just after migration).

If q = < q_{Max} then

$$N(St,y,a,q+1,Tar) = \sum_{Far=1}^{Ar_{Max}} MC(St,a,q,FAr,TAr) * N1(St,y,a,q,Ar)$$

if q = q_{Max} (and a < a_{max}(St)) then (A.6.3.1)

$$N(St,y+1,a,1,TAr) = \sum_{FAr=1}^{Ar_{Max}} MC(St,a,q_{Max},FAr,TAr) * N1(St,y,a,q_{Max},Ar)$$

where

MC(St, a, q, FAr, TAr) = Migration coefficient for age group "a" of stock "St" moving from area "FAr" to area "TAr" in time period "q" .

N1(St, y, a, q, Ar) = Stock number of stock "St", at the end of quarter "q" of year "y" in area "Ar" (before migration).

A.6.4. STOCK NUMBER IN PLUS GROUP, JUST AFTER MIGRATION

Number of stock "St", at the end of quarter "q" of year "y" in area "Ar" (before migration) in the oldest age group a_{max}(St), which is here modelled as a plus-group, that is, it contains al the age groups, a_{max}(St), a_{max}(St)+1, a_{max}(St)+2, …, a_{max}(St)+∞:)

If $q < q_{Max}$ and $a = a_{Max}(St)$ then

$$N(St, y, a_{Max}(St), q+1, TAr) = \sum_{FAr=1}^{NU_{Area}} MC(St, a_{Max}(St), q, FAr, TAr) * N1(St, y, a_{Max}(St), q, FAr) \qquad \text{(A.6.4.1)}$$

If $q = q_{Max}$ and $a = a_{Max}(St)$ then

$$N(St, y+1, a_{\max}(St), 1, TAr) =$$
$$\sum_{FAr=1}^{NU_{Area}} MC(St, a_{Max}(St), q_{Max}, FAr, TAr) * N1(St, y, a_{Max}(St), q_{Max}, FAr) +$$
$$\sum_{FAr=1}^{NU_{Area}} MC(St, a_{Max}(St)-1, q_{Max}, FAr, TAr) * N1(St, y, a_{Max}(St)-1, q_{Max} FAr)$$

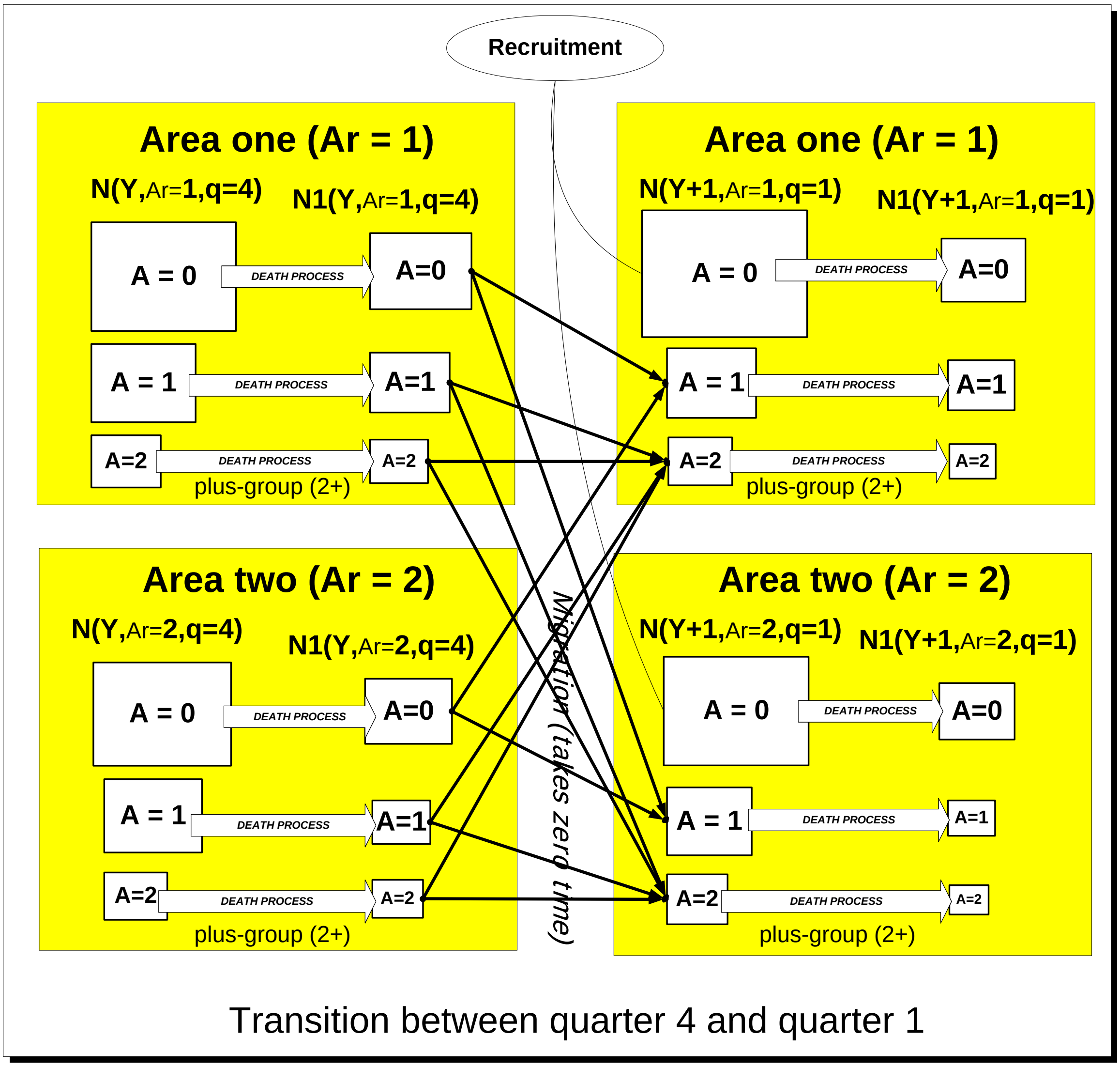


Figure A.6.4.1. Hypothetical example using the quarter as time step, with two areas, one stock and 3 age groups. Illustration of the flow of number of survivors between components of TEMAS during quarter 4. Note that the plus group is treated different from the other age groups in the case q = 4. Note further that recruitment can take place in any quarter of the year.

A.6.5. STOCK BIOMASS AND SPAWNING STOCK BIOMASS

Mean number of survivors during time period, q, is:

$$N_{Mean}(St,y,a,q,Ar) = N(St,y,a,q,Ar)\frac{1-\exp(-Z(St,y,a,q,Ar)*dt)}{Z(St,y,a,q,Ar)*dt} \qquad (A.6.5.1)$$

Mean stock biomass in period q is defined as

$$B(St,y,q,Ar) = \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*Wgt(St,y,a,q) \qquad (A.6.5.2)$$

The conventional stock biomass, is the sum over areas:

$$B(St,y,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*Wgt(St,y,a,q)$$

The spawning stock biomass in area “Ar” is:

$$SSB(St,y,q,Ar) = \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*Wgt(St,y,a,q)*Mat(St,a,q) \qquad (A.6.5.3)$$

The conventional spawning stock biomass in time period q is the sum over areas $SSB(St,y,q,\bullet)$

$$SSB(St,y,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*Wgt(St,y,a,q)*Mat(St,a,q) \qquad (A.6.5.4)$$

The SSB concept used as input to the stock/recruitment model (to be introduced in Chapter 9) is related to the overage annual spawning stock, $SSB_{Total}(St,y,\bullet,\bullet)$, defined as:

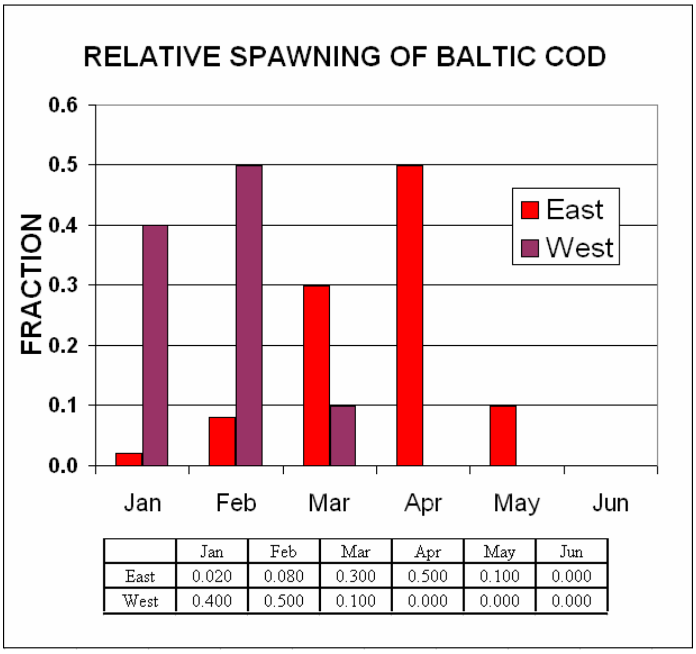
$$SSB_{Total}(St,y,\bullet,\bullet) = \frac{1}{q_{Max}} \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}} \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*Wgt(St,y,a,q)*Mat(St,a,q) \qquad (A.6.5.5)$$

However, the spawning of cod is confined to a spawning season. Naturally the SSB should be the average biomass of spawners during the spawning season.
Let $RecDist_{Period}(St,q)$, be the relative temporal distribution of spawning on time periods.

$$RDist_{Period}(St,q) = \frac{Egg\ \ production\ in\ \ period\ q}{Total\ \ Annual\ egg\ \ production} \qquad (A.6.5.6)$$

Figure A.6.5.1 shows the observed temporal relative spawning intensity of the two Baltic cod stocks. The Western cod stock has its peak spawning in February. The eastern cod has the peak spawning in April and a longer spawning season. This leads to the definition of the “effective SSB”

$$SSB_{Effective}(St,y,\bullet,\bullet) = \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}} \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*Wgt(St,y,a,q)*Mat(St,a,q)*RDist_{Period}(St,q) \qquad (A.6.5.7)$$



	Jan	Feb	Mar	Apr	May	Jun
East	0.020	0.080	0.300	0.500	0.100	0.000
West	0.400	0.500	0.100	0.000	0.000	0.000

Figure A.6.5.1. Relative temporal distribution of Baltic cod egg production.

A.6.6. SPAWNING STOCK BIOMASS OF THE REPRODUCTIVE VOLUME.

Figure A.6.6.1 indicates the three main spawning areas of Eastern Baltic cod (Bornholm basin (BB), Gdansk deep (GD) and Gotland Basin (GB). Kuster et al, 2004. As can be seen spawning is correlated with depth. The spawning areas are (largely) the areas of depth 60 m or more.

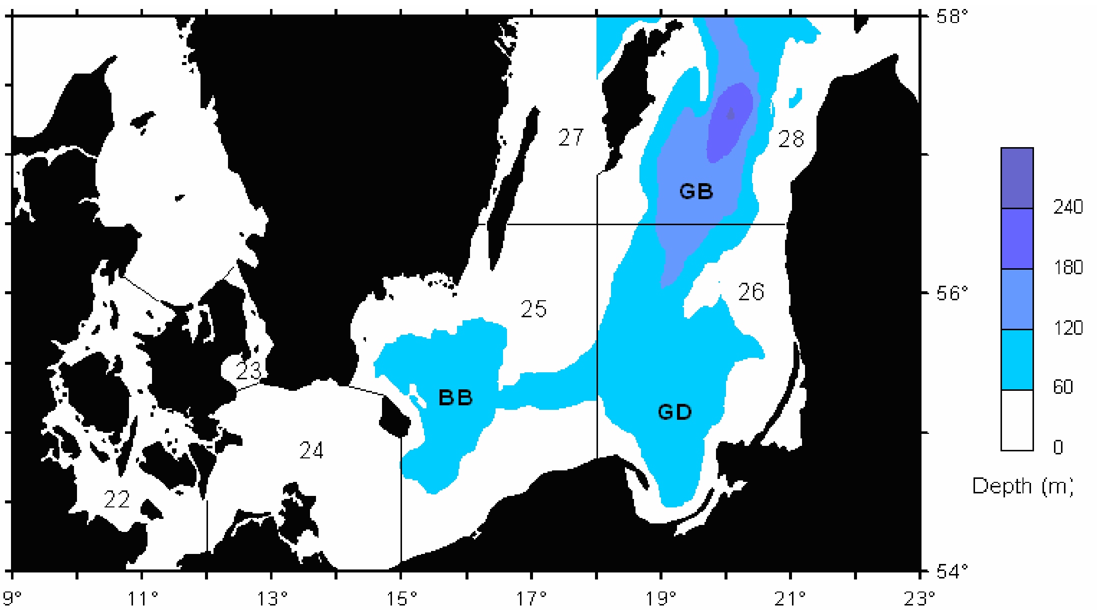


Figure A.6.6.1. The spawning areas of Eastern Baltic cod with depth contours and major spawning areas: Bornholm basin: BB, Gdansk deep: GD and Gotland Basin: GB. (source: Kuster et al, 2004).

The "spawning success", is defined as a proxy for the survival of eggs into juveniles. In the Baltic, the spawning success is area specific, as it (largely) depends on the depth, which in turns determines temperature, salinity and oxygen concentration of the water. Figure A.6.6.2 shows a time series of temperature, oxygen and salinity in the Bornholm basin, which is the major spawning area for Eastern Baltic cod (Kuster *et al*, 2001a, 2001b, 2004, 2005, Andersen & Mollmann, 2004)

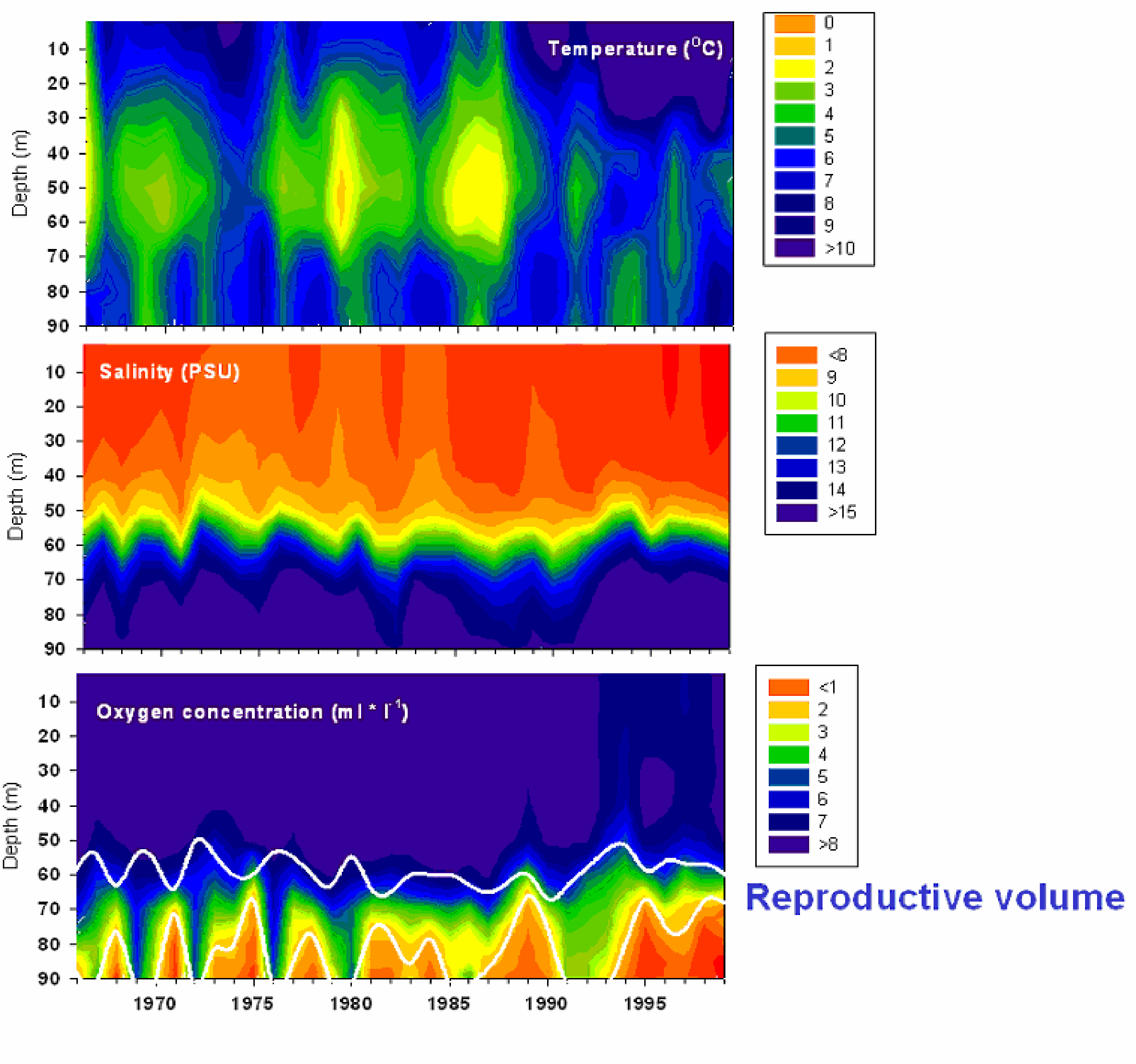


Figure A.6.6.2 Temperature, Oxygen concentration and salinity in the Bornholm Basin (SD 25) (source: Köster et al, 2004).

The red areas shown in Figure A.6.6.2 are those not favourable for the egg survival, which are when temperature < 2°C, salinity < 11 practical salinity units, and oxygen < 2 ml/l. These limit-values determine the so-called "reproductive volume". The spawning success is assumed to be proportional to the reproductive volume. Therefore, spawning success is area-specific, and it varies from year to year. We shall come back to the stochastic nature of the reproductive volume in Chapter 9.

The average spawning success factor, r_{NotMPA}, thus becomes a function of area and year. We select the area of highest spawning success, and here we name it "MPA", assuming that the marine protected area (MPA) is chosen as the one with the best spawning success. The MPA may one or more areas, but to make things simple we assume that there is only one MPA (the Bornholm deep in the case of Baltic cod). We introduce the "Recruitment Success Factor" as

$$RSF_{MPA}(St,Ar)(= \begin{cases} rsf_{NotMPA}(St,Ar) \text{ if } & Ar \neq MPA \\ 1 \text{ if } & Ar = MPA \end{cases} \qquad \text{(A.6.6.1)}$$

where $0 \leq rsf_{NotMPA}(St,Ar,) \leq 1$. "$rsf_{NotMPA}$ " is the "reduction factor recruitment success outside the MPA". We shall come back to this concept in Chapter 9 and ad some stochastic features to its definition, related to the stochastic nature of the reproductive volume.

To account for the reproductive volume and spawning success in the stock/recruitment models (Chapter 9) we introduce the concept of SSB_{RV}, the "spawning stock biomass of the reproductive volume"

$$SSB_{RV}(St,y,\bullet,\bullet)=\sum_{q=1}^{q_{Max}}\sum_{Ar=1}^{Ar_{Max}}\sum_{a=0}^{a_{Max}(St)}N_{Mean}(St,y,a,q,Ar)*$$
$$Wgt(St,y,a,q)*Mat(St,a,q)*RDist_{Period}(St,q)*RSF_{MPA}(St,Ar) \qquad (A.6.6.2)$$

This concept makes the SSB_{RV} depend on the timing of recruitment, $RDist_{Period}$ and the migration of spawning cod, MC(St,a,q,Far,Tar). If the cod migrate to the MPA during the spawning season the SSB_{RV}, gets bigger than if they remained outside the MPA. Ignoring the special case of $q = q_{Max}$, the expression for SSB_{RV} is

$$SSB_{RV}(St,y,\bullet,\bullet)=\sum_{q=1}^{q_{Max}}\sum_{Ar=1}^{Ar_{Max}}\sum_{a=0}^{a_{Max}(St)}\sum_{FAr=1}^{Ar_{Max}}MC(St,a,q-1,FAr,TAr)*N1(St,y,a,q-1,Ar)*$$
$$\frac{1-\exp(-Z(St,y,a,q-1,Ar)*dt)}{Z(St,y,a,q-1,Ar)*dt}*Wgt(St,y,a,q)*Mat(St,a,q)*RDist_{Period}(St,q)*RSF_{MPA}(St,Ar) \qquad (A.6.6.3)$$

Tables A.6.6.1.a and b show two hypothetical applications of Eq A.6.6.3. To make this hypothetical example simple, Z is assumed to be zero, so the number of survivors remain constant in all time periods, q=1,2,3,4. The factor $\frac{1-exp(-Z(St,y,a,q-1,Ar)*dt)}{Z(St,y,a,q-1,Ar)*dt}$ in Eq. A.6.6.3 is given the value 1.0. Furthermore only three age groups are considered, and only three areas (Bornholm Basin, Gotland Basin and the remaining part of Eastern Baltic). In table a, the migration coefficients are chosen so that all spawners move to Bornholm Basin, (the area of highest spawning success) during the entire spawning season (q=1,2). The calculated values of SSB_{RV} are shown in right hand side of the last column. Table b uses the same parameters, except for the migration coefficients. In table b, not all spawners go to the Bornholm Basin, and since the spawning success outside the Bornholm Basin is lower, the resulting value of SSB_{RV} becomes lower.

If furthermore, Z had been assigned a positive value, with a smaller value in the Bornholm Basin due to area closure (smaller fishing mortality), the effect of spawning migration would even larger than that of Table a.

Herby, a model is designed that (in theory) can shown a relationship between an area closure and the SSB_{RV}

From East Baltic (EB)

	q=1	MC(a,1,1,TAr)		q=2	MC(a,2,1,TAr)		q=3	MC(a,3,1,TAr)		q=4	MC(a,4,1,TAr)	
to	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
Age2	0.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
Age3	0.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
Age4	0.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00

From Bornholm Basin (BB)

	q=1	MC(a,1,2,TAr)		q=2	MC(a,2,2,TAr)		q=3	MC(a,3,2,TAr)		q=4	MC(a,4,2,TAr)	
to	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
Age2	0.00	1.00	0.00	0.00	1.00	0.00	0.75	0.25	0.00	0.75	0.25	0.00
Age3	0.00	1.00	0.00	0.00	1.00	0.00	0.75	0.25	0.00	0.75	0.25	0.00
Age4	0.00	1.00	0.00	0.00	1.00	0.00	0.75	0.25	0.00	0.75	0.25	0.00

From Gotland Basin (GB)

	q=1	MC(a,1,3,TAr)		q=2	MC(a,2,3,TAr)		q=3	MC(a,3,3,TAr)		q=4	MC(a,4,3,TAr)	
to	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
Age2	0.00	1.00	0.00	0.00	1.00	0.00	0.25	0.00	0.75	0.25	0.00	0.75
Age3	0.00	1.00	0.00	0.00	1.00	0.00	0.25	0.00	0.75	0.25	0.00	0.75
Age4	0.00	1.00	0.00	0.00	1.00	0.00	0.25	0.00	0.75	0.25	0.00	0.75

Wgt	Mat	RSF	Area		Stock numbers, N(y,q)				
					Y=1, q=4, a-1	Y=2, q=1 a	Y=2, q=2 a	Y=2, q=3 a	Y=2, q=4 a
1.00	0.20	0.10	EB	Age2	146.0	0.0	0.0	131.3	164.1
1.50	0.65	0.10		Age3	95.0	0.0	0.0	84.8	105.9
2.00	1.00	0.10		Age4	60.0	0.0	0.0	53.3	66.6
			EB	Total	301.0	0.0	0.0	269.3	336.6
1.00	0.50	0.50	BB	Age2	22.0	175.0	175.0	43.8	10.9
1.50	0.90	0.50		Age3	15.0	113.0	113.0	28.3	7.1
2.00	1.00	0.50		Age4	9.0	71.0	71.0	17.8	4.4
			BB	Total	46.0	359.0	359.0	89.8	22.4
1.00	0.50	0.10	GB	Age2	7.0	0.0	0.0	0.0	0.0
1.50	0.90	0.10		Age3	3.0	0.0	0.0	0.0	0.0
2.00	1.00	0.10		Age4	2.0	0.0	0.0	0.0	0.0
			GB	Total	12.0	0.0	0.0	0.0	0.0
			Grand Total		359.0	359.0	359.0	359.0	359.0

	Rdist.$_{Period}$(q)			
	0.40	0.60	0.00	0.00
Wgt* Mat* RSF	Y=2, q=1	Y=2, q=2	Y=2, q=3	Y=2, q=4
	Wgt*Mat*RSF*N			
0.02	0.0	0.0	0.0	0.0
0.098	0.0	0.0	0.0	0.0
0.2	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0
0.25	17.5	26.3	0.0	0.0
0.675	30.5	45.8	0.0	0.0
1	28.4	42.6	0.0	0.0
Total	76.4	114.6	0.0	0.0
0.05	0.0	0.0	0.0	0.0
0.135	0.0	0.0	0.0	0.0
0.2	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0
SSB_{RV}	76.4	114.6	0.0	0.0

Table A.6.6.1.a. Hypothetical example illustrating the impact of migration on SSB_{RV} (Spawning stock biomass of the reproductive volume). In this case all spawners go to the Bornholm Basin (BB) during spawning. Note the high values of SSB_{RV} (q1)=76.4 and of SSB_{RV} (q2)=114.6. compared to the values in Table b. The calculations were made with the EXCEL sheet shown in Figure A.6.6.3.

The calculations behind Tables A.6.5.1 are indeed very trivial, as can be inspected in Figure A.6.6.3. This Figure shows the formulas of the EXCEL spreadsheet, by which the tables were produced. To explain Tables 5.5.1.a+b, consider the calculations of numbers in age group 2 in area BB in first and second quarter of year 2 in Table b. These numbers are 109.6 and 114.7 (underlined) To achieve these results, the calculations are:

MC(a=1,q=1,EB,BB) * N(a=1,y=1,q=4,EB) + MC(a=1,q=1,BB,BB) * N(a=1,y=1,q=4,BB) + MC(a=1,q=1,GB,BB) * N(a=1,y=1,q=4,GB) = N(a=2,y=2,q=1,BB)
*0.6*146 + 1.0*22 + 0.0*2 = 109.6*

MC(a=2,q=1,EB,BB) * N(a=2,y=2,q=4,EB) + MC(a=2,q=1,BB,BB) * N(a=2,y=2,q=4,BB) + MC(a=2,q=1,GB,BB) * N(a=2,y=2,q=4,GB) = N(a=2,y=2,q=2,BB)
*0.55*29.2+0.9*109.6+0*36.2=114.7*

From East Baltic (EB)

	q=1	MC(a,1,1,TAr)		q=2	MC(a,2,1,TAr)		q=3	MC(a,3,1,TAr)		q=4	MC(a,4,1,TAr)	
To	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
Age2	0.20	0.60	0.20	0.30	0.55	0.15	1.00	0.00	0.00	1.00	0.00	0.00
Age3	0.15	0.65	0.20	0.20	0.60	0.20	1.00	0.00	0.00	1.00	0.00	0.00
Age4	0.10	0.65	0.25	0.15	0.65	0.20	1.00	0.00	0.00	1.00	0.00	0.00

From Bornholm Basin (BB)

	q=1	MC(a,1,2,TAr)		q=2	MC(a,2,2,TAr)		q=3	MC(a,3,2,TAr)		q=4	MC(a,4,2,TAr)	
To	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
Age2	0.00	1.00	0.00	0.10	0.90	0.00	0.50	0.50	0.00	0.60	0.40	0.00
Age3	0.00	1.00	0.00	0.10	0.90	0.00	0.50	0.50	0.00	0.60	0.40	0.00
Age4	0.00	1.00	0.00	0.10	0.90	0.00	0.50	0.50	0.00	0.60	0.40	0.00

From Gotland Basin (GB)

	q=1	MC(a,1,3,TAr)		q=2	MC(a,2,3,TAr)		q=3	MC(a,3,3,TAr)		q=4	MC(a,4,3,TAr)	
To	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
Age2	0.00	0.00	1.00	0.10	0.00	0.90	0.50	0.00	0.50	0.70	0.00	0.30
Age3	0.00	0.00	1.00	0.10	0.00	0.90	0.55	0.00	0.45	0.75	0.00	0.25
Age4	0.00	0.00	1.00	0.10	0.00	0.90	0.60	0.00	0.40	0.80	0.00	0.20

Wgt	Mat	RSF	Area		Stock numbers, N(y,q)				
					Y=1, q=4 a-1	Y=2, q=1 a	Y=2, q=2 a	Y=2, q=3 a	Y=2, q=4 a
1.00	0.20	0.10	EB	Age2	146.0	29.2	23.3	99.2	146.5
1.50	0.65	0.10		Age3	95.0	14.3	12.7	64.0	94.9
2.00	1.00	0.10		Age4	60.0	6.0	7.4	40.9	60.3
			EB	Total	301.0	49.5	43.5	204.0	301.7
1.00	0.50	0.50	BB	Age2	22.0	109.6	114.7	57.4	22.9
1.50	0.90	0.50		Age3	15.0	76.8	77.6	38.8	15.5
2.00	1.00	0.50		Age4	9.0	48.0	47.1	23.6	9.4
			BB	Total	46.0	234.4	239.4	119.7	47.9
1.00	0.50	0.10	GB	Age2	7.0	36.2	37.0	18.5	5.5
1.50	0.90	0.10		Age3	3.0	22.0	22.7	10.2	2.5
2.00	1.00	0.10		Age4	2.0	17.0	16.5	6.6	1.3
			GB	Total	12.0	75.2	76.1	35.3	9.4
			Grand Total		359.0	359.0	359.0	359.0	359.0

	Rdist.$_{Period}$(q)			
	0.40	0.60	0.00	0.00
Wgt* Mat* RSF	Y=2 q=1 Wgt*Mat*RSF*N	Y=2, q=2	Y=2, q=3	Y=2, q=4
0.02	0.2	0.3	0.0	0.0
0.098	0.6	0.7	0.0	0.0
0.2	0.5	0.9	0.0	0.0
Total	1.3	1.9	0.0	0.0
0.25	11.0	17.2	0.0	0.0
0.675	20.7	31.4	0.0	0.0
1	19.2	28.3	0.0	0.0
Total	50.9	76.9	0.0	0.0
0.05	0.7	1.1	0.0	0.0
0.135	1.2	1.8	0.0	0.0
0.2	1.4	2.0	0.0	0.0
Total	3.3	4.9	0.0	0.0
SSB_{RV}	55.4	83.7	0.0	0.0

Table A.6.6.1.b. Hypothetical example illustrating the impact of migration on SSB_{RV} (Spawning stock biomass of the reproductive volume). In this case not all spawners go to the Bornholm Basin (BB) during spawning. Note the low values of SSB_{RV} (q1)=55.4 and of SSB_{RV} (q2)=83.6. compared to the values in Table a. The calculations were made with the EXCEL sheet shown in Figure A.6.6.3.

The numbers needed in the calculations are indicated by italic font. The remaining calculation is a simple multiplication of five numbers, for example:

$N_{Mean}(y=2,a=2,q=2,Ar=BB)*Wgt(y,a,q)*RSF_{MPA}(BB)*Mat(a,q)*RDist_{Period}(q)$

114.7 * 1.0 * 0.5 * 0.5 * 0.6 = 17.2

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	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1															
2			From Ea												
3				q=1	MC(a,1		q=2	MC(a,2,1,TAr)		q=3	MC(a,3,		q=4	MC(a,4,1,	
4			to	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
5			Age2	0	1	=1-E5-F5	0	1	=1-H5-I5	1	0	=1-K5-L5	1	0	=1-N5-O5
6			Age3	0	1	=1-E6-F6	0	1	=1-H6-I6	1	0	=1-K6-L6	1	0	=1-N6-O6
7			Age4	0	1	=1-E7-F7	0	1	=1-H7-I7	1	0	=1-K7-L7	1	0	=1-N7-O7
8			From Bc												
9				q=1	MC(a,1		q=2	MC(a,2,2,TAr)		q=3	MC(a,3,		q=4	MC(a,4,2,	
10			to	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
11			Age2	0	1	=1-E11-F11	0	1	=1-H11-I11	0.75	0.25	=1-K11-L11	0.75	0.25	=1-N11-O11
12			Age3	0	1	=1-E12-F12	0	1	=1-H12-I12	0.75	0.25	=1-K12-L12	0.75	0.25	=1-N12-O12
13			Age4	0	1	=1-E13-F13	0	1	=1-H13-I13	0.75	0.25	=1-K13-L13	0.75	0.25	=1-N13-O13
14			From Gc												
15				q=1	MC(a,1		q=2	MC(a,2,3,TAr)		q=3	MC(a,3,		q=4	MC(a,4,3,	
16			to	EB	BB	GB	EB	BB	GB	EB	BB	GB	EB	BB	GB
17			Age2	0	1	=1-E17-F17	0	1	=1-H17-I17	0.25	0	0.75	0.25	0	0.75
18			Age3	0	1	=1-E18-F18	0	1	=1-H18-I18	0.25	0	0.75	0.25	0	0.75
19			Age4	0	1	=1-E19-F19	0	1	=1-H19-I19	0.25	0	0.75	0.25	0	0.75

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Microsoft Excel - Migration_Coefficients_1Mar07

	A	B	C	D	E	F	G	H	I	J	K
22											
23									Stock numbers, N(y,q)		
24		Wgt	Mat	RSF	Area		Y=1,q=4	Y=2,q=1	Y=2,q=2	Y=2,q=3	Y=2,q=4
25		1	0.2	0.1	EB	Age2	146	=G25*E5+E11*G29+G33*E17	=H25*H5+H29*H11+H33*H17	=I25*K5+I29*K11+I33*K17	=J25*N5+J29*N11+J33*N17
26		1.5	0.65	0.1		Age3	95	=G26*E6+E12*G30+G34*E18	=H26*H6+H30*H12+H34*H18	=I26*K6+I30*K12+I34*K18	=J26*N6+J30*N12+J34*N18
27		2	1	0.1		Age4	60	=G27*E7+E13*G31+G35*E19	=H27*H7+H31*H13+H35*H19	=I27*K7+I31*K13+I35*K19	=J27*N7+J31*N13+J35*N19
28					EB	Total	=SUM(G	=SUM(H25:H27)	=SUM(I25:I27)	=SUM(J25:J27)	=SUM(K25:K27)
29		=B25	0.5	0.5	BB	Age2	22	=G25*F5+G29*F11+G33*F17	=H25*I5+H29*I11+H33*I17	=I25*L5+I29*L11+I33*L17	=J25*O5+J29*O11+J33*O17
30		=B26	0.9	0.5		Age3	15	=G26*F6+G30*F12+G34*F18	=H26*I6+H30*I12+H34*I18	=I26*L6+I30*L12+I34*L18	=J26*O6+J30*O12+J34*O18
31		=B27	1	0.5		Age4	9	=G27*F7+G31*F13+G35*F19	=H27*I7+H31*I13+H35*I19	=I27*L7+I31*L13+I35*L19	=J27*O7+J31*O13+J35*O19
32					BB	Total	=SUM(G	=SUM(H29:H31)	=SUM(I29:I31)	=SUM(J29:J31)	=SUM(K29:K31)
33		=B29	0.5	0.1	GB	Age2	7	=G25*G5+G29*G11+G33*G17	=H25*J5+H29*J11+H33*J17	=I25*M5+I29*M11+I33*M17	=J25*P5+J29*P11+J33*P17
34		=B30	0.9	0.1		Age3	3	=G26*G6+G30*G12+G34*G18	=H26*J6+H30*J12+H34*J18	=I26*M6+I30*M12+I34*M18	=J26*P6+J30*P12+J34*P18
35		=B31	1	0.1		Age4	2	=G27*G7+G31*G13+G35*G19	=H27*J7+H31*J13+H35*J19	=I27*M7+I31*M13+I35*M19	=J27*P7+J31*P13+J35*P19
36					GB	Total	=SUM(G	=SUM(H33:H35)	=SUM(I33:I35)	=SUM(J33:J35)	=SUM(K33:K35)
37					Grand	Total	=G28+G	=H28+H32+H36	=I28+I32+I36	=J28+J32+J36	=K28+K32+K36
38											

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Microsoft Excel - Migration_Coefficients_1Mar07

	L	M	N	O	P	Q
20						
21				Rdist.Period(q)		
22			0.4	0.6	0	0
23		Wgt*Mat*	Y=2,q=1	Y=2,q=2	Y=2,q=3	Y=2,q=4
24		RSF		Wgt*Mat*RSF*N		
25		=B25*C25*D25	=H25*$M25*N$22	=I25*$M25*O$22	=J25*$M25*P$22	=K25*$M25*Q$22
26		=B26*C26*D26	=H26*$M26*N$22	=I26*$M26*O$22	=J26*$M26*P$22	=K26*$M26*Q$22
27		=B27*C27*D27	=H27*$M27*N$22	=I27*$M27*O$22	=J27*$M27*P$22	=K27*$M27*Q$22
28		Total	=SUM(N25:N27)	=SUM(O25:O27)	=SUM(P25:P27)	=SUM(Q25:Q27)
29		=B29*C29*D29	=H29*$M29*N$22	=I29*$M29*O$22	=J29*$M29*P$22	=K29*$M29*Q$22
30		=B30*C30*D30	=H30*$M30*N$22	=I30*$M30*O$22	=J30*$M30*P$22	=K30*$M30*Q$22
31		=B31*C31*D31	=H31*$M31*N$22	=I31*$M31*O$22	=J31*$M31*P$22	=K31*$M31*Q$22
32		Total	=SUM(N29:N31)	=SUM(O29:O31)	=SUM(P29:P31)	=SUM(Q29:Q31)
33		=B33*C33*D33	=H33*$M33*N$22	=I33*$M33*O$22	=J33*$M33*P$22	=K33*$M33*Q$22
34		=B34*C34*D34	=H34*$M34*N$22	=I34*$M34*O$22	=J34*$M34*P$22	=K34*$M34*Q$22
35		=B35*C35*D35	=H35*$M35*N$22	=I35*$M35*O$22	=J35*$M35*P$22	=K35*$M35*Q$22
36		Total	=SUM(N33:N35)	=SUM(O33:O35)	=SUM(P33:P35)	=SUM(Q33:Q35)
37		SSBRV	=N28+N32+N36	=O28+O32+O36	=P28+P32+P36	=Q28+Q32+Q36
38						

Figure A.6.6.3. The EXCEL sheets used to compute the results in Tables A.6.5.1.a+b.

A.7. CATCH, LANDINGS, DISCARDS AND MEAN STOCK NUMBERS

"Catches" are the numbers caught, the sum of discards and landings. They are derived at the product of fishing mortality and the mean number of survivors.
Mean number of survivors during time period, q, is (Eq. A.6.5.1):

$$N_{Mean}(St,y,a,q,Ar) = N(St,y,a,q,Ar)\frac{1-\exp(-Z(St,y,a,q,Ar)*dt)}{Z(St,y,a,q,Ar)*dt}$$

where Z (St, y, a, q, Ar) = F(•, •, •, •, St,y, a, q, Ar) + M(St, y, a, q) = Total mortality, and

$$F(\bullet,\bullet,\bullet,\bullet,St,y,a,q,Ar) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} F(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$$

Number caught during time period q is

$$C(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = F(Fl,Vs,Rg,Ct,St,y,a,Ar) * N_{Mean}(St,y,a,q,Ar) \qquad \text{(A.7.1)}$$

Note that the catch created by an annual F

$$F_{annual} = F_{Period=1} * dt + F_{Period=2} * dt + \ldots \quad + F_{Last\ Period} * dt \qquad \text{(A.7.2)}$$

can give infinitely many different catches, depending on its distribution on time periods. Only if M=0, will there be only one unique value of the catch.

The larger M is, the larger will the difference be between Catches created by different distributions of F on the time periods. Figure A.7.1 shows an example of the different catches achieved by two different F-distributions on time periods.

$$C_{Annual} = C(First\ \ Period) + \ldots + C(Last\ \ period) =$$
$$N_{Mean}(Year) * F_{annual} =$$
$$N_{Mean}(First\ \ Period) * F_{Period=1} * dt + \ldots.. + N_{Mean}(Last\ \ period) * F_{Last\ Period} * dt$$

The 3 examples of F all produces an annual F of 0.5.
It also shows that the difference gets bigger when M gets bigger. The differences in catches and stocks numbers are relatively small, when M0=0.2, the preferred value amongst ICES experts.

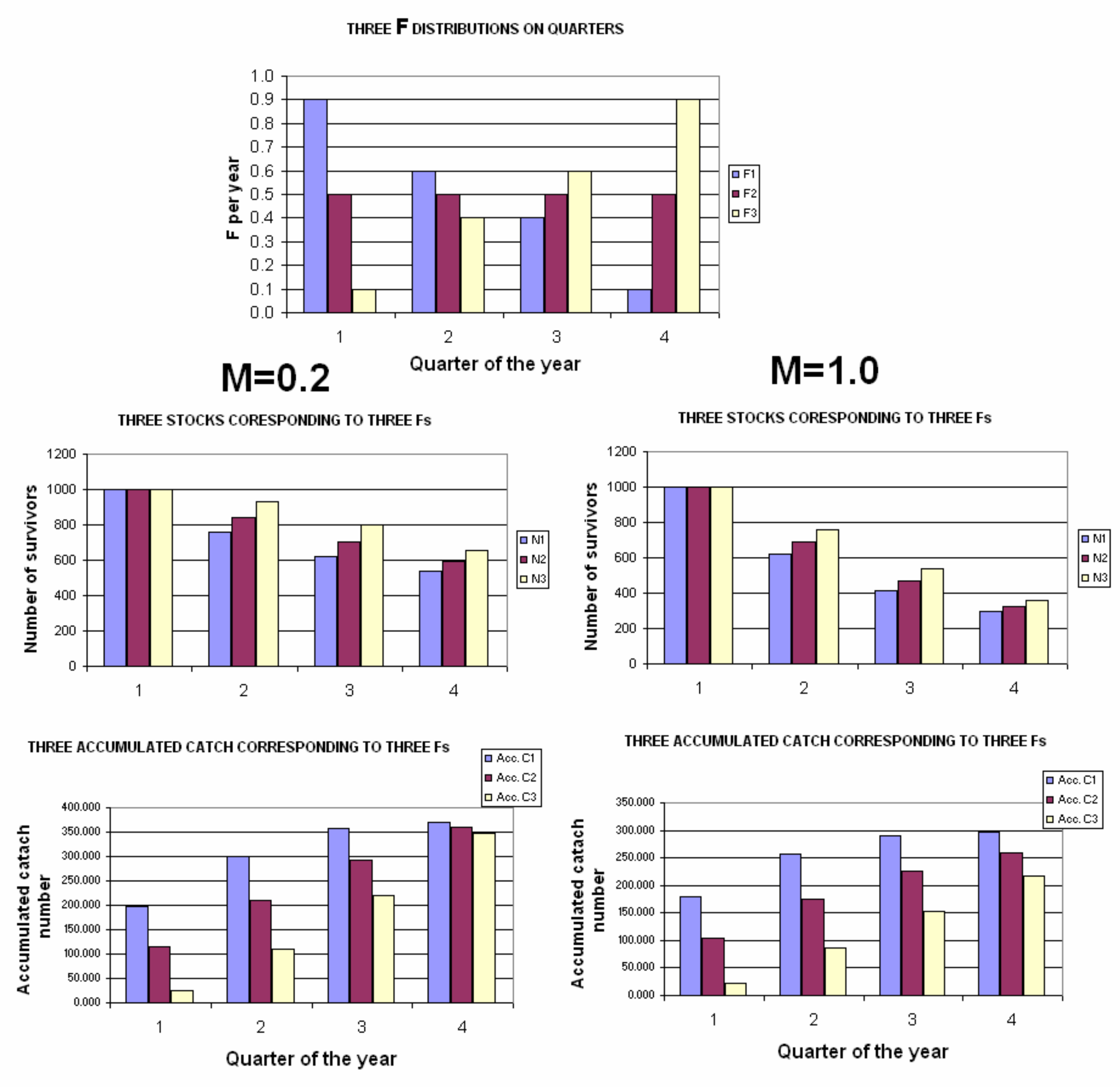

Figure A.7.1. Illustration of the influence on catches and stock numbers of F-distribution on time periods combined with natural mortality.

Numbers landed

$$C_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = F_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) * N_{Mean}(St,y,a,q,Ar) \qquad (A.7.4)$$

Numbers discarded

$$C_{Disc}(Fl, Vs,Rg,Ct,St,y,a,q,Ar) = F_{Disc}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) * N_{Mean}(St,y,a,q,Ar) \qquad (A.7.5)$$

Weight of fish landed (Yield) is

$$Y_{Land}(Fl, Vs,Rg,Ct, St, y, a, q, Ar) = C_{Land}(Fl, Vs,Rg,Ct, St, y, a, q, Ar) * Wgt(St, y, a, q) \qquad (A.7.6)$$

The total annual fleet specific landings of all age groups caught in area "Ar" becomes

$Y_{Land}(\, Fl, Vs, Rg, Ct, St, y, \bullet, q, Ar \,)$

Weight of Numbers discarded becomes

Y_{Disc}(Fl, Vs,Rg,Ct, St, y, a, q, Ar) = C_{Disc}(Fl, Vs,Rg,Ct, St, y, a, q, Ar) * Wgt(St, y, a, q) (A.7.7)

The total annual fleet specific discards of all age groups caught in area "Ar" becomes

$Y_{Disc}(\, Fl, Vs, Rg, Ct, St, y, \bullet, q, Ar \,)$

The landings and discards for the stock summed over areas and age groups becomes

$Y_{Land}(\, Fl, Vs, Rg, Ct, St, y, \bullet, q, \bullet \,)$ and $Y_{Disc}(\, Fl, Vs, Rg, Ct, St, y, \bullet, q, \bullet \,)$

and the annual landings and discards of the stock become

$Y_{Land}(\, Fl, Vs, Rg, Ct, St, y, \bullet, \bullet, \bullet \,)$ and $Y_{Disc}(\, Fl, Vs, Rg, St, y, \bullet, \bullet, \bullet \,)$

Eventually we arrive at the total landings and discards by fleet Fl of country Ct

$$LANDINGS(\, Fl, Ct, y \,) = Y_{Land}(\, Fl, \bullet, \bullet, Ct, y, \bullet, \bullet, \bullet \,) \text{ and}$$
$$DISCARDS(\, Fl, Ct, y \,) = Y_{Disc}(\, Fl, \bullet, \bullet, Ct, y, \bullet, \bullet, \bullet \,) \quad \text{(A.7.8)}$$

Fleet F:

$$F(Fl, \bullet, St, y, a, q, \bullet) = F(\bullet, \bullet, St, y, a, q, \bullet) * C(Fl, \bullet, St, y, a, q, \bullet) / C(\bullet, \bullet, St, y, a, q, \bullet)$$

Rigging F:

$$F(Fl, Rg, St, y, a, q, \bullet) = F(\bullet, \bullet, St, y, a, q, \bullet) * C(Fl, Rg, St, y, a, q, \bullet) / C(\bullet, \bullet, St, y, a, q, \bullet)$$

$$Q(Fl, Rg, St, y, a, q, Ar) = E(Fl, y, q, Ar) / F(Fl, Rg, St, y, a, q, Ar)$$

A.8. AREA BASED MORTALITY AND STOCK-MORTALITY

The concept "Mortality" as it is traditionally applied refers to the entire stock, not to the fraction of a stock, which is in a certain area. Consequently, the number of deaths in a sub-area of the total distribution area of a stock, should not be associated with a "mortality", but with some other concept (Sparre & Hart, 2002). Here we use the term "area-specific mortality", as the concept required to describe the death process within a sub-area, naturally, is closely related to the real mortality concept.

Let Z_{stock}(St,y,q,a) indicate the traditional total mortality of the stock. The relation ship between Z_{stock} and the area specific total mortalities, Z(St,Ar,y,q,a), is given by:

$$Z_{Stock}(St,y,q,a) = -\frac{1}{dt}\ln\left\{\frac{\sum_{Ar=1}^{Ar_{Max}} \exp(-Z(St,y,a,q,Ar)dt)N(St,y,a,q,Ar)}{N(St,y,a,q,\bullet)}\right\} \quad \text{(A.8.1)}$$

where the stock number is $N(St,y,a,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} N(St,Ar,y,q,a)$.

Or when Z is divided into fishing and natural mortality

$$Z_{Stock}(St,y,q,a) = F_{Stock}(St,y,q,a) + M_{Stock}(St,y,q,a) = -\frac{1}{dt}\ln\left\{\frac{\sum_{Ar=1}^{Ar_{Max}} \exp(-F(St,y,a,q,Ar)dt - M(St,y,a,q,Ar)dt)N(St,y,a,q,Ar)}{N(St,y,a,q,\bullet)}\right\} \quad \text{(A.8.2)}$$

If the natural mortality remains the same in each area, Eq (A.6.5.1) also holds for F

$$F_{Stock}(St,y,q,a) = -\frac{1}{dt}\ln\left\{\frac{\sum_{Ar=1}^{Ar_{Max}} \exp(-F(\bullet,\bullet,\bullet,\bullet,St,y,a,q,Ar)dt)N(St,y,a,q,Ar)}{N(St,y,a,q,\bullet)}\right\} \quad \text{(A.8.3)}$$

The reasoning behind these definitions of Z_{Stock} and F_{Stock} are explained in the framed text below. Three alternative ways of defining F_{Stock} is presented. Unfortunately, the three methods yield slightly different values of F_{Stock}. Table A.8.1. illustrates the calculation of Z_{Stock} by Eq. A.8.1, and F_{Stock} by the 3 alternative methods, explained in the frame below. Table A shows an example where the 3 methods give approximately the same values of FStock, whereas table B shows an example with larger discrepancies between methods. Table C compares the 3 alternative definitions.

Somehow, these stock concepts are not very important in TEMAS, as the catches, stocks etc. all are based on the area concepts. They are needed mainly to make the output of TEMAS compatible with results from, for example, ICES WG reports, which are still based on the stock. If, e.g. a harvest control rule uses the stock fishing mortality, there is a need to know the stock fishing mortality.

ON THE DEFINITION OF F_{Stock} AND Z_{Stock}

To facilitate the understanding, the only the relevant indices are use in the following explanation for the expressions defining F_{Stock} and Z_{Stock},.

For the stock (in all areas combined) we assume the exponential decay model (with dt=1)

$$N^{Start}_{Stock}\exp(-Z_{Stock}) = N^{End}_{Stock} \qquad (A)$$

Here Z_{Stock} is the conventional mortality (stock mortality), which is not modelled in TEMAS.

And for each area we also assume the exponential decay model:

$$N^{Start}(Ar)\exp(-Z(Ar)) = N^{End}(Ar) \qquad (B)$$

where $Z(Ar)$ is the "area-mortality"

Z(Ar) = F(Ar)+M , is modelled in TEMAS. M is given as input and F(Ar) is derived from the effort.

Thus the task here is to derive Z_{Stock} from Z(Ar), Ar=1,…,Ar_{MAX},

To define Z_{Stock} we assume that the equality is valid

$$N^{Start}_{Stock} * \exp(-Z_{Stock}) = \sum_{Ar=1}^{Ar_{Max}} N^{Start}(Ar) * \exp(-Z(Ar)) \qquad (C)$$

$$N^{Start}_{Stock} = \sum_{Ar=1}^{Ar_{Max}} N^{Start}(Ar) \qquad (D)$$

That is, we define, Z_{Stock} so that (C) is valid . That assumption leads to the definition of Z_{Stock}

$$Z_{Stock} = -\ln\left\{\sum_{Ar=1}^{Ar_{Max}} \frac{N^{Start}(Ar)}{N^{Start}_{Stock}} \exp(-Z(Ar))\right\} \qquad (E)$$

$$F_{Stock} + M_{Stock} = -\ln\left\{\sum_{Ar=1}^{Ar_{Max}} \frac{N^{Start}(Ar)}{N^{Start}_{Stock}} \exp(-F(Ar) - M(Ar))\right\}$$ *so if M(Ar) remains constant over areas then the expression (E) also holds for F:*

$$F_{Stock} = -\ln\left\{\sum_{Ar=1}^{Ar_{Max}} \frac{N^{Start}(Ar)}{N^{Start}_{Stock}} \exp(-F(Ar))\right\} \qquad (F)$$

Eq. (F) is used as definition of F_{Stock}, when M remains constant over areas.

The mean number of survivors for each area and from the stock are

$$N^{Mean}(Ar) = N^{Start}(Ar)\frac{1-\exp(-Z(Ar))}{Z(Ar)} \quad \text{and} \quad N^{Mean}_{Stock} = N^{Start}_{Stock}\frac{1-\exp(-F_{Stock} - M_{Stock})}{F_{Stock} + M_{Stock}} \qquad (G)$$

And the catch number of area Ar and the catch of the stock are

$$C(Ar) = F(Ar)N^{Mean}(Ar) \quad \text{and} \quad C_{Stock} = F_{Stock} * N^{Mean}_{Stock} = \sum_{Ar=1}^{Ar_{Max}} F(Ar)N^{Mean}(Ar) \qquad (H)$$

This leads to the alternative definition of F_{Stock},

$$F_{Stock} = \sum_{Ar=1}^{Ar_{Max}} F(Ar)\frac{N^{Mean}(Ar)}{N^{Mean}_{Stock}} \qquad (I)$$

Finally, we could define F_{Stock} by the solution to the equation (F_{Stock} is the unknown)

$$C_{Stock} = \sum_{Ar=1}^{Ar_{Max}} C(Ar) \quad or \quad F_{Stock}N^{Start}_{Stock}\frac{1-\exp(-F_{Stock} - M_{Stock})}{F_{Stock} + M_{Stock}} = \sum_{Ar=1}^{Ar_{Max}} C(Ar) \qquad (J)$$

However, (I) and (J) lead to slightly different values of F_{Stock}

A: **(Moderate variation in Fs)**						**(E)**		**(F)**			**(I)**
	F(Ar)	M(Ar)	Z(Ar)	$N^{Start}(Ar)$	exp(-Z(Ar))	N* exp(-Z(Ar))	exp(-F(Ar))	N* exp(-F(Ar))	$N^{Mean}(Ar)$	C(Ar)	$N^{Mean}(Ar)$ $F(Ar)$
Area 1	0.5	0.2	0.70	800	0.497	397.3	0.6065	485.2	575.3	287.7	287.7
Area 2	1	0.2	1.20	500	0.301	150.6	0.3679	183.9	291.2	291.2	291.2
Area 3	0.2	0.2	0.40	1000	0.670	670.3	0.8187	818.7	824.2	164.8	164.8
Total		2300		2300		1218.2		1487.9	1690.7	743.7	743.7
					Z_{Stock}	0.635547	F_{Stock}	0.435547		F_{Stock}	0.439862

B: **(Large variation in Fs)**						**(E)**		**(F)**			**(I)**
	F(Ar)	M(Ar)	Z(Ar)	$N^{Start}(Ar)$	exp(-Z(Ar))	N* exp(-Z(Ar))	exp(-F(Ar))	N* exp(-F(Ar))	$N^{Mean}(Ar)$	C(Ar)	$N^{Mean}(Ar)$ $F(Ar)$
Area 1	0.5	0.2	0.70	800	0.497	397.3	0.6065	485.2	575.3	287.7	287.7
Area 2	2	0.2	2.20	500	0.111	55.4	0.1353	67.7	202.1	404.2	404.2
Area 3	0.1	0.2	0.30	1000	0.741	740.8	0.9048	904.8	863.9	86.4	86.4
Total		2300		2300		1193.5		1457.7	1641.4	778.2	778.2
					Z_{Stock}	0.656029	F_{Stock}	0.456029		F_{Stock}	0.474143

Method	A:F_{Stock}	B: F_{Stock}
(F)	0.435547	0.456029
(I)	0.439862	0.474143
(J)	0.437223	0.462796

Table A.8.1. Calculation of ZStock by 1 method, and FStock by 3 methods, illustrated by 3 numerical examples. The variations in stock numbers $N^{Start}(Ar)$ has no influence on discrepancies between the three methods. The variation in the Fs is the significant factor (Compare tables A and B). In case B, the difference between methods (F) and (I) comes up to 4%.

$$F_{Stock,a-Max}(Fl,Vs,Rg,Ct,St,y,q) = MAX_a \{ \; F_{Stock}(Fl,Vs,Rg,Ct,St,y,a,q) \; \} \quad \text{(A.8.4)}$$

Eventually, we introduce the stock version of the area specific maximum F over age groups, $F_{a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar)$, by

$$F_{Stock,a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} F_{Stock,a-Max}(Fl,Vs,Rg,Ct,St,y,q) \quad \text{(A.8.5)}$$

$$F_{Stock,REL-Max}(Fl,Vs,Rg,Ct,St,y,q) = F_{Stock,a-Max}(Fl,Vs,Rg,Ct,St,y,q) / F_{Stock,a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,a) \quad \text{(A.8.6)}$$

A.9. DEFINITION AND ESTIMATION OF INITIAL NUMBER OF VESSELS

An initial number of vessels have to be defined and estimated to be used in the model.

A.10. "OTHER" COMPONENTS

The TEMAS model aims at a complete description of the fisheries system, comprising all important components. However, often there are minor components, which are not well covered with data or knowledge. Often a component "unknown" ("Unknown species", "unknowns gear" etc.) appears in the statistics. The unknown component may or may not origin from an important species or an important gear. These minor components or unknown components, when combined, may make up a part of the system which cannot be ignored. In that case, the lack of knowledge and data, are replaced by a combination of assumptions and whatever data is available. This process is a compromise between the avoidance of errors introduced by ignoring the components and the error introduced by making assumptions about it.

A.10.1. "OTHER RIGGINGS", "OTHER FLEETS", AND "OTHER COUNTRIES"

When calculating the total fishing mortality by summing over fleets and countries (Eq. A.5.1.10)

$$F_{a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} F_{a-Max}(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

the individual fleets and the individual countries may be of three categories

1) Real countries, like Denmark, Sweden etc, for which catch and effort data are available.

2) "Other countries". Countries which usually collectively will make up a minor part of the total, and for which limited data and knowledge are available.

3) "Unknown country" (landings for which country is not reported)

Group 3, the "unknown" will often be distributed on countries in the same proportions as the known countries. The "unknown" will then contribute to the "other" with the same proportion as the "known" countries.

The hypothetical "Other fleets" will often consist in a variety of gears all of which take only a small part of the total. To account for this fishing mortality, we may introduce a non-existing fleets with one hypothetical gear and one hypothetical rigging. The "Other fleet" will usually be assigned only one vessel size class.

Likewise, "Other countries" will usually get assigned one "Other Fleet", with one vessel size group and one rigging.

The typical set up when defining fleets and countries is illustrated by the text table:

Countries		**Fleets**	
Country A	Fleet A.1 (Trawlers)	Fleet A.2 (Gill netters)	Fleet A.3 ("Other fleets")
Country B	Fleet B.1 (Trawlers)	Fleet B.2 (Gill netters)	Fleet B.3 ("Other fleets")
"Other countries"	Other fleets		

If required, "Other riggings" and "Other vessel sizes" can also be defined.

As a matter of principle, "Other"-groups should always be defined, unless they make up a very small fraction of the total.

Table A.10.1.1 and Figure A.10.1.1 show the total landings of cod by gear 1993-2005. As can be seen the majority of landings were made by trawlers and gill netters. Based on these data, it was decided to use only three fleets in the TEMAS simulation for the Baltic. Namely “Trawlers”, “Gill netters” and “Other”. Which gears were allocated to the three groups is shown in the right most column in Table A.10.1.1

Fleet/Gear	Cod Landings 93-05 (tons)	TEMAS Fleets
Boat Dredge	21.37	OTHER
Pound nets	1594.42	OTHER
Pots	2.92	OTHER
FWR	1.87	OTHER
Fyke nets	0.84	OTHER
Gillnet	30709.06	Gill Netters
Gillnet-2	3.12	Gill Netters
Driftnet	382.63	Gill Netters
Set gillnet	200401.07	Gill Netters
Set gillnet	6180.34	Gill Netters
Hooks	4816.34	OTHER
Hand and pole lines	112.88	OTHER
Longlines	4613.30	OTHER
Trolling lines	0.63	OTHER
Drifting longlines	15.20	OTHER
Set longlines	6836.42	OTHER
Bottom otter trawl	466600.18	Trawlers
Multi-rig otter trawl	0.34	OTHER
Pelagic otter trawl	61877.57	Trawlers
Purse seine	2.57	OTHER
Bottom pair trawl	25558.07	Trawlers
Pelatic pair trawl	3664.99	Trawlers
Anchored seine	13845.61	Trawlers
Fly shooting seine	614.52	Trawlers
Beam trawl	78.00	OTHER
Other longlines and hooks	0.45	OTHER
Other fixed gears	26.67	OTHER
Other demersal trawl	4.80	Trawlers
Other pelagic trawl	19.05	OTHER
Other	1149.93	OTHER
Unknown	425.09	OTHER

Table A.10.1.1. Landings of Baltic cod 1993-2005 by gear.

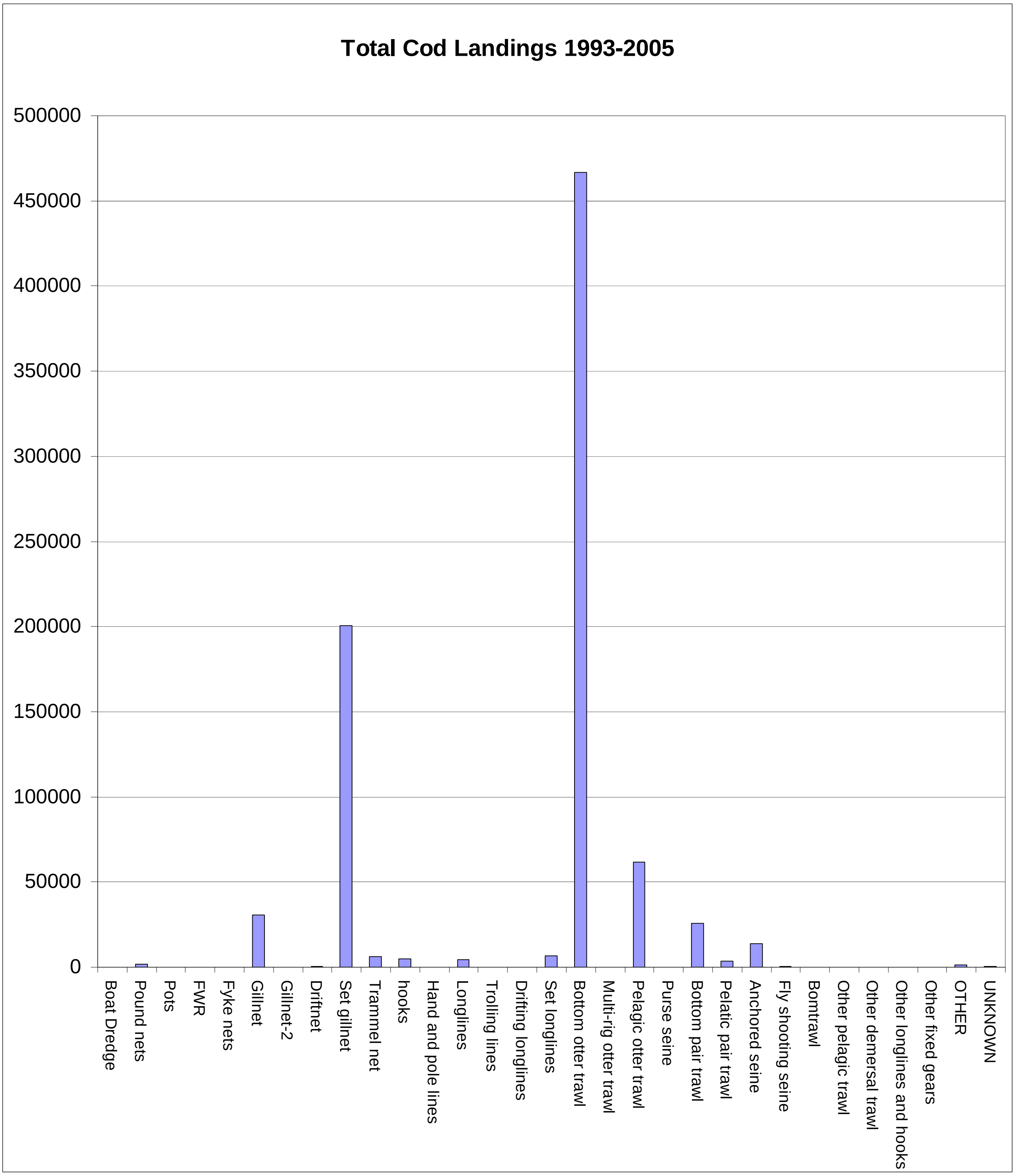

Figure A.10.1.1. Cod landings, 1993-2005 by gear (from official statistics), based in Table A.10.1.1.

Perhaps the most weak data is information about rigging, such as "mesh size". Statistics from e.g. logbooks may not contain information on gear rigging.

A.10.2. "OTHER STOCKS"

When making an technical/economic analysis of fisheries, it is obviously important to account for all major components of revenue from landings. When calculating the revenue, it is important that all major stocks are accounted for. Some minor parts of the revenue may origin from rare stocks, for which data and knowledge are less than for the important stocks. There may for such stocks only be total landings data available, but no estimates mortality and stock sizes from stock assessment. Sometimes small bycatches make up a considerable part of the value of the landing, such as bycatches of turbot, monkfish etc.

Such minor stocks are often grouped into a lump group "Other stocks". There are two ways to deal with "Other stocks" in TEMAS. One way is to let the "Other group" be represented by a "hypothetical fish", with hypothetical parameters and age distribution. In that case, the "Other stocks" component is treated as the real stocks. That is, there is a full biological/technical model for "Other stocks". In that case you may choose the parameters from the most valuable bycatch.

The second option is to let the revenue from "Other stocks" become a time specific constant, that is added to the revenue each time period. In that case, there is no account of biological/technical features of "other stocks".

Figure A.10.2.1 shows landings of the three species modelled in the TEMAS simulation for the Eastern Baltic (Cod, sprat and "Other"). Figure A.10.2.2 shows the landings of the most important other species. Currently, the bulk of landings (in weight) comes from sprat and herring. Note that herring makes up the major part of "other" species (Figure A.10.2.2)

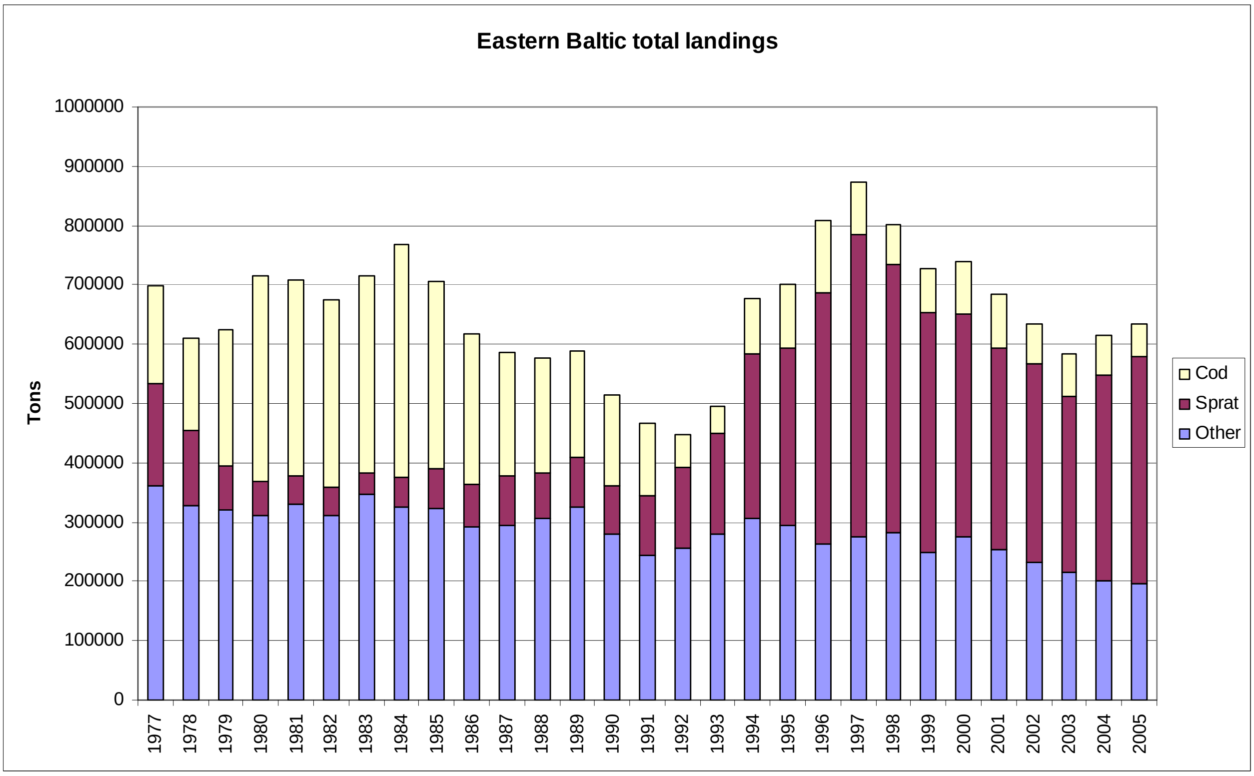

Figure A.10.2.1. Landings of Cod, Sprat and "other" species in the Eastern Baltic (tons).

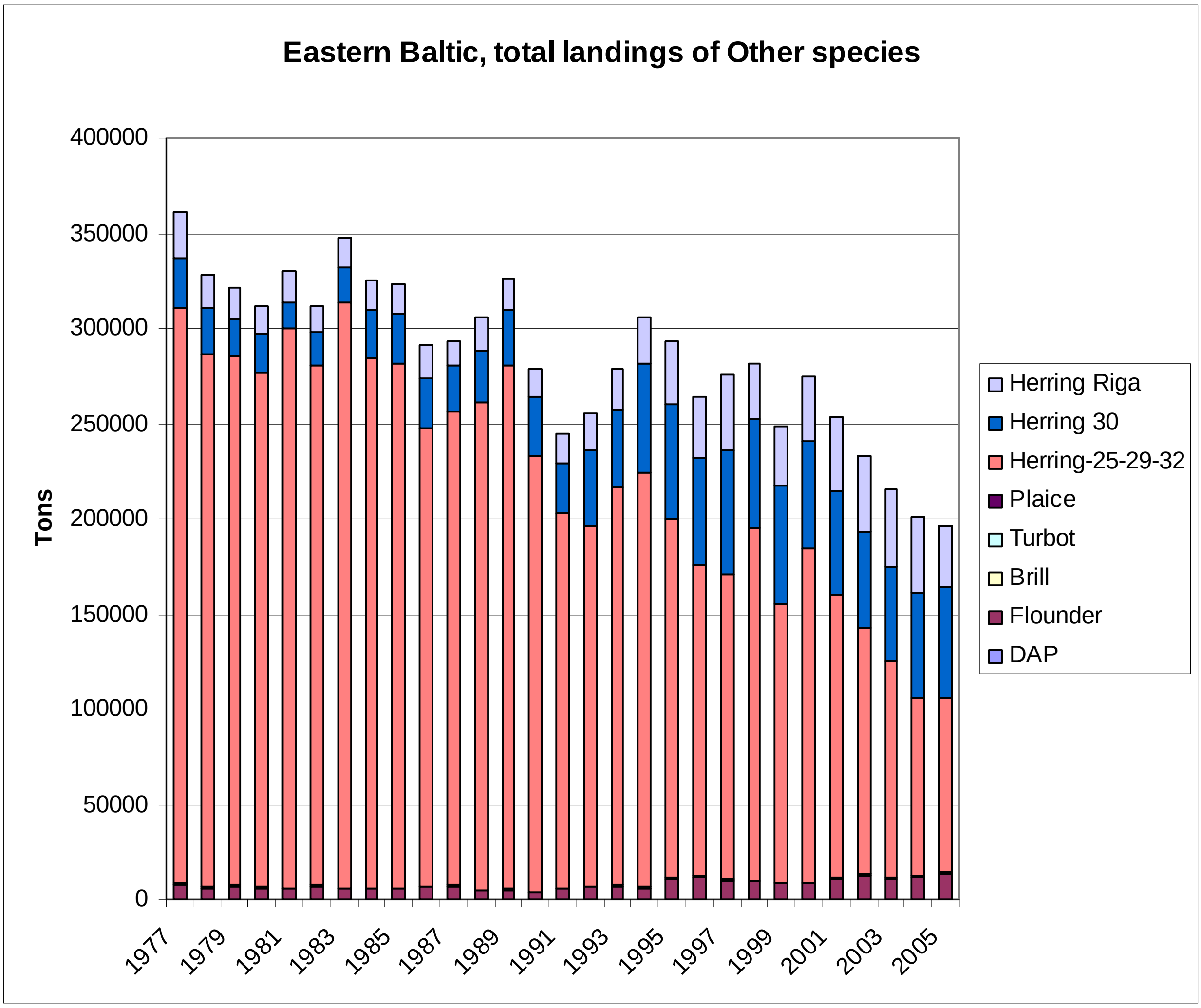

Figure A.10.2.2. Landings of selected "other" species in the Eastern Baltic.

Annex F ("basic features of the Baltic fisheries") shows the landings of some of the most important species of the about 100 fish species found in the Baltic.

A.11. STOCK AND RECRUITMENT MODELS

There are four options for stock and recruitment model in TEMAS: (1) Beverton and Holt model (Beverton & Holt, 1957) (2) "Hockey stick" model (Barrowman & Meyers, 1999), (3) Ricker Model (Ricker, 1954) (4) the general Deriso-Schnute Model (Deriso 1980, Schnute, 1985). The deterministic recruitment model in TEMAS is a function of spawning stock, SSB, only. Dependence of environmental factors, can be accounted for by "stochastic factors", as will be explained in section A.11.3. The four standard S/R-models are extended to account for spatial and temporal variation in recruitment for Baltic cod, as will explained in Section A.11.2.

	Cod 22-24		Cod 25-32	
Year	SSB	Age 1	SSB	Age 2
1966			172018	430264
1967			228679	370921
1968			233958	354062
1969			222659	306727
1970	39257	263058	208842	240010
1971	45391	207154	184181	264787
1972	46555	286660	198995	322278
1973	45812	92998	211991	432140
1974	47388	251942	262952	506893
1975	38840	114659	339545	303683
1976	45222	111321	355564	293397
1977	34726	191434	326914	479002
1978	31040	132120	379201	829398
1979	41099	57987	579671	615355
1980	58658	162179	696743	425886
1981	52600	107078	666132	689812
1982	49418	146332	670940	693588
1983	51529	176912	645257	472372
1984	48853	53791	657664	302917
1985	49845	36378	544905	253068
1986	29969	95791	399361	260185
1987	23943	59191	320445	368020
1988	30948	17611	299218	224226
1989	26825	25862	240171	122080
1990	15169	23623	215707	128178
1991	10989	40105	151037	83164
1992	9121	93619	92473	140320
1993	16731	46975	113516	182779
1994	30221	80559	193795	127081
1995	31369	126436	242301	119287
1996	38326	41668	168813	115315
1997	38889	98017	146437	87797
1998	19674	127965	110977	149345
1999	24937	57917	89336	152645
2000	30265	63822	114682	174984
2001	25117	45892	103944	135710
2002	17973	67821	82879	121987
2003	17238	34919	80533	102133
2004	22969	66557	77172	72718
2005	22210	23759	65444	162300

Table A.11.01. Stock and recruitment of Baltic cod, from ICES WGBFAS, 2006.

Table A.11.0.1 shows the stock (Spawning Stock Biomass, SSB) and recruitment as estimated by the ICES working group (ICES, 2006) for the two Baltic cod stocks. The WGBFAR uses age group 2 as the recruits for the eastern stock, whereas it age group 1 for the western stock. These data are used to produce the graphs for Baltic cod shown in the following subsection.

Figures A.11.0.1a and b show the time series of SSB and recruitment, with a time lag of 1 and 2 years respectively.

Figures A.11.0.2a and b show the plot of SSB on recruitment, with a time lag of 1 and 2 years respectively.

Figures A.11.0.3a and b show the frequency of recruitment, with a time lag of 1 and 2 years respectively. The intervals of the frequency classes are shown in Table A.11.0.2.

Cod 22-24				Cod 25-32			
Lower*)	Upper*)	Index	Frequency	Lower*)	Upper*)	Index	Frequency
10	30	1	4	0	100	1	3
30	50	2	6	100	200	2	14
50	70	3	7	200	300	3	6
70	90	4	1	300	400	4	7
90	110	5	5	400	500	5	5
110	130	6	4	500	600	6	1
130	150	7	2	600	700	7	4
150	170	8	1	700	800	8	0
170	190	9	1	800	900	9	1
190	210	10	2	900	1000	10	0
210	230	11	0	1000	1100	11	0
230	250	12	0	1100	1200	12	0
250	270	13	2	*) Unit of recruitment: Million of recruits.			
270	290	14	1				

Table A.11.0.2. Recruitment frequencies shown in Figure A.11.0.3.a-b.

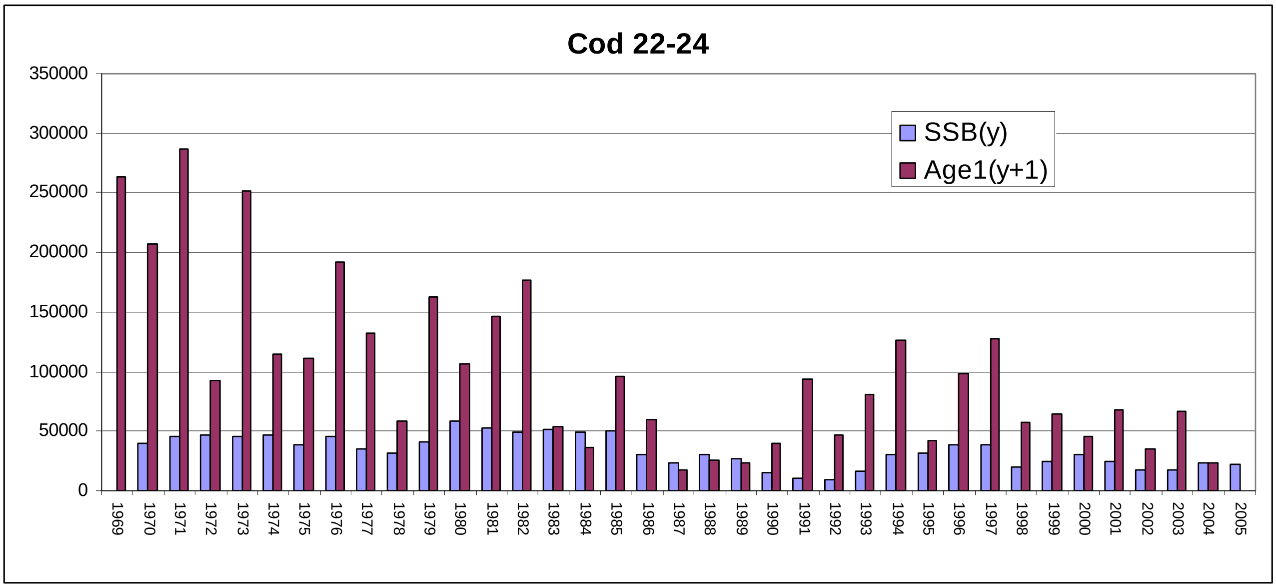

Figure A.11.01a. Stock and recruitment (age group 1) of Western Baltic cod Source ICES, WGBFAR,2006

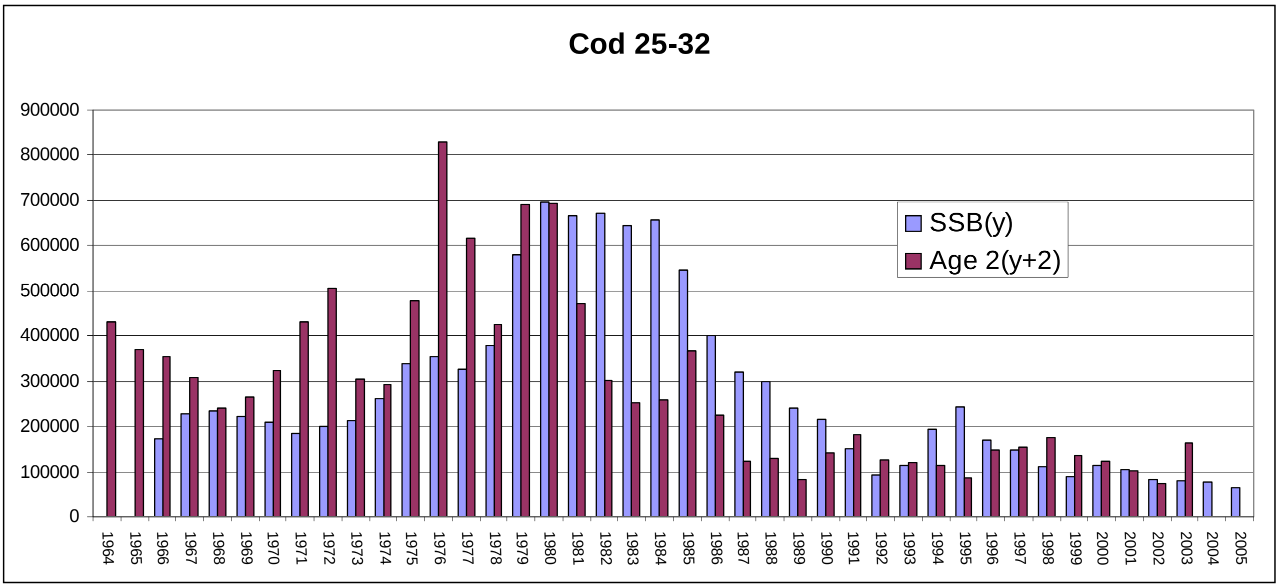

Figure A.11.0.1b. Stock and recruitment (age group 2) of Eastern Baltic cod Source ICES, WGBFAR,2006

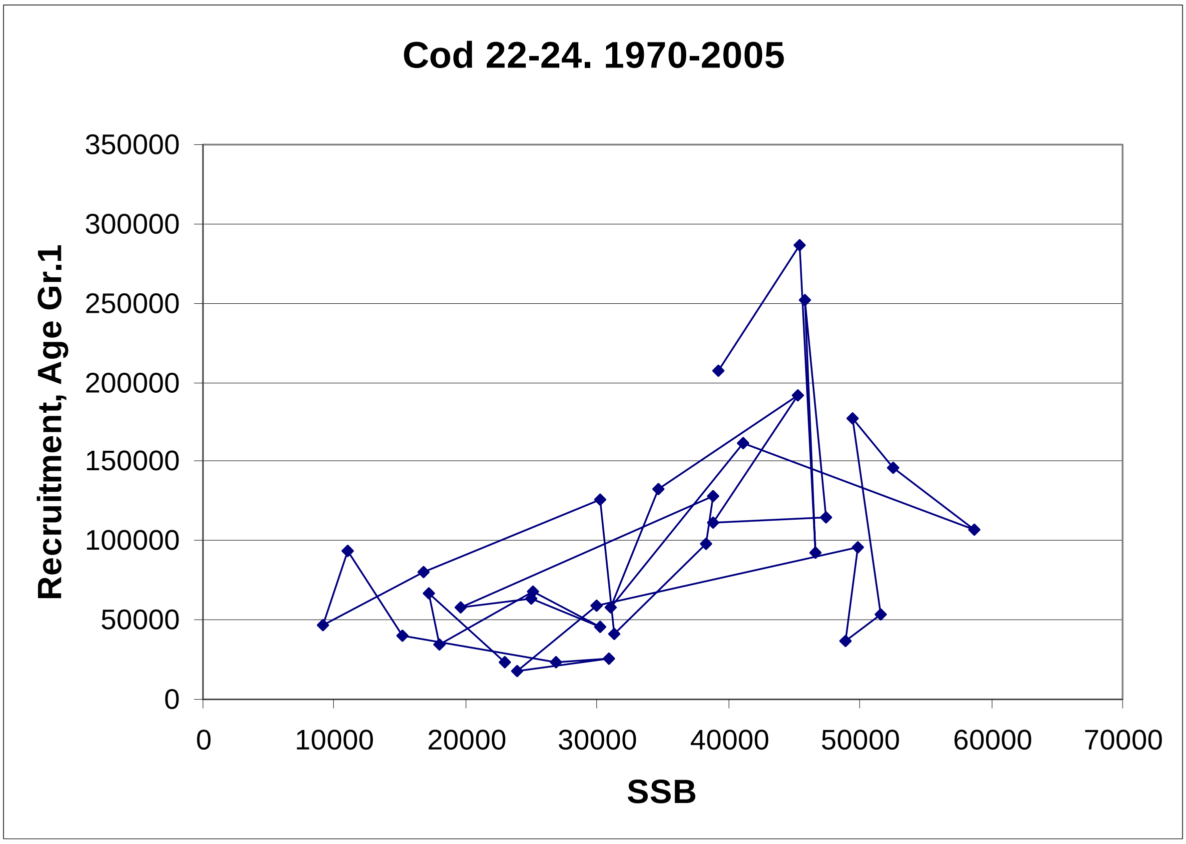

Figure A.11.0.2a. Stock and recruitment plot (age group 1) of Western Baltic cod Source ICES, WGBFAR,2006

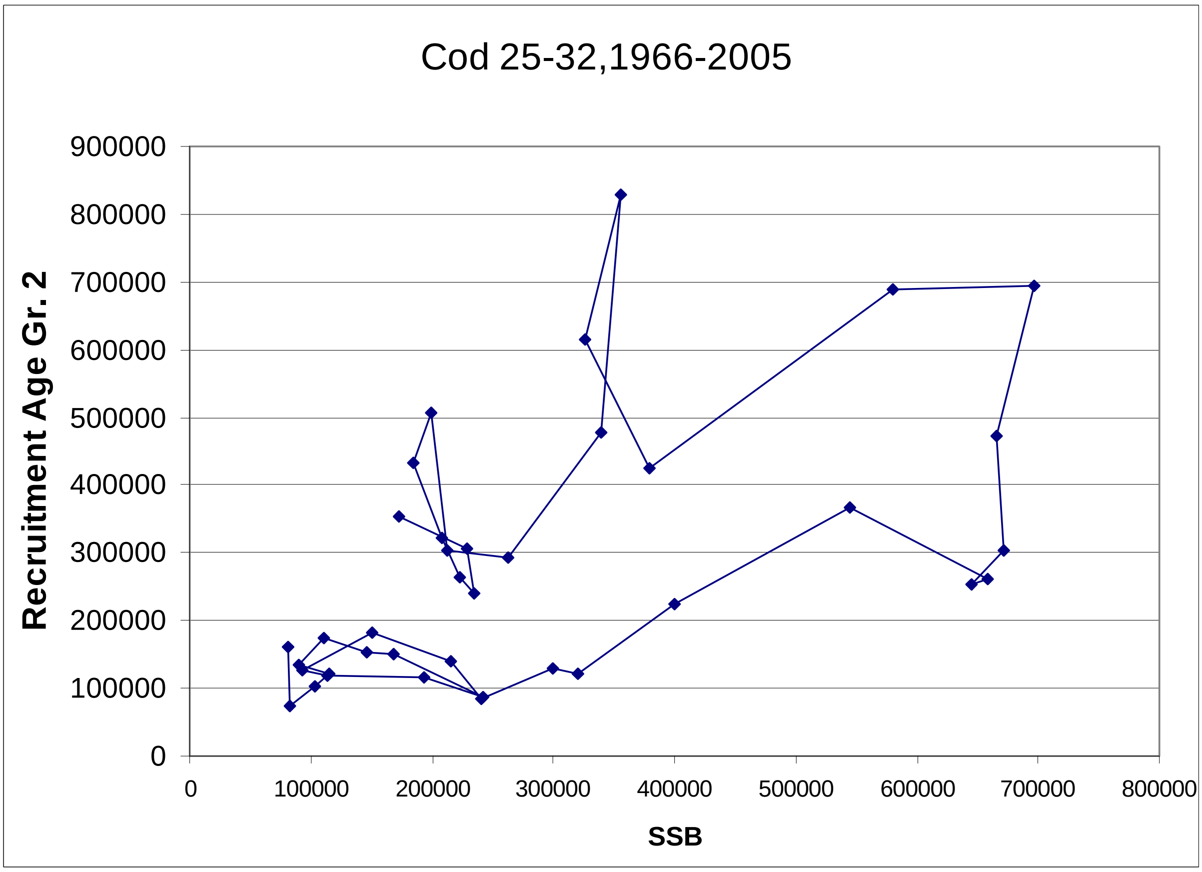

Figure A.11.0.2b. Stock and recruitment plot (age group 2) of Eastern Baltic cod Source ICES, WGBFAR,2006

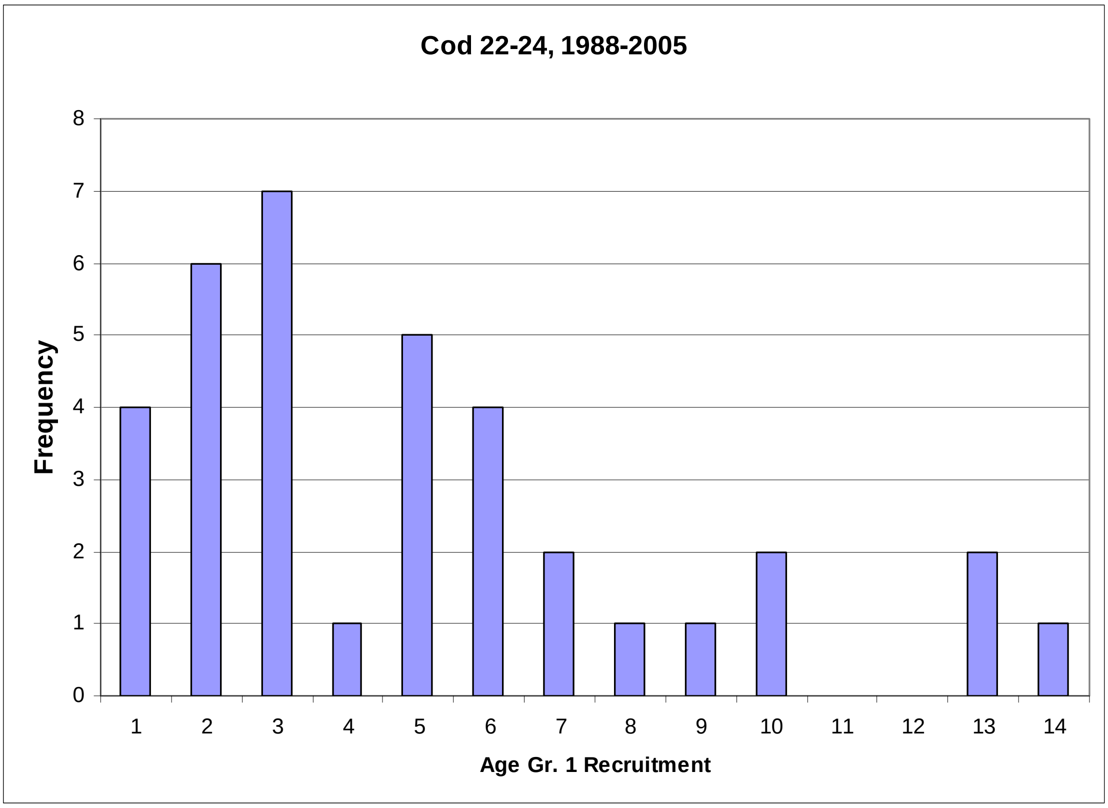

Figure A.11.0.3a. Recruitment frequency (age group 1) of Western Baltic cod Source ICES, WGBFAR ,2006

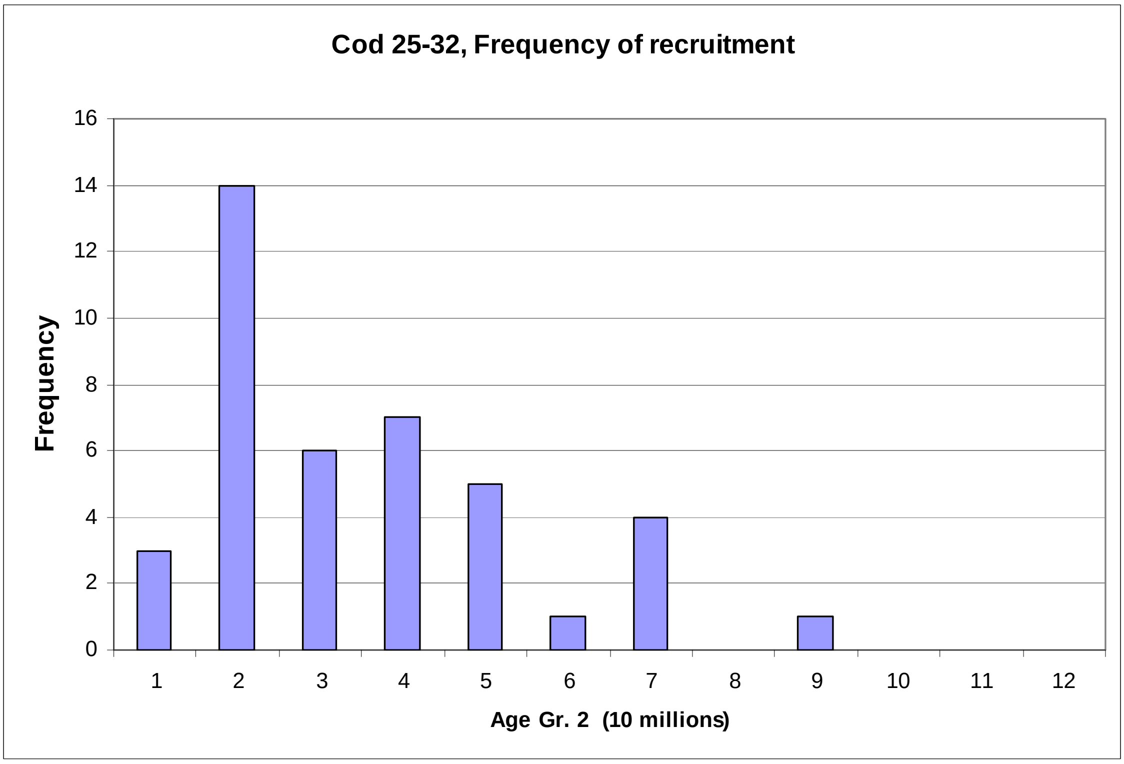

Figure A.11.0.3b. Recruitment frequency (age group 2) of Eastern Baltic cod Source ICES, WGBFAR, 2006

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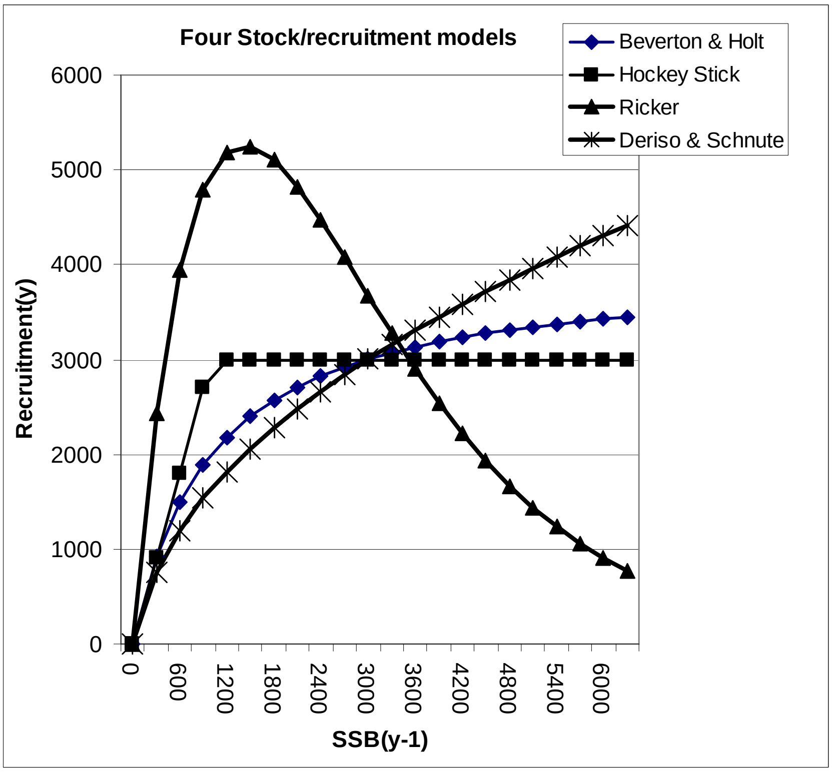


Figure A.11.1.1. Examples of the four alternative Stock-Recruitment models available in TEMAS, SR_1: Beverton & Holt, SR_2: Hockey-stick, SR_3: Ricker, SR_4:Deriso-Schnute.

A.11.1. DETERMINISTIC STOCK RECRUITMENT MODEL

The deterministic recruitment is in TEMAS derived from the "average annual stock SSB of the reproductive volume" (Introduced in Section A.6.6) of last year. [3]

$$SSB_{RV}(St,y,\bullet,\bullet) = \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}} \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St,y,a,q,Ar)*$$

$$Wgt(St,y,a,q)*Mat(St,a,q)*RDist_{Period}(St,q)*RSF_{MPA}(St,Ar)$$

where

$$RDist_{Period}(St,q) = \frac{Egg\ \ production\ in\ period\ q}{Total\ Annual\ egg\ \ production} \quad \text{and} \quad RSF_{MPA}(St,Ar)(= \begin{cases} rsf_{NotMPA}(St,Ar)\ if\ \ Ar \neq MPA \\ 1\ \ if\ \ Ar = MPA \end{cases}$$

where $0 \le rsf_{NotMPA}(St,Ar,) \le 1$ is the "reduction factor recruitment success outside the MPA".

3

	Index	Explanation	Range	Note that the sequence of indices will be (Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar) for all variables. Time variables in alphabetical order dt: Basic time step (fraction of year). dt < 1.0. dt = $1/q_{Max}$ y_{first} ,y_{last}: First year, Last year Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j) = \sum_u X(i,u,j)$.
1	a	Age group	$a = 0,1,2,\ldots,a_{max}(St)$	
2	Ar	Area	$Ar = 1,2,\ldots,Ar_{max}$	
3	Ct	Country	$Ct = 1,\ldots,Ct_{Max}$	
4	Fl	Fleet	$Fl = 1,2,\ldots,Fl_{max}(Ct)$	
5	q	Time period (as time)	$q = 1,..,q_{max}$	
6	qa	Time period (as age)	$qa = 1,..,q_{max}$,	
7	Rg	Rigging of gear	$Rg = 1,\ldots,Rg_{max}(Fl,Ct)$	
8	y	Year	$y = y_{firSt,\ yfirst}+1,\ldots,y_{last}$	
9	St	Stock	$St = 1,\ldots,St_{max}$	
10	Va	Vessel age group	$Va = 1,\ldots Va_{max}(Fl,Ct)$	
11	Vs	Vessel size group	$Vs = 1,\ldots Vs_{max}(Fl,Ct)$	

The general stock/and recruitment model used in TEMAS for predicting recruitment becomes

$$Rec(St,y,\bullet,\bullet) = STR_X(SSB_{RV}(St,y-1,\bullet,\bullet)) \qquad \text{(A.11.1.1)}$$

where suffix "x" can take the values 1,2,3,4 according the the choice of S/R model. (1) Beverton & Holt (2) "Hockey stick" (3) Ricker (4) Deriso-Schnute (Figure A.11.1.1)

A.11.2. TEMPORAL AND SPATIAL RECRUITMENT MODEL

After the total stock recruitment is derived, it is subsequently distributed on areas and time periods by the input parameters, $RecDist_{Area}(St,Ar)$ and $RecDist_{Period}(St,q)$, the relative distribution of recruitment on areas and time periods as will be discussed below.

$$Rec(St,y,q,Ar) = RecDist_{Area}(St,Ar) * RecDist_{Period}(St,q) * STR_X(SSB_{RV}(St,y-1,\bullet,\bullet)) \qquad \text{(A.11.2.1)}$$

$$RecDist_{Area}(St,Ar) = \frac{Recruitment\ number\ in\ area\ "ar"}{Total\ Recruitment\ Number} = \frac{N(St,y,0,q,Ar)}{\sum_{i=1}^{Ar_{Max}} N(St,y,0,q,i)}$$

(A.11.2.2)

Thus, $RecDist_{Area}(St, Ar)$ is assumed to be independent of time period, "q". The distribution on time periods is defined the same way, $RecDist_{Period}(St, q)$ is assumed to be independent of area, "Ar". A hypothetical example of area and period distributions is shown in Table A.11.2.1. The recruitment is distributed on all areas and periods in Table a, whereas Table b concentrates all spawning in area 3 in period 2.

		$RecDist_{Period}$				
		Period 1	Period 2	Period 3	Period 4	Total
	$RecDist_{Area}$	0.333	0.556	0.111	0.000	1.000
Area 1	0.136	0.045	0.076	0.015	0.000	0.136
Area 2	0.682	0.227	0.379	0.076	0.000	0.682
Area 3	0.136	0.045	0.076	0.015	0.000	0.136
Area 4	0.045	0.015	0.025	0.005	0.000	0.045
Total	1.000	0.333	0.556	0.111	0.000	1.000

*Table A.11.2.1a. Hypothetical example of $RecDist_{Area}$, $RecDist_{Period}$ and $RecDist_{Area}$*$RecDist_{Period}$*

		$RecDist_{Period}$				
		Period 1	Period 2	Period 3	Period 4	Total
	$RecDist_{Area}$	0.000	1.000	0.000	0.000	1.000
Area 1	0.000	0.000	0.000	0.000	0.000	0.000
Area 2	0.000	0.000	0.000	0.000	0.000	0.000
Area 3	1.000	0.000	1.000	0.000	0.000	1.000
Area 4	0.000	0.000	0.000	0.000	0.000	0.000
Total	1.000	0.000	1.000	0.000	0.000	1.000

*Table A.11.2.1b. Hypothetical example of $RecDist_{Area}$, $RecDist_{Period}$ and $RecDist_{Area}$*$RecDist_{Period}$*

The recruitment model now reads

$$Rec(St,y,q,Ar) =$$
$$RecDist_{Area}(St,ar) * RecDist_{Period}(St,q) * STR_X(SSB_{RV}(St,y-1,\bullet,\bullet))$$

Table A.11.2.2 shows a hypothetical example of spawning migration. Table A.11.2.2 shows the migration coefficients, MC. Recall the model of migration (Section A.6.3), which in its simplest form reads.

$$N(St,Tar,y,q+1,a) = \sum_{Far=1}^{Ar_{Max}} MC(St,FAr,TAr,q,a) * N1(St,Ar,y,q,a)$$

In this case there are 3 areas, "West", "East" and "MPA". The MPA is the spawning area, and in this hypothetical case most of the spawners migrate to the MPA in period 2, and then gradually migrates back to the other areas. The time step used in Table A.11.2.2 is a month. By playing with the migration coefficient, various assumptions on the spawning migration can be evaluated. Changing the migration coefficients will change the stock recruitment relationship, when the RSF_{MPA} (St,Ar) allocates higher SSB to the MPA than to the other areas.

	From West to West	From West to East	From West to MPA	From East to West	From East to East	From East to MPA	From MPA to West	From MPA to East	From MPA to MPA
Age 2 - Per. 1	1	0	0	0	1	0	0.25	0.25	0.25
Age 2 - Per. 2	0.167	0	0.833	0	0.167	0.833	0	0	1
Age 2 - Per. 3	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 4	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 5	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 6	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 7	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 8	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 9	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 10	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 11	1	0	0	0	1	0	0.33	0.33	0.33
Age 2 - Per. 12	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 1	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 2	0.167	0	0.833	0	0.167	0.833	0	0	1
Age 3 - Per. 3	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 4	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 5	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 6	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 7	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 8	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 9	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 10	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 11	1	0	0	0	1	0	0.33	0.33	0.33
Age 3 - Per. 12	1	0	0	0	1	0	0.33	0.33	0.33
Age 4 - Per. 1	1	0	0	0	1	0	0.33	0.33	0.33
Age 4 - Per. 2	0.167	0	0.833	0	0.167	0.833	0	0	1
Age 4 - Per. 3	1	0	0	0	1	0	0.33	0.33	0.33
Age 4 - Per. 4	1	0	0	0	1	0	0.33	0.33	0.33
…….. etc …..									

Table A.11.2.2. Hypothetical example of migration coefficients, MC, that makes the stock gather in the MPA in period no. 2 (the year is here divided into 12 months). After period 2, they will gradually migrate out of the MPA.

TEMAS allows for analysing the effect of a "recruitment trend", that is, analysing the effect of average recruitment slowly going downwards or going upwards.

$$\mathrm{Re}c(St,y,q,Ar) = \mathrm{Re}cDist_{Area}(St,Ar) * \mathrm{Re}cDist_{Period}(St,q) * STR_X(SSB_{RV}(St,y-1,\bullet,\bullet)) * \mathrm{Re}cTrend(St,y) \quad \text{(A.11.2.3)}$$

RecTrend(St,y) can be any function of y (year). Recruitment sometimes shows such a trend over a long series of years, for reasons which are not understood by science. As such phenomena do occur in reality, and sometimes with catastrophic consequences for fisheries and ecosystem, they are accounted for as exogenous impacts. Thus RecTrend(St,y) can take any value (based on any assumption) the user of TEMAS want to test.

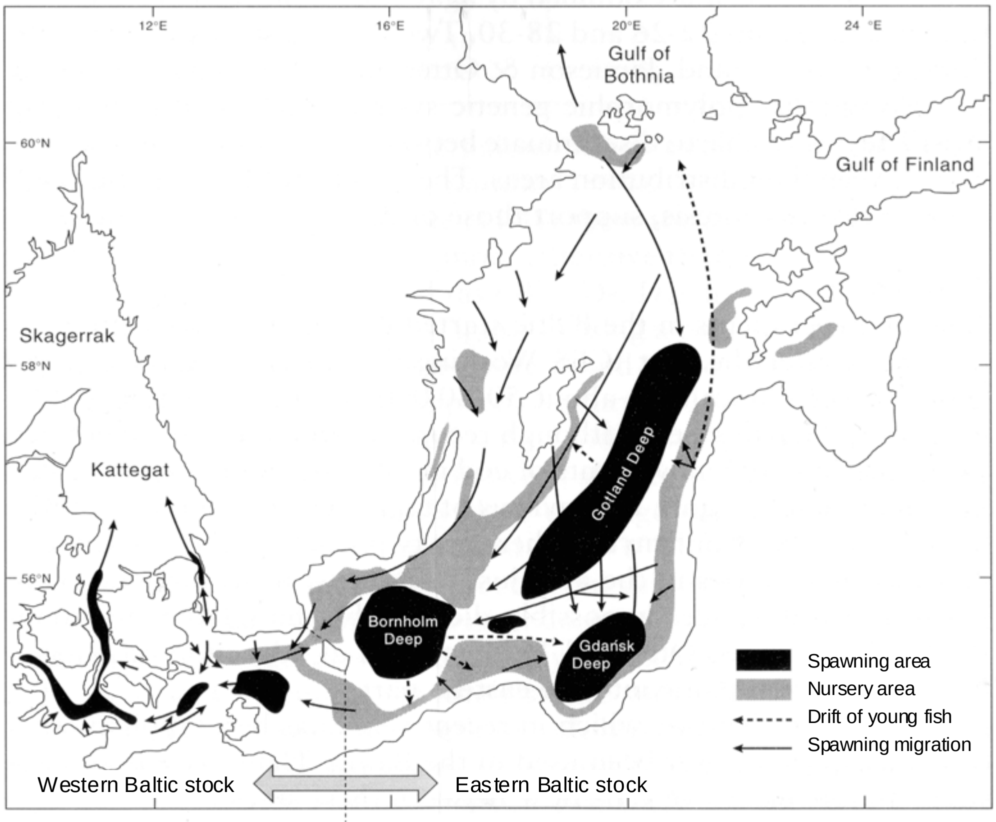


Figure A.11.2.1. Distribution of spawning and nursery areas of cod in the Baltic Sea (Aro 2000, redrawn after Bagge et al. 1994).

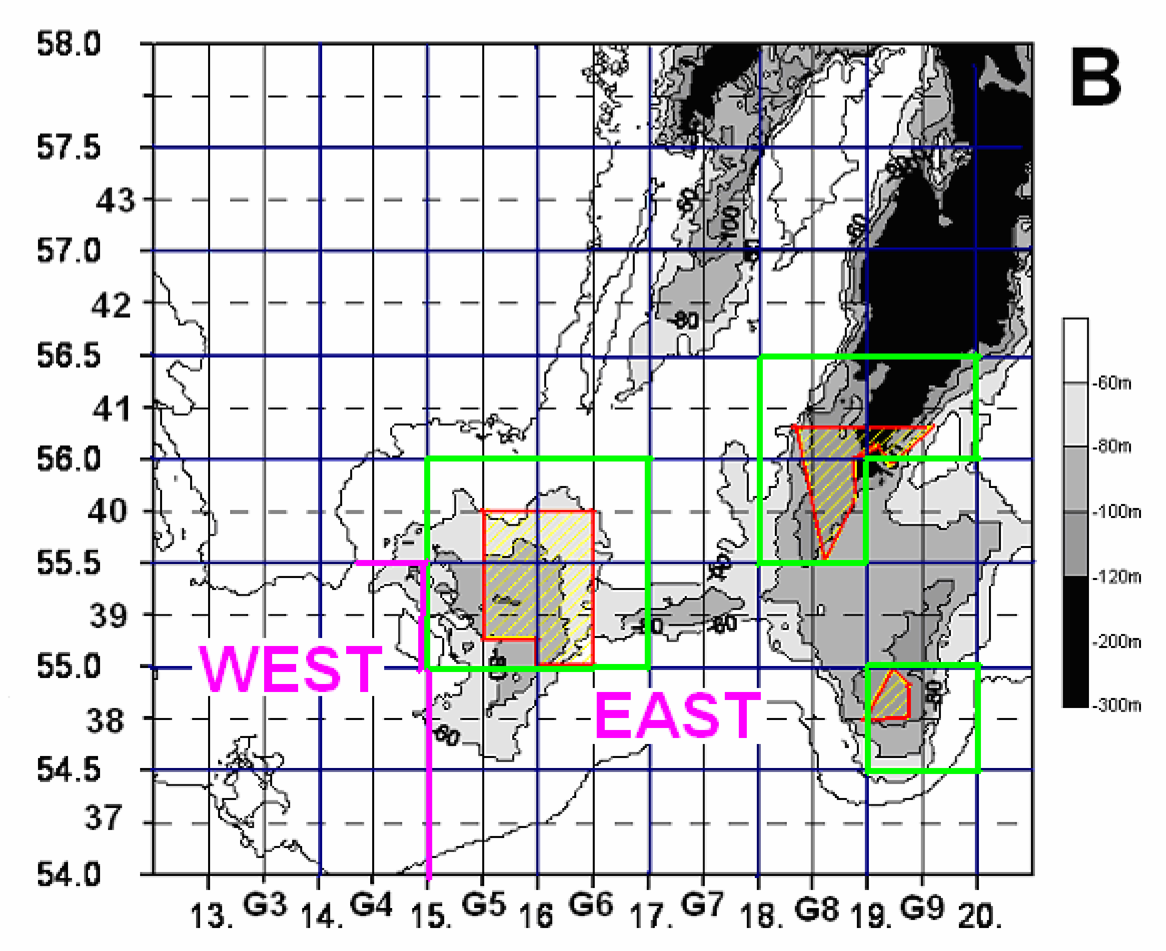


Figure A.11.2.2. The three spawning areas to be used in TEMAS simulation (Green frames). Bornholm:39G5-6 40G5-6, Gotland: 41G8-9, 40G8, Gdansk 38G9.

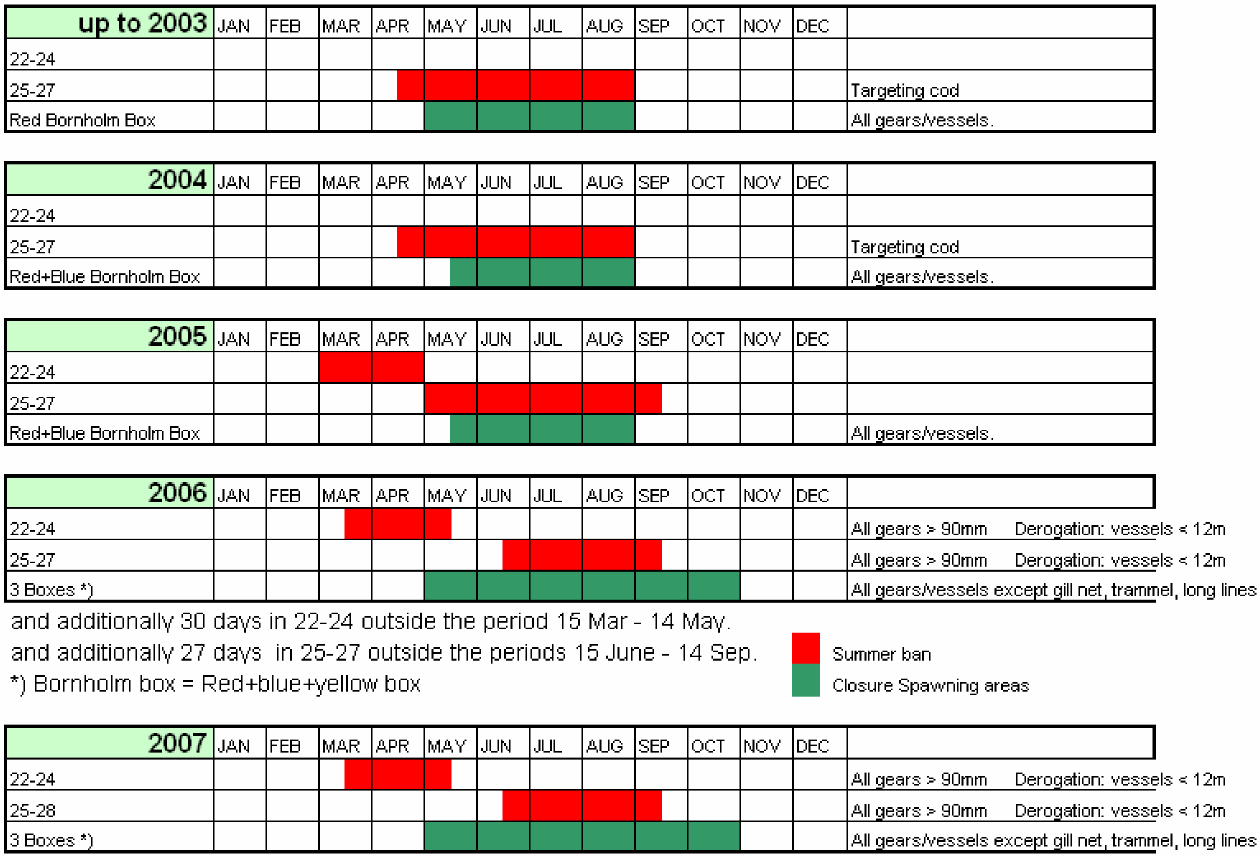


Figure A.11.2.3. Closed seasons in the Baltic.

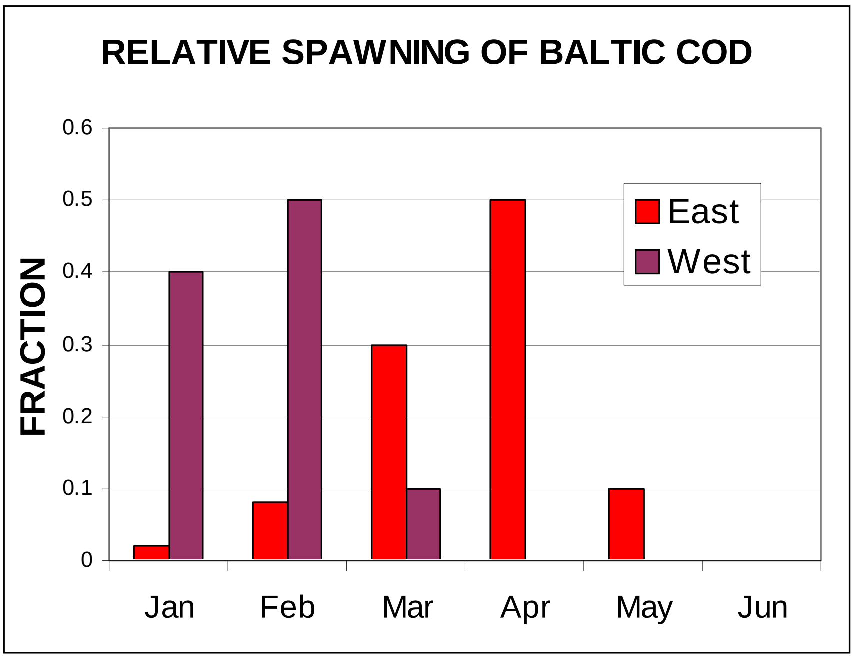


Figure A.11.2.4. Temporal distribution of spawning in the Baltic

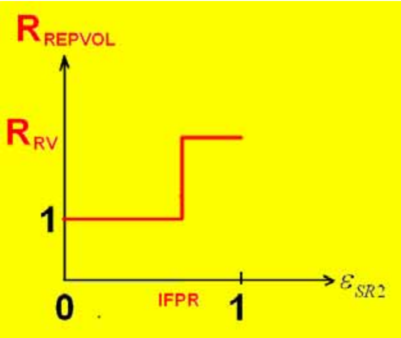
A.11.3. STOCHASTIC MODEL OF RECRUITMENT

TEMAS has the option to let recruitment becomes a stochastic variable, through the stochastic factor $\varepsilon_{SR}(St)$, as shown in Eq. A.11.1.2.

$$Rec(St,y,\bullet,\bullet) = STR_X(SSB_{RV}(St,y-1,\bullet,\bullet))*\varepsilon_{SR}(St) \quad \text{(A.11.3.1)}$$

Where $\varepsilon_{SR}(St) = \varepsilon_{SR1}(St) * R_{RepVol}(St)$ (A.11.3.2)

is the product of two stochastic factors of stock/recruitment relationship, of stock “St”.
The factor $\varepsilon_{SR1}(St)$ is a stock dependent log-normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{SR}.



The factor $R_{REPVOL}(St)$, the “reproductive volume factor”, is specially designed to accommodate the dynamics of Baltic cod, where the recruitment is believed to be enhanced by large reproductive volumes. The reproductive volume becomes big, when the inflow of salty water from the North Sea is big. This happens only in certain years, and $\varepsilon_{SR2}(St)$ is a uniformly distributed stochastic variable controlling a reproductive volume factor, $R_{RepVol}(St)$

$$R_{REPVOL}(St,y) = \begin{cases} R_{RV}(St) \ \ if \ \varepsilon_{SR2}(st) > IFPR(St,y) \\ 1 \ \ if \ \varepsilon_{SR2}(St) \le IFPR(St,y) \end{cases} \quad \text{(A.11.3.2)}$$

where the “Inflow probability is defined

$$IFPR(St,y) = (1 + RAC(St)*Inflow(y-1))/N_{REPVOL}(St) \quad \text{(A.11.3.3)}$$

Where $N_{RepVol}(St)$ is the average number of years between occurrences of large reproductive volumes (Inflow years).

$R_{RV}(St)$ is the average relative magnitude of recruitment in years of high reproductive volume.

$$Inflow(y) = \begin{cases} 1 \ \ if \ \ \inf low \ year \\ 0 \ \ otherwise \end{cases} \quad \text{(A.11.3.4)}$$

and RAC(St) is an “Recruitment Autocorrelation parameter”. When

RAC > 0, it will increase the probability of a year being an inflow year, when the foregoing year was an inflow year. With RAC = 0, there is no recruitment autocorrelation between years.

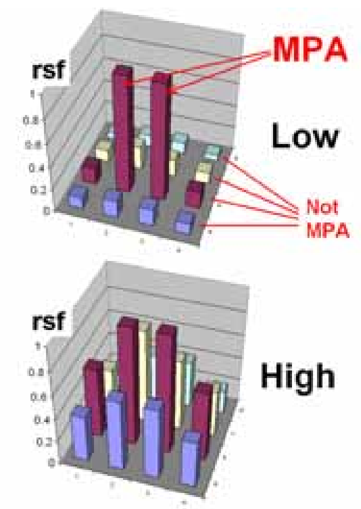
Cod 22-24 (St=1)				Cod 25-32 (St=2)			
Lower*)	Upper*)	Index	Frequency	Lower*)	Upper*)	Index	Frequency
Normal 10	30	1	4	Normal 0	100	1	3
Normal 30	50	2	6	Normal 100	200	2	14
Normal 50	70	3	7	Normal 200	300	3	6
Normal 70	90	4	1	Normal 300	400	4	7
Normal 90	110	5	5	Normal 400	500	5	5
Normal 110	130	6	4			Total	35
Normal 130	150	7	2	Out St. 500	600	6	1
Normal 150	170	8	1	Out St. 600	700	7	4
		Total	30	Out St. 700	800	8	0
Out standing 170	190	9	1	Out St. 800	900	9	1
Out standing 190	210	10	2			Total	6
Out standing 210	230	11	0			Grand total	41
Out standing 230	250	12	0	$N_{REPVOL}(1) = 36/6 = 6$			
Out standing 250	270	13	2	$N_{REPVOL}(2) = 41/6 = 6.8$			
Out standing 270	290	14	1				
		Total	6				
		Grand total	36				

Table A.11.3.1. Estimation of $N_{REPVOL}(St)$ (average number of years between occurrences of large reproductive volumes) for Baltic cod based on the data in Figures A.11.0.3.a and b, (Source: ICES WGBFAR, 2006).

Estimation of the average number of years between occurrences of large reproductive volumes, $N_{REPVOL}(St)$ for Baltic cod, is illustrated in Table A.11.3.1. The data the data used to produce Figures A.11.0.3.a and b. The definition of "normal years" and "outstanding years" is subjective, and is based on visual splitting of the recruitment frequencies into two lognormal distributions. The result is that every sixth year is outstanding (is an "inflow year") for western Baltic cod, whereas every seventh year is outstanding for eastern Baltic cod, whereas. This is indeed a rather crude way of estimating $N_{\mathrm{Re}\,pVol}(St)$, but is probably the best we can do for the time being.

Figure A.11.4.1 Shows a hypothetical example of simulated recruitments with the model described above.

When the reproduction volume is high, the size of the spawning grounds becomes larger, or in other words, the spawning success increases in all areas. Therefore the spawning success becomes a function of, $\varepsilon_{SR2}(St)$, the uniformly distributed stochastic variable, that determines the years of outstandingly high reproductive volume. The spawning success factor, r_{NotMPA}, becomes a function of $\varepsilon_{SR2}(St)$.



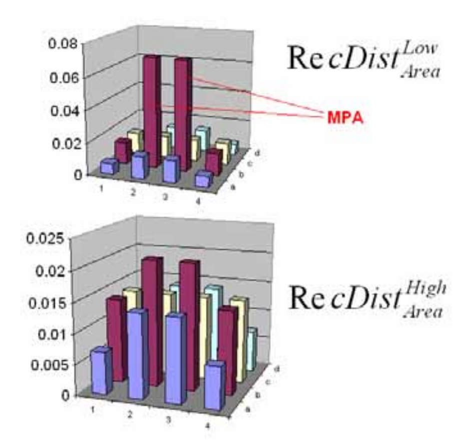
$$RSF_{MPA}(St, Ar, \varepsilon_{SR2}(St)) = \\ = \begin{cases} rsf_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) \;\; if \;\; Ar \neq MPA \\ 1 \;\; if \;\; Ar = MPA \end{cases} \qquad (A.11.3.5)$$

where $0 \leq rsf_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) \leq 1$

The spawning success factor outside the MPA (or the "outside MPA reduction factor"), rsf_{NotMPA} is defined similarly to $R_{\mathrm{Re}\,pVol}(St)$, (reproductive volume factor)

$$rsf_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) = \begin{cases} rsf_{NotMPA}^{High}(St, Ar) \ \ if \ \varepsilon_{SR2}(St) \le IF\,\Pr(St, y) \\ rsf_{NotMPA}^{Low}(St, Ar) \ \ if \ \varepsilon_{SR2}(St) > IF\,\Pr(St, y) \end{cases} \qquad \text{(A.11.3.6)}$$

where $0 \le rsf_{NotMPA}^{Low}(St, Ar, \varepsilon_{SR2}(St)) \le rsf_{NotMPA}^{High}(St, Ar, \varepsilon_{SR2}(St)) \le 1$

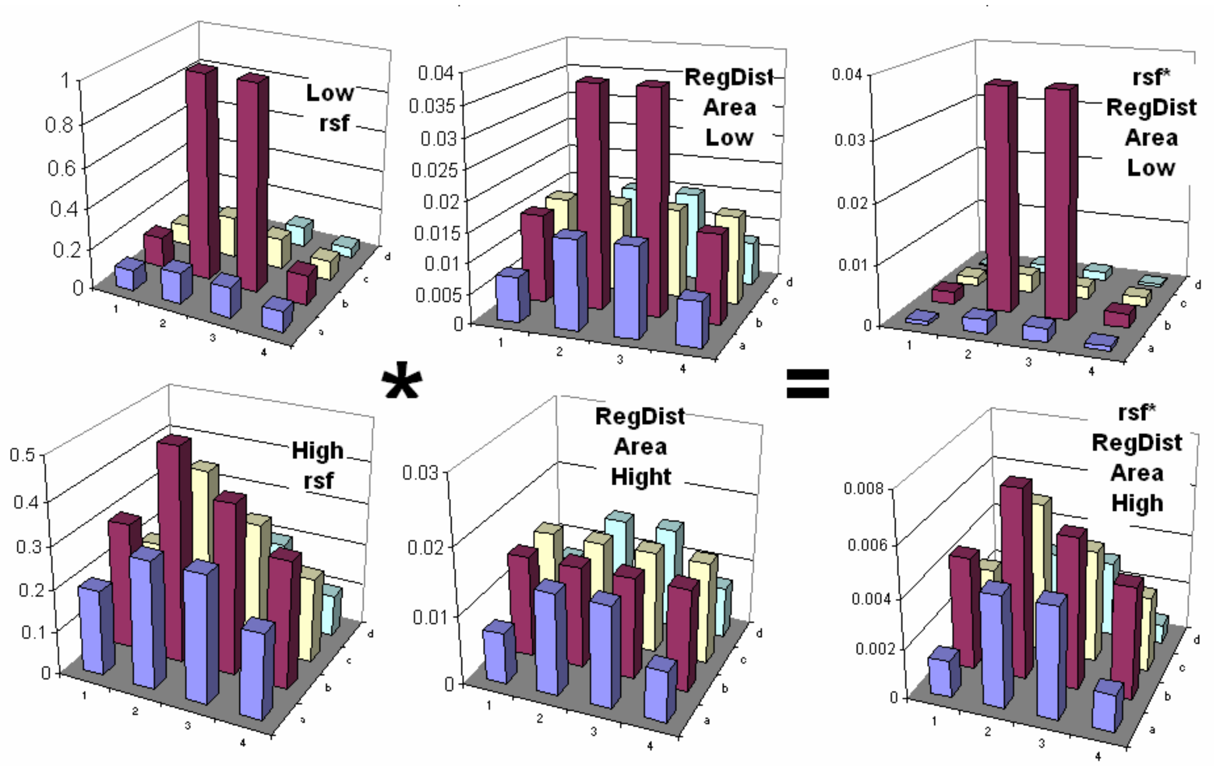


The distribution on areas will also change when the reproductive volume is high, so that there will bee two distributions depending on high or low reproductive volume, $\mathrm{Re}\,cDist_{Area}^{High}(St, Ar)$ .and $\mathrm{Re}\,cDist_{Area}^{Low}(St, Ar)$ respectively. This gives the model for distribution of total biomass on areas and periods:

$$\mathrm{Re}\,c(St, y, q, Ar) =$$

$$\begin{cases} \mathrm{Re}\,c(St, y, \bullet, \bullet) * \mathrm{Re}\,cDist_{Area}^{High}(St, Ar) * \mathrm{Re}\,cDist_{Period}(St, q) \ \ if \ \varepsilon_{SR2}(st) \le IFPR(St, y) \\ \mathrm{Re}\,c(St, y, \bullet, \bullet)) * \mathrm{Re}\,cDist_{Area}^{Low}(St, Ar) * \mathrm{Re}\,cDist_{Period}(St, q) \ \ if \ \varepsilon_{SR2}(st) > IFPR(St, y) \end{cases} \qquad \text{(A.11.3.7)}$$

)



A.11.4. THE COMPLETE RECRUITMENT MODEL OF TEMAS

Figure A.11.4.1. hypothetical example of simulated recruitments with the model used for Baltic cod.

Eventually, we arrive at the S/R model for Baltic cod, which allow for more spawning success in the MPA, and account for years of outstanding reproductive volume.

$$REC(St,y,q,Ar) = RECTREND(St,y) * \mathrm{Re}\,cDist_{Area}(St,Ar) * \mathrm{Re}\,cDist_{Period}(St,q) * STR_X(SSB_{RV}(St,y-1,\bullet,\bullet)) * \varepsilon_{SR1}(St) * R_{\mathrm{Re}\,pVol}(St) \quad \text{(A.11.4.1)}$$

The occurrence of years with outstanding reproductive volume is accounted for by the uniformly distribute stochastic variable $\varepsilon_{SR2}(St)$ (same probability between 0 and 1)

$$R_{\mathrm{Re}\,pVol}(St) = \begin{cases} R_{RV}(St) \ \ if \ \ \varepsilon_{SR2}(St) \le IFPR(St,y) \\ 1 \ \ if \ \ \varepsilon_{SR2}(St) > IFPR(St,y) \end{cases} \quad \text{(A.11.4.2)}$$

Where the “Inflow probability is defined

$$IFPR(St,y) = (1 + RAC(St) * Inflow(y-1)) / N_{\mathrm{Re}\,pVol}(St) \quad \text{(A.11.4.3)}$$

Where N_{RepVol}(St) is the average number of years between occurrences of large reproductive volumes (Inflow years). R_{RV}(St) is the average relative magnitude of recruitment in years of high reproductive volume.

$$Inflow(y) = \begin{cases} 1 \ \ if \ \ \inf low \ year \\ 0 \ \ otherwise \end{cases} \quad \text{(A.11.4.4)}$$

and RAC(St) is an “Recruitment Autocorrelation parameter”. When
R_{RV}(St) is the overage relative magnitude of recruitment in outstanding reproductive volume years. R_{RV}(St) is relative to overage recruitment in stagnation years (years of normal reproductive volume).
The MPA-factor is

$$RSF_{MPA}(St,Ar,\varepsilon_{SR2}(St)) = \begin{cases} rsf_{NotMPA}(St,Ar,\varepsilon_{SR2}(St)) \ \ if \ \ Ar = MPA \\ 1 \ \ if \ \ Ar = MPA \end{cases} \quad \text{(A.11.4.5)}$$

where $0 \le rsf_{NotMPA}(St) \le 1$

The spawning success factor, $rsf_{NotMPA}(St,Ar,\varepsilon_{SR2}(St))$ is

$$rsf_{NotMPA}(St,Ar,\varepsilon_{SR2}(St)) = \begin{cases} rsf_{NotMPA}^{High}(St,Ar,\varepsilon_{SR2}(St)) \ \ if \ \ \varepsilon_{SR2}(St) \le IFPR(St,y) \\ rsf_{NotMPA}^{Low}(St,Ar,\varepsilon_{SR2}(St)) \ \ if \ \ \varepsilon_{SR2}(St) > IFPR(St,y) \end{cases} \quad \text{(A.11.4.6)}$$

where $0 \leq rsf^{Low}_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) \leq rsf^{High}_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) \leq 1$

$\varepsilon_{SR1}(St)$ is a log-normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{SR}. To summarise all components of the Baltic cod stock/recruitment model:

$$\mathrm{Re}\,c(St, y, \bullet, \bullet) =$$

$$\begin{cases} STR_X(SSB_{VP}(St, y-1, \bullet, \bullet)) * \varepsilon_{SR1}(St) * R_{RV}(st) & if\ \varepsilon_{SR2}(st) \leq IF\,\mathrm{Pr}(St, y) \\ STR_X(SSB_{VP}(St, y-1, \bullet, \bullet)) * \varepsilon_{SR1}(St) & if\ \varepsilon_{SR2}(st) > IF\,\mathrm{Pr}(St, y) \end{cases}$$

where the "Inflow probability is defined

$$IFPR(St, y) = (1 + RAC(St) * Inflow(y-1)) / N_{REPVOL}(St)$$

Where $N_{REPVOL}(St)$ is the average number of years between occurrences of large reproductive volumes (Inflow years). $R_{RV}(St)$ is the average relative magnitude of recruitment in years of high reproductive volume.

$Inflow(y) = \begin{cases} 1\ if\ INFLOW\ year \\ 0\ otherwise \end{cases}$ and RAC(St) is an "Recruitment Autocorrelation parameter".

and where $R_{RV}(St) > 1$ accounts for "outstanding recruitments" or "inflow years"

$$SSB_{RV}(St, y, \bullet, \bullet) = \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}} \sum_{a=0}^{a_{Max}(St)} N_{Mean}(St, y, a, q, Ar) *$$

$$Wgt(St, y, a, q) * Mat(St, a, q) * RDist_{Period}(St, q) * RSF_{MPA}(St, Ar)$$

$$RSF_{MPA}(St, Ar, \varepsilon_{SR2}(St)) = \begin{cases} rsf_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) & if\ \ Ar \neq MPA \\ 1 & if\ \ Ar = MPA \end{cases}$$

where the "Spawning success factor" is defined as

$$rsf_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) = \begin{cases} rsf^{High}_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) & if\ \varepsilon_{SR2}(St) \leq IFPR(St, y) \\ rsf^{Low}_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) & if\ \varepsilon_{SR2}(St) > IFPR(St, y) \end{cases}$$

where $0 \leq rsf^{Low}_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) \leq rsf^{High}_{NotMPA}(St, Ar, \varepsilon_{SR2}(St)) \leq 1$

$$\mathrm{Re}\,c(St, y, q, Ar) = RECTREND(St, y) *$$

$$\begin{cases} REC(St, y, \bullet, \bullet) * \mathrm{Re}\,cDist^{High}_{Area}(St, Ar) * \mathrm{Re}\,cDist_{Period}(St, q) & if\ \varepsilon_{SR2}(st) \leq IFPR(St, y) \\ REC(St, y, \bullet, \bullet)) * \mathrm{Re}\,cDist^{Low}_{Area}(St, Ar) * \mathrm{Re}\,cDist_{Period}(St, q) & if\ \varepsilon_{SR2}(st) > IFPR(St, y) \end{cases}$$

Tables A.11.4.1-2. Illustration of the stock recruitment model of TEMAS, by a numerical (hypothetical) example. Tables A.11.4.1.a-e contain the input values to the model, and Table 6.4.2 shows the results.

The input parameters to the Baltic stock/recruitment model are

a. Recruitment trend, RecTrend(St,y)

b. Spawning success factors rsf^{High}_{NotMPA} and rsf^{Low}_{NotMPA}

c. Input: Temporal distribution: $\mathrm{Re}\,cDist_{Period}(St, q)$

d. Reproductive Volume and B & H S/R Parameters, R_{RV}, N_{RepVol}, RAC(St), STR_{11}And STR_{12}

e. High and low distribution on areas $\mathrm{Re}\,cDist^{Low}_{Period}(St, Ar)$ and $\mathrm{Re}\,cDist^{Low}_{Period}(St, Ar)$

f. Input: Stochastic factors and SSB of six years $\varepsilon_{SR1}(St, y)$, $\varepsilon_{SR2}(St, y)$ and $SSB_{Total}(St, y, \bullet, Ar)$ (y = 2005,…,2010) for the four areas "West", "East" "Bornholm" and "Gotland"

and to these parameters should be added the usual stock parameters, including the migration coefficients.

	Area	
rsf^{High}_{NotMPA}	West	*0.8*
	East	*0.8*
	MPA=Bornholm	*1*
	Gotland	*1*
rsf^{Low}_{NotMPA}	West	*0.2*
	East	*0.2*
	Bornholm	*0.8*
	Gotland	*0.1*

Table 6.4.1.a. Input: Spawning success factor

$\mathrm{Re}\,cDist_{Period}(St,q)$

Per1	*0.25*
Per2	*0.70*
Per3	*0.05*
Per4	*0.00*

Table 6.4.1.b. Input: Temporal distribution

R_{RV}	*2.0*
N_{RepVol}	*5.0*
$1/N_{RepVol}$	*0.2*
STR_{11}	*2.0*
STR_{12}	*0.0001*

Table 6.4.1.c. Input: Reproductive volume and Beverton & Holt S/R Parameters

	$\mathrm{Re}\,cDist^{Low}_{Period}(St,Ar)$	$\mathrm{Re}\,cDist^{High}_{Period}(St,Ar)$
West	*0.05*	*0.05*
East	*0.05*	*0.06*
MPA=Bornholm	*0.65*	*0.43*
Gotland	*0.25*	*0.46*

Table 6.4.1.d. Input: High and low distribution on areas

Stochastic factors						
Year	2005	2006	2007	2008	2009	2010
$\varepsilon_{SR1}(St,y)$	*1.130*	*0.955*	*0.995*	*1.006*	*0.987*	*1.001*
$\varepsilon_{SR2}(St,y)$	*0.110*	*0.769*	*0.148*	*0.662*	*0.644*	*0.959*
Outstand. Year	Yes	No	Yes	No	No	No
$SSB_{Total}(St,y,\bullet,Ar)$						
West	*100*	*110*	*115*	*131*	*121*	*108*
East	*300*	*320*	*334*	*370*	*364*	*313*
MPA=Bornholm	*100*	*110*	*124*	*132*	*118*	*103*
Gotland	*100*	*105*	*111*	*121*	*139*	*112*
TOTAL	*600*	*645*	*684*	*754*	*742*	*636*

Table A.11.4.1.e. Input: Stochastic factors and SSB of six years (hypothetical example)

To explain some of the caluculation in Table A.11.4.1, consider the Beverton and Holt stock recruitment model in 2005:

Deterministic B&H: 1884.1 = 2.0*1040/(1+0.0001*1040) (see subsection A.11.5)

(Deterministic B&H)* $\varepsilon_{SR1}(St,y)$ = 1884.1*1.130 = 2128.7

Note that 2005 is an inflow year (and outstanding year for the reproductive volume). Therefore the spatial distribution is made by the "High Reproductive Volume" distribution.

	Rec * $\mathrm{Re}\,cDist^{High}_{Period}(St,Ar)$
West	*0.05**2128.7 = 106.4
East	*0.06**2128.7 = 127.7
MPA=Bornholm	*0.43**2128.7 = 915.3
Gotland	*0.46**2128.7 = 979.2

West	Rec* $\mathrm{Re}\,cDist^{High}_{Period}(St,Ar=West)$ * $\mathrm{Re}\,cDist_{Period}(St,q)$
Per1	0.25*106.4 = 26.61
Per2	0.70*106.4 = 74.50
Per3	0.05*106.4 = 5.32
Per4	0.00*106.4 = 0

Eventually recruits are distributed on time periods as shown in the right hand side of the text table.

	Year	2005	2006	2007	2008	2009	2010
$SSB_{RV}(St,y,\bullet,\bullet)=\sum_{Ar=1}^{Ar_{Max}} SSB(St,y,\bullet,Ar)*RSF_{MPA}(St,Ar)$ $RSF_{MPA}(St,Ar,\varepsilon_{SR2}(St))=\begin{cases} rsf_{NotMPA}(St,Ar,\varepsilon_{SR2}(St)) \ if \ Ar\neq MPA \\ 1 \ if \ Ar=MPA \end{cases}$							
High Reproductive Volume $SSB*rsf_{NotMPA}^{High}$	West	100*08 =80	88	92	104.8	96.8	86.4
	East	300*0.8=240	256	267.2	296	291.2	250.4
	MPA=Bornholm	100*1.0=100	110	124	132	118	103
	Gotland	100*1.0=100	105	111	121	139	112
	TOTAL	**520**	**559**	**594.2**	**653.8**	**645**	**551.8**
	TOTAL*R_{RV}= TOTAL*2	**1040**	**1118**	**1188.4**	**1307.6**	**1290**	**1103.6**
Low Reproductive Volume $SSB*rsf_{NotMPA}^{Low}$.	West	100*02=20	22	23	26.2	24.2	21.6
	East	300*02=60	64	66.8	74	72.8	62.6
	MPA=Bornholm	100*02=80	88	99.2	105.6	94.4	82.4
	Gotland	100*01=10	10.5	11.1	12.1	13.9	11.2
	TOTAL	**170**	**184.5**	**200.1**	**217.9**	**205.3**	**177.8**
	Outstanding year	Yes	No	Yes	No	No	No
Low Rep.. Vol.	**SSB_{RV}**	**NA**	**184.5**	**NA**	**217.9**	**205.3**	**177.8**
High Rep.. Vol.	**SSB_{RV}**	**1040.0**	**NA**	**1188.4**	**NA**	**NA**	**177.8**

	Year	2006	2007	2008	2009	2010	2011
Low Rep.. Vol.	Deterministic BH model	NA	362.3	NA	426.5	402.3	349.4
High Rep.. Vol.	Deterministic BH model	1884.1	NA	2124.3	NA	NA	NA
Low Rep.. Vol.	BH * $\varepsilon_{SR1}(St,y)$	NA	346.1	NA	429.1	397.0	349.8
High Rep.. Vol.	BH* $\varepsilon_{SR1}(St,y)$	2128.7	NA	2113.0	NA	NA	NA

		Recruitment distributed on areas					
	Outstanding year	Yes	No	Yes	No	No	No
	Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Low Rep.. Vol.	West	NA	18.12	NA	21.33	20.12	17.47
	East	NA	18.12	NA	21.33	20.12	17.47
	MPA=Bornholm	NA	235.50	NA	277.23	261.52	227.10
	Gotland	NA	90.58	NA	106.63	100.58	87.35
High Rep.. Vol.	West	106.43	NA	105.65	NA	NA	NA
	East	127.72	NA	126.78	NA	NA	NA
	MPA=Bornholm	915.34	NA	908.60	NA	NA	NA
	Gotland	979.20	NA	971.99	NA	NA	NA

		Recruitment distributed on areas and periods					
	Outstanding year	Yes	No	Yes	No	No	No
Time period	**Year**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Q1	West	26.61	4.53	26.41	5.33	5.03	4.37
Q1	East	74.50	12.68	73.96	14.93	14.08	12.23
Q1	MPA=Bornholm	5.32	0.91	5.28	1.07	1.01	0.87
Q1	Gotland	0.00	0.00	0.00	0.00	0.00	0.00
Q2	West	31.93	4.53	31.70	5.33	5.03	4.37
Q2	East	89.41	12.68	88.75	14.93	14.08	12.23
Q2	MPA=Bornholm	6.39	0.91	6.34	1.07	1.01	0.87
Q2	Gotland	0.00	0.00	0.00	0.00	0.00	0.00
Q3	West	228.83	58.88	227.15	69.31	65.38	56.78
Q3	East	640.74	164.85	636.02	194.06	183.06	158.97
Q3	MPA=Bornholm	45.77	11.78	45.43	13.86	13.08	11.36
Q3	Gotland	0.00	0.00	0.00	0.00	0.00	0.00
Q4	West	244.80	22.64	243.00	26.66	25.15	21.84
Q4	East	685.44	63.41	680.39	74.64	70.41	61.14
Q4	MPA=Bornholm	48.96	4.53	48.60	5.33	5.03	4.37
Q4	Gotland	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	2128.69	362.32	2113.02	426.51	402.34	349.39

Table A.11.4.2. Illustration of the stock recruitment model of TEMAS, by a hypothetical example with input from Table A.11.4.1.

The following section compares a suite of stock-recruitment models, (SR_{Model}, Model = 1,2,3,4) to observations presented by the ICES WGBFAS. The SSB concept used is not the SSB_{RV}, but the conventional SSB concept as defined by the ICES WGBFAS.
The recruitment estimated by the ICES WGBFAS is not in terms of age group 0, but age group 1 for western cod and age group 2 for eastern cod. We introduce the concept of "ICES recruitment age" $a^{ICES}_{\mathrm{Re}g}=1$ for wesetern cod and $a^{ICES}_{\mathrm{Re}g}=2$ for eastern cod. This leads to the definition of "ICES recruitment"

$$\mathrm{Re}c^{ICES}(St,y,\bullet,\bullet)=N(St,y-a^{ICES}_{\mathrm{Re}g},a^{ICES}_{\mathrm{Rec}},\bullet,\bullet)=\sum_{Ar=1}^{Ar_{Max}}\sum_{q=1}^{q_{Max}}N(St,y-a^{ICES}_{\mathrm{Rec}},a^{ICES}_{\mathrm{Rec}},q,Ar)$$

The residual variance between model and observations is defined,

$$\sigma^{OBS}_{Model}=\frac{1}{y_{last}-y_{first}-1}\sum_{y=y_{fisrt}}^{y_{last}}(STR_{Model}(SSB^{OBS}_y(St))-\mathrm{Re}c^{ICES}(St,y,\bullet,\bullet))^2$$

And the residual standard deviation is $s^{OBS}_{Model}=\sqrt{\sigma^{OBS}_{Model1}}$

A.11.5. BEVERTON AND HOLT MODEL STOCK/RECRUITMENT MODEL.

The Beverton and Holt model

$$STR_1(SSB(St,y-1,\bullet,\bullet))=\frac{STR_{11}(St)*SSB(St,y-1,\bullet,\bullet)}{1+STR_{12}(St)*SSB(St,y-1,\bullet,\bullet)}$$

where $STR_{11}(St)$ and $STR_{12}(St)$ are the parameters. .

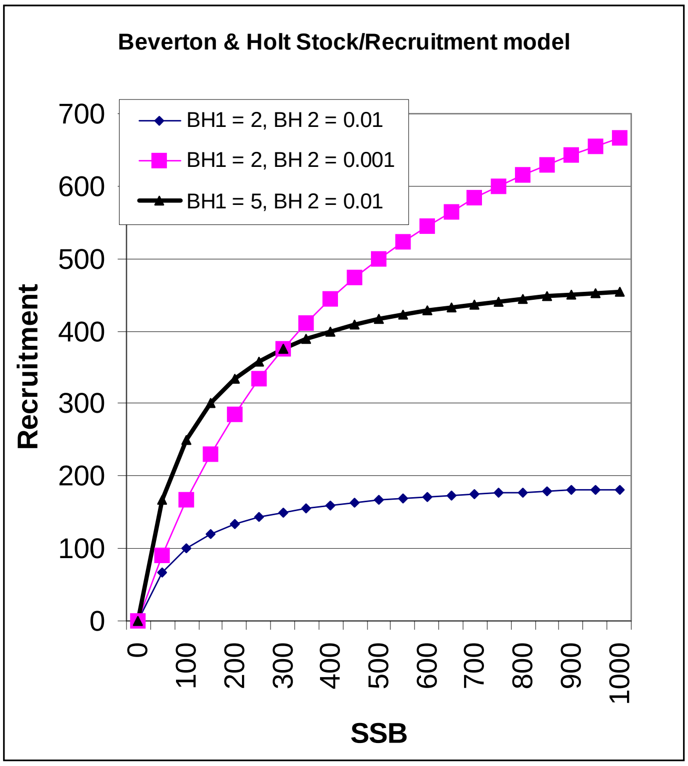


Figure A.11.5.1. Examples of Beverton & Holt stock/recruitment curves.

Figure A.11.5.1. shows three examples of hypothetical Beverton and Holt stock-recruitment curves. Figures A.11.5.2.a and b show the stock-recruitment plots with Beverton and Holt fitted with least squares, for western Baltic cod and eastern Baltic cod, respectively.

	Cod 22-24	Cod 25-32
STR_{11}	2.808	1.074
STR_{12}	1.89E-07	6.23E-07
s_1^{OBS}	64217	166519

As can be seen, the fit is not convincing for any of the cod stocks. In particular, the western cod fit looks like a straight line rather than the curved B&H model. The fit for eastern cod is slightly more curved, but still not convincing due to the large variation around the predicted recruitment.

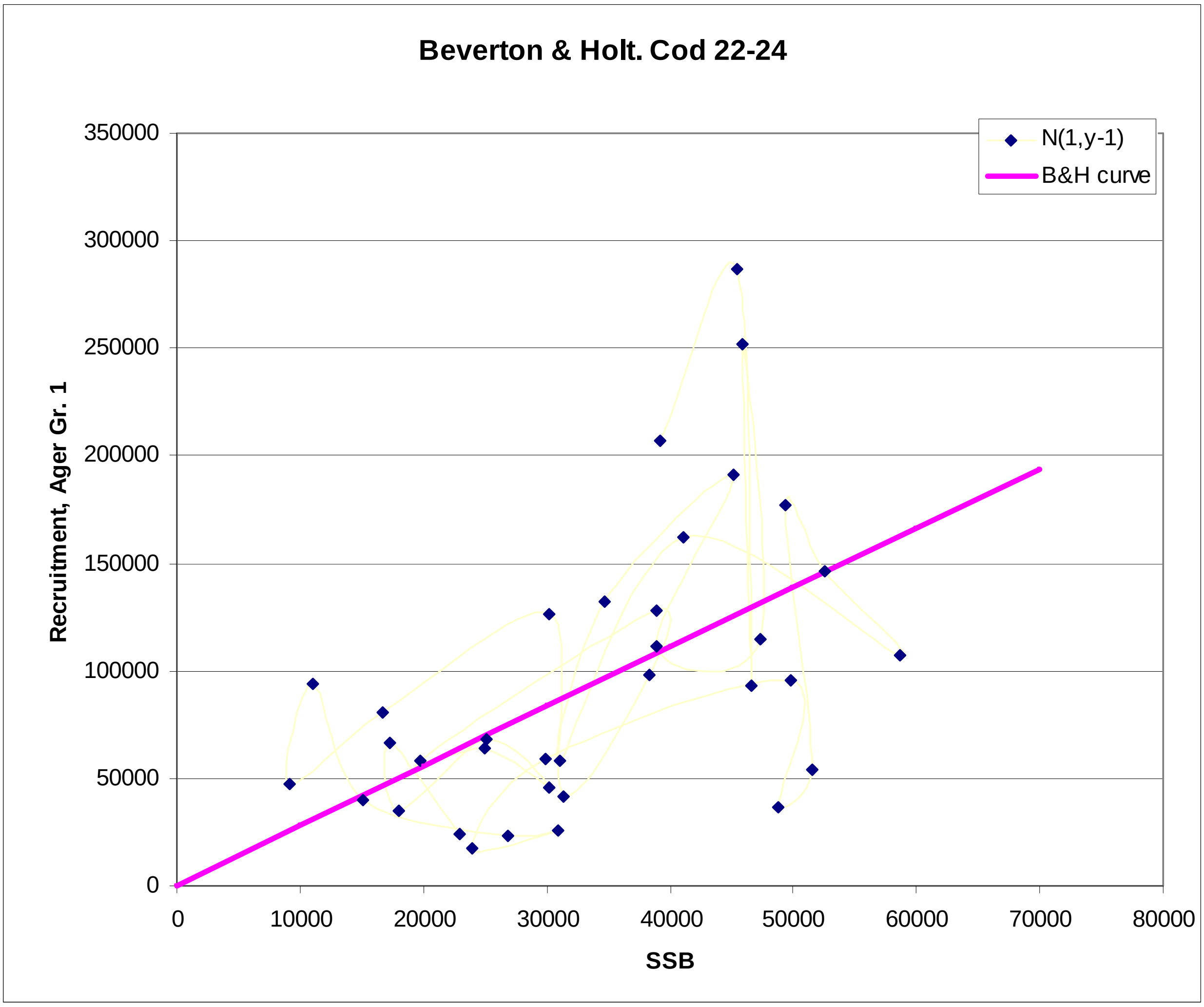


Figure A.11.5.2a. Beverton and Holt Plot for Western Baltic cod. Source ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

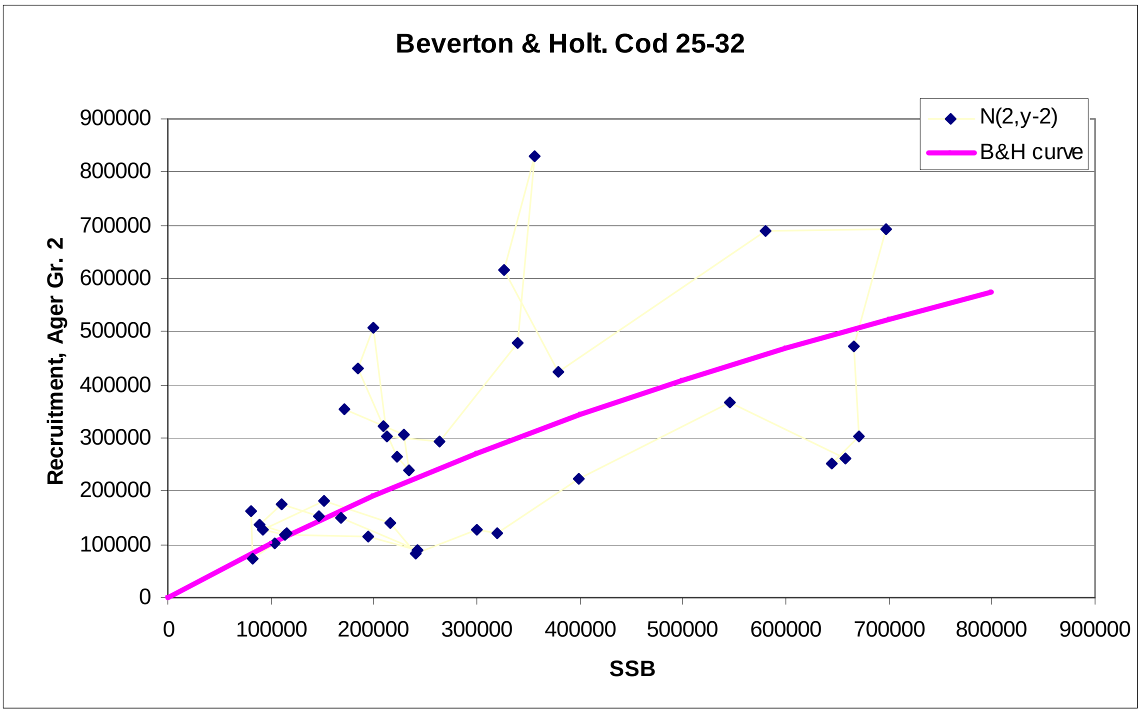


Figure A.11.5.2b. Beverton and Holt Plot for eastern Baltic cod. Source ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

A.11.6. "HOCKEY STICK" STOCK/RECRUITMENT MODEL

If SSB > $STR_{21}(St)$ then $STR_2(SSB(St, y-1,\bullet,\bullet)) = STR_{22}(St)$

If SSB < $STR_{21}(St)$ then $STR_2(SSB(St, y-1,\bullet,\bullet)) = STR_{23}(St) * SSB(St, y-1,\bullet,\bullet)$

where the parameters are STR_{21} and STR_{22}.The slope STR_{23} is not a parameter as it is defined by the two parameters: $STR_{23}= STR_{22}/ STR_{21}$.

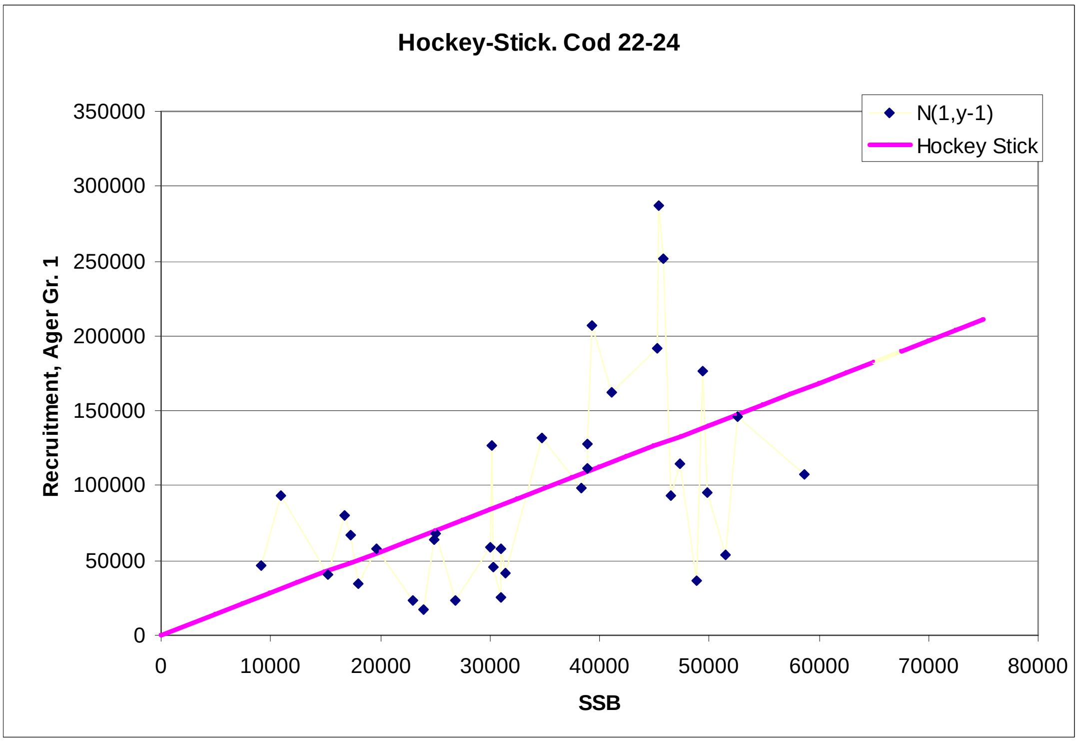


Figure A.11.6.1a. "Hockey stick" Plot for Western Baltic cod. Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

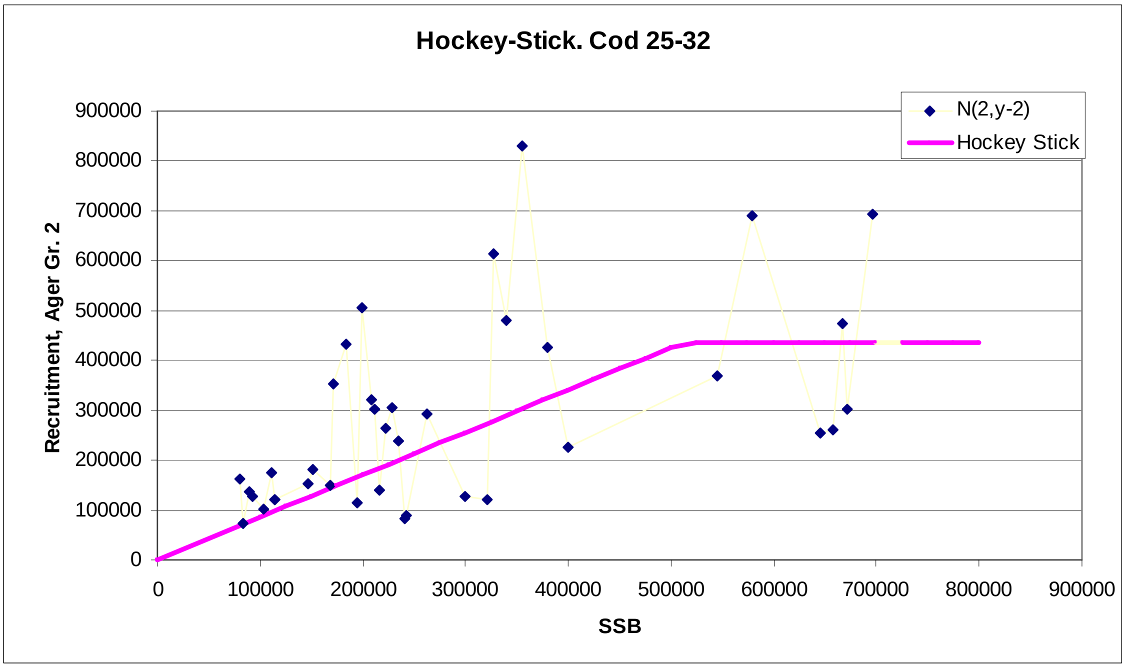


Figure A.11.6.1b. "Hockey stick" Plot for eastern Baltic cod. Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

The least squares estimated parameters for the "hockey-stock" plot are.

	Cod 22-24	Cod 25-32
STR_{21}	253112	509217
STR_{22}	710724	434279
s_2^{OBS}	56466	169256

A.11.7. RICKER STOCK/RECRUITMENT MODEL

$$STR_3(SSB(St,y-1,\bullet,\bullet)) = STR_{31}(St) * SSB(St,y-1,\bullet,\bullet) * \exp(-STR_{32}(St) * SSB(St,y-1,\bullet,\bullet))$$

where the parameters are SR_{31} and SR_{32}

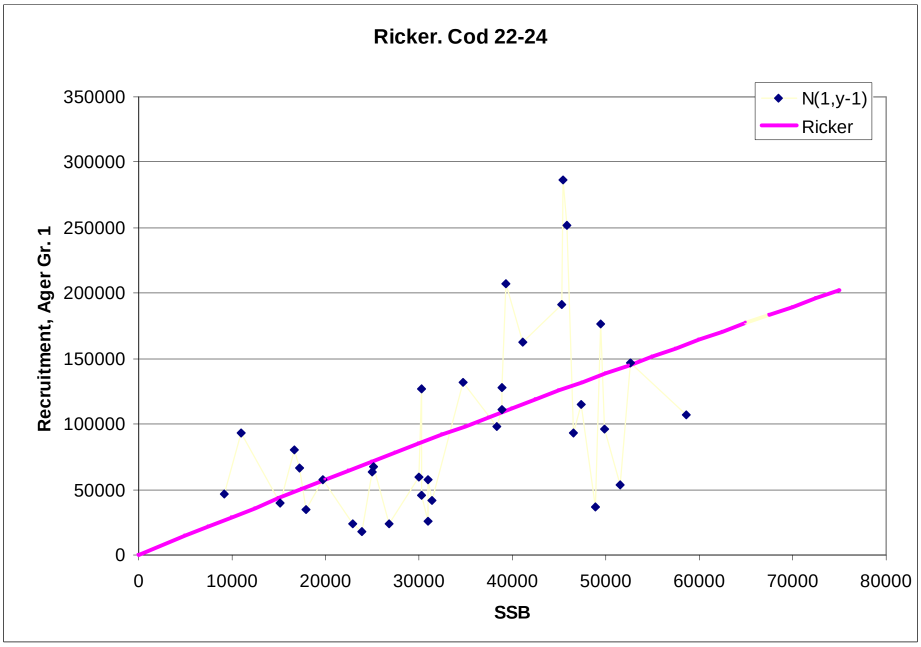


Figure A.11.7.1a. Ricker Plot for Western Baltic cod. Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

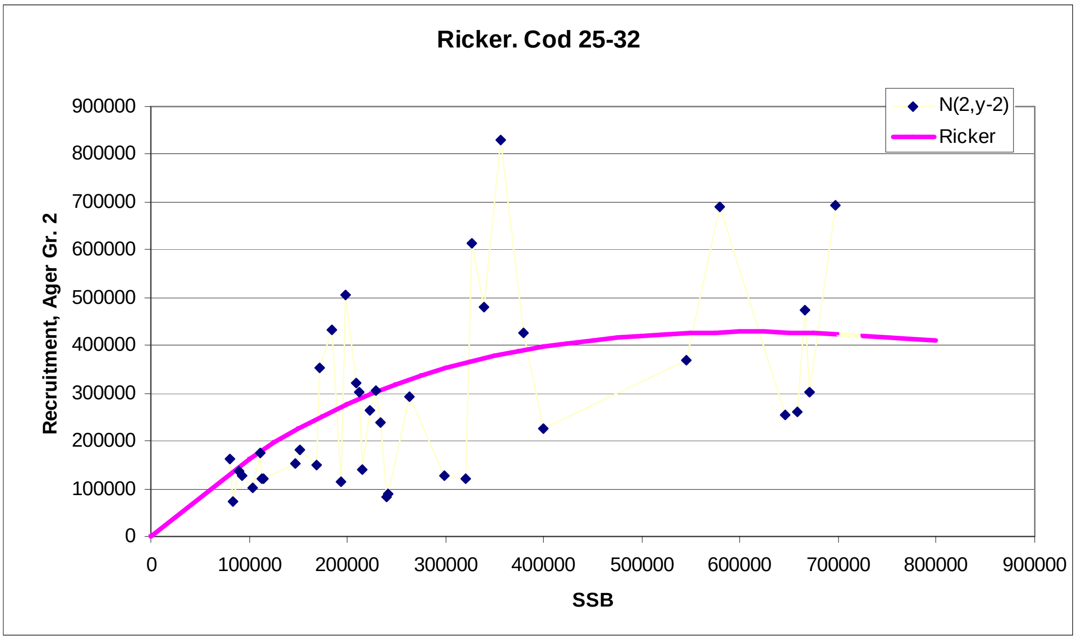


Figure A.11.7.1b. Ricker Plot for eastern Baltic cod. Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

The least squares estimated parameters for the Ricker plot are:

	Cod 22-24	Cod 25-32
STR_{31}	2.930	1.927
STR_{32}	0.000001109	0.000001656
s_3^{OBS}	56413	157606

A.11.8. DERISO-SCHNUTE STOCK / RECRUITMENT MODEL

$$STR_4(SSB(St,y-1,\bullet,\bullet)) =$$

$$STR_{41}(St) * SSB(St,y-1,\bullet,\bullet) * \{ 1 - STR_{42}(St) * SSB(St,y-1,\bullet,\bullet) \}^{STR_{43}(St)}$$

where the parameters are: STR_{41}, STR_{42}, STR_{43}.

Note that when $STR_{43} = -1$, and $STR_{42} < 0$ the Deriso-Schnute model becomes the Beverton and Holt model. The Deriso-Schnute model may also substitute for the Richer model, as illustrated in Figure A.11.8.1.

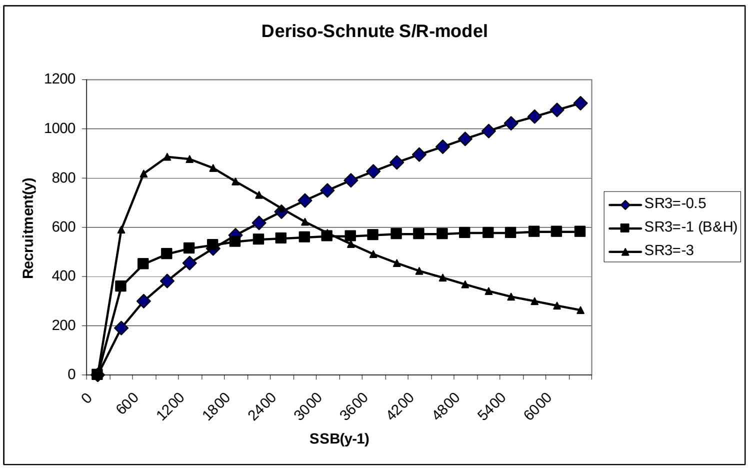


Figure A.11.8.1. Three shapes of the Deriso-Schnute S/R-model. (Hypothetical example)

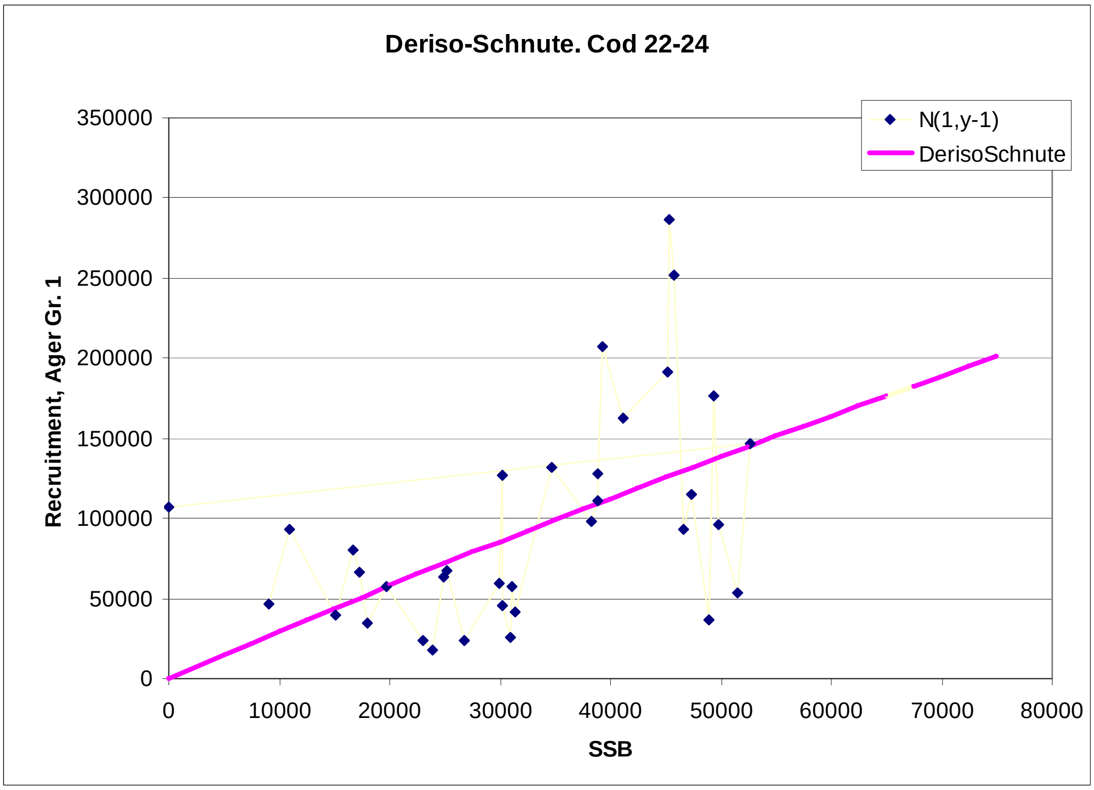


Figure A.11.8.2a. Deriso-Schnute Plot for Western Baltic cod. Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

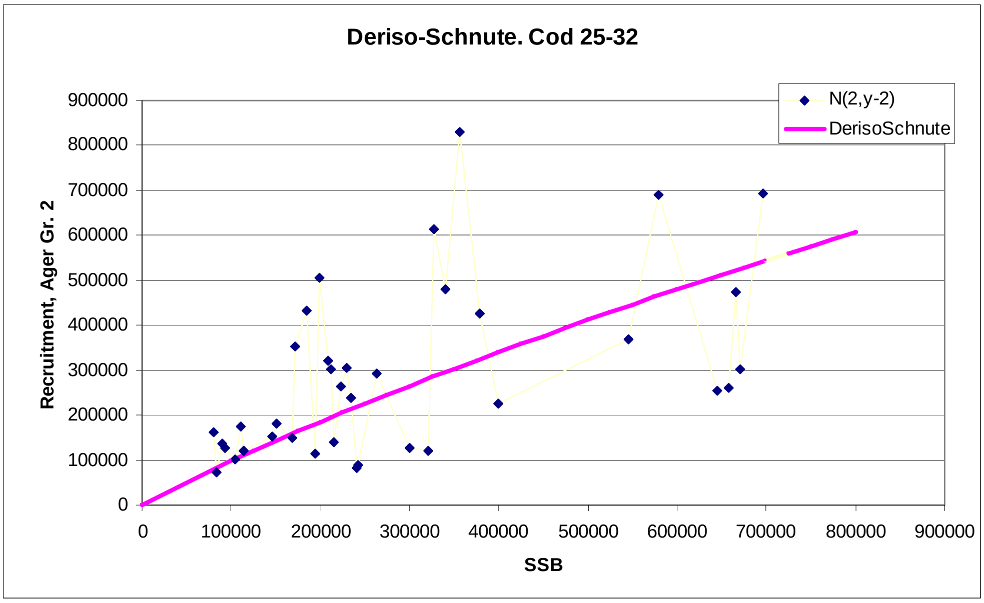


Figure A.11.8.2b. Deriso-Schnute Plot for eastern Baltic cod. Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

The least squares estimated parameters for the Deriso-Schnute plot are:

	Cod 22-24	Cod 25-32
STR_{41}	3.005	1.045
STR_{42}	-0.0000059	-0.0000030
STR_{43}	-0.311	-0.263
s_4^{OBS}	56409	169236

A.11.9. WHICH STOCK / RECRUITMENT MODEL TO CHOOSE FOR THE BALTIC COD?

The rational approach would be to choose the stock-recruitment model with the best fit - that is with the lowest value of the standard deviation between observation and model. That would allocate the Deriso-Schnute model to the western Baltic cod, and the Ricker model to the eastern Baltic cod, as appears from the text table:

Relative standard deviation	Cod 22-24	Cod 25-32
Beverton and holt	64217	166519
Hockey stick	56466	169256
Ricker	56413	**157606**
Deriso-Schnute	**56409**	169236

However, inspecting the graphs for the western Baltic cod, gives the impression that none of the four models really fits the data. That the Deriso-Schnute gives the best fit is likely to be by change, perhaps because this model has 3 parameters, whereas the other have only two.

We could have taken another approach, which accounts for the theory introduced in section A.11.3. If we, as an example, define outstanding recruitment years by

Western Baltic cod: > 170 Millions Age 1
Eastern Baltic cod: > 500 Millions Age 2

This choice is illustrated by Table A.11.9.1 and Figure A.11.0.2.
And then make a separate analysis for outstanding recruitment years and normal recruitment years, then we might get better results, in terms of curve fitting.

Cod 22-24				Cod 25-32			
Lower*)	Upper*)	Index	Frequency	Lower*)	Upper*)	Index	Frequency
10	30	1	4	0	100	1	3
30	50	2	6	100	200	2	14
50	70	3	7	200	300	3	6
70	90	4	1	300	400	4	7
90	110	5	5	400	500	5	5
110	130	6	4	**500**	**600**	**6**	**1**
130	150	7	2	**600**	**700**	**7**	**4**
150	170	8	1	**700**	**800**	**8**	**0**
170	**190**	**9**	**1**	**800**	**900**	**9**	**1**
190	**210**	**10**	**2**	**900**	**1000**	**10**	**0**
210	**230**	**11**	**0**	**1000**	**1100**	**11**	**0**
230	**250**	**12**	**0**	**1100**	**1200**	**12**	**0**
250	**270**	**13**	**2**	*) Unit of recruitment: Million of recruits.			
270	**290**	**14**	**1**				

Table A.11.9.1. (Compare Table A.11.0.2. Recruitment frequencies shown in Figure A.11.0.3.a-b) Division of recruitment observations into "normal" and "outstanding (bold)".

9.10. RECRUITMENT OF BALTIC SPRAT

	N(y-1,1)	SSB(y)
Unit	Thousand	tonnes
		1137055
1974	88776312	820807
1975	38876604	623149
1976	198313968	888294
1977	40265340	614834
1978	16189915	365488
1979	32357310	233092
1980	21775124	205419
1981	61433612	253692
1982	38347768	376163
1983	138819632	522499
1984	49881212	484763
1985	37756908	449606
1986	15672043	386365
1987	36607488	372741
1988	13180027	410941
1989	42911756	575545
1990	53830324	811913
1991	57577968	1073910
1992	84115808	1322805
1993	89887376	1355575
1994	60971996	1424727
1995	248944080	1816839
1996	164075184	1794631
1997	54056748	1331148
1998	164114336	1347128
1999	53224024	1271422
2000	101540040	1158569
2001	52866440	960543
2002	67030936	876464
2003	146869088	1212783
2004	229709584	1437246
2005	45809204	

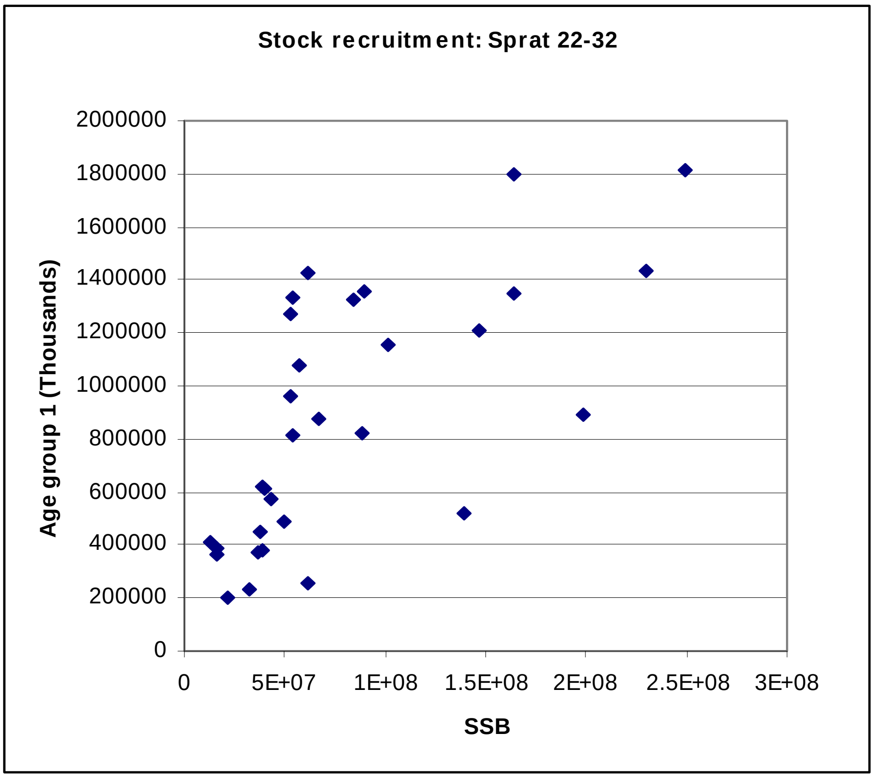


Figure A.11.10.1. Stock recruitment of Baltic sprat

Table A.11.10.1. Stock recruitment of Baltic sprat (22-32). Source ICES, WGBFAR,2006.

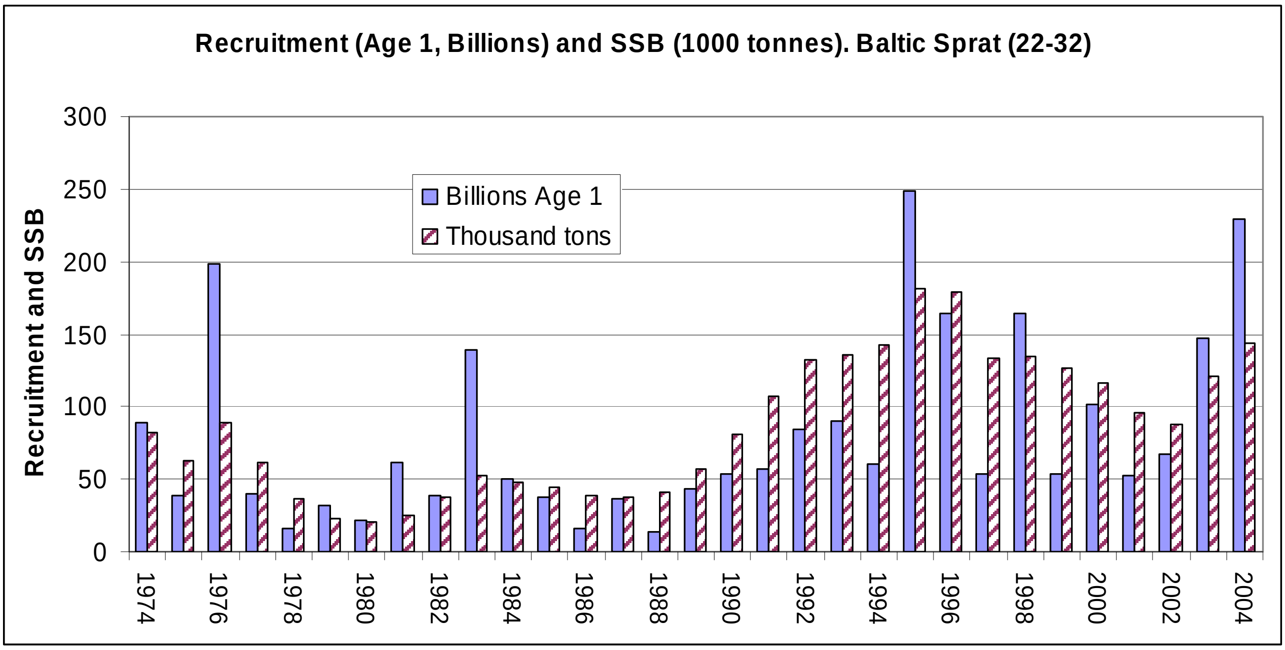


Figure A.11.10.2. Time series of recruitment and SSB of Baltic sprat (22-32). Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

Index	Lower	Upper	Freq-uency
1	0	25	4
2	25	50	9
3	50	75	8
4	75	100	3
5	100	125	1
6	125	150	2
7	150	175	2
8	175	200	1
9	200	225	0
10	225	250	2

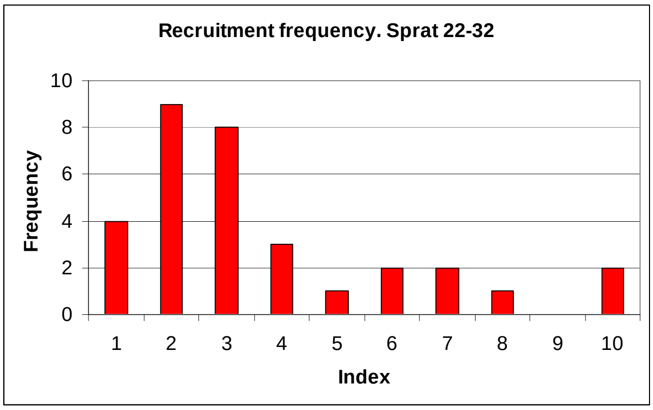


Figure A.11.10.3. Recruitment frequency of Baltic sprat (22-32).

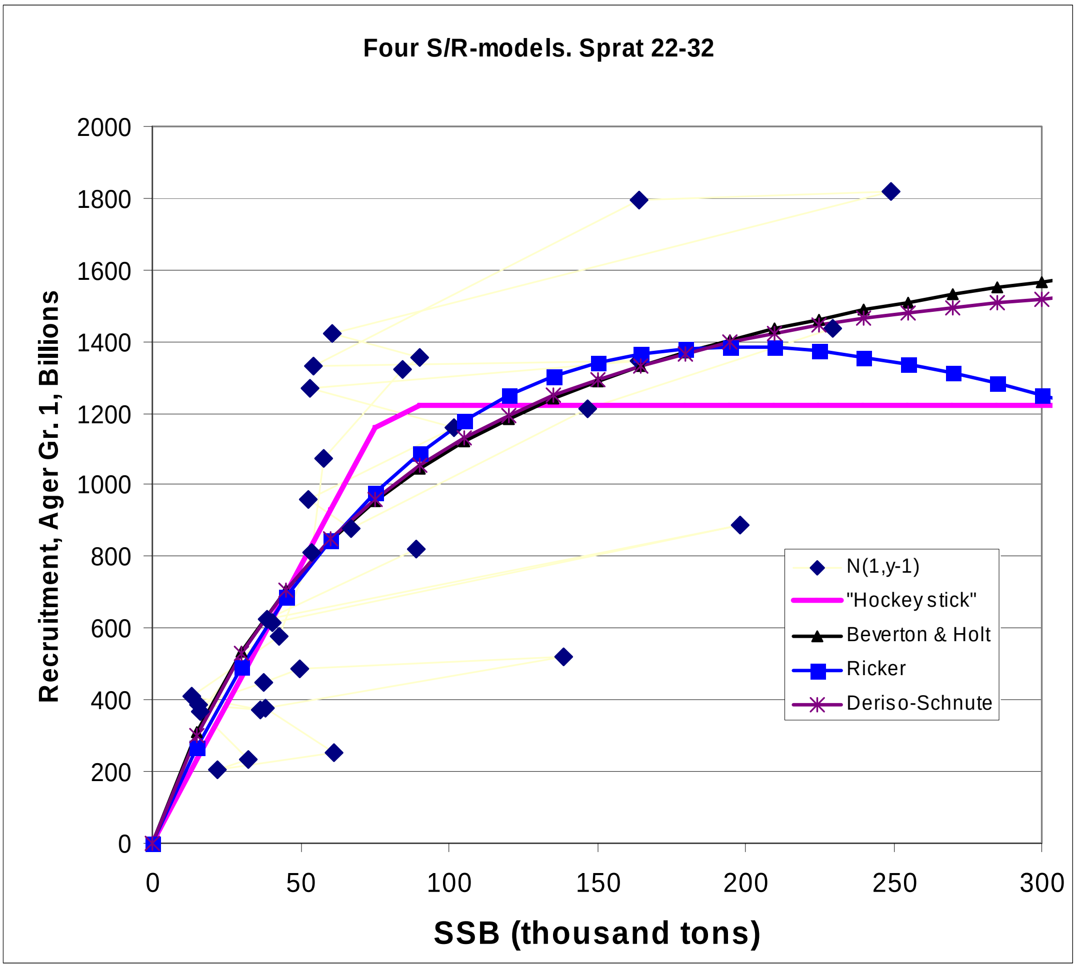


Figure A.11.10.4. Four stock-recruitment plots of Baltic sprat (22-32). Source: ICES WGBFAS, 2006. Note that SSB is the conventional SSB concept.

Beverton and Holt		"Hockey stick"		Ricker		Deriso-Schnute	
STR_{11}	24.4	STR_{21}	79.0	STR_{31}	19.1	STR_{41}	23.3
STR_{12}	0.01225	STR_{22}	1224.0	STR_{32}	0.00508	STR_{42}	-0.00881
s_1^{OBS}	327.6	s_2^{OBS}	326.6	s_3^{OBS}	331.8	STR_{43}	-1.181
						s_4^{OBS}	327.4

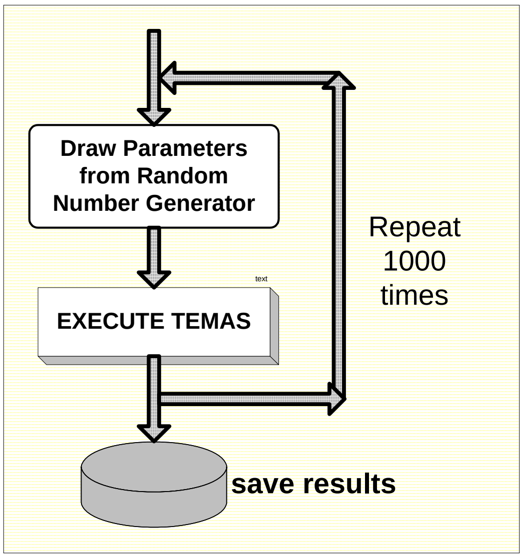
Table 9.10.2. Results of fitting of four S-R models for Baltic sprat (22-32).

A.12. STOCHASTIC SIMULATION

Nothing is known for sure when trying to predict the events of the future. In case you possess knowledge on the probability distribution of input parameters, TEMAS can provide probability distributions of the output (based on the assumption that the TEMAS model reflects the reality, (which, needless to say, is questionable).

TEMAS offers three types of predictions:

1) One single Deterministic prediction
2) One stochastic prediction
3) Multiple stochastic prediction



Stochastic simulation means that some (or all) parameters are drawn by a random number generator. The parameters of the probability distributions of parameters are given as input. TEMAS offers (in its present version) two probability distributions: (1) Normal distribution (2) Log normal distribution.

The most prominent stochastic term is that which accounts for the stochastic features of recruitment. Although no particular stock recruitment model is suggested, the Beverton and Holt model (1956) has been implemented in TEMAS. The only reason for this is that it passes through the (0,0)-point on the stock-recruitment graph, the only point we can be sure about. However, with a stochastic variation around the stock-recruitment model, it does not matter so much which model you choose. TEMAS also offers three alternative stock recruitment models namely the “Hockey stick” model (Barrowman & Meyers, 1999), the Ricker Model (Ricker, 1954) and the general Deriso-Schnute Model (Deriso 1980, Schnute, 1985). The standard models have been extended to account for environmental factors in the Baltic, such as the reproductive volume (for details see Chapter 9).

A problematic element of the current ICES approach, is the assumption of a unique stock recruitment-relationship, which is the basis for the definition of the reference points. There may be some sort of weak relationship between stock and recruitment, but the only point we know for sure is the (0,0)-point. “With no parents there can be no children”, but apart from that we know (almost) nothing about the shape of the stock-recruitment relationship. What we know is something about the distribution of recruitment, and TEMAS admits these limitations of our knowledge basis. TEMAS therefore uses only the knowledge we have, namely the accumulated knowledge on the probability distribution of recruitment. The Beverton and Holt S/R-model is not very important, and can easily be replaced with any other S/R model. However, it would probably not improve the prediction power to use any alternative S/R-model.

A.12.1. RANDOM NUMBER GENERATORS

TEMAS can operate in two modes (1) Deterministic and (2) Stochastic. “Stochastic” means that selected parameters are drawn from a random number generator.
“Stochastic” means that selected parameters are drawn from a random number generator. For example, the growth parameter, K, is assumed to be normally distributed, with a relative standard deviation (=(Standard deviation)/(Mean value)), given as input to TEMAS. The mean value is also given as input to TEMAS. Figure A.12.1.1 shows an example of a frequency bar diagram produced

by TEMAS. It shows the frequency distribution of 25000 random numbers (which could have been the growth parameter, K).

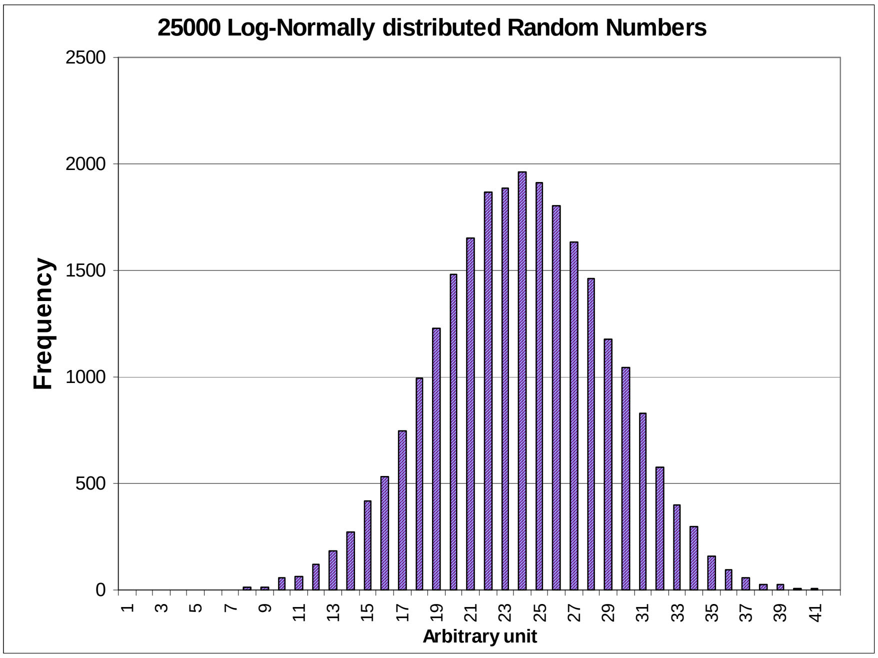


Figure A.12.1.1. Frequency diagram of 25000 normally distributed numbers produced by TEMAS.

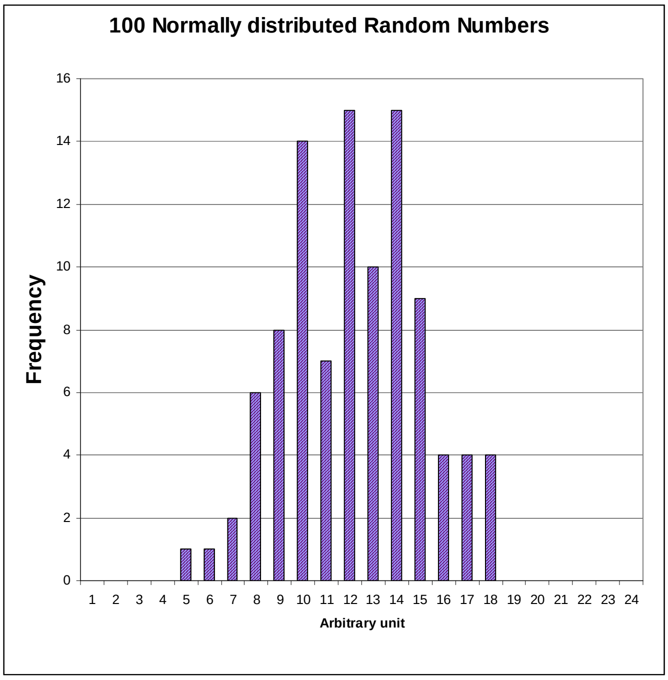


Figure A.12.1.2. Frequency diagram of 100 normally distributed numbers produced by TEMAS.

Figure A.12.1.1. clearly reflects the characteristic shape of a normal distribution. Figure A.12.1.2 shows the frequency diagram of only 100 normally distributed random numbers, and now it is less easy to recognise the normal distribution. Thus, the choice of number of simulations is a compromise between the desired generation of the probability distributions, and the time of computations.

TEMAS is capable of drawing random numbers with two types of probability distribution, namely:

1) Normally distributed
2) Log normally distributed

Figure A.!!.1.3. Show the frequency diagram of 10000 log-normally distributed numbers, produced by TEMAS. The lognormal distribution is used to model stochastic recruitment.

A selection of input parameters of TEMAS have been made stochastic variable by multiplication with a "stochastic factor" with mean value 1.0 and a standard deviation, which is an input parameter to TEMAS (the blue cells in the input worksheet).

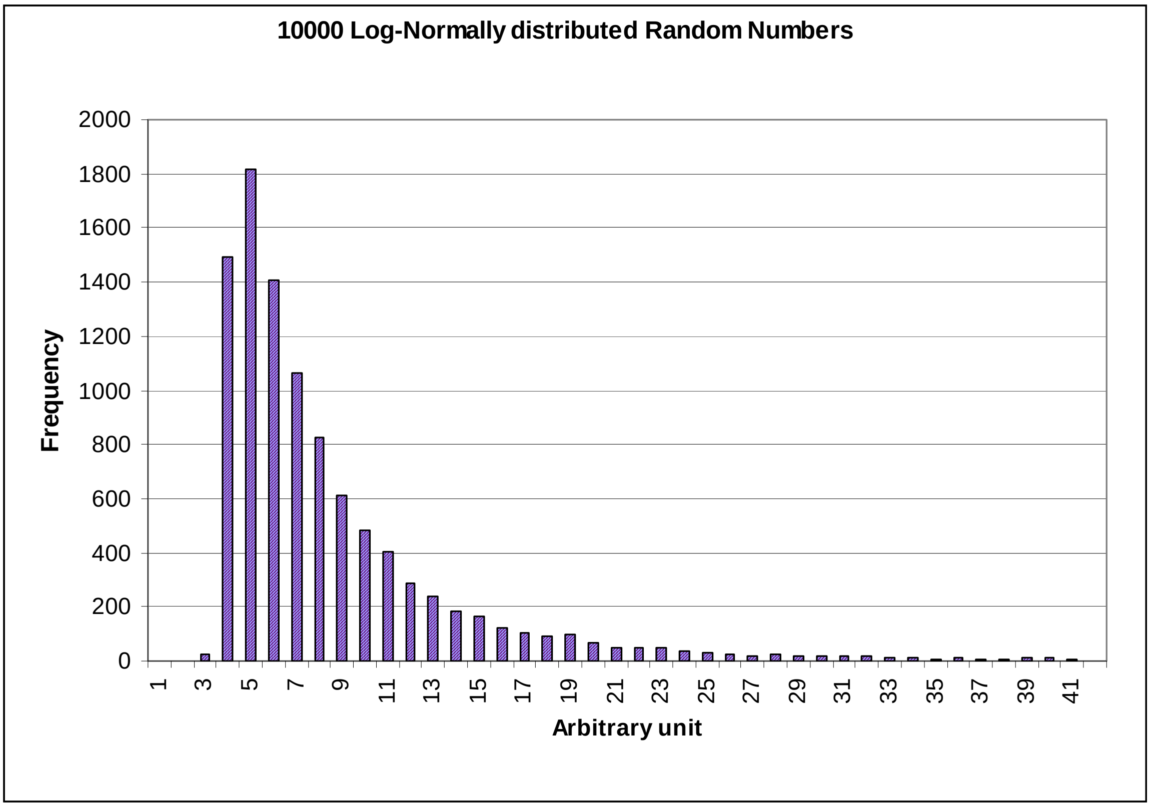


Figure A.12.1.3. Frequency diagram of 10000 log-normally distributed numbers produced by TEMAS.

The growth parameter K, for example, is made stochastic by replacing K (the input parameter) with:
K * ε_K(St,y)

That means that a new value of K * ε_K(St,y) is drawn by the random number generator, for each stock every year. K is assumed to be normally distributed.

The probability that a random variable, X, will fall in the interval from L to L+dL (dL is some small value) is

$$P\{L \leq X < L + dL\} = \frac{1}{\sigma\sqrt{2\pi}} * e^{-\frac{(L+\frac{dL}{2}-\mu)^2}{2\sigma^2}} * dL$$

when the random variable X is normally distributed with mean value μ and standard deviation σ. If a number of simulations are made where the normally distributed random variable is drawn by a random number generator, then the expected frequency in the interval, [L , L+dL] is

$$Frequency\left\{ X \in \left[L\ ,L+dL\right] \right\} = \frac{Number\ of\ Simulations}{\sigma\sqrt{2\pi}} * e^{-\frac{(L+\frac{dL}{2}-\mu)^2}{2\sigma^2}} * dL$$

("X∈" mean "X belongs to"). This is the kind of stochastic simulation results TEMAS requires. TEMAS however, does not do the calculations according to the formulas above. TEMAS, uses the RND-function, which is a standard function in VISUAL BASIC. When called, the RND produces a random (decimal) number between o and 1. The table below shows 100 random numbers between 0 and 1 produced with RND.

0.4340	0.6290	0.4677	0.1150	0.6321	0.4383	0.8944	0.2710	0.2936	0.9671
0.6314	0.2767	0.0346	0.4471	0.8153	0.8186	0.8328	0.6924	0.0801	0.0398
0.5218	0.7240	0.1018	0.9610	0.4724	0.8565	0.4518	0.4103	0.9149	0.6758
0.4823	0.2681	0.4062	0.6620	0.9301	0.7700	0.3754	0.0897	0.5487	0.7211
0.5299	0.7646	0.0756	0.4540	0.5477	0.5924	0.3126	0.8971	0.7840	0.6402
0.6400	0.8104	0.8136	0.5791	0.3101	0.9507	0.3870	0.2549	0.7276	0.4451
0.6762	0.7021	0.0595	0.3864	0.1701	0.8828	0.4203	0.0090	0.1884	0.6877
0.6381	0.1120	0.6350	0.2898	0.9161	0.4084	0.4691	0.9471	0.4378	0.0507
0.4754	0.3340	0.9419	0.6037	0.1022	0.8787	0.8824	0.0388	0.8360	0.5044
0.5800	0.9373	0.1993	0.6087	0.3420	0.0699	0.1894	0.1152	0.2107	0.0246

It is so (the mathematical proof is outside the scope of this manual) that the random variable

$$X = \mu * \left(1 + \left(\sum_{i=1}^{12} RND_i - 6 \right) \frac{\sigma}{\mu} \right)$$

is approximately normally distributed with mean value μ and standard deviation σ. That is the way TEMAS generates normally distributed random variables. In "Rel.Std:Dev" in the input sheets of TEMAS_INPUT is σ/μ. As negative values of, for example, the curvature parameter K, makes no sense, TEMAS discards all negative values of X. The VISUAL BASIC routine, which creates the normally distributed random variables is:

```
Function Normal_Distribution(Rel_Std_Dev As Single)
TRY_AGAIN:
Normal_Distribution = zero
For I  = 1 To 12
   Normal_Distribution = Normal_Distribution + Rnd()
Next I
Normal_Distribution = 1 + (Normal_Distribution - 6) * Rel_Std_Dev  *)
If Normal_Distribution <= zero Then GoTo TRY_AGAIN
End Function
```

The approximation to the log-normally distributed random variable is obtained almost the same way in TEMAS. The line indicated by "*)" is replaced by:

```
Log_Normal_Distribution = 1 + [(Exp(Normal_Distribution - 6) - 1.6487)/ 2.161] *
Rel_Std_Dev
```

A.12.1. INPUT TO STOCHASTIC SIMULATION

A selection of input parameters of TEMAS have been made stochastic variable by multiplication with a “stochastic factor” with mean value 1.0 and a standard deviation, which is an input parameter to TEMAS (the blue cells in the input worksheet). The growth parameter K, for example, is made stochastic by replacing K (the input parameter) with:
$K * \varepsilon_K(St,y)$. That means that a new value of $K * \varepsilon_K(St,y)$ is drawn by the random number generator, for each stock every year. K is assumed to be normally distributed.
That a new K is drawn every year may result in negative growth, if no prevention of negative growth is made. TEMAS, however, allocates the growth rate 0, in case the random numbers generating K produces negative growth.

$\varepsilon_K(St,y)$, σ_K	Stochastic factor of von Bertalanffy parameter K, of stock “St” and year “y” dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_K
$\varepsilon_Q(St,Fl,y)$, σ_Q	Stochastic factor of catchability, a year, fleet and stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_Q .
$\varepsilon_{QF}(St,y)$, σ_{QF}	Stochastic factor of condition factor, of stock “St” and year “y” dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{QF} . $\varepsilon_{QF}(St,y) = (\varepsilon_K(St,y) + \varepsilon'_{QF}(St,y))/2$, where $\varepsilon'_{QF}(St,y))$ is a year and stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{QF}. Note that the K and the condition factors are positively correlated, so that a fast growth is associated with a good condition .
$\varepsilon_{SR}(St)$, σ_{SR}	Stochastic factor of stock/recruitment relationship, of stock “St”, a stock dependent log-normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{SR} . This model does not account for the effect of a reproductive volume, as is the case for the Baltic cod.
$\varepsilon_{SR1}(St)$, σ_{SR1} $\varepsilon_{SR2}(St)$	These parameters are used in the case where a reproductive volume and the concepts of “stagnation years” and “inflow years” are accounted for (Baltic cod). $\varepsilon_{SR1}(St)$ is defined as ε_{SR} (St), whereas is uniformly distributed (same probability for all values between 0 and 1). For details, see Chapter A.9.

Table A.12.1.1. List of stochastic factors available in TEMAS.

Table A.12.1.1 presents a list of the variables of TEMAS which (in the present) version of TEMAS have been made stochastic parameters. It should be stressed that this choice is the subjective choice of the present authors. Any input parameter is a candidate for a stochastic status, as all parameters are subject to estimation errors and variation, which is not explained by the model. Recruitment is perhaps the most famous stochastic (unpredictable) variable in fisheries science. It is a fact that yet no reliable model exists, which can predict recruitment with a known precision. Fisheries managers simply have to live with the fact that recruitment cannot be predicted. The Beverton & Holt model applied in TEMAS does not imply that we believe it has any predictive power, except when SSB (Spawning Stock Biomass) is very low. The only thing we know for sure about stock and recruitment is that if there are no parents there will be no offspring. That is about all the Beverton and Holt model says. When SSB is very low, it may affect recruitment, but otherwise recruitment is independent of SSB.

A.12.2. OUTPUT FROM STOCHASTIC SIMULATION

Stochastic output means a probability distribution of an output variable.

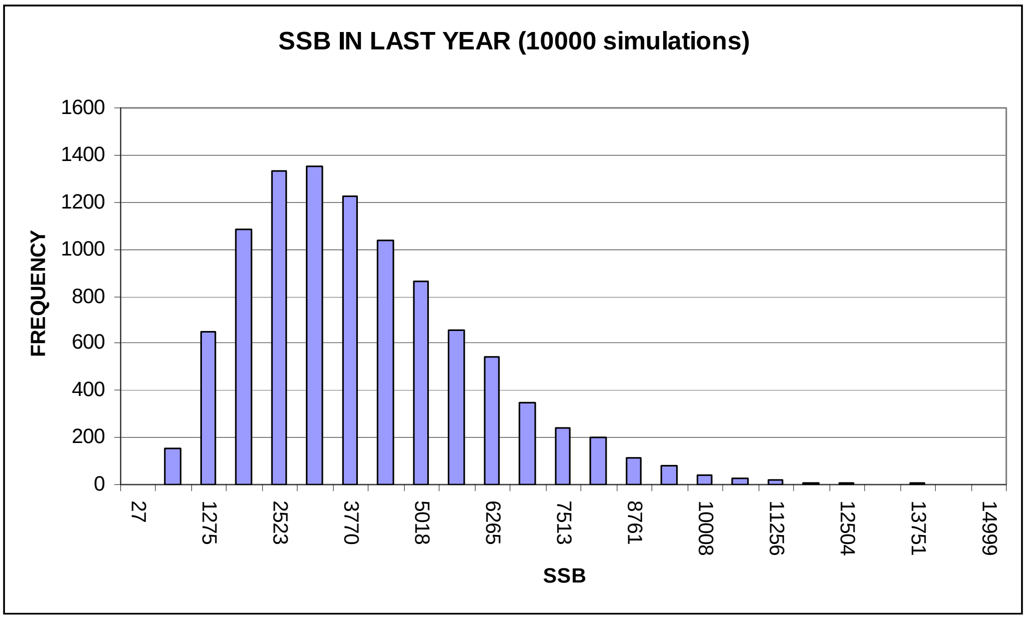


Figure A.12.2.1. Example of output from stochastic simulation with TEMAS. Frequency diagram produced by 10000 run of the TEMAS model.

Figure A.12.2.1 shows the distribution of SSB in the last year of the simulation. In this case, the TEMAS simulation has been repeated 10000 times, each time with new values of the stochastic input parameters. Each simulation produces a new value of the SSB, and the 10000 values of SSB can be organised in a frequency diagram like Figure A.12.2.1. From this diagram one can derive conclusions like "The probability that SSB < X where X is a given value of SSB. The probability distribution corresponding to Figure 4.2.1 is shown in Figure A.12.2.2. Thus, with the management strategy given as input to TEMAS, we can conclude that the SSB will fall below (as an example) 3770 (weight units) with a probability of 60%. It is then up to the managers to decide if they will accept that risk.

The graphs shown in this chapter are not produced automatically by TEMAS, but have to be made by the user, applying the graph "wizard" of EXCEL.

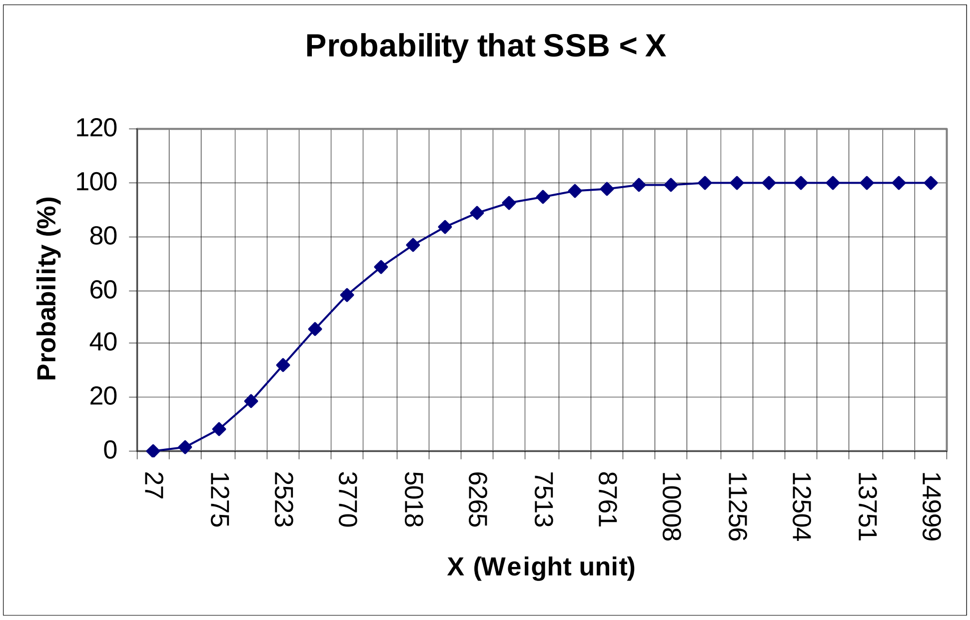


Figure A.12.2.2. Example of Output from stochastic simulation with TEMAS. Derived from the frequency diagram of Figure 4.2.1

Figure A.12.2.3 shows another example of output from stochastic simulation. In this case is shown the time series of total revenues from the fisheries. In this case 1000 simulations were made, and the graph shows the mean value of revenue each year, together with the standard deviations and extreme values simulated.

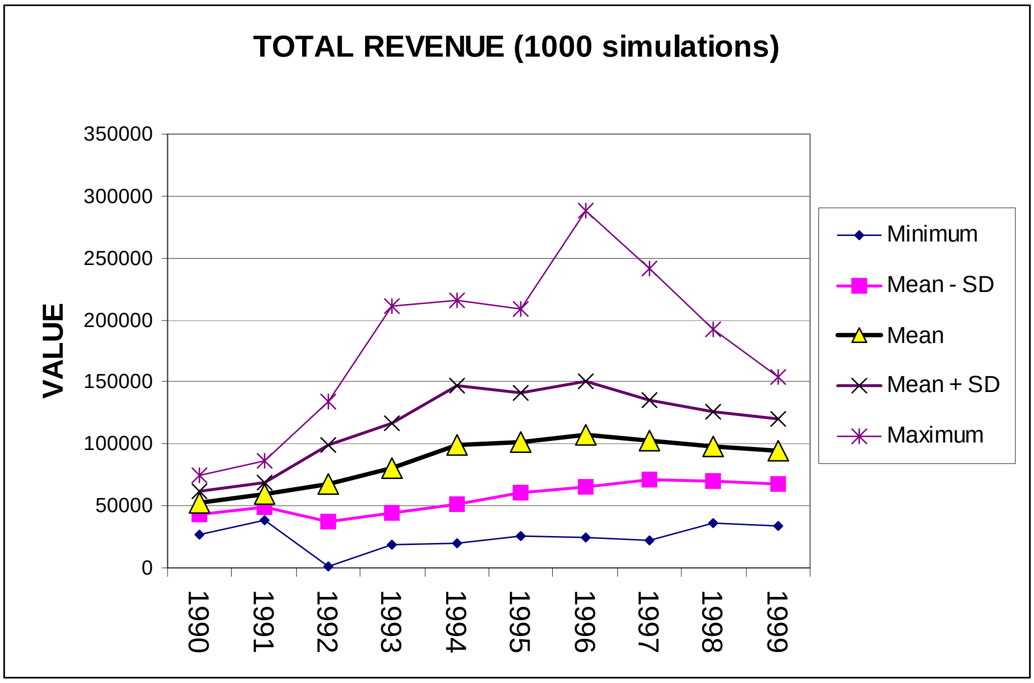


Figure A.12.2.3. Example of Output from stochastic simulation with TEMAS.Time series of Total Revenue.

Figure 6.2.4 shows the same output as Figure 6.1.1, but this time the output is based on 1000 simulations only. As can be seen, the structure of the diagram is not so “smooth” as the when 10000 simulations are made.

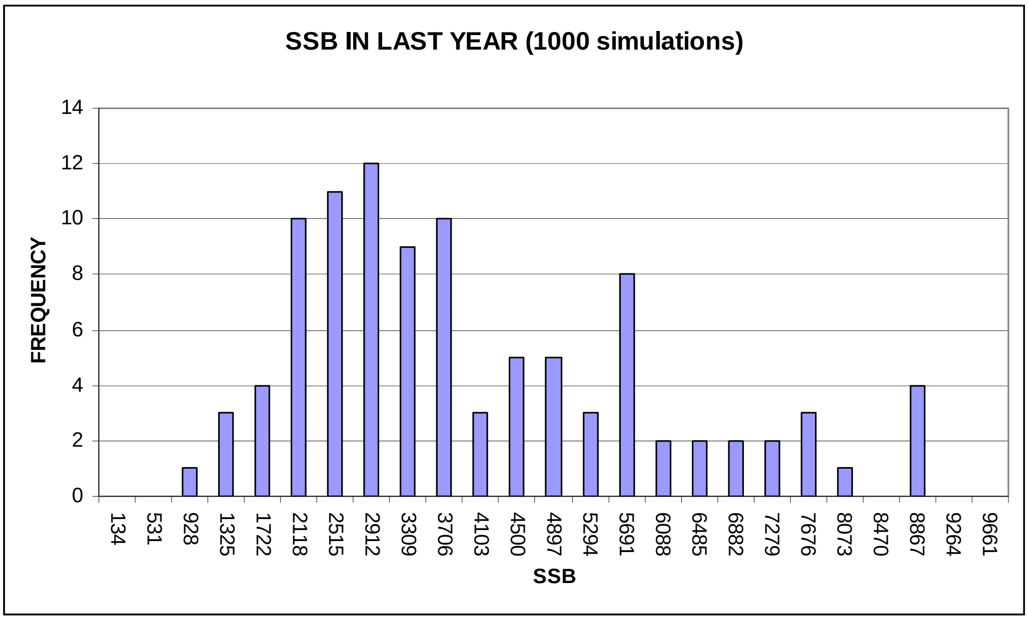


Figure A.12.2.4. Example of output from stochastic simulation with TEMAS. The same output as in Figure A.12.2.1, but here only with 1000 simulations.

ANNEX B. FISHERS BEHAVIOUR – R.U.M.

TEMAS contains several options to model the behaviour of fishing firms during the fishing season and from year to year. The inspiration for this section comes from the textbook by Vani K. Borooah (2002), as a general reference in behaviour theory. We also expect to apply elements from various papers dealing with fishermens behaviour (e.g. Mistiaen & Strand, 2000, Wilen et al, 2002, Bockstael & Opaluch, 1983, Dupont, 1993).

B.1. SUMMARY OF BEHAVIOUR THEORY

This section contains a summary description of the theory of fisher's behaviour applied in TEMAS. The following sections, contains further explanation for readers not familiar with the theory.

There are short-term and long term behaviour rules in TEMAS. The short term (trip) behaviour is a model by which we can predict the probabilities of the different choices a fisher makes on the trip-level.

$$\hat{p}_{j\,t} = F_{Before\ t}(X, \beta, W, \gamma)$$

where X is associated with the fishing trip (the so-called characteristics of the trip, for example the size of the vessel) and W is associated with the "attributes" of the trip, for example the catch or the revenue from the catch. X and W may be vectors:
$X = (X_1, X_2, ...X_r, ..., X_R)$ and $W = (W_1, W_2, ...W_s, ..., W_S)$

The parameter β (which may be a vector) is associated with the trip characteristics and the parameter γ is associated with the attributes. The common approach in literature is to use a "Random Utility Model . Utility, U is "something" which determines the choice. To each choice is allocated a utility. U_{im} is the utility of trip "i" when selecting choice "m", where the number of choices is final, 1 ≤ m ≤ M. Thus, there are M alternatives (choices).
The random utility model postulates that the fisher will select choice (alternative) m if

$$U_{im} = Max\left\{ U_{i1}, U_{i2}, ..., U_{iM} \right\}$$

Let Yi denote the choice made by vessel i. Then the probability of vessel i choosing m is denoted $\Pr\{Y_i = m\}$.

Thus $p_{im} = \Pr\{Y_i = m\} = \Pr\left\{ U_{im} > U_{ij} \ \ for \ \ all \ \ j = 1,...,M.\ m \neq j \right\}$

The general logit model: $\Pr(Y_i = j) = \dfrac{\exp(U_{im})}{\sum_{J=1}^{M} \exp(U_{ij})}$

The utility of the "general logit model" is composed of three terms, (1) Related to the characteristics of the trip (2) Related to the attributes of the choices, and (3) The error term

$$U_{i(trip)\,j(Choice)} = \sum_{r=1(Characteristics)}^{R} \beta_{jr} X_{ir} + \sum_{s=1(Attribute\ of\ choice)}^{S} \gamma_{is} W_{js} + \varepsilon_{ij}$$

i: Trip index, j: Index of alternative (or Choice) made by trip i. , r: Index of trip-characteristics and s: Index of choice-attribute. ε_{ij} is the error term, which capture the inexact elements of the model (e.g. measurement errors)

If β is positive it means that more of X will give more utility and higher probability that the corresponding choice is made. If β is negative the opposite effect will show. Similar conclusions hold for γ.

A similar model is used for the long-term behaviour. The five rules currently in the TEMAS package are:

Fishing effort rule: This is a rule for where to fish at which time with which gear. So far, the rule implemented only decides whether to fish or not to fish. The remaining behaviour is fixed by input parameters.
The model for the "trip-related" behaviour is based on a mixture of "tradition" and "recent experience". "Tradition" here means what was done last year (at the same time) and recent experience means the value of landings in the foregoing period relative to the costs of fishing.

Decommission (Rule). This (and the three following rules) is the so-called long term rules which determine the capacity of the fishing fleets. The decommission rules takes the decision on accept of a decommission compensation based on the recent economic performance of the fleet and the age structure of the fleet.
Dis-investment rule. This rule decides on the bankruptcy of a vessel based on the recent economic performance of the fleet.
Attrition rule: The attrition rule takes the decision on scrapping a vessel due to old age based on the age structure of the fleet.
Investment rule: This rule decides on the investment in a new vessel based on the recent economic performance of the fleet.

When predicting the effect of management measures, it is obviously very interesting to predict both the short-term and the long-term reaction of fishers.

B.2. HOW TO CONSTRUCT A FISHERS' BEHAVIOUR-MODEL.

If you are familiar with RUM, and discrete choice models, you may skip Section B.2.

This section attempts to

1) Identify the elements of a model for "fishers' behaviour"
2) Put the "behaviour of fishers" into a fisheries management context.

Behaviour of fishers can mean many things. In the context of fisheries management we will mainly think of fisher's reaction to management measures, which may be technical measures as well as quotas (effort or catch). The behavioural aspects of fisheries management has been largely ignored by the ACFM of ICES. The concept of "fisheries" hardly exists in the world of ACFM. The work of ACFM and the assessment working groups of ICES largely ignore the reaction of fishers or fishing fleets on the management measure they advice. Thus, being fisheries biologists, with a background in ICES, we have no experience in working with behaviour of fishers. In general we have little experience in working with fisheries or fishing fleets at all. In ICES the whole complex of features of fisheries and their behaviour is squeezed into one simple symbol, "F", the fishing mortality referring to a fish stock. We are used to think in terms of fish stocks not fisheries, fishers or fishing fleets. Some cautious first steps into the field of fisheries assessment is taken with the ICES study group on "Fleet based forecast" (ICES, 2003).

B.2.1. SOME INITIAL QUESTIONS ON THE CONCEPT OF "FISHERS' BEHAVIOUR".

The problem to be discussed here is not what makes the fishers behave as they do. **The problem dealt with, is to suggest a tool by which we can analyse the behaviour of fishers**. We will in the following illustrate the theory by examples, but we are here and now not interested in the examples in themselves, we use them only to illustrate the theory. In this context, it hardly matters if the examples are correct or not, as long as they can illustrate the theory.

As mentioned above, behaviour of fishers is not a topic which has received much attention from fisheries biologists. There is a long tradition for research in human behaviour in the sociology and economy, initiated by the work of McFadden (1973) with his theory on discrete choice models. We will attempt to apply his findings to fisheries. The theory has been applied to fisheries by economists/sociologists, (Bockstael, & Opaluch, 1983; Sampson, D.B., 1994; Dupont, 1993; Leung *et al*, 1998; Campbell & Hand, 1999; Mardle & Pascoe, 1999 (review paper); Holland & Sutinen,1999; Mistiaen, &. Strand, 2000; Babcock & Pikitch, 2000; Wilen, Smith, Lockwood & Botsford, 2002; Hutton, Mardle & Pascoe, 2003) and naturally we will try to build on the fisheries-specific experience.

Behaviour theory and/or methodology deals with modelling of "making choices"
The first questions to answer in this context, as we (who are beginners in the field) see it, are

1) What is a choice in fisheries?
2) Who is the fisheries choice-maker?
3) What are the fisheries choices?
4) What is a fisheries behaviour model?
5) What is the duration of a fisheries choice?
6) Are choices nested in fisheries?
7) How many choices can there be (an infinite or a finite number)?
8) Which parameters and independent variables determine the fisheries choice?
9) Which mathematical model?
10) Which choices are nested and which ones are on same level?
11) Is our definition of choices checked for "IIA" (Independence of Irrelevant Alternatives")?
12) What is the effect of tradition on making the choice?

The answers are not obvious. It depends on the model-concept we are applying. We consider two model concepts:

1) Model for behaviour parameter estimation (analysis of historical data)
2) Model for prediction of behaviour (module of the TEMAS model).

B.2.2. WHAT IS A CHOICE IN FISHERIES?

A "Choice" in the present case, is a "Choice" made by a "Choice-maker". The "choice-maker" is a fishing trip, made by a vessel belonging to a "fleet". A choice could be selection of fishing ground for a given trip, it could also be the selection of rigging of gear. We will use index as follows:

Index	Variable/Parameter
i	Choice maker (Fishing trip)

j Choice

The probability that choice maker "i" will select choice "j" is designated
p_{ij} = The probability that choice-maker "i" will select choice "j"
Let C designate the set (the choice-set) of all choices. Then $\sum_{j \in C} p_{ij} = 1$ and $0 < p_{ij} < 1$

We suggest a finite number of choices, following the theory of McFadden (1973). An infinite number of choices could appear if we defined, for example, the area (fishing ground) by the position of the fishing operation, or used, for example, the mesh size as a continuous variable in the definition of the rigging.
Some models, for example the so-called IBM (Individual based models, often used for individual fish) works with continuous descriptions of the individual fishes search for the highest food concentrations. Similar models could be used for fishers search for high concentrations of fish. Approaches along these lines were applied for fisheries by Olivier & Gascuel and 1999, Pelletier & Ferraris, 2000. These models were created to describe the spatial movements of fishing vessels rather than the behaviour of fishers.

We made the choice to apply the theory of "Multiple discrete choices" to describe the behaviour of fishers. That means, that we choose the approach most often taken by sociologists and economists (see, for example, the textbooks by Allison 1999, Vani, 2002 and Greene (Chapter 21) 2003).

The set of possible choices, C, thus has a finite number of elements. We can consider various choice sets, and when writing p_{ij}, the choice set, C is tacitly assumed. Thus, $p_{ij} = p_i(j|C)$, or the probability of choice "j" given that the choice set is C. $p_i(x|\{x,y\})$, thus designates the probability of choice x, in a choice set containing only two choices, x and y.

B.2.3. THE IIA ASSUMPTION.

McFadden (1973), considered a family multiple choice model, where it was assumed that for any two members of C, $\{x,y\} \in C$, that

$\frac{p_i(x|\{x,y\})}{p_i(y|\{x,y\})} = \frac{p_i(x|C)}{p_i(y|C)}$ where C is the set of all choices and $\{x,y\}$ is the set of two choices.

This means that the odds of x being chosen over y in a multiple choice situation equals the odds of a binary situation.

This is the condition known as "**IIA**" or "**Independence of Irrelevant Alternatives**".

The classical example of IIA-violence in literature is that of choosing transport means, where you have the choices: (1) Train (2) Car (3) Red bus (4) Blue bus. The red and the blue bus are competing for the same routes. Which colour the bus has, makes no difference to the travellers utility (irrelevant alternatives). There is full substitution between the blue and the red bus, as an economist would express it.
If all four transport means has the same utility, then p = 0.25 for all of then, and for any two the odds ratio $\frac{p_j}{p_k}$=1. Now suppose that the blue bus company stops operations and the former blue-bus

travellers all take the red bus. Then p(red bus) = 0.5, p(car)=0.25, p(Train)=0.25. But now p(red bus)/p(train) = 2. Thus the odds-ratio p(red bus)/p(train) is dependent on the blue bus.

McFadden,1973, further assumed that $p_i(x|C) > 0$ for all choice sets C. This is a innocent assumption, as $p_i(x|C) = 1^{-100}$ *or* $p_i(x|C) = 0$ in practice is the same.

Models meeting these assumptions are relatively easy to analyse with statistical methods, such as estimation by the maximum likelihood principle. As indicated by the example above, we may easily encounter situations where the IIA cannot be assumed to apply. Then we will be forced to apply more complicated models, and we shall in the following present one of the models which relaxes on the IIA.

B.2.4. WHAT ARE ODDS AND LOGITS?

As indicated above, the concept of "odds" is essential for the theory of discrete choices. The common definition of "odds" is intuitively straight forward. Here we give a strict mathematical definition:
In the binary case, the "odds" that a trip (choice maker) will make choice j is defined**:**
$Odds(p_{ij}) = \frac{p_{ij}}{1-p_{ij}}$**.** The odds are the number of times the choice will be made relative to the number of times it will not be made.
Rather than using the probability in the model formulation, we shall be using the "Odds", or we shall be using the "**logit**", that is the natural logarithm of the Odds:

$$Z_j = \text{logit}(p_{ij}) = \log\left\{\frac{p_{ij}}{1-p_{ij}}\right\}$$

Note that $0 \le p_{ij} \le 1$, that $0 \le Odds < \infty$ and that $-\infty \le Logit < \infty$.

Working directly with the odds expression or working with the logarithm of the odds makes no difference for the results in terms of locations of maximum and minimum. That is, if the function f(x) has minimum (or maximum) for x = x_0, then ln(f(x)) has the same minimum (or maximum), as $\frac{d}{dx}\ln(f(x)) = f'(x)/f(x)$ is zero when f'(x) ix zero. This conclusion applies to any monotonously increasing function.

The inverse logit becomes $p_{ij} = \frac{\exp(Z_{ij})}{1+\exp(Z_{ij})}$. The inverse logit is called the "logistic curve"
(see Annex A, which presents the odds, logits and logistics in graphical form)

The concept of odds can applied also to compare two choices. The odds of choice "j" over choice "k" is defined $Odds(p_{ij}\ over\ p_{ik}) = \frac{p_{ij}}{p_{ik}}$
It can easily be shown that the case of multiple choice can be written in terms of binary odds. Therefore, the concept of "odds" plays a special role in the theory of multiple discrete choices.

B.2.5. WHAT ARE THE CHOICES IN FISHERIES?

The "choices" appear to be easier to define than the "choice-makers" so we start with the choices.

In the TEMAS model we operate with two types of behaviour models:

1) Trip-related behaviour
2) Structural behaviour

There are four trip related behaviour models in the current version of the TEMAS model:

1) Model for fishing/not fishing
2) Model for choice of area (fishing grounds)
3) Model for choice of rigging
4) Model for discarding

There are four structural behaviour models in the current version of the TEMAS model:

1) Model for decommission
2) Model for disinvestment
3) Model for attrition
4) Model for investment

A "behaviour model" in the TEMAS-model tells how many percentages of the vessels in a fleets that will make each of the alternative decisions in a given quarter of the year in a given year. For example, the rigging-model for "small trawlers" in second quarter of year 2003, tells that:

Choice	Rigging	Decision
1	Lobster trawl	20%
2	Cod trawl	60%
3	Other riggings	20%
	TOTAL	100%

In the context of the TEMAS model, we assume that all vessels in a fleet are identical (Same length, same engine power, same skill and experience of skipper, same electronic equipment etc.). Note that there are only two decisions to make, as the third decision is given because the sum must be 100%. Thus the number of choices is the number of riggings minus one.
For fishing/not fishing there is only one choice to make:

Choice	Activity	Decision
1	Go fishing	60%
2	Do not go fishing	40%
	TOTAL	100%

For the choice of areas (fishing grounds) an example is:

Choice	Rigging	Decision
1	Northern Kattegat	30%
2	Southern Kattegat	50%
3	Not Kattegat	20%
	TOTAL	100%

Thus the number of choices is the number of area minus one
The model for discarding could be formulated as discrete choices

Choice	Discard $L_{50\%}$	Decision
1	No Discard	10%
2	$L_{50\%}$ = Min.Land.size	50%
3	All discarded	40%
	TOTAL	100%

One might also consider L50% of discarding a continues variable, and we have then moved into a new model concept, namely the so-called the mixed models. "Mixed models" are models with both continuous and categorical variables.

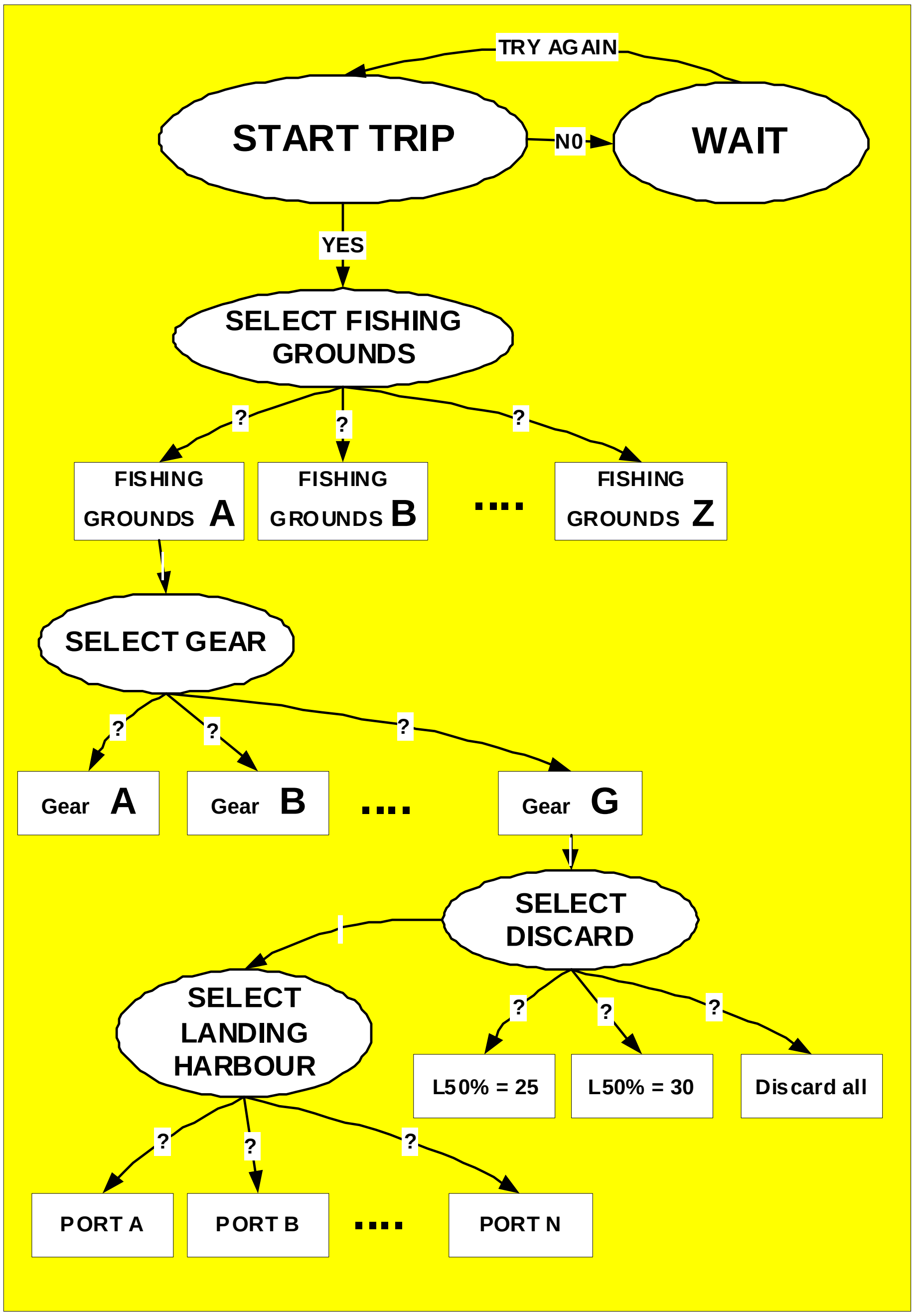


Figure B.2.5.1. shows an example of a decision tree for the trip related behaviour. In this case the decisions also include the selection of landing harbour. Making the choice of landing harbour a trip specific choice depends on the actual case. If vessels always land in the same harbour, say the home port, then there is obviously no reason to consider the landing port as a choice.

Figure B.2.5.1. Example of decision tree for trip related behaviour.

The obvious choice regarding the duration of a choice appears to be:

1. Model for behaviour parameter estimation (analysis of historical data)

Duration: One trip (some number of days).

2. Model for prediction of behaviour (module of the TEMAS model)
   Duration: The time period used in the actual application of the TEMAS model (e.g. one quarter of the year)

Perhaps there is a problem of scaling from trip-days to quarters of the year, but right now I don't see any problem.

B.2.6. ARE CHOICES NESTED?

Are all choices on the same level or is there a hierarchy of choices? One could think the highest level as being the two choices:

1) Go to Kattegat
2) Go to Baltic

Once that choice is made there will be two choice sets in the second highest level

1: Given that we are in Kattegat
  11: Use trawl
  21: Use gill net
2: 12: Use gill net

Then we have on the lowest level, three choice-sets:

1: Given that we are in Kattegat
    11: Given that we are in Kattegat fishing with trawl
        111: Use lobster trawl
        211: Use cod trawl
        311: Use flatfish trawl
    21: Given that we are in Kattegat fishing with gill net
        121: Use Sole net
        221: Use Plaice net
        321: Use cod net
2: Given that we are in Baltic
    12: Given that we are in Baltic fishing with gill net
        112: Fish with plaice net
        212: Fish with cod net.

The tree of choices (of this weird hypothetical example) is illustrated in Figure B.2.6.1.

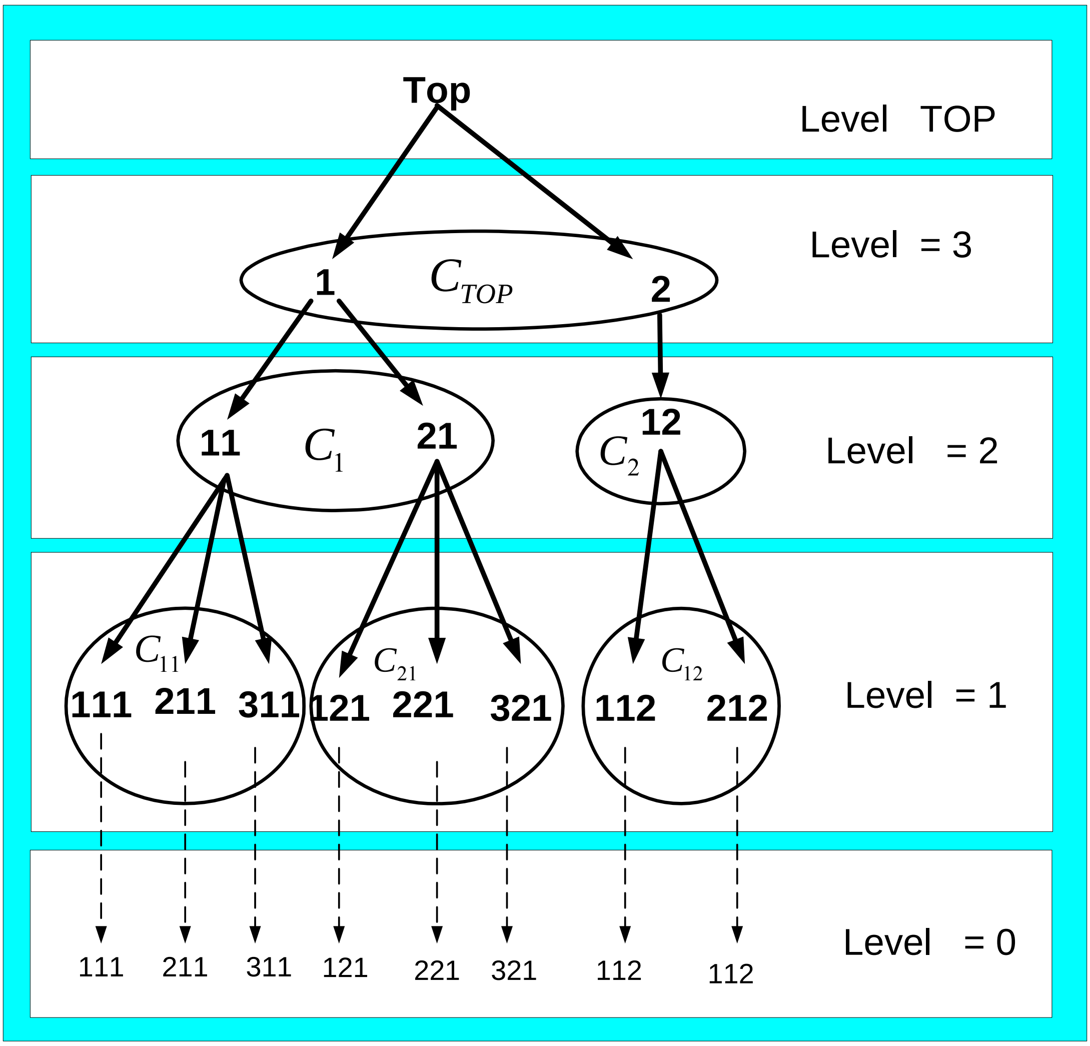


Figure B.2.6.1. Example of nested choices.

Note the way the notes are indexed: (Level 1, Level 2, Level 3), and that level "0" is the bottom-level, where all possible choices occur. The top level has the highest index. The choices are organized in "choice-groups" C_π within which the "simple choice-model" can be applied. The subscript π indicates the level index.

As you will see below, the nested structure results in very complicated mathematical formulas, and complicated statistical procedures. The question is to which degree we must make life difficult by using a nested structure.

B.2.7. WHO OR WHAT IS A DECISION-MAKER?

Now, the tricky question: Who or what make the decisions, in the two model concepts. It is not a person because we do not use personalized data.

The choice-maker, for example, is not the "Skipper" in the context of the TEMAS-model, for the simple reason that the concept of a "skipper" does not appear in the TEMAS model.

Furthermore, we are not interested in the behaviour of a particular skipper, we are interested in the behaviour of the average skipper. We are interested in modelling fleets, not individual skippers or vessels.

We suggest the following definition of a "decision-maker"

- Model for behaviour parameter estimation (analysis of historical data)
  The decision-maker is a "Fishing trip" made by a vessel belonging to a fleet.

- Model for prediction of behaviour (module of the TEMAS model).
  The decision-maker is a "Fleet" (the collective fishing trips made by all vessel in the fleet).

It does not really make sense to say that a "Trip" makes a "Decision", so we use the term "decisions made for the trip"

A behaviour model in our context is fleet-specific. There will be a set of 7 behaviour models for each fleet. For the analysis of historical data, it does not make sense to say how many percent of a fishing trip made choice X, as we assume that only one choice can be made for one trip. But it makes sense to operate with the probability of making a choice, for example:

HISTORICAL ANALYSIS OF TRIP-DATA

Choice	Rigging	Probability of Decision
1	Lobster trawl	0.2
2	Cod trawl	0.6
3	Other riggings	0.2
	TOTAL	1.0

B.2.8. WHAT IS A BEHAVIOUR MODEL?

As indicated above we consider a behaviour model as something which relates choices to time and other parameters. A behaviour model is fleet-specific. The output (or dependent variable) from a behaviour model is

Option	Explanation	Symbol
1	Probability of decision	p_{Choice}^{Fleet} or p_{Choice}
2	Frequency (number of trips making decision)	Y_{Choice}^{Fleet} or Y_{Choice}

Somehow, the two options represent the same thing expressed with different words. The "Fleet" index will usually be tacitly assumed. All models will be fleet specific, so the fleet-index is not really needed, as long as you remember it.

The output is time-dependent, $p_{Choice}^{Fleet}(Time)$ and $Y_{Choice}^{Fleet}(Time)$

Time refers to (Year, Period), where period is optional and could be month or quarter of the year.

The model, here named "F", in it's most general form reads

$$p_{Choice}^{Fleet}(Time) = F_{Choice}^{Fleet}(Time, U(Time))$$

where U(time) is a vector of "Utilities"

$U(Time) = (U_1(Time), U_2(Time), \; .... \; , U_M(Time))$

The Utility $U_j(Time)$, is some measure of the choice-makers "happiness" for making decision "j"

Thus, the higher the utility of a choice, the higher is the probability that the choice will be made.

U is a stochastic variable

$$U_{Choice}(Time) = Z_{Choice}(Time) + \varepsilon_{Choice}(Time) \text{ ,}$$

where ε is a stochastic variable with mean zero. Z is thus the mean value of U.

The error term ε is assumed to be “extreme value distributed” (see Annex C for a description of the Extreme Value Distribution).

We shall call $Z_{Choice}(Time)$ for the “deterministic” utility.

If ε = 0, then all trips (or fleets) would make the decision with the highest utility, but since this is (usually) not the case, the trips (or fleets) will make more than one choice. Written with mathematical symbols, the model says that

$$p_j = \Pr\left\{ U_j \geq Max_{k \in C} U_k \right\} \quad \text{where C is the set of all choices.}$$

We shall discuss the concept of “Utility” in the following sections.

Omitting the fleet index, the general model reads, for the two output options:

$$p_{Choice}(Time) = F^{\text{Probability}}(Time, U(Time))$$

$$Y_{Choice}(Time) = F^{\text{Frequency}}(Time, U(Time))$$

We will in the following mainly use the probability version and omit the indication of output option.

We shall use the “logit model”:

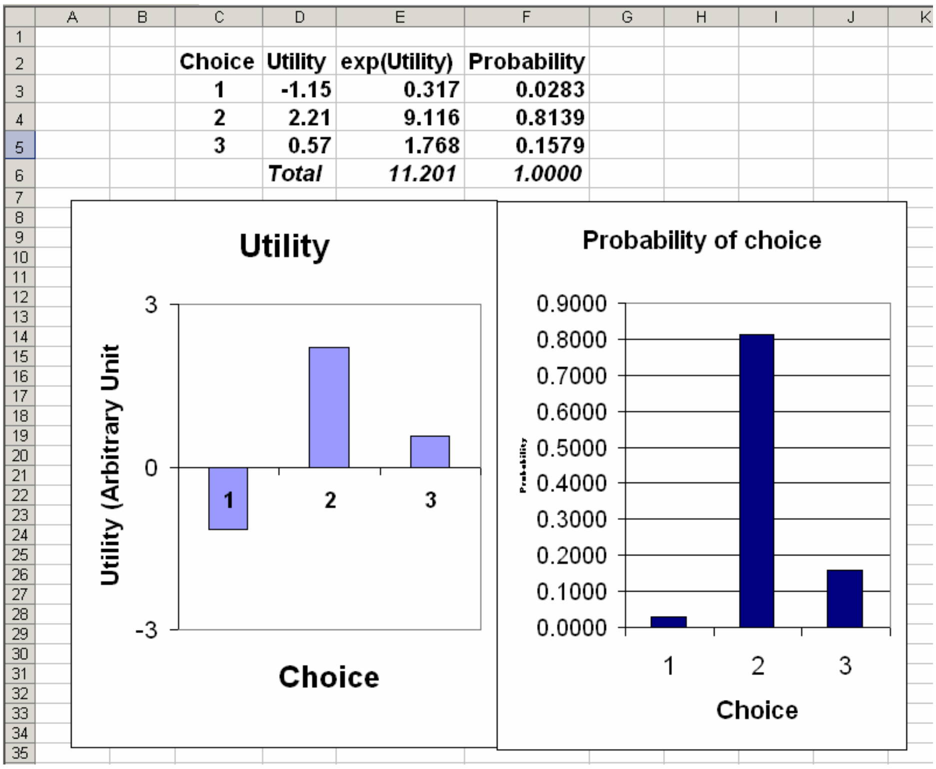
$$p_{Choice}(Time) = \frac{\exp(U_{Choice}(Time))}{\sum_{j=1}^{M} \exp(U_j(Time))}$$

The mathematical justification for the above formula was given in Annex B. It was shown how the multiple choice expressed in terms of odds naturally leads to the expression. The concepts of “odds” is the basics for theory, which leads to the so-called “logit model”, the cornerstone of the theory for discrete choices. Annex A gives a short introduction to the logit and logistic curves

We can see that this model makes the probabilities sum up to 1.0 (as they must) and that the higher utility a choice has the higher is the probability that it will be made.

Figure B.2.8.1.a shows a spreadsheet example, of how the general logit model transforms utilities into probabilities.
With the logit model we have started to answer question: “Which mathematical model?”

The great guru in this topic is McFadden, (e.g. 1973). A general introduction by a sociologist is Vani, (2002). Another sociologist who gave an introduction to the theory together with practical advice on how to do it with the SAS system is Allison (1999). A more mathematical/statistical introduction is given in Greene, 2003 (Chapter 21). There is a huge literature on the theory of interpreting and analyzing discrete choice data.



Choice	Utility	exp(Utility)	Probability
1	-1.15	0.317	0.0283
2	2.21	9.116	0.8139
3	0.57	1.768	0.1579
	Total	*11.201*	*1.0000*

Figure B.2.8.1.a . An Example of the general logit model.

Choice	Utility	exp(Utility) = EXP(Dx)	Probability	= Ex/SUM(A3,A5)
1	-10	0.00	0.000	
2	10	22026.47	0.881	
3	8	2980.96	0.119	
Total	=SUM(A3,A5)	*25007.42*	*1.000*	

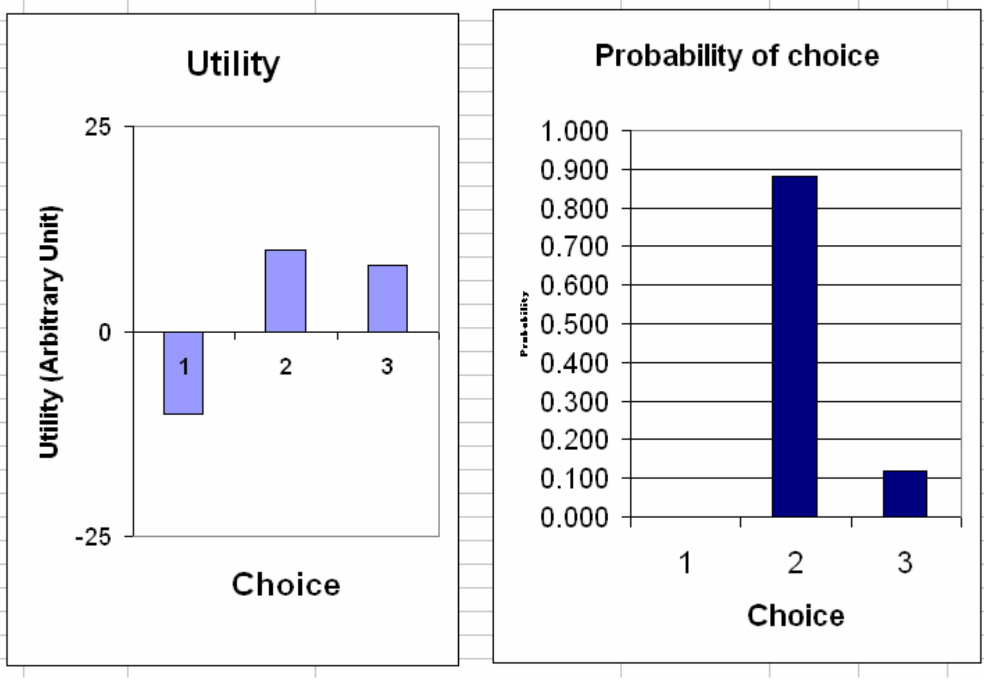


Figure B.2.8.1.b.. Another Example of the general logit model.

Figure B.2.8.1.b should illustrate the effect of the exponential function. Small relative differences in utilities are transformed into large relative differences in probabilities. This should be a reflection of the probability distribution of utilities.

The general logit model combined with the utility, is called the "Random Utility Model", because the Utility is treated as a "random variable" (or stochastic variable) in this model.

This is the main-stream approach of behaviour modelling in social science.

B.2.9. WHICH PARAMETERS AND VARIABLES DETERMINE THE CHOICE.

The specification of a model is now reduced to the specification of the utility (here in the parameter estimation version):

$$U_{Trip,Choice}(Time) = Z_{Trip,Choice}(Time) + \varepsilon_{Trip,Choice}(Time)$$

For the time being we forget about the stochastic term and concentrate on the deterministic term $Z_{Trip,Choice}(Time)$.

We introduce two types of independent variables to model Z (see e.g. Vani 2002):

Independent variable	Features of variable	Symbol	Associated Parameter	Index

Characteristics	Dependent of choice-maker Independent of choice	$X_{Trip,\ r}$	$\beta_{Choice,\ r}$	r = 1,2,…R. index of characteristics
Attributes	Independent of choice-maker Dependent of choice	$W_{Choice,\ s}$	$\gamma_{Trip,\ s}$	s = 1,2,…,S. Index of attributes

Characteristics:

Thus, the independent variable, "X", the characteristics, is related to the trip (or the fleet). It could be the length of the vessel, which will not change no matter which fishing grounds are chosen. Therefore is has index "Trip". If there is more than one characteristics, say R characteristics, we need the index r (r = 1,2,…R) for characteristics.
When the choice is made we want to predict the combined effect of characteristics and choice, and therefore the parameter, $\beta_{Choice,\ r}$, has index "Choice": As an example, consider the length of the vessel. Going far away to a remote fishing ground may be fine for a large vessel but give trouble for a small vessel. The set of parameters $(\beta_{\text{Nearby Area, r=cost index}}, \beta_{\text{Remote Area, r=cost index}})$ may thus be different for two trips (or fleets). We will probably not use the index "trip", but only "fleet", as we will allocate every trip to a fleet, or as being executed by a vessel belonging to a fleet.

Attributes:

Independent variable, attributes, "W", is related to the choice, and therefore is has index "Choice" If there is more than one attribute, say S attributes, we need the index s (s = 1,2,…,S) for attribute.

An attribute could be the "Value per unit of effort". When the choice is made we want to predict the combined effect of attribute and trip, and therefore the parameter, $\gamma_{Trip,s}$, has index "Trip". This is slightly easier to understand if you replace "Trip" by "Person", as is usually the case in sociology. The $\gamma_{Person,s}$ measures the persons utility of a characteristics. As a weird example, assume that one fisher wants to catch plaice and another fisher wants to catch cod. The two persons will then have different values of the parameter set $(\gamma_{Person,s=cod},\ \gamma_{Person,s=plaice})$. Now we will probably not assume different utilities for the different trips (or fleets), and therefore we may skip index "trip".

We introduced the general logit model above. The job left to introduce is the model for utility as a function of characteristics and attributes together with their parameters. Assuming that the time variable "i" not continuous, but an index for a time period, we can make in a subscript "t".

The model we choose for the deterministic utility is the simplest possible model, namely the linear model:

$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

If we assume all vessels in a fleet to behave according to the model, then the trip-index can be replaced by the "fleet-index"

$$Z_{t,Fleet,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Fleet,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Fleet,s} * W_{t,Choice,s}$$

If we have a specific model for each fleet, then we don't need the fleet index. For each fleet:

$$Z_{t,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,s} * W_{t,Choice,s}$$

Below is presented the classification given in Vani (2002)

The model with both characteristics and attributes is called the
"**General logit model**".

$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

…

It there are no attributes, that is if all $\gamma = 0$, then we get the
"**Multinomial logit model**"

$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r}$$

…

If there are no characteristics, that is if all β = 0, then we have the
"**Conditional logit model**"

$$Z_{t,Trip,Choice} = \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

However, there is some confusion in the literature on the terminology. The SAS manual, for example, use "Conditional logit model" as synonym for "Multinomial logit model", so perhaps we should not use these terms too much, and use terms like "Only Trip-dependent utility" and "Only Choice-dependent utility".

B.2.10. NUMERICAL EXAMPLE OF RANDOM UTILITY MODEL.

The example is hypothetical and deals with choosing fishing grounds. There are two species of fish and three sizes of vessels.
The choices are between 3 areas with the following features

Name	Distance	Resources
Area 1	Close to homeport	Species A most abundant
Area 2	Farer than area 1 and closer than area 3	Species A and B equally abundant
Area 3	Far from homeport	Species B most abundant

Obviously, the small vessels prefer area 1, to where they make one-day trips. The larger vessels prefer area 3, where they have little competition from the small vessels. The trips of large vessels are of longer duration and the quality of landings is lower than that of small vessels.
The characteristics and attributes are:

Index: r	Characteristics	Index s	Attributes
1	Vessel length	1	Value of species A per unit of effort
2	Costs/Day	2	Value of species A per unit of effort
3	Quality of landings		

The constructed example contains 3 trips

Index	Trip
1	With a small Vessel
2	With a medium size vessel
3	With a large vessel

The task is now to choose parameter values (β and γ) so that the vessels behave as we expect, that is, the large vessel go to area 2 and 3 and the small vessel go to area 1 and 2, and the middle sized vessel go to all areas.

The example is made with EXCEL. Figure 16.1 shows the calculation for choice 1 of trip 1. This is the small vessel going to area 1. Column E contains the characteristics (X) and the associated coefficients (Beta), and column G contains the attributes (W) with its coefficients (Gamma). Below is calculated

$$\text{SUM(B*X)} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} \quad \text{and SUM(G*W)} = \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

for Choice = 1 and Trip = 1.

Figure B.2.10.1. shows the same calculations for all 3 choices. Note that Beta and W varies between choices, whereas X and Gamma remain the same. X and Gamma will vary between trips. Figure B.2.10.1 also illustrates the calculations of probabilities of choices, and the graph shows the results. Note that the probability is highest for area 1 which is the expected result, as we are dealing with a small vessel.

RUM_EXAMPLE_23Nov03_bak

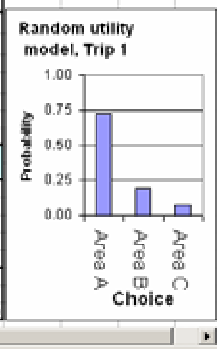
	A	B	C	D	E	F	G
1		B = Beta		Species A prefers Fishing Ground 1			
2		G = Gamma		Fishing ground close to port			
3	SMALL	Explanation	Explanation	CHOISE	1		TRIP 1
4	VESSEL	B (Beta)	G (Gamma)	FISHING GROUND A			
5		Charact.	Attributes	Index	B	Index	G
6	TRIP 1	Vessel length	VPUE Sp A	r=1	0.2	s=1	1.5
7		Cost/day	VPUE Sp B	r=2	0.3	s=2	0.2
8		Quality		r=3	1		
9				Charact.	X	Attributes	W
10		Vessel length	VPUE Sp A	r=1	0.2	s=1	0.8
11		Cost/day	VPUE Sp B	r=2	0.1	s=2	0.2
12		Quality		r=3	2		
13					B*X		G*W
14		Vessel length	VPUE Sp A	r=1	0.04	s=1	1.2
15		Cost/day	VPUE Sp B	r=2	0.03	s=2	0.04
16		Quality		r=3	2		
17		Sum(exp(U)) =	37.682	SUM B*X	2.07	SUM G*W	1.24

TableZero / Table 2 Beta / Table 3 Gamma / Table4_

Figure B.2.10.1. Calculation for one trip and one choice

RUM_EXAMPLE_23Nov03_bak

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		B = Beta		Species A prefers Fishing Ground 1				Species A and B are in Fishing Ground 2				Species B prefers Fishing Ground 3			
2		G = Gamma		Fishing ground close to port				Fishing ground medium distance from p				Fishing ground far from port			
3	SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
4	VESSEL	B (Beta)	G (Gamma)	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
5		Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
6	TRIP 1	Vessel length	VPUE Sp A	r=1	0.2	s=1	1.5	r=1	0.5	s=1	1.5	r=1	0.8	s=1	1.5
7		Cost/day	VPUE Sp B	r=2	0.3	s=2	0.2	r=2	0.45	s=2	0.2	r=2	0.6	s=2	0.2
8		Quality		r=3	1			r=3	0.5			r=3	0.2		
9				Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	-2	Attributes	W
10		Vessel length	VPUE Sp A	r=1	0.2	s=1	0.8	r=1	0.2	s=1	0.5	r=1	0.2	s=1	0.2
11		Cost/day	VPUE Sp B	r=2	0.1	s=2	0.2	r=2	0.1	s=2	0.5	r=2	0.1	s=2	0.8
12		Quality		r=3	2			r=3	2			r=3	2		
13					B*X		G*W		B*X		G*W		B*X		G*W
14		Vessel length	VPUE Sp A	r=1	0.04	s=1	1.2	r=1	0.1	s=1	0.75	r=1	0.16	s=1	0.3
15		Cost/day	VPUE Sp B	r=2	0.03	s=2	0.04	r=2	0.045	s=2	0.1	r=2	0.06	s=2	0.16
16		Quality		r=3	2			r=3	1			r=3	0.4		
17		Sum(exp(U)) =	37.682	SUM B*X	2.07	SUM G*W	1.24	SUM B*X	1.145	SUM G*W	0.850	SUM B*X	0.62	SUM G*W	0.460
18				Utility, U() =	3.31			Utility, U() =	1.995			Utility, U() =	1.00		
19				exp(U(1))=	27.4	Prob.	0.727	exp(U(1))=	7.4	Prob.	0.19511	exp(U(1))=	2.945	Prob.	0.07815



TableZero / Table 2 Beta / Table 3 Gamma / Table4_B+G / Table5 / Paper

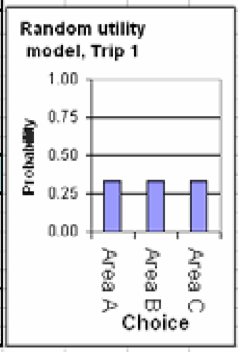
Figure B.2.10.2. Calculation for one trip and all choices.

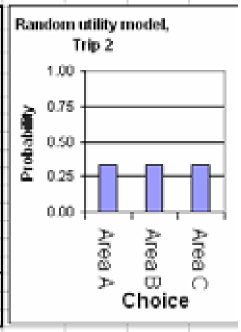
Figures B.2.10.3.A-D shows the calculations for all trip and all choices. The figures illustrates the different logit models:

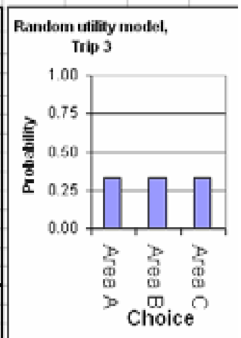
Figure	Beta and X	Gamma and W	Model
A	= 0	= 0	Trivial
B	≠ 0	= 0	Multinomial logit
C	= 0	≠ 0	Conditional logit
D	≠ 0	≠ 0	General logit

In figure A the probabilities are all equal as $p_{Choice} = \frac{\exp(Z)}{\sum_{choice} \exp(Z)} = \frac{1}{3}$ because exp(0) = 1

	B = Beta G = Gamma		Species A prefers Fishing Ground 1 Fishing ground close to port				Species A and B are in Fishing Ground 2 Fishing ground medium distance from p				Species B prefers Fishing Ground 3 Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
				B'X		G'W		B'X		G'W		B'X		G'W
	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
	Sum(exp(U)) =	3.000	SUM B'X	0	SUM G'W	0.00	SUM B'X	0	SUM G'W	0.000	SUM B'X	0	SUM G'W	0.000
			Utility, U()	0.00			Utility, U() =	0			Utility, U() =	0		
			exp(U(1))=	1.0	Prob.	0.333	exp(U(1))=	1.0	Prob.	0.33333	exp(U(1))=	1.000	Prob.	0.33333
MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	1			r=3	1			r=3	1		
				B'X		G'W		B'X		G'W		B'X		G'W
	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
	Sum(exp(U)) =	3.000	SUM B'X	0	SUM G'W	0.00	SUM B'X	0	SUM G'W	0.000	SUM B'X	0	SUM G'W	0.000
			Utility, U()	0			Utility, U() =	0			Utility, U() =	0		
			exp(U(1))=	1.00	Prob.	0.333	exp(U(1))=	1.0	Prob.	0.33333	exp(U(1))=	1.000	Prob.	0.33333
LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	2			r=3	2			r=3	2		
				B'X		G'W		B'X		G'W		B'X		G'W
	Vessel length	VPUE Sp A	r=1	0	s=1	0	r=1	0	s=1	0	r=1	0	s=1	0
	Cost/day	VPUE Sp B	r=2	0	s=2	0	r=2	0	s=2	0	r=2	0	s=2	0
	Quality		r=3	0			r=3	0			r=3	0		
	Sum(exp(U)) =	3.000	SUM B'X	0	SUM G'W	0.00	SUM B'X	0	SUM G'W	0.000	SUM B'X	0	SUM G'W	0.000
			Utility, U()	0			Utility, U() =	0			Utility, U() =	0		
			exp(U(1))=	1.0	Prob.	0.333	exp(U(1))=	1.0	Prob.	0.333	exp(U(1))=	1	Prob.	0.333







$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

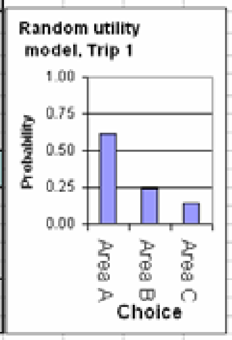
Table B.2.10.3.a. Illustration of Random utility model (all β and γ equal to zero, the trivial case)

In figure b, the characteristics are chosen to reflect the size of the vessels. The betas indicate how important a characteristic is in certain area. If a characteristic math well to an area one will choose

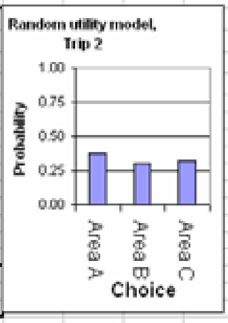
that area. So if both beta and X are large, they will give a high score to that combination of characteristic and choice.
The betas are chosen to give high weight to quality in area 1 and low weight for area 3. It is the other way around for the length of the vessel. The cost/per day is weighted higher in area 3, than in area 1, but that is arbitrary.

Note that with chosen values of X and beta, we manage to allocate the small vessels to area 1 and the large vessels to area 3. The middle sized vessels fish in all three areas, and everybody fish in area 2.

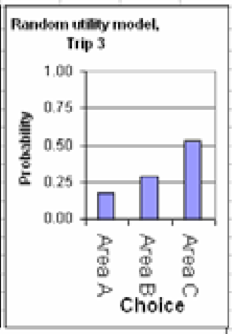
	B = Beta G = Gamma		Species A prefers Fishing Ground 1 Fishing ground close to port				Species A and B are in Fishing Ground 2 Fishing ground medium distance from port				Species B prefers Fishing Ground 3 Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Vessel length	VPUE Sp A	r=1	0.2	s=1	0	r=1	0.5	s=1	0	r=1	0.8	s=1	0
	Cost/day	VPUE Sp B	r=2	0.3	s=2	0	r=2	0.45	s=2	0	r=2	0.6	s=2	0
	Quality		r=3	1			r=3	0.5			r=3	0.2		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	-2	Attributes	W
	Vessel length	VPUE Sp A	r=1	0.2	s=1	0	r=1	0.2	s=1	0	r=1	0.2	s=1	0
	Cost/day	VPUE Sp B	r=2	0.1	s=2	0	r=2	0.1	s=2	0	r=2	0.1	s=2	0
	Quality		r=3	2			r=3	2			r=3	2		
				B*X		G*W		B*X		G*W		B*X		G*W
	Vessel length	VPUE Sp A	r=1	0.04	s=1	0	r=1	0.1	s=1	0	r=1	0.16	s=1	0
	Cost/day	VPUE Sp B	r=2	0.03	s=2	0	r=2	0.045	s=2	0	r=2	0.06	s=2	0
	Quality		r=3	2			r=3	1			r=3	0.4		
	Sum(exp(U)) =	12.926	SUM B*X	2.07	SUM G*W	0.00	SUM B*X	1.145	SUM G*W	0.000	SUM B*X	0.62	SUM G*W	0.000
			Utility, U(j)	2.07			Utility, U(j) =	1.145			Utility, U(j) =	0.62		
			exp(U(1))=	7.9	Prob.	0.613	exp(U(1))=	3.1	Prob.	0.24311	exp(U(1))=	1.859	Prob.	0.14381



MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Vessel length	VPUE Sp A	r=1	0.2	s=1	0	r=1	0.5	s=1	0	r=1	0.8	s=1	0
	Cost/day	VPUE Sp B	r=2	0.3	s=2	0	r=2	0.45	s=2	0	r=2	0.6	s=2	0
	Quality		r=3	1			r=3	0.5			r=3	0.2		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	1.1	s=1	0	r=1	1.1	s=1	0	r=1	1.1	s=1	0
	Cost/day	VPUE Sp B	r=2	0.55	s=2	0	r=2	0.55	s=2	0	r=2	0.55	s=2	0
	Quality		r=3	1.25			r=3	1.25			r=3	1.25		
				B*X		G*W		B*X		G*W		B*X		G*W
	Vessel length	VPUE Sp A	r=1	0.22	s=1	0	r=1	0.55	s=1	0	r=1	0.88	s=1	0
	Cost/day	VPUE Sp B	r=2	0.165	s=2	0	r=2	0.248	s=2	0	r=2	0.33	s=2	0
	Quality		r=3	1.25			r=3	0.625			r=3	0.25		
	Sum(exp(U)) =	13.583	SUM B*X	1.635	SUM G*W	0.00	SUM B*X	1.423	SUM G*W	0.000	SUM B*X	1.46	SUM G*W	0.000
			Utility, U(j)	1.635			Utility, U(j) =	1.423			Utility, U(j) =	1.46		
			exp(U(1))=	5.13	Prob.	0.378	exp(U(1))=	4.1	Prob.	0.30535	exp(U(1))=	4.306	Prob.	0.31701



LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Vessel length	VPUE Sp A	r=1	0.2	s=1	0	r=1	0.5	s=1	0	r=1	0.8	s=1	0
	Cost/day	VPUE Sp B	r=2	0.3	s=2	0	r=2	0.45	s=2	0	r=2	0.6	s=2	0
	Quality		r=3	1			r=3	0.5			r=3	0.2		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	2	s=1	0	r=1	2	s=1	0	r=1	2	s=1	0
	Cost/day	VPUE Sp B	r=2	1	s=2	0	r=2	1	s=2	0	r=2	1	s=2	0
	Quality		r=3	0.5			r=3	0.5			r=3	0.5		
				B*X		G*W		B*X		G*W		B*X		G*W
	Vessel length	VPUE Sp A	r=1	0.4	s=1	0	r=1	1	s=1	0	r=1	1.6	s=1	0
	Cost/day	VPUE Sp B	r=2	0.3	s=2	0	r=2	0.45	s=2	0	r=2	0.6	s=2	0
	Quality		r=3	0.5			r=3	0.25			r=3	0.1		
	Sum(exp(U)) =	18.768	SUM B*X	1.2	SUM G*W	0.00	SUM B*X	1.7	SUM G*W	0.000	SUM B*X	2.3	SUM G*W	0.000
			Utility, U(j)	1.2			Utility, U(j) =	1.7			Utility, U(j) =	2.3		
			exp(U(1))=	3.3	Prob.	0.177	exp(U(1))=	5.5	Prob.	0.292	exp(U(1))=	10	Prob.	0.531



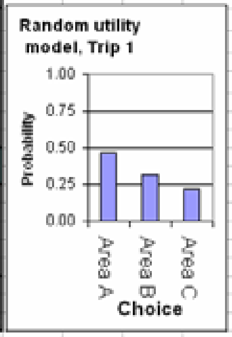
$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

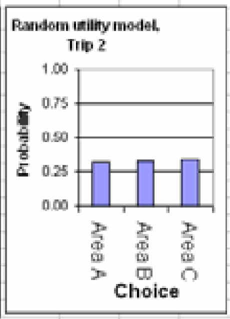
Figure B.2.10.3.b. Illustration of Random utility model (β ≠0 and γ = 0, the multinomial logit model)

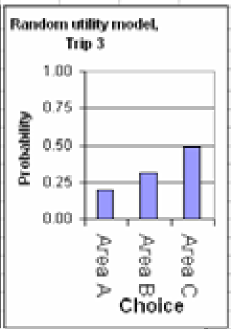
By manipulating the beta-values we can create any allocation of choices between the three vessel sizes. Somehow, we can achieve any allocation by the multinomial logit model.

In Figure B.2.10.3.c, we use the same techniques and show that we can achieve similar results by the conditional logit model. By manipulating gamma and W we can again move the small vessel to area 1 and the large vessel to area 3.

	B = Beta		Species A prefers Fishing Ground 1				Species A and B are in Fishing Ground 2				Species B prefers Fishing Ground 3			
	G = Gamma		Fishing ground close to port				Fishing ground medium distance from p				Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Vessel length	VPUE Sp A	r=1	0	s=1	1.5	r=1	0	s=1	1.5	r=1	0	s=1	1.5
	Cost/day	VPUE Sp B	r=2	0	s=2	0.2	r=2	0	s=2	0.2	r=2	0	s=2	0.2
	Quality		r=3	0			r=3	0			r=3	0		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	0	s=1	0.8	r=1	0	s=1	0.5	r=1	0	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0	s=2	0.2	r=2	0	s=2	0.5	r=2	0	s=2	0.8
	Quality		r=3	0			r=3	0			r=3	0		
				B'X		G'W		B'X		G'W		B'X		G'W
	Vessel length	VPUE Sp A	r=1	0	s=1	1.2	r=1	0	s=1	0.75	r=1	0	s=1	0.3
	Cost/day	VPUE Sp B	r=2	0	s=2	0.04	r=2	0	s=2	0.1	r=2	0	s=2	0.16
	Quality		r=3	0			r=3	0			r=3	0		
	Sum(exp(U)) =	7.379	SUM B'X	0	SUM G'W	1.24	SUM B'X	0	SUM G'W	0.850	SUM B'X	0	SUM G'W	0.460
			Utility, U()	1.24			Utility, U() =	0.85			Utility, U() =	0.46		
			exp(U(1))=	3.5	Prob.	0.468	exp(U(1))=	2.3	Prob.	0.31705	exp(U(1))=	1.584	Prob.	0.21466
MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Vessel length	VPUE Sp A	r=1	0	s=1	1	r=1	0	s=1	1	r=1	0	s=1	1
	Cost/day	VPUE Sp B	r=2	0	s=2	1.1	r=2	0	s=2	1.1	r=2	0	s=2	1.1
	Quality		r=3	0			r=3	0			r=3	0		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	0	s=1	0.8	r=1	0	s=1	0.5	r=1	0	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0	s=2	0.2	r=2	0	s=2	0.5	r=2	0	s=2	0.8
	Quality		r=3	1			r=3	1			r=3	1		
				B'X		G'W		B'X		G'W		B'X		G'W
	Vessel length	VPUE Sp A	r=1	0	s=1	0.8	r=1	0	s=1	0.5	r=1	0	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0	s=2	0.22	r=2	0	s=2	0.55	r=2	0	s=2	0.88
	Quality		r=3	0			r=3	0			r=3	0		
	Sum(exp(U)) =	8.576	SUM B'X	0	SUM G'W	1.02	SUM B'X	0	SUM G'W	1.050	SUM B'X	0	SUM G'W	1.080
			Utility, U()	1.02			Utility, U() =	1.05			Utility, U() =	1.08		
			exp(U(1))=	2.77	Prob.	0.323	exp(U(1))=	2.9	Prob.	0.33323	exp(U(1))=	2.945	Prob.	0.34338
LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Vessel length	VPUE Sp A	r=1	0	s=1	0.5	r=1	0	s=1	0.5	r=1	0	s=1	0.5
	Cost/day	VPUE Sp B	r=2	0	s=2	2	r=2	0	s=2	2	r=2	0	s=2	2
	Quality		r=3	0			r=3	0			r=3	0		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	0	s=1	0.8	r=1	0	s=1	0.5	r=1	0	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0	s=2	0.2	r=2	0	s=2	0.5	r=2	0	s=2	0.8
	Quality		r=3	2			r=3	2			r=3	2		
				B'X		G'W		B'X		G'W		B'X		G'W
	Vessel length	VPUE Sp A	r=1	0	s=1	0.4	r=1	0	s=1	0.25	r=1	0	s=1	0.1
	Cost/day	VPUE Sp B	r=2	0	s=2	0.4	r=2	0	s=2	1	r=2	0	s=2	1.6
	Quality		r=3	0			r=3	0			r=3	0		
	Sum(exp(U)) =	11.190	SUM B'X	0	SUM G'W	0.80	SUM B'X	0	SUM G'W	1.250	SUM B'X	0	SUM G'W	1.700
			Utility, U()	0.8			Utility, U() =	1.25			Utility, U() =	1.7		
			exp(U(1))=	2.2	Prob.	0.199	exp(U(1))=	3.5	Prob.	0.312	exp(U(1))=	5	Prob.	0.489





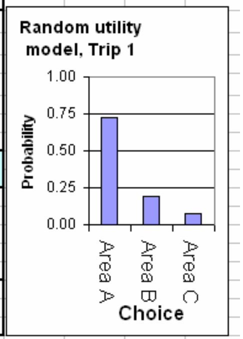


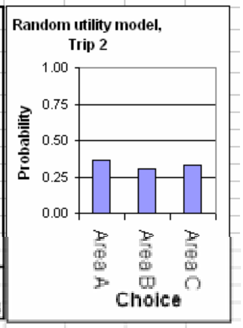
$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

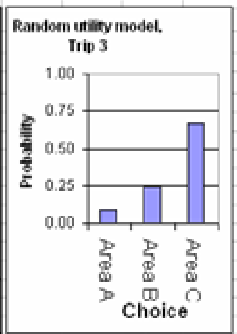
Figure B.2.10.3.c. ***Illustration of Random utility model (all β = 0 and γ ≠ 0, the conditional model)***

Figure B.2.10.3.d illustrates the general logit model, and naturally, we can still achieve the desired distribution on areas. Note that in the general model, where effect of characteristics and attributes are combined, the probabilities for small vessels in area 1 and large vessels in area 3, are larger than those of the multinomial logit and the conditional logit.

	B = Beta		Species A prefers Fishing Ground 1				Species A and B are in Fishing Ground				Species B prefers Fishing Ground 3			
	G = Gamma		Fishing ground close to port				Fishing ground medium distance from				Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Vessel length	VPUE Sp A	r=1	0.2	s=1	1.5	r=1	0.5	s=1	1.5	r=1	0.8	s=1	1.5
	Cost/day	VPUE Sp B	r=2	0.3	s=2	0.2	r=2	0.45	s=2	0.2	r=2	0.6	s=2	0.2
	Quality		r=3	1			r=3	0.5			r=3	0.2		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	-2	Attributes	W
	Vessel length	VPUE Sp A	r=1	0.2	s=1	0.8	r=1	0.2	s=1	0.5	r=1	0.2	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0.1	s=2	0.2	r=2	0.1	s=2	0.5	r=2	0.1	s=2	0.8
	Quality		r=3	2			r=3	2			r=3	2		
				B*X		G*W		B*X		G*W		B*X		G*W
	Vessel length	VPUE Sp A	r=1	0.04	s=1	1.2	r=1	0.1	s=1	0.75	r=1	0.16	s=1	0.3
	Cost/day	VPUE Sp B	r=2	0.03	s=2	0.04	r=2	0.045	s=2	0.1	r=2	0.06	s=2	0.16
	Quality		r=3	2			r=3	1			r=3	0.4		
	Sum(exp(U)) =	37.682	SUM B*X	2.07	SUM G*W	1.24	SUM B*X	1.145	SUM G*W	0.850	SUM B*X	0.62	SUM G*W	0.460
			Utility, U(j)	3.31			Utility, U(j) =	1.995			Utility, U(j) =	1.08		
			exp(U(1))=	27.4	Prob.	0.727	exp(U(1))=	7.4	Prob.	0.19511	exp(U(1))=	2.945	Prob.	0.07815
MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Vessel length	VPUE Sp A	r=1	0.2	s=1	1	r=1	0.5	s=1	1	r=1	0.8	s=1	1
	Cost/day	VPUE Sp B	r=2	0.3	s=2	1.1	r=2	0.45	s=2	1.1	r=2	0.6	s=2	1.1
	Quality		r=3	1			r=3	0.5			r=3	0.2		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	1.1	s=1	0.8	r=1	1.1	s=1	0.5	r=1	1.1	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0.55	s=2	0.2	r=2	0.55	s=2	0.5	r=2	0.55	s=2	0.8
	Quality		r=3	1.25			r=3	1.25			r=3	1.25		
				B*X		G*W		B*X		G*W		B*X		G*W
	Vessel length	VPUE Sp A	r=1	0.22	s=1	0.8	r=1	0.55	s=1	0.5	r=1	0.88	s=1	0.2
	Cost/day	VPUE Sp B	r=2	0.165	s=2	0.22	r=2	0.248	s=2	0.55	r=2	0.33	s=2	0.88
	Quality		r=3	1.25			r=3	0.625			r=3	0.25		
	Sum(exp(U)) =	38.757	SUM B*X	1.635	SUM G*W	1.02	SUM B*X	1.423	SUM G*W	1.050	SUM B*X	1.46	SUM G*W	1.080
			Utility, U(j)	2.655			Utility, U(j) =	2.473			Utility, U(j) =	2.54		
			exp(U(1))=	14.22	Prob.	0.367	exp(U(1))=	11.9	Prob.	0.30581	exp(U(1))=	12.680	Prob.	0.32716
LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Vessel length	VPUE Sp A	r=1	0.2	s=1	0.5	r=1	0.5	s=1	0.5	r=1	0.8	s=1	0.5
	Cost/day	VPUE Sp B	r=2	0.3	s=2	2	r=2	0.45	s=2	2	r=2	0.6	s=2	2
	Quality		r=3	1			r=3	0.5			r=3	0.2		
			Charact.	X	Attributes	W	Charact.	X	Attributes	W	Charact.	X	Attributes	W
	Vessel length	VPUE Sp A	r=1	2	s=1	0.8	r=1	2	s=1	0.5	r=1	2	s=1	0.2
	Cost/day	VPUE Sp B	r=2	1	s=2	0.2	r=2	1	s=2	0.5	r=2	1	s=2	0.8
	Quality		r=3	0.5			r=3	0.5			r=3	0.5		
				B*X		G*W		B*X		G*W		B*X		G*W
	Vessel length	VPUE Sp A	r=1	0.4	s=1	0.4	r=1	1	s=1	0.25	r=1	1.6	s=1	0.1
	Cost/day	VPUE Sp B	r=2	0.3	s=2	0.4	r=2	0.45	s=2	1	r=2	0.6	s=2	1.6
	Quality		r=3	0.5			r=3	0.25			r=3	0.1		
	Sum(exp(U)) =	81.093	SUM B*X	1.2	SUM G*W	0.80	SUM B*X	1.7	SUM G*W	1.250	SUM B*X	2.3	SUM G*W	1.700
			Utility, U(j)	2			Utility, U(j) =	2.95			Utility, U(j) =	4		
			exp(U(1))=	7.4	Prob.	0.091	exp(U(1))=	19.1	Prob.	0.236	exp(U(1))=	55	Prob.	0.673







$$Z_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$

Figure B.2.10.3.d. Illustration of Random utility model (all β ≠ 0 and γ ≠ 0, the general logit model)

Note that X and Gamma varies over “trips” and W and beta varies over “Choices”
X is independent of choice, and W is independent of “trip”. The combined effect og X*Beta and W*Gamma must be to measure how well a “trip match to a choice”, and there fore beta must depend on the choice and gamma must depend on the trip.

B.2.11. THE EFFECT OF TRADITION ON MAKING CHOICES (AUTO-REGRESSION)

This model assumes that fishers' have a tendency to follow the same patterns as foregoing years. This assumption is based on the assumption that fishers' possess specialized knowledge on certain fishing techniques combined with certain fishing grounds. Also the capability (e.g. range) of the vessel may support the idea of following the same pattern. Thus, we expect a certain positive utility for following the traditions. In this model the probability of making a choice is determined by the utility

$$Z_{t,Trip,Choice} = Tradition \quad +$$

$$+ \left\{ \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s} \right\}$$

.where the tradition term is defined:

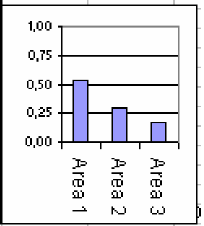
$$Tradition = \sum_{u=1}^{U} \left\{ \sum_{r=1(Characteristics)}^{R^T} \beta^T{}_{t-u,Choice,r} * X^T{}_{t-u,Trip,r} \right\}$$

u=1,2,…U is index of past years. The tradition is supposed to go U years back in time. U = 0 gives the usual model without tradition. U = 1 goes one year back in time. The variables are considered characteristics, as they are not dependent on the choice made now (this year). The X'es and β's may or may not be the same type as those of the current year. The number of tradition-variables is designated R^T, with suffix "T" to indicate that it may be different from R.

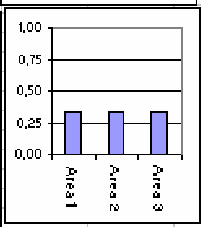
$$Tradition = \sum_{u=1}^{U} \left\{ \sum_{r=1(Characteristics)}^{R^T} \beta^T{}_{t-u,Choice,r} * p_{t-u,Trip,r} \right\}$$

TIME = 1

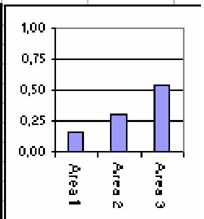
	B = Beta		Species A prefers Fishing Gr. 1				Spec. A+B are in Fishing Ground 2				Species B prefers Fishing Ground 3			
	G = Gamma		Fishing ground close to port				Fishing gr. medium dist. from port				Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	1	r=1	0,275	s=1	1	r=1	0,050	s=1	1,000
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,1	r=2	0,100	s=2	0,1	r=2	0,100	s=2	0,100
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,500		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,7	s=1	2	r=1	0,7	s=1	1,5	r=1	0,700	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,2	s=2	1	r=2	0,2	s=2	1,5	r=2	0,200	s=2	2
TIME = 1	Was in Area 3		r=3	0,1			r=3	0,1			r=3	0,100		
			exp(U(1))=	11,8	Prob.	0,535	exp(U(1))=	6,6	Prob.	0,299	exp(U(1))=	3,688	Prob.	0,167



MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,55	r=1	0,275	s=1	0,550	r=1	0,05	s=1	0,55
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,55	r=2	0,100	s=2	0,550	r=2	0,1	s=2	0,55
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	ttribut	V	Charact.	X	tribut	V
	Was in Area 1	VPUE Sp A	r=1	0,4	s=1	2	r=1	0,400	s=1	1,500	r=1	0,4	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,2	s=2	1	r=2	0,200	s=2	1,500	r=2	0,2	s=2	2
TIME = 1	Was in Area 3		r=3	0,4			r=3	0,400			r=3	0,4		
			exp(U(1))=	6,5	Prob.	0,331	exp(U(1))=	6,667	Prob.	0,333	exp(U(1))=	6,619	Prob.	0,336

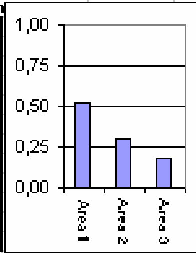


LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,1	r=1	0,275	s=1	0,1	r=1	0,05	s=1	0,1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	1	r=2	0,1	s=2	1	r=2	0,1	s=2	1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	0,1	Attrib	V	Charact.	X	ttribut	V	Charact.	X	tribut	V
	Was in Area 1	VPUE Sp A	r=1	0,1	s=1	2	r=1	0,1	s=1	1,5	r=1	0,1	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,2	s=2	1	r=2	0,2	s=2	1,5	r=2	0,2	s=2	2
TIME = 1	Was in Area 3		r=3	0,7			r=3	0,7			r=3	0,7		
			exp(U(1))=	3,6	Prob.	0,163	exp(U(1))=	6,5	Prob.	0,297	exp(U(1))=	11,882	Prob.	0,540

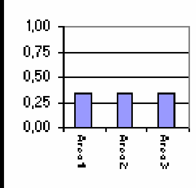


TIME = 2

	B = Beta		Species A prefers Fishing Groun				Species A and B are in Fishing Gro				Species B prefers Fishing Groun			
	G = Gamma		Fishing ground close to port				Fishing ground medium distance fr				Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	1	r=1	0,275	s=1	1	r=1	0,05	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,1	r=2	0,100	s=2	0,1	r=2	0,1	s=2	0,1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,535	s=1	2	r=1	0,535	s=1	1,5	r=1	0,535	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,299	s=2	1	r=2	0,299	s=2	1,5	r=2	0,299	s=2	2
TIME = 2	Was in Area 3		r=3	0,167			r=3	0,167			r=3	0,167		
			exp(U(1))=	11,0	Prob.	0,517	exp(U(1))=	6,485	Prob.	0,304	exp(U(1))=	3,819	Prob.	0,179



MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,55	r=1	0,275	s=1	0,55	r=1	0,05	s=1	0,55
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,55	r=2	0,1	s=2	0,55	r=2	0,1	s=2	0,55
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	tribut	V
	Was in Area 1	VPUE Sp A	r=1	0,331	s=1	2	r=1	0,331	s=1	1,5	r=1	0,331	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,333	s=2	1	r=2	0,333	s=2	1,5	r=2	0,333	s=2	2
TIME = 2	Was in Area 3		r=3	0,336			r=3	0,336			r=3	0,336		
			exp(U(1))=	6,4	Prob.	0,331	exp(U(1))=	6,4	Prob.	0,333	exp(U(1))=	6,474	Prob.	0,336



LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,1	r=1	0,275	s=1	0,1	r=1	0,05	s=1	0,1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	1	r=2	0,1	s=2	1	r=2	0,1	s=2	1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	0,1	Attrib	V	Charact.	X	Attrib	V	Charact.	X	tribut	V
	Was in Area 1	VPUE Sp A	r=1	0,163	s=1	2	r=1	0,1630	s=1	1,5	r=1	0,1630	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,297	s=2	1	r=2	0,2968	s=2	1,5	r=2	0,2968	s=2	2
TIME = 2	Was in Area 3		r=3	0,540			r=3	0,5402			r=3	0,5402		
			exp(U(1))=	3,7	Prob.	0,175	exp(U(1))=	6,4	Prob.	0,303	exp(U(1))=	11,111	Prob.	0,522

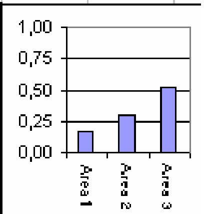
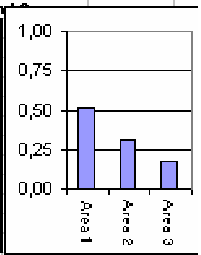


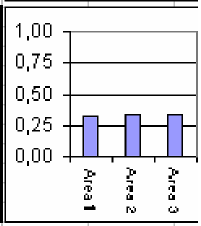
Figure B.2.11.1. The first two years in an illustrative example of choice as a function of tradition.

TIME = 3

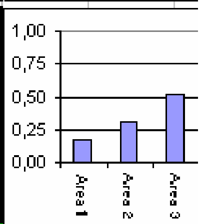
	B = Beta		Species A prefers Fishing Groun				Species A and B are in Fishing Gro				Species B prefers Fishing Groun			
	G = Gamma		Fishing ground close to port				Fishing ground medium distance fr				Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	1	r=1	0,275	s=1	1	r=1	0,05	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,1	r=2	0,1	s=2	0,1	r=2	0,1	s=2	0,1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,517	s=1	2	r=1	0,516603	s=1	1,5	r=1	0,5166	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,304	s=2	1	r=2	0,30423	s=2	1,5	r=2	0,3042	s=2	2
TIME = 3	Was in Area 3		r=3	0,179			r=3	0,173161			r=3	0,1792		
			exp(U(1))=	10,9	Prob.	0,514	exp(U(1))=	6,5	Prob.	0,305	exp(U(1))=	3,841	Prob.	0,181



MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,55	r=1	0,275	s=1	0,55	r=1	0,05	s=1	0,55
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,55	r=2	0,100	s=2	0,55	r=2	0,1	s=2	0,55
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,331	s=1	2	r=1	0,331	s=1	1,5	r=1	0,331	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,333	s=2	1	r=2	0,333	s=2	1,5	r=2	0,333	s=2	2
TIME = 3	Was in Area 3		r=3	0,336			r=3	0,336			r=3	0,336		
			exp(U(1))=	6,4	Prob.	0,331	exp(U(1))=	6,4	Prob.	0,333	exp(U(1))=	6,474	Prob.	0,336

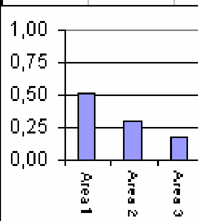


LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,1	r=1	0,275	s=1	0,1	r=1	0,050	s=1	0,1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	1	r=2	0,100	s=2	1	r=2	0,100	s=2	1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,500		
			Charact.	0,1	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,175	s=1	2	r=1	0,175	s=1	1,5	r=1	0,175	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,303	s=2	1	r=2	0,303	s=2	1,5	r=2	0,303	s=2	2
TIME = 3	Was in Area 3		r=3	0,522			r=3	0,522			r=3	0,522		
			exp(U(1))=	3,8	Prob.	0,177	exp(U(1))=	6,4	Prob.	0,303	exp(U(1))=	11,024	Prob.	0,520

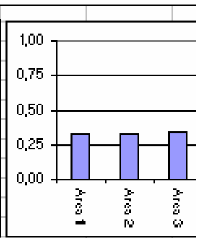


TIME = 4

	B = Beta		Species A prefers Fishing Groun				Species A and B are in Fishing Gro				Species B prefers Fishing Ground 3			
	G = Gamma		Fishing ground close to port				Fishing ground medium distance fr				Fishing ground far from port			
SMALL	Explanation	Explanation	CHOISE	1		TRIP 1	CHOICE	2		TRIP 1	CHOICE	3		TRIP 1
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 1	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	1	r=1	0,275	s=1	1	r=1	0,05	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,1	r=2	0,1	s=2	0,1	r=2	0,1	s=2	0,1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,514	s=1	2	r=1	0,514	s=1	1,5	r=1	0,514	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,305	s=2	1	r=2	0,305	s=2	1,5	r=2	0,305	s=2	2
TIME = 4	Was in Area 3		r=3	0,181			r=3	0,181			r=3	0,181		
			exp(U(1))=	10,9	Prob.	0,514	exp(U(1))=	6,475	Prob.	0,305	exp(U(1))=	3,845	Prob.	0,181



MEDIUM	Explanation	Explanation	CHOISE	1		TRIP 2	CHOICE	2		TRIP 2	CHOICE	3		TRIP 2
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 2	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,55	r=1	0,275	s=1	0,55	r=1	0,05	s=1	0,55
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	0,55	r=2	0,100	s=2	0,55	r=2	0,1	s=2	0,55
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	X	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,331	s=1	2	r=1	0,331	s=1	1,5	r=1	0,331	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,333	s=2	1	r=2	0,333	s=2	1,5	r=2	0,333	s=2	2
TIME = 4	Was in Area 3		r=3	0,336			r=3	0,336			r=3	0,336		
			exp(U(1))=	6,4	Prob.	0,331	exp(U(1))=	6,4	Prob.	0,333	exp(U(1))=	6,474	Prob.	0,336



LARGE	Explanation	Explanation	CHOISE	1		TRIP 3	CHOICE	2		TRIP 3	CHOICE	3		TRIP 3
VESSEL	B	G	FISHING GROUND A				FISHING GROUND B				FISHING GROUND C			
	Charact.	Attributes	Index	B	Index	G	Index	B	Index	G	Index	B	Index	G
TRIP 3	Was in Area 1	VPUE Sp A	r=1	0,5	s=1	0,1	r=1	0,275	s=1	0,1	r=1	0,05	s=1	0,1
	Was in Area 2	VPUE Sp B	r=2	0,1	s=2	1	r=2	0,100	s=2	1	r=2	0,1	s=2	1
	Was in Area 3		r=3	0,01			r=3	0,255			r=3	0,5		
			Charact.	0,1	Attrib	V	Charact.	X	Attrib	V	Charact.	X	Attril	V
	Was in Area 1	VPUE Sp A	r=1	0,177	s=1	2	r=1	0,177	s=1	1,5	r=1	0,177	s=1	1
	Was in Area 2	VPUE Sp B	r=2	0,3033	s=2	1	r=2	0,303	s=2	1,5	r=2	0,303	s=2	2
TIME = 4	Was in Area 3		r=3	0,5197			r=3	0,520			r=3	0,520		
			exp(U(1))=	3,8	Prob.	0,177	exp(U(1))=	6,4	Prob.	0,303	exp(U(1))=	11,012	Prob.	0,519

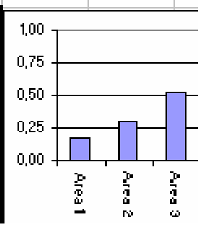


Figure B.2.11.2. The 3rd and 4th years in an illustrative example of choice as a function of tradition.

B.3. FLEET DYNAMICS AND STRUCTURAL BEHAVIOUR

TEMAS contains two options to model the behaviour of fishing firms during the fishing season and from year to year

1) Random Utility Model (RUM)
2) Ad hoc behaviour rules.

The statistical model and theory behind the RUM is comprehensive (see Sections B.1-3). However, it is also complicated and data demanding. The "Ad hoc" approach is kind of a short cut method, which indeed can be questioned and is not supported by a huge literature as the RUM is.

B.3.1. NUMBER OF VESSELS DYNAMICS (STRUCTURAL BEHAVIOUR)

The number of vessels, $NU_{vessel}(Fl, Vs, Ct, y, q,Va)$, is defined by iteration:

	q > 1	q = 1
Va = 0	$NU_{Vessel}(Fl, Vs, Ct, y, q, 0) = NU_{New-Vessel}(Fl, Vs, Ct, y,q)$	$NU_{Vessel}(Fl, Vs, Ct, y,1,0) = NU_{New-Vessel}(Fl, Vs, Ct, y,q)$
Va = 1,2,…,Va_{max}-1	$NU_{Vessel}(Fl, Vs, Ct, y, q,Va) = NU_{vessel}(Fl, y , q-1,Va) - NU_{Decomm}(Fl, Vs, Ct, y, q,Va) - NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va) - NU_{Attrition}(Fl, Vs, Ct, y, q, Va)$	$NU_{Vessel}(Fl, Vs, Ct, y,Va) = NU_{vessel}(Fl, y-1, q_{Max},Va) - NU_{Decomm}(Fl, Vs, Ct, y, 1,Va) - NU_{Withdrawal}(Fl, Vs, Ct, y, 1, Va) - NU_{Attrition}(Fl, Vs, Ct, y, 1, Va)$
Va = Va_{Max} (plus group)	$NU_{vessel}(Fl, Vs, Ct, y, q,Va) = NU_{vessel}(Fl, Vs, Ct, y, q-1, Va_{Max}) + NU_{Decomm}(Fl, Vs, Ct, y, q, Va_{Max}) - NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va_{Max}) - NU_{Attrition}(Fl, Vs, Ct, y, q, Va_{Max})$	$NU_{vessel}(Fl, Vs, Ct, y, 1,Va) = NU_{vessel}(Fl, y-1, q_{Max}, Va_{Max}) + NU_{vessel}(Fl, y-1, q_{Max}, Va_{Max}-1) - NU_{Decomm}(Fl, Vs, Ct, y, 1, Va_{Max}) - NU_{Withdrawal}(Fl, Vs, Ct, y, 1, Va_{Max}) - NU_{Attrition}(Fl, Vs, Ct, y, 1, Va_{Max})$

Where NU_{Decomm}, $NU_{Attrition}$ and $NU_{Withdrawal}$ are the numbers of vessels withdrawn due to a vessel decommissioning, retired vessels having reached the end of their techno-economic lifetime and withdrawn and due to bad financial performance.

$NU_{New-Vessel}(Fl, Vs, Ct, y, q)$ is the (simulated or predicted) number of new vessels (number of investments in new vessels).

The fraction of the vessels that accept decommission is named $\Pr_{Decomm}^{Accept}$. The symbol "Pr" is chosen because the "fraction" can also be interpreted as the probability that a vessel will accept decommission.

Then the number of decommissions become.

$$NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet) = NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet) * \Pr_{Decomm}^{Accept} \quad \text{(C.7.1.1)}$$

The $NU_{Decomm}(Fl,y,q,\bullet)$ decommissions are selected from the oldest end of the vessel age distribution.

Then we are left with $NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet) - NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet)$ vessels. Of these the fraction $\Pr_{Withdrawal}^{Accept}$ withdraws from the industry. The order of decommission and withdrawal is essential, as it is assumed that decommission is always selected when the choice is between decommission and withdrawal. Withdrawal (or bankrupts) does not give compensation to the vessel owner.

$$\begin{aligned}&NU_{Withdrawal}(Fl,Vs,Ct,y,q,\bullet) = \\&(NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet) - NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet)) * \Pr_{Withdrawal}^{Accept}\end{aligned} \quad \text{(C.7.1.2)}$$

The $NU_{Withdrawal}(Fl,Vs,Ct,y,q,\bullet)$ withdrawals are selected from the oldest end of the vessel age distribution.

Then we are left with

$$NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet) - NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet) - NU_{WithDrawal}(Fl,Vs,Ct,y,q,\bullet)$$

vessels.

To get the number of attritions we use the number of the oldest vessels as the basis:

$$\begin{aligned}&NU_{Vessel}(Fl,Vs,Ct,y,q-1,Va_{Max}-1) + NU_{Vessel}(Fl,Vs,Ct,y,q-1,Va_{Max}) - \\&NU_{Decomm}(Fl,Vs,Ct,y,q,Va_{Max}) - NU_{WithDrawal}(Fl,Vs,Ct,y,q,Va_{Max})\end{aligned} \quad \text{(C.7.1.3)}$$

The vessels of age Va_{Max} is a plus group, as all vessels older than Va_{Max} are in the plus group. In the case q = 1

The number of attritions, naturally is linked to the number of old vessels

$$\begin{aligned}&NU_{Attrition}(Fl,Vs,Ct,y,q,Va_{Max}) = (NU_{Vessel}(Fl,Vs,Ct,y,q-1,Va_{Max}-1) + \\&NU_{vessel}(Fl,Vs,Ct,y,q-1,Va_{Max}) - NU_{Decomm}(Fl,Vs,Ct,y,q,Va_{Max}) - \\&NU_{WithDrawal}(Fl,Vs,Ct,y,q,Va_{Max})) * \Pr_{Attrition}^{Accept}\end{aligned} \quad \text{(C.7.1.4)}$$

Eventually we compute the number of new vessels by the factor $\Pr_{New-vessel}^{Accept}$

$$\begin{aligned}&NU_{New-Vessel}(Fl,Vs,Ct,y,q) = (NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet) - \\&NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet) - NU_{WithDrawal}(Fl,Vs,Ct,y,q,\bullet) - \\&NU_{Attrition}(Fl,Vs,Ct,y,q,\bullet)) * \Pr_{New-vessel}^{Accept}\end{aligned} \quad \text{(C.7.1.5)}$$

B.3.2. RANDOM UTILITY MODEL FOR STRUCTURAL BEHAVIOUR

The five structural rules currently in the TEMAS

Decommission (Rule). This (and the three following rules) is the so-called long term rules which determine the capacity of the fishing fleets. The decommission rules takes the decision on accept of a decommission compensation based on the recent economic performance of the fleet and the age structure of the fleet.
Dis-investment rule. This rule decides on the bankruptcy of a vessel based on the recent economic performance of the fleet.
Attrition rule: The attrition rule takes the decision on scrapping a vessel due to old age based on the age structure of the fleet.
Investment rule: This rule decides on the investment in a new vessel based on the recent economic performance of the fleet.

The decommision rule is one of the structural rules. It is presented here as an example of the structural rules. The mathematical fotmulations is similr for all 4 structural rules.

The factors, $\Pr_{Decomm}^{Accept}$, $\Pr_{Withdrawal}^{Accept}$, $\Pr_{Attrition}^{Accept}$, $\Pr_{New-Vessel}^{Accept}$ thus determines the exit/entry model.

They can be modelled by the RUM, the Random Utility Model.

$$\Pr_{Decomm}^{Accept} = \frac{\exp(U_{Decomm}^{Accept})}{\exp(U_{Decomm}^{Reject}) + \exp(U_{Decomm}^{Accept})} \quad \text{and} \quad \Pr_{Decomm}^{Reject} = 1 - \Pr_{Decom}^{Accept} \qquad \text{(B.3.2.1)}$$

U_{Decomm}^{Accept} is the "utility" of accepting decommission and U_{Decomm}^{Reject} is the utility of rejecting decommission.
The general expression for utility fransformed to the vessel exit/entry model reads

The general expression for utility fransformed to the vessel exit/entry model reads

$$\begin{aligned} &U_{Decomm}^{Accept}(Fl,Vs,Ct,y,q) = \\ &\sum_{r=1(Characteristics)}^{R_{Decomm}} \beta_{Decomm.\ r}^{Accept} * X_{Decomm,\ r}(Fl,Vs,Ct,y,q) \\ &+ \sum_{s=1(Attributes)}^{S_{Decomm}} \gamma_{Decomm,\ s} * W_{Decomm,\ s}^{Accept}(Fl,Vs,Ct,y,q) \end{aligned} \qquad \text{(B.3.2.2)}$$

Four potential characteristics There are in the case of decommission

$X_{Decomm,\ 1}(Fl,Vs,Ct,y,q)$ = Decommission Fee
$X_{Decomm,\ 2}(Fl,Vs,Ct,y,q)$ = Historical profitability (Annual Value of landings – Annual Costs) /Investment
$X_{Decomm,\ 3}(Fl,Vs,Ct,y,q)$ = Investment
$X_{Decomm,\ 4}(Fl,Vs,Ct,y,q)$ = Age of vessel and value of original Investment.

Two potential attributes in the case of decommission

$W^{Accept}_{Decomm,1}(Fl,Vs,Ct,y,q)$ =
Expected profitability (Annual Value of landings – Annual Costs)/Investment

$W^{Accept}_{Decomm,2}(Fl,Vs,Ct,y,q)$ = Expected revenue.

Table B.3.2.1 list sets of potential characteristics for the four fleet capacity RUMs cosidered in TEMAS.
.

Characteristics	Decommission	Dis-Investment	Attrition	Investment
Characteristics	Decommission fee			
Characteristics	Historical profitability	Historical profitability	Historical profitability	Historical profitability
Characteristics	Age of vessel	Age of vessel	Age of vessel	
Characteristics	Investment value	Investment value	Investment value	Investment value
Attributes	Expected profitabilty	Expected profitabilty	Expected profitabilty	Expected profitabilty
Attributes	Expected revenue	Expected revenue	Expected revenue	Expected revenue

Table B.3.2.1. Potential characteristics and attributes for four RUM models of fleet capacity dynamics.

B.3.3. AD HOC RANDOM UTILITY MODEL FOR STRUCTURAL BEHAVIOUR

These "*ad hoc methods*" were introduced in the BEAM4 (Sparre and Willmann, 1993) in various versions according to the actual applications. They are believed to be more straight forward and easier to comprehend than the random utility models, but naturally, their foundation (believed to be only common sense) is weaker than the that of the RUM. In one respect, however, are the "ad hoc" models more complete than the RUM's. The RUM model tells how many vessels should enter/leave the industry, but it does not tell which vessels should leave. The *Ad hoc* rules also contain algorithms for selection of the vessels to leave the industry.

B.3.3.1. AD HOC DECOMMISSION RULE.

The total number of vessels that are being decommissioned is not determined by a fisher's "behaviour rule". This is a decision by government or the fishery management authority (and subject to the assumed acceptance of the adequacy by vessel owners of the compensation/ decommissioning payment) and thus given as an input to TEMAS. The number of decommissioned vessels may be given as input for each vessel age group or they may be given as a fraction of the total number of vessels. Only in the case where decommissions are given as a fraction do we need a rule, namely a rule to select the vessels for decommissioning.
The decommission rule is active only when the other behaviour rules are also active.

Let "$Va_{DecommMinA}$" be the youngest age of vessel, which can become decommissioned. (Input parameter).
"DecommFactor (Fl,Vs,Ct)" is the fraction of vessels at age, or older than $va_{DecommMinA}$ which are decommissioned.
"DecommFactorOld(Fl,Vs,Ct)" is the fraction of the oldest age group which is decommissioned before any other vessels are decommissioned.

The total number of Decommissions is:

$$NU_{Decomm}(Fl,Vs,Ct,y\ ,\bullet) =$$

$$Round\left[DecommFactor(Fl) * \sum_{Va=Va_{DecommMinA}}^{va_{max}} NU_{Vessel}(Fl,Vs,Ct,y,Va) + 0.5 \right] \quad \text{(B.3.3.1)}$$

Where "Round" stands for the integer part of a real number.

When selecting the vessels to be decommissioned the following algorithm (written in idealized VISUAL BASIC) is applied:

```
T = NU_Decomm(Fl, Vs, Ct, y, •) '--- (total number of Decommissions)
 NU_Decomm(Fl, Vs, Ct, y, Va_Max) =
Round(DecommFactorOld(Fl) * NU_Vessel(Fl, Vs, Ct, y, Va_Max) +0.5)
T = T – NU_Decomm(Fl, Vs, Ct, y, Va_Max)     ' ---- count down -----
 For Va = 1 to Va_Max
        NU_Decomm(Fl, Vs, Ct, y, Va) = 0 '--- assign initial count
Next Va
While T > 0 do '---- continue until all planned withdrawals are counted (up and down)
        Va = Va_max
        While Va >= Va DecommMin-a do
                NU_Decomm(Fl, Vs, Ct, y, Va) =  NU_Decom(Fl, Vs, Ct, y, Va) + 1 '--- count up ----
                Va = Va – 1 '----- count down ----
                T = T –1      ' ---- count down -----
        wend
  wend
```

In words, this means that the vessels are decommissioned one by one from the oldest end of the distribution, until the required total number of vessel reductions is achieved. But firstly, a certain fraction of the vessel oldest age is decommissioned.
While it is optional for the user of TEMAS to assume that decommissioning takes place without decommission compensation to the owners of fishing vessels and/or crew members, that would clearly not be in accordance with a usual buy-back programme.

B.3.3.2. AD HOC DIS-INVESTMENT RULE

If for one or more years, the financial net cash flow of the fleet (disregarding decommissioning cash inflows) is zero or negative, some fishing firms are assumed to withdraw boats from the fleet to avoid future losses.

Let "MaxLowYears(Fl,Vs,Ct)" be the maximum number of low cash flow years in sequence fleet (Fl,Vs,Ct) will accept before it starts to withdraw vessels, and let "WithdrawalFactor(Fl,Vs,Ct)" be the fraction of vessels that are withdrawn when a sequence of low years have occurred.
Let $va_{WithdrawalMinA}$ be the youngest age of vessel, which would be withdrawn (Input parameter).

Let "y_1" be the first year in the "moving" sequence of years : "y_1, y_1+1 ,…, y_1+MaxLowYears(Fl,Vs,Ct)". To simplify notation, let: $\mathbf{Y_2} = y_1 + MaxLowYears(Fl,Vs,Ct) + 1$

Let DECV(Fl,Vs,Ct,y,q,Va) be the decommission payment for one vessel of age group "Va" of Fleet "(Fl,Vs,Ct)" in year "y" (Section C.4.4), which is the product of numbers and the decommission rate $DECV(Fl,Vs,Ct,y,q) = DECR(Fl,Vs,Ct,y,q) * NU_{Decomm}(Fl,Vs,Ct,y,q)$

Let FVDecommFraction(Fl,Vs,Ct,y) be the Fraction of vessel decommission fee "remaining" in fleet "(Fl,Vs,Ct)". Then we have that the income to fleet (Fl,Vs,Ct) from decommission fee is

DecommFee(Fl, Vs, Ct, y) =
FVDecommFraction(Fl,Vs, Ct, y)*Σ_{Va} DECR(Fl,Vs,Ct,Va,y) * NU_{Decomm}(Fl,Vs,Ct y, Va)

The disinvestments rule is flexible and allows the user to simulate different scenarios. It reads as follows:

If for y = y_1, y_1+1,…, y_2 : FNCF(Fl,Vs,Ct,y,q,•) – DECV(Fl,Vs,Ct, y,q) < 0
Then the total number of withdrawals is:

$$NU_{Withdrawal}(Fl,Vs,Ct,y_2,\bullet) = Round\left[\begin{array}{l} WithdrawalFactor(Fl,Vs,Ct)* \\ \sum_{Va=Va_{WithdrawalMinA}}^{Va_{\max}} NU_{Vessel}(Fl,Vs,Ct,y_2-1,va)+0.5 \end{array}\right] \quad \text{(B.3.3.2.1)}$$

Where "Round" stands for the integer part of a real number.

Where FNCF is the "Financial net cash flow" (Section C.4.6)

$$FNCF(Fl,Vs,Ct,y,q,\bullet) = REV(Fl,Vs,Ct,y,q,\bullet) -$$
$$VCO(Fl,Vs,Ct,y,q,\bullet) - CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) - INV^{Total}(-,\bullet) + TSL(-,\bullet) + DECV(-,\bullet)$$

Where VCO is Total variable costs:

$$VCO(Fl,Vs,Ct,y,q,Ar) = CO_{Yield}^{Total}(Fl,Vs,Ct,y,q,Ar) + CO_{E}^{Total}(Fl,Vs,Ct,y,q,Ar) +$$
$$CO_{VAL}^{Total}(Fl,Vs,Ct,y,q,Ar) + CO_{Crew}^{Share}(Fl,Vs,Ct,y,q) + CO_{Crew}^{Salary}(Fl,Vs,Ct,y,q)$$

CO_{Fix}^{Total} is total fixed costs, INV^{Total} is total investments,
TSL is total taxes, subsidies and license fee

$$TSL(Fl,y,q) = SUB_{REV}(Fl,Vs,Ct,y,q) + SUB_{Operation}(Fl,Vs,Ct,y,q) -$$
$$-TAX_{REV}(Fl,Vs,Ct,y,q) - TAX_{Operation}(Fl,Vs,Ct,y,q) - LIC(Fl,Vs,Ct,y,q)$$

When selecting the vessels to be withdrawn the following algorithm (written in idealised VISUAL BASIC) is applied:

```
T = NU_Withdrawal(Fl,  y2,  •) '--- (total number of withdrawals)
    For Va = 1 to Va_max
        NU_Withdrawal(Fl, y2, Va) = 0 '--- assign initial count
    Next va
   While T > 0 do '---- continue until all planned withdrawals are counted (up and down)
        Va = Va_max
        While Va >= va WithdrawalMinA do
                NU_Withdrawal(Fl, y2, Va) =  NU_Withdrawal(Fl, y2, Va) + 1 '--- count up ----
                Va = Va – 1 '----- count down ----
                T = T –1      ' ---- count down -----
        wend
    wend
```

In words, this means that the vessels are withdrawn one by one from the oldest end of the distribution, until the required total number of withdrawals is achieved.

B.3.3.3. AD HOC INVESTMENT RULE

If for one or more years, the financial net cash flow is above a specified value, fishing firms are assumed to invest in additional harvesting capacity. The user of TEMAS can specify the threshold level of cash flow and the number of years this threshold needs to be reached for investors to add a certain number of boats to the fleet.

Let "MaxHighYears(Fl,Vs,Ct)" be the maximum number of years with high net cash flow in fleet (Fl,Vs,Ct), where no investment in new vessels is made, when cash flow is above the threshold.

Let "InvestTreshold(Fl,Vs,Ct)" be the value of net cash flow of fleet (Fl,Vs,Ct), which results in investments in new vessels after MaxHighYears(Fl,Vs,Ct) years of high cash flow.

Let "NewVesselFactor(Fl,Vs,Ct) be the raising factor for number of boats when investment in new vessels occur to fleet (Fl,Vs,Ct). The rule reads as follows:

If for all the years in sequence: $y = y_1, y_1+1, \ldots, y_1+\text{MaxHighYears}(Fl,Vs,Ct)$
$FNCF(Fl,Vs,Ct,y,q)/NU_{Vessel}(Fl,Vs,Cty,\bullet) > InvestTreshold(Fl)$
Then $NU_{NewVessel}(Fl,Vs,Ct, y_1 + Max\_High\_Years + 1,q) =$
$Round(NewVesselFactor(Fl,Vs,Ct) * NU_{vessel}(Fl,Vs,Ct, y_1 + MaxHighYears(Fl,Vs,Ct),\bullet) + 0.5)$

B.3.3.4. AD HOC ATTRITION RULE

The attrition rule serves the sole purpose to simulate the wear and tear of vessels over the years and that they need to cease fishing once the end of their techno-economic lifetime has been reached. It reads as follows:

Let ScrapFactor(Fl,Vs,Ct) be the fraction of old vessels (age av_{max}), which is scrapped due to attrition. Every year a fraction (rounded to integer) of the fleet retires due to having reached the end of the techno-economic lifetime of the vessels.

$NU_{Attrition}(Fl,Vs,Ct, y, Va_{max}) = round(ScrapFactor(Fl,Vs,Ct)* NU_{vessel}(Fl,Vs,Ct, y,Va_{max}) + 0.5)$

For $Va < Va_{Max}(Fl, Ct)$: $NU_{Attrition}(Fl, Vs, Ct, y, Va_{Max}(Fl,Ct)) = 0$

$NU_{Attrition}(Fl, Vs,Ct, y, Va)$ is the number of attrition vessels of age "Va" from fleet "(Fl,Vs,Ct)" in year "y"

B. 4. AD HOC MODEL FOR SHORT TERM BEHAVIOUR

B.4.1. AD HOC RULES FOR SHORT TERM BEHAVIOUR

Effort can be controlled in TEMAS in two ways:

(1) Giving effort as input
(2) Let the "Effort-rule" decide the effort.

The first option was discussed in Section B.4. Here we shall discuss second option second with respect of short term behaviour. Namely choice of fishing ground and choice of gear rigging. We start by reiterating the definitions of effort distributions on areas and rigging given in Section A4.3.

$$E(Fl,Vs,\bullet,Ct,y,q,\bullet) = \sum_{Ar=1}^{NU_{Area}} \sum_{Rg=1}^{Rg(Fl)} E(Fl,Vs,Rg,Ct.y,q,Ar)$$

is the total effort exerted by fleet (Fl,Vs,Ct) during time period q. The input effort in the present version of TEMAS is E(Fl, Vs, Ct, y, q,•), that is the total effort summed over areas, together with the relative distribution of effort over areas (Eq. B.4.3.1):

$$E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) = \frac{E(Fl,Vs,\bullet,Ct,y,q,Ar)}{E(Fl,Vs,\bullet,Ct,y,q,\bullet)}$$

Thus, effort is the product of the two input parameters, which in turn gives the effort distribution on fleets, vessels sizes and countries (Eq. B.4.3.2):

$$E(Fl, Vs, \bullet, Ct, y, q, Ar) = E(Fl, Vs, \bullet, Ct, y, q, \bullet)* E_{Area\text{-}Dist}(Fl, Vs, \bullet, Ct, y, q, Ar)$$

The next step in the distribution of effort is the distribution on riggings for given area (Eq. B.4.3.3)

$$E(Fl, Vs, Rg, Ct, y, q, Ar) = E(Fl, Vs, \bullet, Ct, y, q, Ar)* E_{Rig\text{-}Dist}(Fl, Vs, Rg, Ct, y, q, Ar)$$

where effort distribution on riggings for given area, Ar is

$$E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar) = \frac{E(Fl,Vs,Rg,Ct,y,q,Ar)}{E(Fl,Vs,\bullet,Ct,y,q,Ar)}$$

The two effort distributions may also be considered the probability that a vessel will choose and area, and then given that area the probability that a it will choose a rigging. Thus, the effort distributions $E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$ and $E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar)$ is linked to the model of fisher's behaviour. To summarize the distribution, the complete model of effort distribution on areas, and on rigs for given area read:

$$E(Fl,Vs,Rg,Ct,y,q,Ar) = E_{\mathrm{Re}\,f}(Fl,Vs,\bullet,Ct,y,q,\bullet)*$$
$$E_{Rig-dist}(Fl,Vs,Rg,y,q,Ar)*E_{Area-dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$$

As probabilities the area and rigging distribution will sum up to one,

$$\sum_{Ar=}^{Ar_{Max}} E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) = 1.0 \quad \text{and} \quad \sum_{Rg=}^{Rg(Fl,Ct)} E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar) = 1.0$$

There it falls natural to use RUM also for the Ad hoc version, for example.

$$Pr(choosing\ area\ "Ar") = \frac{exp(U_{Ar})}{\sum_{j(Area)=1}^{Ar_{Max}} exp(U_j)}$$

as that will automatically produce probabilities, for choosing area and rigging.

B.4.2. AD HOC FISHING EFFORT RULE

The overall rule is that fleets use the full capacity. That is

$$\Sigma_{Ar}E(Fl, Vs, \bullet.Ct,y, a, Ar) = NU_{Vessel}(Fl, Vs,Ct,y, \bullet)* EY_{MAX}(Fl, Vs, Ct, y, q)$$

where the capacity is the maximum number of fishing units (fishing days or sea days) that a fleet can exert in a time period. It is given by the variable EY_{MAX}(Fl, Vs, Ct, y, q), the maximum number of effort units per vessel per time unit. However, the fleet is assumed to change its level of fishing activity (fishing days per time period) when harvesting costs, i.e. the sum of financial operating costs for handling and harvesting and sale's cost, crew share and effort income are higher than gross revenues for a suite of time periods.

Let "MaxLowPer(Fl, Vs, Ct)" be the maximum number of periods fleet (Fl ,Vs, Ct) will continue to fish with unchanged effort. Or in other words, fleet "(Fl,Vs,Ct)" continues with unchanged effort in "MaxLowPer" time periods, before it changes its level of effort, due to low cash flow.
And let "EffortReductionFactor(Fl, Vs, Ct)" be the "number of vessels reduction factor" fleet (Fl, Vs, Ct) applies after "MaxLowPer" of less profitable time periods
The rule is flexible and allows the user to simulate different scenarios. It reads as follows in pseudo VISUAL BASIC:

If for all the periods in sequence: q = q_1, q_1 +1 ,..., q_1+MaxLowPer(Fl,Vs,Ct)
the condition for the "financial net cah flow", FNCF

FNCF(Fl, Vs, •,Ct, y, q) > 0

is met, then Effort is reduced by the factor "EffortReductionFactor" in the following period:
Effort(Fl, Vs, •,Ct, y, q+1 , •) = Effort(Fl,Vs, •,Ct, y, q, •) * EffortReductionFactor(Fl,Vs,Ct),

The same reduction factor is applied to all areas.

If the condition is then no longer met, effort is raised to the capacity, that is:
Σ_{Ar}E(Fl, Vs, •,Ct,y, a, qr) = NU_{Vessel}(Fl,Vs,Ct, y, •) * EY_{MAX}(Fl,Vs,Ct,y,q)

B.4.3. AD HOC RULE FOR CHOOSING FISHING GROUND

The probability of choosing a fishing ground is modelled by the logit model:

Pr("Choosing fishing ground Ar") = $\dfrac{\exp(U_{Ar}^{Area})}{\sum_{j(Area)=1}^{Ar_{Max}} \exp(U_{j}^{Area})}$ as that will automatically produce

probabilities Pr("Choosing fishing ground Ar") = $E_{Area-Dist}(Fl, Vs, \bullet, Ct, y, q, Ar)$.
The utility is defined as the sum of a "revenue term" and a "tradition term"

$$\begin{aligned} &U_{Area}(Fl, Vs, \bullet, Ct, y, q, Ar) = U_{MPA}^{General}(Fl, Vs, Ct, y, q, Ar) + \\ &REVFac_{Area}(Fl, Vs, \bullet, Ct, y, q, Ar) * EXPREV(Fl, Vs, \bullet, Ct, y, q, Ar) + \\ &Trad^{Area}(Fl, Vs, \bullet, Ct, y, q, Ar) * Effort(Fl, Vs, \bullet, Ct, y-1, q, Ar) + \end{aligned} \qquad \text{(B.4.3.1.a)}$$

The value factor $REVFac_{Area}(Fl, Vs, \bullet, Ct, y, q, Ar)$ determines the importance of the value of the expected landings. The tradition factor, $Trad^{Area}(Fl, Vs, \bullet, Ct, y, q, Ar)$, determines the importance of what the fishers used to do.

The expected revenue of landings from area Ar is defined as the revenue last year (in the same time period)

$$EXPREV(Fl,Vs,\bullet,Ct,\bullet,y,q,Ar) = REV(Fl,Vs,Ct,y-1,q,Ar) \quad \text{(B.4.3.2.a)}$$

The total closure of and area during a time period, q, is modelled by a "Total MPA-Utility" defined as:

$$U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar) = \begin{cases} 0 & \text{if area Ar not total MPA} \\ -\infty & \text{if area Ar is a total MPA} \end{cases} \quad \text{(B.4.3.3)}$$

A "total MPA" is an area closed for all fishing gears. With the (ideal) utility of "-∞" a total MPA will never be chosen as fishing ground. Alternatively $U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar)$ could be given the value of costs of violating the MPA regulation. That might be a fine, the confiscation of landings and/or gear. If the closure of the MPA is gear rigging specific, then the MPA is modelled as a part of the behaviour model for rigging choice (see following subsection).

The expected revenue can be replaced with the expected cash flow in Eq. C.7.5.2.1.a

$$\begin{aligned} &U_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) = U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar) + \\ &REVFac_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) * EXPFNCF(Fl,Vs,\bullet,Ct,y,q,Ar) + \\ &Trad^{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) * Effort(Fl,Vs,\bullet,Ct,y-1,q,Ar) \end{aligned} \quad \text{(B.4.3.1.b)}$$

Where the expected cash is defined as the cashflow last year (in the same time period)

$$EXPFNCF(Fl,Vs,\bullet,Ct,\bullet,y,q,Ar) = FNCF(Fl,Vs,\bullet,Ct,\bullet,y-1,q,Ar) \quad \text{(B.4.3.2.b)}$$

Where the financial cash flow of fleet (Fl,Vs,Ct) is defined (Eq. C.4.6.1.a)

$$\begin{aligned} &FNCF(Fl,Vs,Ct,y,q,Ar) = REV(Fl,Vs,Ct,y,q,Ar) - VCO(Fl,Vs,Ct,y,q,Ar) - \\ &CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) - INV^{Total}(-,Ar) + TSL(-,Ar) + DECV(-,Ar) \end{aligned}$$

B.4.4. AD HOC RULE FOR CHOOSING GEAR RIGGING

The probability of choosing a gear rigging for given fishing ground is modelled by the logit model:

$$Pr(\text{choosing rig "Rg"}) = \frac{exp(U_{Rg}^{Rig})}{\sum_{j(Rig)=1}^{Rg_{Max}(Fl,Ct)} exp(U_j^{Rig})} \quad \text{(B.4.4.1)}$$

The rigging utility is defined as the area utility

$$\begin{aligned} &U^{Rig}(Fl,Vs,Rg,Ct,y,q,Ar) = U_{MPA}^{Rig}(Fl,Vs,Rg,Ct,y,q,Ar) + \\ &REVFac_{Area}^{Rig}(Fl,Vs,Rg,Ct,Ar) * \sum_{St=1}^{St_{Max}} EXPREV(Fl,Vs,Ct,Rg,St,y,q,Ar) + \\ &Trad_{Area}^{Rig}(Fl,Vs,Rg,Ct,Ar) * Effort(Fl,Vs,Rg,Ct,y-1,q,Ar) \end{aligned} \quad \text{(B.4.4.2)}$$

where the utility contains the same three terms as the utility for choice of area. The indices is now extended with index "Rg".

$$U_{MPA}^{Rig}(Fl,Vs,Ct,y,q,Ar)=\begin{cases} 0 & if\ \ rig\ \ Rg\ \ is\ \ allowed\ \ in\ \ MPA \\ -\infty & if\ \ rig\ \ Rg\ \ is\ \ not\ \ allowed\ \ in\ \ MPA \end{cases} \qquad \text{(B.4.4.3)}$$

ANNEX C. ECONOMIC SUBMODEL

The economic model in TEMAS serves two purposes

1) Modelling of fishers behaviour
2) Provision of measures of system performance

Economics plays an important role in the evaluation of fisher's reaction to the introduction of regulations. In the context of the Baltic case study, the important regulations under study are the MPAs in time and space. How fishers reallocate or moderate their effort in reaction to technical regulations, (like MPAs), is in the TEMAS model dependent on three factors:

1) Economy of fishing operations
2) Tradition (Whish fishing operations were made in the past)
3) The regulation (e.g. MPA in space and time)

Economy in the context of TEMAS is similar to an examination of accounts. The key issue in the TEMAS economic model is the cash flow, the difference between income and costs. Income, costs and cash flow are key issues in choice making of fishers in the TEMAS model. This Annex describes the economic model and its linking to the behaviour models. The income (the value of the landings) links the economic model to the "production model", the technical/biological model of TEMAS.

Like the biological models has a suite of measures of performance, such as SSB (Spawning Stock Biomass), fishing mortality, Landings, value of landings etc., the economic model can provide overall measures for the performance of the system. These measures are stakeholder specific, as the evaluation of fisheries depends on who is evaluator. For example, Fishing industry, Government Treasury, Society (in general) do usually not evaluate the same way. TEMAS allows for an optional number of economic models, each of which reflects the view of a stakeholder group. The outputs are a suite of measures of performance of the fishing industry or individual fleets.

C.1. INTRODUCTION

There are no fixed economic models in TEMAS, but there is a frame by which the user can select the desired model(s) from a family of economic models. It has been attempted to make the family of economic models as wide as possible. A common feature is that the models are all dynamic models, as is the biological model of TEMAS.

There are 3 economic models in the current version of TEMAS, reflecting the views of three groups of stakeholders

1) FINANCIAL ANALYSIS OF FLEETS: From the point of view of vessel owners.
2) GOVERNMENT BUDGET: The impact of the fleets on the government budget
3) ECONOMIC ANALYSIS: The economic performance from of the economy as a whole.

All three models operate with the same concepts of costs, earnings and investments, but (possibly) with different parameters.

The economic model calculates the cash flow (Revenue – costs) for each time period and eventual it computes the net present value over the time horizon simulated. The economic model was designed by Mr. Rolf Willmann, of the fisheries department of FAO, Rome (Sparre and Willmann, 1993).

The economic part of TEMAS uses the concepts developed for project analysis to evaluate the financial and economic performance of the fishery during the project horizon (i.e. simulation life span) given different fisheries management measures, government financial transfers, and assumptions about the investment and operational behaviour of fishing firms. The financial performance is assessed from the point of view of both the fishing firms and the government treasury (Gittinger, 1984, Little & Mirrlees, 1974, Squire & Tak , 1975 and Dasgupta et al, 1972).

The key performance measures of project analysis are the net present value (NPV), equal to the discounted net cash flow. The NPV is defined:

$$NPV(r) = \sum_{y=y_{first}}^{y_{last}} \frac{Value_y}{(1+r)^{y-y_{first}}}$$

where "r" is a user defined input parameter, the "discount rate". In purely financial terms, a project would usually be considered beneficial to the investor when the NPV is positive at a discount rate that is equal to the average commercial interest rate on capital.
For the economic analysis, on the other hand, the appropriate discount rate would reflect the benefit forgone by the economy by using capital in fisheries rather than elsewhere in the economy (i.e. the opportunity cost of capital).

Table C.1.1 shows an example, a suite of values from 2007 to 2016 sum up to the same total, 550, whereas the net present values reflects the distribution over the years.

Year	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	
$\frac{1}{(1+r)^{y-2007}}$	*1.00*	*0.95*	*0.91*	*0.86*	*0.82*	*0.78*	*0.75*	*0.71*	*0.68*	*0.64*	**Total**
$Value_1$	100	90	80	70	60	50	40	30	20	10	**550**
$\frac{Value_1}{(1+r)^{y-2007}}$	100.0	85.7	72.6	60.5	49.4	39.2	29.8	21.3	13.5	6.4	**NPV=478.4**
$Value_2$	10	20	30	40	50	60	70	80	90	100	**550**
$\frac{Value_2}{(1+r)^{y-2007}}$	10	19.0	27.2	34.6	41.1	47.0	52.2	56.9	60.9	64.5	**NPV=413.4**

Table C.1.1. Examples of NPV calculations, with discount rate, r = 0.05.

TEMAS allows for country specific discount rates as well as model-specific discount rates, $r^{Economic\ Moodel}(Ct)$

C.2. PRICES AND VALUE OF LANDINGS

The price concept used in TEMAS is the "Ex-vessel price", that is the price of the landings given to the vessel (the vessel owner). They are given as a maximum price over age groups and a relative price by age: [4]

C.2.1. MAXIMUM PRICE AND RELATIVE PRICE

P_{Max}(Fl, Vs, Rg, Ct, St, y) = Maximum Price (over age groups)
and
P_{Rel}(Fl,Vs, Rg, Ct, St, a, q) is the relative price of age group "a".

Note that P_{Max} depends on the year, but not the age group, whereas P_{Rel} depends on the age group of the animals but not the year. The product becomes the age-dependent absolute price:

$$P(Fl, Vs, Rg, Ct, St, y, a, q) = P_{Max}(Fl, Vs, Rg, Ct, St, y) * P_{Rel}(Fl, Vs, Rg, Ct, St, q, a) \qquad (C.2.1.1)$$

In the current version of TEMAS, prices are given as input parameters. They can either be assumed to remain constant (i.e. no changes in response to changes in supply) or to vary as a result of changes in supply (i.e. in landings). Where variations in supply are assumed to have an effect on prices, TEMAS provides a simple price formation function that, however, disregards changes in demand. In the simple version, price flexibility is only related to changes in the supply (i.e. landings of the fishery) of the same species:

$$P_{Max}(Fl,Vs,Rg,Ct,St,y) = P_{Max,0}(Fl,Vs,Rg,Ct,St) * Y_{Land}(\bullet,St,y-1,\bullet,\bullet,\bullet)^{PFlex(Fl,St)} \qquad (C.2.1.2)$$

where PFlex(Fl,Vs, Rg, Ct,St), is the price flexibility and $P_{max,0}$ (Fl, Vs, Rg, Ct, St, y) is a constant coefficient

The price may have a lower limit due to intervention by the EU commission (the PO-price), P_{MinPO}(Fl,Vs, Rg, Ct, St, y, a, q). The intervention price usually applies to the small size categories of landings.

$$P_{Int}(Fl,Vs, Rg, Ct, St, y, a, q) =$$
$$Max\{ P_{MinPO}(Fl,Vs, Rg, Ct, St, y, a, q), P(Fl,Vs, Rg, Ct, St, y, a, q) \} \qquad (C.2.1.3)$$

2.2. REVENUE FROM LANDINGS

Value of fish landed (Yield) is

4:

	Index	Explanation	Range
1	a	Age group	$a = 0,1,2,\ldots,a_{max}(St)$
2	Ar	Area	$Ar = 1,2,\ldots,Ar_{max}$
3	Ct	Country	$Ct = 1,\ldots,Ct_{Max}$
4	Fl	Fleet	$Fl = 1,2,\ldots,Fl_{max}(Ct)$
5	q	Time period (as time)	$q = 1,..,q_{max}$
6	qa	Time period (as age)	$qa = 1,..,q_{max}$,
7	Rg	Rigging of gear	$Rg = 1,\ldots,Rg_{max}(Fl,Ct)$
8	y	Year	$y = y_{firSt, yfirst}+1,\ldots,y_{last}$
9	St	Stock	$St = 1,\ldots,St_{max}$
10	Va	Vessel age group	$Va = 1,\ldots Va_{max}(Fl,Ct)$
11	Vs	Vessel size group	$Vs = 1,\ldots Vs_{max}(Fl,Ct)$

Note that the sequence of indices will be (Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar) for all variables.

Time variables in alphabetical order
dt: Basic time step (fraction of year). dt < 1.0. $dt = 1/q_{Max}$
y_{first}, y_{last}: First year, Last year

Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j) = \sum_u X(i,u,j)$.

:

$$VAL(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = Y_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)* P(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \quad \text{(C.2.2.1)}$$

or in case intervention price is applied

$$VAL(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = Y_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)* P_{Int}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \quad \text{(C.2.2.2)}$$

where Y_{Land} = Weight of landings.

The total annual fleet specific value of all age groups is $VAL(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$.
The value for the landings from the entire stock (all areas combined) becomes $VAL(Fl,Vs,Rg,Ct,St,y,\bullet,q,\bullet)$.
And the annual value of the stock caught by fleet Fl becomes $VAL(Fl,Vs,Rg,Ct,St,y,\bullet,\bullet,\bullet)$.
The total revenue of fleet (Fl,Vs,Rg,Ct) in time period q of year y in area Ar is the sum over time periods

$$REV(Fl,Vs,Ct,y,q,Ar) = VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet.q,Ar). \quad \text{(C.2.2.3)}$$

and period revenue summed over area

$$REV(Fl,Vs,Ct,y,q,\bullet) = VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet,q,\bullet). \quad \text{(C.2.2.4)}$$

The annual revenues by area and summed over areas become

$$REV(Fl,Vs,Ct,y,\bullet,Ar) = VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet,\bullet,Ar). \quad \text{(C.2.2.5)}$$
$$REV(Fl,Vs,Ct,y,\bullet,\bullet) = VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet,\bullet,\bullet). \quad \text{(C.2.2.6)}$$

The area specific revenue is needed for the subsequent definition of short term behaviour rules, for example the choice of fishing ground, which is dependent on the expected revenue.

2.3. REVENUE FROM ”OTHER STOCKS”

When making an economic analysis, it is obviously important to account for all major components of revenue and costs. When calculating the revenue, it is important that all major stocks are accounted for. Some minor parts of the revenue may origin from rare stocks, for which data and knowledge are less than for the important stocks. Such minor stocks are often grouped into a lump group “Other stocks”. There are two ways to deal with “Other stocks” in TEMAS. One way is to let the “Other group” be represented by a “hypothetical fish”, with hypothetical parameters and age distribution. In that case, the “Other stocks” component is treated as the real stocks. That is, there is a full biological/technical model for “Other stocks”.

The second option is to let the revenue from “Other stocks” become a time specific constant REV^{Other}, that is added to the revenue each time period. In that case, there is no account of biological/technical features of “other stocks”.

$$REV^{Other}(Fl,Vs,Ct,y,q,Ar) = Cons\tan t. \quad \text{(C.2.3.1)}$$

The total revenue now becomes the sum of "real stocks" and "Other stocks"

$$REV(Fl,Vs,Ct,y,q,Ar) = VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet.q,Ar) + REV^{Other}(Fl,Vs,Ct,y,q,Ar) \quad \text{(C.2.3.2)}$$

C.3. CREW

By the "number of crew rate" is meant the number potential number of crew, that can be onboard a vessel (whether they are there or not).

CREWR(Fl, Vs, Ct, y, q) = Number of crew per vessel (C.3.1)

The "total Number of crew" means the potential number of crew on all vessels in the fleet.

CREW(Fl, Vs, Ct, y, q) = NU_{Vessel}(Fl, Vs, Ct, y,q) * CREWR(Fl, Vs, Ct, y, q) (C.3.2)

By "crew days" is meant the number of crew-days corresponding to the number of sea days (or number of effort units).

CREWDAY(Fl,Vs, Ct, y, q) = CREW(Fl,Vs, Ct, y, q)* E(Fl,Vs, Ct, y, q, •) (C.3.3)

The number of full time crew during a period reflects the employment in the fleet

EMPL(Fl,Vs, Ct, y, q) = CREWDAY(Fl,Vs, Ct, y, q)/ EY_{MAX}(Fl,Vs, Ct, y, q) (C.3.4)

To summarise, the crew-concepts of TEMAS are

CREWR(Fl, Vs, Ct, y, q)	Potential number of crew per vessel.
CREW(Fl, Vs, Ct, y, q)	Potential number of crew on all vessels.
CREWDAY(Fl, Vs, Ct, y, q)	Number of crew-days corresponding to effort (sea-days)
EMPL(Fl, Vs, Ct, y, q)	Number of full time crew during a period (employment)

C.4. FINANCIAL ANALYSIS OF THE HARVESTING SECTOR

The financial analysis of fleets looks at system performance from the point of view of vessel owners.

C.4.1. FINANCIAL VARIABLE HARVESTING COSTS

Financial operating costs of handling

Costs incurred by fishing firms in the landing, handling and sale of the fish. They are calculated on a per unit weight basis (e.g. cost per kilogram or ton of landed fish) and may encompass specific items such as costs of offloading, sorting, transport to the point of first sale and auctioning. The costs of yield which depends on the area is

$$CO^{Total}_{Yield}(Fl,Vs,Rg,Ct,y,q,Ar) = Y_{Land}(Fl,Vs,Rg,Ct,\bullet,y,q,\bullet,Ar)\sum_{i=1}^{NU^{CO}_{Yield}} COR^{i}_{Yield}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.1.a)}$$

And the cost of yield summed over areas becomes

$$CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} Y_{Land}(Fl,Vs,Rg,Ct,\bullet,y,q,\bullet,Ar) \sum_{i=1}^{NU_{Yield}^{CO}} COR_{Yield}^{i}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.1.b)}$$

$CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet)$	Total costs depending on the yield (weight of the landings) summed over areas
$COR_{Yield}^{i}(Fl,Vs,Rg,Ct,y,q,Ar)$	Cost rate (cost per weight unit) depending on the yield (weight of the landings)
NU_{Yield}^{i}	Number of costs depending on the yield (weight of the landings).

The number of costs and their associated names are optional. NU_{Yield}^{CO} can take the value 0, if this type of costs is considered irrelevant.

Financial operating costs of harvesting:

Costs incurred by fishing firms in the actual fishing operations. They are calculated on a per unit of fishing effort basis and usually include specific items such as costs of fuel, oil, ice, repair and maintenance, food, etc. This is an approximation on reality because these kinds of costs may not always increase linearly proportional to effort as is assumed in TEMAS. Note that the operating costs may be different for different fishing areas.

$$CO_{E}^{Total}(Fl,Vs,Rg,Ct,y,q,Ar) = E(Fl,Vs,Rg,Ct,y,q,Ar) \sum_{i=1}^{NU_{E}^{CO}} COR_{E}^{i}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.2.a)}$$

Summed over areas the cost of effort becomes

$$CO_{E}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} E(Fl,Vs,Rg,Ct,y,q,Ar) \sum_{i=1}^{NU_{E}^{CO}} COR_{E}^{i}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.2.b)}$$

$CO_{E}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet)$	Total costs depending on the effort (summed over areas)
$COR_{E}^{i}(Fl,Vs,Rg,Ct,y,q,Ar)$	Cost rate (cost per effort unit) depending on the effort in area Ar.
NU_{E}^{CO}	Number of costs depending on the effort.

Financial operating costs of landings:

Costs incurred by fishing firms when selling the landings, such as auction fee is proportional to the value of the landings. The area-depending version of the cost definition reads

$$CO_{VAL}^{Total}(Fl,Vs,Rg,Ct,y,q,Ar) = VAL(Fl,Vs,Rg,Ct,\bullet,y,q,\bullet,Ar) \sum_{i=1}^{NU_{VAL}^{CO}} COR_{VAL}^{i}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.3.a)}$$

and summed over areas the costs of landings becomes

$$CO_{VAL}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} VAL(Fl,Vs,Rg,Ct,\bullet,y,q,\bullet,Ar) \sum_{i=1}^{NU_{VAL}^{CO}} COR_{VAL}^{i}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.3.b)}$$

$CO_{VAL}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet)$	Total costs depending on the value of landings
$COR_{VAL}^{i}(Fl,Vs,Rg,Ct,y,q,Ar)$	Cost rate (cost per value unit) depending on the value of landings.
NU_{VAL}^{CO}	Number of costs depending on the value of landings

Total Financial operating costs

The total financial area specific operating cost is

$$CO_{Operating}^{Total}(Fl,Vs,Rg,Ct,y,q,Ar)=$$
$$CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,Ar)+CO_{E}^{Total}(-,Ar)+CO_{VAL}^{Total}(-,Ar) \quad \text{(C.4.1.4.a)}$$

And summed over areas

$$CO_{Operating}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet)=$$
$$CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet)+CO_{E}^{Total}(-,\bullet)+CO_{VAL}^{Total}(-,\bullet) \quad \text{(C.4.1.4.b)}$$

The split into "area specific costs" and "costs summed over areas" is needed when modelling the short term behaviour of fishers, namely the choice of fishing grounds. This choice is influenced by the economics.

Crew share income

Costs of fishing firms based on a share system. The crew share is calculated as a fraction of the difference between the gross revenues and selected financial operating costs of harvesting, the so-called "divisible earnings". The area dependent expression for divisible earnings reads

$$DE(Fl,Vs,Rg,Ct,y,q,Ar)=VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet,q,Ar)-$$
$$I_{Yield}^{DE}*CO_{Yield}^{Total}(-,Ar)-I_{E}^{DE}*CO_{E}^{Total}(-,Ar)-I_{VAL}^{DE}*CO_{VAL}^{Total}(-,Ar) \quad \text{(C.4.1.5.a)}$$

and summed over areas

$$DE(Fl,Vs,Rg,Ct,y,q,\bullet)=VAL(Fl,Vs,Rg,Ct,\bullet,y,\bullet,q,\bullet)-$$
$$I_{Yield}^{DE}*CO_{Yield}^{Total}(-,\bullet)-I_{E}^{DE}*CO_{E}^{Total}(-,\bullet)-I_{VAL}^{DE}*CO_{VAL}^{Total}(-,\bullet) \quad \text{(C.4.1.5.b)}$$

I_{Yield}^{DE} , I_{E}^{DE} and I_{VAL}^{DE} are 0 or 1 depending on the definition of divisible earnings.
The fraction, the relative crew share, is an input parameter $COF_{Crew}^{Share}(Fl,Vs,Ct,y,q)$

$$CO_{Crew}^{Share}(Fl,Vs,Rg,Ct,y,q,Ar)=DE(Fl,Vs,Rg,Ct,y,q,Ar)*COF_{Crew}^{Share}(Fl,Vs,Ct,y,q)) \quad \text{(C.4.1.6.a)}$$

and summed over areas

.

$$CO_{Crew}^{Share}(Fl,Vs,Rg,Ct,y,q,\bullet)=DE(Fl,Vs,Rg,Ct,y,q,\bullet)*COF_{Crew}^{Share}(Fl,Vs,Ct,y,q) \quad \text{(C.4.1.6.b)}$$

The fraction, the relative crew share, is an input parameter COF_{Crew}^{Share}

. $$CO_{Crew}^{Share}(Fl,Vs,Rg,Ct,y,q,Ar)=DE(Fl,Vs,Rg,Ct,y,q,Ar)*COF_{Crew}^{Share} \quad \text{(C.4.1.6.a)}$$

and summed over areas

.

$$CO_{Crew}^{Share}(Fl,Vs,Rg,Ct,y,q,\bullet)=DE(Fl,Vs,Rg,Ct,y,q,\bullet)*COF_{Crew}^{Share} \quad \text{(C.4.1.6.b)}$$

Crew effort income

Crew income that is independent from share income. It is usually a monthly wage or salary given to the crew members independently from the catch and value of the catch of the vessel. We have expressed such crew income as dependent on fishing effort to maintain the idea that a higher work effort (i.e. more days at seas) would result in a higher wage. The wage may be area specific

$$CO_{Crew}^{Salary}(Fl,Vs,Rg,Ct,y,q,Ar) = E(Fl,Vs,Rg,Ct,y,q,Ar) * COR_{Crew}^{Salary}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.7.a)}$$

Summed over area the crew salary becomes

$$CO_{Crew}^{Salary}(Fl,Vs,Rg,Ct,y,q,\bullet) = \sum_{Ar=1}^{Ar_{Max}} E(Fl,Vs,Rg,Ct,y,q,Ar) * COR_{Crew}^{Salary}(Fl,Vs,Rg,Ct,y,q,Ar) \quad \text{(C.4.1.7.b)}$$

$COR_{Crew}^{Salary}(Fl,Vs,Rg,Ct,y,q,Ar)$ is the salary per unit of effort.

In case, salary is not used for remuneration of crew, $COR_{Crew}^{Salary}(Fl,Vs,Rg,Ct,y,q,Ar) = 0$

Total variable costs

The total area dependent variable costs, excluding taxes, subsidies and vessel licenses, thus becomes

$$VCO(Fl,Vs,Rg,Ct,y,q,Ar) = CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,Ar) + CO_{E}^{Total}(-,Ar) + CO_{VAL}^{Total}(-,Ar) + CO_{Crew}^{Share}(-,Ar) + CO_{Crew}^{Salary}(-,Ar) \quad \text{(C.4.1.8.a)}$$

and summed over areas

$$VCO(Fl,Vs,Rg,Ct,y,q,\bullet) = CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) + CO_{E}^{Total}(-,\bullet) + CO_{VAL}^{Total}(-,\bullet) + CO_{Crew}^{Share}(-,\bullet) + CO_{Crew}^{Salary}(-,\bullet) \quad \text{(C.4.1.8.b)}$$

C.4.2. FINANCIAL FIXED HARVESTING COSTS

Annually fixed costs per vessel of fishing firms. They are independent of whether the fishing vessels operate or not and encompass specific items such as insurance, capital servicing costs, i.e. payments of interest and principal, etc. NU_{Vessel}(Fl, Vs, Ct, y, q,Va)

$CO_{Fix}^{Total}(Fl,Vs,Ct,y,q)$	Total fixed costs
$COR_{Fix}^{Total}(Fl,Vs,Ct,y,q)$	Fixed cost rate (fixed cost per vessel)
NU_{Fix}^{CO}	Number of fixed costs

The current implementation of TEMAS contains three fixed costs, with the rates

$COR_{Fix}^{1}(Fl,Vs,Ct,y,q)$: Period Licence fee per vessel

$COR_{Fix}^{2}(Fl,Vs,Ct,y,q)$: Period Insurance per vessels

$COR_{Fix}^{3}(Fl,Vs,Ct,y,q)$: Other fixed costs per vessel

However, as all fixed costs are per vessel, it will make no difference in the overall output that the fixed costs are divided.

The profit before tax and subsidies, is the difference between value of landings and total costs:

$$PROF(Fl,Vs,\bullet,Ct,y,q) = VAL(Fl,Vs,\bullet,Ct,y,\bullet,q,\bullet) - VCO(Fl,Vs,\bullet,Ct,y,\bullet,q,\bullet) - CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) \quad \text{(C.4.2.2)}$$

C.4.3. FINANCIAL INVESTMENT COST IN HARVESTING CAPACITY

Financial investment cost in harvesting capacity: A financial cash outflow arises when a fishing firm invests in a new fishing vessel (and fishing gear) during the simulation period. The cash outflow arises only in the (period,year) when the investment has taken place.

$$INVR^{Total}(Fl,Vs,Ct,y,q) = \text{Cost of one new vessel} \quad \text{(C.4.3.1)}$$

The total investment rate may be separated into, for example, hull, engine, gears, electronics, etc.

$$INVR^{Total}(Fl,Vs,Ct,y,q) = \sum_{i=1}^{NU_{INV}^{CO}} INVR_i\ (Fl,Vs,Ct,y,q) \quad \text{(C.4.3.2)}$$

The total investment is the investment rate times the number of investments $NU_{New-vessel}(Fl,y,q)$

$$INV^{Total}(Fl,Vs,Ct,y,q) = INVR^{Total}(Fl,Vs,Ct,y,q) * NU_{New-vessel}(Fl,Vs,Ct,y,q) \quad \text{(C.4.3.3)}$$

Investments into new fishing vessels can be simulated in TEMAS in two manners. One is by directly entering the number of new boats in any one of the project (period,year). The other way is by using the TEMAS structural behaviour rules that establish the criteria and threshold values when the program would add automatically one or several new vessels.

C.4.4. DECOMMISSION TO HARVESTING SECTOR

Vessel decommission payment: A financial cash inflow provided by the government treasury to fishing firms as an incentive (and compensation) for the withdrawal of fishing vessels from the fishery. The level of compensation acceptable to a fishing firm is likely to depend on (a) the expected net earnings of the vessel during its remaining lifetime and (b) the value of the entitlement to exploit the fishery in future, the age of the vessel. [5]

$$DECVR(Fl,Vs,Ct,y,q,Va) = \text{Decommission fee of one vessel (Decommission rate)}$$

The total decommission payment is the decommission rate times the number of decommissions, $NU_{Decomm}(Fl,Vs,Ct,y,q,Va)$, becomes

$$DECV(Fl,Vs,Ct,y,q,Va) = DECR(Fl,Vs,Ct,y,q,Va) * NU_{Decomm}(Fl,Vs,Ct,y,q,Va) \quad \text{(C.4.4.1)}$$

TEMAS handles decommissioning payments as a financial benefit to fishing firms (and the fleet) only then, if they decide to continue to stay in the fishery. In practice, that would imply that whenever a fishing firm has decided to surrender its only fishing vessel, or all its fishing vessels, it will exit from the fleet and fishery and, thus the decommissioning payment will not be further considered in the financial analysis of the fleet. The reason such payment is disregard is that no

[5] See formula (7) in Anderson, Lee. A closer look at buybacks: a simulation approach. (Anderson, 1998)

modelling is undertaken of the eventual benefits that could arise in other sectors (or in other fisheries) of the economy where it may be invested.

C.4.5. TAXES, SUBSIDIES AND LICENSE FEE

Tax on gross revenue:

For purposes of fisheries management, the ideal type of tax is either a tax on gross revenues, i.e. a tax on the value of landings or a tax on profit. This is because such taxes do not cause any type of distorting incentive to fishing firms in deciding, for example, on how much labour and capital to use in harvesting activities and when and which species to harvest. Nor does a tax on gross revenues create an incentive for high-grading (as against an ITQ system (on this see Anderson, 1994; Arnason 1994; Willmann 1996)). However, there are various difficulties in using a tax as a sole fisheries management instrument. These include the need for frequent adjustments of the tax rate to changes in stock abundance and to apply a different tax rate to each stock in relation to its resource rent potential (Hannesson 1993).

In TEMAS, only one and the same tax rate is applied to the aggregate value of landings. Therefore, differential tax rates in accordance with the varied rent potential of different stocks cannot be modelled.

$TAXR_{REV}(Fl,Vs,Ct,y,q)$ = Tax rate of revenue (tax per value unit)

The total revenue tax becomes

$$TAX_{REV}(Fl,Vs,Ct,y,q) = TAXR_{REV}(Fl,Vs,Ct,y,q) * VAL(Fl,Vs,\bullet,Ct,y,q,\bullet) \quad \text{(C.4.5.1)}$$

Tax on Operating Costs.

In most or all fisheries, one or several items of operating costs are taxed including fuel, ice, food, repairs & maintenance, and others. Such taxes are usually economy-wide taxes and have not been introduced as a fisheries management measure. The primary reason for incorporating this tax in TEMAS is to account for impacts of fisheries management on the government budget. Only of secondary consideration is the use of such an effort-related tax for fisheries management purposes. The reason is that a tax on any component of fishing effort (e.g. fuel, ice, maintenance) could potentially have distorting impacts and cause efficiency losses. Vessel operators would attempt to economize on the taxed input and substitute it through other kinds of inputs. A tax on fuel may, however, in many instances be desirable for several reasons including fisheries management, environment protection (air quality and green house gases) and balance of payments (reduction of imports).

$TAXR_{Operation}(Fl,Vs,Rg,Ct,y,q)$ = Tax rate of operation costs (tax per value unit)

The total tax becomes on operation costs

$$\begin{aligned} &TAX_{Opreation}(Fl,Vs,Rg,Ct,y,q) = \\ &TAXR_{Operation}(Fl,Vs,Rg,Ct,y,q) * CO^{Total}_{Operating}(Fl,Vs,Rg,Ct,y,q) \end{aligned} \quad \text{(C.4.5.2)}$$

Subsidy on Operating Costs and prices

Subsidy on Operating Costs (the input parameter is a fraction of the operating costs. The inclusion of such an effort-related subsidy is indeed the fact that especially subsidies on fuel are often demanded by the fishing industry in times of economic hardship. As such hardship is often caused by overfishing and overcapitalization, in the absence of fisheries management the introduction of a fuel subsidy can be highly damaging to the fishery. Apart from simulating the introduction (or withdrawal) of an effort-related subsidy on the fishery, another reason for accounting for it in TEMAS is to assess its impact on the government treasury.

The total operation cost is composed of three parts:

$$CO_{Operating}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) = \quad \text{(C.4.5.3)}$$
$$CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) + CO_{E}^{Total}(-,\bullet) + CO_{VAL}^{Total}(-,\bullet)$$

We introduce a subsidy rate for each type of operation costs

$SUBR_{Yield}(Fl,Vs,Rg,Ct,y,q)$ = Subsidy rate on landings

$SUBR_{E}(Fl,Vs,Rg,Ct,y,q)$ = Subsidy rate on effort

$SUBR_{VAL}(Fl,Vs,Rg,Ct,y,q)$ = Subsidy rate on value of landings

Total subsidy on landings:

$$SUB_{Yield}(Fl,Vs,Rg,Ct,y,q) =$$
$$SUBR_{Yield}(Fl,Vs,Rg,Ct,y,q) * CO_{Yield}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) \quad \text{(C.4.5.4)}$$

Total Subsidy on effort:

$$SUB_{E}(Fl,Vs,Rg,Ct,y,q) = SUBR_{E}(Fl,Vs,Rg,Ct,y,q) * CO_{E}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) \quad \text{(C.4.5.5)}$$

Total subsidy on value of landings:

$$SUB_{VAL}(Fl,Vs,Rg,Ct,y,q) = SUBR_{VAL}(Fl,Vs,Rg,Ct,y,q) * CO_{VAL}^{Total}(Fl,Vs,Rg,Ct,y,q,\bullet) \quad \text{(C.4.5.6)}$$

Total subsidy on operation costs

$$SUB_{Operating}(Fl,Vs,Rg,Ct,y,q) = SUB_{Yield}(Fl,Vs,Rg,Ct,y,q) + SUB_{E}(-) + SUB_{VAL}(-) \quad \text{(C.4.5.7)}$$

Price subsidy

The price may have a lower limit due to intervention by the EU commission (the PO-price), P_{MinPO}(Fl,Vs, Rg, Ct, St, y, a, q). The intervention price usually applies to the small size categories of landings.

This subsidy comes into the model via the value of the landings

License fee

An annual cost per vessel. When license fees are not just charged to cover administrative costs of vessel registration (as they often do) but amount to substantial sums, they obviously have an impact on profits and thus on fishing capacity by making investments into fishing less attractive than would be the case otherwise.

$LICR(Fl,Vs,Ct,y)$ = Annual license fee of one vessel

The total license fee of year y becomes, assuming that new vessels do not pay full annual license.

$$LIC(Fl,Vs,Ct,y,1) = LICR(Fl,Vs,Ct,y)*(NU_{vessel}(Fl,Vs,Ct,y,1) + NU_{New-vessel}(Fl,Vs,Ct,y,1)) \qquad \text{(C.4.5.8)}$$

$$LIC(Fl,Vs,Ct,y,q) = LICR(Fl,Vs,Ct,y)*NU_{New-vessel}(Fl,Vs,Ct,y,q)*\frac{q_{Max}-q+1}{q_{Max}} \qquad \text{(C.4.5.9)}$$

Total tax, subsidy and license fee

Adding up taxes, subsedies and license fee yilds the total, TSL

$$TSL(Fl,Vs,Ct,y,q) = SUB_{REV}(Fl,Vs,Ct,y,q) + SUB_{Operation}(-) - -TAX_{REV}(-) - TAX_{Operation}(-) - LIC(-) \qquad \text{(C.4.5.10)}$$

C.4.6. REVENUE FROM “OTHER FLEETS” AND ”OTHER COUNTRIES”

When making the economic analysis for a country, it is desirable to account for major components of the fishing sector. Some components of the fishing sector, may be made by a collection of minor fleets and riggings, which individually are very small, by collectively accumulates to a component of a certain importance. This lump group is called “Other fleets”. If this “Other fleets” makes up a very small part of the total it may be ignored. Recall that TEMAS is not supposed to predict details, but only (in the best case) the overall trend in the system. Sometimes, however, it may be desirable to account for “Other fleets”, and then it may be included as a hypothetical fleet with a hypothetical gear and rigging. Usually this fleet will contain only one vessel size and one rigging, as its purpose is not to make a realistic modelling of the “Other-fleets”, but to make the economic analysis of a country realistic.

Likewise it is desirable to complete the biological/technical analysis of an ecosystem, by accounting for all catches. Landings may origin from major fishing nations and from a lump group of “Other countries”, which are given hypothetical parameters. Usually, “Other countries” will be assigned only one hypothetical fleet with one vessel size group and one rigging.

C.4.7. FINANCIAL ANALYSIS OF HARVESTING

The financial Net Cash Flow is computed as the Gross revenue from landings, minus F(Financial)-Operating costs of landings, minus F-Operating costs of effort, minus Crew share income , minus Crew effort income, minus F-Fixed harvesting costs, minus F-Investment in harvesting capacity, plus decommission payments remaining in the fleet. The present value is computed by applying the financial discount rate. In mathematical formulas the area specific Net cash Flow, FNCF, becomes:

$$FNCF(Fl,Vs,Ct,y,q,Ar) = REV(Fl,Vs,Ct,y,q,Ar) - VCO(Fl,Vs,Ct,y,q,Ar) - CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) - INV^{Total}(-,Ar) + TSL(-,Ar) + DECV(-,Ar) \qquad \text{(C.4.6.1.a)}$$

and the net cash flow summed over areas

$$FNCF(Fl,Vs,Ct,y,q,\bullet) = REV(Fl,Vs,Ct,y,q,\bullet) - VCO(Fl,Vs,Ct,y,q,\bullet) - CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) - INV^{Total}(-,\bullet) + TSL(-,\bullet) + DECV(-,\bullet) \qquad \text{(C.4.6.1.b)}$$

Where

VCO Total variable costs

$$VCO(Fl,Vs,Ct,y,q,Ar) = CO^{Total}_{Yield}(Fl,Vs,Ct,y,q,Ar) + CO^{Total}_{E}(Fl,Vs,Ct,y,q,Ar) +$$
$$CO^{Total}_{VAL}(Fl,Vs,Ct,y,q,Ar) + CO^{Share}_{Crew}(Fl,Vs,Ct,y,q) + CO^{Salary}_{Crew}(Fl,Vs,Ct,y,q)$$

CO^{Total}_{Fix} Total fixed costs

INV^{Total} Total investments

TSL Total Taxes, subsidies and license fee

$$TSL(Fl,Vs,Ct,y,q) = SUB_{REV}(Fl,Vs,Ct,y,q) + SUB_{Operation}(Fl,Vs,Ct,y,q) -$$
$$-TAX_{REV}(Fl,Vs,Ct,y,q) - TAX_{Operation}(Fl,Vs,Ct,y,q) - LIC(Fl,Vs,Ct,y,q)$$

DECV Decommission fee to vessels

The present value (NPV) of the Financial Net Cash Flow is defined

$$\mathrm{FNCF_{NPV}(Fl,Vs,Ct,r_F)} = \sum_{y=y_{first}}^{y_{last}} \frac{FNCF(Fl,Vs,Ct,y,\bullet,\bullet)}{(1+r_F)^{y-y_{first}+1}} \quad \text{(C.4.6.2)}$$

where r_F is the financial discount rate.

C.5. FINANCIAL ANALYSIS OF GOVERNMENT TREASURY

The financial analysis of the government shows all cash inflows and cash outflows of the treasury related to a fleet and the fishery as a whole during the project horizon.

Note that names of all parameters of the financial analysis of government treasury start with "FT".

C.5.1. TAXES AND SUBSIDIES

Subsidies:
Cash outflows arise from direct or indirect transfers by the treasury to fishing firms in the form of subsidies for investments into new fishing vessels

Price subsidies:

The price may have a lower limit due to intervention by the EU commission (the PO-price), P_{MinPO}(Fl,Vs, Rg, Ct, St, y, a, q). The intervention price usually applies to the small size categories of landings.

P_{Int}(Fl,Vs, Rg, Ct, St, y, a, q) =
Max{ P_{MinPO}(Fl,Vs, Rg, Ct, St, y, a, q) ,P(Fl,Vs, Rg, Ct, St, y, a, q) } (C.5.1.1)

This subsidy comes into the model via the value of the landings

$$VAL(Fl,Vs,Ct,\bullet,\bullet,y,q,\bullet) =$$
$$\sum_{Ar=1}^{Ar_{Max}} \sum_{St=1}^{St_{Max}} \sum_{a=0}^{a_{Max}(St)} Y_{Land}(Fl,Vs,Ct,St,Ar,y,q,a) * P_{Int}(Fl,Vs,Ct,St,y,q,a) \quad \text{(C.5.1.2)}$$

The explicit value of the price subsidy is:

$$SUB_{Price}(Fl,Vs,Ct,y,q) = \sum_{Ar=1}^{Ar_{Max}} \sum_{St=1}^{St_{Max}} \sum_{a=0}^{a_{Max}(St)} Y_{Land}(Fl,Vs,Ct,St,Ar,y,q,a) * Max\{\ 0,\ P_{Int}(Fl,Vs,Ct,St,y,q,a) - P\,(Fl,Vs,Ct,St,y,q,a)\ \} \quad \text{(C.5.1.3)}$$

C.5.2. DECOMMISSION PAYMENTS.

Vessel decommission payment: A financial cash inflow provided by the government treasury to fishing firms as an incentive (and compensation) for the withdrawal of fishing vessels from the fishery.

$DECVR(Fl,Vs,Ct,y,q,Va)$ = Decommission fee of one vessel

The total decommission payment is

$$DECV(Fl,Vs,Ct,y,q,\bullet) = DECR(Fl,Vs,Ct,y,q,\bullet) * NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet) \quad \text{(C.5.2.1)}$$

Decommission payments to crew for the retirement of excess capacity and to compensate displaced crew.

$DECCR(Fl,Vs,Ct,y,q)$ = Decommission fee of one crew member

The total crew decommission payment is the decommission rate times the number of decommissioned crew $NU_{Decomm}(Fl,Vs,Ct,y,q) * CREWR(Fl,Vs,Ct,y,q)$

$$DECC(Fl,Vs,Ct,y,q) = DECCR(Fl,Vs,Ct,y,q) * NU_{Decomm}(Fl,Vs,Ct,y,q) * CREWR(Fl,Vs,Ct,y,q) \quad \text{(C.5.2.2)}$$

The total decommission then becomes

$$DEC(Fl,Vs,Ct,y,q) = DECC(Fl,Vs,Ct,y,q) + DECV(Fl,Vs,Ct,y,q) \quad \text{(C.5.2.3)}$$

C.5.3. FINANCIAL COSTS OF FISHERIES MANAGEMENT

Cash outflows associated with the management of the fishery. They encompass expenditures for fisheries research, administration and, surveillance and enforcement and include items such as wages and salaries, costs of materials and equipment, and others. Frequently, they cannot be readily drawn from government budget figures but need to be specifically compiled. At times, judgements would need to be made which items to consider a fisheries management expenditure and which a general cost of fishery administration. (Arnason, *et al*, 2000). Once the total financial fisheries management costs have been estimated, for the purposes of TEMAS they have to be proportioned to each fleet. This can be based on various factors including the share of the fleet on total fisheries gross revenues, the difficulties, and thus costs of surveillance and enforcing management measures in one fleet as compare to other fleets having larger (or smaller) numbers of boats or operating from larger or smaller numbers of landing places, and other factors such as the fishing grounds where the fleet operates and the focus of current research efforts.

The financial costs of fisheries management is a fixed annual cost to the government

$CO_{Management}(Ct, y, q)$=Cost of fisheries management

C.5.4. FINANCIAL ANALYSIS OF GOVERNMENT TREASURY

The financial Net Cash flow of the government treasury is the difference between inflows through taxes, duties, license fees and cash outflows due to subsidies, decommission payments for vessels and crew, expenditures of fisheries management

$$FTNCF(Ct, y, q) = TSL(Ct, \bullet, y, q) - DEC(Ct, \bullet, y, q) - CO_{Man}(Ct, y, q) - SUB_{Price}(Ct, \bullet, y, q) \quad \text{(C.5.4.1)}$$

where

TSL — Total Taxes, subsidies and license fee

$$TSL(Fl, Vs, Ct, y, q) = SUB_{REV}(Fl, Vs, Ct, y, q) + SUB_{Operation}(Fl, Vs, Ct, y, q) -$$
$$- TAX_{REV}(Fl, Vs, Ct, y, q) - TAX_{Operation}(Fl, Vs, Ct, y, q) - LIC(Fl, Vs, Ct, y, q)$$

DEC — Total decommission fee

$$DEC(Fl, Vs, Ct, y, q) = DECC(Fl, Vs, Ct, y, q) + DECV(Fl, Vs, Ct, Y, q)$$

$CO_{Man}(Ct, y, q)$ — Cost of management

SUB_{Price} — Price subsidy

The net present value is computed with r_F,the financial discount rate.
The present value (NPV) of the Financial Net Cash Flow of the government is defined

$$\mathrm{FTNCF_{NPV}(Fl, Vs, Ct, r_F)} = \sum_{y=y_{first}}^{y_{last}} \frac{FTNCF(Fl, Vs, Ct, y, \bullet, \bullet)}{(1+r_F)^{y-y_{first}+1}} \quad \text{(C.5.4.2)}$$

C.6. ECONOMIC ANALYSIS

The economic analysis shows the costs and benefits of the fishery from the point of view of the economy as a whole. It does not consider how these costs and benefits are distributed between the fishery and the government, or within the fishery between boat owners and fishing crew. Therefore, financial flows that just transfer funds from one hand, say the government, to the other hand, say the fishing firms, in the form of taxes, license fees, subsidies, or decommissioning payments, are not considered in the analysis and netted out from the expenditures or revenues.

C.6.1. OPPORTUNITY COSTS

The other major adjustment made in the economic analysis is to consider the real cost to the economy of using an input including capital and labour in the fishery rather than elsewhere in the economy. This is done by applying shadow prices for a cost or a benefit wherever appropriate. Shadow prices are estimates of efficiency prices. For final goods and services, the shadow price is the "Value in Use". For intermediate goods and services (i.e. production inputs such as fuel, labour, etc.), the shadow price is the opportunity cost (Gittinger, 1984, p. 499). Where markets function reasonably well, observed prices could be assumed to reflect efficiency prices. Opportunity costs would usually have to be applied to labour costs. Where macro-economic policies result in currency exchange controls and trade restrictions, shadow prices may have to be applied to most or all production inputs and outputs. Information on shadow prices by product categories can often be obtained from ministries of finance, economics or planning.

Opportunity cost of fishing crew:

In general terms, an opportunity cost is defined as the benefit foregone by using a scarce resource for one purpose instead of its next best alternative. In the financial analysis, crew remuneration is based on a sharing system and/or on a fixed income per unit of fishing effort. This crew income may not adequately reflect the forgone benefit to society of using labour effort in the fishery rather than elsewhere in the economy. This is especially the case where unemployment is high and where people have chosen to enter fisheries as an economic activity of ‘last resort’. In these instances, the opportunity cost of labour is very likely lower than is reflected in current crew income. This would apply mostly to unskilled crewmembers. Skilled crewmembers, on the other hand, could often be presumed to have working opportunities elsewhere in the economy at similar wage rates.

$$CO_{Oppurtunity}(Fl,Vs,Ct,y,q) = CREW(Fl,Vs,Ct,y,q) * COR_{Oprtunity}(Fl,Vs,Ct,y,q) \qquad \text{(C.6.1.1)}$$

where

$COR_{Oprtunity}(Fl,Vs,Ct,y,q)$ = opportunity cost rate (per crew member per period)

C.6.2. ECONOMIC COSTS

Economic operating costs of handling:
Where there are no reasons to apply economic shadow prices, these would be equal to financial operating costs of handling. Where taxes, subsidies, duties, apply, these need to be netted out.

Economic operating costs of harvesting:
Where there are no reasons to apply economic shadow prices, these would be equal to financial operating costs of harvesting. Where taxes, subsidies, duties, apply, these need to be netted out.

Economic fixed harvesting costs:
Where there are no reasons to apply economic shadow prices, these would be equal to financial fixed harvesting costs. Taxes, license fees , duties and subsidies need to be netted out.

Economic investment cost in harvesting capacity:
These would usually correspond to financial investment costs in harvesting capacity net of all taxes, duties and/or subsidies.

Economic costs of fisheries management:
These would largely correspond with financial costs of fisheries management as discussed above but certain adjustments may have to be made. For example, it might be necessary to apply opportunity labour costs to some categories of government employees.

C.6.3. ECONOMIC ANALYSIS.

The economic net cash flow is the Gross Revenue from fishing, minus E (Economic) -Operating costs of landings, minus E-Operating costs of effort, minus Opportunity Cost of Labour , minus E-Fixed harvesting costs, minus E-Investment in harvesting capacity and minus E-Fisheries management costs

$$\begin{aligned} ENCF(y,q) = {} & REV(\bullet,\bullet,\bullet,y,q) - CO^{Total}_{Operational}(\bullet,\bullet,\bullet,y,q) - CO^{Total}_{Fix}(\bullet,\bullet,\bullet,y.q) - \\ & CO_{Oppurtunity}(\bullet,\bullet,\bullet,y,q) - INV^{Total}(\bullet,\bullet,\bullet,y,q) - CO_{Man}(y,q) \end{aligned} \qquad \text{(C.6.3.1)}$$

where

REV	Revenue
$CO_{Operating}^{Total}$	Total operational costs $CO_{Operating}^{Total}(Fl,Vs,Ct,y,q) = CO_{Yield}^{Total}(Fl,Vs,Ct,y,q) + CO_{E}^{Total}(Fl,Vs,Ct,y,q) +$ $CO_{VAL}^{Total}(Fl,Vs,Ct,y,q)$
CO_{Fix}^{Total}	Fixed costs
$CO_{Oppurtunity}$	Opportunity costs
INV^{Total}	Investment
$CO_{Management}$	Costs of management

The net present value is computed with r_E,the economic discount rate.

C.7. BEHAVIOURAL MODEL OF FISHING FIRMS

TEMAS contains two options to model the behaviour of fishing firms during the fishing season and from year to year

3) Random Utility Model (RUM)
4) Ad hoc behaviour rules.

The statistical model and theory behind the RUM is comprehensive (see Appendix B). However, the RUM is also complicated and data demanding. The "Ad hoc" approach is kind of a short cut method, which indeed can be questioned and is not supported by a huge literature as the RUM is.

The present EXCEL implementation of TEMAS, however, does not yet contain the "Ad Hoc" rules. The reason for this is that the philosophy behind the RUM essentially is the same as the Ad Hoc models, but the RUM has "nicer" mathematically properties. It was not considered necessary to have two almost equal options for behaviour models in TEMAS.

The behaviour of fisher's are divided into two major groups

1) Short term behaviour (trip related behaviour, also called "trip-rules")
2) Long term behaviour or structural behaviour (entry/exit to the fishing industry, also called "capacity rules")

The "long term behaviour" refers to the entry/exit of vessels to the fishing industry. The number of vessels by vessel size and type categories, the capacity (Item 1), makes a natural upper limit to the maximum effort that can be exerted. The regulation of capacity is perhaps the strongest tool for fisheries management (reference to Green book).
An example of capacity regulation is the MAGPs (Multi-Annual Guidance Programmes) of EU, aimed at bringing fishing capacity more into line with available resources. Fishing effort is defined as vessel capacity, in both tonnage and engine power, multiplied by activity (days spent at sea).
The rationale behind MAGPs is that the available resources should determine the size of the fleet and not, as has often been the case, that the size of TACs be determined by the size of the fleet. The MAGP was implemented in four phases: I (1983-86), II (1987-91), III (1992- 96) and IV (1997-2002). A new system for limiting the fishing capacity of the EU fleet was adopted in 2002. It replaced the former MAGPs. The MAGP and its continuation combined with TAC measures have not been sufficient to bring effort down to a sustainable level, and a suite of additional measures has been introduced, notably mesh size regulation, closed areas and limitation of sea-days. The report of

the "TECTAC" EU project contains a description and discussion of the structural programs for fishing fleets of the EU, (TECTAC, 2005).

C.7.1. RUM (RANDOM UTILITY MODEL)

This section starts with a summary description of the theory of fisher's behaviour applied in TEMAS (see also Appendix B), and ends with a short description of the RUM for structural behaviour. The report of the "TECTAC" EU project contains a description and discussion of structural behaviour for fishing fleets of the EU, (TECTAC, 2005). The approach taken in TEMAS with the application of RUM to describe fisher's behaviour is a result of the TEMAS groups involvement in the TECTAC project. The TECTAC report contains a long discussion of this theory, and many tables describing the historical development of fishing fleet structure in the EU.

The common approach in literature is to use a "Random Utility Model" (RUM) to model behaviour. Utility, U, is "something" which determines the choice. The Utility, is some measure of the choice-makers "happiness" for making a decision. Thus, the higher the utility of a choice, the higher is the probability that the choice will be made.

To each choice is thus allocated a utility. "U_{im}" is the utility of trip "i" when selecting choice "m", where the number of choices is final, $1 \le m \le M$.

The random utility model postulates that the fisher will select choice (alternative) m if

$$U_{im} = Max\left\{ U_{i1}, U_{i2}, ..., U_{iM} \right\} \tag{C.7.1.1}$$

Let Y_i denote the choice made by vessel "i". Then the probability of vessel "i" choosing "m" is denoted $Pr\{Y_i = m\}$. Thus $p_{im} = \Pr\{Y_i = m\} = \Pr\left\{ U_{im} > U_{ij} \ \ for \ \ all \ \ j = 1,...,M. \ m \neq j \right\}$

A "behaviour model" in the TEMAS-model tells how many percentages of the vessels in a fleets that will make each of the alternative decisions in a given quarter of the year in a given year. For example, the rigging-model for "small trawlers" in second quarter of year 2003, tells that (as a hypothetical example):

Choice	Rigging	Decision
1	Lobster trawl	20%
2	Cod trawl	60%
3	Other riggings	20%
	TOTAL	100%

In the context of the TEMAS model, we assume that all vessels in a fleet are identical (Same length, same engine power, same skill and experience of skipper, same electronic equipment etc.). The output (or dependent variable) from a behaviour model is

Option	Explanation	Symbol
1	Probability of decision	p_{Choice}^{Fleet} or p_{Choice}
2	Frequency (number of trips making decision)	Y_{Choice}^{Fleet} or Y_{Choice}

Somehow, the two options represent the same thing expressed with different units.

The output is time-dependent, $p_{Choice}^{Fleet}(Time)$ and $Y_{Choice}^{Fleet}(Time)$

Time refers to (Year, Period), where period is optional and could be month or quarter of the year.

The model, here named "F", in it's most general form reads

$p_{Choice}^{Fleet}(Time) = F_{Choice}^{Fleet}(Time, U(Time))$ where U(time) is a vector of "Utilities"

$U(Time) = (U_1(Time), U_2(Time), \; .... \; , U_M(Time))$. (C.7.1.2)

Omitting the fleet index, the general model reads, for the two output options:

$$p_{Choice}(Time) = F^{\text{Probability}}(Time, U(Time)) \text{ and}$$ (C.7.1.3)
$$Y_{Choice}(Time) = F^{\text{Frequency}}(Time, U(Time))$$

We will in the following mainly use the probability version and omit the indication of output option. We shall use the "logit model" for the probability of a choice (McFadden, 1973)

$$p_{Choice}(Time) = \frac{\exp(U_{Choice}(Time))}{\sum_{j=1}^{M} \exp(U_j(Time))}$$ (C.7.1.4)

The specification of a model is now reduced to the specification of the utility $U_{Fleet,Choice}(Time)$
There are two types of independent variables to model U:

Independent variable	Features of variable	Symbol	Associated Parameter	Index
Characteristics	Dependent of choice-maker Independent of choice	$X_{Fleet,\; r}$	$\beta_{Choice,\; r}$	r = 1,2,…R. index of characteristics
Attributes	Independent of choice-maker Dependent of choice	$W_{Choice,\; s}$	$\gamma_{Trip,\; s}$	s = 1,2,…,S. Index of attributes

The independent variable, "X", the "Characteristics", is related to the trip (or the fleet). It could be the length of the vessel, which will not change no matter which fishing grounds are chosen. Therefore is has index "Fleet" or "Trip". If there is more than one characteristics, say R characteristics, we need the index r (r = 1,2,…R) for characteristics.
When the choice is made we want to predict the combined effect of characteristics and choice, and therefore the parameter, $\beta_{Choice,\; r}$, has index "Choice.

Independent variable, "Attributes", "W", is related to the choice, and therefore is has index "Choice" If there is more than one attribute, say S attributes, we need the index s (s = 1,2,…,S) for attribute.
An attribute could be the "Value per unit of effort". When the choice is made we want to predict the combined effect of attribute and trip, and therefore the parameter, $\gamma_{Trip,s}$, has index "Trip".

This is slightly easier to understand if you replace "Trip" by "Person", as is usually the case in sociology. The $\gamma_{Person,s}$ measures the persons utility of a characteristic.
The model for the utility is the simplest possible model, namely the linear model:

$$U_{t,Trip,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Trip,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Trip,s} * W_{t,Choice,s}$$ (C.7.1.5.a)

If we assume all vessels in a fleet to behave according to the model, then the trip-index can be replaced by the "fleet-index"

$$U_{t,Fleet,Choice} = \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Fleet,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Fleet,s} * W_{t,Choice,s}$$ (C.7.1.5.b)

It is assumed that fishers' have a tendency to follow the same patterns as foregoing years. This assumption is based on the assumption that fishers' possess specialized knowledge on certain fishing techniques combined with certain fishing grounds. Also the capability (e.g. range) of the vessel may support the idea of following the same pattern. Thus, we expect a certain positive utility for following the traditions. In this model the probability of making a choice is determined by the utility

$$U_{t,Fleet,Choice} = Tradition \quad + \\ + \left\{ \sum_{r=1(Characteristics)}^{R} \beta_{t,Choice,r} * X_{t,Fleet,r} + \sum_{s=1(Attributes)}^{S} \gamma_{t,Fleet,s} * W_{t,Choice,s} \right\} \qquad \text{(C.7.1.6.a)}$$

.where the tradition term is defined:

$$Tradition = \sum_{v=1}^{V} \left\{ \sum_{r=1(Characteristics)}^{R^T} \beta^T{}_{t-v,Choice,r} * X^T{}_{t-v,Fleet,r} \right\} \qquad \text{(C.7.1.6.b)}$$

v=1,2,…V is index of past years. The tradition is supposed to go u years back in time. v = 0 gives the usual model without tradition. V = 1 goes one year back in time. The variables are considered characteristics, as they are not dependent on the choice made now (this year). The X'es and β's may or may not be the same type as those of the current year. The number of tradition-variables is designated R^T, with suffix "T" to indicate that it may be different from R.

$$Tradition = \sum_{v=1}^{V} \left\{ \sum_{r=1(Characteristics)}^{R^T} \beta^T{}_{t-v,Choice,r} * p_{t-v,Trip,r} \right\} \qquad \text{(C.7.1.6.c)}$$

We shall come back to this model in Section C.7.4.

C.7.1. NUMBER OF VESSELS DYNAMICS (STRUCTURAL BEHAVIOUR)

The number of vessels, $NU_{vessel}(Fl, Vs, Ct, y, q, Va)$, is defined by iteration:

	q > 1	q = 1
Va = 0	$NU_{Vessel}(Fl, Vs, Ct, y, q, 0)$ = $NU_{New\text{-}Vessel}(Fl, Vs, Ct, y, q)$	$NU_{Vessel}(Fl, Vs, Ct, y, 1, 0)$ = $NU_{New\text{-}Vessel}(Fl, Vs, Ct, y, q)$
Va = 1,2,…,Va_{max}-1	$NU_{Vessel}(Fl, Vs, Ct, y, q, Va)$ = $NU_{vessel}(Fl, y, q-1, Va)$ – $NU_{Decomm}(Fl, Vs, Ct, y, q, Va)$ – $NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va)$ – $NU_{Attrition}(Fl, Vs, Ct, y, q, Va)$	$NU_{Vessel}(Fl, Vs, Ct, y, Va)$ = $NU_{vessel}(Fl, y-1, q_{Max}, Va)$ – $NU_{Decomm}(Fl, Vs, Ct, y, 1, Va)$ – $NU_{Withdrawal}(Fl, Vs, Ct, y, 1, Va)$ – $NU_{Attrition}(Fl, Vs, Ct, y, 1, Va)$
Va = Va_{Max} (plus group)	$NU_{vessel}(Fl, Vs, Ct, y, q, Va)$ = $NU_{vessel}(Fl, Vs, Ct, y, q-1, Va_{Max})$ + $NU_{Decomm}(Fl, Vs, Ct, y, q, Va_{Max})$ – $NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va_{Max})$ – $NU_{Attrition}(Fl, Vs, Ct, y, q, Va_{Max})$	$NU_{vessel}(Fl, Vs, Ct, y, 1, Va)$ = $NU_{vessel}(Fl, y-1, q_{Max}, Va_{Max})$ + $NU_{vessel}(Fl, y-1, q_{Max}, Va_{Max}-1)$ – $NU_{Decomm}(Fl, Vs, Ct, y, 1, Va_{Max})$ – $NU_{Withdrawal}(Fl, Vs, Ct, y, 1, Va_{Max})$ – $NU_{Attrition}(Fl, Vs, Ct, y, 1, Va_{Max})$

Where NU_{Decomm}, $NU_{Attrition}$ and $NU_{Withdrawal}$ are the numbers of vessels withdrawn due to a vessel decommissioning, retired vessels having reached the end of their techno-economic lifetime and withdrawn and due to bad financial performance.

$NU_{New\text{-}Vessel}(Fl, Vs, Ct, y, q)$ is the (simulated or predicted) number of new vessels (number of investments in new vessels).

The fraction of the vessels that accept decommission is named $\Pr_{Decomm}^{Accept}$. The symbol "Pr" is chosen because the "fraction" can also be interpreted as the probability that a vessel will accept decommission.

Then the number of decommissions become.

$$NU_{Decomm}(Fl, Vs, Ct, y, q, \bullet) = NU_{Vessel}(Fl, Vs, Ct, y, q-1, \bullet) * \Pr_{Decomm}^{Accept} \qquad (C.7.1.1)$$

The $NU_{Decomm}(Fl, y, q, \bullet)$ decommissions are selected from the oldest end of the vessel age distribution.

Then we are left with $NU_{Vessel}(Fl, Vs, Ct, y, q-1, \bullet) - NU_{Decomm}(Fl, Vs, Ct, y, q, \bullet)$ vessels. Of these the fraction $\Pr_{Withdrawal}^{Accept}$ withdraws from the industry. The order of decommission and withdrawal is essential, as it is assumed that decommission is always selected when the choice is between decommission and withdrawal. Withdrawal (or bankrupts) does not give compensation to the vessel owner.

$$\begin{aligned} &NU_{Withdrawal}(Fl, Vs, Ct, y, q, \bullet) = \\ &(NU_{Vessel}(Fl, Vs, Ct, y, q-1, \bullet) - NU_{Decomm}(Fl, Vs, Ct, y, q, \bullet)) * \Pr_{Withdrawal}^{Accept} \end{aligned} \qquad (C.7.1.2)$$

The $NU_{Withdrawal}(Fl, Vs, Ct, y, q, \bullet)$ withdrawals are selected from the oldest end of the vessel age distribution.

Then we are left with

$$NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet)-NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet)-NU_{WithDrawal}(Fl,Vs,Ct,y,q,\bullet)$$
vessels.

To get the number of attritions we use the number of the oldest vessels as the basis:

$$NU_{Vessel}(Fl,Vs,Ct,y,q-1,Va_{Max}-1)+NU_{Vessel}(Fl,Vs,Ct,y,q-1,Va_{Max})- NU_{Decomm}(Fl,Vs,Ct,y,q,Va_{Max})-NU_{WithDrawal}(Fl,Vs,Ct,y,q,Va_{Max}) \quad (C.7.1.3)$$

The vessels of age Va_{Max} is a plus group, as all vessels older than Va_{Max} are in the plus group. In the case q = 1

The number of attritions, naturally is linked to the number of old vessels

$$NU_{Attrition}(Fl,Vs,Ct,y,q,Va_{Max})=(NU_{Vessel}(Fl,Vs,Ct,y,q-1,Va_{Max}-1)+ NU_{vessel}(Fl,Vs,Ct,y,q-1,Va_{Max})-NU_{Decomm}(Fl,Vs,Ct,y,q,Va_{Max})- NU_{WithDrawal}(Fl,Vs,Ct,y,q,Va_{Max}))*\Pr_{Attrition}^{Accept} \quad (C.7.1.4)$$

Eventually we compute the number of new vessels by the factor $\Pr_{New-vessel}^{Accept}$

$$NU_{New-Vessel}(Fl,Vs,Ct,y,q)=(NU_{Vessel}(Fl,Vs,Ct,y,q-1,\bullet)- NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet)-NU_{WithDrawal}(Fl,Vs,Ct,y,q,\bullet)- NU_{Attrition}(Fl,Vs,Ct,y,q,\bullet))*\Pr_{New-vessel}^{Accept} \quad (C.7.1.5)$$

C.7.2. RANDOM UTILITY MODEL FOR STRUCTURAL BEHAVIOUR

The four structural rules currently in the TEMAS package are:

1) Decommission (Rule). This (and the three following rules) are the so-called long term rules which determines the capacity of the fishing fleets. The decommission rules takes the decision on accept of a decommission compensation based on the recent economic performance of the fleet and the age structure of the fleet.
2) Dis-investment rule. This rule decides on the bankruptcy of a vessel based on the recent economic performance of the fleet.
3) Attrition rule: The attrition rule takes the decision on scrapping a vessel due to old age based on the age structure of the fleet.
4) Investment rule: This rule decides on the investment in a new vessel based on the recent economic performance of the fleet.

The decommision rule is presented here as an example of the structural rules. The mathematical fotmulations is similar for all 4 structural rules.

The probabilities of accepting, p_{Decomm}^{Accept}, $p_{Withdrawal}^{Accept}$, $p_{Attrition}^{Accept}$, $p_{New-Vessel}^{Accept}$ thus determines the exit/entry model.

They can be modelled by the RUM, (Random Utility Model). For a more comprehensive explanation of the RUM applied to fisheries, see Annex A. ,

$$p_{Decomm}^{Accept}=\frac{\exp(U_{Decomm}^{Accept})}{\exp(U_{Decomm}^{\mathrm{Re}ject})+\exp(U_{Decomm}^{Accept})} \quad \text{and} \quad p_{Decomm}^{\mathrm{Re}ject}=1-p_{Decom}^{Accept} \quad (C.7.2.5)$$

U^{Accept}_{Decomm} is the "utility" of accepting decommission and U^{Reject}_{Decomm} is the utility of rejecting decommission. The general expression for utility fransformed to the vessel exit/entry model reads

$$U^{Accept}_{Decomm}(Fl,Vs,Ct,y,q) = \sum_{r=1(Characteristics)}^{R_{Decomm}} \beta^{Accept}_{Decomm.\ r} * X_{Decomm,\ r}(Fl,Vs,Ct,y,q) + \sum_{s=1(Attributes)}^{S_{Decomm}} \gamma_{Decomm,\ s} * W^{Accept}_{Decomm,\ s}(Fl,Vs,Ct,y,q) \quad \text{(C.7.2.6)}$$

Four potential characteristics There are in the case of decommission

$X_{Decomm,\ 1}(Fl,Vs,Ct,y,q)$ = Decommission Fee

$X_{Decomm,\ 2}(Fl,Vs,Ct,y,q)$ = Historical profitability (Annual Value of landings – Annual Costs) /Investment

$X_{Decomm,\ 3}(Fl,Vs,Ct,y,q)$ = Investment

$X_{Decomm,\ 4}(Fl,Vs,Ct,y,q)$ = Age of vessel and value of original Investment.

Two potential attributes in the case of decommission

$W^{Accept}_{Decomm,1}(Fl,Vs,Ct,y,q)$ =
Expected profitability (Annual Value of landings – Annual Costs)/Investment

$W^{Accept}_{Decomm,2}(Fl,Vs,Ct,y,q)$ = Expected revenue.

Table C.7.2.1 list sets of potential characteristics for the four fleet capacity RUMs cosidered in TEMAS.

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Coefficient	**Structural rule**			
	Decommission	**Dis-Investment**	**Attrition**	**Investment**
Characteristics	Historical profitability	Historical profitability	Historical profitability	Historical profitability
Characteristics	Historical cash flow	Historical cash flow	Historical cash flow	Historical cash flow
Characteristics	Historical revenue	Historical revenue	Historical revenue	Historical revenue
Characteristics	Age of vessel	Age of vessel	Age of vessel	
Characteristics	Investment value	Investment value	Investment value	Investment value
Characteristics				Dis-investment
Characteristics		Max. Allowed capacity		Max. Allowed capacity
Characteristics	Taxes and subsidies	Taxes and subsidies	Taxes and subsidies	Taxes and subsidies
Characteristics	Opputunity costs	Opputunity costs	Opputunity costs	Opputunity costs
Attributes	Expected profitabilty	Expected profitabilty	Expected profitabilty	Expected profitabilty
Attributes	Expected revenue	Expected revenue	Expected revenue	Expected revenue
Attributes	Decommission fee			
Attributes	Employment	Employment	Employment	Employment

Table C.7.2.1. Potential characteristics and attributes for four RUM models of fleet capacity dynamics.

The suggested RUM applied in the Baltic case (Table C.7.2.2) is only a small subset of the suggestions given in Table C.7.2.1. The Attrition rule is cancelled in the case of the Baltic because age distribution of vessels is not considered in the Baltic case. This rule for dis-investment and attrition are merged. The idea is that if the "historical cash flow" is low during a certain period then decommission is accepted if it exists, and if no decommission is available, dis-investment (withdrawal from fishing industry) applies. If cash flow has been high for a while, and there are free licenses investments are made. If no free licenses are available, investments may be preceded by scrapping (dis-investment) of old vessels. For example, small vessels may be replaced by large vessels if large vessels gives higher cash flow. Also move of investments from one fleet to another fleet can occur.

Coefficient	**Structural rule**		
	Decommission	**Dis-Investment**	**Investment**
Characteristics (1)	Historical cash flow	Historical cash flow	Historical cash flow
Characteristics (2)		Maximum Allowed capacity	Maximum Allowed capacity
Attributes (1)	Decommission fee		

Table C.7.2.2. Characteristics and attributes for three RUM models of fleet capacity dynamics applied to the Baltic Case study.

Characteristics in the three rules are

$$X_{Decomm,\ 1}(Fl,Vs,Ct,y,q) = CF_{RUM}(Fl,Vs,Ct,y,q)$$
$$X_{Dis-Invest,\ 1}(Fl,Vs,Ct,y,q) = CF_{RUM}(Fl,Vs,Ct,y,q)$$
$$X_{Dis-Invest,\ 2}(Fl,Vs,Ct,y,q) = \text{Vacant Licenses}$$
$$X_{Invest,\ 1}(Fl,Vs,Ct,y,q) = CF_{RUM}(Fl,Vs,Ct,y,q)$$
$$X_{Invest,\ 2}(Fl,Vs,Ct,y,q) = \text{Vacant Licencses}$$

and the single attribute considered in the decommission rule is

$$W^{Accept}_{Decomm,1}(Fl,Vs,Ct,y,q) = \text{Decommission fee for one vessel}$$

The cash flow concept, $CF_{RUM}(Fl,Vs,Ct,y,q)$, used in the present RUM is the average cashflow per period during the period $y-dy_{RUM}, y-dy_{RUM}+1,...,y-1$ and the periods for year y: 1,2,…,q-1. The cash flows of hesorical years are weighted by a factor, Fac^{RUM}_u, which could be $Fac^{RUM}_u = (Fac^{RUM})^{-(y-u)}$ where Fac^{RUM} is a constant $0 < Fac^{RUM} \le 1$.

$$CF_{RUM}(Fl,Vs,Ct,y,q) = \frac{1}{dy_{RUM} * q_{Max}} \sum_{u=y-dy_{RUM}}^{y-1} \sum_{q=1}^{q_{Max}} FNCF_{RUM}(Fl,Vs,Ct,u,q,\bullet) * Fac^{RUM}_u$$
$$+ \frac{1}{q-1} \sum_{v=1}^{q-1} FNCF_{RUM}(Fl,Vs,Ct,y,q,\bullet)$$

and the net cash flow summed over areas is defined

$$FNCF_{RUM}(Fl,Vs,Ct,y,q,\bullet) =$$
$$REV(Fl,Vs,Ct,y,q,\bullet) - VCO(Fl,Vs,Ct,y,q,\bullet) - CO^{Total}_{Fix}(Fl,Vs,Ct,y,q)$$

where REV is the revenue from landings, VCO is the total variable costs, and CO^{Total}_{Fix} is the total fixed costs. This definition deviates from that given by Eq. C.4.6.1.b

$$FNCF(Fl,Vs,Ct,y,q,\bullet) = REV(Fl,Vs,Ct,y,q,\bullet) -$$
$$VCO(Fl,Vs,Ct,y,q,\bullet) - CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) - INV^{Total}(-,\bullet) + TSL(-,\bullet) + DECV(-,\bullet)$$

where INV^{Total} is the total investments, TSL is total taxes, subsidies and license fee and DECV is decommission fee to vessels.

The capacity concept is discussed in Section A.4.6. The number of vessels is usually limited. The usual condition for introduction of a new vessel is that a vessel of similar size is removed from fishery. These conditions are often linked to capacity rather than the number of vessels, so that, for example, one big vessel, can be replacement three small vessel, if the total fishing capacity of the small vessels equals that of the new big vessel. Let TON(Fl, Vs, Ct) be the tonnage of an average vessel in vessel size Vs in Fleet Fl country Ct. If the entry of new vessels is conditions of removal of old vessels with the same tonnage, this would lead to lead to the country specific constraint:

$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{New-Vessel}(Fl,Vs,Ct,y,q,\bullet) * TON(Fl,Vs,Ct) \le$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet) * TON(Fl,Vs,Ct) +$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Withdrawal}(Fl,Vs,Ct,y,q,\bullet) * TON(Fl,Vs,Ct) +$$
$$\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Attrition}(Fl,Vs,Ct,y,q.\bullet) * TON(Fl,Vs,Ct)$$

If furthermore, decommisioned vessels cannot be replaced the term $\sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Decomm}(Fl,Vs,Ct,y,q,\bullet) * TON(Fl,Vs,Ct)$ should be removed from the inequality above. The vessel tonnage is just one example of a "fleet characteristics". Other examples of fleet characteristics are "Length of vessel" and "KgW of engine".

The "maximum regulations" are thought of as an upper limit, MAL (Maximum allowed level) of the characteristics summed over vessels. TEMAS allows for limitations of total characteristics of three levels Country, Fleet and Vessel Size:

Level 1: Country level

$$\sum_{Fl=}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * TON(Fl,Vs,Ct) \le MAL_{Ton}^{Level\ 1}(Ct,y)$$

Level 2: Fleet level:

$$\sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * TON(Fl,Vs,Ct) \le MAL_{Ton}^{Level\ 2}(Fl,Ct,y)$$

Level 3: Vessel size level:

$$NU_{Vessel}(Fl,Vs,Ct,y,\bullet) * TON(Fl,Vs,Ct) \le MAL_{Ton}^{Level\ 3}(Fl,Vs,Ct)$$

To indicate a maximum regulation defined by a fleet characteristics, is thus required a specification of the characteristics (tonnage, vessel length, KWat etc.) and the level at which the MAL shall be applied. As illustrated by the example above on investment/replace above, the characteristics may be used for other types of regulations than maximum regulations.

$X_{Dis-Invest,\ 2}(Fl,Vs,Ct,y,q) = X_{Invest,\ 2}(Fl,Vs,Ct,y,q) =$ Max Capacity - Actual capacity

is not (Fl,Vs)-specific, it depends only on the country in the present TEMAS version for the Baltic

(Max Capacity - Actual capacity) =

$$MAL_{Ton}^{Level\ 1}(Ct) - \sum_{Fl=}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y.q,\bullet) * TON(Fl,Vs,Ct,y)$$

The variable "vacant licenses" is defined to prevent investment when no licenses are vacant, that is

$Vacant\ Licenses =$

$$\begin{cases} 0\ if\ MAL_{Ton}^{Level\ 1}(Ct) > \sum_{Fl=}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y.q,\bullet) * TON(Fl,Vs,Ct,y) \\ -\infty\ if\ MAL_{Ton}^{Level\ 1}(Ct) \le \sum_{Fl=}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} NU_{Vessel}(Fl,Vs,Ct,y.q,\bullet) * TON(Fl,Vs,Ct,y) \end{cases}$$

C.7.3. AD HOC RANDOM UTILITY MODEL FOR STRUCTURAL BEHAVIOUR

These "*ad hoc methods*" were introduced in the BEAM4 (Sparre and Willmann, 1993) in various versions according to the actual applications. They are believed to be more straight forward and easier to comprehend than the random utility models, but naturally, their foundation (believed to be only common sense) is weaker than the that of the RUM. In one respect, however, are the "ad hoc" models more complete than the RUM's. The RUM model tells how many vessels should enter/leave the industry, but it does not tell which vessels should leave. The *Ad hoc* rules also contain algorithms for selection of the vessels to leave the industry.

C.7.3.1. AD HOC DECOMMISSION RULE.

The total number of vessels that are being decommissioned is not determined by a fisher's "behaviour rule". This is a decision by government or the fishery management authority (and subject to the assumed acceptance of the adequacy by vessel owners of the compensation/ decommissioning payment) and thus given as an input to TEMAS. The number of decommissioned vessels may be given as input for each vessel age group or they may be given as a fraction of the total number of vessels. Only in the case where decommissions are given as a fraction do we need a rule, namely a rule to select the vessels for decommissioning.
The decommission rule is active only when the other behaviour rules are also active.

Let "$Va_{DecommMinA}$" be the youngest age of vessel, which can become decommissioned. (Input parameter).
"DecommFactor (Fl,Vs,Ct)" is the fraction of vessels at age, or older than $va_{DecommMinA}$ which are decommissioned.
"DecommFactorOld(Fl,Vs,Ct)" is the fraction of the oldest age group which is decommissioned before any other vessels are decommissioned.

The total number of Decommissions is:

$NU_{Decomm}(Fl,Vs,Ct,y\ ,\bullet) =$

$$Round\left[DecommFactor(Fl) * \sum_{Va=Va_{DecommMinA}}^{va_{max}} NU_{Vessel}(Fl,Vs,Ct,y,Va) + 0.5 \right] \quad (C.7.3.1.1)$$

Where "Round" stands for the integer part of a real number.

When selecting the vessels to be decommissioned the following algorithm (written in idealized VISUAL BASIC) is applied:

```
T = NU_Decomm(Fl, Vs, Ct, y, •) '--- (total number of Decommissions)
 NU_Decomm(Fl, Vs, Ct, y, Va_Max) =
Round(DecommFactorOld(Fl) * NU_Vessel(Fl, Vs, Ct, y, Va_Max) +0.5)
T = T – NU_Decomm(Fl, Vs, Ct, y, Va_Max)     ' ---- count down -----
 For Va = 1 to Va_Max
       NU_Decomm(Fl, Vs, Ct, y, Va) = 0 '--- assign initial count
Next Va
While T > 0 do '---- continue until all planned withdrawals are counted (up and down)
       Va = Va_max
       While Va >= Va DecommMin-a do
              NU_Decomm(Fl, Vs, Ct, y, Va) = NU_Decom(Fl, Vs, Ct, y, Va) + 1 '--- count up ----
              Va = Va – 1 '----- count down ----
              T = T –1      ' ---- count down -----
       wend
  wend
```

In words, this means that the vessels are decommissioned one by one from the oldest end of the distribution, until the required total number of vessel reductions is achieved. But firstly, a certain fraction of the vessel oldest age is decommissioned.

While it is optional for the user of TEMAS to assume that decommissioning takes place without decommission compensation to the owners of fishing vessels and/or crew members, that would clearly not be in accordance with a usual buy-back programme.

C.7.3.2. AD HOC DIS-INVESTMENT RULE

If for one or more years, the financial net cash flow of the fleet (disregarding decommissioning cash inflows) is zero or negative, some fishing firms are assumed to withdraw boats from the fleet to avoid future losses.

Let "MaxLowYears(Fl,Vs,Ct)" be the maximum number of low cash flow years in sequence fleet (Fl,Vs,Ct) will accept before it starts to withdraw vessels, and let "WithdrawalFactor(Fl,Vs,Ct)" be the fraction of vessels that are withdrawn when a sequence of low years have occurred.

Let $va_{WithdrawalMinA}$ be the youngest age of vessel, which would be withdrawn (Input parameter).

Let "y_1" be the first year in the "moving" sequence of years : "y_1, y_1+1 ,…, y_1+MaxLowYears(Fl,Vs,Ct)". To simplify notation, let: $\mathbf{Y_2} = y_1 + MaxLowYears(Fl,Vs,Ct) + 1$

Let DECV(Fl,Vs,Ct,y,q,Va) be the decommission payment for one vessel of age group "Va" of Fleet "(Fl,Vs,Ct)" in year "y" (Section C.4.4), which is the product of numbers and the decommission rate $DECV(Fl,Vs,Ct,y,q) = DECR(Fl,Vs,Ct,y,q) * NU_{Decomm}(Fl,Vs,Ct,y,q)$

Let FVDecommFraction(Fl,Vs,Ct,y) be the Fraction of vessel decommission fee "remaining" in fleet "(Fl,Vs,Ct)". Then we have that the income to fleet (Fl,Vs,Ct) from decommission fee is

DecommFee(Fl, Vs, Ct, y) =

$FVDecommFraction(Fl,Vs, Ct, y)*\sum_{Va} DECR(Fl,Vs,Ct,Va,y) * NU_{Decomm}(Fl,Vs,Ct\ y, Va)$

The disinvestments rule is flexible and allows the user to simulate different scenarios. It reads as follows:

If for y = y_1, y_1+1,…, y_2 : FNCF(Fl,Vs,Ct,y,q,•) – DECV(Fl,Vs,Ct, y,q) < 0
Then the total number of withdrawals is:

$$NU_{Withdrawal}(Fl,Vs,Ct,y_2,\bullet) = Round\left[\begin{array}{l} WithdrawalFactor(Fl,Vs,Ct)* \\ \sum_{Va=Va_{WithdrawalMinA}}^{Va_{\max}} NU_{Vessel}(Fl,Vs,Ct,y_2-1,va)+0.5 \end{array}\right] \quad (C.7.3.2.1)$$

Where "Round" stands for the integer part of a real number.

Where FNCF is the "Financial net cash flow" (Section C.4.6)

$$FNCF(Fl,Vs,Ct,y,q,\bullet) = REV(Fl,Vs,Ct,y,q,\bullet) - VCO(Fl,Vs,Ct,y,q,\bullet) - CO_{Fix}^{Total}(Fl,Vs,Ct,y,q)$$

Where VCO is Total variable costs: CO_{Fix}^{Total} is the total fixed costs.

When selecting the vessels to be withdrawn the following algorithm (written in idealised VISUAL BASIC) is applied:

```
T = NU_Withdrawal(Fl,  y2,  •) '--- (total number of withdrawals)
    For Va = 1 to Va_max
        NU_Withdrawal(Fl, y2, Va) = 0 '--- assign initial count
    Next va
  While T > 0 do '---- continue until all planned withdrawals are counted (up and down)
        Va = Va_max
        While Va >= va WithdrawalMinA do
                NU_Withdrawal(Fl, y2, Va) =  NU_Withdrawal(Fl, y2, Va) + 1 '--- count up ----
                Va = Va – 1 '----- count down ----
                T = T –1      ' ---- count down -----
        wend
    wend
```

In words, this means that the vessels are withdrawn one by one from the oldest end of the distribution, until the required total number of withdrawals is achieved.

C.7.3.3. AD HOC INVESTMENT RULE

If for one or more years, the financial net cash flow is above a specified value, fishing firms are assumed to invest in additional harvesting capacity. The user of TEMAS can specify the threshold level of cash flow and the number of years this threshold needs to be reached for investors to add a certain number of boats to the fleet.

Let "MaxHighYears(Fl,Vs,Ct)" be the maximum number of years with high net cash flow in fleet (Fl,Vs,Ct), where no investment in new vessels is made, when cash flow is above the threshold.

Let "InvestTreshold(Fl,Vs,Ct)" be the value of net cash flow of fleet (Fl,Vs,Ct), which results in investments in new vessels after MaxHighYears(Fl,Vs,Ct) years of high cash flow.

Let "NewVesselFactor(Fl,Vs,Ct) be the raising factor for number of boats when investment in new vessels occur to fleet (Fl,Vs,Ct). The rule reads as follows:

If for all the years in sequence: y = y_1, y_1+1,…, y_1+MaxHighYears(Fl,Vs,Ct)
FNCF(Fl,Vs,Ct,y,q)/NU_{Vessel}(Fl,Vs,Cty,•) > InvestTreshold(Fl)
Then $NU_{NewVessel}$(Fl,Vs,Ct, y_1 + Max_High_Years + 1,q) =
Round(NewVesselFactor(Fl,Vs,Ct) * NU_{vessel}(Fl,Vs,Ct, y_1 + MaxHighYears(Fl,Vs,Ct),•) + 0.5)

C.7.3.4. AD HOC ATTRITION RULE

The attrition rule serves the sole purpose to simulate the wear and tear of vessels over the years and that they need to cease fishing once the end of their techno-economic lifetime has been reached. It reads as follows:

Let ScrapFactor(Fl,Vs,Ct) be the fraction of old vessels (age av_{max}), which is scrapped due to attrition. Every year a fraction (rounded to integer) of the fleet retires due to having reached the end of the techno-economic lifetime of the vessels.

$NU_{Attrition}(Fl,Vs,Ct, y, Va_{max})$ = round(ScrapFactor(Fl,Vs,Ct)* $NU_{vessel}(Fl,Vs,Ct, y,Va_{max})$ + 0.5)
For Va < Va_{Max}(Fl, Ct): $NU_{Attrition}(Fl, Vs, Ct, y, Va_{Max}(Fl,Ct))$ = 0
$NU_{Attrition}$(Fl, Vs,Ct, y, Va) is the number of attrition vessels of age "Va" from fleet "(Fl,Vs,Ct)" in year "y"

C.7.4. RANDOM UTILITY MODEL FOR SHORT TERM BEHAVIOUR

There are four trip related behaviour models in the current version of the TEMAS model:

5) Model for fishing/not fishing (Effort rule)
6) Model for choice of area (fishing grounds)
7) Model for choice of rigging
8) Model for discarding

C.7.4.1. RANDOM UTILITY MODEL FOR CHOICE OF AREA

The general model for utility was introduced in Eq. (C.7.1.6.a-c) . Now suppose as an example, that the utility U=1, R^T=1,R=0 and S=2, in Eq. C.7.1.6.a-c. This the setup chosen for model for choice of area in the Baltic case. Then

$$U_{t,Choice} = \sum_{u=1}^{U=1} \left\{ \sum_{r=1(Characteristics)}^{R^T=1} \beta^T{}_{t-u,Choice,r} * p_{t-u,Trip,r} \right\} + \sum_{r=1(Characteristics)}^{R=0} \beta_{t,Choice,r} * X_{t,r} + \sum_{s=1(Attributes)}^{S=2} \gamma_{t,s} * W_{t,Choice,s} \qquad \text{(C.7.4.1.1.a)}$$

or skipping the summation symbols:

$$U_{t,Choice} = \beta^T{}_{t-1,Choice,r} * p_{t-1,Choice} + \gamma_{t,1} * W_{t,Choice,1} + \gamma_{t,2} * W_{t,Choice,2} \qquad \text{(C.7.4.1.1.b)}$$

This example represents the actual model used for the Baltic case study.
Let the choice be area (Fishing grounds), let W_1 be the expected value of the landings per unit of effort, and W_2 a variable that signifies an MPA. Then we have the simple RUM model used for the selection of area in the Baltic case study.

$$U_{y,q,Ar}(Fl,Vs,Ct) = \beta^T{}_{y-1,q,Ar}(Fl,Vs,Ct) * p_{y-1,q,Ar}(Fl,Vs,Ct) + \gamma_{y,1}(Fl,Vs,Ct) * W_{y,q,Ar,1} + \gamma_{t,2}(Fl,Vs,Ct) * W_{y,q,Ar,2}(Fl,Vs,Ct) \qquad \text{(C.7.4.1.2)}$$

where

$p_{y-1,q,Ar}(Fl,Vs,Ct)$ =The share of vessels in area "Ar" in period q of year y-1

$W_{y,q,Ar,1}(fl,Vs,Ct)$ = Value of landings per day in period q in year y-1 in area "Ar".

$$W_{y,q,Ar,2}(Fl,Vs,Ct) = \begin{cases} 0 & if\ \ Ar\ \ is\ \ MPA\ \ for\ (Fl,Vs,Ct) \\ -\infty & if\ \ Ar\ \ not\ \ MPA\ \ for\ \ (Fl,Vs,Ct) \end{cases} \qquad \text{(C.7.4.1.3)}$$

Minus infinity "$-\infty$" in practice is some very large negative number, say "-1000". This will assign (almost) zero utility to an MPA, and will in practice prevent fishing in an MPA.

Small Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
West	5	0.001	1	0.229	900	0
East	5			0.286	1100	0
Not Baltic	2			0.200	500	0
Bornholm	4			0.157	800	-1000
Gotland	4			0.129	400	-1000
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	Probability
West	1.143	0.900	0	2.0429	7.713	0.352
East	1.429	1.100	0	2.5286	12.536	0.572
Not Baltic	0.400	0.100	0	0.5000	1.649	0.075
Bornholm	0.629	0.800	-1000	-998.6	0.000	0.000
Gotland	0.514	0.400	-1000	-999.1	0.000	0.000
Sum	4.114	3.300	-2000	Sum	21.897	1.000

Large Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
West	3	0.0005	1	0.229	1800	0
East	3			0.286	2200	0
Not Baltic	3			0.200	1000	0
Borhnholm	2.5			0.157	1600	-1000
Gotland	2.5			0.129	800	-1000
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	Probability
West	0.686	0.900	0	1.5857	4.883	0.326
East	0.857	1.100	0	1.9571	7.079	0.473
Not Baltic	0.600	0.500	0	1.1000	3.004	0.201
Bornholm	0.393	0.800	-1000	-998.8	0.000	0.000
Gotland	0.321	0.400	-1000	-999.3	0.000	0.000
Sum	2.857	3.700	-2000	Sum	14.966	1.000

Table C.7.4.1.a. Distribution on area with 2 closed areas (2 MPAs).

The logit function for choice of area takes the form

$$p_{Ar}(Fl,Vs,Ct,y,q) = \frac{\exp(U_{y,q,Ar}(Fl,Vs,Ct))}{\sum_{j=1}^{Ar_{Max}} \exp(U_{y,q,j}(Fl,Vs,Ct))} \qquad \text{(C.7.4.1.4)}$$

which equals the distributions on areas

$$E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) = p_{Ar}(Fl,Vs,Ct,y,q)$$

Tables C.7.4.1.a and b shows a numerical example of distribution of effort on areas with MPAs (Table a) and with out MPAs (Table b). The parameters are fleet specific, and each table contains two fleets (small and large trawlers). The MPAs are removed in Table b by replacing the negative utility in Table a (-1000) with zero in Table b.

Thus, the behaviour model used for the Baltic case study is indeed very simple.

Small Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
West	5	0.001	1	0.229	900	0
East	5			0.286	1100	0
Not Baltic	2			0.200	500	0
Bornholm	4			0.157	800	0
Gotland	4			0.129	400	0
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	Probability
West	1.143	0.900	0	2.0429	7.713	0.270
East	1.429	1.100	0	2.5286	12.536	0.439
Not Baltic	0.400	0.100	0	0.5000	1.649	0.058
Bornholm	0.629	0.800	0	1.4	4.173	0.146
Gotland	0.514	0.400	0	0.9	2.495	0.087
Sum	4.114	3.300	0	Sum	28.565	1.000

Large Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
West	3	0.0005	1	0.229	1800	0
East	3			0.286	2200	0
Not Baltic	3			0.200	1000	0
Bornholm	2.5			0.157	1600	0
Gotland	2.5			0.129	800	0
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	Probability
West	0.686	0.900	0	1.5857	4.883	0.240
East	0.857	1.100	0	1.9571	7.079	0.348
Not Baltic	0.600	0.500	0	1.1000	3.004	0.148
Bornholm	0.393	0.800	0	1.2	3.296	0.162
Gotland	0.321	0.400	0	0.7	2.057	0.101
Sum	2.857	3.700	0	Sum	20.320	1.000

Table C.7.4.1.b. Distribution on area with no closed areas (no MPAs).

With MPAs						
Small Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
Fishing	2	0.001	0.0011	0.600	200	-200
Not Fishing	1			0.400	-100	100
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	probability
Fishing	1.200	0.200	-0.22	1.1800	3.254	0.684
Not Fishing	0.400	-0.100	0.11	0.4100	1.507	0.316
Sum	**1.600**	**0.100**	**-0.11**	**Sum**	**4.761**	**1.000**
With MPAs						
Large Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
Fishing	2	0.0012	0.0013	0.600	200	-200
Not Fishing	1			0.400	-100	60
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	probability
Fishing	1.200	0.240	-0.26	1.1800	3.254	0.695
Not Fishing	0.400	-0.120	0.078	0.3580	1.430	0.305
Sum	**1.600**	**0.120**	**-0.182**	**Sum**	**4.685**	**1.000**

No MPAs						
Small Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
Fishing	2	0.001	0.0011	0.600	200	0
Not Fishing	1			0.400	0	0
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	probability
Fishing	1.200	0.200	0	1.4000	4.055	0.731
Not Fishing	0.400	0.000	0	0.4000	1.492	0.269
Sum	**1.600**	**0.200**	**0**	**Sum**	**5.547**	**1.000**
No MPAs						
Large Trawlers, Baltistan						
	Tradition	Value	MPA	Tradition	Value	MPA
	β	γ	γ	X	W	W
Fishing	2	0.0012	0.0013	0.600	200	0
Not Fishing	1			0.400	0	0
	Tradition	Value	MPA			
	$\beta * X$	$\gamma * W$	$\gamma * W$	U	exp(U)	probability
Fishing	1.200	0.240	0	1.4400	4.221	0.739
Not Fishing	0.400	0.000	0	0.4000	1.492	0.261
Sum	**1.600**	**0.240**	**0**	**Sum**	**5.713**	**1.000**

Table C.7.4.2. Numerical illustration of the rule for "Go Fishing / Not Go Fishing".

C.7.4.2. RANDOM UTILITY MODEL FOR FISHING/NOT FISHING

The model used for fishing/not fishing is equally simple in the case of the Baltic. This choice is assumed to depend on (1) the tradition, (2) the average value of landings per day for all area combined and (3) closed areas (MPAs). The utility for going fishing is

$$U_{y,q,GoFishing}(Fl,Vs,Ct) = \beta^T{}_{y-1,q,GoFishing}(Fl,Vs,Ct) * p_{y-1,q,GoFishing}(Fl,Vs,Ct) + \gamma_{y,q,1}(Fl,Vs,Ct) * W_{y,q,1} + \gamma_{y,q,2}(Fl,Vs,Ct) * W_{y,q,2} \qquad \text{(C.7.4.2.1)}$$

and the utility for not going fishing

$$U_{y,q,NotGoFishing}(Fl,Vs,Ct) = \beta^T{}_{y-1,q,NotGoFishing}(Fl,Vs,Ct) * p_{y-1,q,NotGoFishing}(Fl,Vs,Ct) + \gamma_{y,q,1}(Fl,Vs,Ct) * W_{y,q,1} + \gamma_{y,q,2}(Fl,Vs,Ct) * W_{y,q,2} \qquad \text{(C.7.4.2.2)}$$

where

$p_{y-1,q,GoFishing}(Fl,Vs,Ct)$ = Share of vessels fishing in period q last year

$p_{y-1,q,NotGoFishing}(Fl,Vs,Ct) = 1 - p_{y-1,q,GoFishing}(Fl,Vs,Ct)$

$W_{y,q,1}$ = Average value per day last year (all areas combined)

$$W_{y,q,2}(Fl,Vs,Ct) = \begin{cases} Value\ of\ landings/day\ last\ year\ in\ MPAs\ if\ MPAs \\ 0\ if\ no\ MPAs\ for\ (Fl,Vs,Ct) \end{cases}$$

Table C.7.4.2 shows a numerical example of the “Go Fishing” rule. Two scenarios are illustrated, one with MPAs and one without MPAs. The effect of the MPA is to reduce the fishing.

The logit function for choice of “go fishing / stay in port” takes the form

$$p_{GoFishing}(Fl,Vs,Ct,y,q) = \frac{\exp(U_{y,q,GoFishing}(Fl,Vs,Ct))}{\exp(U_{y,q,GoFishing}(Fl,Vs,Ct)) + \exp(U_{y,q,NotGoFishing}(Fl,Vs,Ct))} \qquad \text{(C.7.4.2.3)}$$

$$p_{NotGoFishing}(Fl,Vs,Ct,y,q) = 1 - p_{GoFishing}()$$

The effort exerted in area Ar was given an upper limit with Eq A.4.4.1

$$E(Fl,Vs,\bullet,Ct,y,q,Ar) \le NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * EY_{Max}(Fl,Vs,Ct,y,q,Ar)$$

where EY_{MAX}(Fl, Vs, Ct, y, q, Ar) is the maximum physical number of effort units per vessel per time unit in Area Ar.

The actual number of effort units exerted is given by EQ. A.4.4.1 and $p_{GoFishing}(Fl,Vs,Ct,y,q)$

$$E(Fl,Vs,\bullet,Ct,y,q,Ar) = p_{GoFishing}(Fl,Vs,Ct,y,q) * NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * EY_{Max}(Fl,Vs,Ct,y,q,Ar) \qquad \text{(C.7.4.2.4)}$$

C.7.4.3. RANDOM UTILITY MODEL FOR CHOICE OF RIGGING

The choices of area and rigging are nested. The choice of area is made firstly, and the choice of rigging made secondly. The choice of rigging is thus dependent on the area. Let the choice be gear rigging, let W_1 be the expected value of the landings per unit of effort, and W_2 a variable that signifies an MPA. Then we have the simple RUM model used for the selection of rigging in the Baltic case study.

$$U_{y,q,Rg}(Fl,Vs,Ct,Ar) = \beta^T{}_{y-1,q,Rg}(Fl,Vs,Ct,Ar) * p_{y-1,q,Rg}(Fl,Vs,Ct,Ar) +$$
$$\gamma_{y,1}(Fl,Vs,Ct,Ar) * W_{y,q,Rg,1} + \gamma_{t,2}(Fl,Vs,Ct,Ar) * W_{y,q,Rg,2}(Fl,Vs,Ct,Ar)$$

where

$p_{y-1,q,Rg}(Fl,Vs,Ct,Ar)$ = The share of vessels using rigging "Rg" in period q of year y-1 in area "Ar"

$W_{y,q,Ar,1}(Fl,Vs,Ct,Ar)$ = Value of landings per day in period q in year y-1 in with rigging "Rg" in area "Ar".

$$W_{y,q,Ar,2}(Fl,Vs,Ct,Ar) = \begin{cases} 0 & if\ Rg\ \ is\ allowed\ \ for\ (Fl,Vs,Ct)\ in\ MPA\ (=Ar) \\ -\infty & if\ Rg\ not\ allowed\ \ for\ (Fl,Vs,Ct)\ in\ MPA\ (=Ar) \end{cases}$$

The current implementation of TEMAS for the Baltic case does not contain the rule for choice of rigging.

C.7.4.4. RANDOM UTILITY MODEL FOR CHOICE OF DISCARDING

Model for discard behaviour is not yet decided. It appears rather complicated, for example because discarding is stock-specific. However, the idea is to consider 4 different discard options:

1) No Discard
2) Undersized Fish discarded.
3) Undersized Fish discarded. High grading.
4) Undersized Fish discarded. High grading. Excess TAC discarded.

"No discards" means that all catches are landed. Discarding is banned in Norway, and there has been discussion on the topic in the EU.

"Undersized Fish discarded" means that fish of length below the minimum allowed landing size. That means that cod of length less than or equal to 38 cm are discarded. There is no minimum landing length for sprat and herring in the Baltic.

"High grading" means that low value sizes and species are discarded. That could for example be that all species/size groups with a price/kg less than a certain value are discarded.

"Excess TAC discarded" means that when a TAC is exhausted, all catches of that species are are discarded. The harvest control rule of ICES (using B_{pa} and F_{pa}) can be met in TEMAS in two ways

1) Fixing effort to match the TAC
2) Let effort be independent of TAC, and discarding of catches in excess of the TAC

C.7.5. AD HOC RULES FOR SHORT TERM BEHAVIOUR

Effort can be controlled in TEMAS in two ways:

(1) Giving effort as input
(2) Let the "Effort-rule" decide the effort (see Section 5).

The first option was discussed in Section A.4. Here we shall discuss second option second with respect of short term behaviour. Namely choice of fishing ground and choice of gear rigging. We start by reiterating the definitions of effort distributions on areas and rigging given in Section A4.3.

$$E(Fl,Vs,\bullet,Ct,y,q,\bullet) = \sum_{Ar=1}^{NU_{Area}} \sum_{Rg=1}^{Rg(Fl)} E(Fl,Vs,Rg,Ct.y,q,Ar)$$

is the total effort exerted by fleet (Fl,Vs,Ct) during time period q. The input effort in the present version of TEMAS is E(Fl, Vs, Ct, y, q,•), that is the total effort summed over areas, together with the relative distribution of effort over areas (Eq. A.4.3.1):

$$E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) = \frac{E(Fl,Vs,\bullet,Ct,y,q,Ar)}{E(Fl,Vs,\bullet,Ct,y,q,\bullet)}$$

Thus, effort is the product of the two input parameters, which in turn gives the effort distribution on fleets, vessels sizes and countries (Eq. A.4.3.2):

$$E(Fl, Vs, \bullet, Ct, y, q, Ar) = E(Fl, Vs, \bullet, Ct, y, q, \bullet) * E_{Area-Dist}(Fl, Vs, \bullet, Ct, y, q, Ar)$$

The next step in the distribution of effort is the distribution on riggings for given area (Eq. A.4.3.3)

$$E(Fl, Vs, Rg, Ct, y, q, Ar) = E(Fl, Vs, \bullet, Ct, y, q, Ar) * E_{Rig-Dist}(Fl, Vs, Rg, Ct, y, q, Ar)$$

where effort distribution on riggings for given area, Ar is

$$E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar) = \frac{E(Fl,Vs,Rg,Ct,y,q,Ar)}{E(Fl,Vs,\bullet,Ct,y,q,Ar)}$$

The two effort distributions may also be considered the probability that a vessel will choose and area, and then given that area the probability that a it will choose a rigging. Thus, the effort distributions $E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$ and $E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar)$ is linked to the model of fisher's behaviour. To summarize the distribution, the complete model of effort distribution on areas, and on rigs for given area read:

$$E(Fl,Vs,Rg,Ct,y,q,Ar) = E_{\mathrm{Re}f}(Fl,Vs,\bullet,Ct,y,q,\bullet) *$$
$$E_{Rig-dist}(Fl,Vs,Rg,y,q,Ar) * E_{Area-dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$$

As probabilities the area and rigging distribution will sum up to one,

$$\sum_{Ar=}^{Ar_{Max}} E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) = 1.0 \quad \text{and} \quad \sum_{Rg=}^{Rg(Fl,Ct)} E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar) = 1.0$$

It comes natural to use the logit model for the Ad hoc version, for example.

$$Pr(\,choosing\ area\ "Ar"\,) = \frac{exp(U_{Ar})}{\sum_{j(Area)=1}^{Ar_{Max}} exp(U_j)}$$

as that will automatically produce probabilities, for choosing area and rigging.

C.7.5.1. AD HOC FISHING EFFORT RULE

The overall rule is that fleets use the full capacity. That is

$$\Sigma_{Ar}E(Fl, Vs, \bullet.Ct,y, a, Ar) = NU_{Vessel}(Fl, Vs,Ct,y, \bullet)* EY_{MAX}(Fl, Vs, Ct, y, q)$$

where the capacity is the maximum number of fishing units (fishing days or sea days) that a fleet can exert in a time period. It is given by the variable $EY_{MAX}(Fl, Vs, Ct, y, q)$, the maximum number of effort units per vessel per time unit. However, the fleet is assumed to change its level of fishing activity (fishing days per time period) when harvesting costs, i.e. the sum of financial operating costs for handling and harvesting and sale's cost, crew share and effort income are higher than gross revenues for a suite of time periods.

Let "MaxLowPer(Fl, Vs, Ct)" be the maximum number of periods fleet (Fl ,Vs, Ct) will continue to fish with unchanged effort. Or in other words, fleet "(Fl,Vs,Ct)" continues with unchanged effort in "MaxLowPer" time periods, before it changes its level of effort, due to low cash flow.
And let "EffortReductionFactor(Fl, Vs, Ct)" be the "number of vessels reduction factor" fleet (Fl, Vs, Ct) applies after "MaxLowPer" of less profitable time periods
The rule is flexible and allows the user to simulate different scenarios. It reads as follows in pseudo VISUAL BASIC:

If for all the periods in sequence: $q = q_1$, $q_1 +1$,..., q_1+MaxLowPer(Fl,Vs,Ct)
the condition for the "financial net cah flow", FNCF

FNCF(Fl, Vs, •,Ct, y, q) > 0

is met, then Effort is reduced by the factor "EffortReductionFactor" in the following period:
Effort(Fl, Vs, •,Ct, y, q+1 , •) = Effort(Fl,Vs, •,Ct, y, q, •) * EffortReductionFactor(Fl,Vs,Ct),

The same reduction factor is applied to all areas.

If the condition is then no longer met, effort is raised to the capacity, that is:
$\Sigma_{Ar}E(Fl, Vs, \bullet,Ct,y, a, qr) = NU_{Vessel}(Fl,Vs,Ct, y, \bullet) * EY_{MAX}(Fl,Vs,Ct,y,q)$

C.7.5.2. AD HOC RULE FOR CHOOSING FISHING GROUND

The probability of choosing a fishing ground is modelled by the logit model:

Pr("Choosing fishing ground Ar") = $\frac{\exp(U_{Ar}^{Area})}{\sum_{j(Area)=1}^{Ar_{Max}} \exp(U_j^{Area})}$ as that will automatically produce

probabilities Pr("Choosing fishing ground Ar") = $E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$.
The utility is defined as the sum of a "revenue term" and a "tradition term"

$$U_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) = U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar) +$$
$$REVFac_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) * EXPREV(Fl,Vs,\bullet,Ct,y,q,Ar) + \quad \text{(C.7.5.2.1.a)}$$
$$Trad^{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) * Effort(Fl,Vs,\bullet,Ct,y-1,q,Ar) +$$

The value factor $REVFac_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar)$ determines the importance of the value of the expected landings. The tradition factor, $Trad^{Area}(Fl,Vs,\bullet,Ct,y,q,Ar)$, determines the importance of what the fishers used to do.
The expected revenue of landings from area Ar is defined as the revenue last year (in the same time period)

$$EXPREV(Fl,Vs,\bullet,Ct,\bullet,y,q,Ar) = REV(Fl,Vs,Ct,y-1,q,Ar) \quad \text{(C.7.5.2.2.a)}$$

The total closure of and area during a time period, q, is modelled by a “Total MPA-Utility” defined as:

$$U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar) = \begin{cases} 0 & if\ \ area\ \ Ar\ \ not\ \ total\ \ MPA \\ -\infty & if\ \ area\ \ Ar\ \ is\ \ a\ \ total\ \ MPA \end{cases} \quad \text{(C.7.5.2.3)}$$

A “total MPA” is an area closed for all fishing gears. With the (ideal) utility of “-∞” a total MPA will never be chosen as fishing ground. Alternatively $U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar)$ could be given the value of costs of violating the MPA regulation. That might be a fine, the confiscation of landings and/or gear. If the closure of the MPA is gear rigging specific, then the MPA is modelled as a part of the behaviour model for rigging choice (see following subsection).

The expected revenue can be replaced with the expected cash flow in Eq. C.7.5.2.1.a

$$U_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) = U_{MPA}^{General}(Fl,Vs,Ct,y,q,Ar) +$$
$$REVFac_{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) * EXPFNCF(Fl,Vs,\bullet,Ct,y,q,Ar) + \quad \text{(C.7.5.2.1.b)}$$
$$Trad^{Area}(Fl,Vs,\bullet,Ct,y,q,Ar) * Effort(Fl,Vs,\bullet,Ct,y-1,q,Ar)$$

Where the expected cash is defined as the cash flow last year (in the same time period)

$$EXPFNCF(Fl,Vs,\bullet,Ct,\bullet,y,q,Ar) = FNCF(Fl,Vs,\bullet,Ct,\bullet,y-1,q,Ar) \quad \text{(C.7.5.2.2.b)}$$

Where the financial cash flow of fleet (Fl, Vs, Ct) is defined (Eq. C.4.6.1.a)

$$FNCF(Fl,Vs,Ct,y,q,Ar) = REV(Fl,Vs,Ct,y,q,Ar) - VCO(Fl,Vs,Ct,y,q,Ar) -$$
$$CO_{Fix}^{Total}(Fl,Vs,Ct,y,q) - INV^{Total}(-,Ar) + TSL(-,Ar) + DECV(-,Ar)$$

C.7.5.3. AD HOC RULE FOR CHOOSING GEAR RIGGING

The probability of choosing a gear rigging for given fishing ground is modelled by the logit model:

$$Pr(\,choosing\ \ rig\ \ "Rg"\,) = \frac{exp(U_{Rg}^{Rig})}{\sum_{j(Rig)=1}^{Rg_{Max}(Fl,Ct)} exp(U_j^{Rig})} \quad \text{(C.7.5.3.1)}$$

The rigging utility is defined as the area utility

$$U^{Rig}(Fl,Vs,Rg,Ct,y,q,Ar) = U^{Rig}_{MPA}(Fl,Vs,Rg,Ct,y,q,Ar) +$$

$$REVFac^{Rig}_{Area}(Fl,Vs,Rg,Ct,Ar) * \sum_{St=1}^{St_{Max}} EXPREV(Fl,Vs,Ct,Rg,St,y,q,Ar) + \qquad \text{(C.7.5.3.2)}$$

$$Trad^{Rig}_{Area}(Fl,Vs,Rg,Ct,Ar) * Effort(Fl,Vs,Rg,Ct,y-1,q,Ar)$$

where the utility contains the same three terms as the utility for choice of area. The indices is now extended with index "Rg".

$$U^{Rig}_{MPA}(Fl,Vs,Ct,y,q,Ar) = \begin{cases} 0 & if\ \ rig\ \ Rg\ \ is\ \ allowed\ \ in\ \ MPA \\ -\infty & if\ \ rig\ \ Rg\ \ is\ \ not\ \ allowed\ \ in\ \ MPA \end{cases} \qquad \text{(C.7.5.3.3)}$$

C.8. ECONOMIC MEASURES OF PERFORMANCE

The three economic models each yield a net present value of the cash flow, which can be used as measures of performance. Many other measures could be chosen, for example, the employment.

Analysis	Stakeholder	Measure of performance
FINANCIAL FLEETS	Vessel owners	**Net present value of cash flow** $\mathrm{FNCF_{NPV}(Fl,r_F)} = \sum_{y=y_{first}}^{y_{last}} \frac{FNCF(Fl,y,\bullet)}{(1+r_F)^{y-y_{first}+1}}$ **Economic performance (ROI - Risk_free_rate) (%)** Added Value/Revenue; Gross Operative Margin/Revenue ROS (Return on Sale); ROI (Return on Investment) (%) Revenue/Invested Capital (%); Net Profit per vessel (000 €) Landings per vessel (ton); Landings per GRT (ton) Landings per day (ton); CPUE (kg) Revenue per vessel (000 €); Revenue per GRT (000 €) Revenue per day (000 €); RPUE (€) Average price (€/kg); Fuel cost per vessel (000 €) Fuel cost per day (000 €); Maintenance cost per vessel (000 €)
GOVERNMENT BUDGET	Government budget	**Net present value of cash flow** $\mathrm{FTNCF_{NPV}(Fl,r_F)} = \sum_{y=y_{first}}^{y_{last}} \frac{FTNCF(Fl,y,\bullet)}{(1+r_F)^{y-y_{first}+1}}$
ECONOMIC ANALYSIS	Economy as a whole.	**Net present value of cash flow** $\mathrm{ENCF_{NPV}(Fl,r_F)} = \sum_{y=y_{first}}^{y_{last}} \frac{ENCF(Fl,y,\bullet)}{(1+r_E)^{y-y_{first}+1}}$
Employment	Society	EMPL(•, y, •) **Social sustainability (Salary - Minimum_salary) (000 €)** Employed persons (num.); Landings per crew (ton) Revenue per crew (€); Crew/GRT Salary per crew (000 €)

D = Deflated by general consumption price index

D1 = Deflated by employed consumption price index

ANNEX. D. MANAGEMENT MODEL.

Recall that the ultimate objective of TEMAS is to compare two alternative management regimes, by simulating the fisheries system over a series of years for both regimes, and eventually it compare the performance of the two regimes during the time period (as explained in the introduction).
The operating system generates ("fake" or "hypothetical") input data to the alternative management models, and it predicts the effect of the alternative management regulations on the eco-system and the fisheries. Eventually it compares the two alternatives by comparison of selected measures of performance.

The mathematical formulas given below are extensive and complicated. Actually, the creation of the expression has been a rather tedious process, and the probability of mistakes in the formulas should be considered. The problems arise because the legislation by EU is far more complicated in terms of details and formulations, than the scientific models used by, for example, ICES WG, ACFM and STECD. The complexity of scientific models does not match the complexity of EU legislation. There is a data problem parallel to model problem. The quality and quantity of scientific data do not match the EU legislation. Thus, most of the formulations given below are new relative to the present state of the art in fisheries science. Needless to say, this fact makes it a hard intellectual task to comprehend the formulas. Furthermore, as this is the first time the author attempts to express the EU legislation in mathematical formulas, it is not likely that he chose the most elegant way of expression.

The EU legislation (basically) aims at controlling fishing effort and employment in fishing in five different ways:

1) Reducing the capacity of fishing fleets (e.g. by decommission programs).
2) Reducing the number of sea days (by fleet and gear rigging) and by closed seasons
3) Reducing the effort on selected age groups by technical management measures (for example by MPAs)
4) Reducing effort (indirectly) by TACs.
5) Controlling effort by socio-economic measures (e.g. taxes, subsidies, intervention prices)

Restrictions of the number of vessels by vessel size and type categories (Item 1), makes a natural upper limit to the maximum effort that can be exerted. An example of capacity regulation is the MAGPs (Multi-Annual Guidance Programmes) of EU, aimed at bringing fishing capacity more into line with available resources. Fishing effort is defined as vessel capacity, in both tonnage and engine power, multiplied by activity (days spent at sea). The rationale behind MAGPs is that the available resources should determine the size of the fleet and not, as has often been the case, that the size of TACs be determined by the size of the fleet. The MAGP was implemented in four phases: I (1983-86), II (1987-91), III (1992- 96) and IV (1997-2002). A new system for limiting the fishing capacity of the EU fleet was adopted in 2002. It replaced the former MAGPs. The MAGP and its continuation combined with TAC measures have not been sufficient to bring effort down to a sustainable level, and a suite of additional measures has been introduced, notably mesh size regulation, closed areas and limitation of sea-days. The report of the "TECTAC" EU project contains a description and discussion of the structural programs for fishing fleets of the EU, (TECTAC, 2005).

Limitation of sea-days is combined with a suite of technical management measures and TAC regulations, but the regulations are not independent, as they are all derivatives of the overall principle, the attempt to reduce fishing mortalities.

The overall effect of both direct effort limitations with respect of reducing fishing mortality is in the same direction. They are not necessarily proportional, in the sense that an X percent reduction in number of fishing vessels results in an X percent reduction in the number of fishing days by all vessels combined. The difference between the two types of effort management is rather caused by their effect on the reaction of the fishing industry. It is to be expected that limitations in sea-days will lead to investment in more efficient vessels, whereas limitations in capacity may have the opposite effect on investments in vessel efficiency. The economic effect is consequently different, with limitations in sea-days leading to increase in costs of fishing per unit of effort, but not necessarily an increase in resources (a reduction in F).

The economic performance of individual vessels will improve when the total number of vessels is reduced, whereas this is not to be expected when sea-days are reduced (at least not in the short term). The long term effect of a sea-day reduction is not very obvious, but the expectation is that resources will benefit, and as a consequence fisheries will also benefit in the long term. Reduction in sea-days may or may not lead to better economic performance, depending on the reaction of the resources. On the other hand, reducing the maximum number of sea-days, makes the planning and execution of fishing more difficult and will increase the cost of fishing. Consequently, the profitability of fishing will be reduced, which may have an indirect effect on the capacity. The incitement for investment in new vessels will go down and the incitement to withdraw will increase. The uncertainty on the effects of effort reduction is based on the fact that fluctuations in resources are not only determined by the behaviour of fishing fleets, but on a suite of phenomena which are poorly understood perhaps not even recognized by fisheries science.

Notice that items 1+2 theoretically should make item 4, the TAC superfluous. To each effort level should correspond a catch of each species. The commission probably has chosen to maintain the TAC for historical reasons, and probably also “to be on the safe side”. Should one measure fail, the other measure may work out as expected. Furthermore, there is a great uncertainty concerning the effect of both effort and TAC regulations.

Traditionally, ICES has dealt with mainly item 4, the TACs and has done that by making single species forecasts, where multi-species, fleet, gear rigging, season and area aspects have been ignored. The EU on the other hand tends to move from using predictions to the “Adaptive Approach”, where, for example, effort is reduced by 10% each year until a certain objective has been achieved. To the author knowledge, ICES has not made any attempt to base their advice on the adaptive approach.

This Chapter attempts to cover all major items in the EU legislation (some of the most complicated regulation are not covered). Therefore, the ICES advice and harvest control rules plays an inferior role, because the author does not consider them very important in the context of EU legislation.

The introduction of most recent fleet (effort) based management measures in the EU has not been based on scientific advice from the ICES (and to the author knowledge no other scientific body). The effect of the effort based management has after the implementation been evaluated by various working groups under the STECF (STECF, 2004, 2005, 2006). To the authors knowledge there exists no technical or scientific report on the rational behind the effort based management regulations (maximum number of sea days by fleet and rigging). Naturally, this lack of knowledge has made it more problematic to convert the EU management measures into mathematical models, and computer programs.

Appendix G presents the original text of “EU Proposal for a Council Regulation establishing a multi-annual plan for the cod stocks in the Baltic Sea and the fisheries exploiting those stocks” from

May 2007. It has been attempted to make TEMAS match this proposal. Four of the regulation items essential for the TEMAS simulation, are reproduced from the EU text:

(6) In order to achieve the objective the Eastern stock must be rebuilt to safe biological limits and for both stocks levels where their full reproductive capacity is maintained and the highest long-term yields can be reached must be ensured.
(7) This can be achieved by establishing an appropriate method for gradually reducing the fishing effort in fisheries catching cod to levels that are consistent with the objective, and by fixing the total allowable catches (TACs) for the cod stocks at levels consistent with the fishing effort.
(9) To ensure stability in the fishing possibilities, it is appropriate to limit the variation in the TACs from one year to the next.
(10) An appropriate implementation of the control of fishing effort is to regulate the length of the periods when cod fishing is allowed.

For the MPAs, the proposal merely lists the definition of three closed areas, and which gears are not allowed to fish where and when, but does not add further comments that could explain or justify the existence of the three MPA's

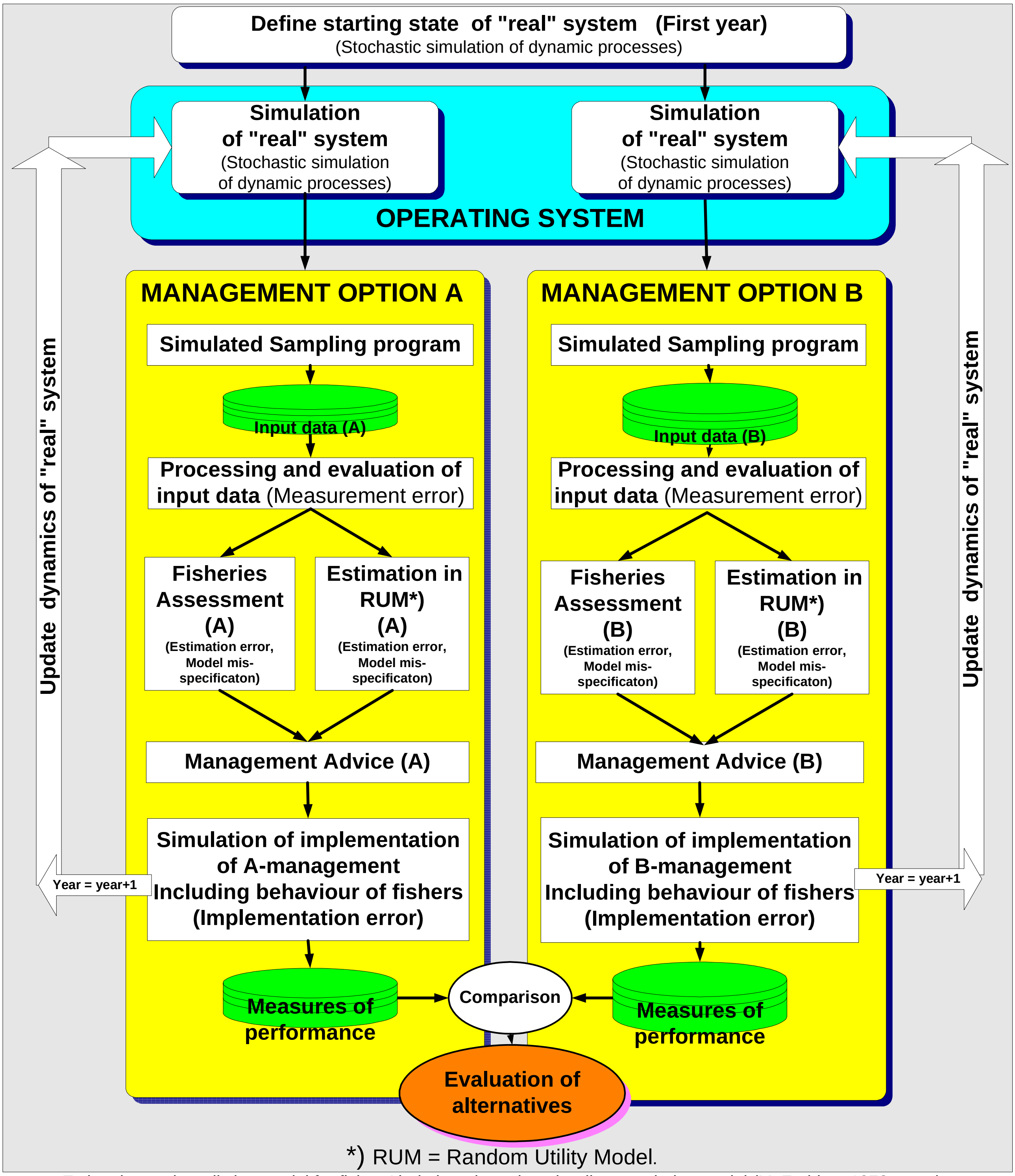
As appears from the quotation above, the proposal will be based on the adaptive approach, as defined in the present context. The EU commission does not apply the term "adaptive approach".

D.1. SUMMARY OF EVALUATION FRAME FEATURE

The features introduced so far, does not cover the full set of features of TEMAS. So far we have considered representatives of characteristic features only. Figure D.1.1 attempts to summarize these basic features in a single graph. Some details were not yet discussed, such as the different types of "errors" in the system. An error means a "deviation from the model", or "something that can go wrong".
Figure D.1.1 operates with four types of errors:

1. Measurement error. Errors in input data, such as catch at age data, caused by data being estimated from samples, and not from complete enumeration.
2. Estimation error. Errors caused by the method used to estimate parameters, or erroneous assumption about the data.
3. Model misspecification error. Errors caused by incomplete or wrong understandings of the mechanism behind the system dynamics. The assumed Stock/recruitment relationships may be candidates for model misspecifications.
4. Implementation error. The errors caused by regulations not being reacted to as assumed. The fishers may find ways to implement regulations, which do not lead to the achievements of the intensions of regulations.

The software will be able to simulate the effect of errors and bias, by stochastic simulations. Stochastic simulation is simply to repeat the same calculations a large number of times, each time with new parameter-values drawn by a random number generator (see Section 11 Annex. A). The stochastic simulation requires specifications of probability distributions of those parameters which are considered stochastic variables.



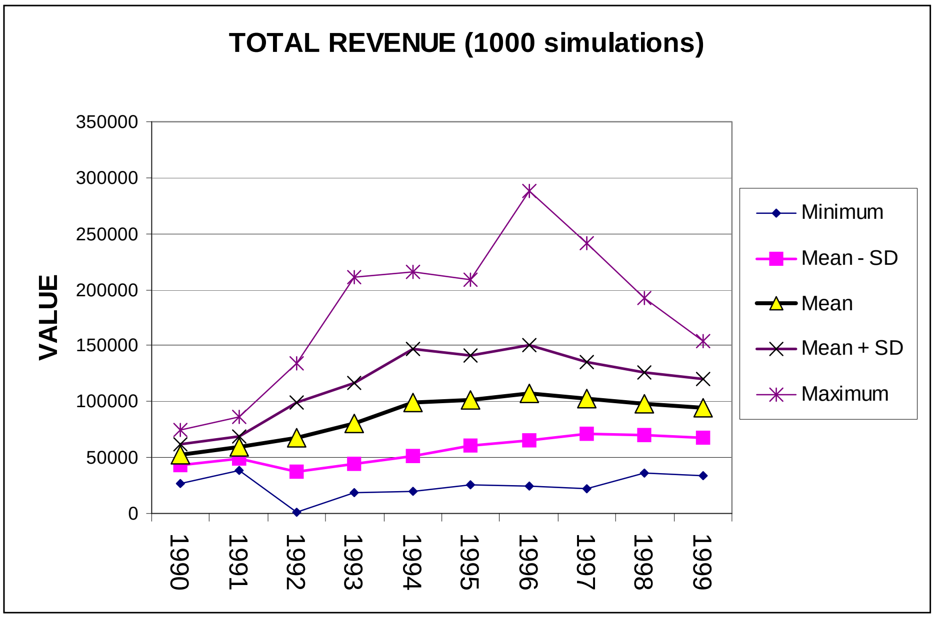
Estimation and prediction model for fishers' behviour, based on the discrete choice model (McFadden, 1973, etc.,)

Figure D.1.1. Summary of the Evaluation Framework, as implemented by the TEMAS software.

Figure D.1.1 should be considered as an illustration of the calculations for one time period. These calculations are repeated for as many time periods (and years) as chosen the user of the software. Chronologically, the events taking place are:

- The operating model produces input to the management model for year "y"
- The management produces management regulations for year "y+1"
- The management regulations for year "y+1" is used as input to the operational model, to produce input to the management model in year y+1, …. Etc.

The stochastic simulation module simply executes TEMAS a large number of times (say, 1000 times), and each time it draws parameters and initial condition variables by random number generators, executes a simulation over a series of years. At the end it retrieves the results of all 1000 simulations and converts them into, for example, frequency diagrams. Below is shown an example of output from stochastic simulation with TEMAS, namely a time series of total Revenue with indication of the stochastic variation, in the form of SD (Standard deviation) and maximum/ minimum values. (redrawn from Figure A.12.2.3)



Finally it should be noted that the operational model of TEMAS contains many parameters which cannot be estimated by the data currently available. Therefore a large number of parameters will have be assigned "plausible" values, that is, values not estimated by statistical methods and observations but values which are believed to be "reasonable". Likewise, TEMAS will contain a number of sub-models which has not been verified by recognized statistical tests. Therefore, the concept of "prediction power" may not be applicable to TEMAS.

We will simply not be in a position to say anything about the prediction power. The output of the model is in the best case of the nature: "It is likely that management regime A gives a better performance than management regime B" with respect of a selected measure of performance. TEMAS should not be used to quantify, for example, the expected spawning stock biomasses.

There is no alternative to this approach, when it comes to test alternative management regimes, which has not been tested earlier. A real statistical experimental design would require that the two alternative management regimes were test on two identical ecosystems, and such an experiment will never become possible in practice.

D.2. THE LINKS BETWEEN THE COMPONENTS OF TEMAS.

The operational model of TEMAS integrates the biology, technical features, economy and behavioural features as illustrated in Figure D.2.1. TEMAS integrates seven components :

- Management model.
- Generation of stochastic input from ecosystem.
- Biological/technical model.
- Short term behaviour model (trip related behaviour of fishers).

- Economic model (costs and earnings).
- Long term behaviour model (investment/disinvestment related behaviour of fishers).
- Evaluation of system performance.

As mentioned earlier, the focal point in TEMAS is the capacity (the number of vessels by fleet). The capacity is determined by the long term behaviour model, which predicts the number of investments in new vessels, the number of disinvestments, the number of attritions (vessels "dying" from old age) and removals (scrapings) of vessels due to decommission (See Annex B and Annex C).
The long term behaviour is determined by the economic model (Annex C), which predicts costs and earnings. Costs are variable and fixed costs. The variable costs are derived from the effort, and the earnings from the value of the catch.

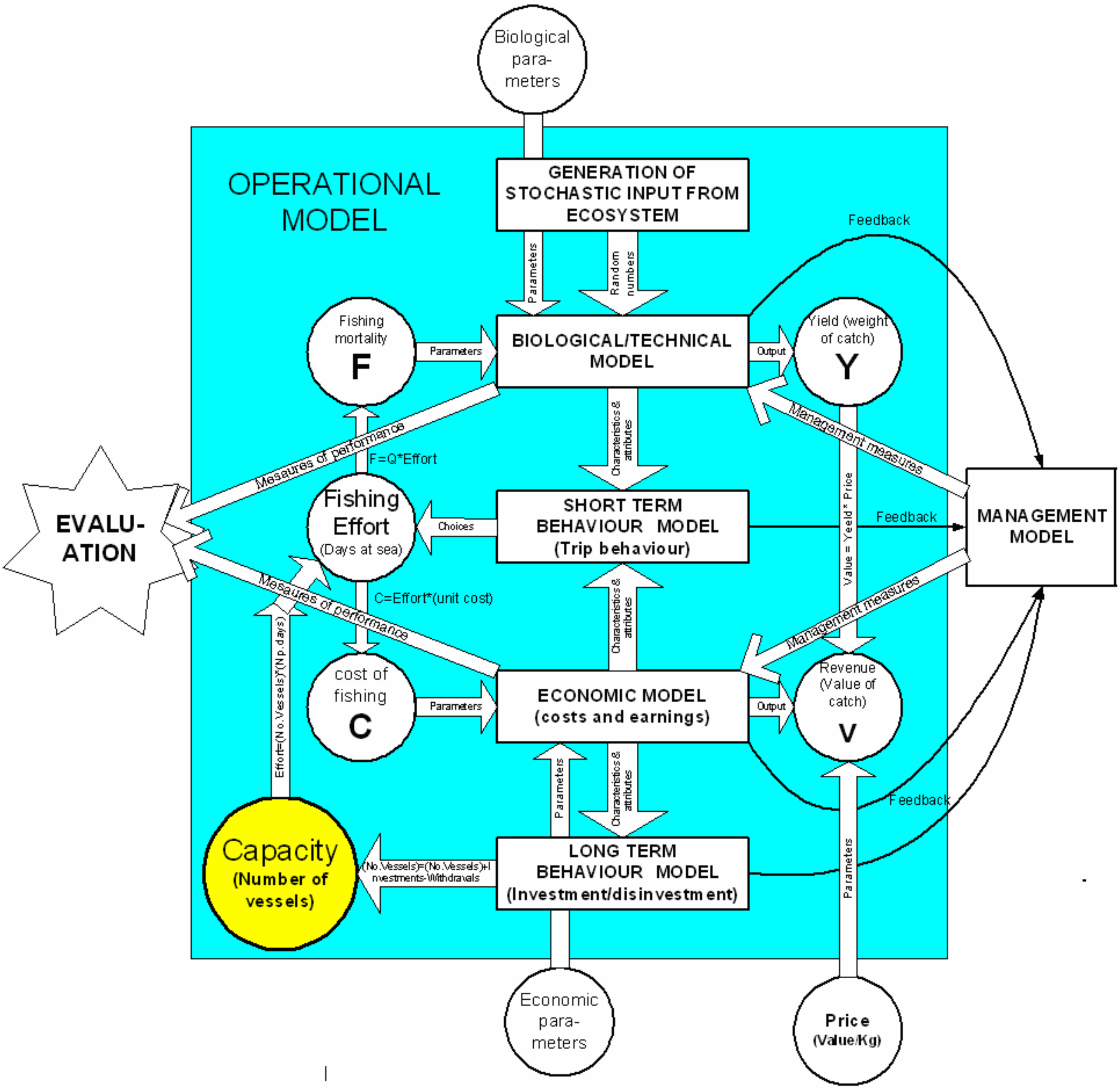


Figure D.2.1. The complete operational model, combining biology, technical features, economy and behavioural features, together with it's links to the management model and the evaluation.

The effort is derived from the number of sea-days, which in turn is determined by capacity and the short term behaviour model. Both the short term and the long term behaviour are influenced by the management regulations. The management model simulates the bodies that give advice (e.g. ICES) and which decide on the management measures (e.g. the EU fisheries commission). The effort produces the fishing mortality, which is input to the biological model together with stochastically generated input.

The stochastic input represents the "unpredictable ecosystem". The main stochastic component is the unpredictable recruitment. The mechanisms that determine the recruitment of fish stocks is highly variable for most fish stocks. The relationship between stock and recruitment is not understood, and the only knowledge currently available, is the series of historical observations of recruitment. Other parameters in TEMAS can be treated as stochastic variables, in principle, any parameter. Output from the biological system is the yield (the catch in weight). The yield combined with the price/kg determines the revenue from fishing which is input to the economic model together with the costs.

The political "evaluation" is not a part of TEMAS. TEMAS attempts to create a suite of useful measures of performance that can be used in a political evaluation of the system performance. TEMAS thus does not range the alternatives amongst management strategies. It does not attempt to give the optimum to a maximization problem. TEMAS does not contain a goal function. What is "best" is a decision left to the users of TEMAS.

D.3. SIMULATION OF MANAGEMENT IN TEMAS.

TEMAS contains a suite of options for pre-prepared pairs of management regimes. The natural reference for comparison is the "traditional management regime", based on the total TAC. This section explains how TEMAS simulates an ICES procedure, and transformation of a TAC into effort by fleet. TEMAS also simulates the most recent adaptive approach of the EU commission, where effort and TACs are reduced / increased with a maximum percentage per year, until a desired goal is achieved. As the principal input to the operational model of TEMAS is effort by fleet (derived from fleet capacity), TAC must be converted into effort, in order to establish the feed back from the management to the operational model of TEMAS.

The evaluation of TAC/effort management is combined with the evaluation of simultaneously implemented technical management measures, such as gear regulation, closed areas (MPAs) and closed seasons. Essentially, these measures also aim at reducing or redistribution of effort.

Below is made an attempt to formulate a fleet-based harvest control rule combined with the adabtive approah. This effort-based rule is derived from the TAC-based rule of ICES, and is not considered realistic, in the sense that we do not believe that it will ever be implemented in practise. Thus, there is a big unsolved problem in TEMAS. The nature of this issue is not scientific, but political. The maximum, a scientific approach can do, is to discuss the problem and suggest a plausible solution, that is, attempt to make plausible predictions of what politicians/ administrators/managers might do in case they were to formulate fleet-based harvest control rules. The adabtive approach, to change the system stepwise until an desired goal is achieved, appears to overrule the harvest control rule in the short term. Therefore, the strict implementation of harvest control rule, appears not to be the strategy of the EU, rather the adaptive approach appears to be the cornerstone of the contemporary CFP (Commen Fisheries Policy). The control of TACs and effort is combined with the structural management of fishing fleets, that is the control of fishing capacity (number of vessels) by a variety of regulations, such as decmmission programs, licensing, tax and subsidies.

For further information on the views of the EU commssion, see

- *EU COMMISSION, 2006. Council regulation (EC) No 52/2006 of 22 December 2005. Fixing the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks applicable in the Baltic Sea for 2006*

- *EU COMMISSION, 2006. Implementing sustainability in EU fisheries through maximum sustainable yield Communication from the commission to the council and the European parliament, {SEC(2006) 868}, Brussels, 4.7.2006. COM(2006) 360.*

The working group on "mixed fisheries" under the STECF has approached a definition of the problem, but has not suggested any effort-based harvest control rules. (STECF, 2003 and 2004. Kraak, 2004, Vinther, Reeves, Patterson, 2003). A suite of ICES WGs have on the request of the EU-commission started to work with fleet based assessment, but yet no fleet-based harvest control rules have been suggested (ICES SGMAS, 2007 and ICES SGMIXMAN 2007), although ICES is in a process of developing something. The so-called "F-cubed method" appears to be the first step in developing a a fleet based harvest control rule (ICES SGMIXMAN, 2006, 2007).

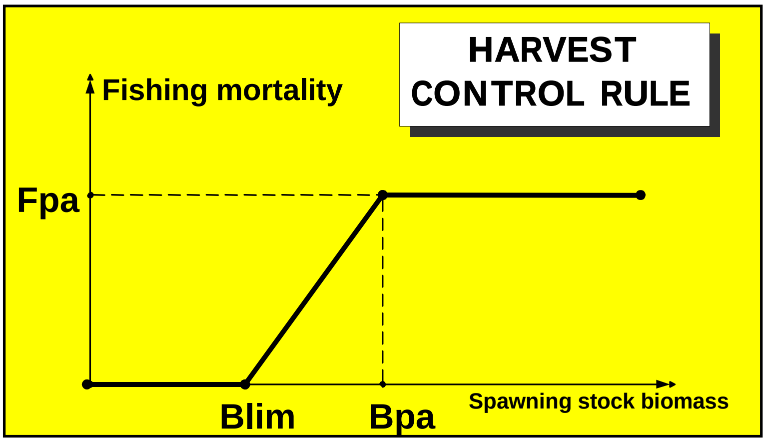


Figure D.3.1. The harvest control rule of ICES.

The advice given by ICES and the management measures by EU all have the objective to prevent over-fishing which is defined by the resource evaluation of ICES. Therefore, one can say that all measures are derivatives of the ICES advice. The current advice by ICES is given as advice for a single stock, for all fleets combined and areas combined. This advice is suitable for setting a total TAC for a single stock, but does not give any indications on the adequate effort levels, and does not account for the effect of mixed fisheries.

The rules for fixing the catch quotas, the so-called "Harvest Control Rules" (HCR) use three parameters, F_{PA}, B_{PA} and B_{lim}. F_{PA} is the fishing mortality of the "precautionary approach" (Figure D.3.1). B_{PA} is the SSB (spawning stock biomass) corresponding to F_{PA}. B_{lim} is the lowest acceptable level of SSB, which allow fishing to continue. If SSB gets below B_{lim} the stock is in immediate danger of being depleted and fisheries must be stopped. ICES applies the HCR on a single species basis. That means that ICES ignores that (almost) all fish are caught I mixed fisheries. "Mixed fishery" means that a vessel catches several species. It is usually impossible to avoid catching certain species together with other species. That means that a quota on one species has influence on the catch of all the other species caught together with the quota-species.

The ICES advice on resource management is tacitly based on the assumption that fish stocks do not interact. Interaction between fish stocks can be grouped into "technical" and "biological" interaction. Technical interaction refers to the fact that several fleets compete for the same species and one fleet catches several species. Biological interaction refers to the interaction between stocks created by predation and food competition.

ICES assessment usually counts the catch quota against the landings, not the catches (landings + discards). In theory, the catch quotas set by ICES is therefore not related to fishing mortality, as it should be according to the philosophy of ICES. Furthermore, for many stocks, the discards are not known and fishing mortalities are estimated from the landing only.

The ultimate goal of ICES is to get the fishing mortality at the level of F_{PA} for all stocks. Fishing mortality is created by fishing effort. It is believed that there is some relationship between effort and fishing mortality. The simplest model is that of proportionality between fishing mortality and fishing effort, "F = Effort*Catchability". Should that model be accepted, then the ultimate goal is to fix the fishing effort of all fleets so that $F = F_{PA}$, that is

$$F(Species\ A) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ A) = ? = F_{PA}(Species\ A)$$

$$F(Species\ B) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ B) = ? = F_{PA}(Species\ B)$$

$$F(Species\ C) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ C) = ? = F_{PA}(Species\ C)$$

•••••••••••

However, usually, there will be no solution in terms of "Effort". The simple case of one fleet gives the solution, Effort = F_{PA}/Catchability. That solution will give the same effort for species A and B only if F_{PA}(Species A)/Catchability(Species A) = F_{PA}(Species B)/Catchability(Species B). That will usually not be the case for any combination of species.

What can be achieved in reality is the set of inequalities:

$$F(Species\ A) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ A) \le F_{PA}(Species\ A)$$

$$F(Species\ B) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ B) \le F_{PA}(Species\ B)$$

$$F(Species\ C) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ C) \le F_{PA}(Species\ C)$$

•••••••••••

with equality for only one species. One simple approach would then be to apply the same factor to all efforts (of all fleets), so that the inequality is met and equality is achieved for one species. In the following Section we introduced another approach.

When the distribution of effort on areas is used as a tool, for example by MPA the achievable inequalities become, (using the expressions for area-mortalities introduced in Section A.8)

$$F(Sp.A) = -\ln\left\{ \sum_{Area} \sum_{Fleet} \frac{N(Area)}{N_{Stock}} \exp(-E(Fleet, Area) * Q(Fleet, Sp.A)) \right\} \le F_{Pa}(Sp.A)$$

$$F(Sp.B) = -\ln\left\{ \sum_{Area} \sum_{Fleet} \frac{N(Area)}{N_{Stock}} \exp(-E(Fleet, Area) * Q(Fleet, Sp.B)) \right\} \leq F_{Pa}(Sp.B)$$

$$F(Sp.C) = -\ln\left\{ \sum_{Area} \sum_{Fleet} \frac{N(Area)}{N_{Stock}} \exp(-E(Fleet, Area) * Q(Fleet, Sp.C)) \right\} \leq F_{Pa}(Sp.C)$$

…………

Management by area allows the manager to reallocate effort between areas including closing an area for fishing in a season and all year round. However, evaluation of the effect of effort reallocation between areas becomes a minor adjustment on top of the overall effort regulation. In practice it is expected to become rather difficult to show the effect of area-based management measures, unless the areas of reduced effort make up a very large part of the total area. This in turn leads to the conclusion that the ICES harvest control rule is almost impossible to transform into any meaningful rule for area based management.

The objective of closed areas, MPA is usually to improve the conditions for spawning or to improve the conditions for juvenile survival. Thus, the nature of area-based management is long term, and not directly linked to area-fishing-mortality. If a big part of the area is closed, the remaining area can stand a very high fishing mortality, while maintaining an F below F_{PA}. We shall come back to the intricate question of the assessment of MPA in Section 8.

D.4. SIMULATION OF CURRENT MANAGEMENT REGIME

Recall, the structure of the evaluation frame of TEMAS as explained in the introduction. The operational model has the main objective to produce simulated input to the module that simulates the management procedure. The management procedure, in turn, produces input for the simulation of "next year" by the operational model. The management module produces TAC, effort regulations, closed areas and other technical management measures as input to the operational model.

The traditional management regime in North European waters (In the "ICES area") is the annual total TAC, distributed between countries according to the "relative stability" (Section D.6). The management body is the EU council of ministers and the Fisheries Commission of EU in negotiations with neighbouring countries, notably Norway. The traditional regulations has in recent years (since 2003) been extended with various effort based measures, such as maximum number of sea days for selected demersal gears, in connection with the recovery plans for cod. The effort based regulations were introduced without any prior advice from ICES, but they were subsequently evaluated by STECF and to a certain degree by ICES. The TAC is based on scientific advice given by the ACFM of ICES. The advice of ACFM is based on the fish stock assessment executed by the assessment working groups of ICES. TEMAS can simulate the entire process from assessment to implementation of regulation.

D.4.1. SIMULATION OF INPUT TO ICES WG.

D.4.1.1. SIMULATION OF PERFECT (UNBIASED, NO NOISE) INPUT TO ICES WG .[6]

The "perfect" input to ICES assessment (that is, unbiased input samples) were made by running the operational model of TEMAS, and then using the simulated age distributions as input to the simulated ICES assessment working groups. That means that the simulated ICES assessment working groups will estimate the true (correct) fishing mortalities and the true stocks numbers, spawning stock biomass etc.

D.4.1.2. SIMULATION OF NOISE AND BIAS IN INPUT TO ASSESSMENT.

As the operational model of TEMAS represents the "true" system, it can produce all the above types of input data without any random noise and/or any bias. TEMAS adds some noise and some bias to the perfect data created by the operational model.

Let us use superscript "True" to indicate the true value of the catches:

$$C^{True}_{Catch}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = C^{True}_{Land}(-) + C^{True}_{Disc}(-)$$

We go from the "true value" to the "Simulated value" by application of stochastic factors, (1+σ) and (1+β). The σ(Fl, Vs, Rg, Ct, St, y, a, q, Ar) is the relative standard deviation of the measuring error and β(Fl, Vs, Rg, Ct, St, y, a, q, Ar) is the "relative bias".
Thus, the simulated catch numbers is given by

$$C^{Sim}_{Catch}(-) = C^{Sim}_{Land}(-) + C^{Sim}_{Disc}(-)$$

where the simulated numbers landed are defined

$$C^{Sim}_{Land}(-) = C^{Mis}_{Land}(-) + C^{True}_{Land}(-) * (1+\sigma_{Land}(-)) * (1+\beta_{Land}(-))$$

The symbol $C^{Mis}_{Land}(-)$ indicates the misreported landings, which will be discussed in the following section. The simulated numbers discarded are defined

$$C^{Sim}_{Disc}(-) = C^{True}_{Disc}(-) * (1+\sigma_{Disc}) * (1+\beta_{Disc}(-))$$

D.4.1.3. SIMULATION OF MISREPORTING.

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[6] The indices used in the following are:

	Index	Explanation	Range
1	A	Age group	$a = 0,1,2,\ldots,a_{max}(St)$
2	Ar	Area	$Ar = 1,2,\ldots,Ar_{max}$
3	Ct	Country	$Ct = 1,\ldots,Ct_{Max}$
4	Fl	Fleet	$Fl = 1,2,\ldots,Fl_{max}(Ct)$
5	Q	Time period (as time)	$q = 1,..,q_{max}$
6	Qa	Time period (as age)	$qa = 1,..,q_{max}$,
7	Rg	Rigging of gear	$Rg = 1,\ldots,Rg_{max}(Fl,Ct)$
8	Y	Year	$y = y_{firSt,\ yfirst}+1,\ldots,y_{last}$
9	St	Stock	$St = 1,\ldots,St_{max}$
10	Va	Vessel age group	$Va = 1,\ldots Va_{max}(Fl,Ct)$
11	Vs	Vessel size group	$Vs = 1,\ldots Vs_{max}(Fl,Ct)$

Note that the sequence of indices will be (Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar) for all variables.

Time variables in alphabetical order
dt: Basic time step (fraction of year). dt < 1.0. dt = $1/q_{Max}$
y_{first} ,y_{last}: First year, Last year

Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j) = \sum_u X(i,u,j)$.

Misreporting ("Mis") is a more complicated concept. "Misreporting" may, for example, stand for a stock wrongly being reported as another stock. It may also refer a stock being reported caught in the wrong area.

The following five types of misreporting can be simulated by TEMAS:

X	Type	Explanation of type of misreporting	Parameter (number landed or yield)
NA 0	Black	Landings (in numbers) not reported (illegal, "black" landings).	$C^{Mis}_{N-Black}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ $Y^{Mis}_{N-Black}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
1	Stock	Fraction reported as a wrong species.	$MisR^{CorrectSt}_{C-Stock}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ $MisR^{CorrectSt}_{Y-Stock}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
2	Area	Fraction reported from a wrong area.	$MisR^{CorrectAr}_{C-Area}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ $MisR^{CorrectAr}_{Y-Area}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
3	Rig	Fraction reported from a wrong rigging.	$MisR^{CorrectRg}_{C-Rigging}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ $MisR^{CorrectRg}_{Y-Rigging}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
4	Period	Fraction reported from a wrong period.	$MisR^{Correctq}_{C-Period}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ $MisR^{Correctq}_{Y-Period}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$

Table D.4.1.3.1. The five types of misreporting accounted for in the TEMAS simulations.

The five types can be applied in relation with

1) Landings, $C_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$
2) Yield (weight of landings) summed over age groups $C_{Land}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$

The second option is likely to be most commonly used one, as illegal/wrong reports are usually not directly observed, but rather qualified guesses or estimates from indices, such as informal information from the industry, accidental observations, inconsistencies in statistics (e.g. landing statistics compared to export statistics). By its nature, it is not very likely that age distribution data are available for misreports.
The parameter value for black landings (illegal landings) is given in absolute value, whereas the other parameters are given as fractions (between 0 and 1).

$MisR^{CorrectX}_{X}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ = The fraction of $C_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ or $Y_{Land}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$ that is misreported as "X", instead of "CorrectX".

The black landings changes the total official landings to the "true" lndings, whereas X=1,2,34 (Table D.4.1.3.1) reallocate between, stocks, areas, riggings and periods, respectively, but do not change the total true landings.

$$MisR^{CorrectX}_{X}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = \begin{cases} 0 \quad if \;\; X = CorrectX \\ 0 \le X \le 1 \;\; if \;\; X \ne CorrectX \end{cases} \qquad (4.1.3.1)$$

For X = 1,2,3,4 as one cannot reallocate more than a total fraction of 1.0, $MisR^{CorrectX}_{X}$, must meet the conditions

Type of misreporting		Parameter condition	
1	Stock	$\sum_{i=1}^{St_{Max}} MisR_{Stock}^{CorrectX}(Fl,Vs,Rg,Ct,i,y,a,q,Ar) \le 1.0$	(4.1.3.2)
2	Area	$\sum_{i=1}^{Rg_{Max}(Fl,Ct)} MisR_{Area}^{CorrectX}(Fl,Vs,Rg,Ct,St,y,a,q,i) \le 1.0$	
3	Rigging	$\sum_{i=1}^{Vs_{Max}(Fl,Ct)} MisR_{Rig}^{CorrectX}(Fl,Vs,i,Ct,St,y,a,q,Ar) \le 1.0$	
4	Period	$\sum_{i=1}^{q_{Max}} MisR_{Period}^{CorrectX}(Fl,Vs,Rg,Ct,St,y,a,i,Ar) \le 1.0$	

Table D.4.1.3.2. Conditions for misreporting parameters.

One can imagine misreporting that combines two or more of the misreporting causes two to five. TEMAS however, can simulate only misreporting of the simple types.
The total number of "CorrectSt" reported as other species (the "under-reporting" of "CorrectSt") is

$$C_{X,Land}^{UnderRep}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) =$$

$$\sum_{St=1}^{St_{Max}} MisR_X^{CorrectX}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) * C_{Land}^{True}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \quad (4.1.3.4)$$

Where $C_{Land}^{True}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$ is the simulated number landed. Here, "true" means the true number landed in the case of no misreporting. This is the landings number simulated by TEMAS before misreporting is accounted for.

Type of misreporting		Calculation of simulated Yield accounting for misreporting, in chronological order.
1	Stock	For all (Fl, Vs, Rg, Ar, q) do: For all St do: $Y_{Stock,Land}^{Simulated}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) = Y_{Land}^{True}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) +$ $Y_{Stock,Land}^{OverRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) - C_{Stock,Land}^{UnderRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$ (4.1.3.3.a) $- Y_{Black}^{Mis}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
2	Area	For all (Fl, Vs, Rg, St, q) do: For all Ar do: Y_{Land}^{True} is assigned the (simulated) value $Y_{Land}^{Simulated}$ from the "Stock misreporting". $Y_{Area,Land}^{Simulated}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) = Y_{Stock,Land}^{Simulated}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) +$ (4.1.3.3.b) $Y_{Area,Land}^{OverRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) - C_{Area,Land}^{UnderRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
3	Rigging	For all (Fl, Vs, St, Ar, q) do: For all Rg do: Y_{Land}^{True} is assigned the (simulated) value $Y_{Land}^{Simulated}$ from the "Area misreporting". $Y_{Rig,Land}^{Simulated}(Fl,Vs,Rg,Ct,CorrectSt,y,\bullet,q,Ar) = Y_{Area,Land}^{Simulated}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) +$ (4.1.3.3.c) $Y_{Rig,Land}^{OverRep}(Fl,Vs,Rg,Ct,CorrectSt,y,\bullet,q,Ar) - C_{Rig,Land}^{UnderRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$
4	Period	For all (Fl, Vs, Rg, St, Ar) do: For all q do: Y_{Land}^{True} is assigned the (simulated) value $Y_{Land}^{Simulated}$ from the "Rigging misreporting". $Y_{Period,Land}^{Simulated}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) = Y_{Rig,Land}^{Simulated}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) +$ (4.1.3.3.d) $Y_{Period,Land}^{OverRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) - C_{Period,Land}^{UnderRep}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar)$

Table D.4.1.3.3. Computational procedure for misreporting account.

The total number reported from other species is (the "over-reporting") to the stock "CorrectSt" is

$$C^{Over\,Rep}_{X,Land}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) = \sum_{CorrectSt=1}^{CorrectSt_{Max}} MisR^{CorrectX}_{X}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) * C^{True}_{Land}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) \quad (4.1.3.5)$$

Therefore we get the expression for the reported landings simulated after simulation of misreporting

$$C^{Simulated}_{Land}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) = C^{True}_{Land}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) + C^{Over\,Rep}_{X,Land}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) - C^{Under\,Rep}_{X,Land}(Fl,Vs,Rg,Ct,CorrectSt,y,a,q,Ar) - C^{Mis}_{Black}(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \quad (4.1.3.6.a)$$

Stock (X)	True Landings	Fraction Misreport. A As X $MisR^{A}_{Stock}(X)$	Fraction Misreport. B As X $MisR^{B}_{Stock}(X)$	Fraction Misreport. C As X $MisR^{C}_{Stock}(X)$	Fraction Misreport. D As X $MisR^{D}_{Stock}(X)$	
Stock A	1000	0	0.04	0.05	0.03	
Stock B	800	0.05	0	0.12	0.09	
Stock C	600	0.08	0.08	0	0.06	
Stock D	400	0.07	0.05	0	0	
Total true	**2800**	**0.20** a)	**0.17** a)	**0.17** a)	**0.18** a)	
a) Must be ≤ 1.00		Total fraction misrep. of A	Total fraction misrep. of B	Total fraction misrep. of C	Total fraction misrep. of D	
Stock (X)	True Landings	Number (or yield) Misreport. A As X $MisR^{A}_{Stock}(X) * C^{True}_{Land}(A)$	Number (or yield) Misreport. B As X $MisR^{B}_{Stock}(X) * C^{True}_{Land}(B)$	Number (or yld) Misreport. C As X $MisR^{C}_{Stock}(X) * C^{True}_{Land}(C)$	Number (or yld) Misreport. D As X $MisR^{D}_{Stock}(X) * C^{True}_{Land}(D)$	Total Misreported $\sum_{i=1}^{St_{Max}} MisR^{i}_{Stock}(X) * C^{True}_{Land}(i)$
Stock A	1000	0	32	30	12	**74**
Stock B	800	50	0	72	36	**158**
Stock C	600	80	64	0	24	**168**
Stock D	400	70	40	0	0	**110**
Total Misreported *)		**200**	**136**	**102**	**72**	**510**
Stock (X)	True Landings	Total Simulated landings **)				
Stock A	1000	1126				
Stock B	800	778				
Stock C	600	534				
Stock D	400	362				
Total	**2800**	**2800**				

*) $\sum_{X=1}^{St_{Max}} MisR^{j}_{Stock}(X) * C^{True}_{Land}(j)$

**) $C^{Sim}_{Land}(St) = C^{True}_{Land}(St) + \sum_{i=1}^{St_{Max}} MisR^{i}_{Stock}(St) * C^{True}_{Land}(i) - \sum_{X=1}^{St_{Max}} MisR^{St}_{Stock}(X) * C^{True}_{Land}(St)$

Table D.4.1.3.4.a. Numerical example of stock-misreporting.

Or in case the basis for misreporting is yield (summed over age groups):

$$Y^{Simulated}_{Land}(Fl,Vs,Rg,Ct,CorrectSt,y,\bullet,q,Ar) = Y^{True}_{Land}(Fl,Vs,Rg,Ct,CorrectSt,y,\bullet,q,Ar) + Y^{Over\,Rep}_{X,Land}(Fl,Vs,Rg,Ct,CorrectSt,y,\bullet,q,Ar) - C^{Under\,Rep}_{X,Land}(Fl,Vs,Rg,Ct,CorrectSt,y,\bullet,q,Ar) - Y^{Mis}_{Black}(Fl,Vs,Rg,Ct,St,y,\bullet,q,Ar) \quad (4.1.3.6.b)$$

When actually calculating the effect of misreporting, it is done in the sequence indicated by Table D.4.1.3.3.

The number that appears in the output tables of TEMAS, the “simulated” numbers are the “true” numbers plus/minus misreporting. The simulated numbers are the input to ICES stock assessment.

Table D.4.1.3.4.a shows a numerical example of the computational procedure for stock-misreporting account. Note that eventually, the sum of misreported data is the same as the sum of the true data, 2800 fish (summed over 4 stocks).

Table D.4.1.3.4.b contains the same calculation as Table D.4.1.3.4.a, but now for 3 different areas. The results of table b is then transported to Table 4.1.3.5, which shows the a numerical example of area-misreporting for two of the four species.

All areas For each Fleet: (Fl,Vs,•,Ct)

Area A

CorrectAr		Area A	Area B	Area C	Area D
True Land.	True Land.	1000	800	600	400
Stock (X)	True Land.	Fraction of A misreported As X	Fraction of B misreported As X	Fraction of C misreported As X	Fraction of D misreported As X
Stock A	1000	0	0.04	0.05	0.03
Stock B	800	0.05	0	0.12	0.09
Stock C	600	0.08	0.08	0	0.06
Stock D	400	0.07	0.05	0	0
Total	**2800**	**0.20**	**0.17**	**0.17**	**0.18**

Area B

CorrectSt	Stock A	Stock B	Stock C	Stock D
True Land.	1000	800	600	400
True Land.	Fraction of A misreported As X	Fraction of B misreported As X	Fraction of C misreported As X	Fraction of D misreported As X
500	0	0.04	0.05	0
400	0.05	0	0.1	0.09
350	0.05	0.07	0	0.06
400	0.07	0.05	0.06	0
1650	**0.17**	**0.16**	**0.21**	**0.15**

Area C

Correct St	Stock A	Stock B	Stock C	Stock D
True Land.	1000	800	600	400
True Land.	Fraction of A misreported As X	Fraction of B misreported As X	Fraction of C misreported As X	Fraction of D misreported As X
1500	0	0.04	0.05	0.02
1100	0.06	0	0.1	0.09
900	0.05	0.07	0	0.04
750	0.07	0.05	0.08	0
4250	**0.18**	**0.16**	**0.23**	**0.15**

Area A

Stock (X)	True Land.	Number of A misreported As X	Number of B misreported As X	Number of C misreported As X	Number of D misreported As X	**Total number Misreported**
Stock A	1000	0	32	30	12	**74**
Stock B	800	50	0	72	36	**158**
Stock C	600	80	64	0	24	**168**
Stock D	400	70	40	0	0	**110**
Total	**2800**	**200**	**136**	**102**	**72**	**510**

Area B

True Land.	Number of A misreported As X	Number of B misreported As X	Number of C misreported As X	Number of D misreported As X	**Total number Misreported**
500	0	32	30	0	**62**
400	50	0	60	36	**146**
350	50	56	0	24	**130**
400	70	40	36	0	**146**
1650	**170**	**128**	**126**	**60**	**484**

Area C

True Land.	Number of A misreported As X	Number of B misreported As X	Number of C misreported As X	Number of D misreported As X	**Total number Misreported**
1500	0	32	30	8	**70**
1100	60	0	60	36	**156**
900	50	56	0	16	**122**
750	70	40	48	0	**158**
4250	**180**	**128**	**138**	**60**	**506**

True number landed

Stock (X)	Area A	Area B	Area C	Total
Stock A	1000	500	1500	3000
Stock B	800	400	1100	2300
Stock C	600	350	900	1850
Stock D	400	400	750	1550
Total	2800	1650	4250	8700

Simulated numbers landed

Stock (X)	Area A	Area B	Area C	Total
Stock A	1126	608	1610	3344
Stock B	778	382	1072	2232
Stock C	534	346	916	1796
Stock D	362	314	652	1328
Total	2800	1650	4250	8700

Table D.4.1.3.4.b. Numerical example of stock-misreporting for three areas (same calculations as for Table 4.1.3.4.a)

Stock A

	CorrectAr	Area A	Area B	Area C
	True Land.	1126	608	1610
Area (X)	True Land.	Fraction of A misre-ported As X	Fraction of B misre-ported As X	Fraction of C misre-ported As X
Area A	1126	**0**	0.17	0.15
Area B	608	0.22	**0**	0.12
Area C	1610	0.28	0.15	**0**
Total	**3344**	**0.50**	**0.32**	**0.27**

Stock B

CorrectAr	Area A	Area B	Area C
True Land.	778	382	1072
True Land.	Fraction of A misre-ported As X	Fraction of B misre-ported As X	Fraction of C misre-ported As X
778	**0**	0.17	0.15
382	0.22	**0**	0.12
1072	0.28	0.15	**0**
2232	**0.50**	**0.32**	**0.27**

Stock A

Area (X)	True Land.	Number of A misre-ported As X	Number of B misre-ported As X	Number of C misre-ported As X	**Total number Misreported**
Area A	1126	**0**	103.36	241.5	**344.86**
Area B	608	247.72	**0**	193.2	**440.92**
Area C	1610	315.28	91.2	**0**	**406.48**
Total	**3344**	**563.00**	**194.56**	**434.70**	**1192.26**

Stock B

True Land.	Number of A misre-ported As X	Number of B misre-ported As X	Number of C misre-ported As X	**Total number Misreported**
778	**0**	103.36	241.5	**344.86**
382	247.72	**0**	193.2	**440.92**
1072	315.28	91.2	**0**	**406.48**
2232	**563.00**	**194.56**	**434.70**	**1192.26**

Stock A

Area (X)	True Land.	**Total Simulated Number**
Area A	1126	**1344**
Area B	608	**362**
Area C	1610	**1638**
Total	**3344**	**3344**

Stock B

True Land.	**Total Simulated Number**
778	**996**
382	**136**
1072	**1100**
2232	**2232**

Table 4.1.3.5. Numerical example of area-misreporting for two species (continuation of Table 4.1.3.4.b)

D.4.2. SIMULATION OF CURRENT ASSESSMENT BY AN ICES WG

The VPA of TEMAS is the traditional VPA[7] (Derzhavin, 1922, Fry, 1949). A resent summary of the contemporary practice of VPA is given in Lassen & Medley, 2001. Input is the numbers caught by all fleets (landings + discards) and terminal Fs, as is illustrated by the example:

Age/year	1994	1995	1996	1997	1998	1999
0	C(1994,0)	C(1995,0)	C(1995,0)	C(1997,0)	C(1998,0)	C(1999,0)
1	C(1994,1)	C(1995,1)	C(1995,1)	C(1997,1)	C(1998,1)	C(1999,1)
2	C(1994,2)	C(1995,2)	C(1995,2)	C(1997,2)	C(1998,2)	C(1999,2)
3	C(1994,3)	C(1995,3)	C(1995,3)	C(1997,3)	C(1998,3)	C(1999,3)
4	C(1994,4)	C(1995,4)	C(1995,4)	C(1997,4)	C(1998,4)	C(1999,4)
5	C(1994,5)	C(1995,5)	C(1995,5)	C(1997,5)	C(1998,5)	C(1999,5)
6+	C(1994,6)	C(1995,6)	C(1995,6)	C(1997,6)	C(1998,6)	C(1999,6)

Age/year	1994	1995	1996	1997	1998	1999
0						**F(1999,0)**
1						**F(1999,1)**
2						**F(1999,2)**
3						**F(1999,3)**
4						**F(1999,4)**
5	**F(1994,5)**	**F(1995,5)**	**F(1995,5)**	**F(1997,5)**	**F(1998,5)**	**F(1999,5)**
6+						

Ideally, the input should be catch (Landings + Discards), but in practice, often the catch is not know, only the landings are observed. Therefore, TEMAS contains the option to let input to VPA be catch or landings. The option is fleet specific in TEMAS.

The simulated input, C_{VPA}, comes from the operational model, by summation over the predicted catches

$$C_{VPA}(St,y,a) = C(\bullet,\bullet,\bullet,\bullet,St,y,a,\bullet,\bullet) = C_{Land}(-) + C_{Disc}(-)$$

$$\sum_{Ar=1}^{Ar_{Max}} \sum_{Ct=1}^{Ct_{Max}} \sum_{F=1l}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} \sum_{q=1}^{q_{Max}} C(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \qquad \text{(D.4.2.1.a)}$$

or the VPA input can be only the landings

$$C_{VPA}(St,y,a) = C_{Land}(\bullet,\bullet,\bullet,\bullet,St,y,a,\bullet,\bullet) \qquad \text{(D.4.2.1.b)}$$

The VPA is thus an annual VPA, although TEMAS could provide input for a quarterly VPA.

[7] The methodology of ICES has (more or less) remained unchanged since the very start of the advisory function of ICES. Only one attempt to create a milestones in the ICES FSA (Fish Stock Assessment) methodology has occurred since 1956. The attempted milestone was the multispecies model by Andersen and Ursin (1977), which exploited stomach content data. The multispecies model was implemented by ICES in the form of the "MSVPA" (Multi-Species VPA, Sparre 1991) and Multispecies Forecast "MSFOR". Although MSVPA & MSFOR have had some limited use in ICES, they never developed into an ICES standard methodology. Then there was the introduction of the so-called "VPA-tuning". The "Single-Species Tuned VPA" has become the standard methodology of ICES fish stock assessment. Numerous scientific papers on VPA-tuning were published, and a suite of different versions were applied in ICES WGs. The most striking feature of ICES's inability to introduce innovation in its system is the fact that ICES WGs are still operating with single species methodology.

Actually, the Fs of the second oldest age group is not really input, but is computed by the VPA as the mean value of some younger age groups. The specification of this mean value calculation (which age groups) is made by the input parameters.

Outputs are Fishing mortalities and stock numbers as illustrated by the example:

Age/year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
0	F(1994,0)	F(1995,0)	F(1995,0)	F(1997,0)	F(1998,0)	
1	F(1994,1)	F(1995,1)	F(1995,1)	F(1997,1)	F(1998,1)	
2	F(1994,2)	F(1995,2)	F(1995,2)	F(1997,2)	F(1998,2)	
3	F(1994,3)	F(1995,3)	F(1995,3)	F(1997,3)	F(1998,3)	
4	F(1994,4)	F(1995,4)	F(1995,4)	F(1997,4)	F(1998,4)	
5						
6+	*F(1994,6)*	*F(1995,6)*	*F(1995,6)*	*F(1997,6)*	*F(1998,6)*	*F(1999,6)*

Age/year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
0	N(1994,0)	N(1995,0)	N(1995,0)	N(1997,0)	N(1998,0)	**N(1999,0)**
1	N(1994,1)	N(1995,1)	N(1995,1)	N(1997,1)	N(1998,1)	**N(1999,1)**
2	N(1994,2)	N(1995,2)	N(1995,2)	N(1997,2)	N(1998,2)	**N(1999,2)**
3	N(1994,3)	N(1995,3)	N(1995,3)	N(1997,3)	N(1998,3)	**N(1999,3)**
4	N(1994,4)	N(1995,4)	N(1995,4)	N(1997,4)	N(1998,4)	**N(1999,4)**
5	**N(1994,5)**	**N(1995,5)**	**N(1995,5)**	**N(1997,5)**	**N(1998,5)**	**N(1999,5)**
6+	*N(1994,6)*	*N(1995,6)*	*N(1995,6)*	*N(1997,6)*	*N(1998,6)*	*N(1999,6)*

The F_{VPA}s are found by solving the "backward" VPA equation for F, cohort by cohort:

$$\frac{C_{VPA}(St,y,a)}{N_{VPA}(St,y+1,a+1)} = \left\{\exp\left[\ F_{VPA}(St,y,a)+M(St,a)\ \right]+1\right\} * \frac{F_{VPA}(St,a,y)}{F_{VPA}(St,y,a)+M(St,a)} \qquad \text{(D.2.2.2)}$$

TEMAS uses ordinary Newton iteration to solve the non-linear equation. Thus, TEMAS does not use, say, "separable VPA", as is customary in some ICES methods, the reason being that it would not matter much in the present context if one method or another method is used. Therefore, the simplest solution for computation is chosen.

The F of the two oldest age groups are not computed by solving the VPA equation (as indicated by the arrows on the N-table above). For the second oldest age group is used:

$$F_{VPA}(St,y,a_{\max}(st)-1)) = \frac{1}{a_{TF-last} - a_{TF-first} + 1} \sum_{a=a_{TF-first}}^{a_{TF-last}} F_{VPA}(St,y,a) \qquad \text{(D.2.2.3)}$$

where a_{first} and a_{last} are input parameters to VPA.

The oldest age group, the plus-group gets the same fishing mortality as the second oldest age group.

$$F_{VPA}(St,y,a_{\max}(st))) = F_{VPA}(St,y,a_{\max}(st)-1)) \qquad \text{(D.2.2.4)}$$

The terminal F, that is, the F of the last data year is in ICES assessment usually derived from some indices of F or indices of N (e.g. young fish survey results). Taking into account the uncertainly involved in predicting F (or N) from survey indices, TEMAS does something similar to using an F index. It uses the F predicted by the forecast program (see next section) multiplied by a stochastic factor:

$$F_{VPA}(St,Y_{Last},a) = F_{FOR}(St,2,a) * \frac{\{\ \varepsilon_{TF-Year}(St) * W_{\varepsilon-Year} + \varepsilon_{TF-age}(St,a)\ \}}{(W_{\varepsilon-Year} + 1)} \quad \text{(D.2.2.5)}$$

where

$\varepsilon_{TF\text{-}Age}(St,a)$	Stochastic factor of terminal F in VPA accounting for the age-group-effect, of stock "St", a stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation $\sigma_{TF\text{-}Age}$.
$\sigma_{TF\text{-}Age}(St)$	Standard deviation for stochastic age-group-effect factor of terminal F in VPA
$W_{\varepsilon\text{-}Year}$	Weight of year effect the stochastic factor for terminal F in VPA (input parameter).
$\varepsilon_{TF\text{-}Year}(St)$	Stochastic factor of terminal F in VPA accounting for the year-effect, of stock "St", a stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation $\sigma_{TF\text{-}Year}$.
$\sigma_{TF\text{-}Year}(St)$	Standard deviation for stochastic year-effect factor of terminal F in VPA

The randomly drawn year effect is the same for all age groups.

The F predicted in the forecast is the F predicted in year Y_{last} –1. The forecast is always one year "behind" as the prediction is made for last data year + 1.

The mean fishing mortality to be used in the ICES Harvest Control Rule may either co computed as the straight mean value

$$F_{VPA-MEAN}(St,y) = \frac{1}{a_{Fmen-last} - a_{Fmean-first} + 1} \sum_{a=a_{Fmean-first}}^{a_{Fmean-last}} F_{VPA}(St,y,a) \quad \text{(D.2.2.6.a)}$$

or it may be computed as the weighted mean, where the weighing factors are the stock numbers.

$$F_{VPA-WMEAN}(St,y) = \frac{\sum_{a=a_{Fmean-first}}^{a_{Fmean-last}} F_{VPA}(St,y,a) * N_{VPA}(St,y,a)}{\sum_{a=a_{Fmean-first}}^{a_{Fmean-last}} N_{VPA}(St,y,a)} \quad \text{(D.2.2.6.b)}$$

where

$a_{Fmean\text{-}first}$ = First age group used to compute the mean F_{VPA}
$a_{Fmean\text{-}last}$ = Last age group used to compute the mean F_{VPA}

The spawning stock biomass in VPA is computed as the biomass at the beginning of the year:

$$SSB_{VPA}(St,y) = \sum_{a=0}^{a_{\max}(St)} N_{VPA}(St,y,a) * Wgt(St,a) * Mat(St,a) \quad \text{(D.2.2.7)}$$

This SSB concept of ICES WGs should not be mixed up with concept "SSB of the reproductive volume", which is used in the operational model only.

D.4.3. SIMULATION OF ICES FORECAST

The traditional ICES forecast model (the Thompson & Bell Model, 1934) is the same as the simulation model, but with no stochastic factors. It predicts the stock and the fishery of all combined fleets for two years. The predicted yield is based on F derived from the harvest control rule for each stock, the predicted yield is used as TAC in the simulation model.

D.4.3.1. FORECAST MODEL

The forecast is illustrated in Table D.4.3.1.1 as a continuation of the VPA. In this case the working group meeting takes place in 2000, and the last (full) data-year is 1999. Year 2001 is the year for which the ICES WG is to set the TAC (the future TAC). However, as fishery of year 2000 has not been completed, the WG has to make also a prediction for 2000 (the present TAC).

	Past (History)						Present	Future
Age/ year	1994 VPA	1995 VPA	1996 VPA	1997 VPA	1998 VPA	1999 VPA	2000 WG-Year	2001 TAC-year
0	N(1994,0)	N(1995,0)	N(1995,0)	N(1997,0)	N(1998,0)	N(1999,0)	N(2000,0)	N(2001,0)
1	N(1994,1)	N(1995,1)	N(1995,1)	N(1997,1)	N(1998,1)	N(1999,1)	N(2000,1)	N(2001,1)
2	N(1994,2)	N(1995,2)	N(1995,2)	N(1997,2)	N(1998,2)	N(1999,2)	N(2000,2)	N(2001,2)
3	N(1994,3)	N(1995,3)	N(1995,3)	N(1997,3)	N(1998,3)	N(1999,3)	N(2000,3)	N(2001,3)
4	N(1994,4)	N(1995,4)	N(1995,4)	N(1997,4)	N(1998,4)	N(1999,4)	N(2000,4)	N(2001,4)
5	**N(1994,5)**	**N(1995,5)**	**N(1995,5)**	**N(1997,5)**	**N(1998,5)**	N(1999,5)	N(2000,5)	N(2001,5)
6+	*N(1994,6)*	*N(1995,6)*	*N(1995,6)*	*N(1997,6)*	*N(1998,6)*	*N(1999,6)*	*N(2000,6)*	*N(2001,6)*

Table D.4.3.1.1. Illustration of the ICES forecast procedure.

The fishing mortality for year 2000 can be assumed to the taste of the WG. For example, the WG may assume that the TAC decided for 2000 in the 1999 assessment may equal the catch in year 2000, and they may assume that fishing pattern (the relative fishing mortality at age) in 2000 remains the same as that of 1999., so that for ages there is a factor, x_{2000}, that relates the fishing mortality for ages by $F(2000,a) = x_{2000} * F(1999,a)$ and that x_{2000}, is given a value so that the TAC equals the Yield

$$\sum_{a=0}^{a_{Max}} C(2000,a)*Wgt(a) = \sum_{a=0}^{a_{Max}} \frac{x_{2000} * F(1999,a)}{x_{2000} * F(1999,a) + M} (N(1999,a-1) - N(2000,a))*Wgt(a) = TAC(2000)$$

where the shock numbers a the beginning of year 2000 becomes
$N(2000,a)=N(1999,a-1)*\exp(-M-x_{2000}*F(1999,a-1))$

The F of the following year, the TAC year, can be chosen to equal the F_{PA}, that is with $x_{2001} = 1$ in

$$\sum_{a=0}^{a_{Max}} C(2001,a)*Wgt(a) = \sum_{a=0}^{a_{Max}} \frac{x_{2001} * F_{PA}(1999,a)}{x_{2001} * F_{PA}(1999,a) + M} (N(2000,a-1) - N(2001,a))*Wgt(a) = TAC(2001)$$

where $N(2001,a)=N(2000,a-1)*\exp(-M-x_{2001}F(2000,a-1))$

It is customary in ICES WG to give a table showing the predicted catch for a suite of x_{2001}-values. The recruitment, N(2000,0) and N(2001,0) is often taken as the overage estimated recruitment or in the case of the “present” year, 2000, from a survey-based index.

Figure D.4.3.1.2. illustrates the interaction between the VPA, the FORECAST and the operational model in TEMAS. The first logical step in TEMAS's simulation of management advice, is the VPA, which is followed by the FORECAST and subsequent application of HCR (Harvest Control Rule) to compute the F_{HCR} and the corresponding TAC for next year. In the TEMAS, however, the F_{HCR} is also used as a parameter in the stochastic simulation of the F in the operational model. The solid arrows indicates that the simulation is stochastic, where the mean value of the stochastic fishing mortality is derived from the forecast model. The philosophy behind this (somehow weird approach) is that we assume some relationship between ICES assessment and the real world.

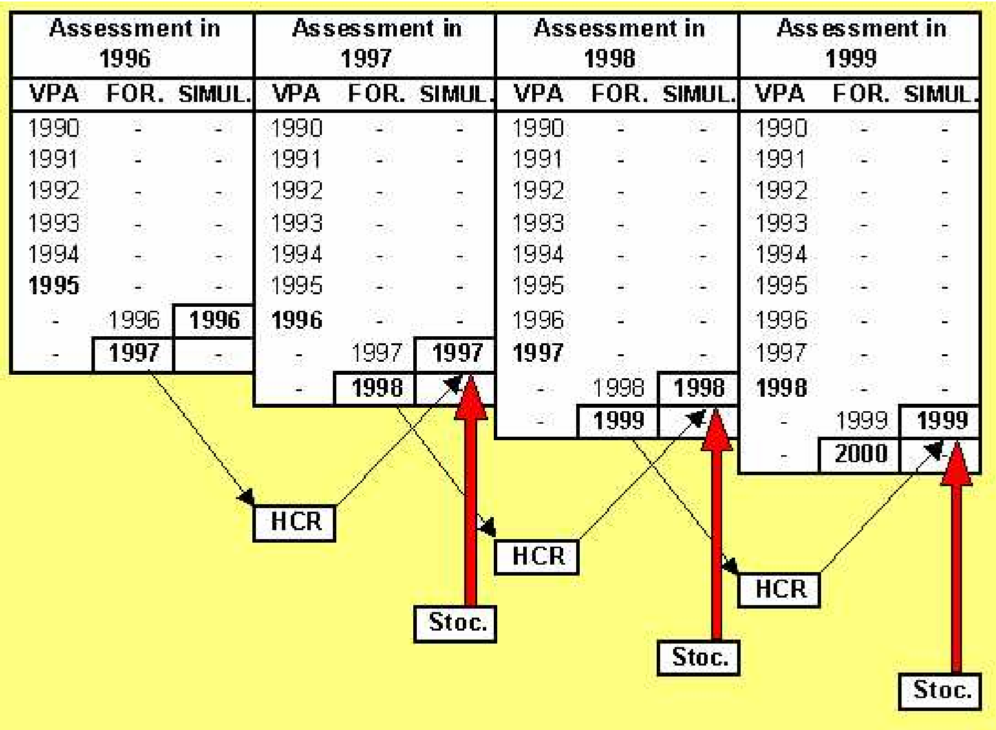

Figure D.4.3.1.2. The years for which new results are produced by TEMAS in each year-step (each assessment year). The columns ""SIMUL." indicate the simulation of data by the operational model.

In TEMAS, survey indices of year class strength are not applied. The recruitment of the two future years, are derived from the VPA-estimates of recruitment, as the "overage historical recruitment".

$$\mathrm{Re}\,c(St, Future\ \ year) = \frac{1}{Last\ \ VPA\ \ year - First\ \ VPA\ \ year + 1} \sum_{y=FirstVPAyear}^{LastVPAyear-1} N_{VPA}(St, y, 0) \qquad \text{(D.4.3.1.1)}$$

The same recruitment is used for both forecast years. This part of the ICES assessment is always highly questionable, and it is not considered worthwhile to elaborate on an assessment detail, that is so unstable. And furthermore, for most stocks the prediction of the juveniles have little impact on the TAC for the two following years. For the long term the recruitment numbers matter.

D.4.3.2. HARVEST CONTROL RULE OF ICES

The Harvest control rule is implemented by assigning a value, F_{HCR},to the mean fishing mortality in the forecast program, $F_{FOR\text{-}Mean}$(St,y+2), The forecast is made in year y+1 (this year) , based on data in last data year, y, for next year, "y+2" : F_{HCR} (St,y+2) = $F_{FOR\text{-}Mean}$(St,y+2). The mathematical expression for the ICES harvest control rule, with all indices, reads.

$$F_{HCR}(St,y+2)=\begin{cases}0 \ \ if \ \ SSB(St.y)\le B_{\lim}(St)\\ F_{pa}(St)\dfrac{SSB(St,y)-B_{\lim}}{B_{pa}(St)-B_{\lim}(St)} \ \ if \ \ B_{\lim}(St)\le SSB(St,y)\le B_{pa}(St)\\ F_{pa}(St) \ \ if \ \ SSB(St,y)>B_{pa}\end{cases} \qquad \text{(D.4.3.2.1)}$$

That means that the F dictated by the HCR is used in the catch prediction "next year" relative to the assessment year, y+1. Year y is the last "data-year". The same HCR dictated fishing mortality derived foregoing year is used in the simulation model for the "current" year, that is, the year of the ICES assessment (y+1).

The F_{HCR} is also used as a parameter (the mean value) in the distribution from which F_{SIM} is drawn.

D.4.3.3. HARVEST CONTROL RULE UNDER CATCH QUOTA REGIME

The F_{HCR} of the HCR is converted into a TAC for the quota management regime

$$TAC(St,y)=\sum_{a=o}^{a_{Max}(St)} C_{FOR}(St,y,a)*w(St,y,a) \qquad \text{(D.4.3.3.1.a)}$$

which will be applied in the simulation model to stop the fishery under quota regime, if the TAC is exceeded. In practice, however, the TAC is often counted against the landings
In section D.6 we shall introduce the concept of "Adaptive approach TAC", that is, a TAC that is not allowed to deviate more that a certain percentage from the TAC of foregoing year.

The catch is divided into landings and discards, and the condition for quota management now becomes

$$TAC(St,y)\ge \sum_{a=o}^{a_{Max}(St)}\sum_{Ct=1}^{Ct_{Max}}\sum_{Fl=1}^{Fl_{Max}(Ct)}\sum_{Vs=1}^{Vs(Fl,Ct)}\sum_{Rg=1}^{Rg_{Max}(Fl,Ct)}\sum_{Ar=1}^{Ar_{Max}} C_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)*w(St,y,a,q) \qquad \text{(D.4.3.3.2)}$$

Technically, the TEMAS program does not search for the F that produces a given TAC. It starts with the F_{PA} and from that it produces the "right" TAC. The overall F_{PA}, is subsequently distributed on countries, fleets, riggings and areas, and the combined landings will automatically sum up to the desired TAC.

If the effort corresponding to F_{PA} exceeds the capacity of the fleets,

$$E(Fl,Vs,\bullet,Ct,y,q,\bullet)\le NU_{Vessel}(Fl,Vs,Ct,y,q)*EY_{Max}(Fl,Vs,Ct,y,q) \qquad \text{(D.4.3.3.3)}$$

then fishing mortality is reduced below F_{PA}, with the reduction factor

$$E(Fl,Vs,\bullet,Ct,y,q,\bullet)/NU_{Vessel}(Fl,Vs,Ct,y,q)*EY_{Max}(Fl,Vs,Ct,y,q)$$

That is, no F can be bigger than the maximum capacity allows for. The capacity conditions converted into fishing mortality, involves two more indices, namely rigging and area

$$\sum_{Ar=}^{Ar_{Max}} \sum_{Rg=1}^{Rg_{Max}} F_{a-MAX}(Fl,Vs,Rg,Ct,St,y,q,Ar) \quad =$$

$$\sum_{Ar=1}^{Ar_{Max}} \sum_{Rg=1}^{Rg_{Max}} E(Fl,Vs,\bullet,Ct,y,Ar) * E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,Ar) *$$

$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \leq \quad NU_{Vessel}(Fl,Vs,Ct,y) * EY_{Max}(Fl,Vs,Ct,y) * \qquad \text{(D.4.3.3.4)}$$

$$\sum_{Ar=}^{Ar_{Max}} \sum_{Rg=1}^{Rg_{Max}} E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

where "a-MAX" refers to maximum over age groups, recall Eq. A.5.1.8. :

$$F_{a-MAX}(Fl,Vs,Rg,Ct,St,y,q,Ar) = MAX_a \{ \; F(Fl,Vs,Rg,Ct,St,y,a,q,Ar) \; \}$$

TEMAS contains an option to distribute effort according to the relative stability, that is the distribution of effort is in the same proportions as the historical rights (see Section D.6).

D.4.3.4. HOW TO CONVERT TAC'S INTO EFFORT

The first step in converting the F_{HCR} into effort is rather hypothetical, in that introduce the concept of "Stock dependent-effort", E_{HCR}^{Stock} . The "stock-dependent-effort" is the effort you need to produce a certain fishing mortality on a given stock, disregarding all other activities of the fleet. Only in real clean, one-stock fisheries, one can observe "Stock-dependent-effort" in reality

$$E_{HCR}^{Stock}(Fl,Vs,Rg,Ct,St,y,q,Ar) = \frac{F_{HCR}(St,y) * F_{REL-MAX}(Fl,Vs,Rg,Ct,St,y,q,Ar)}{Q(Fl,Vs,Rg,Ct,St,y,q,Ar)} \qquad \text{(D.4.3.4.1)}$$

where Eqs. A.5.1.8,9-10 defined the relative maximum fishing mortality, over countries, fleets, vessel sizes and riggings,:

$$F_{REL-MAX}(Fl,Vs,Rg,Ct,St,y,q,Ar) =$$

$$F_{a-MAX}(Fl,Vs,Rg,Ct,St,y,q,Ar) / F_{a-Max}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar)$$

Note that $F_{REL-MAX}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = 1$ for all (St, y, q, Ar)

Thus, the fishing mortality is divided into fleet segments (partial fishing mortalities) by multiplication with the relative fishing mortality, F_{HCR}(St, y)*$F_{REL\text{-}MAX}$(Fl, Vs, Rg, Ct, St, y, q, Ar). The partial fishing mortality is then converted into stock-specific effort by dividing with the catchability coefficient.

Eq D.4.3.4.1 allocates a (usually different) effort value for each stock to a given fleet. To get a unique effort value, E(Fl,Vs,Rg,Ct,y,q,Ar) of a fleet, we must assume some rule for how the stock-dependent efforts are combined into one effort value[8]. We need therefore, to suggest a functional relationship between the stock-independent effort and the stock dependent effort:

[8] *Unfortunately, ICES, give us no guidance on this matter.*

$$E_{HCR}(Fl,Vs,Rg,Ct,y) = \text{Function}\{\ E^{Stock}_{HCR}(Fl,Vs,Rg,Ct,St=1,y), E^{Stock}_{HCR}(2Fl,Vs,Rg,Ct,St=2,y),....,E^{Stock}_{HCR}(Fl,Vs,Rg,Ct,St=St_{Max},y)\ \} \quad \text{(D.4.3.4.2)}$$

One such functional relationship could be the minimum value of the stock-dependent efforts:

$$E_{HCR}(Fl,Vs,Rg,Ct,y) = Min\{\ E^{stock}_{HCR}(Fl,Vs,Rg,Ct,St=1,y), E^{stock}_{HCR}(2,Fl,Vs,Rg,Ct,St=2,y),....,E^{stock}_{HCR}(Fl,Vs,Rg,Ct,St=St_{Max},y)\ \}$$
(D.4.3.4.3a)

another option is the maximum value:

$$E_{HCR}(Fl,Vs,Rg,Cty) = Max\{\ E^{Stock}_{HCR}(Fl,Vs,Rg,Ct,St=1,y), E^{Stock}_{HCR}(Fl,Vs,Rg,Ct,St=2,y),....,E^{Stock}_{HCR}(Fl,Vs,Rg,Ct,St=St_{Max}.y)\ \} \quad \text{(D.4.3.4.3b)}$$

The first approach would mean that fisheries is reduced or stopped as soon as the precautionary approach is exceeded for one stock and the other one that fishing is reduced or stopped only when the precautionary approach is exceeded for all stocks[9].

A third option could be some weighted average

$$E_{HCR}(Fl,Vs,Rg,Ct,y) = \frac{\sum_{St} E^{Stock}_{HCR}(Fl,Vs,Rg,Ct,St,y) * W_{FAC}(Fl,Vs,Rg,Ct,St,y)}{\sum_{St} W_{FAC}(Fl,Vs,Rg,Ct,St,y)} \quad \text{(D.4.3.4.3c)}$$

Where W_{FAC} is a weighting factor. Some possible options for W are

- W_{FAC} = Weight of landings last year of stock St
- W_{FAC} = Value of landings last year of stock St
- W_{FAC} = A politically assigned value for stock St.

The third option, the politically assigned weighing of stocks, could reflect some recovery plan for a stock of high priority, such as the cod in the North Sea.

The assumption behind Eq. D.4.3.4.3a-c, is that effort quotas can be set for riggings. Suppose we want to set effort quotas by fleet $E_{HCR}(Fl,Vs,\bullet,Ct,y)$, we want to predict the effort of a fleet for all rigging combined. That is, we look for version of Eq D.4.3.4.1 that combines all riggings

$$E^{Stock}_{HCR}(Fl,Vs,\bullet,Ct,St,y,q,Ar) = \frac{F_{HCR}(St,y) * F_{REL-MAX}(Fl,Vs,\bullet,Ct,St,y,q,Ar)}{Q_{Mean}(Fl,Vs,Ct,St,y,q,Ar)} \quad \text{(D.4.3.4.4)}$$

[9] *Actually we don't know what ICES thinks about these two extreme alternatives. Perhaps ICES would go for something in between. One could imagine that fishery would be stopped when on average the precautionary approach was exceeded. However, one might want to weight the stock-dependent efforts with the yield it represent, which would give another definition. One could also weigh by the stock biomass or by the value of the yield. In that case we would have to use the yield of an earlier year as weighing factor, as the effort is related to the yield. One can think of more options. The point here is that there are many options, and we have no idea on which one would be chosen in case ICES was forced to make a choice.*

In TEMAS, we have (more or less) arbitrarily chosen the weighted average for effort calculation in the case of catch quota management, because it is simple, and because it is a kind of compromise between the two extremes. But there is no real convincing argument for using that option. [10]

Setting effort quotas for fleets (all riggings combined) appears easier to implement (to control and enforce) than rigging based effort quotas. Controlling the activity of a vessel is a simpler job than controlling each individual gear rigging of the vessel.
The definition of the combined catchability, Q(Fl, Vs, •, Ct, St, y, q, Ar), is not obvious One simple option would be some weighted mean value over riggings

$$Q_{Mean}(Fl,Vs,Ct,St,y,q,Ar) = \frac{\sum_{Rg=1}^{Rg_{Max}} Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * Q_{Wgt}(Fl,Vs,Rg,Ct,St,y,q,Ar)}{\sum_{Rg=1}^{Rg_{Max}} Q_{Wgt}(Fl,Vs,Rg,Ct,St,y,q,Ar)} \quad \text{(D.4.3.4.5)}$$

Using the effort distribution of last year as weighting factor gives (the rig-distribution sums up to 1 over riggings)

$$Q_{Mean}^{Effort}(Fl,Vs,Ct,St,y,q,Ar) = \sum_{Rg=1}^{Rg_{Max}} Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * E_{Rig-Dist}(Fl,Vs,Rg,Ct,y-1,q,Ar) \quad \text{(D.4.3.4.6)}$$

This is the core idea of the method known as "F^3" or "F-cubed" (ICES SGMIXMAN, 2006, 2007). The F^3 method, predicts the catch by fleet and rigging one year ahead, and represents a suggestion for how ICES might implement fleet based advice. Figure. D.4.3.4.1. illustrates the F^3 method. The figure actually illustrates a family of methods in TEMAS, of which F^3 is one member. The left hand side of the figure illustrates the chronological steps in prediction of effort in year y based on

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[10] *The STECF WG (STECF, 2004) on mixed fisheries suggested a frame for the definition of fleet-based harvest control rules, named MTAC. The MTAC approach is to minimize the sum of squares of deviations (SSD) between the target fishing mortalities (defined by ICES) and the fishing mortalities advised by the fisheries management. The minimization of SSD is an approach similar to meeting the inequalities of foregoing Section. It will make some of the inequalities met and other will be violated, but altogether, it will attempt to minimize the "damage".*

$$F(Species\ A) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ A) \le F_{PA}(Species\ A)$$

$$F(Species\ B) = \sum_{Fleet} Effort(Fleet) * Catchability(Fleet,\ Species\ B) \le F_{PA}(Species\ B)$$

......etc......

That means that we allow some stock to violate the precautionary approach, but we try to minimize the violations. Meeting the inequality by species may have different priority for the managers. Some species may be more important than other. This can be accounted for by introduction of the so-called "decision weights". These are species specific numbers indicating how important a species is. The choice of "decision weights" is a political one, as no objective method for setting the value appears to be available. Another set of political inputs, are in the "effort-reduction rates" which determine how fast the effort of a fleet should be reduced. Furthermore, the model uses one more a priory (political) weighing factor, namely the so-called "relative importance of a species for a fleet" (the "fleet-target-factor"). Thus, the MTAC approach assumes that the "decision weights", "effort-reduction rates" and "fleet-target-factors" are given beforehand. There are no established rules for setting these inputs. The MTAC (Vinther et al, 2004) suggests 3 options for the effort reduction rates. This illustrates some of the problems encountered when approaching effort based regulation of fisheries. There is no established procedure for conversion of stock-based advice (catch quotas, TAC) to fleet based advice (Effort quotas). In general: There are no harvest control rules based on fleets and aiming at effort regulation.

the effort in forgoing year y-1. Two methods for effort prediction are suggested in Figure D.4.3.4.1, namely

1) Effort distribution in year y-1 assumed for year y (F-cubed)
2) Effort distribution given by a behaviour rule for fishers (the Random Utility Model)

The right hand side of the figure illustrates chronological steps the catch-prediction. The partial fishing mortalities are calculated from the catches in year y-1, which in turn are used to compute the catchability in year y-1, by division with the effort. This calculation of catchability may be made as the average over a suite of years (in the figure exemplified by mean over five years). The forecast of effort is then made by Eq D.4.3.4.6. Next step is "Forecast stock dependent effort", which can be made in different ways. In TEMAS one option is to use the "relative stability", that is to distribute the total F between fleets as the quota-shares are distributed (see Section D.6).
The quota-shares are usually distributed due to historical rights (relative stability). The F is then converted into stock-specific effort by division with the mean catchability. The allocated stock-specific effort then has to be converted into a management-effort due to some management rule (MR), such as "Min", "Max", or "weighted average" over stocks. Eventually the fishing mortality can be calculated for each combination of fleet and rigging (using the effort distribution of last year). To complete the total forecast, the figure as the last step computes the fleet and rigging specific discards.

TEMAS offers two more weighting options in addition to the F^3, namely the weight and the value of the landings:

$$Q^{Land}_{Mean}(Fl,Vs,Ct,St,y,q,Ar) =$$
$$\sum_{Rg=1}^{Rg_{Max}} Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * \frac{Y_{Land}(Fl,Vs,Rg,Ct,St,y-1,\bullet,Ar)}{Y_{Land}(Fl,Vs,\bullet,Ct,St,y-1,\bullet,Ar)} \quad \text{(D.4.3.4.7.a)}$$

$$Q^{VAL}_{Mean}(Fl,Vs,Ct,St,y,q,Ar) =$$
$$\sum_{Rg=1}^{Rg_{Max}} Q(Fl,Vs,Rg,Ct,St,y,q,Ar) * \frac{VAL(Fl,Vs,Rg,Ct,St,y-1,\bullet,Ar)}{VAL(Fl,Vs,\bullet,Ct,St,y-1,\bullet,Ar)} \quad \text{(D.4.3.4.7.b)}$$

They are both linked with the allocation of effort between fleets based on historical rights (relative stability, Section D.6), as the F^3-option.

TEMAS further extends the F-cubed method, in that it offers the effort distribution to be generated by a behaviour model, such as the random utility model (as indicated in the left hand side of Figure D.4.3.4.1.)

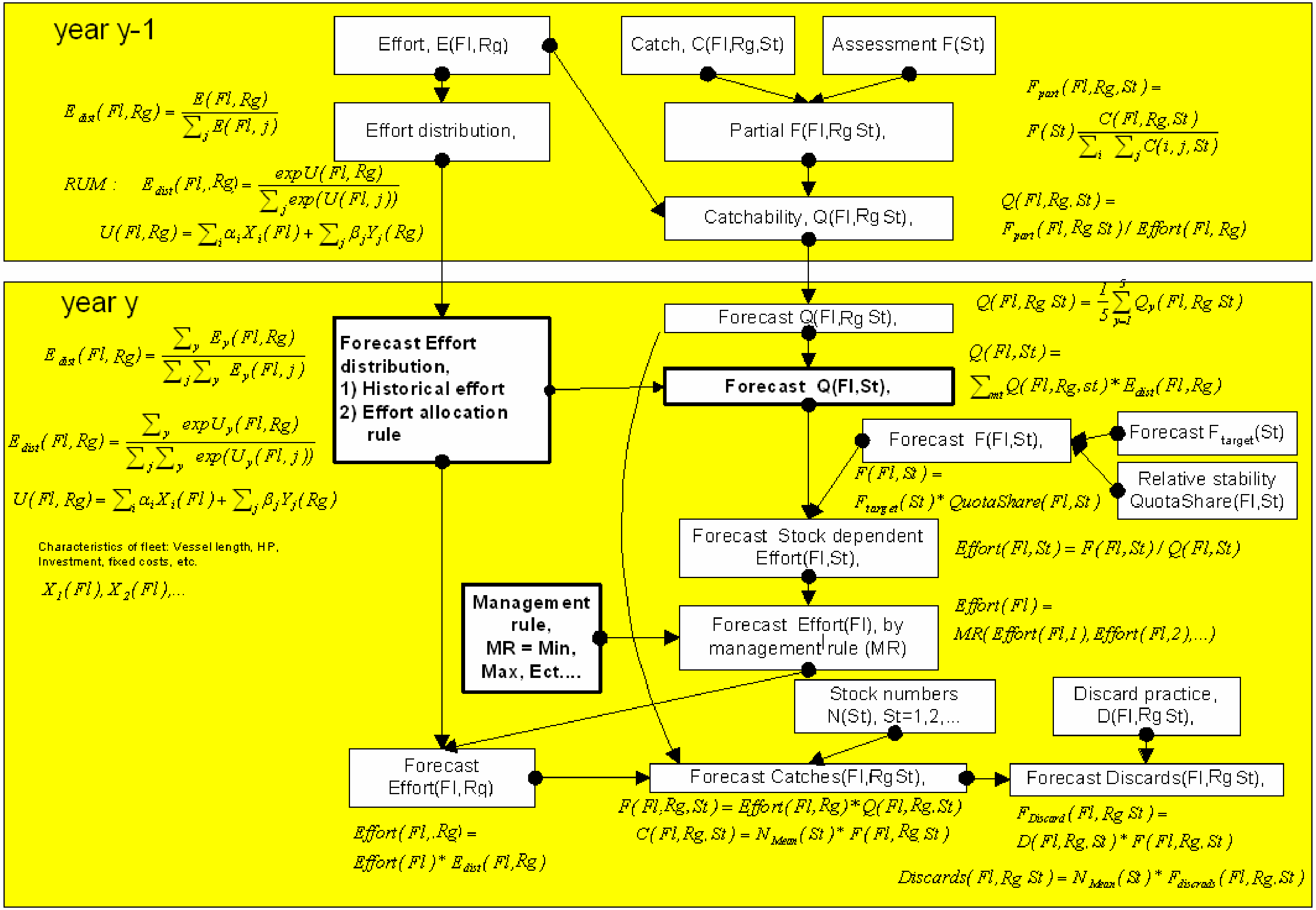

Figure. D.4.3.4.1. Fleet/rigging based catch prediction, exemplified by the F-cubed method (ICES, SGMIXMAN, 2007).

D.5. HARVEST CONTROL RULE UNDER EFFORT/MPA REGIME

The objective of this analysis of harvest control rules is to compare the traditional ICES approach to the modern HCR introduced by the EU commission, more or less independently of ICES. The management measures considered are "effort based management" and "MPA (Marine protected areas)", in conjunction with the so-called "adaptive approach". The effort based management measures have not been analysed by ICES, whereas the certain aspects of the biological background of MPAs have been addressed by special ICES WGs. The management aspects of MPA, however, has not been analysed by ICES WGs. Certain aspects of the new EU management measures have been analyzed by working groups under the STECF, but a full analyses do not exists, to the present authors knowledge.[11] The ultimate objective is to evaluate the ICES fish stock assessment as the basis for fisheries management relative to the modern management measures.

One problem we face here is that ICES never has formulated an effort based management strategy, so the ICES strategy is difficult to compare to the modern effort based management. We compensate by assuming that ICES has formulated such an effort based strategy, and then we compare the assumed ICES strategy to the modern strategy. To implement the effort based strategy are required suite of rules. These rules are used to decide on the management regulations. For example, when should management introduce a closed season? What are the events that releases the reduction/extension of a closed season?

Another problem is the "principle of relative stability", which is perhaps the most important element of EU management of fisheries, both in modern management and in the past, but which is largely ignored by the traditional ICES WG assessments. In practical EU management, the relative stability seems more important than the advice given by ICES. Naturally, the relative stability is also the cornerstone in the TEMAS simulation of modern EU management.

Here we assume that ICES has formulated a harvest control rule in terms of effort, "Effort-HCR". As an example of a hypothetical harvest control rule, we assume that this effort HCR is exactly the same as that for fishing mortality in the sense, that the "Effort-HCR" cannot violate the "F-HCR" for any stock. That means, that we (in this hypothetical example) assume that ICES will advice that the F-HCR is not exceeded for any stock.

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D.5.1. RELATIONSHIP BETWEEN F-HCR AND EFFORT

Using the single species HCR, for all stocks a set of fishing mortalities[12],

$$F_{HCR}^{Before}(St, y, Ar)\text{ , } St = 1,2,\ldots,St_{Max}$$

is achieved. For each stock one can then set the efforts of fleets to match each stock specific F:

$$F_{HCR}^{Before}(St,y,Ar) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} E_{St.Dep}^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \quad \text{for } St = 1,2,\ldots,St_{Max} \qquad \text{(D.5.1.1)}$$

The relative distribution of efforts on (Fl,Vs,Rg,Ct), i.e. $\frac{E(Fl,Vs,Rg,Ct)}{E(\bullet,\bullet,\bullet,\bullet)}$ is assume to be given, for example by the relative stability (historical rights, Section D.6) and a common factor is applied to all *(Fl,Vs,Rg,Ct)* to achieve $F_{HCR}^{Before}(St, y, Ar)$.

$$E_{St.Dep}^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar) = Factor_{St.Dep} * \frac{E(Fl,Vs,Rg,Ct)}{E(\bullet,\bullet,\bullet,\bullet)}$$

Eq. D.5.1.1 fix the effort for the HCR of only one particular stock, but we face the problem to make it valid for all stocks, for which there are HCR's.
The suffix "Before" refers to "Before the modifications of efforts to match the set of HCRs for all stocks combined". The $E_{St.Dep.}^{Before}$ has "St" index, so this (artificial) effort concept is stock specific.

The "after modification" the effort concept $E_{Not.St.Dep.}^{After}$ has no "St"-index, and the equal sign in Eq. D.5.1.1 is replaced by an "smaller than" sign in Eq. D.5.1.2.

$$F_{HCR}^{Before}(St,y,Ar) \geq \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} E_{Not.St.Dep}^{After}(Fl,Vs,Rg,Ct,y,q,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \quad \text{for } St = 1,2,\ldots,St_{Max} \qquad \text{(D.5.1.2)}$$

The equal sign in Eq. D.5.1.2 is achieved in Eq. D.5.1.3, which defines the "After modification" (or "homogenization") of fleet specific fishing mortality, F_{HCR}^{After}

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	Index	*Explanation*	*Range*
1	a	Age group	$a = 0,1,2,\ldots,a_{max}(St)$
2	Ar	Area	$Ar = 1,2,\ldots,Ar_{max}$
3	Ct	Country	$Ct = 1,\ldots,Ct_{Max}$
4	Fl	Fleet	$Fl = 1,2,\ldots,Fl_{max}(Ct)$
5	q	Time period (as time)	$q = 1,..,q_{max}$
6	qa	Time period (as age)	$qa = 1,..,q_{max}$,
7	Rg	Rigging of gear	$Rg = 1,\ldots,Rg_{max}(Fl,Ct)$
8	y	Year	$y = y_{firSt,\ yfirst}+1,\ldots,y_{last}$
9	St	Stock	$St = 1,\ldots,St_{max}$
10	Va	Vessel age group	$Va = 1,\ldots Va_{max}(Fl,Ct)$
11	Vs	Vessel size group	$Vs = 1,\ldots Vs_{max}(Fl,Ct)$

Note that the sequence of indices will be (Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar) for all variables.

Time variables in alphabetical order
dt: Basic time step (fraction of year). $dt < 1.0$. $dt = 1/q_{Max}$
y_{first} ,y_{last}: First year, Last year

Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j) = \sum_u X(i,u,j)$.

$$F_{HCR}^{After}(St,y,Ar) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} \quad \text{for } St = 1,2,\ldots,St_{Max} \qquad \text{(D.5.1.3)}$$

$$E_{Not.St.Dep.}^{After}(Fl,Vs,Rg,Ct,y,q,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

Thus $F_{HCR}^{Before} \geq F_{HCR}^{After}$

To summarise the "Before" and "After" concepts for fishing mortality and effort:

Concept	***Explanation***
Before	Before multispecies considerations
After	After multispecies considerations
$E_{St.Dep.}^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar)$	A set of efforts that produces exactly F_{HCR}^{Before} for one stock *St*, with given effort distribution on *(Fl,Vs,Rg,Ct)* , the single species concept.
$E_{Not.St.Dep.}^{After}(Fl,Vs,Rg,Ct,y,q,Ar)$	A set of efforts that produces F_{HCR}^{Before} for all stocks St = 1,…,St_{Max}, the multi species concept. Note that $E_{St.Dep}^{Before} \geq E_{Not.St.Dep}^{After}$
$F_{HCR}^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar)$	The F produced by $E_{St.Dep.}^{Before}$, the single species concept
$F_{HCR}^{After}(Fl,Vs,Rg,Ct,St,y,q,Ar)$	The F produced by $E_{Not.St.Dep.}^{After}$ the multi species concept. Note that $F_{HCR}^{Before} \geq F_{HCR}^{After}$

D.5.2. MODIFICATION OF EFFORT TO MATCH F-HCR

This section explains how the reduction factor to modify all Efforts in one go, must be a function of the set of all single species F_{HCR}'s.

Total single species F_{HCR} means the Fs summed over countries, fleets, vessel sizes and riggings.

$$F_{HCR}^{Before}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = \sum_{Ct=1}\sum_{Fl=1}\sum_{Vs=1}\sum_{Rg=1} F_{HCR}^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar) \qquad \text{(D.5.2.1)}$$

The total fishing mortality in a multispecies context is a function of the single species fishing mortalities

$$F_{HCR}^{After}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = \\ Function\begin{Bmatrix} F_{HCR}^{Before}(\bullet,\bullet,\bullet,\bullet,St=1,y,q,Ar), F_{HCR}^{Before}(\bullet,\bullet,\bullet,\bullet,St=2,y,q,Ar), \\ \ldots\ldots.., \quad F_{HCR}^{Before}(\bullet,\bullet,\bullet,\bullet,St=St_{Max},y,q,Ar) \end{Bmatrix} \qquad \text{(D.5.2.2)}$$

A		**Effort Factor**	*Ref.E(Fl=1)*	*Ref.E(Fl=2)*	*Ref.E(Fl=3)*	*Ref.E(Fl=4)*	
		0.3	**1000**	**2000**	**3000**	**4000**	
			E(Fl=1)=	***E(Fl=2)***	***E(Fl=3)***	***E(Fl=4)***	$E^{After}_{Not.St.Dep.}$
St	***Effort =Factor*Ref.Effort***		**300**	**600**	**900**	**1200**	
1	*Q(Fl,St=1)*		0.000100	0.000090	0.000080	0.00007	
2	*Q(Fl,St=2)*		0.000085	0.000100	0.000090	0.00008	
3	*Q(Fl,St=3)*		0.000075	0.000085	0.000100	0.00009	
4	*Q(Fl,St=4)*		0.000065	0.000075	0.000085	0.00010	
St	F_{HCR}	***Total F = Total Q*E***	**F=Q*E**	**F=Q*E**	**F=Q*E**	**F=Q*E**	**(Total Q*E)-(F_{HCR})**
1	***0.5***	***0.4675***	0.030000	0.11250	0.15000	0.17500	**-0.03250**
2	***0.6***	***0.5469***	0.053125	0.12500	0.16875	0.20000	**-0.05313**
3	***0.7***	***0.5656***	0.046875	0.10625	0.18750	0.22500	**-0.13438**
4	***0.6***	***0.5437***	0.040625	0.09375	0.159375	0.25000	**-0.05625**
			Max (Total Q*E)-(F_{HCR})				**-0.03250**

B		**Effort Factor**	*Ref.E(Fl=1)*	*Ref.E(Fl=2)*	*Ref.E(Fl=3)*	*Ref.E(Fl=4)*	
		0.8	**1000**	**2000**	**3000**	**4000**	
	$E^{After}_{Not.St.Dep.}$		***E(Fl=1)=***	***E(Fl=2)***	***E(Fl=3)***	***E(Fl=4)***	$E^{After}_{Not.St.Dep.}$
St	***Effort =Factor*Ref.Effort***		**800**	**1600**	**2400**	**3200**	
1	*Q(Fl,St=1)*		0.000100	0.000090	0.000080	0.00007	
2	*Q(Fl,St=2)*		0.000085	0.000100	0.000090	0.00008	
3	*Q(Fl,St=3)*		0.000075	0.000085	0.000100	0.00009	
4	*Q(Fl,St=4)*		0.000065	0.000075	0.000085	0.00010	
St	F_{HCR}	***Total F = Total Q*E***	**F=Q*E**	**F=Q*E**	**F=Q*E**	**F=Q*E**	**(Total Q*E)-(F_{HCR})**
1	***0.5***	***0.5175***	0.080000	0.11250	0.150000	0.17500	**0.01750**
2	***0.6***	***0.5469***	0.053125	0.12500	0.168750	0.20000	**-0.05313**
3	***0.7***	***0.5656***	0.046875	0.10625	0.187500	0.22500	**-0.13438**
4	***0.6***	***0.5437***	0.040625	0.09375	0.159375	0.25000	**-0.05625**
			Max (Total Q*E)-(F_{HCR})				**0.01750**

C		**Effort Factor**	*Ref.E(Fl=1)*	*Ref.E(Fl=2)*	*Ref.E(Fl=3)*	*Ref.E(Fl=4)*	
		0.625	**1000**	**2000**	**3000**	**4000**	
			E(Fl=1)	***E(Fl=2)***	***E(Fl=3)***	***E(Fl=4)***	$E^{After}_{Not.St.Dep.}$
St	***Effort =Factor*Ref.Effort***		**625**	**1250**	**1875**	**2500**	
1	*Q(Fl,St=1)*		0.000001	0.000009	0.00008	0.00007	
2	*Q(Fl,St=2)*		0.000085	0.000001	0.00009	0.00008	
3	*Q(Fl,St=3)*		0.000075	0.000085	0.00001	0.00009	
4	*Q(Fl,St=4)*		0.000065	0.000075	0.000085	0.00001	
St	F_{HCR}	***Total F = Total Q*E***	**F=Q*E**	**F=Q*E**	**F=Q*E**	**F=Q*E**	**(Total Q*E)-(F_{HCR})**
1	***0.5***	***0.5000***	0.062500	0.11250	0.150000	0.175000	**0.00000**
2	***0.6***	***0.5469***	0.053125	0.12500	0.168750	0.200000	**-0.05313**
3	***0.7***	***0.5656***	0.046875	0.10625	0.187500	0.225000	**-0.13438**
4	***0.6***	***0.5437***	0.040625	0.09375	0.159375	0.250000	**-0.05625**
			Max (Total Q*E)-(F_{HCR})				**0.00000**

Table D.5.2.1. Illustration of solving the equation D.5.2.3.

This is the F_{HCR} for a particular stock, defined so that it is not in conflict with the F_{HCR} of any other stock. Conflicts occur because the different F_{HCR} are created by the same fleet efforts
An example (introduced in section D.4.3) is the "maximum requirement", that all HCR are fulfilled. In this simple example, we assume that the relative distribution of effort on (Fl,Vs,Gg,Ct) remain constant. That is, we assume a fixed reference effort $E^{\mathrm{Re}\,f}_{Not.St.Dep.}(Fl,Vs,Rg,Ct,y,q,Ar)$ and assume that effort can be changed only by one common factor (application of the "the relative stability" with respect of effort), $X_{E.Factor} * E^{\mathrm{Re}\,f}_{Not.St.Dep.}(Fl,Vs,Rg,Ct,y,q,Ar)$

Then, to find the level of effort that meets all HCRs is equivalent to solving the equation

$$0 = MAX_{u=Stock}\left\{ \left\{ \begin{array}{l} \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct} X_{E.Factor} * \\ E^{After}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) * Q(Fl,Vs,Rg,Ct,u,y,q,Ar) \end{array} \right\} - F_{HCR}(u,Ar) \right\} \quad \text{(D.5.2.3)}$$

With respect of $X_{E.Factor}$. Table 5.2.1 shows a example of solving Eq D.5.2.3, by iteration. Table A shows the calculation of MIN with $X_{E.Factor}$=0.3 which gives a negative MIN, Table B with $X_{E.Factor}$=0.8 give a positive MIN, whereas, eventually Table C with $X_{E.Factor}$=0.65 is just right, giving a MIN of zero.

If trying to meet the F_{HCR} for all stocks, this could be achieved (for example) by letting the effort factor be fleet dependent $X_{E.Factor}(Fl,Vs,Rg,Ct)$, and then be minimizing the sum of absolute deviations between F_{HCR} and the generated fishing mortality. This leads to the minimization problem:

$$Minimum = \sum_{u=1(Stock)}^{St_{Max}} abs\left\{ \left\{ \begin{array}{l} \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct} X_{E.Factor}(Fl,Vs,Rg,Ct) * \\ E^{After}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) * Q(Fl,Vs,Rg,Ct,u,y,q,Ar) \end{array} \right\} - F_{HCR}(u,Ar) \right\} \quad \text{(D.5.2.4)}$$

One can easily solve the problem corresponding to Table D.5.2.1 (e.g. by the “solver” in EXCEL). The solution is shown in Table D.5.2.2. The solution is reasonable, with respect of finding F that matches the F_{HCR} for all four species. Stock one has a too high F, but the others are not too far from the goal. However, this example illustrates the problem of letting the factors vary freely between fleets. It allocates no effort to fleets 1 and 2, very little to fleet 4, whereas fleet 3 gets almost all the available effort. For many reasons (e.g. the relative stability) such solutions cannot be accepted in the real world.

With fleet specific effort factors			*Factor (Fl=1)*	*Factor (Fl=2)*	*Factor (Fl=2)*	*Factor (Fl=2)*	$E^{After}_{Not.St.Dep.}$
			0	**0**	**2.33**	**0.01**	
			Ref-Effort	Ref-Effort	Ref-Effort	Ref-Effort	
			1000	2000	3000	4000	
			E(Fl=1)	*E(Fl=2)*	*E(Fl=3)*	*E(Fl=4)*	
St		*Effort*	0	0	6977	25	
1		*Q(St=1)*	0.000100	0.000090	0.000080	0.000070	
2		*Q(St=2)*	0.000085	0.000100	0.000090	0.000080	
3		*Q(St=3)*	0.000075	0.000085	0.000100	0.000090	
4		*Q(St=4)*	0.000065	0.000075	0.000085	0.000100	
St	*F_{HCR}*	*Total F*	F=Q*E	F=Q*E	F=Q*E	F=Q*E	Abs((Total QE)-(F_{HCR}))
1	*0.5*	*0.560*	0.0000	0.0000	0.5582	0.0018	0.05995
2	*0.6*	*0.630*	0.0000	0.0000	0.6280	0.0020	0.02997
3	*0.7*	*0.700*	0.0000	0.0000	0.6977	0.0023	0.00000
4	*0.6*	*0.596*	0.0000	0.0000	0.5931	0.0025	0.00441
						Sum	**0.0943**

Table D.5.2.2. Solution of the minimization problem of Eq. D.5.2.4. by the "solver" of EXCEL.

Another options for definition of the "Function" (Eq. D.5.2.2) could be the minimum requirement, namely that only one stock is required to meet the HCR. Then one could imagine many other options between the two extremes (Mininum and maximum requirement), defined by a weighted average instead of "MIN" in Eq D.5.2.3.a. But in all cases, we need to define constraints on the solutions that make them acceptable in the real world, such as relative stability. The relative stability may not need to so rigid as that of Eq. D.5.2.3, the extreme relative stability.

An alternative model to define the effort allocation could be a model for fisher's behaviour with respect of effort allocation, such as the RUM (Random Utility Model, Appendix B).

D.5.3. EFFORT MANAGEMENT BY CAPACITY OR SEA DAY REDUCTION

Effort can be reduced in two major different ways

1) Reduction of capacity (reduce upper limit of total sea days)
2) Reduction of maximum number of sea days

We shall combine the two effort reduction methods in one combined model.

The maximum fleet specific effort $E^{Max.Sea.Days}_{Not.St.Dep}$ can be expressed as the product of the maximum effort, $EY_{Max}(Fl,Vs,Ct,y,q,Ar)$, and a "Maximum sea days regulation factor" $X^{SeaDays}$

$$E^{Max.Sea.Days}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) = X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar)* \\ NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet)* EY_{Max}(Fl,Vs.Ct,y,q,Ar) \} \qquad \text{(D.5.3.1)}$$

where the factor is defined by the management regulation and the upper limit for sea days (the "maximum possible number of sea days per period")

$$X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar) = \frac{Maximum\ allowed\ sea\ days\ per\ period}{Maximum\ possible\ sea\ days\ per\ period} \qquad \text{(D.5.3.2.a)}$$

Effort cannot exceed a physical upper limit (Eq. A.4.4.1)

$$E(Fl,Vs,\bullet,Ct,y,q,Ar) \le NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * EY_{Max}(Fl,Vs,Ct,y,q,Ar)$$

where EY_{MAX} is The maximum physical number of effort units per vessel per time unit. Let $EY_{\mathrm{Re}g}(Fl,Vs,Rg,Ct,y,q,Ar)$ .be the maximum number of sea days per time period dictated by the regulation, that is:

$$X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar) = \frac{EY_{\mathrm{Re}g}(Fl,Vs,Rg,Ct,y,q,Ar)}{EY_{Max}(Fl,Vs,Ct,y,q,Ar)} \quad \text{(D.5.3.2.b)}$$

When modelling the effect of maximum number of sea days regulation, this regulation must be analysed in conjunction with other factors influencing the effort allocation. Let the effort after allocation be $E^{After}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar)$, in case there had been no maximum sea days regulation. Then if the effort allocation effects from max sea days regulation is independent from other factors effecting the effort allocation, then

$$MIN\{ E^{Max.Sea.Days}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) \ , \quad E^{After}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) \}$$

would be the resulting effort of sea days regulation and other factors.
Thus, here we assume that $E^{Max.Sea.Days}_{Not.St.Dep}$ is only dependent on regulation by maximum number of sea days, as is independent of $E^{After}_{Not.St.Dep}$, which is determined by TAC, other regulations (e.g. MPA) and fisher's behaviour. This assumption is not realistic in many cases, in the sense that maximum fishing days regulations will influence the behaviour of fishers with respect of effort allocation.

Combining maximum number of sea days and capacity with other factors gives the fishing mortality expression after modification of stock specific effort.

$$\begin{aligned}
&F^{After}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = \\
&\sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} MIN\{ \\
&E^{Max.Sea.Days}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) \ , \ E^{After}_{Not.St.Dep}(Fl,Vs,Rg,Ct,y,q,Ar) \} * \\
&Q(Fl,Vs,Rg,Ct,St,y,q,Ar)
\end{aligned} \quad \text{(D.5.3.3)}$$

The number of vessels was introduced in Section A.4.1. Omitting all special cases the general equations

Vessel age	**Number of vessels in period q where q > 1**
Va = 0	NU_{Vessel}(Fl, Vs, Ct, y, q, 0) = $NU_{New\text{-}Vessel}$(Fl, Vs, Ct, y,q)
Va = 1,2,…,Va_{max}-1	NU_{Vessel}(Fl, Vs, Ct, y, q,Va) = NU_{vessel}(Fl, y , q-1,Va) – NU_{Decomm}(Fl, Vs, Ct, y, q,Va) – $NU_{Withdrawal}$(Fl, Vs, Ct, y, q, Va) – $NU_{Attrition}$(Fl, Vs, Ct, y, q, Va)

The dynamics of the number of vessels, that is what creates an investment in a new vessel or withdrawal of a vessel (due to attrition, bankruptcy or decommission) is covered in the economic section of the TEMAS model. So far no specific model has been introduced. However, a simple approach has been adopted for TEMAS (Sparre and Willmann, 1993). An alternative approach is the RUM ("Random Utility Model" or the "Discrete choice model", is discussed in Annexes A and C).

D.5.4. EU EFFORT REGULATION

There is yet no regulation for maximum number of sea days in the Baltic. Therefore this section (Subsection D.5.4.1) summarises the sea day legislations for, Kattegat, Skagerak, areas II, North Sea, VIId, VIIa and area VIb. A corresponding effort based management is expected to be introduced in the Baltic in 2008 (see Annex F (Section F.4), which contains the original text of the EU *"Proposal for a Council Regulation establishing a multi-annual plan for the cod stocks in the Baltic Sea and the fisheries exploiting those stocks"*.15 May 2007)

Note the complexity of these regulations in relation to modelling and available data. It will not be possible to simulate this complex of regulations by TEMAS.

Gear group	Gear	mesh size mm From	mesh size To mm	Katte-gat	Skag-gerak	II, IVabc	VIId	VIIa	VIb
4.a.i	TD	16	32	228	228	228	228	228	228
4.a.ii	TD	70	90	n.r.	n.r.	227	227	227	227
4.a.iii	TD	90	100	103	103	227	227	227	227
4.a.iv	TD	100	120	103	103	103	103	114	91
4.a.v	TD	120	inf	103	103	103	103	114	91
4.b.i	BT	80	90	n.r.	143	143	Unl.	143	143
4.b.ii	BT	90	100	n.r.	143	143	Unl.	143	143
4.b.iii	BT	100	120	n.r.	143	143	Unl.	143	143
4.b.iv	BT	120	inf	n.r.	143	143	Unl.	143	143
4.c.i	GE	0	110	140	140	140	140	140	140
4.c.ii	GE	110	220	140	140	140	140	140	140
4.d	TR	0	inf	140	140	140	140	140	140
4.e	LL	0	inf	173	173	173	173	173	173

TD = Trawl or Danish seine	n.r. = not relevant
BT = Beam Trawl	inD. = infinite (no upper limit)
GE = Gill net or entangling net	Unl. = unlimited
TR = Trammel net	
LL = Long lines	
Gear group = The numbering used in Annex II, Reg (EC) No 51/2006	

Table D.5.4.1.1. Maximum number of days a vessel may be present in 2006 within an area by fishing gear. General regulations, excluding the special conditions (see Table 2.3.2).

D.5.4.1. EU EFFORT REGULATION IN AREAS II, IIIA, IV, VI AND VII.

The effort regulations limiting the maximum number of sea days for 2006 for various areas are given in Annex II of

COUNCIL REGULATION (EC) No 51/2006 of 22 December 2005, fixing for 2006 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required Annex IIa is the relevant Annex in the case of Danish fisheries:

ANNEX IIA: FISHING EFFORT FOR VESSELS IN THE CONTEXT OF THE RECOVERY OF CERTAIN STOCKS.

The effort regulation is summarized in Table 2.3.1, showing the maximum number of days a vessel can fish. The regulation applies to all vessels of length >= 10 meters, that had a record for fishing in the areas with the gears listed in Table 2.3.1 in years 2001, 2002, 2003, 2004 or 2005 (quoting only the principal part of the text in Annex II) .

Special conditions of effort regulations.

The “special conditions” are derogations from the general rules for the Maximum number of days a vessel may be present in 2006.
The maximum number of days are gear/mesh size and area specific are shown in Table 2.3.2. The table is derived from Annex II of Reg (EC) No 51/2006. The codes for the special conditions (second column) refers to section 8.1 od Annex IIA: The table below is an extract of the principal content of Annex IIa, and explains the codes for special conditions.

8.1. For the purpose of fixing the maximum number of days a fishing vessel may be present within the area, the following special conditions shall apply in accordance with Table I *(Here table 2.3.1):*

Code	Year(s)	Short explanation
8.1.(a)	2002-2005	The vessel must comply with Appendix 1 *(Escape window, 120 mm square meshed)*
8.1.(b)	2002-2005	The vessel must comply with Appendix 2 *(Grid)*
8.1.(c)	2002	The landings of cod in 2002, must represent less than 5%
8.1.(d)	2002	The landings of cod, sole and plaice in 2002, must represent less than 5%
8.1.(e)	2002	The landings in 2002, must be less than 5% cod and more than 60% plaice
8.1.(f)	2002	The landings in 2002 must be less than 5% cod and more than 5% turbot and lumpsucker
8.1.(g)	2002-2005	Trammel net ≤ 110 mm and absent from port for no more than 24 hours at a time.
8.1.(h)	2002-2005	Be from member state with automatic suspension of fishing licenses when infringements
8.1.(i)	2003-2006	The vessel shall have been in the area in 2003, 2004 or 2005 with gear 4, and in 2006 the cod shall be less than 5%. During a management period the vessel may not carry gear other than 4.b.iii. or 4.b.iv *(Beam trawl, 100- 120 mm or >120).*
8.1.(j)	2002-2005	The vessel must comply with Appendix 3. *(Escape window, 140 mm square meshed)*
8.1.(k)	2002	The total landings in 2002, must represent less than 5% cod and more than 60% plaice May-Oct. At least 55% of days shall apply in the area east of 4°30'W in May-Oct.

Table D.5.4.1.2. The coding system for special conditions. Explanation of column 2 in Table 2.4.2. The explanations given here are short versions of those of Annex IIa (sub-section 8.1) Reg (EC) No 51/2006

												Days/year Areas as defined in point:					
												2a	**2b**	**2b**	**2b**	**2c**	**2d**
Gear group Point 4	Special con-dition Point 8	**Gear**	mesh size mm From	mesh size To mm	squ-are mesh win-dow	< 5 % cod	> 60 % plai-ce	< 5 % of cod, sole, plaice	App. 3	App 2 GRID	See (#)	Katte -gat	(1) Skag - gera k	(2) II IVab c	(3) VIId	VIIa	VIb
4.a.i		**TD**	16	32								228	228	228	228	228	228
4.a.ii		**TD**	70	90								n.r.	n.r.	227	227	227	227
4.a.iii		**TD**	90	100								103	103	227	227	227	227
4.a.iv		**TD**	100	120								103	103	103	103	114	91
4.a.v		**TD**	120	inf								103	103	103	103	114	91
4.a.iii	8.1.(a)	**TD**	90	100	120							137	137	227	227	227	227
4.a.iv	8.1.(a)	**TD**	100	120	120							137	137	103	103	114	91
4.a.v	8.1.(a)	**TD**	120	inf	120							137	137	103	103	114	91
4.a.v	8.1.(j)	**TD**	120	inf	140							149	149	115	115	126	103
4.a.ii	8.1.(b)	**TD**	70	90						x		Unl.	Unl.	Unl.	Unl.	Unl.	Unl.
4.a.iii	8.1.(b)	**TD**	90	100						x		Unl.	Unl.	Unl.	Unl.	Unl.	Unl.
4.a.iv	8.1.(c)	**TD**	100	120		x						148	148	148	148	148	148
4.a.v	8.1.(c)	**TD**	120	inf		x						160	160	160	160	160	160
4.a.iv	8.1.(k)	**TD**	100	120		x	X					n.r.	n.r.	n.r.	n.r.	166	n.r.
4.a.v	8.1.(k)	**TD**	120	inf		x	X					n.r.	n.r.	n.r.	n.r.	178	n.r.
4.a.v	8.1.(h)	**TD**	120	inf							(#) 1	115	115	115	115	126	103
4.a.ii	8.1.(d)	**TD**	70	90				x				280	280	280	280	280	280
4.a.iii	8.1.(d)	**TD**	90	100				x				Unl.	Unl.	280	280	280	280
4.a.iv	8.1.(d)	**TD**	100	120				x				Unl.	Unl.	Unl.	Unl.	Unl.	Unl.
4.a.v	8.1.(d)	**TD**	120	inf				x				Unl.	Unl.	Unl.	Unl.	Unl.	Unl.
4.b.i		**BT**	80	90								n.r.	143	143	Unl.	143	143
4.b.ii		**BT**	90	100								n.r.	143	143	Unl.	143	143
4.b.iii		**BT**	100	120								n.r.	143	143	Unl.	143	143
4.b.iv		**BT**	120	inf								n.r.	143	143	Unl.	143	143
4.b.iii	8.1.(c)	**BT**	100	120		x						n.r.	155	155	Unl.	155	155
4.b.iii	8.1.(i)	**BT**	100	120					x			n.r.	155	155	Unl.	155	155
4.b.iv	8.1.(c)	**BT**	120	inf		x						n.r.	155	155	Unl.	155	155
4.b.iv	8.1.(i)	**BT**	120	inf					x			n.r.	155	155	Unl.	155	155
4.b.iv	8.1.(e)	**BT**	120	inf		x	X					n.r.	155	155	Unl.	155	155
4.c.i		**GE**	**0**	**110**								**140**	**140**	**140**	**140**	**140**	**140**
4.c.ii		**GE**	110	220								140	140	140	140	140	140
4.c.iii	8.1.(f)	**GE**	220	inf		x					(#) 2	162	140	162	140	140	140
4.d		**TR**	0	inf								140	140	140	140	140	140
4.d	8.1.(g)	**TR**	0	110							(#) 3	140	140	205	205	140	140
4.e		**LL**	0	inf								173	173	173	173	173	173

TD = Trawl or Danish seine
BT = Beam Trawl
GE = Gill net or entangling net
TR = Trammel net
LL = Long lines

(#) 1 automatic suspension licences
(#) 2 >5% turbot & lumpsucker
(#) 3 absent from port < 24 h.

Table D.5.4.1.3. Maximum number of days a vessel may be present in 2006 within an area by fishing gear. For explanation of special condition codes, see Table D.5.4.1.2. This table extends Table D.5.4.1.2.

Special conditions referring to year 2002:

The full text of 8.1.(c) in Table 2.4.1 is ***:***

> *"The total landings of cod in 2002 made by the vessel, or by the vessel or vessels using similar gears and qualifying for this special condition, mutatis mutandis, that it has replaced in accordance with Community law, must represent less than 5% of the total landings of all species made by the vessel in 2002 according to the landings in live weight consigned in the Community logbook."*

"mutatis mutandis" is a latin term meaning "things being changed which are to be changed"

That means that (as far as I can read English) that a vessel belongs to the group qualifying for 8.1.(c) if (and only if) it in 2002 landed less than 5% cod. What the vessel landed in 2003-2005 does not matter and/or which gears it used 2003-2005 does not matter as well, with respect of qualifying to special condition 8.1.(c). However, if the vessel (for example) did not exist in 2002 (was build in 2003-2005), it can still qualify if it replaced a vessel that qualified (in 2002) and if it uses the same gear. Again, it does not matter what the vessel landed in 2003-2005, but now it matters which gear it uses. Whether this capability of "replacing" only applies to new vessel I am not sure about. Does the old vessel have to give up its fishing license, - stop fishing or can it transfer to other types of fishing?

To assign a special condition to a vessel in 2002-2005 we have to go back to 2002 and see what it landed and which gear it used. Should it use the same gear all year round? Or would it qualify if it fished with the gear in question (say 100-120 mm OB trawl) for one months only, and during that month landed <5% cod. Would it also qualify if it in the remaining 11 months of 2002 caught more than 5% cod (with, say, >120 mm OB trawl).

If the conditions was met in 2002 it can be assigned to all years 2003-2005 without checking what the vessel did (which gear it used and what it landed).

That mean that a vessel fishing with 100-120 mm OB trawl in 2002 and which landed <5% cod , shall be assigned special condition 8.1.(c) in 2005, even if it in 2005 OB trawl 70-90 mm during all 2005 and landed >5% cod.

D.5.4.2 EU EFFORT REGULATION IN THE BALTIC.

The existing regulations in the Baltic are listed in Annex G. The proposed effort regulations for the Baltic (Annex F) appears to be very similar to those applied elsewhere (Section D.5.4.1). Effort regulation will be supplemented by TAC regulations as well as technical management measures. Both regulations will be applied in the "adaptive manner". Effort in terms of sea days will be reduced by maximum 10% per year, and TAC be a maximum of 15%. The framed text below is extracted (unedited) from the proposed EU-regulation.

> ***Procedure for setting periods when fishing with certain types of gear is allowed***
>
> *1. It shall be prohibited to fish with trawls, Danish seines or similar gear of a mesh size equal to or larger than 90 mm, with gillnets, entangling nets or trammel nets of a mesh size equal to or larger than 90 mm, or with bottom set lines, or longlines except drifting lines, or or handlines or jigging equipment:*
>
> *(a) from 1 to 30 April in Area A (*), and*
>
> *(b) from 1 July to 31 August in Area B.*
>
> *When fishing with drifting lines within the periods and days mentioned in subparagraphs (a) and (b) no cod shall be retained on board.*
>
> *2. The Council shall decide each year by a qualified majority on the maximum number of days absent from port outside the periods specified under (a) and (b) in the following year when fishing*

with the gear referred to in paragraph 1 is allowed, in accordance with the rules set out in paragraphs 3 and 4.

3. Where the fishing mortality rate for one of the cod stocks concerned has been estimated by the STECF to be at least 10% higher than the minimum fishing mortality rate defined in Article 4, the total number of days when fishing with the gear referred to in paragraph 1 is allowed shall be reduced by 10% compared to the total number of days allowed in the current year.

4. Where the fishing mortality rate for one of the cod stocks concerned has been estimated by the STECF to be less than 10% above the minimum fishing mortality rates defined in Article 4, the total number of days where fishing with the gear referred to in paragraph 1 is allowed shall be equal to the total number of days allowed in the current year, multiplied by the minimum fishing mortality rate defined in Article 4 divided by the fishing mortality rate estimated by STECD.

(*) "Area A" means Subdivisions 22 to 24.
"Area B" means Subdivisions 25 to 28.
"Area C" means Subdivisions 29 to 32.

The core of the proposal for TAC setting in the Baltic is as follows:

Procedure for setting the TACs for the cod stocks concerned

1. The Council shall adopt the TAC for the cod stocks concerned that, according to a scientific evaluation carried out by the Scientific, Technical and Economic Committee for Fisheries (STECF), is the higher of:

(a) the TAC that would result in a 10% reduction in the fishing mortality rate in its year of application compared to the fishing mortality rate estimated for the preceding year.
(b) the TAC that would result in the level of fishing mortality rate defined in Article 4.

2.Where the application of paragraph 1 would result in a TAC that exceeds the TAC for the preceding year by more than 15%, the Council shall adopt a TAC which is 15% greater than the TAC of that year.

3. Where the application of paragraph 1 would result in a TAC that is more than 15% below the TAC of the preceding year, the Council shall adopt a TAC which is 15% less the TAC of that year.

4. Paragraph 3 shall not apply where a scientific evaluation carried out by the STECF shows that the fishing mortality rate in the year of application of the TAC will exceed a value of 1 per year from the ages 3 to 6 years for the cod stock in Subdivisions 22, 23 and 24 Area A or a value of 0.6 per year for the ages 4 to 7 years for the cod stock in Subdivisions 25 to 32.Areas B and C.

D.6. THE RELATIVE STABILITY

The "relative stability" has been the basic principle for sharing of resources between countries in the EU management. In words it says that "a country should get the share of the total it is used to take". Without the relative stability or a similar unique rule, it would be impossible to find solutions to the problem of effort allocation between fleets/riggings and countries.

D.6.1. DEFINITION OF HISTORICAL RIGHTS

The historical right relative to landings is defined as the historical overage shares of landings

$$RELHRgt_{Land}(Fl,Vs,Rg,Ct,St,y,q,Ar) = \frac{HRgt_{Land}(Fl,Vs,Rg,Ct,St,y,q,Ar)}{HRgt_{Land}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar)} \qquad \text{(D.6.1.1)}$$

where

$$HRgt_{Land}(Fl,Vs,Rg,Ct,St,y,q,Ar) = \sum_{u=y-Ny_{Hist}}^{y-1} Y_{Land}(Fl,Vs,Rg,Ct,St,y,q,Ar) * HFac^{u-y} \qquad \text{(D.6.1.2)}$$

where HFac is a discount factor, assigning lower values to years the longer in the past. Therefore, HFac ≤ 1.0. When HFac = 1.0, all years have assigned the same importance. This reduction factor is not used explicitly in the EU management, but intuitively, we believe that it is acceptable to assume that recent catches are more important than catches taken long time ago.

Note that $RELHRgt_{Land}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = 1$

The general historical right with respect of measure "X" is

$$RELHRgt_{X}(Fl,Vs,Rg,Ct,St,y,q,Ar) = \frac{HRgt_{X}(Fl,Vs,Rg,Ct,St,y,q,Ar)}{HRgt_{X}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar)}$$

$$HRgt_{X}(Fl,Vs,Rg,Ct,St,y,q,Ar) = \sum_{u=y-Ny_{Hist}}^{y-1} X(Fl,Vs,Rg,Ct,St,y,q,Ar) * HFac^{u-y} \qquad \text{(D.6.1.3)}$$

Note that $RELHRgt_{X}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = 1$

For X-options , one can think of, for example,

1) X = Landings (in weight)
2) X = Value of landings
3) X = Effort (in this case index "St" is omitted)

The current version of TEMAS, however, has only one option for X, namely X=Landings in weight.

From the basic definition with all indices in use, various aggregated historical rights can be defined. The present version of TEMAS contains the following options aggregated historical rights:

X=Landings and Value of landings:	**X=Effort:**
$RELHRgt_X(Fl,Vs,Rg,Ct,St,y,q,\bullet)$	$RELHRgt_X(Fl,Vs,Rg,Ct,y,q,\bullet)$
$RELHRgt_X(Fl,Vs,\bullet,Ct,St,y,q,\bullet)$	$RELHRgt_X(Fl,Vs,\bullet,Ct,y,q,\bullet)$
$RELHRgt_X(\bullet,\bullet,\bullet,Ct,St,y,q,\bullet)$	
$RELHRgt_X(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar)$	
$RELHRgt_X(\bullet,\bullet,\bullet,\bullet,St,y,q,\bullet)$	

D.6.2. THE USE OF HISTORICAL RIGHTS IN MANAGEMENT

One traditional use of historical rights concerns distribution of a total TAC on countries. The TAC of a country in time period q of year y is

$$TAC(Ct,St,y,q) = TAC(\bullet,St,y,q) * RELHRgt_{Land}(\bullet,\bullet,\bullet,Ct,y,q,\bullet) \qquad \text{(D.6.2.1.a)}$$

If the TAC is annual, and we assign the same value, $RELHRgt_{Land}^{Annual}(\bullet,\bullet,\bullet,Ct,y,\bullet)$, of the historical right to all time periods, then the annual TAC share of country Ct becomes

$$TAC(Ct,St,y,\bullet) = TAC(\bullet,St,y,\bullet) * RELHRgt_{Land}^{Annual}(\bullet,\bullet,\bullet,Ct,y,\bullet) \qquad \text{(D.6.2.1.b)}$$

This is the basic principle behind the TAC sharing between counties as is has been executed by the EU (and other management bodies) for decades.

The relative stability could be extended to effort quotas, but this option has not yet been implemented in TEMAS, because the actual legislation (the EU regulations) has not been formulated along that line. Effort based management in the EU is introduced in the form of "structural policy for fishing capacity", "Maximum number of sea days" (Section D.7.2) and closed areas (Section D.8).

TEMAS offers options to use the principle of relative stability on various disaggregated levels and based on various different measures (landings, value of landings and effort).

D.7. THE ADAPTIVE APPROACH

To introduce the concept of the "Adaptive approach" we start by quoting two recent papers from the EU commission on the CFP (Common Fisheries Policy)

Extract from ***EU COMMISSION, 2006. Fishing Opportunities for 2007. Policy Statement from the European Commission. Brussels, 15.9.2006. COM(2006) 499 final. Communication from the commission to the council***

1.1. Guiding principles for decision-making under the Common Fisheries Policy

Annual fishing opportunities should be set in accordance with the objectives of the Common Fisheries Policy[13]*1, that is, to achieve the exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions.*

The Community should aim to meet these objectives by the progressive implementation of an ecosystem based approach to fisheries management, contributing to efficient and economical fishing activities and providing a fair standard of living for those who depend on fishing activities.

Economic and social sustainability depends on biological sustainability: there are no fisheries where there are no fish. The Commission therefore places biological sustainability at the heart of decision-making in fisheries.

However, the Commission does not always directly translate scientific advice on sustainability into proposals for regulations, for two reasons. Firstly, scientific forecasts are at times quite uncertain and their direct application would result in substantial changes in fishing opportunities from one year to the next, which could often be greater than those necessary to achieve the needed conservation benefits.
The second reason is of a political nature. Although many fish stocks are depleted or over-fished, the Commission and Member States have considered that it is acceptable to take a relatively high biological risk by allowing more fishing than is sustainable in the short term, in order to maintain a certain continuity of fishing activity.

Remedial measures to redress over fishing should be implemented gradually, provided that fishing mortality is steadily and gradually reduced.

…..

Extract from: ***EU COMMISSION, 2006. Implementing sustainability in EU fisheries through maximum sustainable yield Communication from the commission to the council and the European parliament, {SEC(2006) 868}, Brussels, 4.7.2006. COM(2006) 360 final. Commission of the European communities***

4. MANAGING THE ADJUSTMENT

The Community and its Member States have subscribed to reaching the MSY objective. Now we need to decide on the pace of change to reach this objective and how to manage the transition. The success in the implementation of this new approach depends very much on the capacity of the fisheries sector, at national level, to accommodate to a new situation.
Once long term plans establishing adequate stock targets are adopted, Member States will have to decide on the pace of change to reach these objectives, and how to manage the transition. There are two broad approaches for managing this change.

1. One approach would be to focus on economic efficiency by reducing fishing capacity, investment and employment to no more than what is needed to fish at the maximum sustainable yield rate. Catches would be larger, fishing fleets would be smaller, fewer fishermen would be employed (although onshore processing employment might increase), fishing would be more profitable and fisheries regulation simpler and less burdensome. Some fisheries and some Member States are experiencing a shortage of qualified fishermen, so the social implications of reducing the size of fleets may be limited there.

[13] Article 2, para. 1 of Regulation 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy, O.J. L 358 31.12.2002, p.59

2. Another approach would be to keep current levels of employment at the price of economic inefficiencies. This would mean maintaining the size of the fleet but reducing the efficiency of fishing, by limiting the vessels' capacity to catch fish (e.g. by limiting its size, power or fishing gear) or imposing limitations on days-at-sea. Some Member States have used these instruments already and the Community has in the past three years imposed day-at-sea restrictions in several demersal fisheries. Compared with present conditions, overall catches would be larger, fishing fleets would be subject to more restrictive regulations, employment and vessel activity would be more part-time, but fishing would be more profitable because catches would be maintained but variable costs (e.g. fuel costs) would be reduced. Changing to smaller-scale fisheries with lower levels of fishing efficiency could also bring increased yields while having less direct effect on employment at sea. Maintaining employment can be compatible with reducing rates of fishing by moving to less capital intensive forms of fishing.

Of the two approaches, the former implies reducing the capacity of national fleets, which the Commission considers is the most easily controllable fisheries management measure. Under either approach, change can be managed more easily if it occurs gradually, so it is important to start the process soon.

D.7.1. MAXIMUM RELATIVE CHANGE OF TAC

Therefore we introduce the amendment to the HCR that the change of TAC from year to year, TAC(St, y)-TAC(St, y-1) is not allowed to exceed a certain percentage of TAC(St,y-1) if the TAC increases, $TAC_{CH}^{UP}(St,y)$ and if TAC decreases $TAC_{CH}^{Down}(St,y)$.

$$\frac{TAC(St,y-1)-TAC(St,y)}{TAC(St,y-1)} \quad \leq \quad TAC_{CH}^{Down}(St,y) \;\; if \;\; TAC(St,y-1) \geq TAC(St,y) \qquad \text{(D.7.1.1.a)}$$

$$\frac{TAC(St,y)-TAC(St,y-1)}{TAC(St,y-1)} \quad \leq \quad TAC_{CH}^{Down}(St,y) \;\; if \;\; TAC(St,y-1) < TAC(St,y) \qquad \text{(D.7.1.1.b)}$$

This lead to the definition of a TAC concept, we call "TAC of the adaptive approach":

$$TAC_{ADapt}(St,y) =$$
$$\begin{cases} Min\left\{ TAC(St,y),\; TAC(St,y-1)*(1-TAC_{CH}^{Down}(St,y))\right\} \; if \;\; TAC(St,y) < TAC(St,y-1) \\ Max\left\{ TAC(St,y),\; TAC(St,y-1)*(1+TAC_{CH}^{Up}(St,y))\right\} \; if \;\; TAC(St,y) > TAC(St,y-1) \end{cases} \qquad \text{(D.7.1.2)}$$

D.7.2. MAXMUM RELATIVE CHANGE OF EFFORT

The effort regulation is assumed to take the form of

1) Maximum number of sea-days per time period, as has been the case for other areas regulated by the EU
2) Structural regulations (regulation of capacity, or number of vessels)

The capacity induced constraint of effort is modelled by

$$F^{After}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar)=\sum_{Ct=1}^{Ct_{Max}}\sum_{Fl=1}^{Fl_{Max}(Ct)}\sum_{Vs=1}^{Vs_{Max}(Fl,Ct)}\sum_{Rg=1}^{Rg_{Max}(Fl,Ct)}MIN\{$$
$$X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar)*E^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar),$$
$$NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet)*EY_{Max}(Fl,Vs.Ct,y,q,Ar)\ \}$$
$$*Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \qquad \text{(D.7.2.1)}$$

The regulation of capacity by fleet (Fl,Vs,Ct) takes the form

$$NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet)\le NU_{Vessel}^{Max}(Fl,Vs,Ct,y,q,\bullet) \qquad \text{(D.7.2.2)}$$

Where the maximum number given as input to TEMAS and is counted down in accordance with decommissions. The national legislations limit the entry to the fishing industry. New vessels can be introduced only when a corresponding capacity is removed. Decommissioned vessels cannot be replaced by new vessels.

The relative change of effort caused by changes in capacity (number of vessels) by decommission is under full control of the national administrations. Any decision on the funds made available for decommission (and thereby the number of decommissioned vessels) is given as input to TEMAS. There is (currently), no rule in TEMAS that determines the number of decommissions. However, a rule that made the number of decommissions proportional to the cash flow of fleets could be made. The required modification of the program would be minor.

The current practice of reducing fleet/rigging specific effort of 10% each year is modelled by

$$F^{After}(\bullet,\bullet,\bullet,\bullet,St,y,\bullet,Ar)=\sum_{q=1}^{Q_{Max}}\sum_{Ct=1}^{Ct_{Max}}\sum_{Fl=1}^{Fl_{Max}(Ct)}\sum_{Vs=1}^{Vs_{Max}(Fl,Ct)}\sum_{Rg=1}^{Rg_{Max}(Fl,Ct)}MIN\{$$
$$NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet)*EY_{Max}(Fl,Vs,Ct,y,q,Ar),$$
$$X_{Effort}(Fl,Vs,Rg,Ct,y,q,Ar)*E^{After}(Fl,Vs,Rg,Ct,y-1,q,Ar)\ \}*$$
$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar) \qquad \text{(D.7.2.3)}$$

Where $X_{Effort}(Fl,Vs,Rg,Ct,y,q,Ar)$ is the reduction factor. In case of 10% annual reduction $X_{Effort}(Fl,Vs,Rg,Ct,y,q,Ar)=0.9$.

Currently $X_{Effort}(Fl,Vs,Rg,Ct,y,q,Ar)$ is given the value of 0.9 for all indices combined.

Currently the reduction factor of 0.9 is applied until it considered that the stock within "safe biological limits", for example when SSB(St) $\geq$ B_{PA}(St), where St is the stock given first priority, notably St=cod. This stop-rule is generalized and made numerical in TEMAS by introducing an "importance" factor (In line with the MTAC-model, Vinther *et al*, 2004)

$$SSB(St)\ge IMPFAC(St)*B_{PA}(St) \qquad \text{(D.7.2.4.a)}$$

Where the "importance factor" IMPFAC(St) is

$$IMPFAC(St) = \begin{cases} 1 \quad for\ the\ first\ priority\ stock\ (e.g.\ cod) \\ \leq 1\ for\ other\ stocks \end{cases} \qquad \text{(D.7.2.4.b)}$$

In MTAC the cod was considered 20 time as important as any other stock (STECF, 2004).
There is no rule in TEMAS that sets the 10% reduction per year, i.e. there is no rule that assigns a value to $X_{Effort}(Fl, Vs, Rg, Ct, y, q, Ar)$.

Table 2.7.2.1 shows the introduction of effort based management in Kattegat, North Sea , Skagerrak, Eastern Channel, West of Scotland and Irish Sea. It can be seen how effort is reduced by approximately 10% each year. The tendency shown in Table 2.7.2.1 was continued in 2007 (see Section D.5.4.1)

		Grouping of fishing gears					
		a) Demersal trawls and seines	b) Beam trawls	c) Static demersal nets	d) Demersal long lines	e) Demersal trawls, seines	f) Demersal trawls, seines
Mesh size		>100 mm SK*) >90mm	> 80 mm			80-99 mm SK*) 70-89 mm	16-31 mm
Except		Beam trawl				Beam trawl	Beam trawl
Max. days/month	2003	9	15 a)	16	19	25	23
	2004	10	14	14	17	22	20
	2005	9	13	13	16	21	19
	2006	*See Tables D.5.4.1.2-3*					
	2007						
*) SK = Skagerak & Kattegat		Source: EU 2003, EU 2004, EU 2005. ANNEX IVa. FISHING EFFORT FOR VESSELS IN THE CONTEXT OF THE RECOVERY OF CERTAIN STOCKS. a) except Kattegat & Skegerak					

Table 7.2.2.1. Maximum days/month present within the area and absent from port by fishing gear in Kattegat, North Sea and Skagerrak, Eastern Channel, West of Scotland and Irish Sea.

D.7.3. IMPLEMENTAION OF ADAPTIVE APPROACH FOR THE BALTIC.

Yet No legislation on effort based management has been implemented, but the proposal made by the council (See Section D.5.4.2), makes it natural to assume that the regulations will be almost the same as in other areas (For example, Kattegat, North Sea and Skagerrak, Eastern Channel, West of Scotland and Irish Sea). TEMAS is constructed to reflect the effort based management of EU in the areas where it is implemented.

D.8. CLOSED AREAS / SEASONS (MPA)

What can be simulated in the context of MPAs with TEMAS has to be on a rather more crude spatial resolution. Any simulation will have to be based on a suite of questionable assumptions, such as the migration of spawners and juveniles, as well as the extension of the reproductive volume, and its effect of survival of cod larvae.

D.8.1. OPTIONS CONSIDERED FOR MPA'S IN THE BALTIC

The hypotheses to be tested are based on Article 10 in the suggested regulation (Table D.8.1 and Figure D.8.1). With the present knowledge basis we do not consider it possible to draw any firm conclusion with regard of the effect of MPAs on the success of cod reproduction.

The text of article 10 (Table D.8.1), with the coordinates of three relatively small MPAs, gives the wrong impression that science can monitor resources on a fine scale. Needless to say, that is very far from reality.

J.Fuchs (EU commission) has suggested an extension (Figure D.8.1, B, source: D.Kuster) to the existing boxes. The extended boxes are shown on the lower map in Figure B.

Three scenarios will be tested (1) No MPA (2) Existing MPAs and (3) Boxes defined by Fig. B
The box suggested by Fuchs has been extended so that it is made of whole rectangles (the green box, and the two boxes are united).
The boxes are extended to whole rectangles (red boxes in Figure A). This is necessary as log-book data are given by rectangle

Article 10: Area restrictions on fishing

1. It shall be prohibited to conduct any fishing activity from 1 May to 31 October within the areas enclosed by sequentially joining with rhumb lines the following positions, which shall be measured according to the WGS84 coordinate system:

(a) Area 1 Bornholm Box	(b) Area 2::Gdansk Box	(c) Area 3: Gotland Box
– 55°45'N, 15°30'E	– 55°00'N, 19°14'E	– 56°13'N, 18°27'E
– 55°45'N, 16°30'E	– 54°48'N, 19°20'E	– 56°13'N, 19°31'E
– 55°00'N, 16°30'E	– 54°45'N, 19°19'E	– 55°59'N, 19°13'E
– 55°00'N, 16°00'E	– 54°45'N, 18°55'E	– 56°03'N, 19°06'E
– 55°15'N, 16°00'E	– 55°00'N, 19°14'E	– 56°00'N, 18°51'E
– 55°15'N, 15°30'E		– 55°47'N, 18°57'E
– 55°45'N, 15°30'E		– 55°30'N, 18°34'E
		– 56°13'N, 18°27'E.

2. By way of derogation from paragraph 1, fishing with gillnets, entangling nets and trammel nets of a mesh size equal to or larger than 157 mm or with lines shall be permitted.
3. No other gear than defined in paragraph 2 shall be kept on board.
4. When fishing with any of the gear types defined in paragraph 2, no cod shall be retained on board.

Table D.8.1. Baltic MPAs suggested by the EU (modified from Annex G)

This gives 7 scenarios to be tested:

1) No MPA.
2) Current MPA (extended to whole rectangles). 8 Rectangle
   a. 6 months (1 May – 31 Oct, Current regulation)
   b. 9 months (1 Apr - 31 Dec)
   c. All year
3) Figure B (with green box). 17 Rectangles
   a. 6 months (1 May – 31 Oct)
   b. 9 months (1 Apr - 31 Dec)
   c. All year

D.8.2. THE ADAPTIVE APPROACH APPLIED TO MPA'S IN THE BALTIC

We suggest some sort of an adaptive approach for the gradual introduction of MPAs
Every third year (or general every "Y_{Lack} " year) the area/season will be extended (in the sequence: 1-2a-2b-2c-3a-3b-3c) until recruitment is improved.

But the definition of "improvement of recruitment" is problematic. Therefore it is suggested that the test is made on SSB rather than on recruitment. In case recruitment is improved, SSB will subsequently be improved.

Some time is required to detect the effect of an MPA. Therefore, the new MPA is given 3 years (general: Y_{Lack} (St) years) to show its effect on recruitment/SSB. It is obvious to assume that the time lack needed to show the effect of an MPA is stock specific. The success criterion is the traditional one of ICES, namely that SSB > SSB_{PA} with 50% (general X(St) %) probability (recall that TEMAS makes stochastic simulations).

Table 8.2 lists the MPA extensions to be tested in chronological order.

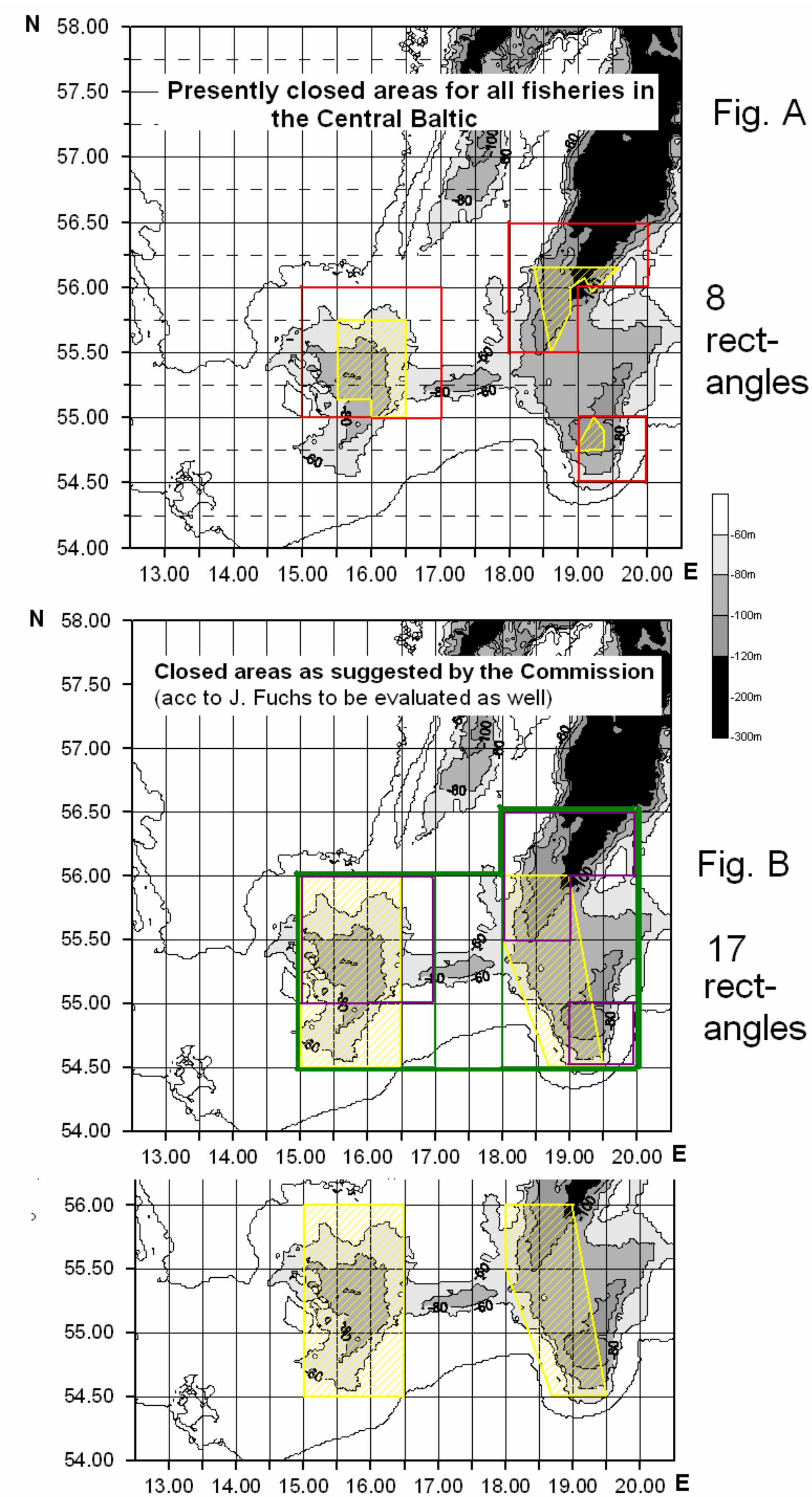

Figure 8.1. Existing MPAs (yellow boxes in A), existing MPAs extended to whole rectangles (Red boxes in A), and extended MPAs suggested by J. Fuchs (yellow boxes in B) and extended MPAs extended to one large MPA composed of whole rectangles (green Box in B).

Potential year of introduction	Definition of MPA.	Criterion for stopping extension of MPA/Season
0	No MPA	Always
Y_{Lack}(St)	Figure A, Closed 6 months (1 May – 31 Oct)	If SSB > SSB_{PA}
2*Y_{Lack}(St)	Figure A, Closed 9 months (1 Apr - 31 Dec)	If SSB > SSB_{PA}
3*Y_{Lack}(St)	Figure A, Closed All year	If SSB > SSB_{PA}
4*Y_{Lack}(St)	Figure B, Closed 6 months (1 May – 31 Oct)	If SSB > SSB_{PA}
5*Y_{Lack}(St)	Figure B, Closed 9 months (1 Apr - 31 Dec)	If SSB > SSB_{PA}
6*Y_{Lack}(St)	Figure B, Closed All year	Maximum MPA/Season

Table 8.2. Chronological list of (potential) MPA extensions

D.8.3. EFFORT MANAGEMENT BY MAXIMUM SEA DAYS COMBINED WITH MPA AND TAC.

Area specific effort can be reduced in four major different ways

1) Reduction of overall capacity (reduce upper limit of total sea days for all areas)
2) Area specific reduction of maximum number of sea days
3) MPA, - seasonal closure of selected areas.
4) Indirectly through TAC (and/or maximum catch rates)

We shall combine the four effort reduction methods in one combined model.

Recall the definitions of the concepts $F_{HCR}^{Before}(St,y,q,Ar)$, $E^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar)$ and $E^{After}(Fl,Vs,Rg,Ct,y,q,Ar)$ given in Section 5.1. For each stock one can then set the efforts of fleets to match each stock specific F (Eq. D.5.1.1):

$$F_{HCR}^{Before}(St,y,Ar) = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} E^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

The relative distribution of efforts on (Fl, Vs, Rg, Ct) is assumed to be given by some model, for example by the relative stability and a common factor applied to all (Fl, Vs, Rg, Ct) to achieve it. An alternative approach would be a behaviour model, such as the Random Utility Model, to modify the effort. The two models could also be used collectively, in the sense that catch quotas and/or effort quotas were given by the relative stability, and in turn the behaviour model was used within the frame of the catch/effort quotas. This is all based on the idea that management remains based on single species TAC, the traditional ICES approach. One completely new approach would be to base management on "maximum acceptable limits of negative impacts**"** introduced by the EU commission in, for example, Call: FP7-KBBE-2008-2B[14] This approach represents a fundamentally new approach to fisheries. The "maximum acceptable limits of negative impacts" is mentioned here, just to underline that the current approach taken, the assumption that ICES thinking will remain dominant is fisheries management is perhaps not what will match the future demands to a system like TEMAS. Whether in fact TEMAS can cope with this new approach of fisheries management is not entirely clear for the time being.

Coming back to the traditional ICES approach, recall that the suffix "Before" refers to "Before the modifications of efforts to match the set of HCRs for all stocks combined". The E^{Before} has "St"

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[14] ***KBBE-2008-1-4-03: Fisheries management approach based on 'maximum acceptable limits of negative impacts' Call: FP7-KBBE-2008-2B:*** *The Common Fisheries Policy (CFP) must increasingly integrate environmental concerns and seek to apply an ecosystem approach. These issues are presently addressed by regulation of the technologies that can be used to fish, by closed areas and by limits on landings. This approach has led to increasingly detailed micromanagement of the fishing technologies with some negative results including high levels of discarding in some fisheries. An alternative approach is instead to manage fisheries in a similar way as is done in some other sectors, i.e. by defining a maximum acceptable negative impact and by then leaving it to those concerned to identify the means to meet such requirements ("results-based management"). As a first step such an approach is initiated in relation to the elimination of discards in European fisheries. The project will review the international experiences with such "results-based management" in relation to environmental impacts of fisheries including discards and investigate the options for management on basis of such principles in Europe. The project will address research questions relating to the performance of "results-based management" in relation to minimising ecological impacts of fisheries, the social and economic outcomes and institutional aspects relating to decision making and implementation. The research will include studies of institutional, legal and technical aspects of such management approaches.*
Funding scheme*: Small collaborative project.*
Expected impact: *The project will develop a fundamentally new approach to fisheries*
management in Europe. The results from this project will find immediate use in the development of the new discards policy in accordance with the Common Fisheries Policy.

index, so this (artificial) effort concept is stock specific. The "after modification" effort concept E^{After} has no "St"-index, and the equal sign is replaced by an "smaller than" sign.

$$F_{HCR}^{Before}(St,y,Ar) \geq \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} E^{After}(Fl,Vs,Rg,Ct,y,q,Ar) * Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

The F/effort after modification of fleet specific effort can be expressed as the product of the effort before modification multiplied with the reduction factors $X^{SeaDays}$ and $X^{MPA-Closure}$

$$F^{After}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) = \sum_{Ct=1}\sum_{Fl=1}\sum_{Vs=1}\sum_{Rg=1} X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar)*$$

$$X^{MPA-Closure}(Fl,Vs,Rg,Ct,y,q,Ar)* E^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar)* \qquad \text{(D.8.3.)}$$
$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

where the factor, $X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar)$, is defined by the management regulation, combined with some harvest control rule and the upper limit for sea days (the "maximum possible number of sea days per period" (Eqs. D.5.3.2.a and b)

$$X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar) = \frac{EY_{Reg}(Fl,Vs,Rg,Ct,y,q,Ar)}{EY_{Max}(Fl,Vs,Ct,y,q,Ar)}$$ where EY_{MAX} is The maximum physical number of effort units per vessel per time unit and $EY_{Reg}(Fl,Vs,Rg,Ct,y,q,Ar)$ is the maximum number of sea days per time period dictated by the regulation,

and the "MPA-factor", $X^{MPA-Closure}(Fl,Vs,Rg,Ct,y,q,Ar)$, is the fraction of time period (y,q) which is closed for fishing. Thus

$$0 \leq X^{MPA-Closure}(Fl,Vs,Rg,Ct,y,q,Ar) \leq 1 \qquad \text{(D.8.3.2)}$$

Effort cannot exceed a physical upper limit (Eq. A.4.4.1)

$$E(Fl,Vs,\bullet,Ct,y,q,Ar) \leq NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet)* EY_{Max}(Fl,Vs,Ct,y,q,Ar)$$

Combining maximum number of sea days, capacity and MPA gives the F/effort expression after modification of stock specific effort.

$$F^{After}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) =$$
$$\sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} MAX\{ X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar)*$$
$$X^{MPA-Closure}(Fl,Vs,Rg,Ct,y,q,Ar)* E^{Before}(Fl,Vs,Rg,Ct,St,y,q,Ar), \qquad \text{(D.8.3.3)}$$
$$NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet)* EY_{Max}(Fl,Vs.Ct,y,q,Ar) \}*$$
$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$$

The modification of stock specific effort is contained in the factor $X^{SeaDays}(Fl,Vs,Rg,Ct,y,q,Ar)$

The number of vessels was introduced in Section A.4.1. Omitting all special cases the general equations

Vessel age	Number of vessels in period q where q > 1
Va = 0	$\mathbf{NU_{Vessel}(Fl, Vs, Ct, y, q, 0) = NU_{New\text{-}Vessel}(Fl, Vs, Ct, y,q)}$
Va = 1,2,…,Va$_{max}$-1	$\mathbf{NU_{Vessel}(Fl, Vs, Ct, y, q,Va) = NU_{vessel}(Fl, y , q\text{-}1,Va) - NU_{Decomm}(Fl, Vs, Ct, y, q,Va) - NU_{Withdrawal}(Fl, Vs, Ct, y, q, Va) - NU_{Attrition}(Fl, Vs, Ct, y, q, Va)}$

The dynamics of the number of vessels, that is what creates an investment in a new vessel or withdrawal of a vessel (due to attrition, bankruptcy or decommission) is covered in the economic section of the TEMAS model.

Maximum number of sea days and MPA may be combined with a single species TAC, which in the TEMAS formulation takes the form:

$$F^{After}(\bullet,\bullet,\bullet,\bullet,St,y,q,Ar) \le F^{After}_{HCR}(St,y,q,Ar)$$

D.8.4. IMPLEMENTATION OF AN EVALUATION FRAME FOR EFFORT BASED MANAGEMENT, MPA AND TAC.

To make an evaluation of two alternative MPA/effort-management systems involves a long suite of simulation steps. The four principal steps of the complete evaluation involve:

Step 1:

Estimate parameters by calibration. "Fiddle" with the parameters until you achieve a fair similarity between observations and simulation results, using minimum sum of squares of observations (or maximum likelihood).

Step 2:

Execute Alternative 1:

For year = 1 to 20 do

1. ICES WG to set TAC, including sampling of input data to ICES assessment.
2. EU Commission to modify ICES TAC according to relative stability and maximum deviations between TAC this year and TAC last year (EU rule 1).
3. EU Commission to set maximum number of sea days, Effort based management, according to rule (EU Rule 2).
4. EU Commission to set closed seasons and/or number of non-fishing days/year, according to rule (EU Rule 3).
5. EU Commission to set MPA, according to rule (EU Rule 4).
6. EU commission to set other technical management measures E.g. max. mesh sizes, min landing size, eyc, according to rule (EU Rule 5).
7. Invest/disinvest in fishing capacity, by RUM (according to structural behaviour rules).
8. Make decisions on effort allocation, by RUM and relative stability (according to trip behaviour rules)
9. Execute model for biology/fishing, including enforcement/compliance (According to an "Enforcement Rule" and a "Compliance Rule").

   a. Biological spatial model for growth, spawning and migration.
   b. Technical/spatial model for fishing, with fishing limited by TAC, max fishing days, closed seasons, technical management measures and MPA.
   c. Model of enforcement/compliance (e.g. stop of fishery when TAC exceeded)
10. Execute economic model (costs and earnings).
11. Evaluate fishing (input to EU commission). These EU working groups are in TEMAS used to simulate incomplete knowledge. That is, to simulate wrong conclusions made by managers.
   a. STECF WG on effort based management, including sampling of input data.
   b. STECF WG on closed periods, including sampling of input data.
   c. STECF WG on MPA, including sampling of input data.
   d. STECF WG on bio-economics, including sampling of input data.
12. Compute measures of performance

Next year

Each alternative is evaluated by, say, 1000 simulations, and distributions of selected measures of performance are produced.

Step 3:

Execute Alternative 2.

As alternative 1, but with different rules for points 4 and 5 above. For example: (a) No MPA and No closed periods (b) As (a) combined with no TAC, i.e. no input from ICES.

Step 4:

Compare the two alternatives.

Make risk assessment by comparison of probability distributions of measures of performance. For example, find the probability of $SSB < SSB_{PA}$ efter (say) 10 years for each of the two alternatives.

One set of problems with the above plan for evaluation is the set of management/behaviour rules we need to define before the simulation can run. I never managed to start a discussion on these rules. I tried several times to initiate a discussion, but nobody seemed to understand the problem or have any interest in it.

In addition to this fundamental problem there are the problem of getting data for calibration, and the coding of the rules in Visual basic (the coding is trivial, but takes time).

ANNEX E CALIBRATION OF MODEL

E.1. INTRODUCTION

The statistical estimation of parameters in TEMAS is more or less assumed to be a problem isolated from the simulations with TEMAS. Somehow, we assume that parameters are available from various (not specified, by "reliable" sources). Needless to say, this will never strictly be the case in any application of TEMAS. Actually, many of the crucial parameters of TEMAS cannot be estimated by robust statistical methods, involving estimation of variance and co-variances and all their derivatives in the form of statistical diagnostics. The general parameter estimation problem in fisheries is illustrated by the fact that most fish stock assessments in ICES are made by highly questionable non-standard methods like the XSA, that is methods that do not live up to the standards of textbooks in bio-statistical analysis (e.g. Sokal and Rohlf, 1981). ICES could have chosen to apply strict statistical methods, like those of the SAS, the S or the R system of methods, but have so far refrained from using the standard approach. The TEMAS is not in any better situation, than any other current model currently available to fisheries science. TEMAS perhaps differs from other approaches in that it accepts and fully accounts for its limited capability in parameter estimation. TEMAS lacks a proper methodology for parameter estimation, and many (most) parameters of TEMAS are "guesstimates" rather than "estimates" (as defined in standard textbooks of statistical inference). The reason for this is not that parameter estimation methodology is not available, but that available data are of a poor quality, but perhaps more important is, that the basic mechanism behind the system dynamics is not understood. The so-called "process errors" of TEMAS are not known. Thus, it is not possible to separate "process errors" and "measurement errors", but both are probably big

However, it is not satisfactory to make a complete separation between the "real world" and the simulations by TEMAS. One would like to maintain the humble illusion that TEMAS does indeed resemble to the real world, although we do not dare make statements about the "prediction power" of TEMAS. The calibration of TEMAS is a rather ad hoc attempt to make TEMAS not deviate "too much" from the reality.

E.2. CALIBRATION OF TEMAS

The idea of "calibration" means to adjust certain parameters of TEMAS, so that TEMAS can make a simulated prediction for a historical period, that does not "deviate too much" from the observed fisheries. For example, TEMAS should be able to simulate predicted catches from 1995 to 2005 that do not deviate too much from the actual (observed) catches 1995-2005.

TEMAS calibrates some of its parameters by aid of the so-called modified χ^2-criterion (Sokal and Rohlf, 1981)

$$\chi_X^2 = \sum_{Indices} \frac{(X_{Observed} - X_{Calculated})^2}{X_{Calculated}} \qquad \text{(E.1.2.1)}$$

where "$X_{calculated}$" symbolises a prediction-variable of the model, for example, the weight of cod, caught by a certain gear rigging of a fleet fleet, at a certain time, in a certain area. "$X_{observed}$" indicates the value of X observed from a historical period. The variables "X" are selected so that they are easy to access. The example given above can be easily extracted from the logbooks. The same model is used for both prediction and estimation. $X_{calculated}$ depends on the indigenous parameters, and χ^2 is minimised with respect of the indigenous parameters. "Indices" is a subset of the indices available in TEMAS[15] The most detailed version of Eq E.1.2.1 is achieved with the complete set of all indices used in TEMAS, i.e. (Fl, Vs, Rg, Ct, St, y, a, q, Va, Ar) is given by Eq. E.1.2.2

$$\chi^2_{Yield} = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{a=1}^{a_{Max}(St)} \sum_{q=1}^{q_{Max}} \sum_{Va=}^{Va_{Max}(Ct,Fl)} \sum_{Ar=1}^{Ar_{Max}}$$

$$\frac{(Y^{Obs}_{Landings}(Fl,Vs,Rg,Ct,St,y,a,q,Va,Ar) - Y^{Calc}_{Landings}(Fl,Vs,Rg,Ct,St,y,a,q,Va,Ar))^2}{Y^{Calc}(Fl,Vs,Rg,Ct,St,y,a,q,Va,Ar)} + \qquad \text{(E.1.2.2)}$$

$$\frac{(Y^{Obs}_{Discards}(Fl,Vs,Rg,Ct,St,y,a,q,Va,Ar) - Y^{Calc}_{Discards}(Fl,Vs,Rg,Ct,St,y,a,q,Va,Ar))^2}{Y^{Calc}_{Discards}(Fl,Vs,Rg,Ct,St,y,a,q,Va,Ar)}$$

Eq. contains the sum of squares of deviation (SSD) for both landings and discards, for each vessel age group. Removing the discards, which are usually not (rather never) direct observations, as well as the vessel age group data, which will usually not be available, we come to Eq E.1.2.3.

$$\chi^2_{Yield} = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{a=1}^{a_{Max}(St)} \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}}$$

$$\frac{(Y^{Obs}_{Landings}(Fl,Vs,Rg,Ct,St,y,a,q,\bullet,Ar) - Y^{Calc}_{Landings}(Fl,Vs,Rg,Ct,St,y,a,q,\bullet,Ar))^2}{Y^{Calc}(Fl,Vs,Rg,Ct,St,y,a,q,\bullet,Ar)} + \qquad \textit{(E.1.2.3)}$$

Eq. E.12.3 gives the SSD's by age group, which again will be "observations" estimated from samples. However, Eq, may be applicable in some cases, where a comprehensive biological/technical data collection program is being implemented.

The chi-squared expression for landings summed over age groups is given in Eq. E.1.2.4. This is the standard expression used in the current version of TEMAS.

$$\chi^2_{Yield} = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{Rg=1}^{Rg_{Max}(Fl,Ct)} \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}}$$

$$\frac{(Y^{Obs}_{Landings}(Fl,Vs,Rg,Ct,St,y,\bullet,q,\bullet,Ar) - Y^{Calc}_{Landings}(Fl,Vs,Rg,Ct,St,y,\bullet,q,\bullet,Ar))^2}{Y^{Calc}(Fl,Vs,Rg,Ct,St,y,\bullet,q,\bullet,Ar)} \qquad \text{(E.1.2.4)}$$

Landings summed over vessel age groups and fish age groups, are the "observations" expected in the current version of TEMAS. This feature of the current TEMAS can easily be changed.

15 15:

	Index	*Explanation*	*Range*
1	a	Age group	A = 0,1,2,…,a_{max}(St)
2	Ar	Area	Ar = 1,2,…,Ar_{max}
3	Ct	Country	Ct = 1,…,Ct_{Max}
4	Fl	Fleet	Fl = 1,2,…,Fl_{max}(Ct)
5	q	Time period (as time)	Q = 1,..,q_{max}
6	qa	Time period (as age)	qa = 1,..,q_{max},
7	Rg	Rigging of gear	Rg = 1,…,Rg_{max}(Fl,Ct)
8	y	Year	Y = $y_{firSt, yfirst}$+1,…,y_{last}
9	St	Stock	St = 1,…,St_{max}
10	Va	Vessel age group	Va = 1,…Va_{max}(Fl,Ct)
11	Vs	Vessel size group	Vs = 1,…Vs_{max}(Fl,Ct)

Note that the sequence of indices will be (Fl, Vs, Rg, Ct, St, y, a, qa, Va, Ar) for all variables.

Time variables in alphabetical order
dt: Basic time step (fraction of year). dt < 1.0. dt = 1/q_{Max}
y_{first} ,y_{last}: First year, Last year

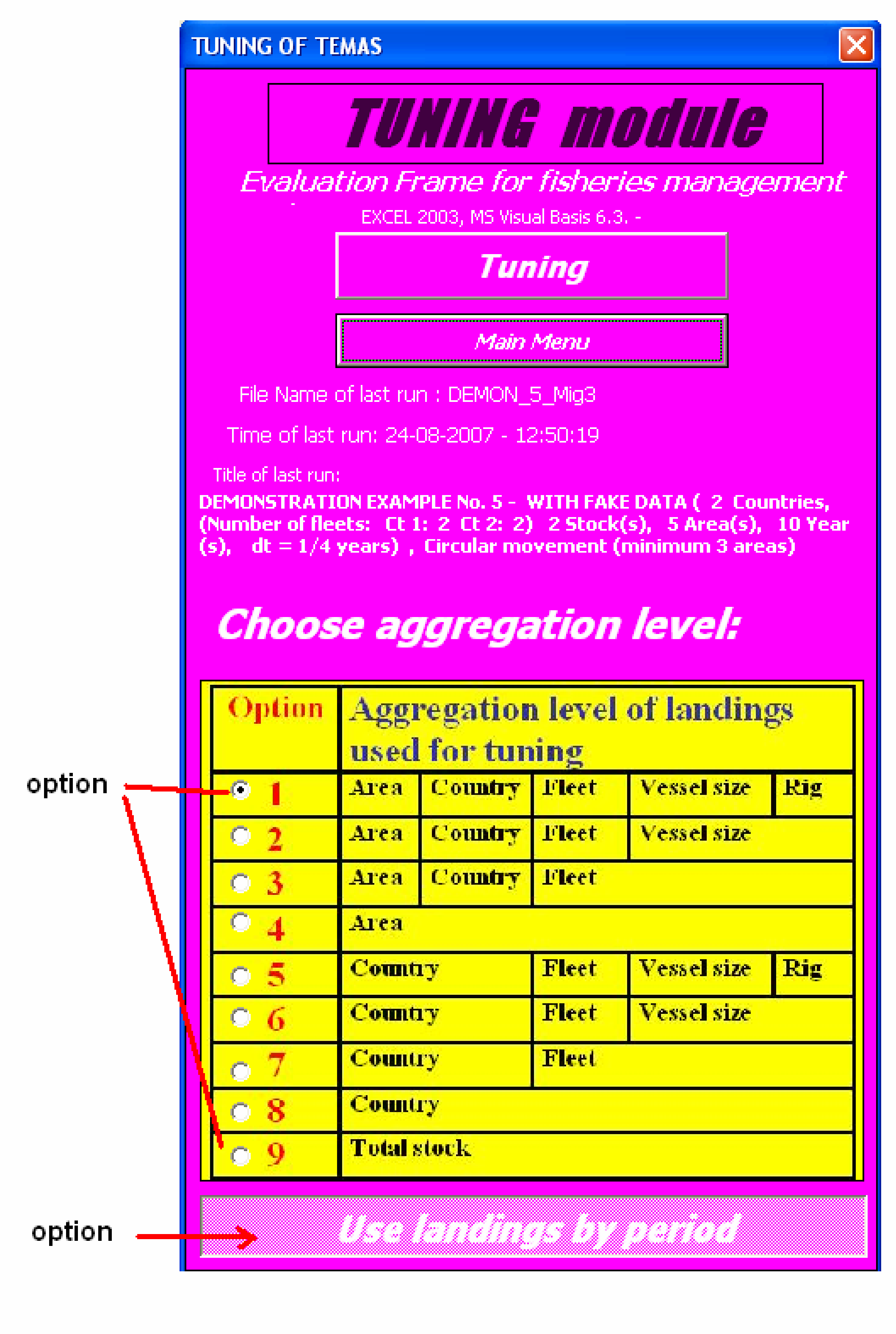
Note that dot "•" instead of an index means summation over the index in question. Thus $X(i,\bullet,j) = \sum_u X(i,u,j)$.

Eq. E.1.2.4 calculates SSD by rigging. In case rigging data are not available, the next version with landings aggregated over riggings is shown in Figure E.1.2.5.

$$\chi^2_{Yield} = \sum_{Ct=1}^{Ct_{Max}} \sum_{Fl=1}^{Fl_{Max}(Ct)} \sum_{Vs=1}^{Vs_{Max}(Fl,Ct)} \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{q=1}^{q_{Max}} \sum_{Ar=1}^{Ar_{Max}} \frac{(Y^{Obs}_{Landings}(Fl,Vs,\bullet,Ct,St,y,\bullet,q,\bullet,Ar) - Y^{Calc}_{Landings}(Fl,Vs,\bullet,Ct,St,y,\bullet,q,\bullet,Ar))^2}{Y^{Calc}(Fl,Vs,\bullet,Ct,St,y,\bullet,q,\bullet,Ar)} \quad \text{(E.1.2.5)}$$

From Eq. E.1.2.5 one may reduce the number of indices of SSD further, depending on the actual case study. E.g. one might consider only the total annual landings by stock:

$$\chi^2_{Yield} = \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \frac{(Y^{Obs}_{Landings}(\bullet,\bullet,\bullet,\bullet,St,y,\bullet,\bullet,\bullet,\bullet) - Y^{Calc}_{Landings}(\bullet,\bullet,\bullet,\bullet,St,y,\bullet,\bullet,\bullet,\bullet))^2}{Y^{Calc}(\bullet,\bullet,\bullet,\bullet,St,y,\bullet,\bullet,\bullet,\bullet)} \quad \text{(E.1.2.6)}$$


TUNING OF TEMAS
TUNING module
Evaluation Frame for fisheries management
EXCEL 2003, MS Visual Basis 6.3. -
Tuning
Main Menu
File Name of last run : DEMON_5_Mig3
Time of last run: 24-08-2007 - 12:50:19
Title of last run:
DEMONSTRATION EXAMPLE No. 5 - WITH FAKE DATA (2 Countries, (Number of fleets: Ct 1: 2 Ct 2: 2) 2 Stock(s), 5 Area(s), 10 Year (s), dt = 1/4 years) , Circular movement (minimum 3 areas)
Choose aggregation level:
Option
Aggregation level of landings used for tuning
1 Area Country Fleet Vessel size Rig
2 Area Country Fleet Vessel size
3 Area Country Fleet
4 Area
5 Country Fleet Vessel size Rig
6 Country Fleet Vessel size
7 Country Fleet
8 Country
9 Total stock
Use landings by period
option
option

Annual SSD= (Obs land - Simulated land)/(Simulated land): Diff between Weight of simulated ar

TUNING OF TEMAS
Evaluation Frame for fisheries management systems
Version. EXCEL 2003, MS Visual Basis 6.3. - TEMAS: 15 Aug 2007
Marine Fisheries Department
Danish Tecnical University

RUN INFORMATION:
Date of this r #### 13:11
Name of Run DEMONSTRATION EX
Param. Creat #### 00:00
File Name: DEMON_5_Mig3

Note: To change input parameters, start the INPUT-module

Table 8.1.1 . Regime 1 - West Cod: ANNUAL SSD (Fl,Vs,Rg,Ct,Ar), BASIC DATA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
West Baltic - Baltistan - OB Trawler-Baltistan - Small - <110mm -	---	---	1.0454	2.4571	2.0841	0.6807	2.5724	---	---	---
East Baltic - Baltistan - OB Trawler-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - OB Trawler-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - OB Trawler-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---
Gotland - Baltistan - OB Trawler-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---
West Baltic - Baltistan - OB Trawler-Baltistan - Small - >110mm -	---	---	1.4434	3.4568	2.9631	0.9834	3.5904	---	---	---
East Baltic - Baltistan - OB Trawler-Baltistan - Small - >110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - OB Trawler-Baltistan - Small - >110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - OB Trawler-Baltistan - Small - >110mm -	---	---	0	0	0	0	0	---	---	---
Gotland - Baltistan - OB Trawler-Baltistan - Small - >110mm -	---	---	0	0	0	0	0	---	---	---
West Baltic - Baltistan - OB Trawler-Baltistan - Medium - <110mm -	---	---	0.8311	1.8166	1.4957	0.5047	1.8241	---	---	---
East Baltic - Baltistan - OB Trawler-Baltistan - Medium - <110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - OB Trawler-Baltistan - Medium - <110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - OB Trawler-Baltistan - Medium - <110mm -	---	---	0	0	0	0	0	---	---	---
Gotland - Baltistan - OB Trawler-Baltistan - Medium - <110mm -	---	---	0	0	0	0	0	---	---	---
West Baltic - Baltistan - OB Trawler-Baltistan - Medium - >110mm -	---	---	1.1245	2.5496	2.0069	0.6832	2.5084	---	---	---
East Baltic - Baltistan - OB Trawler-Baltistan - Medium - >110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - OB Trawler-Baltistan - Medium - >110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - OB Trawler-Baltistan - Medium - >110mm -	---	---	0	0	0	0	0	---	---	---
Gotland - Baltistan - OB Trawler-Baltistan - Medium - >110mm -	---	---	0	0	0	0	0	---	---	---
West Baltic - Baltistan - OB Trawler-Baltistan - Large - <110mm -	---	---	0.2552	0.56	0.4243	0.1364	0.4784	---	---	---
East Baltic - Baltistan - OB Trawler-Baltistan - Large - <110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - OB Trawler-Baltistan - Large - <110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - OB Trawler-Baltistan - Large - <110mm -	---	---	0	0	0	0	0	---	---	---
Gotland - Baltistan - OB Trawler-Baltistan - Large - <110mm -	---	---	0	0	0	0	0	---	---	---
West Baltic - Baltistan - OB Trawler-Baltistan - Large - >110mm -	---	---	0.3575	0.7894	0.6199	0.1916	0.6671	---	---	---
East Baltic - Baltistan - OB Trawler-Baltistan - Large - >110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - OB Trawler-Baltistan - Large - >110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - OB Trawler-Baltistan - Large - >110mm -	---	---	0	0	0	0	0	---	---	---
Gotland - Baltistan - OB Trawler-Baltistan - Large - >110mm -	---	---	0	0	0	0	0	---	---	---
West Baltic - Baltistan - Gillnett-Baltistan - Small - <110mm -	---	---	0.992	2.4298	2.0442	0.5122	1.9946	---	---	---
East Baltic - Baltistan - Gillnett-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---
Not Baltic - Baltistan - Gillnett-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---
Bornholm - Baltistan - Gillnett-Baltistan - Small - <110mm -	---	---	0	0	0	0	0	---	---	---

Annual_SSD / Period_SSD / Annual_Land / Period_Land / Annual_Obs / Period_Obs / 1

In addition to yield (landings and discards), the TEMAS software offers three more options for calibration to observations. The options for calibration data are:

1) Catches, (Landings and discards) on various dis-aggregation levels. From
   (Fl, Vs, Rg, Ct, St, y, a, q, Va, Ar) to (•,•,•,•, St, y,•,•,•,•)
2) Index of stock numbers from research vessel survey or from catch per unit of effort of commercial vessels.
3) Index of stock biomass or SSB from research vessel survey or from catch per unit of effort of commercial vessels.
4) Mean stock F (Fishing mortality) from (for example) fish stock assessment of ICES working groups.

The index of stock numbers can be catch per day by age group, converted into relative numbers, to make them compatible with relative numbers predicted by TEMAS.

$$\chi^2_N = \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{q=1}^{q_{Max}} \sum_{a=1}^{a_{Max}(St)} \frac{(N^{Obs}_{Index}(St,y,q,a,Ar) - N^{Calc}_{Index}(St,y,q,a,A))^2}{N^{Calc}_{Index}(St,y,q,a)} \quad \text{(E.1.2.7)}$$

Where, for example, $N^{Calc}_{Index}(St,y,q,a,Ar) = \dfrac{N(St,y,q,a,Ar)}{\sum_{i=1}^{a_{Max}(St)} N(St,y,q,i,Ar)}$ and the survey index is derived from, say, catch per hour, $CPUE_{Survey}$, $N^{Obs}_{Index}(St,y,q,a,Ar) = \dfrac{CPUE_{Survey}(St,y,q,a,Ar)}{\sum_{i=1}^{a_{Max}(St)} CPUE_{Survey}(St,y,q,i,Ar)}$

Also indices of biomass (or SSB) can be made relative and compared to indices predicted by TEMAS.

$$\chi^2_{SSB} = \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{q=1}^{q_{Max}} \frac{(SSB^{Obs}_{Index}(St,y,q) - SSB^{Calc}_{Index}(St,y,q))^2}{SSB^{Calc}_{Index}(St,y,q)} \quad \text{(E.1.2.8)}$$

Fishing mortality can be compared to fishing mortalities estimated by persons independent of TEMAS (e.g. ICES WGs).

$$\chi^2_{F_{MEAN}} = \sum_{St=1}^{St_{Max}} \sum_{y=y_{first}}^{y_{last}} \sum_{q=1}^{q_{Max}} \frac{(F^{Obs}_{Mean}(St,y,q) - F^{Calc}_{Mean}(St,y,q))^2}{F^{Calc}_{Mean}(St,y,q)} \quad \text{(E.1.2.9)}$$

In theory, the χ^2 expression could make the basis for estimating the parameters, (designated "P" in Eq E.1.2.9), by minimization. Because of the large number of parameters, and the small number of degrees of freedom, this approach would be very problematic in practice.

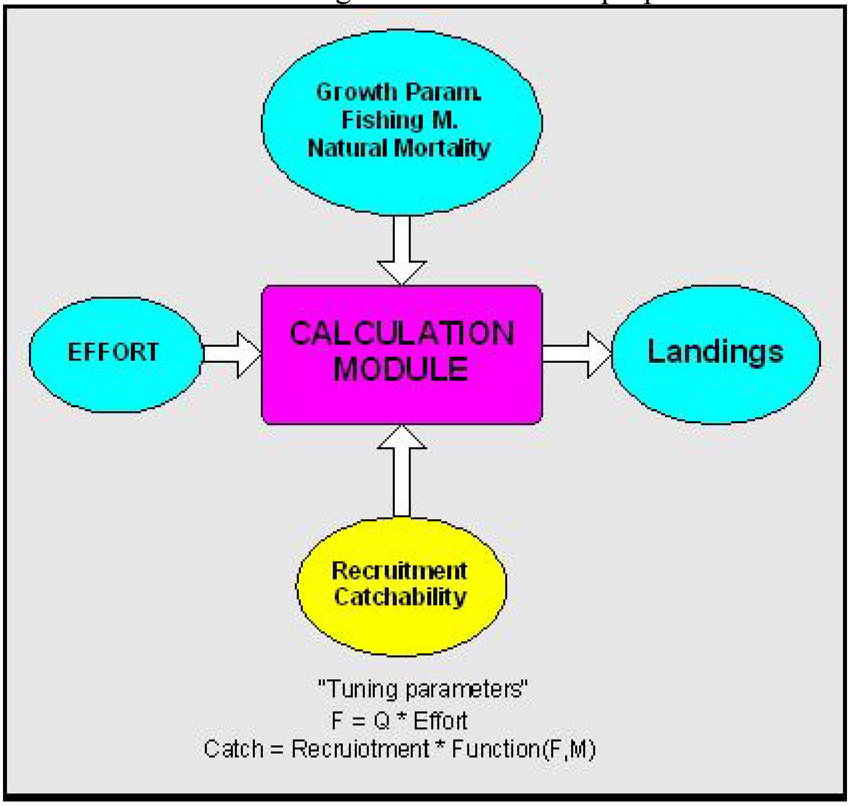
$$\chi^2_X(X^{Obs},P) = \sum_{Indices} \frac{(X^{Obs} - X^{Calc}(P))^2}{X^{Calc}(P)} = Minimum \quad \text{(E.1.2.10)}$$

Some parameters (a subset of P), however, may be estimated that way. That could apply to the catchability coefficients.

Other "observations" than landings can be used to calibrate TEMAS. That could be CPUE observations from research surveys, that are believed to be a proxy for SSB or recruitment.

E.1.3. TUNING OF TEMAS

By "tuning" is meant the processes of finding the reference simulation of TEMAS. The reference simulation is the situation (scenario) relative to which all the other simulations are made, and are compared to in the evaluation frame. Tuning involves the calculation of certain parameters. It should be noted that tuning does not involve a proper statistical estimation of parameters.



The reference simulation will usually be chosen to be a simulation in equilibrium, that is, a simulation where all results are equal in all years of the time series under study. Furthermore, the reference simulation will usually be chosen to be the fisheries situation of the current situation (current year). TEMAS is said to reproduce the current situation when it can reproduce the landings (in weight) observed the last data year for each combination of fleet, stock, time period and area. To achieve this goal completely is usually impossible, so one can only hope for a reasonable approximation. Taking in to account all the sources of uncertainties involved in TEMAS, there is no reason to make too much effort in achieving a complete reproduction of observed catches
The five types of tuning offered by TEMAS is (see also Figure xxxxx showing the tuning menu form)

1) N(first year) = N(last year). To achieve equilibrium
2) BH(New) = BH(old)*Land(Obs)/Land(Calc), or the similar parameter in an alternative S/R-model. . Tune recruitment to observed landings
3) Q(New) = Q(old)*Land(Obs)/Land(Calc). Tune catchability to observed landings
4) Q(New) = Q(old)*F(Obs)/F(Calc). Tune catchability to observed total fishing mortality.
5) Q = F/Effort by area and fleet. Compute individual catchabilities to observed area fishing mortalities

The total landings from a stock is (almost) proportional to the parameters 'BH1' in the stock and recruitment model (Beverton & Holt model), with all other parameters kept constant Thus for a given fishing mortality, BH1 can be selected to give any landings you want. As the parameter 'BH1' is usually an unknown parameter, you may consider the tuning of TEMAS as a pseudo estimation of BH1 (it is not a proper estimation). You calibrate BH1 to produce the observed landings

The procedure of calibrating BH1 gives you the total landings for a given total fishing mortality. Next step in the tuning is then to distribute the landings from the stock in question on the fleets. This is achieved by assigning the values to catchability coefficients that produces the fishing mortalities, which in turn gives the observed landings by fleet, area and time period.

To summarize: Tuning means assigning values to:

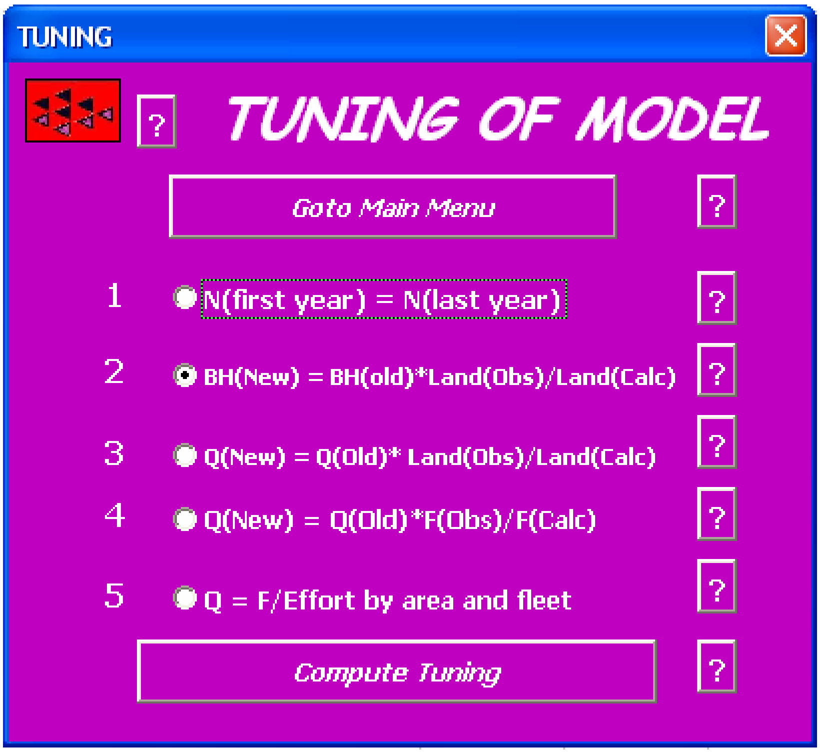
1) The Stock recruitment parameters (e.g. Beverton and Holt parameter BH1(Stock))
2) Catchability coefficient, Q(Fleet, Stock, Time period, Area)

so that: Observed landings = Calculated landings for all combinations of Stock, Fleet, Area and Time period in a given year (which is usually the most recent data year) so that the system is in equilibrium (gives the same results in all years)

Recommendation: The tuning procedure changes the input files in the disk:

1) The stock input files are changed
2) The fleet input files are changed

Therefore: MAKE A BACKUP OF THE DISKFILES BEFORE TUNING. You may regret the tuning, and want to return to the starting point. Returning to the starting point is difficult unless you made a backup.



N(first year) = N(last year)

This tuning is used to make the reference simulation an equilibrium situation "After the completion of a simulation it assigns the calculated stock numbers of the last year, to the initial stock numbers (first years)

N(St, First year, a, q, Ar) := N(St, Last year, a, q, Ar)

BH(New)=BH(old)*Land(Obs)/Land(Calc)

This tuning changes the first stock/recruitment parameter, BH1, so that:

Total Observed Landings (St, First year) = Total Calculated Landings (St, First year)

Recall that:

$$\mathrm{Re}\,c(y,q,Ar) = \mathrm{Re}\,cDist_{Area} * \mathrm{Re}\,cDist_{Period} * \frac{BH1 * SSB(y-1)}{1 + BH2 * SSB(y-1)}$$

where SSB = Spawning Stock Biomass and Recruitment, Rec, is the number in the 0-group: "N(St, year, 0, period, area)

First step is to calculate the tuning factor:

$$TuningFactor = \frac{Total\ Observed\ Landings(St, First\ year)}{Total\ Calculated\ Landings(St, First\ year)}$$

Second step is to change the Beverton & Holt parameter, BH1, by the tuning factor:

BH1(St) is replaced by TuningFactor * BH1(St)

Q(New)=Q(old)*Land(Obs)/Land(Calc)

Tune Catchability to landings. This tuning uses the landings (by weight) for each combination of Stock, fleet area and time period as input. If modifies the catchabilities of each combination so that:

Observed landings = Calculate landings, for each combination.

The tuning factor is thus

$$TuningFactor = \frac{Observed\ Landings(Fl, Vs, Rg, Ct, St, y, q, Ar)}{Calculated\ Landings(Fl, Vs, Rg, Ct, St, y, q, Ar)}$$

And the computation of the tuning becomes (Q = catchability coefficient):

Q(Fl, Vs, Rg, Ct, St, q, q, Ar) is replaced by (Tuning Factor) * Q(Fl, Vs, Rg, Ct,St, y, q, Ar)

Q(New)=Q(old)*F(Obs)/F(Calc)

This tuning uses the total (stock) fishing mortality given as input: 'F_{Tuning}'
The tuning changes the Reference catchability, so that:

$F_{Calculated}$(St, q) = F_{Tuning}(St, q)

"Recall that: $F_{Calculated}$ = Effort * (Reference catchability)* Selection

First step is to calculate the tuning factor:

TuningFactor = F_{Tuning}(St, q) / F_{Stock}(St, First Year, q, a_{Max}(St))

Second step is to change the catchability, Q, by the tuning factor:

Q(Fl,Vs,Rg,Ct,St, y, q, Ar) is replaced by TuningFactor * Q(Fl,Vs,Rg,Ct,St, First year, q, Ar)

Q=F/Effort by area and fleet

This tuning requires that fishing mortalities, F_{TUNING}, has been estimated (or can be assigned plausible values) by period, area and fleet, and that effort also have been been observed. Then the catchability is computed by

$$Q(Fl,Vs,Rg,Ct,St,\ first\ year,q,Ar) = \frac{F_{TUNING}(Fl,Vs,Rg,Ct,St,q,Ar)}{Effort(Fl,Vs,Rg,Ct,First\ year,q,Ar)}$$

for the first year. Subsequently all years are assigned the same values:

$$Q(Fl,Vs,Rg,Ct,St,y,q,Ar) = Q(Fl,Vs,Rg,Ct,St,First\ year,q,Ar)$$

How to tune TEMAS

To tune TEMAS can somewhat be called an art, rather than a science. Basically, you find a satisfactory tuning by trial and error.

The worksheet, “Tuning_Output” in workbook “TEMAS_CALC” contains some diagnostic output, showing the relative deviation between observations and calculated values (see Figure 4.4.2)

Figure 4.6.2. Selected output from Tuning.

The “diagnostics” are the relative differences between observations and model-predicted values:

$$Difference = 100\frac{(Observed\ Value\ -\ Calculated\ Value)}{Calulated\ Value}\ \%$$

which you by manipulation of parameter values tries to make as close as possible to zero. The example of Figure 4.4.2 refers to the entire stock and fishery.

There are other similar tables with area and fleet specific diagnostics in work sheet “Tuning”. Usually, you will firstly, tune the overall results, and subsequently “fine-tune” to the detailed results.

ANNEX F. BASIC FEATURES OF THE BALTIC FISHERIES

F.1. INTRODUCTION.

The present description of the biological features of Baltic fisheries, are mainly extracted from the Report of the Baltic Fisheries Assessment Working Group (WGBFAS) ICES CM 2006/ACFM:24. Figure F.1.1 shows the ICES sub-divisions, statistical rectangles, and the countries of the Baltic region. Western Baltic is defined as the areas 22-24. and Eastern Baltic is composed of 25-32. Kattegat is the border area of the Baltic. The islands of Bornholm and Gotland indicates the Basins with the location of the most important spawning grounds of eastern Baltic cod. The countries of the Baltic sea are Denmark, Sweden, Germany, Poland, Russia, Lithuania, Latvia, Estonia and Finland. Fisheries by other countries are insignificant, and are ignored in the present study. The right hand side of the figure shows the so-called ICES areas, area 22 is IIIc, area 23 is IIIb, and areas 24-32 are IIId. Fishing area IIIa(south) is Kattegat.

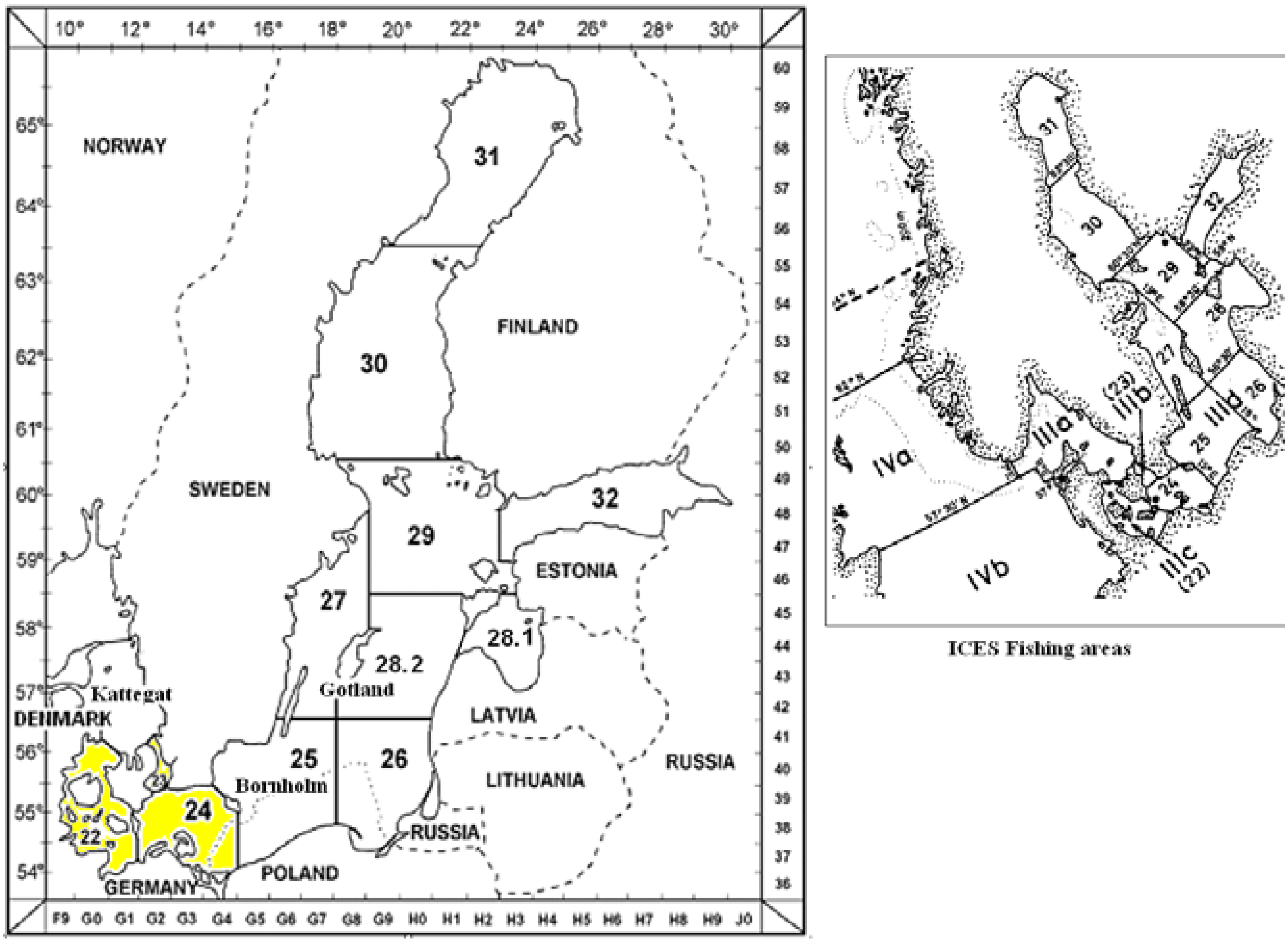


Figure F.1.1. The ICES sub-divisions, statistical rectangles, and the countries of the Baltic region. Western Baltic 22-24. Eastern Baltic 25-32. Kattegat is the border area of the Baltic. The islands of Bornholm and Gotland indicates the location of the most important spawning grounds of the cod. The left hand side shows the ICES Fishing areas. Area 22:IIIc, 23:IIIb, 24-32:IIId.

F.2. BALTIC FISH STOCKS.

The Baltic fisheries system is different from the neighbour areas, Kattegat, Skagerrak and the North Sea, as the number of abundant species is smaller in the Baltic. For example, Nephrops is not found in the Baltic. The spatial distribution of species is uneven in the Baltic.

The WGBFAS assess the stocks, Cod, Sprat, Herring, and it describes the stocks Brill, Turbot, Dab, and Plaice. (the Western Baltic Herring is assessed by the ICES WG on Herring south of 620, because its distribution extends into the Kattegat and Skagerrak).

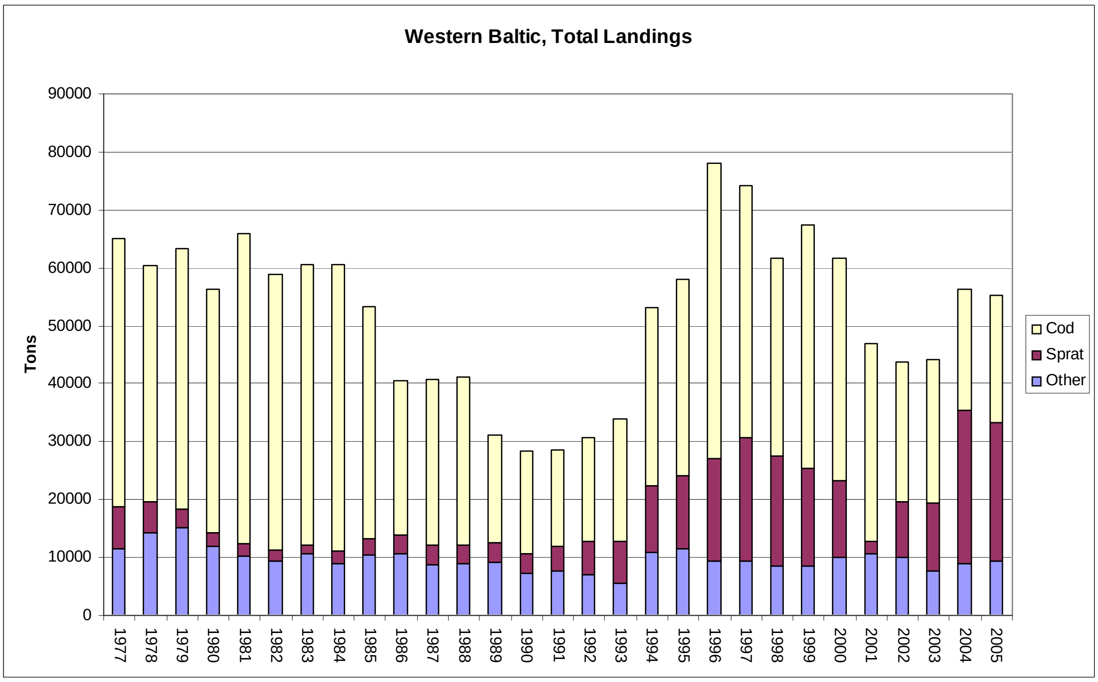


Figure F.2.1 Landings of Cod, Sprat and “other” species (see Fig. 2.1.2) in the Western Baltic.

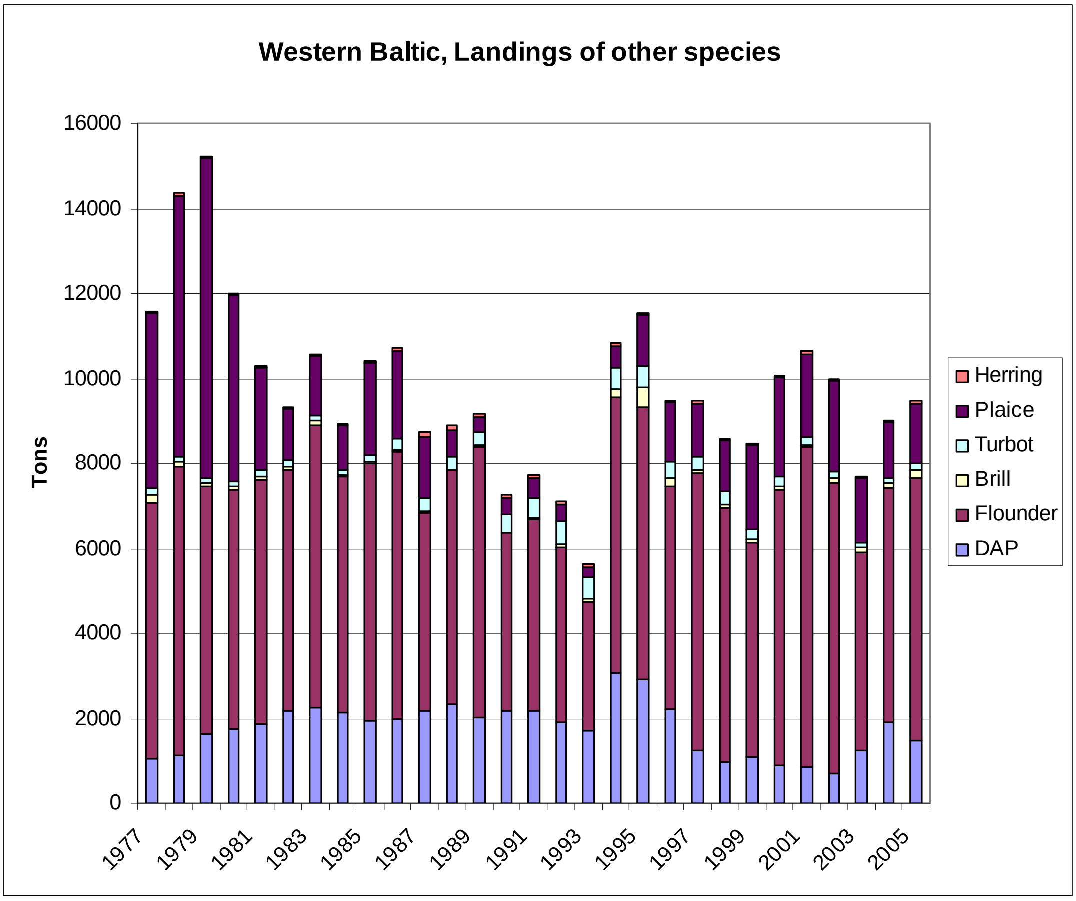


Figure F.2.2. Landings of "other" species (compare Fig. 2.1.1) in the Western Baltic.

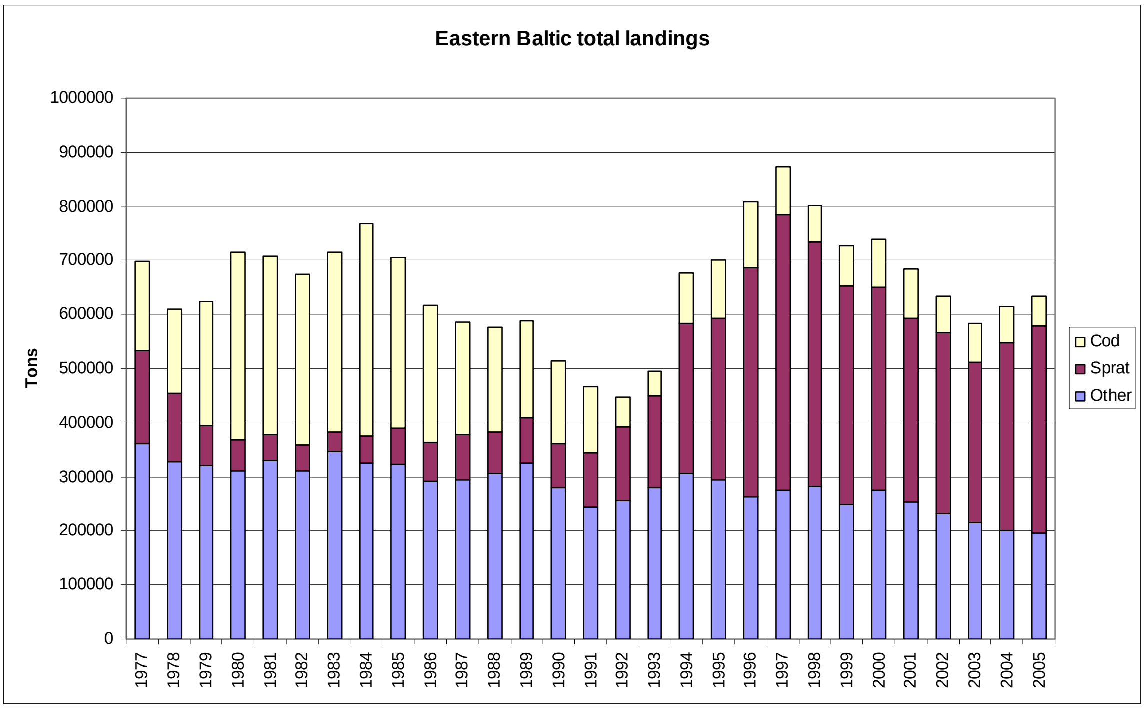


Figure F.2.3. Landings of Cod, Sprat and "other" species (see Fig. F.2.4) in the Eastern Baltic.

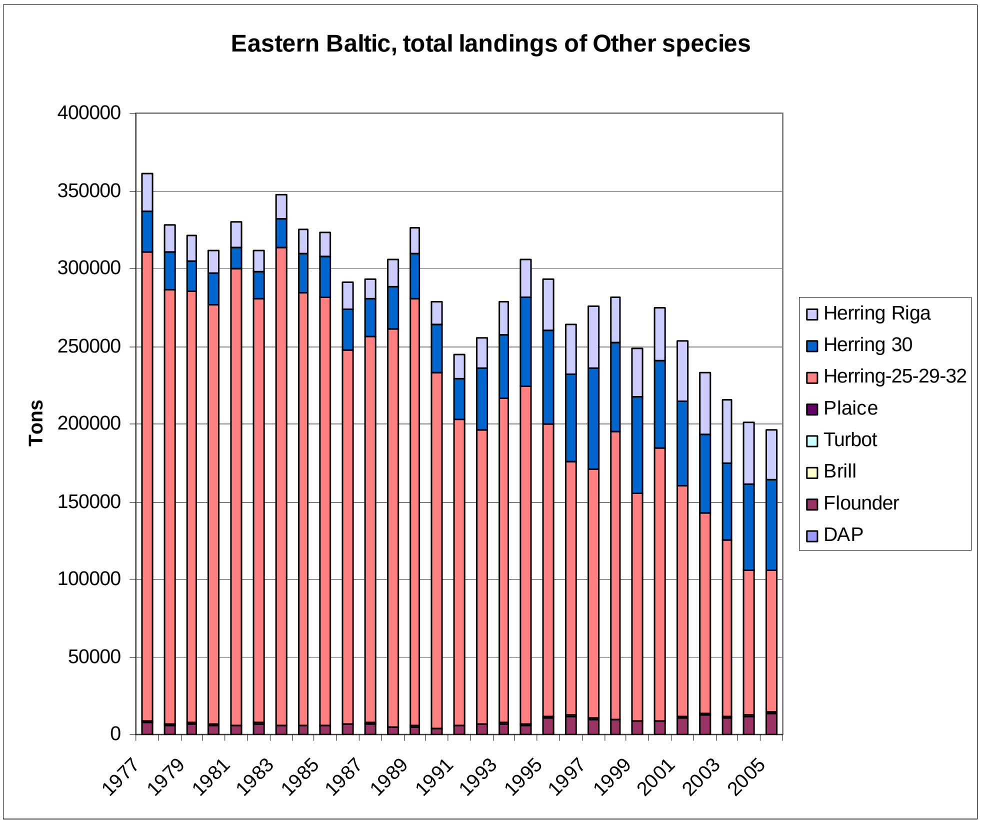


Figure F.2.4 Landings of "other" species (compare Fig. F.2.3) in the Eastern Baltic.

ICES also cover the Salmon and sea trout in the Baltic by the Baltic salmon and trout assessment working group (e.g. ICES, 2006). The Baltic eel stock is dealt with by the Joint EIFAC/ICES Working Group on Eels (e.g. ICES, 2006). The landings of salmon and trout is shown in Figure F.2.6.

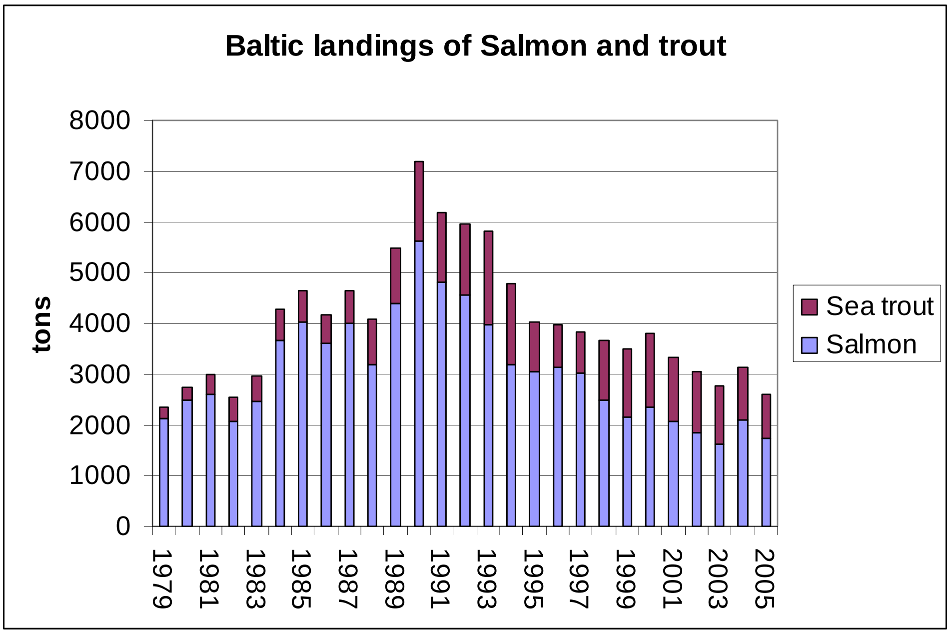


Figure F.2.5. Landings of Baltic salmon and trout from the sea, the lakes and the rivers.

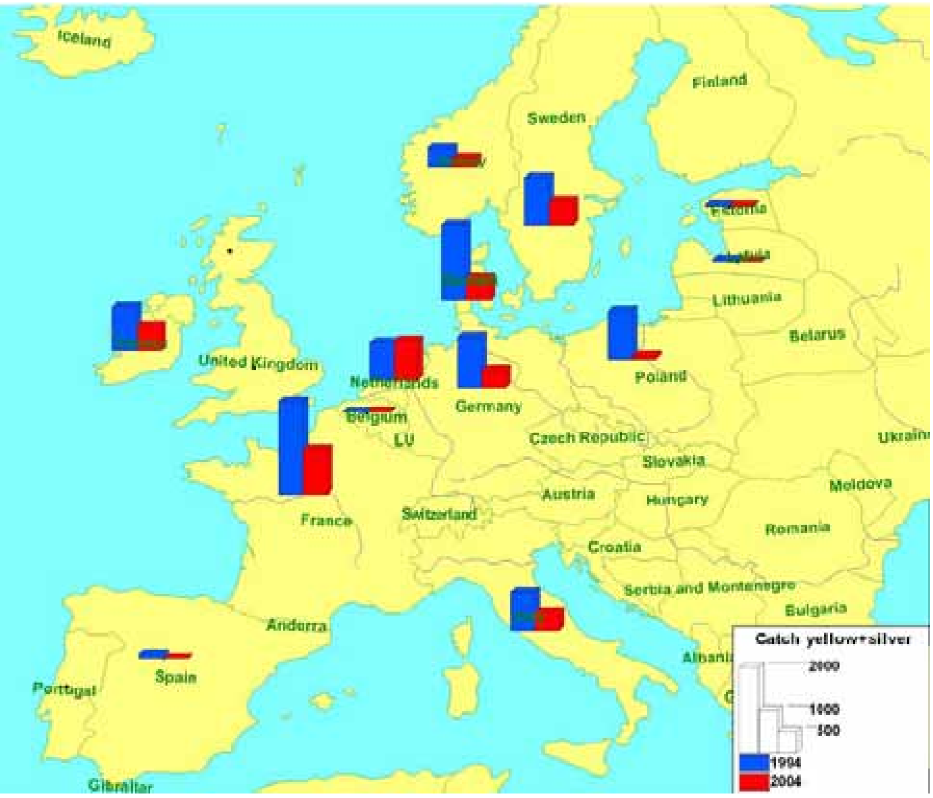


Figure F.2.6. Catches (tons) of European eel in 1994 and 2004 (Source Joint EIFAC/ICES Working Group on Eels, 2006).

F.3. BALTIC FISHING FLEETS.

An essential input to the TEMAS model, is the number of vessels in each fleet, and their effort by gear rigging and area. This is information usually not applied in ICES assessment. The WGBFAR: ICES WG on Baltic Fisheries (ICES 2006), contained a section describing the Baltic fleets, but the information was given in a rather unstructured inhomogeneous manner, which made it almost useless in connection with the TEMAS. A more useful description of selected Baltic fleets was given in the report of ECOPERFORM: Economic performance of Selected European Fishing Fleets (Annual report 2004). Concerted action Q5CA-2001-01502.

Fleet based data (capacity and effort) can be found on various websites linked to the EU fisheries commission and the national fisheries authorities. However, Russian data are not available from these sources.
From the website, http://ec.europa.eu/fisheries/fleet/index.cfm one can down load the full vessel register of each Baltic country, except for Russia.

The Baltic EU member countries deliver annual lists of all fishing vessels permits as well as data on fishing effort (e.g. Comm. Reg. (EC) No 2103/2004 of 9 December 2004 concerning the transmission of data on certain fisheries in the western waters and the Baltic Sea). Lists of vessels with permit to land cod can be found on member countries "control websites" Each Member State in the Baltic Sea maintains an official website on fishery related control and reporting issues .The national websites contain information on:

- National control action programmes;
- List of authorised vessels holding a special permit for fishing for cod in the Baltic Sea;
- Fishing effort limitation schemes;

- Contact details for the submission of logbooks and landing declarations when landing in that Member State
- Lists of designated ports and the addresses for fulfilling notification requirements.

Furthermore, national statistics in the form of year books of fisheries statistics are also available from the websites.
The Websites of national fishing control authorities around the Baltic Sea are:

Denmark	http://www.fd.dk/Default.asp?ID=17406
Estonia	http://www.kki.ee/?id=6601
Finland	http://www.mmm.fi/en/index/frontpage/Fishing,_game_reindeer/Sustainable_fishery/Fisheries_control.html
Germany	http://www.ble.de/index.cfm/C0A5390B31DC4F1F9855AC05798410C7
Latvia	http://www.jiup.gov.lv/Eng/codcontrol.htm
Lithuania	http://www.zum.lt/min/OS/dsp_struktura.cfm?StambesnisID=81&langparam=EN
Poland	http://www.minrol.gov.pl/DesktopDefault.aspx?TabOrgId=1130
Sweden	http://www.fiskeriverket.se/

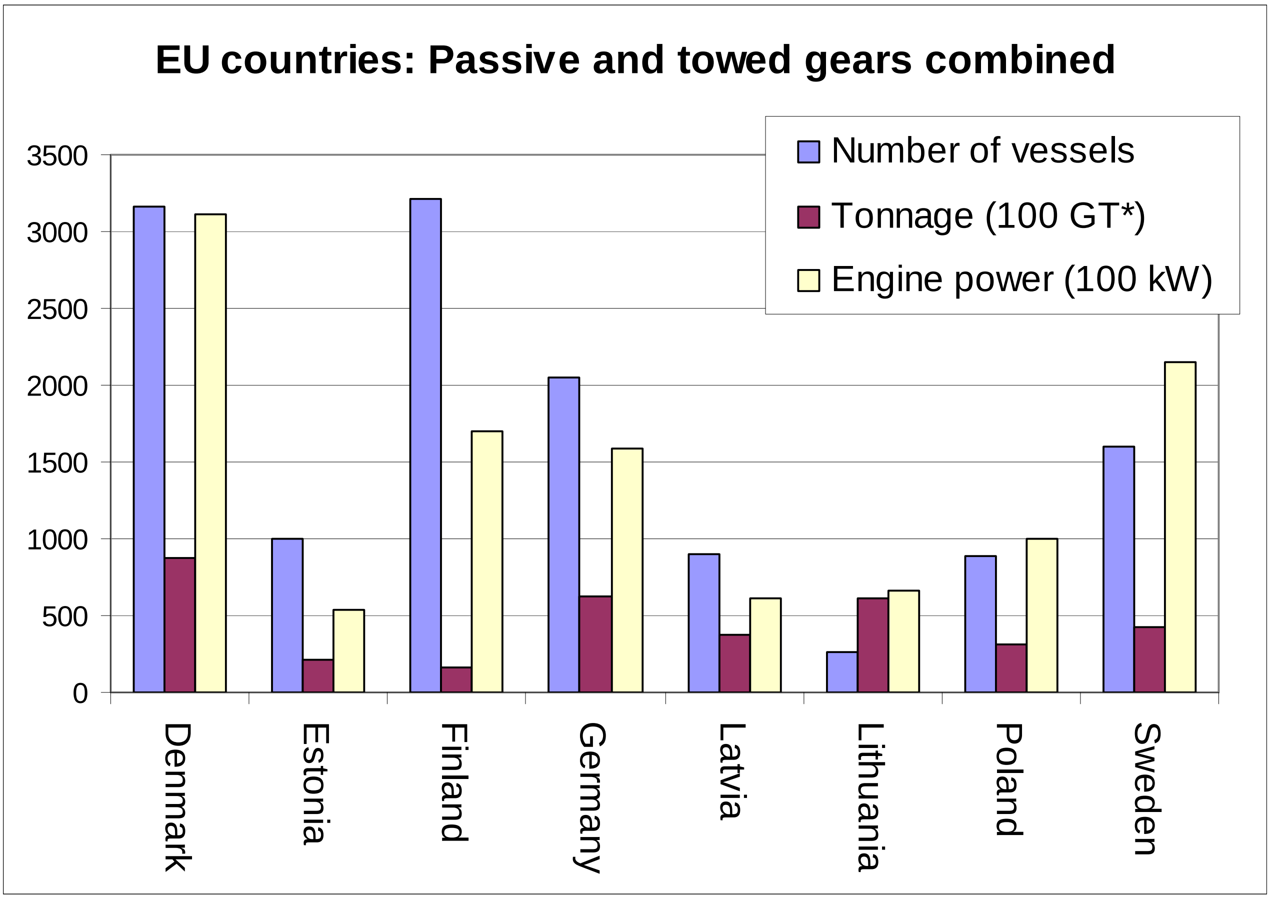
These websites thus comprises all Baltic countries except for Russia.
The source of the summaries of Baltic fishing fleets is extracted from "**European Commission Fisheries**" website "Facts and Figures on the EU Fishing Fleet", except for Russia.
http://ec.europa.eu/fisheries/fleetstatistics/index.cfm?lng=en

This section presents tables of number of vessels by each Baltic country. It also shows that there are public lists of all vessels holding a permit to catch cod in the Baltic. Thus, it appears to be easy to get information on the number of vessels. However, the problem is which of the vessels in the list that are actively fishing in the Baltic, at which part of the year they are active in the Baltic. Thus, to make the information given in the following really useful, it must be combined with effort and its spatial distribution. The definition of "number of Baltic fishing vessels" is not obvious. A vessel that fish only a part of the year in the Baltic, or which are not active part of the year (or all year), may or may not be counted as one vessel. The definition depends on the setup of the model in which the vessel is incorporated. In case, only the geographical Baltic area is considered (activities in other areas ignored), it may be appropriate to work with half or quarter vessels, alternatively to combine part-time Baltic vessels into whole Baltic vessels.

F.3.1. SUMMARY OF BALTIC FLEETS

The number of vessels, tonnage and engine power by mobile gears and towed gears of the EU Baltic countries is shown in the table below. The figures represent the total national fleets, not only the fraction of the fleets fishing in the Baltic. This is important for Germany and Denmark in particular.

	Passive Gear			Towed Gear			Total		
	Number of vessels	Tonnage (GT*)	Engine power (kW)	Number of vessels	Tonnage (GT*)	Engine power (kW)	Number of vessels	Tonnage (100 GT*)	Engine power (100 kW)
Denmark	2547	19740	113789	621	67450	197655	3168	87190	311444
Estonia	706	1350	10649	289	19476	42690	995	20826	53339
Finland	3102	8556	136129	106	8000	33931	3208	16556	170060
Germany	1645	5286	36987	410	57557	122238	2055	62843	159225
Latvia	773	4451	13664	125	32870	47688	898	37321	61352
Lithuania	213	1183	6501	52	59912	59763	265	61095	66264
Poland	715	6629	39580	171	25036	60075	886	31665	99655
Sweden	1251	5960	77413	343	37137	137840	1594	43097	215253
		GT/ves	kW/Ves		GT/ves	kW/ Ves		GT/ ves	kW/ Ves
Denmark		7.75	44.68		108.62	318.29		27.52	98.31
Estonia		1.91	15.08		67.39	147.72		20.93	53.61
Finland		2.76	43.88		75.47	320.10		5.16	53.01
Germany		3.21	22.48		140.38	298.14		30.58	77.48
Latvia		5.76	17.68		262.96	381.50		41.56	68.32
Lithuania		5.55	30.52		1152.15	1149.29		230.55	250.05
Poland		9.27	55.36		146.41	351.32		35.74	112.48
Sweden		4.76	61.88		108.27	401.87		27.04	135.04



F.3.2. FLEETS OF DENMARK

The Danish fishing fleet number about 3 500 vessels. The majority (71%) of vessels are less then 10 metres, but they represent 18% of the total engine power and 6% of the tonnage. Of these smaller vessels 92% are gill netters.

Approximately 180 Danish vessels are greater than 24 metres, representing 65% of the total GT and 38% of the total engine power. In this group trawl and multi-purpose vessels are by far the most important. The majority of these bigger vessels have their homeport in the northern and western parts of Jutland (Skagen, Hirtshals, Hanstholm, Thyborøn and Esbjerg). The most important species caught by these vessels are pelagic species and fish for reduction to fish meal and fish oil.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	2 547	19 740	113 789
Towed Gear	621	67 450	197 655
TOTAL	3 168	87 190	311 444

Passive Gear - Denmark

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	1	0	7	15	5
Set gillnets (anchored)	2 482	19 521	111 774	27	8
Set longlines	64	219	2 008	28	7
TOTAL	**2 547**	**19 740**	**113 789**	**23**	**7**

Towed Gear - Denmark

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Purse seines	5	6 755	13 528	17	63
Boat dredges	74	1 356	8 388	27	12
Hand dredges operating from a boat	1	1	22	2	5
Bottom otter trawls	444	50 483	149 336	32	20
Midwater otter trawls	21	5 395	14 304	30	27
Danish seines	66	2 922	10 185	41	16
Beam trawls	10	538	1 892	17	18
TOTAL	**621**	**67 450**	**197 655**	**24**	**23**

Geographical distribution of the fleet: DANMARK

Region	Region name	Number of vessels	% Number of vessels	Tonnage (GT*)	% Tonnage	Engine power (kW)	% Engine power (kW)
DK001	KØBENHAVN OG FRE-DERIKSBERG KOM.	26	0.82 %	181	0.21 %	1 258	0.40 %
DK002	KØBENHAVNS AMT	26	0.82 %	112	0.13 %	1 075	0.35 %
DK003	FREDERIKSBORG AMT	141	4.45 %	1 887	2.16 %	10 265	3.30 %
DK004	ROSKILDE AMT	68	2.15 %	220	0.25 %	1 781	0.57 %
DK005	VESTSJÆLANDS AMT	194	6.12 %	814	0.93 %	6 505	2.09 %
DK006	STORSTRØMS AMT	469	14.80 %	1 816	2.08 %	15 645	5.02 %
DK007	BORNHOLMS AMT	153	4.83 %	4 324	4.96 %	16 906	5.43 %
DK008	FYNS AMT	354	11.17 %	1 974	2.26 %	14 756	4.74 %
DK009	SØNDERJYLLANDS AMT	91	2.87 %	1 062	1.22 %	5 349	1.72 %
DK00A	RIBE AMT	68	2.15 %	15 848	18.18 %	33 512	10.76 %
DK00B	VEJLE AMT	31	0.98 %	269	0.31 %	1 717	0.55 %
DK00C	RINGKØBING AMT	494	15.59 %	22 943	26.31 %	68 085	21.86 %
DK00D	ÅRHUS AMT	188	5.93 %	1 665	1.91 %	10 227	3.28 %
DK00E	VIBORG AMT	317	10.01 %	10 310	11.82 %	38 193	12.26 %
DK00F	NORDJYLLANDS AMT	548	17.30 %	23 766	27.26 %	86 170	27.67 %
TOTAL		**3 168**	**100.00%**	**87 191**	**100.00 %**	**311 444**	**100.00%**
% share in total EU fleet		**3.62 %**		**4.44 %**		**4.38 %**	

Denmark

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
1998	4 372	104 417	23	389 136	89
1999	4 220	104 456	24	387 859	91
2000	4 139	107 600	25	393 543	95
2001	4 018	105 027	26	385 231	95
2002	3 815	103 301	27	366 585	96
2003	3 568	97 954	27	345 606	96
2004	3 406	96 066	28	335 684	98
2005	3 270	91 468	27	324 825	99

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the Danish control authorities' website. A total of 479 vessels hold the permit.

	EXT ID	Name	EU ID	IRCS	HOME PORT
1	A378	DELFINEN	DNK000008502	XP4674	Løgstør
2	AS111	TESSA	DNK000013920	XPA6141	Studstrup
3	AS16	UMMAGUMMA	DNK000007707	XP3438	Ballen
4	AS341	IDA CAMILLA	DNK000033735	OUPX	Grenå
5	AS40	AMANDA-VEST	DNK000011703	OU4273	Århus
…………………………………………					
477	VE228	JANNE	DNK000004609	OU7424	Brunshuse
478	VE243	GRETHE	DNK000007953	XP7234	Skærbæk
479	VE65	INGE	DNK000008132	XPB4537	Skærbæk

F.3.3. FLEETS OF ESTONIA

The Estonian fishing fleet is divided into three major segments: high - seas, Baltic Sea, and coastal fishing vessels. The high - sea vessels are, on average, 16 years old. Their main species are redfish, Atlantic mackerel, Atlantic horse mackerel, Greenland halibut, flounder, roughhead grenadier and shrimp, caught in the North Atlantic Ocean. For the Baltic vessels, the target species are herring, cod, sprat and salmon. Common fishing gears of the Baltic and the high - seas fleet are trawls. The small scale fishing fleet of Estonian are mainly open boats, operating in the coastal waters, using gillnets, traps and seines. They catch mainly cod, sprat, herring, salmon and some other species.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	706	1 350	10 649
Towed Gear	289	19 476	42 690
TOTAL	995	20 826	53 339

Passive Gear - Estonia

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	79	255	2 217	17	8
Drift nets	25	174	524	15	7
Set gillnets (anchored)	589	903	7 737	17	6
Drifting longlines	1	1	30	35	5
Set longlines	12	17	141	15	6
TOTAL	**706**	**1 350**	**10 649**	**20**	**6**

Towed Gear - Estonia

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Purse seines	100	330	2 252	17	8
Beach seines	16	42	284	19	8
Bottom otter trawls	42	9 694	18 649	23	24
Midwater otter trawls	61	8 646	18 239	23	23
Bottom pair trawls	1	12	55	9	13
Midwater pair trawls	12	572	1 805	27	20
Danish seines	51	164	1 284	19	8
Scottish seines	6	16	122	14	8
TOTAL	**289**	**19 476**	**42 690**	**19**	**14**

Estonia

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
2004	1 052	24 910	23	63 303	60
2005	1 046	24 252	23	62 047	59

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the Estonian control authorities' website. A total of 5 vessels hold the permit.

	Name of vessel	Number	Radio call	Name of captain
1	PIHLA	EK-2152	ESIL	Lõhmus
2	RUHNU	EK-2052	ESHG	Litvinovits
3	LETIPEA	EK-0102	ES2098	Getko
4	RIINA	EK-9208	ESHG	Silk
5	LETIPEA	EK-0102	ESIL	Getko

F.3.4. FLEETS OF FINLAND

There are around 3 400 registered vessels in the Finnish fleet, which is divided into trawlers, gill netters and small coastal vessels (the latter represents 94% of the fleet). Trawlers dominate the fisheries in terms of volume and value, catching Baltic herring and sprat. Traditional gillnet fishing is gradually vanishing. Small-scale fisheries are a very important part of Finnish fisheries in socio-economic terms, even though the share of landings is limited. It catches various (non-quota) species along the Finnish coastline.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	3 102	8 556	136 129
Towed Gear	106	8 000	33 931
TOTAL	3 208	16 556	170 060

Passive Gear - Finland

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	813	1 741	32 799	20	6
Encircling gillnets	29	31	617	17	5
Drift nets	143	817	8 643	26	8
Set gillnets (anchored)	2 071	5 355	88 146	21	6
Drifting longlines	42	587	5 602	29	11
Set longlines	4	25	322	27	8
TOTAL	**3 102**	**8 556**	**136 129**	**23**	**7**

Towed Gear - Finland

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Bottom otter trawls	4	731	1 838	32	27
Midwater otter trawls	83	6 943	28 793	31	19
Bottom pair trawls	1	14	140	24	12
Midwater pair trawls	17	311	3 131	26	12
Scottish seines	1	1	29	20	4
TOTAL	**106**	**8 000**	**33 931**	**26**	**15**

Finland

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
1998	3 881	22 691	5	210 970	54
1999	3 765	21 450	5	203 672	54
2000	3 663	20 746	5	197 432	53
2001	3 612	19 908	5	191 291	52
2002	3 572	19 812	5	189 922	53
2003	3 501	19 529	5	188 091	53
2004	3 393	18 166	5	179 365	52
2005	3 266	17 000	5	171 511	52

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the Finnish control authorities' website. A total of 13 vessels hold the permit.

	Identification	Vessel	EU internal number	Effort Kw	Length m
1	AAL-124	Klondyke	FIN000030489	735.0	35.49
2	AAL-27	Verona	FIN000030054	84.6	12.69
3	FIN-128-K	Della Strada	GBR000A10771	1103.3	40.58
4	FIN-29-K	Suvi-Tuuli	FIN000050124	415.6	16.30
5	FIN-115-K	Magreta	FIN0000	507.5	31.19
6	FIN-213-T	Mareka	FIN000020061	230.0	16.38
7	FIN-216-T	ANI	FIN000020064	290.0	14.96
8	FIN-261-T	Albatross	FIN000020113	254.0	19.45
9	FIN-31394-T	Fanny	FIN000010447	179.0	10.80
10	FIN-274-T	Kalkas	FIN000010048	150.0	16.00
11	FIN-29-V	Carola	FIN000100043	214.8	12.60
12	FIN-219-V	Masi	FIN000100032	233.0	12.50
13	FIN-223-V	Hannele	FIN000101217	262.0	14.96

F.3.5. FLEETS OF GERMANY

The German fleet is composed of roughly 2.200 vessels, representing just 2.5% of the Community fleet in vessel numbers (3.5% in tonnage and 2.3% in engine power). A large part of this number (more than 1 600) are small coastal vessels (<12 meters in length). Most of the other vessels are trawlers fishing for demersal and pelagic species and flatfish in the North Sea and in the Baltic, only 25 vessels over 12 meters length are using passive gear. Since the year 1996 the number of vessels (-7%) and the capacity (-4.5%) of the German fleet have constantly decreased. The average age of the German vessels is 25 years, with big discrepancies according to the size categories.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	1 645	5 286	36 987
Towed Gear	410	57 557	122 238
TOTAL	2 055	62 843	159 225

Passive Gear - Germany

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	18	222	723	18	7
Set gillnets (anchored)	1 619	4 403	34 828	25	6
Set longlines	8	661	1 436	19	15
TOTAL	**1 645**	**5 286**	**36 987**	**20**	**9**

Towed Gear - Germany

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Boat dredges	15	3 249	8 389	20	35
Bottom otter trawls	93	20 633	39 585	35	23
Midwater otter trawls	5	18 857	14 310	23	83
Bottom pair trawls	6	198	1 155	60	17
Midwater pair trawls	2	914	3 260	0	37
Danish seines	2	162	388	33	21
Beam trawls	287	13 544	55 151	30	17
TOTAL	**410**	**57 557**	**122 238**	**28**	**33**

Geographical distribution of the fleet: Germany

Region	Region name	Number of vessels	% Number of vessels	Tonnage (GT*)	% Tonnage	Engine power (kW)	% Engine power (kW)
DE501	BREMEN, KRFR.ST.	1	0.05 %	1 943	3.09 %	1 764	1.11 %
DE502	BREMERHAVEN, KRFR.ST.	6	0.29 %	10 781	17.16 %	12 090	7.59 %
DE801	GREIFSWALD, KRFR.ST.	28	1.36 %	122	0.19 %	811	0.51 %
DE803	ROSTOCK, KRFR.ST.	26	1.27 %	14 809	23.57 %	14 041	8.82 %
DE805	STRALSUND, KRFR.ST.	15	0.73 %	38	0.06 %	176	0.11 %
DE806	WISMAR, KRFR.ST.	39	1.90 %	106	0.17 %	721	0.45 %
DE807	BAD DOBERAN	44	2.14 %	121	0.19 %	1 019	0.64 %
DE80D	NORDVORPOMMERN	136	6.62 %	313	0.50 %	2 107	1.32 %
DE80E	NORDWESTMECKLENBURG	44	2.14 %	109	0.17 %	920	0.58 %
DE80F	OSTVORPOMMERN	199	9.68 %	676	1.08 %	5 508	3.46 %
DE80G	PARCHIM	26	1.27 %	44	0.07 %	401	0.25 %
DE80H	RÜGEN	353	17.18%	1 971	3.14 %	9 979	6.27 %
DE80I	UECKER-RANDOW	81	3.94 %	238	0.38 %	1 911	1.20 %
DEF01	FLENSBURG, KRFR.ST.	45	2.19 %	109	0.17 %	845	0.53 %
DEF02	KIEL, KRFR.ST.	21	1.02 %	109	0.17 %	471	0.30 %
DEF03	LÜBECK, KRFR.ST.	55	2.68 %	224	0.36 %	1 863	1.17 %
DEF05	DITHMARSCHEN	80	3.89 %	4 745	7.55 %	15 484	9.72 %
DEF07	NORDFRIESLAND	84	4.09 %	4 233	6.74 %	16 104	10.11%
DEF08	OSTHOLSTEIN	222	10.80%	3 616	5.75 %	13 415	8.43 %
DEF09	PINNEBERG	17	0.83 %	89	0.14 %	814	0.51 %
DEF0A	PLÖN	112	5.45 %	661	1.05 %	3 530	2.22 %
DEF0B	RENDSBURG-ECKERNFÖRDE	46	2.24 %	193	0.31 %	1 269	0.80 %
DEF0C	SCHLESWIG-FLENSBURG	173	8.42 %	562	0.89 %	4 701	2.95 %
DEF0E	STEINBURG	28	1.36 %	37	0.06 %	326	0.20 %
DE600	HAMBURG	6	0.29 %	839	1.34 %	1 858	1.17 %
DE932	CUXHAVEN	41	2.00 %	8 702	13.85 %	17 164	10.78 %
DE942	EMDEN	9	0.44 %	1 491	2.37 %	4 971	3.12 %
DE947	AURICH	63	3.07 %	2 508	3.99 %	12 326	7.74 %
DE94A	FRIESLAND	9	0.44 %	739	1.18 %	2 515	1.58 %
DE94C	LEER	10	0.49 %	899	1.43 %	3 272	2.05 %
DE94G	WESERMARSCH	16	0.78 %	1 244	1.98 %	3 434	2.16 %
DE94H	WITTMUND	20	0.97 %	572	0.91 %	3 415	2.14 %
TOTAL		**2 055**	**100.00%**	**62 843**	**100.00%**	**159 225**	**100.00%**
% share in total EU fleet		**2.35 %**		**3.20 %**		**2.24 %**	

Germany

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
1998	2 305	67 569	29	159 741	69
1999	2 313	69 656	30	163 743	70
2000	2 315	71 312	30	167 739	72
2001	2 282	71 153	31	167 587	73
2002	2 245	66 850	29	161 098	71
2003	2 211	64 049	28	158 484	71
2004	2 163	66 293	30	161 990	74
2005	2 121	64 075	30	159 295	75

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the German control authorities' website. A total of 365 vessels hold the permit.

	Interne	Nummer	Fischereikennzeichen	Schiffsname Rufzeichen
1	DEU000890300	ACC10	KOMET	DCWK
2	DEU000870300	ACC8	ORION	DCFM
3	DEU000880300	ACC9	OZEAN	DCFI
4	DEU000020618	AHL002	STURMVOGEL	
5	DEU000400618	AHL3		
6	DEU200350220	ARN10	VINETA	DKDL
7	DEU100640223	ARN4	GREIF	DJDN
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363	DEU000050634	WOG7N		
364	DEU301210236	WUL1		
365	DEU000070646	WUS7		

F.3.6. FLEETS OF LATVIA

The Latvian fishing fleet contains about 950 vessels and is divided into three major segments: high seas, Baltic Sea, and costal fishing vessels. The average age of the Latvian fishing fleet is about 20 years. The high - sea fishing fleet carry out their fishing activities mainly in the North and Eastern Central Atlantic economic zone waters of Mauritania and Senegal. Trawls are the main fishing gear for these vessels. This fleet's target species are redfish, shrimp and Greenland halibut, sardinella, mackerel and other pelagic species. The Baltic fleet fish only in the Baltic Sea for sprat, cod and herring. The main fishing gears for these vessels are trawls. Small-scale coastal fishery is crucial for the Latvian coastal regions (Gulf of Riga and the Baltic Sea coastline). They catch relatively small amounts of cod, sprat, salmon, Baltic herring and others using mainly fixed gear.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	773	4 451	13 664
Towed Gear	125	32 870	47 688
TOTAL	898	37 321	61 352

Passive Gear - Latvia

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Set gillnets (anchored)	773	4 451	13 664	20	7
TOTAL	**773**	**4 451**	**13 664**	**20**	**7**

Towed Gear - Latvia

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Bottom otter trawls	6	5 027	7 507	29	46
Midwater otter trawls	119	27 843	40 181	25	26
TOTAL	**125**	**32 870**	**47 688**	**27**	**36**

Latvia

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
2004	942	42 140	44	72 516	76
2005	928	38 579	41	66 209	71

F.3.7. FLEETS OF LITHUANIA

The average age of this fleet is 23 years. It is composed of coastal, Baltic Sea and High Sea vessels. The high - seas fleet are fishing in North Atlantic fishing areas, using trawls. The main species caught are shrimp, redfish and hake. The Baltic fishing vessels are the second major Lithuanian fleet segment which are equipped with trawls or gillnets. The most important species fished are cod, Baltic herring, and sprat. The coastal fishing boats are mainly using gillnets longlines and traps. The common species are sprat, salmon and other species.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	213	1 183	6 501
Towed Gear	52	59 912	59 763
TOTAL	265	61 095	66 264

Passive Gear - Lithuania

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	7	22	173	28	8
Set gillnets (anchored)	205	1 155	6 280	22	7
Set longlines	1	6	48	32	11
TOTAL	**213**	**1 183**	**6 501**	**27**	**9**

Towed Gear - Lithuania

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Bottom otter trawls	38	6 768	12 232	27	28
Midwater otter trawls	14	53 144	47 531	26	90
TOTAL	**52**	**59 912**	**59 763**	**26**	**59**

Lithuania

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
2004	302	75 358	249	77 813	257
2005	271	64 386	237	70 655	260

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the Latvian control authorities' website. A total of 120 vessels hold the permit.

	Name	CFR	Ext.ident.	IRCS	Length m	Engine power kW	Reg.port
1	Kristofers	LVA000000334	LA001		8.5	18	Liepaja
2	Amurs	LVA000000336	LA003		8	44.1	Liepaja
3	Marianne	LVA000000337	LA004		11.4	54	Liepaja
4	Seabreeze	LVA000000339	LA006		9.6	56	Liepaja
5	Liva	LVA000000389	LA010		10.6	44.5	Liepaja
6	Kurzeme	LVA000000390	LA011		10.6	44.5	Liepaja
7	Katarina	LVA000000391	LA013		9.9	50.8	Liepaja
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117	Linda	LVA000000314	VP001		9	29	Ventspils
118	Mara 2	LVA000000324	VP009		9	29	Ventspils
119	Aija	LVA000000332	VP017		9.5	14.7	Ventspils
120	Silva	LVA000000942	VP080		10	59	Ventspils

F.3.8. FLEETS OF POLAND

Poland has approximately 1 280 vessels. Their average age is 26 years. The Polish fishing fleet can be divided into three main segments: coastal fleet, cutter fleet and high - seas fleet. The small fishing vessels operate in the territorial waters and in the Vistula and Szczecin lagoons. The main fishing gear are traps, gillnets and set longlines. The coastal fishery's target species are cod, herring and flatfish. The Baltic cutter fleet are usually equipped to use a variety of fishing gears, including gillnets, driftnets, hooks and trawling gears. The Cutter fleet operate in the Baltic Sea and to a lesser extent in the Northeast Atlantic, fishing mainly cod, sprat, herring and salmon.
The Polish high - seas fleet operates mainly in the North Atlantic and are equipped with trawls. The target species are shrimp, redfish, Antarctic krill and poutassou.

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	715	6 629	39 580
Towed Gear	171	25 036	60 075
TOTAL	886	31 665	99 655

Passive Gear - Poland

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	149	477	6 583	19	8
Drift nets	20	675	3 527	40	16
Set gillnets (anchored)	508	5 040	27 244	25	9
Drifting longlines	1	40	147	40	17
Set longlines	37	397	2 079	33	10
TOTAL	**715**	**6 629**	**39 580**	**32**	**12**

Towed Gear - Poland

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Bottom otter trawls	123	14 352	38 360	34	22
Midwater otter trawls	36	10 432	20 452	25	30
Bottom pair trawls	6	221	1 133	50	18
Scottish seines	6	31	130	25	9
TOTAL	**171**	**25 036**	**60 075**	**34**	**20**

Poland

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
2004	1 248	45 550	36	147 062	117
2005	974	30 253	31	105 452	108

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the Polish control authorities' website. A total of 629 vessels hold the permit.

	Identification number (CFR)	Ext. marking	LoA	GT	Vessel name
1	POL034601811	CHA-10	9.7	7.67	-
2	POL034200532	CHŁ-8	5.6	1.17	-
3	POL022900410	CHY-1	12	15.49	-
4	POL022900423	CHY-11	11.95	12.03	-
5	POL022900424	CHY-12	9.15	6.59	-
6	POL022900425	CHY-15	9.8	9.32	-
7	POL022900426	CHY-16	11.98	13.27	-
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627	POL035600460	ZAG-21	18.19	37	-
628	POL035600461	ZAG-27	18.92	43	-
629	POL035600465	ZAG-31	17.26	33	-

F.3.9. FLEETS OF RUSSIA

The description of Russian fleets is extracted from the WGBFAR-report (ICES,2006)

Russia Pelagic fleets

Sprat is fished in Subdivisions 26 by two type of fleets:

1) vessels type SRTM with engine power of 1050 h.p.,
2) small vessels with engine power up to 300 h.p.

The first fleet (1 vessel), having the trawls with high vertical opening with mesh opening 18 mm, operate in the areas deeper than 50 m and according to national regulation they obliged to use the sorting machines, that can separate herring from sprat. This fleet, targeting sprat for the human consumption, during I-II and IV quarters, has by-catches of herring usually between 1–7 %. In III quarter SRTM fishing did not conduct. During summer and fall small fleet targets sprat for the animal food and by-catches of small herring is increased.

The species composition of the mixed catches is defined from logbooks and, partly, by observers of AtlantNIRO (Kaliningrad), on board of larger commercial vessels in compliance with the special agreement between institute and vessel owners.

The small vessels fleet (up to 34 vessels) operates mainly within 12-NM limit, targeting herring in the period from October to March. Mesh size in the trawl bag is 32 mm opening.
The by-catches of sprat in quarter I can reach 78% and of herring-22%, of sprat in quarters IIIII – 92% and of herring-8%, of sprat in quarter IV – 85%, herring-15%. The species composition of this mixed fishery defined from logbooks and sporadically checked by fishery inspection in harbors.
Russian fishermen utilized their low herring quotas as much as possible and have not utilized the sprat quotas. This fact with increasing sprat TAC and decreasing herring TAC created a strong incentive to misreport herring as sprat. This situation took place in target herring pelagic fishery in SD 32 (Eastern part) where usually sprat by-catches is negligible, but in recent years fishermen reported the by-catch of sprat about 1.0 th. tons annually. The analogous situation may take place in SD 26 in the small fleet mixed sprat and herring fishery.

Russia Demersal trawl fleet
The basic commercial fishes on a demersal trawl catches - a cod and a flounder. Cod and flounder are fished mainly by vessels type MRTK, MRTR with engine power up to 300 h.p. up to 27 m length. These commercial vessels are fishing with bottom trawls using the BACOMA windows (120 mm mesh opening). Parameters of work of a demersal trawl fleet are shown in table.

Parameters of demersal trawl fleet	Quarter				Average for a year
	1	2	3	4	
Number of vessels in 1 day	5	6	10	7	7
Landings of 1 vessel for 1 day, t	1.51	1.02	1.08	1.47	1.27
Cod in catches, %	52.1	80.0	17.6	37.4	46.8
Flounder in catches, %	47.0	18.4	79.8	56.6	50.5

Russia Gillnet fleet
This fishery is targeting for cod with a small landing of a flounder and a turbot (excepting catch in 3 quarter where the landing of a flounder 17.2 % and turbot 1.4% has made) (table 2).
Fishermen caught a cod and a flounder mainly by vessels type SCHS, TB, PTS with engine power up to 225 h.p. This vessels are using the anchored gillnets with mesh opening of 110-120 mm. According to statistics in 2006 more than 66 % of cod were taken by gillnetting.

Parameters of gillnet fleet	Quarter				Average for a year
	1	2	3	4	
Number of vessels in 1 day	21	25	14	21	20
Number of gillnets in 1 day	4993	6312	3243	5467	5004
Landings of 1 net, kg	1.19	1.46	1.41	1.95	1.50
Cod in catches, %	96.6	93.6	81.4	84.9	89.1
Flounder in catches, %	3.4	4.1	17.2	8.0	8.2

Russia Pound net fleet: This type of fishery exists in the Vistula Lagoon and Eastern part of Gulf of Finland. This fishery is targeting herring.

F.3.10. FLEETS OF SWEDEN

The Swedish fishing fleet, constantly decreasing also as a result of national scrapping programmes, consists of about 1.700 vessels. In number, the small fishing vessels are predominant (76% < 12 meters), but in value and volume larger vessels (trawlers and purse seiners > 24 meters) account for the major part of the fishery. The Baltic Sea is the most important fishing area with close to 50% of total catch. Cod is the most important species in economic terms (nearly ¼ of total landing value).

Gear typology	Number of vessels	Tonnage (GT*)	Engine power (kW)
Passive Gear	1 251	5 960	77 413
Towed Gear	343	37 137	137 840
TOTAL	1 594	43 097	215 253

Passive Gear - Sweden

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Pots	560	1 458	27 859	26	7
Drift nets	35	357	3 955	30	10
Set gillnets (anchored)	626	3 952	42 868	30	9
Trammel nets	5	25	405	22	8
Handlines and pole-lines (hand operated)	22	159	2 057	21	9
Set longlines	3	9	269	26	7
TOTAL	**1 251**	**5 960**	**77 413**	**26**	**8**

Towed Gear - Sweden

Fishing gear	Number of vessels	Tonnage (GT*)	Engine power (kW)	Average age	Average Length
Purse seines	17	4 314	14 718	26	24
Beach seines	2	1	27	27	6
Drifting longlines	11	27	651	24	7
Bottom otter trawls	228	17 041	71 301	32	18
Midwater otter trawls	41	14 603	41 294	31	35
Bottom pair trawls	40	478	7 450	22	12
Midwater pair trawls	2	478	1 610	40	29
Danish seines	2	195	789	18	17
TOTAL	**343**	**37 137**	**137 840**	**27**	**19**

Sweden

Year	Number of vessels	Tonnage (GT*)	Average tonnage (GT*)	Engine power (kW)	Average power (kW)
1998	2 226	51 397	23	244 564	109
1999	2 067	50 407	24	235 384	113
2000	2 017	51 597	25	245 019	121
2001	1 889	49 531	26	237 273	125
2002	1 817	45 931	25	225 120	123
2003	1 728	44 818	25	221 613	128
2004	1 601	44 751	27	218 345	136
2005	1 603	44 259	27	218 745	136

The list of vessels holding a permit to fish cod in the EU-waters of Baltic is available from the Swedish control authorities' website. A total of 344 vessels hold the permit.

	Ext. Mark (XR)	Vessel Name	IRCS (RC)	EU internal no (IR)	Length (m)	Effort (kW)
1	FG-6	SALTSKAR	SGTY	SWE00006768	14.58	169
2	FG-24	GLOMFJORD	SBMW	SWE00000030	18.25	300
3	FG-33	SYLVIA	SLCZ	SWE00007122	14.04	162
4	FG-46	SLOMVIK	SMFQ	SWE00007236	14.8	345.68
5	FG-47	SALTVIK	SIMB	SWE00006964	19.89	586
....						
342	AS-25	YNGSJO	SFB-9146	SWE00005178	8.6	40
343	AS-88	JULIA	SFB-4049	SWE00006541	9.5	94.88
344	AS-99	SARA	SFB-4973	SWE00002611	9.85	88.24

F.4. FISHERIES MANAGEMENT IN THE BALTIC.

TACs, closed areas, closed seasons, and technical management measures are applied in the Baltic.

F.4.1. BALTIC TACS FOR 2006-2007.

The TACs or 2006 and 2007 are shown in Table 2.3.1 and illustrated in Figure 2.3.1. Compared the pelagics, cod is a small fraction of the total in 2006-7. In the eighties the cod would have the same magnitude as herring in 2006-7.

	ICES fishing Zones	TAC 2006 (tons, except salmon)	TAC 2007 (tons, except salmon)
Herring	30-31	91600	91600
Herring	22-24	47500	49500
Herring	25-27,28.2,29 and 32	115842	132718
Herring	28.1	40000	37500
Cod	25-32 (EC waters)	45339	40805
Cod	22-24	28400	26696
Plaice	IIIbcd (EC waters)	3766	3766
Salmon	IIIbcd (EC waters) excl.32	451260 a)	428697 a)
Salmon	32	15419 a)	15419 a)
Sprat	IIIbcd (EC waters)	420826	454492

Table F.4.1.1. Baltic TACs for 2006 and 2007. a) Individual fish

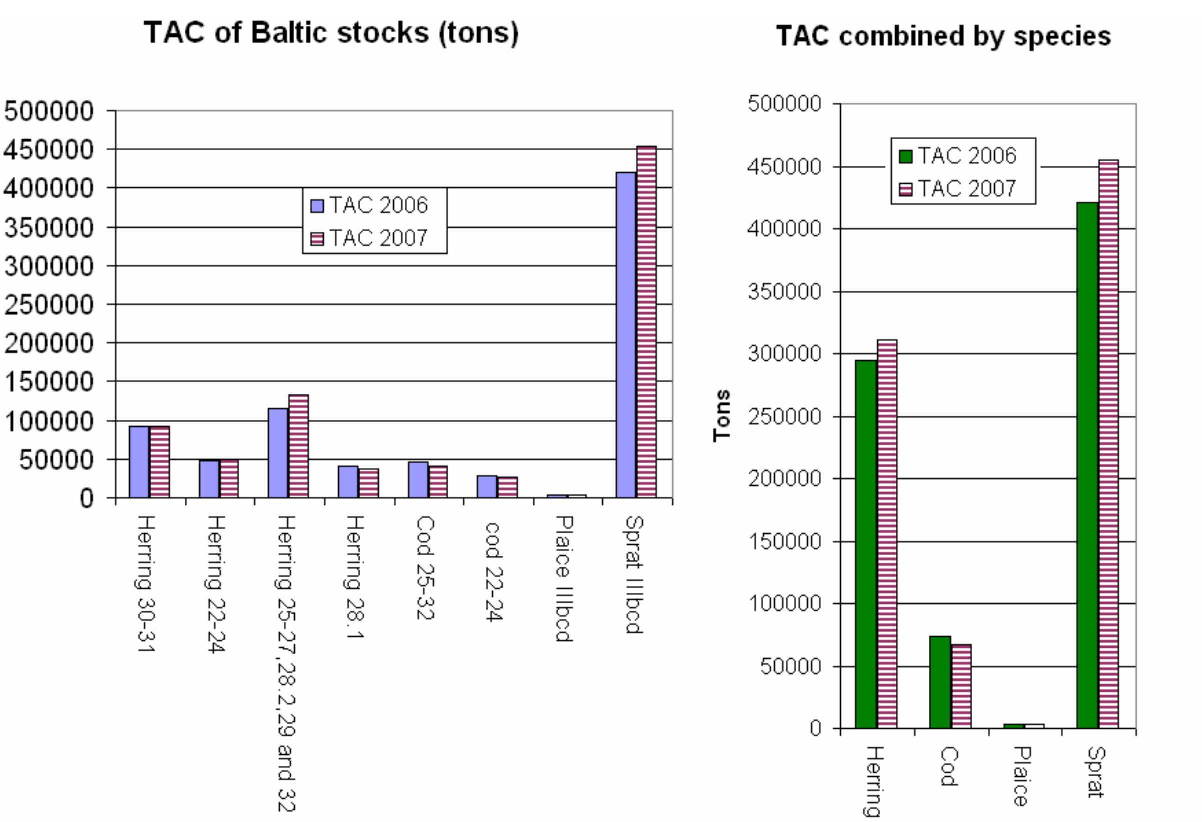


Figure F.4.1.1. Baltic TACs for 2006 and 2007. a) Individual fish

F.4.2. CLOSED SEASONS

The text in Annex II of ”**COUNCIL REGULATION (EC) No 52/2006 of 22 December 2005 fixing the fishing opportu-nities and associated conditions for certain fish stocks and groups of fish stocks applicable in the Baltic Sea for 2006 ”** reads:

1. Fishing with trawls, seines or similar gears of a mesh size equal to or greater than 90 mm or with bottom set gillnets, entangling nets and trammel nets of a mesh size equal to or greater than 90 mm or with bottom set lines shall be prohibited:

(a) From 15 March to 14 May in subdivisions 22-24, and

(b) From 15 June to 14 September in subdivisions 25-27.

2. For vessels flying their flag, Member States shall ensure that fishing with trawls, seines or similar gears of a mesh size equal to or greater than 90 mm or with bottom set gillnets, entangling nets and trammel nets of a mesh size equal to or greater than 90 mm or with bottom set lines shall be prohibited for:

(a) 30 calendar days in subdivisions 22-24 outside the period from 15 March to 14 May, an

(b) 27 calendar days in subdivisions 25-27 outside the period from 15 June to 14 September.

4. By way of derogation from points 1 and 2, Community vessels with an overall length of less than 12 metres shall be permitted to retain on board and land up to 10 % cod by live weight when fishing with gillnets, entangling nets and/or trammel nets with a mesh size equal to or greater than 110 mm.

Figure F.4.2.1 illustrates the temporal closures of 2006 as well earlier years and 2007. These are the so-called “Summer-closures”. Fte figure also illustrates the duration of box-closures (MPAs) discussed in the following sub-sections.

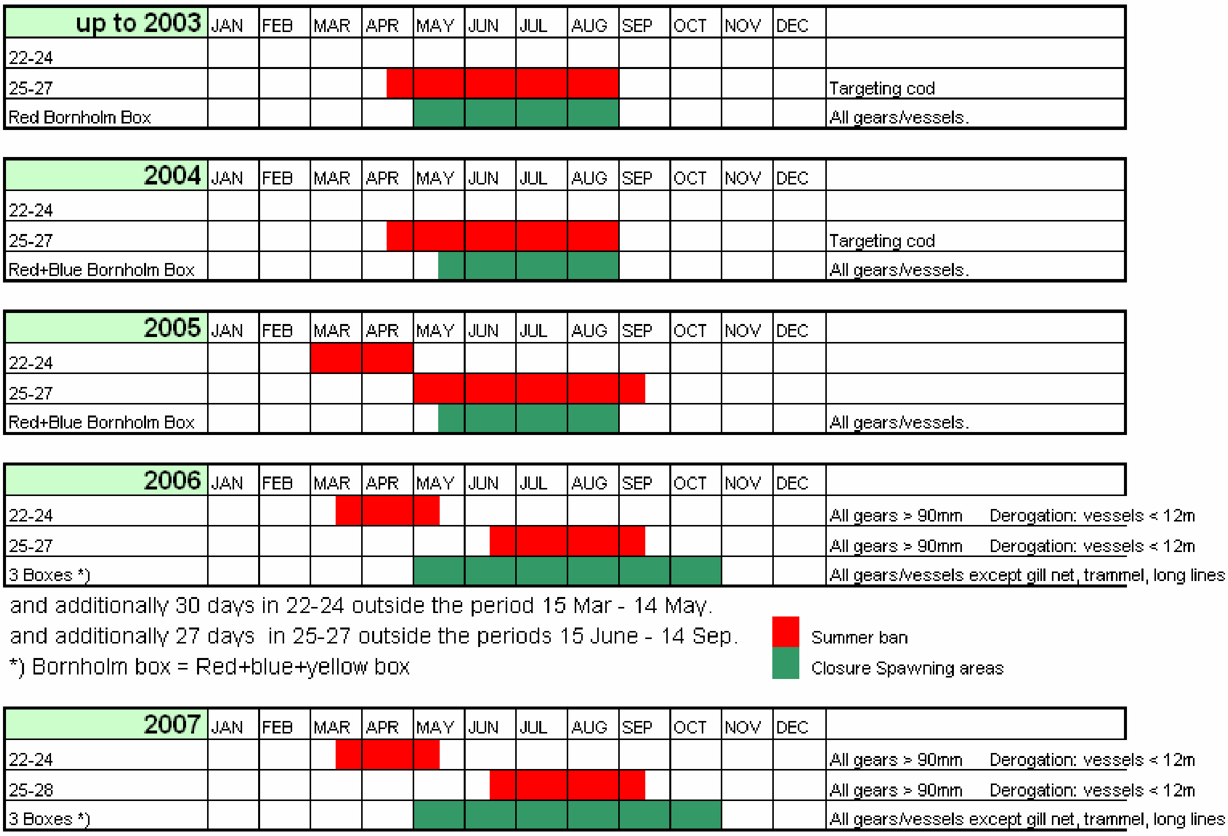


Figure F.4.2.1. Illustration of temporal closures of Baltic fisheries. Compare Figure 2.3.3.1 for the definition of closed boxes.

F.4.3. CLOSED AREAS

The text in Annex III of ”**COUNCIL REGULATION (EC) No 52/2006 of 22 December 2005 fixing the fishing opportu-nities and associated conditions for certain fish stocks and groups of fish stocks applicable in the Baltic Sea for 2006 ”** reads:

1. Restrictions on fishing

1.1. All fishing activity within the areas enclosed by sequentially joining with rhumb lines the following positions, which shall be measured according to the WGS84 coordinate system, is prohibitted from 1 May to 31 October.

Area 1: — 55o45'N, 15o30'E— 55o45'N, 16o30'E— 55o00'N, 16o30'E— 55o00'N, 16o00'E— 55o15'N, 16o00'E— 55o15'N, 15o30'E— 55o45'N, 15o30'E

Area 2: — 55o00'N, 19o14'E— 54o48'N, 19o20'E— 54o45'N, 19o19'E— 54o45'N, 18o55'E— 55o00'N, 19o14'E

Area 3: — 56o13'N, 18o27'E— 56o13'N, 19o31'E— 55o59'N, 19o13'E— 56o03'N, 19o06'E— 56o00'N, 18o51'E— 55o47'N, 18o57'E— 55o30'N, 18o34'E— 56o13'N, 18o27'E

1.2. By way of derogation from point 1.1, fishing with gillnets, entangling nets and trammel nets with mesh size equal to or greater than 157 mm or with lines shall be permitted. When fishing with lines, no cod shall be retained on board.

Figure F.4.3.1 illustrates the closed boxes of 2006 and 2007, together with earlier closed boxes.

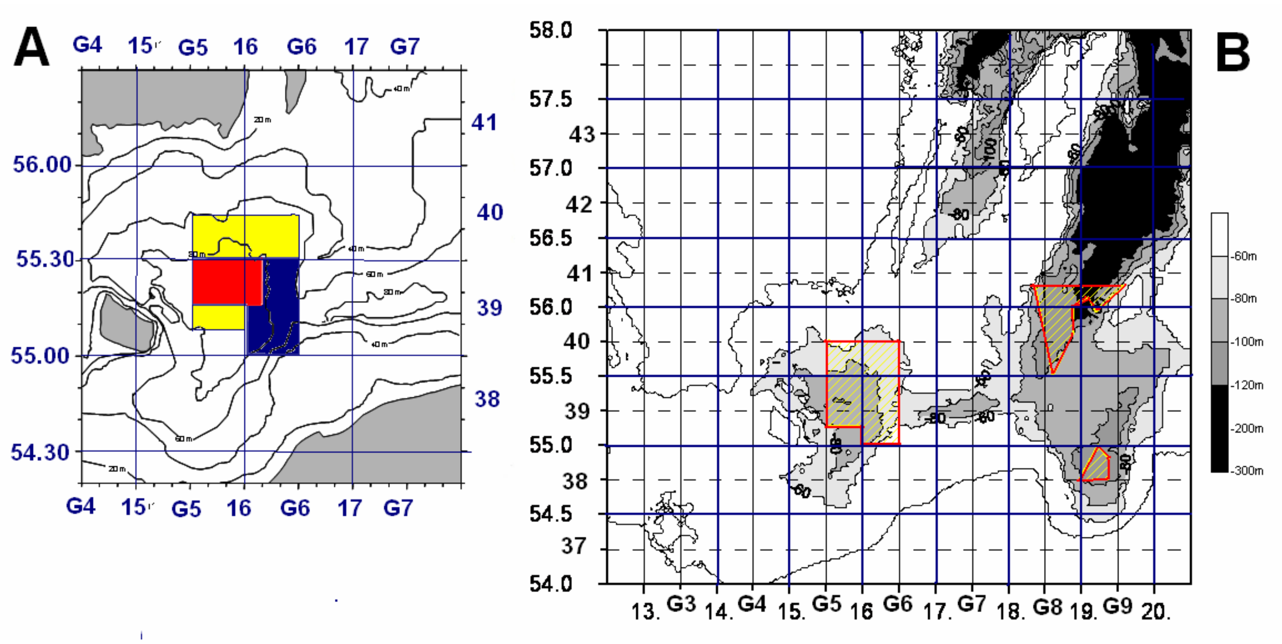


Figure F.4.3.1. Areas closed for certain fishing activities. Compare Figure F.4.2.1 for the duration of the spatial closures.

The red (the smallest) area in the Bornholm deep (see Figure A), was introduced in 1997. Until 2003 the duration of the closure was May to August. In 2004 the red area was extended with the blue area, and the duration was 15 May – 31 Aug. In 2005 the Bornholm MPA was extended further with the yellow area (Figure A) and two new boxes were defined (Figure B), the “Gotland box” and the “Gdansk Box” and the duration was 15 May – 31 Aug in 2005. From 2006 the duration was extended to 1 May to 31 October (Figure F.4.2.1). The background for these MPA’s will be discussed in the following.

F.4.4. GEAR MEASURES

The information given in this section is extracted from
COUNCIL REGULATION (EC) No 2187/2005 of 21 December 2005 for the conservation of fishery resources through technical measures in the Baltic Sea, the Belts and the Sound, amending Regulation (EC) No 1434/98 and repealing Regulation (EC) No 88/98

The mesh size and minimum target species percentage regulation is shown in Table F.4.4.1.

ANNEX III: Trawls, Danish seines and similar gear: Mesh size ranges, target species and required catch percentages applicable							
Mesh size range (mm)	< 16	16 -32	16 -105	32 -90	32 -105	≥ 90 [3]	≥ 105 [2] [3]
Groups of subdivisions	22-32	22-27	28-32	22-23	24-27	22-23	22-32
Minimum percent. of target sp.[6]	90 [1]	90 [1] [5]	90 [1]	90 [1] [4]	90 [1] [4]	90	100
Target species							
Sand eels (*Ammodytidae*)	*	*	*	*	*	*	*
Sprat (*Sprattus sprattus*)		*	*	*	*	*	*
Herring (*Clupea harengus*)			*	*	*	*	*
Sole (*Solea vulgaris*)						*	*
Plaice (*Pleuronectes platessa*)						*	*
Whiting (*Merlangius merlangus*)						*	*
Brill (*Scophthalmus rhombus*)						*	*
Dab (*Limanda limanda*)						*	*
Flounder (*Platichthys flesus*)						*	*
Lemon sole (*Microstomus kitt*)						*	*
Turbot (*Psetta maxima*)						*	*
Cod (*Gadus morhua*)							*

(1) The catch retained on board shall consist of no more than 3 % of cod by live weight.
(2) Only trawls, Danish seines and similar gears with Bacoma exit window or with T90 codend and extension piece with mesh size and specifications as laid down in Appendices I and II (C.Reg. 2187/2005) shall be authorised.
(3) The use of beam trawl shall not be authorised.
(4) The catch retained on board may consist of up to 40 % of whiting by live weight.
(5) The catch retained on board may consist of up to 45 % of herring by live weight.
(6) The percentages of target species shall be calculated as the proportion by live weight of all species listed (“*”).

Tabel F.4.4.1. Baltic mesh size regulations, 2006.

The BACOMA (Baltic Cod Management) trawl with its square meshed panel (escape window), is illustrated in Figure F.4.4.1. The BACOMA and the T90 codend are explained in Apendices 1-2 in Council Reg. 2187/2005.

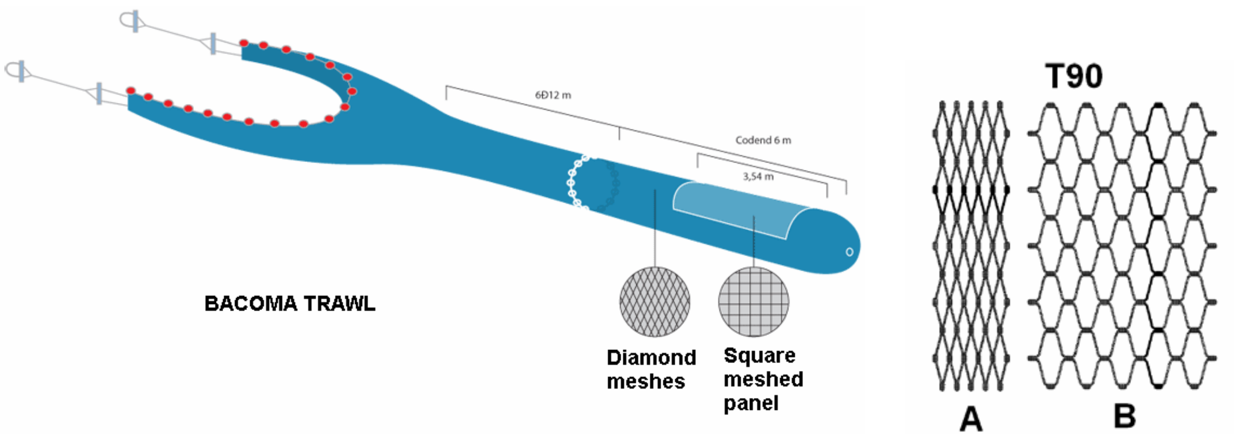


Figure F.4.4.1. Idealized picture of the Bacoma trawl and T90 Codend. (Modified from Swedish Board of Fisheries website: http://www.fiskeriverket.se/laboratorier/havsfiske/publikationer.htm)

T90 trawls are defined as trawls, Danish seines and similar gears having a codend and extension piece produced from diamond knotted netting turned 90° so that the main direction of run of the netting twine is parallel to the towing direction. The direction of run of the netting twine in a standard diamond knotted net (A) and in a net turned 90° (B) is illustrated in Figure F.4.4.1.

F.4.5. MINIMUM LANDING SIZES IN THE BALTIC.

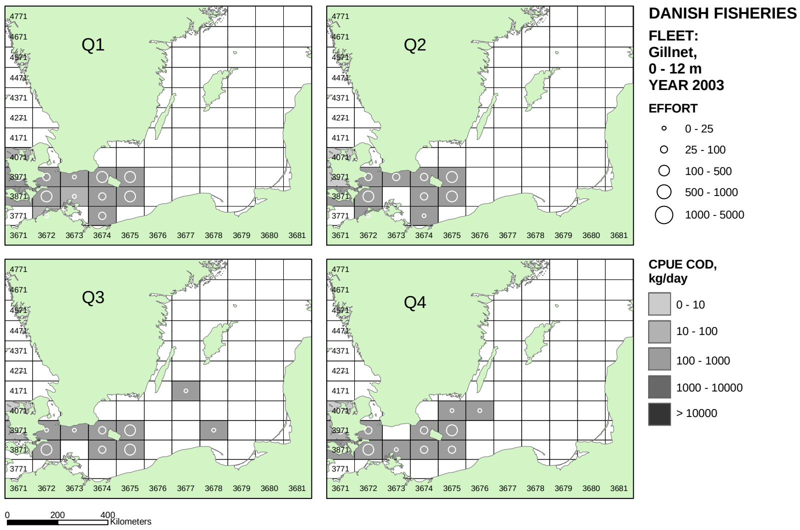
The minimum landing sizes of Baltic species in 2006 are shown in Figure F.4.5.1. The information copied from Annex IV of COUNCIL REG. (EC) No 2187/2005.

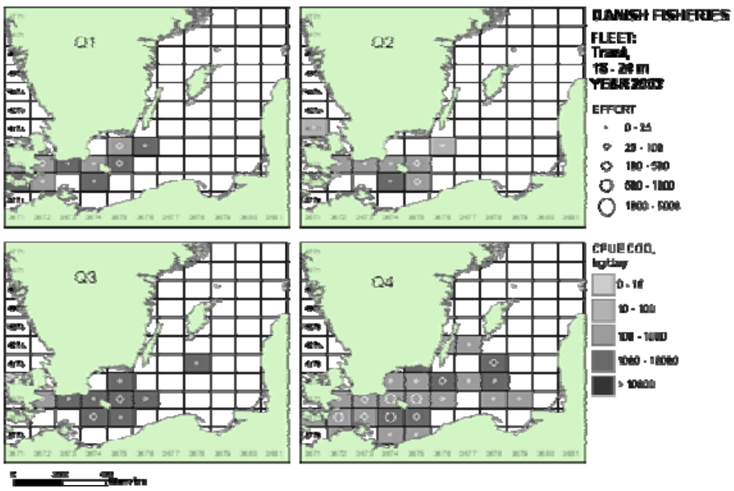
Species	**Geographical area**	**Minimum size**
Cod (*Gadus morhua*)	Subdivisions 22-32	38 cm
Flounder (*Platichthys flesus*)	Subdivisions 22 to 25	23 cm
	Subdivisions 26 to 28	21 cm
	Subdivisions 29 to 32, south of 59° 30’N	18 cm
Plaice (*Pleuronectes platessa*)	Subdivisions 22 to 32	25 cm
Turbot (*Psetta maxima*)	Subdivisions 22 to 32	30 cm
Brill (*Scophthalmus rhombus*)	Subdivisions 22 to 32	30 cm
Eel (*Anguilla anguilla*)	Subdivisions 22 to 32	35 cm
Salmon (*Salmo salar*)	Subdivisions 22 to 30 and 32	60 cm
	Subdivision 31	50 cm
Sea trout (*Salmo trutta*)	Subdivisions 22 to 25 and 29 to 32	40 cm
	Subdivision 26 to 28	50 cm

Figure F.4.5.1. The minimum landing sizes of Baltic species in 2006.

F.5. EFFORT AND RESOURCE DISTRIBUTIONS IN THE BALTIC

(From Nielsen et al. (in revision).





F.6. MISREPORTING OF FISHERIES ACTIVITIES IN THE BALTIC

Extract from the Report of the Baltic Fisheries Assessment Working Group (WGBFAS) ICES CM 2006/ACFM:24

Catch misreporting, mostly in the form of unreported landings, tends to result from a combination of restrictive quotas, the absence of other fishing opportunities and inadequate inspection. However, the precise circumstances can differ between countries, so information was obtained from representatives of each of the countries contributing data to the ICES WG. The information supplied by each country is summarised below in order to illustrate the nature of the information available, and to allow the reliability of the estimates to be evaluated. However, there was a clear consensus amongst WG members that individual countries should not be identified. There were two main reasons for this :

- Information obtained on misreporting is regarded as for assessment purposes only, and the resultant catch estimates should not be made public in case of political problems if these estimates are seen to be different to the official figures.
- The estimates are often based on information which has been provided by fishers as a result of trust being established between fishers and scientists. If the information is then made public, there is a risk that this will lead to loss of trust, which would then make it difficult to obtain information in the future or even to obtain access to fishing vessels for sampling purposes.

As a result of these potentially major problems, the individual countries concerned are not identified below, but are instead clustered into groups of one or more countries according to the information available.

The information supplied is summarised below, together with the raising factors (RFs) applied to the landings data that of that group of countries in order to account for suspected misreporting.

Group A: A rough estimate based on informal contacts with the industry. Assumed RF = 1.2 or RF = 1.5.

Group B: Information available from informal contacts with industry and enforcement sources indicates a reduction in non-reporting compared to 2004, largely due to a reduction in the cod fleet due to decommissioning , meaning that individual vessel quotas are less restrictive.

Group C: Information is available from at sea sampling, formal and informal contacts with the fishing industry and, and from inspection of import/export records. Taken together these sources of information indicate total catches about 100% greater than the reported figure. Assumed RF = 2.0.

Group D: Either no information available, or information indicates no or negligible misreporting. Assumed RF = 1.0

The above figures refer to non-reporting of landings. There is also suspected to be misreporting of catches by area, e.g. between the Western and Eastern cod stock areas, and also the Kattegat and Western Baltic. In the case of the misreporting between the two Baltic areas, this is believed to occur in both directions in response to different catching opportunities and closed seasons. No information is available to quantify this. In addition, there is also suspected to be some misreporting between national sectors in the Eastern Baltic as differences in nation conversion factors for gutted to live weight can make this practice worthwhile.

A recent empirical work on non-compliance behavior (Raakjær Nielsen and Mathiesen, 2003) notes that compliance is closely related to the expected profit from the allocated catch rations. Also, the potential gains in illegal fishing as opposed to the risk of detection are considered import. Fishermen are generally reluctant to discard fish already dead which concord with the finding that only few fishermen found it wrong to land catches exceeding their rations. The fishermen are opposed to the ration-period system as they may experience high landings when the rations is almost caught which provides strong incentives to misreport landings. Most fishermen found that a day at sea regulation would be a preferable measure to regulate the fisheries in order to protect the fish stocks.

The control activities includes paper control (logbooks, sale slips), harbor control (vessels, auctions and factories), at sea controls (bodings) as well as designated campaigns for tougher surveillance when that is deemed necessary. The control authorities have in the most recent years had focused attention on cod fisheries as a consequence of the implementation of the EU's cod recovery plan and the introduction of two management areas in the Baltic Sea.

F.7. ICES ADVICE FOR THE BALTIC STOCKS IN 2006

Baltic Single-stock exploitation boundaries and critical stocks
The state of stocks and single-stock exploitation boundaries from ACFM (ICES) report 2006.

Species	**State of the stock**			**ICES considerations in relation to single-stock exploitation boundaries**			Upper limit corresponding to single-stock exploit.boundary Tonnes or effort in 2007
	SSB in relation to precautionary limits	**F in relation to precautionary limits**	**F in relation to target reference points**	**In relation to agreed management plan**	**In relation to precautionary limits**	**In relation to target reference points**	
Cod in 22–24	Full reproductive capacity	Not available	Overexploited	No formally accepted plan	SSB above Bpa; 20 500 t.	No targets agreed	20 500 t
Cod in 25–32	Reduced repr. capacity	Harvested unsustain.	Overexploited	No formally accepted plan	Fishery closure	No targets agreed	0 t
Herring 22–24 and IIIa	Unknown	Unknown	Unknown	No man. plan	F=F*status quo* ;99 000 t	No targets agreed	99 000 t
Herring in 25–29 (excl GoR) and 32	Unknown	Harvested sustainably	No targets agreed	No man. plan	F below **F**pa 0.19;164 000 t	No targets agreed	164 000 t.
Herring in Gulf of Riga	Full reprod. capacity	Harvested sustainably	No targets agreed	No man. plan	F below **F**pa =0.4;33 900 t.	No targets agreed	33 900 t
Herring in 30	Full reprod. capacity	Harvested sustainably	No targets agreed	No man. plan	F below **F**pa =0.21 83 400 t	No targets agreed	83 400 t.
Herring in 31	Unknown	Unknown	No targets agreed	No man. plan	Recent catches (2002–2005): 4700 t	No targets agreed	4700 t.
Sprat in 22–32	Full reproductive capacity	Harvested sustainably	Harvested sustainably	F (0.4) IBSFC man.plan: 477 000 t in 2007.	F below **F**pa =0.4;477 000 t in 2007.	No targets agreed	477 000 t.
Flounder	Unknown	Unknown	No targets agreed	No man. plan	Unknown	No targets agreed	
Plaice	Unknown	Unknown	No targets agreed	No man. plan	Unknown	No targets agreed	
Dab	Unknown	Unknown	No targets agreed	No man. plan	Unknown	No targets agreed	
Turbot in 22–32	Unknown	Unknown	No targets agreed	No man. plan	Unknown	No targets agreed	
Salmon in Main Basin and Gulf of Bothnia			Target is likely to be met for several large stocks in Northern Baltic.	Catches should not increase. Long-term benefits for smaller stocks are expected from a reduction of F. Technical regulations should be continued. For stocks of unit 5 implement special stock rebuilding measures, including habitat restoration and removal of physical barriers.			
Salmon in Gulf of Finland			Condition of wild stocks poor and will not reach the target.	Catches should not increase. Fisheries should only be permitted at sites where there is virtually no chance of taking wild salmon from the Gulf of Finland stocks along with reared salmon. National conservation programmes to protect wild salmon should be enforced.			
Sea trout			Stocks in Main Basin: good. Gulf of Finland and Gulf of Bothnia: poor.	There is an urgent need to decrease F for some sea trout stocks.A management plan should be established.			

ANNEX G. EU PROPOSAL FOR A COUNCIL REGULATION

ESTABLISHING A MULTI-ANNUAL PLAN FOR THE COD STOCKS IN THE BALTIC SEA AND THE FISHERIES EXPLOITING THOSE STOCKS

COUNCIL OF THE EUROPEAN UNION **Brussels, 15 May 2007**

Interinstitutional File:

2006/0134 (CNS) **9652/07**
LIMITE **PECHE 148**

NOTE

from :	Presidency
to :	Working Party on Internal Fisheries Policy
No. Cion prop. :	11984/06 PECHE 238 - COM(2006) 411 final
Subject :	Proposal for a Council Regulation establishing a multi-annual plan for the cod stocks in the Baltic Sea and the fisheries exploiting those stocks

Delegations will find attached a working document from the Presidency, in agreement with the Commission services, on the above subject.

ANNEX

Proposal for a
COUNCIL REGULATION
Establishing a multi-annual plan for the cod stocks in the Baltic Sea and the fisheries exploiting those stocks
THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 37 thereof,
Having regard to the proposal from the Commission[16],
Having regard to the opinion of the European Parliament[17],
Whereas:

(1) Recent scientific advice from the International Council for the Exploration of the Sea (ICES) indicates that the cod stock in ICES Subdivisions 25 to 32 of the Baltic Sea has declined to levels where it is suffering from reduced reproductive capacity and that the stock is being harvested unsustainably.

(2) Recent scientific advice from ICES indicates that the cod stock in ICES Subdivisions 22, 23 and 24 of the Baltic Sea is over-exploited and has reached levels where it is at risk of reduced reproductive capacity.

(3) Measures need to be taken to establish a multi-annual plan for fisheries management of the cod stocks in the Baltic Sea.

(4) The objective of the plan is to ensure that Baltic cod stocks can be exploited under sustainable economic, environmental and social conditions.

(5) Regulation (EC) No 2371/2002 requires *inter alia* that, to achieve that objective, the Community is to apply the precautionary approach in taking measures to protect and conserve the stock, to provide for its sustainable exploitation and to reduce to a minimum the impact of fishing on marine ecosystems. It should aim at a progressive implementation of an ecosystem-based approach to fisheries management, and should contribute to efficient fishing activities within an economically viable and competitive fisheries industry, providing a fair standard of living for those who depend on fishing Baltic cod and taking the interests of consumers into account.

(6) In order to achieve the objective the Eastern stock must be rebuilt to safe biological limits and for both stocks levels where their full reproductive capacity is maintained and the highest long-term yields can be reached must be ensured.

(7) This can be achieved by establishing an appropriate method for gradually reducing the fishing effort in fisheries catching cod to levels that are consistent with the objective, and by fixing the total allowable catches (TACs) for the cod stocks at levels consistent with the fishing effort.

(8) As catches of cod in the fisheries for herring and sprat and in gillnet and entangling-net fisheries for salmon are very limited, these fisheries should not be subject to the gradual reduction in fishing effort.

(9) To ensure stability in the fishing possibilities, it is appropriate to limit the variation in the TACs from one year to the next.

(10) An appropriate implementation of the control of fishing effort is to regulate the length of the periods when cod fishing is allowed.

(11) Control measures are needed in addition to or by way of derogation from those laid down in Council Regulation (EC) No 1627/94 of 27 June 1994 laying down general provisions concerning special fishing permits[18], Council Regulation (EEC) No 2847/93 of 12 October 1993 establishing a control system applicable to the common fisheries policy[19] and Commission Regulation (EEC) No 2807/83 of 22 September 1983 laying down detailed rules for recording information on Member States' catches of fish[20] in order to ensure compliance with the measures laid down in this Regulation.

(12) During the first three years of its application, the multi-annual plan shall be deemed to be a recovery plan within the meaning of Article 5 of Regulation (EC) No 2371/2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy.

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16 OJ C , , p. .
17 OJ C , , p. .
18 OJ L 171, 6.7.1994, p. 7
19 OJ L 261, 20.10.1993, p. 1. Regulation as last amended by Regulation (EC) No 806/2003 (OJ L 122, 16.5.2003, p. 1).
20 OJ L 276, 10.10.1983, p. 1

HAS ADOPTED THIS REGULATION:

CHAPTER I
SUBJECT MATTER, SCOPE AND DEFINITIONS

Article 1

Subject matter

This Regulation establishes a multi-annual plan for the following cod stocks (hereinafter referred to as 'the cod stocks concerned') and the fisheries exploiting those stocks:

(a) cod which inhabits Area A;

(b) cod which inhabits Areas B and C.

Article 2

Scope

This Regulation shall apply to Community fishing vessels with an overall length equal to or greater than eight meters operating in the Baltic Sea and Member States bordering the Baltic Sea (hereinafter referred to as the Member States concerned).

Article 3

Definitions

For the purposes of this Regulation, the following definitions shall apply in addition to those laid down in Article 3 of Regulation (EC) No 2371/2002 and Article 2 of Regulation (EC) No 2187/05:

(a) the International Council for the Exploration of the Sea (ICES) zones are as defined in Regulation (EEC) No 3880/91;

(b) "Baltic Sea" means ICES Divisions IIIb, IIIc and IIId;

(c) "total allowable catch (TAC)" means the quantity [in metric tonnes] that can be taken from each stock each year.

(d) VMS means a vessel monitoring systems (VMS) according to Commission Regulation (EC) No 2244/2003 laying down detailed provisions regarding satellite-based Vessel Monitoring Systems[21] for vessels of any length,

(e) "Area A" means Subdivisions 22 to 24.
"Area B" means Subdivisions 25 to 28.
"Area C" means Subdivisions 29 to 32.

(f) "Days absent from port" means any continuous period of 24 hours or part thereof during which the vessel is absent from port.

CHAPTER II
OBJECTIVE AND TARGETS

Article 4

Objective and targets

The plan shall ensure the sustainable exploitation of the cod stocks concerned by gradually reducing and maintaining the fishing mortality rates at levels no lower than:

1) 0.6 on ages 3 to 6 years for the cod stock in Area A, and

2) 0.3 on ages 4 to 7 years for the cod stock in Areas B and C.

CHAPTER III
TOTAL ALLOWABLE CATCHES

Article 5

Setting of TACs

1. Each year, the Council shall decide by a qualified majority on the basis of a proposal from the Commission on the TACs for the following year for the cod stocks concerned.

2. The TACs for the cod stocks concerned shall be set in accordance with Articles 6 and 7.

Article 6

Procedure for setting the TACs for the cod stocks concerned

1. The Council shall adopt the TAC for the cod stocks concerned that, according to a scientific evaluation carried out by the Scientific, Technical and Economic Committee for Fisheries (STECF), is the higher of:

(a) the TAC that would result in a 10% reduction in the fishing mortality rate in its year of application compared to the fishing mortality rate estimated for the preceding year.

(b) the TAC that would result in the level of fishing mortality rate defined in Article 4.

2. Where the application of paragraph 1 would result in a TAC that exceeds the TAC for the preceding year by more than 15%, the Council shall adopt a TAC which is 15% greater than the TAC of that year.

3. Where the application of paragraph 1 would result in a TAC that is more than 15% below the TAC of the preceding year, the Council shall adopt a TAC which is 15% less the TAC of that year.

4. Paragraph 3 shall not apply where a scientific evaluation carried out by the STECF shows that the fishing mortality rate in the year of application of the TAC will exceed a value of 1 per year from the ages 3 to 6 years for the cod stock in Area A or a value of 0.6 per year for the ages 4 to 7 years for the cod stock in Areas B and C.

Article 7

Derogation from Article 6

By way of derogation from Article 6, the Council may, where it considers this appropriate, adopt a TAC that is below the TAC that follows from applying Article 6.

CHAPTER IV
FISHING EFFORT LIMITATION

Article 8

Procedure for setting periods when fishing with certain types of gear is allowed

1. It shall be prohibited to fish with trawls, Danish seines or similar gear of a mesh size equal to or larger than 90 mm, with gillnets, entangling nets or trammel nets of a mesh size equal to or larger than 90 mm, or with bottom set lines, or longlines except drifting lines, or handlines or jigging equipment:

(a) from 1 to 30 April in Area A, and

(b) from 1 July to 31 August in Area B.

When fishing with drifting lines within the periods and days mentioned in subparagraphs (a) and (b) no cod shall be retained on board.

2. The Council shall decide each year by a qualified majority on the maximum number of days absent from port outside the periods specified under (a) and (b) in the following year when fishing with the gear referred to in paragraph 1 is allowed, in accordance with the rules set out in paragraphs 3 and 4.

3. Where the fishing mortality rate for one of the cod stocks concerned has been estimated by the STECF to be at least 10% higher than the

21 OJ L 333, 20.12.2003, p. 17

minimum fishing mortality rate defined in Article 4, the total number of days when fishing with the gear referred to in paragraph 1 is allowed shall be reduced by 10% compared to the total number of days allowed in the current year.
4. Where the fishing mortality rate for one of the cod stocks concerned has been estimated by the STECF to be less than 10% above the minimum fishing mortality rates defined in Article 4, the total number of days where fishing with the gear referred to in paragraph 1 is allowed shall be equal to the total number of days allowed in the current year, multiplied by the minimum fishing mortality rate defined in Article 4 divided by the fishing mortality rate estimated by STECF.
5. At the request of the Commission or a Member State, Member States shall make available on their website or provide to the Commission and all Member States a description of the system applied to ensure compliance with paragraph 2, 3 and 4.

[Article 9

Procedure for the recovery of fishing days

1. Days absent from port on which fishing for cod shall be allowed in the areas defined in Article 8 paragraph 1, may be reallocated to Member States by the Commission on the basis of:
a) permanent cessations of fishing activities within the meaning of Article 7 of Council Regulation (EC) No 2792/1999 of vessels holding in 2005 a special permit for fishing for cod in the Baltic Sea in accordance with point 6.2.1 of Annex III to Council Regulation (EC) No 27/2005 of 22 December 2004 that have taken place, without public aid, since 1 January 2005
b) the definitive withdrawal from the area concerned

2. The additional number of days absent from port allocated to vessels in a given gear category will be directly proportional to the capacity expended in 2005 measured in kilowatt days of the withdrawn vessels using the gear in question compared to the comparable level of effort expended by all vessels using that gear during 2005. Any part of a day resulting from this calculation shall be rounded to the nearest whole day.

3. Member States wishing to benefit from the allocations described in paragraphs 1 and 2 shall submit a request to the Commission with reports containing the details of permanent cessations of the fishing activities in question. On the basis of such a request the Commission may amend the fishing periods for that Member State in accordance with the procedure laid down in Article 30 of Regulation (EC) No 2371/2002.]

Article10

Area restrictions on fishing

1. It shall be prohibited to conduct any fishing activity from 1 May to 31 October within the areas enclosed by sequentially joining with rhumb lines the following positions, which shall be measured according to the WGS84 coordinate system:

(a) Area 1:
– 55°45’N, 15°30’E
– 55°45’N, 16°30’E
– 55°00’N, 16°30’E
– 55°00’N, 16°00’E
– 55°15’N, 16°00’E
– 55°15’N, 15°30’E
– 55°45’N, 15°30’E

(b) Area 2:
– 55°00’N, 19°14’E
– 54°48’N, 19°20’E
– 54°45’N, 19°19’E
– 54°45’N, 18°55’E
– 55°00’N, 19°14’E

(c) Area 3:
– 56°13’N, 18°27’E
– 56°13’N, 19°31’E
– 55°59’N, 19°13’E
– 56°03’N, 19°06’E
– 56°00’N, 18°51’E
– 55°47’N, 18°57’E
– 55°30’N, 18°34’E
– 56°13’N, 18°27’E.

2. By way of derogation from paragraph 1, fishing with gillnets, entangling nets and trammel nets of a mesh size equal to or larger than 157 mm or with lines shall be permitted.
3. No other gear than defined in paragraph 2 shall be kept on board.
4. When fishing with any of the gear types defined in paragraph 2, no cod shall be retained on board.

CHAPTER V

MONITORING, INSPECTION AND SURVEILLANCE

Article 11

Special permit for fishing for cod in the Baltic Sea

1. By way of derogation from Article 1(2) of Council Regulation (EC) No 1627/94 of 27 June 1994 laying down general provisions concerning special fishing permits[22], all Community vessels of an overall length equal to or greater than eight metres carrying on board or using any gears for cod fishing in the Baltic Sea in accordance with Article 3 of Regulation (EC) No 2187/2005 shall hold a special permit for fishing for cod in the Baltic Sea.
2. Member States shall issue the special permit for fishing for cod referred to in paragraph 1 only to Community vessels holding in 2005 a special permit for fishing for cod in the Baltic Sea in accordance with point 6.2.1 of Annex III to Council Regulation (EC) No 27/2005 of 22 December 2004 fixing for 2005 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required[23]. However, a Member State may issue a special permit for fishing for cod to a Community vessel, flying the flag of that Member State, not holding a special fishing permit in 2005 if it ensures that at least an equivalent capacity, measured in kilowatts (kW), is prevented from fishing in the Baltic Sea with any gear referred to in paragraph 1.
3. Each Member State concerned shall establish and maintain a list of vessels holding a special permit for fishing for cod in the Baltic Sea and make it available on its official website.

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22 OJ L 171, 6.7.1994, p. 7.
23 OJ L 12, 14.1.2005, p. 1. Regulation as last amended by Regulation (EC) No 1936/2005 (OJ L 311, 26.11.2005, p. 1).

4. The master of a fishing vessel, or his/her authorised representative, to which a Member State has issued a special permit for fishing for cod in the Baltic Sea shall keep a copy of such permit on board the fishing vessel.

Article 12

Logbooks

1. By way of derogation from Article 6(4) of Regulation (EEC) No 2847/93 establishing a control system applicable to the common fisheries policy[24], the masters of all Community vessels of an overall length equal to or greater than eight metres having or retaining cod on board shall keep a logbook of their operations in accordance with Article 6 of that Regulation.
2. For vessels fitted with VMS, Member States shall verify that the information received at the FMC corresponds to activities recorded in the logbook by using VMS data. Such cross-checks shall be recorded in computer-readable form for a period of three years.
3. Each Member State shall maintain and make available on its official website the contact details for the submission of logbooks, landing declarations and prior notifications as specified in Article 18 of this Regulation.

Article 13

Electronic recording and transmission of catch data

By way of derogation from Article 1 of Commission Regulation (EEC) No 2807/83 Member States may permit the master of a fishing vessel equipped with VMS to report the information required in the logbook by electronic means. The information shall be transmitted to the FMC of the flag Member State on a daily basis after the fishing operation of that calendar day has been completed. The logbook information shall be made available on the request of the FMC of the coastal State during the time the fishing vessel is in the waters of the coastal State and on request of inspection.

Article 14

Recording of Fishing Effort Data

1. By way of derogation from Article 19b of Regulation (EEC) No 2847/93 the master of a Community fishing vessel, holding a special fishing permit in accordance with Article 11, when leaving and entering port,or entering and leaving the Baltic Sea, shall transmit an effort report containing the following information to the FMC of the flag Member State:

I) When leaving port or entering the Baltic Sea
(a) The name of the vessel, external identification mark and radio call sign;
(b) The date and time of departure from port or entry into the Baltic Sea (local time);
(c) The area where the vessel will fish as defined in Article 3(e)
II) When entering port or leaving the Baltic Sea
(a) The name of the vessel, external identification mark and radio call sign;
(b) The date and time of entry into port or exit from the Baltic Sea (local time)
3. Paragraphs 1, II. a. and b. and 1, II a. and b. shall not apply to vessels equipped with VMS .
4. The FMC of the flag Member State shall record the effort report it in its computerised database.
5. On request the flag Member State shall provide the information contained in paragraph 2 to the coastal Member State.

Article 15

Monitoring and Control of Fishing Effort

1. The competent authorities of the flag Member State shall monitor and control the compliance with:
(a) fishing effort limits provided for in Article 8 (1) and (2).
(b) restrictions on fishing provided for in Article 10.

Article 16

Margin of tolerance in the logbook

By way of derogation from Article 5(2) of Regulation (EEC) No 2807/83, the permitted margin of tolerance in estimating quantities, in kilograms, of species subject to a TAC that are retained on board vessels shall be 10% of the logbook figure except for cod in which case the margin of tolerance shall be 8% .

For catches which are landed unsorted the permitted margin of tolerance in estimating quantities shall be 10% of the total quantity that are retained on board.

Article 17

Entry Into or Exit from Specific Areas

1. A fishing vessel having a special permit for fishing for cod may only fish in either Area A, B or C during one fishing trip.
2. A fishing vessel may only commence fishing activity in Community waters in either Area A, B or C with no cod on board.
3 When a fishing vessel exits from either Area A, B or Area C with cod on board it shall:
(a) go directly to port outside the Area where it has been fishing and land the fish.
(b) When leaving the Area where the vessel has been fishing, the nets shall be stowed in accordance with the following conditions so that they may not readily be used:
(i) nets, weights and similar gear shall be disconnected from their trawl boards and towing and hauling wires and ropes,
(ii) nets which are on or above deck shall be securely lashed to some part of the superstructure.

Article 18

Prior notification

1. The master of a Community fishing vessel exiting from Area A, B or C with more than 300 kg of cod on board shall notify the competent authorities of the Coastal State in which it will land the fish at least one hour before leaving the Area of:
(a) the time and position of exit,
(b) the quantities of cod and the total weight of other species in live weight retained on board.
(c) the name of the landing location,
(d) the estimated time of arrival at the landing location,

Where appropriate the Coastal State shall notify the flag State of the landing.2. When a Community fishing vessel intends to enter a port in the area where it has been fishing with more than 300 kg of cod on board the master of a Community fishing vessel shall notify the competent authorities of the Coastal State and where appropriate the Coastal State shall notify the flag state at least one hour before entering port all the information referred to in paragraph 1(b), (c) and (d).
3. The submission of information referred to in paragraph 1(a) and (b) shall not apply to vessels subject to Article 13.
4. Paragraph 1 (a) shall not apply to vessels equipped with VMS.
5. The notification provided for in paragraphs 1 and 2 may also be made by a representative of the master of the Community fishing vessel.

Article 19

Designated ports

1. When a vessel retains more than 750 kilograms of cod live weight, the cod may be landed exclusively at designated ports.
2. Each Member State may designate ports at which any quantity of Baltic cod in excess of 750 kilograms is to be landed.

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[24] OJ L 261, 20.10.1993, p. 1. Regulation as last amended by Regulation (EC) No 768/2005 (OJ L 128, 21.5.2005, p. 1).

3. Within 15 days of the date of entry into force of this Regulation, each Member State that has established a list of designated ports, shall maintain and make available on its official website a list of designated ports.

Article 20

Weighing of cod first landed

Any quantity of cod caught in the Baltic Sea and landed in a Community port shall be weighed before sale or before being transported elsewhere from the port of landing. The scales used for the weighing shall be certified as accurate.

Article 21

Inspection Benchmarks

Each Member State of the Baltic Sea shall set specific inspection benchmarks. Such benchmarks shall be revised periodically after an analysis has been made of the results achieved. Inspection benchmarks shall evolve progressively until the target benchmarks defined in Annex I are reached.

Article 22

Prohibition on transiting and transhipping

1. Transit within areas closed for cod fishing is prohibited unless fishing gear on board is securely lashed and stowed in accordance with Article 17, paragraph 2, and subparagraph c.
2. The transhipment of cod is prohibited.

Article 23

Transport of Baltic cod

By way of derogation from Article 8(1) of Regulation (EEC) No 2847/93 the master of a fishing vessel having an overall length equal to or more than eight metres, shall complete a landing declaration when fish is transported to a place other than that of landing.
The landing declaration shall accompany the documents provided for in Article 13 of Regulation (EEC) No 2847/93 pertaining to the quantities transported. The exemption provided for in Article 13 (4) (b) of Regulation (EEC) No 2847/93 shall not apply.

Article 24

Joint surveillance and exchange of inspectors

Member States concerned shall undertake joint inspection and surveillance activities.

Article 25

National control action programmes

1. The Member States of the Baltic Sea shall define a national control action programmes for the Baltic Sea in accordance with Annex II.
2. The Member States of the Baltic Sea shall set specific inspection benchmarks in accordance with Annex I. Such benchmarks shall be revised periodically after an analysis has been made of the results achieved. Inspection benchmarks shall evolve progressively until the target benchmarks defined in Annex I are reached.
3. Before the 31 January each year, the Member States of the Baltic Sea shall make available to the Commission and other Member States bordering the Baltic Sea on its official website their national control action programmes as referred to in paragraph 1, together with an implementation schedule.
4. The Commission shall convene at least once a year a meeting of the Committee for Fisheries and Aquaculture to evaluate compliance with and the results of the national control action programmes for cod stocks in the Baltic Sea.

Article 26

Specific monitoring programme

By way of derogation from Article 34c(1) subparagraph 5 of Regulation (EEC) No 2847/93, the specific control and inspection programme for the cod stocks concerned may last for more than three years.

CHAPTER VI
FOLLOW-UP

Article 27

Evaluation of the plan

1. The Commission shall, on the basis of advice from STECF and the Baltic Regional Advisory Council (RAC), evaluate the impact of the management measures on the stocks concerned and on the fisheries exploiting those stocks in the third year of application of this Regulation and in each of the following years.
2. The Commission shall seek scientific advice from STECF on the rate of progress towards the targets specified in Article 4 in the third year of application of this Regulation and each third successive year of its application. Where the advice indicates that the targets are unlikely to be met, the Council shall decide by a qualified majority on a proposal from the Commission on additional and/or alternative measures required to ensure that the objectives are met.

Article 28

Revision of minimum fishing mortality rates

Where the Commission, on the basis of advice from STECF, finds that the minimum fishing mortality rates given in Article 4 are disaccording with the objectives of the management plan, the Council shall on the basis of a Commission proposal decide by a qualified majority on revised minimum fishing mortality rates that are in accordance with the objective.

Article 29

European Fisheries Fund

During the first three years of its application, the multi-annual plan shall be deemed to be a recovery plan within the meaning of Article 5 of Regulation (EC) No 2371/2002, and for the purpose of Article 21(a)(i) of Regulation (EC) No 1198/2006.

CHAPTER VII
FINAL PROVISIONS

Article 30

Repeal

1. Council Regulation (EC) No 779/97[25] of 24 April 1997, introducing arrangements for the management of fishing effort in the Baltic Sea is hereby repealed.
2. Paragraph 1a of Article 19a of Regulation (EEC) No 2847/93 is hereby repealed.

Article 31

Entry into force

This Regulation shall enter into force on the third day following that of its publication in the *Official Journal of the European Union*.
This Regulation shall apply from 1 January 2008.
This Regulation shall be binding in its entirety and directly applicable in all Member States.

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[25] OJL 113, 30.04.1997

Done at Brussels, For the Council
The President

ANNEX I

SPECIFIC INSPECTION BENCHMARKS

Objective
1. Each Member State shall set specific inspection benchmarks in accordance with this Annex.
Strategy
2. Inspection and surveillance of fishing activities shall concentrate on vessels likely to catch cod. Random inspections of transport and marketing of cod shall be used as a complementary cross-checking mechanism to test the effectiveness of inspection and surveillance.
Priorities
3. Different gear types shall be subject to different levels of prioritisation, depending on the extent to which the fleets are affected by fishing opportunity limits. For that reason, each Member State shall set specific priorities.
Target benchmarks
4. Not later than one month from the date of entry into force of this Regulation, Member States shall implement their inspection schedules taking account of the targets set out below.
Member States shall specify and describe which sampling strategy will be applied.
The Commission can have access on request to the sampling plan used by the Member State.
a. Level of inspection in ports
As a general rule, the accuracy to be achieved should be at least equivalent to what would be obtained by a simple random sampling method, where inspections shall cover 20% all cod landings by weight in a Member State.
b. Level of inspection of marketing
Inspection of 5% of the quantities of cod offered for sale at auction.
c. Level of inspection at sea
Flexible benchmark: to be set after a detailed analysis of the fishing activity in each area. Benchmarks at sea shall refer the number of patrol days at sea in the cod management areas, possibly with a separate benchmark for days patrolling specific areas.
d. Level of aerial surveillance
Flexible benchmark: to be set after a detailed analysis of the fishing activity conducted in each area and taking the available resources at the Member State’s disposal into consideration.

ANNEX II

Contents of national control action programmes

National control action programmes shall aim, *inter alia*, specify the following.
1. MEANS OF CONTROL
Human resources
1.1. The numbers of shore-based and seagoing inspectors and the periods and zones where they are to be deployed.
Technical resources
1.2. The numbers of patrol vessels and aircraft and the periods and zones where these are to be deployed.
Financial resources
1.3. The budgetary allocation for deployment of human resources, patrol vessels and aircraft.
2. ELECTRONIC RECORDING AND REPORTING OF INFORMATION RELATING TO FISHING ACTIVITIES
Description of the systems implemented to ensure compliance with Articles 13, 14, 15 and 18.
3. DESIGNATION OF PORTS
Where relevant, a list of ports designated for cod landings in accordance with Article 19.
4. ENTRY INTO OR EXIT FROM SPECIFIC AREAS.
Description of the systems implemented to ensure compliance with Article 17.
5. LANDINGS CONTROL
Description of any facilities and or systems implemented to ensure compliance with the provisions in Articles 12, 16, 20, 22, and 23of this Regulation.
6. INSPECTION PROCEDURES
The national control action programmes shall specify the procedures that will be followed:
(a) when conducting inspections at sea and on land;
(b) for communicating with the competent authorities designated by other Member States as responsible for the national control action programme for cod;
(c) for joint surveillance and exchange of inspectors, including specification of powers and authority of inspectors operating in other Member States' waters.

LIST OF SYMBOLS IN THE TEMAS DOCUMENTATION

The sequence of indices will be

(Fl, Vs, Rg, Ct, St, y, a, q, Va, Ar)

for all variables. The symbols used for indices are:

	Index	Explanation	Range
1	a	Age group	a = 0,1,2,…,a_{max}(St)
2	Ar	Area	Ar = 1,2,…,Ar_{max}
3	Ct	Country	Ct = 1,…,Ct_{Max}
4	Fl	Fleet	Fl = 1,2,…,Fl_{max}(Ct)
5	q	Time period (as time)	q = 1,..,q_{max}
6	qa	Time period (as age)	qa = 1,..,q_{max},
7	Rg	Rigging of gear	Rg = 1,…,Rg_{max}(Fl,Ct)
8	Y	Year	y = $y_{firSt,\ yfirst}$+1,…,y_{last}
9	St	Stock	St = 1,…,St_{max}
10	Va	Vessel age group	Va = 1,…Va_{max}(Fl,Ct)
11	Vs	Vessel size group	Vs = 1,…Vs_{max}(Fl,Ct)

Variables in alphabetical order:

Symbol	**Explanation**
a	Age group, a = 0,1,2,…,a_{Max}(St)
Age(a,q,qa)	Age of the fish (or cohort) in units of years
Ar	Area, Ar = 1,2,…,Ar_{Max}
B(St, y, a, q, Ar)	Total biomass of stock "St" , at the beginning of time period "q"
SR_I(SSB)	Stock/recruitment model no. I, (I=1,2,3,4)
SR_{IJ}(St)	Stock/recruitment parameter no J in model no I
C(Fl,Vs,Rg,Ct,St,y,a,q,Ar)	Numbers caught (landed or discarded)
C_{Disc}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)	Numbers discarded
C_{Land}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)	Numbers landed
$CO_E^{Total}(Fl,Vs,Ct,y,q)$	Total costs depending on the effort
$CO_{Operating}^{Total}(Fl,Vs,Ct,y,q)$	The total financial operating cost are $= CO_{Yield}^{Total}(Fl,y,q) + CO_E^{Total}(Fl,y,q) + CO_{VAL}^{Total}(Fl,y,q)$
$CO_{VAL}^{Total}(Fl,Vs,Ct,y,q)$	Total costs depending on the value of landings
$CO_{Yield}^{Total}(Fl,Vs,Ct,y,q)$	Total costs depending on the yield (weight of the landings)
$COR_E^i(Fl,Vs,Ct,y,q,Ar)$	Cost rate (cost per effort unit) depending on the effort.
$COR_{Yield}^i(Fl,Vs,Ct,y,q,Ar)$	Cost rate (cost per weight unit) depending on the yield (weight of the landings)
$COR_{VAL}^i(Fl,y,q,Ar)$	Cost rate (cost per value unit) depending on the value of landings.

CREW(Fl, Vs,Ct,y, q)	Potential number of crew on all vessels.
CREWDAY(Fl,Vs,Ct,y,q)	Number of crew-days corresponding to effort (sea-days)
CREWR(Fl,Vs,Ct,y,q)	Potential number of crew per vessel.
Ct	Country, Ct = 1,…,Ct_{Max}
DE(Fl,Vs,Ct,y,q)	Divisible earnings $= VAL(Fl,\bullet,y,q,\bullet,\bullet) - I^{DE}_{Yield} * CO^{Total}_{Yield}(Fl,y,q) - I^{DE}_{E} * CO^{Total}_{E}(Fl,y,q) - I^{DE}_{VAL} * CO^{Total}_{VAL}(Fl,y,$
DIS(Fl,Vs,Rg,Ct,St,y,a,q)	Discard ogive, the fraction of fish caught, which are discarded.
DISCARDS(Fl,Vs,Rg,y)	Total discards (summed over stocks, areas and time periods)
Dis1(Fl,Vs,Rg,Ct,St, y), Dis2()	Parameters in the logistic model of discard
da_{Mean}(St)	Mean time at recruitment
Dt	Basic time step (fraction of year). dt < 1.0. dt = 1/q_{Max}
E(Fl, Vs, Rg, Ct, y, q, Ar)	Effort
$E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar)$	Effort distribution on areas $E_{Area-Dist}(Fl,Vs,\bullet,Ct,y,q,Ar) = \frac{E(Fl,Vs,\bullet,Ct,y,q,Ar)}{E(Fl,Vs,\bullet,Ct,y,q,\bullet)}$
$E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar)$	Effort distribution on riggings for given area $E_{Rig-Dist}(Fl,Vs,Rg,Ct,y,q,Ar) = \frac{E(Fl,Vs,Rg,Ct,y,q,Ar)}{E(Fl,Vs,\bullet,Ct,y,q,Ar)}$
$E_{REG}(Fl,Vs,Rg,Ct,y,q,Ar)$	Regulation effort $= NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * Min\{ EY_{Max}(Fl,Vs,Ct,y,q,Ar), ED_{Max}(Fl,Vs,Rg,Ct,y,q,Ar) \}$
$E_{REF}(Fl,Vs,Ct,y,q,Ar)$	"Refererence effort" or the "maximum effort" $E_{REF}(Fl,Vs,Ct,y,q,Ar) = NU_{Vessel}(Fl,Vs,Ct,y,q,\bullet) * EY_{Max}(Fl,Vs,Ct,y,q,Ar)$
$ED_{Max}(Fl,Vs,Rg,Ct,y,q,Ar)$	Maximum number of effort units per time period given by legislation, to reduce effort.
EMPL(Fl, y, q)	Number of full time crew during a period (employment)
EY_{MAX}(Fl, Vs, Ct, y, q, Ar)	The maximum physical number of effort units per vessel per time unit in Area Ar.
$F(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$	Fishing area-mortality
$F_{Stock}(St,y,a,q)$	Fishing stock-mortality
$F_{Discard}(-)$	Discard area-mortality $F_{Discard}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$
$F_{Landings}(-)$	Landing area-mortality $F_{Landings}(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$
Fl	Fleet, Fl = 1,2,…,Fl_{max}(Ct)
F_{Stock}(Fl, St, y, a, q)	Fishing mortality (of stock)
I^{DE}_{Yield} , I^{DE}_{E} and I^{DE}_{VAL}	Used to define divisible earnings $= VAL(Fl,\bullet,y,q,\bullet,\bullet) - I^{DE}_{Yield} * CO^{Total}_{Yield}(Fl,y,q) - I^{DE}_{E} * CO^{Total}_{E}(Fl,y,q) - I^{DE}_{VAL} * CO^{Total}_{VAL}(Fl,y,$ 0 or 1 depending on the definition of divisible earnings.
K(St)	Von Bertalanffy curvature parameter
L_{∞}(St),	Von Bertalanffy parameter, L-infinity

LANDINGS(Fl, y)	Total landings (summed over stocks, areas and time periods)
Lgt(St, y, a, q)	Mean Body length
$LGT_{x\%}$(Fl, St, y)	Body Length at which x % of the fish entering the gear are retained
$LGT_{x\%Disc}$(Fl, St, y)	Body Length at which x % of the fish caught are discarded
$LGT_{x\%Mat}$(St)	Length at which x % of the stock is mature
M(St, y, a, q)	Natural mortality
Mat(St, a, q)	Maturity ogive
Mat1(St), Mat2(St)	Parameters in the logistic model of maturity
MC(St, a, q, F_{Ar}, T_{Ar})	Migration coefficient.
MS(Fl, y)	Mesh size
N_{Juv}(St, y, a, qa, q, Ar)	Stock number , Age gr. 0-1, at beginning of the period
$N_{Mean}(St,y,a,q,Ar)$	Mean number of survivors during time period q $N(St,y,a,q,Ar)\frac{1-exp(-Z(St,y,a,q,Ar)*dt)}{Z(St,y,a,q,Ar)*dt}$
N(St, y, a, q, Ar)	Stock number, Age gr. 2+, at beginning of the period
N_{RepVol}(St)	Average number of years between occurrences of large reproductive volumes.
$NU_{Attrition}$(Fl, y, q, Va)	Number of vessels withdrawn due to having reached end of lifetime
NU_{Decomm}(Fl, y, q, Va)	Number of vessels withdrawn due to decommissioning
U_{New_Vessel}(Fl, y, q)	Number of new vessels (number of investments in new vessels)
NU_{Vessel}(Fl, y, q,Va)	Number of vessels
$NU_{Withdrawal}$(Fl, y, q, Va)	Number of vessels withdrawn due to bad financial performance
NU_E^{CO}	Number of costs depending on the effort.
NU_{Yield}^{i}	Number of costs depending on the yield (weight of the landings).
NU_{VAL}^{CO}	Number of costs depending on the value of landings
P(Fl, St, y, q, a)	Price/weight unit, P = P_{max}* P_{Rel}.
PFlex(Fl,St)	Price flexibility, used in the price fomation model
P_{Int}(Fl, St, y, q, a)	Intervention price = Max{ P_{MinPO}(Fl, St, y, q, a) ,P(Fl, St, y, q, a) }
P_{Max}(Fl, St, y)	Maximum Price (over age groups) , P = P_{max}* P_{Rel}.
$P_{Max,0}$(Fl, St)	Constant coefficient, used in the price fomation model
P_{MinPO}(Fl, St, y, q, a)	PO-price (Producers Organization)
P_{Rel}(Fl, St, q, a)	Relative price of age group "a", P = P_{max}* P_{Rel}.
q	Time period (as time), q = 1,..,q_{max}
qa	Time period (as age), qa = 1,..,q_{max},
QBexp(Fl,Vs,Rg,St)	Parameter in the catchability model

	$Q(Fl,Vs,Rg,Ct,St,y,q,Ar) = Q_1(Fl,Vs,Rg,Ct,St,y,q,Ar) * B(St,y,q-1,Ar)^{QB\exp(Fl,Vs,Rg,St)}$
$Q(Fl,Vs,Rg,Ct,St,y,q,Ar)$	Catchability coefficient
$Q_{Ref}(Fl,St,Ar)$	Reference catchability, which remains constant over time.
$Q_{Relative}^{Time}(Fl,St,y,q,Ar)$	Relative catchability time-multiplier..
$Q_{Tech-Dev}(Fl,Vs,Rg,St)$	Parameter in the "technical creeping" model $Q(Fl,Vs,Rg,Ct,St,y,q,Ar) = Q_1(Fl,Vs,Rg,Ct,St,y,q,Ar) * B(St,y,q-1,Ar)^{QB\exp(Fl,Vs,Rg,St)} * \exp(y * Q_{Tech-Dev}(Fl,Vs,Rg,St))$
QE(St)	Condition exponent (length/weight relationship)
QF(St,q)	Condition coefficient (length/weight relationship)
$RSF_{MPA}(St,Ar,\varepsilon_{SR2}(St))$	MPA-factor in stock recruitment $= \begin{cases} rsf_{NotMPA}(St,Ar,\varepsilon_{SR2}(St)) \text{ if } Ar \neq MPA \\ 1 \text{ if } Ar = MPA \end{cases}$
$rsf_{NotMPA}(St,Ar,\varepsilon_{SR2}(St))$	Spawning success factor by area $= \begin{cases} rsf_{NotMPA}^{High}(St,Ar) \text{ if } \varepsilon_{SR2}(St) \leq 1/N_{RepVol}(St) \\ rsf_{NotMPA}^{Low}(St,Ar) \text{ if } \varepsilon_{SR2}(St) > 1/N_{RepVol}(St) \end{cases}$ where $0 \leq rsf_{NotMPA}^{Low}(St,Ar) \leq rsf_{NotMPA}^{High}(St,Ar) \leq 1$
$R_{RepVol}(St)$	Reproductive volume factor, in stock/recruitment model $= \begin{cases} R_{RV}(St) \text{ if } \varepsilon_{SR2}(st) \leq 1/N_{RepVol}(St) \\ 1 \text{ if } \varepsilon_{SR2}(St) > 1/N_{RepVol}(St) \end{cases}$ $\varepsilon_{SR2}(St)$ is a uniformly distributed stochastic variable
$R_{RV}(St)$	Average relative magnitude of recruitment in years of high reproductive volume.
RE(Fl,Vs,Rg,Ct,St)	Rigging Effect, parameter in the catchability model $Q(Fl,Vs,Rg,Ct,St,y,a,q,Ar) = Q_1(Fl,Vs,Rg,Ct,St,y,q,Ar) * \exp(RE(Fl,Vs,Rg,Ct,St))$
$Rec(St,y,\bullet,\bullet)$	Recruitment number
$RecDist_{Area}(St,Ar)$	The fraction of the annual recruitment which occurs in area Ar. $Rec(St,y,q,Ar) = RecDist_{Area}(St,Ar) * RecDist_{Period}(St,qa) * Rec(St,y,\bullet,\bullet))$
$RecDist_{Period}(St,qa)$	The fraction of the annual recruitment which occurs in period qa. $Rec(St,y,q,Ar) = RecDist_{Area}(St,Ar) * RecDist_{Period}(St,qa) * Rec(St,y,\bullet,\bullet))$
REV(Fl,y)	Total revenue. $REV(Fl,y) = VAL(Fl,\bullet,y,\bullet,\bullet,\bullet)$.
$RSF_{MPA}(St,Ar)$	MPA-factor $= \begin{cases} rsf_{NotMPA}(St,Ar) \text{ if } Ar \neq MPA \\ 1 \text{ if } Ar = MPA \end{cases}$
$rsf_{NotMPA}(St,Ar)$	
Rg	Rigging of gear, Rg = 1,…,Rg_{max}(Fl,Ct)
SEL(-)	Gear selection ogive $SEL(Fl,Vs,Rg,Ct,St,y,a,q,Ar)$
SF(Fl, St, y)	Selection factor
SR(Fl, St, y)	Selection range
SSB(St, y, q, Ar)	The spawning stock biomass

$SSB_{MPA}(St,y,\bullet,\bullet)$	$=\sum_{Ar=1}^{Ar_{Max}} SSB(St,y,\bullet,Ar)*R_{MPA}(St,Ar)$ Spawning stock biomass weighted by the "spawning success factor", $R_{MPA}(St,Ar)$
$STR_X(SSB(St,y-1,\bullet,\bullet))$	Stock recruitment model X: (1) Beverton & Holt (2) "Hockey stick" (3) Ricker (4) Deriso-Schnute
St	Stock, St = 1,…,St_{Max}
TON(Fl,Vs, Ct)	Average tonnage of a vessel
Y	Year, y = $y_{firSt,\ yfirst}$+1,…,y_{last}
y_{first} ,y_{last}	First year, Last year
Y(Fl, St, y, a, q, Ar)	Total yield (weight of catch) Y=Y_{Lan} +Y_{Disc}
Y_{Disc}(Fl, St, y, a, q, Ar)	Weight of discards, Y_{Disc} = C_{Disc} * Wgt
Y_{Land}(Fl, St, y, a, q, Ar)	Weight of landings, Y_{Land} = C_{Land} * Wgt
Va	Vessel age group, Va = 1,…Va_{Max}(Fl,Ct)
VAL(Fl,St,y,q,a,Ar)	Value of landings, VAL=Y_{Land}*P
Vs	Vessel size group, Vs = 1,…Vs_{max}(Fl,Ct)
Wgt(St, y, a, q)	Body weight (the same in landings, discards and stock)
X_B^A	Multiplier, where A indicate the index group of the multiplier, and B a second index (if required).
$Z(St,y,a,q,Ar)$	Area total mortality Z (St, y, a, q, Ar) = F(•, •, •, •, St,y, a, q, Ar) + M(St, y, a, q)
$Z_{Stock}(St,y,a,q)$	Stock total mortality

Greek letter symbols

$\varepsilon_K(St,y)$, σ_K	Stochastic factor of von Bertalanffy parameter K, of stock "St" and year "y" dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_K
$\varepsilon_Q(Fl,St,y)$, σ_Q	Stochastic factor of catchability, a year, fleet and stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_Q .
$\varepsilon_{QF}(St,y)$, σ_{QF} $\varepsilon_K(St,y)$ $\varepsilon'_{QF}(St,y)$	Stochastic factor of condition factor, of stock "St" and year "y" dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{QF} . $\varepsilon_{QF}(St,y) = (\varepsilon_K(St,y) + \varepsilon'_{QF}(St,y))/2$, where $\varepsilon'_{QF}(St,y))$ is a year and stock dependent normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{QF}.
$\varepsilon_{SR}(St)$	$\varepsilon_{SR}(St) = \varepsilon_{SR1}(St) * R_{RepVol}(St)$ Stochastic factor in stock/recruitment model composed of a log normally distributed factor, $\varepsilon_{SR1}(St)$, and $R_{RepVol}(St)$
$\varepsilon_{SR1}(St)$, σ_{SR}	Stochastic factor of stock/recruitment relationship, of stock "St", a stock dependent log-normally distributed stochastic variable with mean value 1.0 and standard deviation σ_{SR} .
$\varepsilon_{SR2}(St)$	Uniformly distributed stochastic variable in model of reproductive volume factor, in stock/recruitment model $= \begin{cases} R_{RV}(St) \ if \ \varepsilon_{SR2}(st) \leq 1/N_{\mathrm{Re}\,pVol}(St) \\ 1 \ if \ \varepsilon_{SR2}(St) > 1/N_{\mathrm{Re}\,pVol}(St) \end{cases}$

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