DTU Aqua
Institut for Akvatiske Ressourcer

Bevarelse af et bæredygtigt industri-fiskeri: Brisling i Nordsøen og IIIa (BEBRIS)

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Christoffer Moesgaard Albertsen, Alicia Lianne Hamer, Asbjørn Christensen,
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DTU Aqua-rapporter er afrapportering fra forskningsprojekter, oversigtsrapporter over faglige emner, redegørelser til myndigheder o.l. Med mindre det fremgår af kolofonen, er rapporterne ikke fagfællebedømt (peer reviewed), hvilket betyder, at indholdet ikke er gennemgået af forskere uden for projektgruppen.

Forord

Rapporten indeholder en beskrivelse af aktiviteterne og resultaterne fra EHFF projektet med titlen Bevarelse af et bæredygtigt industrifiskeri – Brisling i Nordsøen og IIIa (BEBRIS) (33113-B-17-091).

Rapporten starter med at beskrive baggrunden for projektet. Derefter gennemgås de fire arbejdspakker. Det er forsøgt at holde sproget simpelt og der gengives kun de vigtigste elementer. I forhold til tekniske detaljer og/eller en mere videnskabelig gennemgang af resultater, henvises der enten til ICES-rapporter (med hyperlink) eller til tekniske arbejdsdokumenter, der er vedhæftet som bilag (5 i alt). Desuden kan der i rapporten forefindes lister over præsentationer og dialogmøder.

Projektet blev påbegyndt i september 2018 og blev afsluttet i december 2020.

Projektets deltagere var Bastian Huwer, Peter Munk, Martin Lindegren, Mollie E. Brooks, Christoffer Moesgaard Albertsen, Alicia Lianne Hamer, Asbjørn Christensen, Ole Henriksen, Anna Rindorf, Mikael van Deurs.

Teksten i selve rapporten er skrevet af Mikael van Deurs (arbejdspakke 1, 2 og 4) og Bastian Huwer (arbejdspakke 3). Projektkoordinator var Mikael van Deurs. Arbejdspakkeansvarlige var Mikael van Deurs (arbejdspakke 1), Martin Lindegren (arbejdspakke 2), Bastian Huwer og Peter Munk (arbejdspakke 3) og Mollie E. Brooks og Mikael van Deurs (arbejdspakke 4).

Projektet er finansieret af Den Europæiske Hav- og Fiskerifond og Fiskeristyrelsen.

Den Europæiske Union
Den Europæiske Hav- og Fiskerifond

HAV & FISK

Lyngby, marts 2021

Mikael van Deurs
Seniorforsker

Indhold

Sammenfatning

Projektets formål var at understøtte et bæredygtigt brislingefiskeri i Nordsøen, Skagerrak og Kattegat og sikre at den fælles fiskeripolitik efterleves. Brislingfiskeriet er et fiskeri af stor betydning for danske fiskere og dansk forarbejdningsindustri. Projektet har fokuseret på følgende elementer i den nye Fiskerireform: 1) Bæredygtighed i dybden, 2) Maksimalt Bæredygtigt Udbytte (MSY), 3) Viden om Fiskeri, samt 4) Flerårige Planer. Projektet forløb planmæssigt, hvilket vil sige at samtlige arbejdspakker og i alt fem dialogmøder med repræsentanter for erhvervet er blevet gennemført. Resultaterne har bidraget direkte til en rækker møder og processer i ICES; herunder brisling benchmark WKSPRAT 2018 og evaluering af forvaltningsstrategien WKspratMSE 2019. Projektet har udviklet nye metoder og indhentet ny viden på en række konkrete områder om opnået følgende: (1) en bedre forståelse af bestandstilhørsforholdet for brisling som fanges i Skagerrak/Kattegat, samt et detaljeret arbejde med selve bestandsmodellen, (2) viden om vejrets påvirkning af fangstrater, (3) metode til forudsigelse af vækst og forslag hvordan dette fremadrettet potentielt vil kunne anvendes i udarbejdningen rådgivning, (4) systematiske larveindsamlinger på IBTS Q3 og belysning af muligheden for at udvikle et nyt rekrutteringsindeks (resulterede også i utilsigtet ny viden om udbredelsen af sardin-larver i Nordsøen), og (5) grundig evaluering af den såkaldte Fcap forvaltningsstrategi og det retrospektive mønster i bestandsmodellen. I rapporten her findes en beskrivelse af aktiviteterne og resultaterne i projektets fire arbejdspakker samt en liste over præsentationer og dialogmøder. Der henvises undervejs til vedhæftede tekniske arbejdsdokumenter m.m.

English summary

The purpose of the project was to support a sustainable sprat fishing in the North Sea, Skagerrak and Kattegat and ensure that the common fisheries policy is complied with. The sprat fishery is a fishery of great importance to Danish fishermen and the Danish processing industry. The project has focused on the following elements of the new Fisheries Reform: 1) sustainability in depth, 2) Maximum Sustainable Yield (MSY), 3) knowledge about Fisheries, and 4) multi-annual plans. The project proceeded according to plans, which means that all work packages and a total of five dialogue meetings with representatives of the fishing industry have been completed. The results have directly contributed to a series of meetings and processes in ICES; including sprat benchmark (WKSPRAT 2018) and evaluation of the management strategy for sprat (WKspratMSE 2018). The project has developed new methods and gained new knowledge in a number of specific areas and achieved the following: (1) a better understanding of the stock affiliation of sprat caught in the Skagerrak and Kattegat, (2) improvement of the stock assessment during the benchmark, (3) knowledge of the weather's influence on catch rates, (4) methods for predicting growth and suggestions on how this could potentially be used in the preparation of advice in the future; (5) systematic larval collections on the international bottom trawl survey (IBTS Q3) and elucidation of the possibility of developing a new recruitment index in the North Sea, and (6) thorough evaluation of the so-called Fcap management strategy and the retrospective pattern in the stock assessment model.

1. Baggrund

Danmark følger den internationale rådgivning for brisling i Nordsøen, Skagerrak og Kattegat som udstedes af ICES (International Council for the Exploration of the Seas). Det vil også sige at fiskeriet er underlagt skærpede krav om biologisk bæredygtighed, som skal sikre biodiversiteten i Nordsøen for fremtiden. Fra fiskerens synspunkt er brisling en industrifisk som kan forarbejdes til fiskemel, men fra økosystemets synspunkt er brisling en vigtig fødefisk som bidrager betydeligt den totale biomasse af fødefisk i Nordsøen. Disse fødefisk spiller en vital rolle for en lang række fugle, havpattedyr og fisk, og sikre dermed at produktionen nederst i fødekæden kan finde vej til toppen af fødekæden.

Når man har tilstrækkelig beskrivende data for en given bestand kan man etablere en såkaldt aldersbaseret analytisk bestandsmodel og estimere et biologisk referencepunkt, som udtrykker den kritiske biomasse man ikke ønsker at komme under. For bestande af fødefisk udgør dette referencepunkt også det primære forvaltningsmæssige mål, som skal sikre MSY. Et grundlæggende princip for den rådgivning ICES leverer er, at jo bedre viden man har om den enkelte bestands udvikling jo tættere kan man bevæge sig på bestandens referencepunkt. I de situationer hvor den tilgængelige viden og data ikke er tilstrækkelig til at drive en troværdig aldersbaseret bestandsmodel, kategoriseres bestanden som en såkaldt datasvag bestand, hvilket betyder at ICES giver en ekstra forsigtig rådgivning, ofte med gradvis reduktion af den anbefalede fangstmængde til følge. Disse principper og protokoller er med til at sikre balancen mellem biologisk bæredygtighed og den kommercielle udnyttelse af bestanden (MSY).

Selvom ICES er involveret i dataindsamling og viden-indsamling, så er det hovedsagligt eksterne eksperter som bidrager med modeller, viden og data. Det betyder også, at hvis der er ønske om, eller behov for, at styrke en given rådgivning, så er det op til de nationale forskningsinstitutioner at levere det nødvendige materiale (modeller, data, dokumentation osv). I den forbindelse skelnes der mellem to typer af arbejdsgrupper: (1) En årlig arbejdsgruppe, som primært følger en fast protokol og opdaterer tidsserier, genkører bestandsmodellen og laver udkastet til den årlige standard-rådgivning, og (2) en såkaldt Benchmark-arbejdsgruppe, som finder sted ca. hvert 4. år, og hvor den førnævnte protokol udvikles og kvalitetssikres.

Fiskeriet efter brisling foregår hovedsagligt i EU farvand og betragtes som et internationalt anliggende, hvilket betyder at rådgivningsopgaven er placeret hos det internationale rådgivningsorgan ICES (International Council for Exploration of the Seas). I 2018 blev der åbnet op for ICES benchmark-processen for brisling (ICES WKSPRAT 2018). DTU Aqua deltog også i det forrige benchmark for brisling afholdt i 2013 (ICES WKSPRAT 2013). Før 2013 havde ICES ikke nogen aldersbaseret bestandsmodel for brisling, hvilket betød at den anbefalede samlede fangstmængde stod til at blive reduceret betydeligt ifølge de bæredygtigheds-principper, som er blevet indført for de såkaldte datasvage bestande i ICES. Gennem en intensiv indsats from mod Benchmark-arbejdsgruppen i 2013, lykkedes det imidlertid at sammensætte en bestandsmodel for brisling i Nordsøen, som kunne accepteres af ICES, og dermed undgik brisling i Nordsøen at overgå til de datasvage bestande. Benchmark for brisling i 2018 var ligeledes vigtig for det danske brislingfiskeri, da det her skulle evalueres om modellen vedtaget i 2013 har fungeret og om der kan gøres yderligere for at forbedre rådgivningen.

2. Arbejde med bestandsmodellen og bidrag til brisling benchmark (Arbejdspakke 1)

Der blev lavet en grundig undersøgelse af bestandsstrukturen. Især spørgsmålet om hvor vidt brisling der fanges i Kattegat og Skagerrak tilhører Nordsøbestanden blev undersøgt. På en baggrund af genetiske analyser fra et andet EMFF-projekt (MAKSIBRI) og analyser af størrelse og vækst blev det besluttet at lægge de to bestande sammen. Der blev efterfølgende sat en ny bestandsmodel op for Nordsøen og IIIa samlet, som blev accepteret af ICES. Således er der ikke længere en data-svag IIIa-bestand, men kun en stor samlet bestand. Der blev også lavet en forbedring af modellen som reducerede det såkaldte retrospektivt bias. Yderligere detaljer omkring arbejdet med sammenlægningen af områderne og ændringerne i modellen kan findes i ICES benchmark-rapporten: Benchmark Workshop on Sprat (WKSPRAT 2018)[1].

Se eventuelt også arbejdsdokumenter fra Benchmark-mødet (BILAG 1 og BILAG 2), som dokumenterer dele af arbejdet omkring bestandsstrukturen og reduceringen af det retrospektive bias. Der blev også, som en del af projektet, skrevet en videnskabelig artikel som beskriver en metode til at undersøge bestandsstrukturen ud fra data fra det internationale bundtrawl survey. Metoden blev benyttet som supplement til de genetiske analyser (lavet i MAKSIBRI) og arbejdet beskrevet i BILAG 1.

Ud over dette arbejde blev der senere i projektet kigget nærmere på sammenhængen mellem vejret og fangstraterne i fiskeriet. Dette grundige modellerings-studie påviste en negativ sammenhæng mellem dårligt vejr og fangstrater. De tekniske detaljer omkring studiet kan findes i BILAG 3. Det åbne spørgsmål er om man vil kunne inddrage denne viden i selve bestandsmodellen og på den måde forbedre præcisionen af modellens estimater. Det forventes at man vil kigge nærmere på dette spørgsmål frem imod næste benchmark der dog ikke forventes at finde sted før 2022 eller 2023.

Den videnskabelige artikel beskrevet ovenfor blev indsendt til ICES Journal of Marine Science i februar 2021. Nedenfor ses titel, forfatterliste og abstract.

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[1] https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2018/WKSPRAT/WKSPRAT%202018%20Report.pdf

Videnskabelig artikel indsendt til
ICES Journal of Marine Science i februar 2021

Title: Identifying population structuring for the management of widely distributed marine fish species – European sprat as a case study

Authors: Martin Lindegren, Mikael van Deurs, Aurore Maureaud, James T. Thorson, Dorte Bekkevold

Abstract: Many commercially important fish species are widely distributed over large areas, often spanning across boundaries of national jurisdiction. Failing to acknowledge that such species may be composed of distinct populations with independent dynamics and productivity may result in overestimation of the stock's true harvest potential and ultimately lead to population collapse. Ways to identify population structuring are therefore critically needed to increase the likelihood of sustainable exploitation. In this study, we demonstrate a statistical approach to identify and define biologically relevant population boundaries for a widely distributed marine fish species, European sprat *(Sprattus sprattus)*. Specifically, we compiled available trawl-survey data throughout the Northeast Atlantic Ocean and predicted densities through this area while controlling for spatially unbalanced sampling resulting from different survey protocols. Subsequently, we used a range of statistical tools to assess whether the current management boundaries within northern European shelf seas adequately account for geographical differences in population characteristics. Our results demonstrate clear signs of population structuring of sprat within the study area, illustrated by regional differences in spatial abundance patterns, temporal dynamics and population demographics between four areas identified through hierarchical clustering. Our findings are in line with the most recent population genetic studies of sprat, indicating reproductive isolation between the Baltic Sea/Kattegat and a larger cluster containing the North-, Irish-, Celtic Sea and Bay of Biscay. Our results show that characterising spatially varying population processes can be a cost-effective complement to population genetic methods for detecting population structure. These can be used to guide spatial management efforts and ensure a sustainable exploitation, especially under climate change and the expected changes in species distributions across current management borders.

3. Forudsigelse af vækst og rekruttering (Arbejdspakke 2)

På trods af flere forsøg lykkedes det ikke at finde en sammenhæng mellem rekruttering og miljøfaktorer såsom temperatur eller føde. Til gengæld viste det sig at væksten afhænger af antallet af brisling i bestanden (såkaldt tæthedsafhængighed). Disse resultater blev skrevet sammen til en videnskabelig artikel, der nu er publiceret i ICES Journal of Marine Science i 2020 (77(7-8), 3138–3152. doi:10.1093/icesjms/fsaa218). Artiklen beskriver også en grundig analyse af gevinsten ved at bruge en vækstmodel der tager højde for tætheds-afhængighed frem for et femårigt gennemsnit, som er det ICES benytter i fangst-forudsigelserne på nuværende tidspunkt. Det ser ud til, at man kan forbedre forudsigelserne en lille smule ved at benytte vækstmodellen. Nedenfor kan man se titel, forfatterne og det engelske abstract fra den videnskabelige artikel.

Videnskabelig artikel publiceret i
ICES Journal of Marine Science i 2020

Title: Climate- and density-dependent regulation of fish growth throughout ontogeny: North Sea sprat as a case study

Authors: Martin Lindegren, Anna Rindorf, Tommy Norin, David Johns, and Mikael van Deurs

Abstract: Growth is a fundamental physiological process influencing the state and dynamics of fish stocks, yet the physical and biological conditions affecting individual weight and growth throughout ontogeny are poorly known and often unaccounted for in fisheries management. This is rather surprising given that changes in growth have strong direct effects on the total biomass and potential yield derived from any given stock. In this study, we investigate the underlying factors affecting fish growth throughout the life span of cohorts using statistical modelling and long-term observational data on sprat *(Sprattus sprattus)*, a commercially and ecologically important small-pelagic fish species across European seas. Our results demonstrate a negative relationship between total abundance and weight, as well as a positive and dome-shaped relationship between temperature and zooplankton abundance (i.e. food availability), respectively. Furthermore, we demonstrate how such improved knowledge and understanding of the underlying factors affecting weight and growth could be accounted for in future assessment models, by including these considerations into short-term forecast simulations. This, in turn, would provide a stronger scientific basis for management advice and ensure the sustainability and profitability of fisheries, particularly on small and commercially valuable pelagic species with pronounced spatio-temporal variability in weight and growth.

ICES Journal of Marine Science, 2020 (77(7-8), 3138–3152. doi:10.1093/icesjms/fsaa218

4. Indsamling af brisling larver og muligheden for et nyt rekrutteringsindeks (Arbejdspakke 3)

En eksisterende tidsserie af sildelarver, som bliver fanget om natten på de internationalt koordinerede Q1 IBTS togter, danner baggrund til et rekrutteringsindeks for sild i Nordsøen. Formålet med AP3 i BEBRIS var et vurdere perspektivet for udvikling af en lignende rekrutteringsindeks for brisling i Nordsøen, baseret på larvefangster under Q3 IBTS togterne.

De konkrete formål med arbejdspakke 3 var (1) at gennemføre 2 pilot surveys efter brislingelarver ved at udnytte nattetimerne på de danske Q3 IBTS togter og (2) at benytte resultater fra disse pilot surveys til at vurdere mulighederne for at etablere et rekrutteringsindeks for brisling i Nordsøen, baseret på årlige larve surveys som gennemføres på disse togter. Dvs. formålet var ikke at udvikle en egentlig rekrutteringsindeks, da dette ville kræve en længere tidsserie af larve data samt en bedre rumlig dækning af undersøgelsesområdet.

Perspektivet for udvikling af et rekrutteringsindeks blev vurderet på baggrund af en række forudsætninger eller minimumskrav, som mindst skal være opfyldt til en succesfuld etablering af et rekrutteringsindeks. Følgende fem forudsætninger blev testet under pilot togterne i 2018 og 2019:

1. Brislingelarver forekommer i den periode hvor Q3 IBTS togterne gennemføres.
2. Brislingens gydning er overstået i den periode hvor Q3 IBTS togterne gennemføres, så alle larver er klækket og man ikke mister den sidste del af den årlige larve produktion.
3. Det er muligt at fange larverne kvantitativt på Q3 IBTS togterne.
4. Larverne har nået en størrelse hvor deres mængde kan forudsige rekruttering.
5. Det er muligt at dække de områder som rummer størstedelen af larveforekomsten.

På pilottogterne i 2018 og 2019 blev der gennemført forsøgstræk efter brislingelarver med et MIK net på hhv. 71 og 66 stationer. Det blev opdaget at larverne rent faktisk var en blanding af brisling og sardin, hvilket krævede ekstra opmærksomhed ved prøveanalyserne, da larver af disse to arter ligner hinanden meget. Brislingelarverne var mest udbredt i den nordlige del af undersøgelsesområdet, mens sardin larverne var mest udbredt i den sydlige del. Men det kunne konstateres at brislingelarverne var meget udbredt i store dele af undersøgelsesområdet. **Det betyder, at forudsætning 1 er opfyldt**.

For at undersøge om brislingens gydning er overstået på det tidspunkt hvor Q3 IBTS gennemføres var det store MIK net udrustet med et lille ekstra MIKey net med finere masker, for at se om der stadig er brislingeæg i området. Det viste sig at der var kun lidt prøvemateriale i disse MIKey prøver, og de blev derfor tjekket for æg direkte om bord. Der var ingen forekomst af brislingeæg i prøverne. **Det betyder, at forudsætning 2 er opfyldt.**

På togtet i 2018 blev der gennemført en række forsøgstræk på samme position i dagslys og mørke for at se om der er forskelle i larvernes fangbarhed mellem dag og nat. Der blev kun fanget ganske få brislingelarver i dagslys, men mange larver i mørket. Faktisk var fangsterne i mørket meget højere end typiske fangster af sildelarver på de allerede etablerede MIK sildelarve surveys i Q1. **Det betyder, at forudsætning 3 er opfyldt – dog kun i de mørke timer, hvilket er en udfordring på Q3 IBTS, da det begrænser den effektive arbejdstid til larveundersøgelserne til ca. 7-8 timer per nat.**

På nogle stationer blev der fanget brislingelarver i stort set alle størrelser, fra 10 mm larver til 4-5 cm juveniler. Hovedparten af larverne lå dog i et størrelsesområde mellem 12-20 mm. Dvs. at de fangede brislingelarver var mindre end de sildelarver fra Q1 IBTS, som allerede bliver brugt til et rekrutteringsindeks. Brislingelarver når dog de samme udviklingsstadier ved mindre størrelser end sildelarverne. Derfor er det muligt at brislingelarverne er allerede store nok til at kunne indikere den fremtidige rekruttering, men det er pt svært at vurdere og kræver en længere tidsserie af larvefangster til sammenligning med rekrutteringsestimater fra bestandsvurderingen og fangster af rekrutter fra videnskabelige togter og fra det kommercielle fiskeri. **Det betyder, at forudsætning 4 er muligvis opfyldt, men en endelig vurdering kræver yderligere undersøgelser og frem for alt en længere tidsserie.**

Den rumlige fordeling af brislingelarverne viste, at der kun var få larver i den sydlige del af undersøgelsesområdet. I den nordlige del var der også en tendens til aftagende larve tætheder, men det er sandsynligt at der stadig findes brislingelarver i områder som ligger længere nord. Det vil sige at den sydlige grænse af brislingelarvernes hovedforekomst bliver fint dækket af det danske arbejdsområde på Q3 IBTS togterne, mens den nordlige grænse bliver mindre godt dækket. Desuden var det ikke muligt at dække det område som rummer størstedelen af larveforekomsten med tilstrækkelig mange prøvetagningsstationer. **Det betyder, at forudsætning 5 er delvist opfyldt, men der er brug for internationalt samarbejde med nogle af de andre Q3 IBTS deltagere for at opnå en tilstrækkelig dækning af de relevante områder.**

Sammenfattende kan det konstateres, at de testede forudsætninger er helt eller i det mindste delvist opfyldt. **Det vurderes derfor, at der er potentiale for udvikling af et rekrutteringsindeks for brisling i Nordsøen som er baseret på fangster af brislingelarver under Q3 IBTS togterne. En mere detaljeret vurdering om et larve survey i Q3 kan levere et rekrutterings indeks kræver dog yderligere analyser og frem for alt en længere tidsserie af larve data.**

De foreløbige resultater fra 2018 og 2019 ser lovende nok ud til at retfærdiggøre yderligere undersøgelser. Derfor fortsætter DTU Aqua med undersøgelserne og gennemfører 2 yderligere pilot surveys i 2020 og 2021 i opfølgningsprojektet "PELA – Pelagiske arter".

Under arbejdet med brisling-laverne blev der opdaget overraskende store mængder sardin-larver, som bidrog med helt ny viden om sardinens udbredelse i Nordsøen og åbnede op for nye spørgsmål, såsom hvor disse larver kommer fra, hvilken bestand tilhører de, og er der grobund for et fiskeri. Det blev også fundet at brisling og sardin-larver kun udviser et delvist overlap i deres udbredelse og at forskellen i udbredelse kan forklares ud fra hydrografien. Flere detaljer om dette studie kan findes i vedlagt manuskript (BILAG 4).

5. Evaluering af forvaltningsstrategien for brisling (Arbejdspakke 4)

Det blev på et dialogmøde med erhvervet besluttet at fokusere på Fcap-strategien. Denne strategi blev derfor grundigt evalueret i første halvdel af 2019 med et state-of-the-art modelværktøj udviklet af Mollie E. Brooks sideløbende i EMFF-projektet MSEtools. Der blev både lavet en omfattende såkaldt ”full loop management strategy evaluation” og en såkaldt ”light version”. Sidstnævnte viste sig at kunne reproducere resultatet fra den fulde version, hvilket betyder at den kan benyttes til at undersøge forskellige scenarier, da den er betydeligt lettere at arbejde med og bruger mindre computerkraft. I dag benytter ICES den Fcap som blev beregnet og evalueret her i BEBRIS projektet.

Senere opstod der bekymring om hvor vidt det retrospektive bias i bestandsmodellen stadig var for stort på trods af forbedringerne foretaget under WKSPRAT 2018 (benchmark). For at undersøge dette nærmere benyttede vi igen ovennævnte modelværktøj og kunne vise, at det retrospektive mønster ikke er kritisk. Dette resultat (og metoden) blev fremlagt på en ICES videnskabsgruppe i 2019 i Woods Hole (WKFORBIAS 2019) og er også nævnt på s. 12 i den rapport som den videnskabsgruppen efterfølgende udgav på ICES´ hjemmeside: Workshop on catch forecast from biased assessments[2]. Desuden er præsentationen som blev givet i Woods Hole vedlagt her som bilag (BILAG 5).

Alle tekniske detaljer omkring evalueringen af Fcap findes i WKspratMSE rapporten: Workshop on the management strategy evaluation of the reference point, Fcap, for Sprat in Division 3.a and Subarea 4 (WKspratMSE)[3].

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[2] https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2020/WKFORBIAS_2019.pdf

[3] https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2018/WKspratMSE/WKspratMSE%20Report%202018.pdf

Præsentationsoversigt

Tabel 5.1. Præsentationer givet af Bastian Huwer (arbejdspakke 3)

Year	Month	Venue	ICES WG	Presentation title
2017	October	Boulogne-sur-mer	WGEGGS2	Suggestion for a pilot survey to target sprat larvae on Q3 IBTS
2018	October	Copenhagen	WGALES	A pilot survey on the feasibility of establishing a sprat recruitment index based on larval sampling during Q3 IBTS surveys
2018	December	Ijmuiden	WGEGGS2	A pilot survey on the feasibility of establishing a sprat recruitment index based on larval sampling during Q3 IBTS surveys
2019	October	Bremerhaven	WGSINS	A pilot survey on the feasibility of establishing a sprat recruitment index based on larval sampling during Q3 IBTS surveys
2020	October	Online	WGALES	Sprat and sardine larvae in the North Sea -Recent results from MIK pilot surveys during the Q3 IBTS in 2018 –2020
2020	December	Online	WGSINS	Sprat and sardine larvae in the North Sea -Recent results from MIK pilot surveys during the Q3 IBTS in 2018 –2020

Tabel 5.2. Præsentationer givet af Mikael van Deurs (arbejdspakke 1 og 4).

Hvornår	Hvor	Titel
September 2018	Online møde afholdt af ICES (forberedelse til brisling benchmark)	Indication of stock structure
November 2018	København, (ICES brisling benchmark WKSPRAT)	Explaining residuals in the assessment model
November 2019	Woods Hole US (ICES WKFORBIAS)	Do we have a Mohns Rho problem for sprat?
December 2019	Ålborg (workshop afholdt af DPPO)	Brisling Workshop

Mødeoversigt

Tabel 5.3 Dialogmøder afholdt med repræsentanter fra erhvervet. Der eksisterer referater fra alle møderne (kontakt: mvd@aqua.dtu.dk).

Hvornår	Hvor	Hvem
Juni 2018	DTU	Udeladt på grund af persondataloven
Oktober 2018	DTU	Udeladt på grund af persondataloven
Maj 2019	DTU	Udeladt på grund af persondataloven
Oktober 2019	Axelborg	Udeladt på grund af persondataloven
November 2020	DTU (afholdt online på grund af Covid-19 restriktioner)	Udeladt på grund af persondataloven

Bilag 1. External and internal consistency in survey data and mean length at age in commercial catches - for use in the discussion about merging or not merging North Sea (Div. 4) and IIIa

Working document

WKSPRAT 2018

Mikael van Deurs

External and internal consistency in survey data and mean length at age in commercial catches - for use in the discussion about merging or not merging North Sea (Div. 4) and IIIa

Here we looked at the external consistency in the IBTS survey between ICES roundfish areas and internal consistency in the IBTS survey index calculated using the delta GAM method (see the working document on new methods for sprat indices for further details about the method, Casper Berg). Lastly, we also compared the length at age observed in commercial samples.

External consistency in the IBTS survey between ICES roundfish areas

CPUE by age and roundfish area were extracted from the ICES web site. The question in focus was whether population dynamics follow the same patterns in the North Sea (Div. 4) and IIIa (Skagerrak and Kattegat). We therefore focused on inter-annual variation in the survey CPUE for roundfish area 6 and 7 (the main sprat fishing grounds in the North Sea) and roundfish area 8 and 9 (IIIa) (see map in Fig. 1). Pairwise correlation analyses revealed a significant relationship between adjacent roundfish areas, also when comparing area 7 and 8, indicating that the stock dynamics of sprat in the North Sea is not decoupled from the dynamics in IIIa (Fig. 2 and 3). This tendency was reflected in both the Q1 and Q3 survey.

Internal consistency in delta GAM indices

Internal consistency analyses for the delta GAM survey indices showed a reduction in consistency when including IIIa into the modeled Q1 indices, but a marked improvement in consistency for Q3 indices (Fig. 4 and 5, figures were taken from a working document by Casper Berg about the new methods for sprat indices).

Length at age in commercial catches

Figure 6 shows the distribution of catches based on VMS data from a representative year. As the map shows the majority of catches inside IIIa is taken from a relatively confined area on the border between Kattegat and Skagerrak. Based on this map and information about where and when sampling intensity was highest we selected three geographical boxes. A comparison between the offshore box and the box in IIIa was possible only in quarter 4, whereas, a comparison between the inshore box and the box in IIIa was possible only in quarter 4 (due to lag of samples from the inshore box in quarter 4 and the offshore box in quarter 3). We only included statistical ICES rectangles with a minimum of 5 samples and we only included years where there were at least one rectangle inside the boxes used in the comparison. The final mean length at age was derived as stratified averages by first averaging across squares (within each box) and thereafter across years. The resulting length at age is presented in Fig. 4. The standard errors (s.e.) were derived from the averaging across years and lag of overlap between s.e. was taken as an indication of a significant difference (as indicated by “*” in Fig. 4). We did not find indications of size differences between the box in IIIa and the offshore box in the North Sea, whereas, significant differences was found when comparing the inshore box and the box in IIIa, indicating that the observed geographical differences in length at age cannot alone be explained by the existence of a distinct IIIa sub stock.

Conclusion

In conclusion, these results does not support a stock division between North Sea and IIIa. However, the decision to merge or not merge North Sea (Div. 4) and IIIa into one stock should not be based on these results alone, but should be combined with other methods, such as population genetics etc.

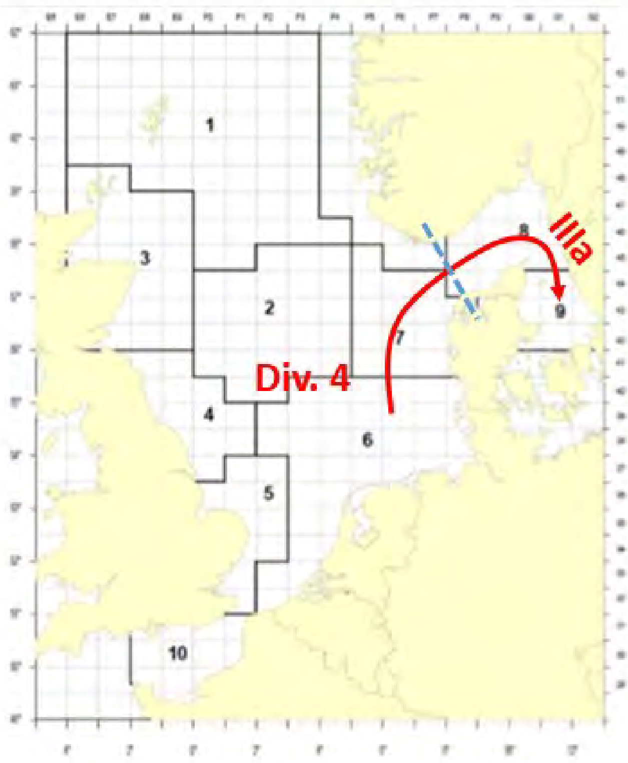


Figure 1. ICES roundfish areas (see the main text for details).

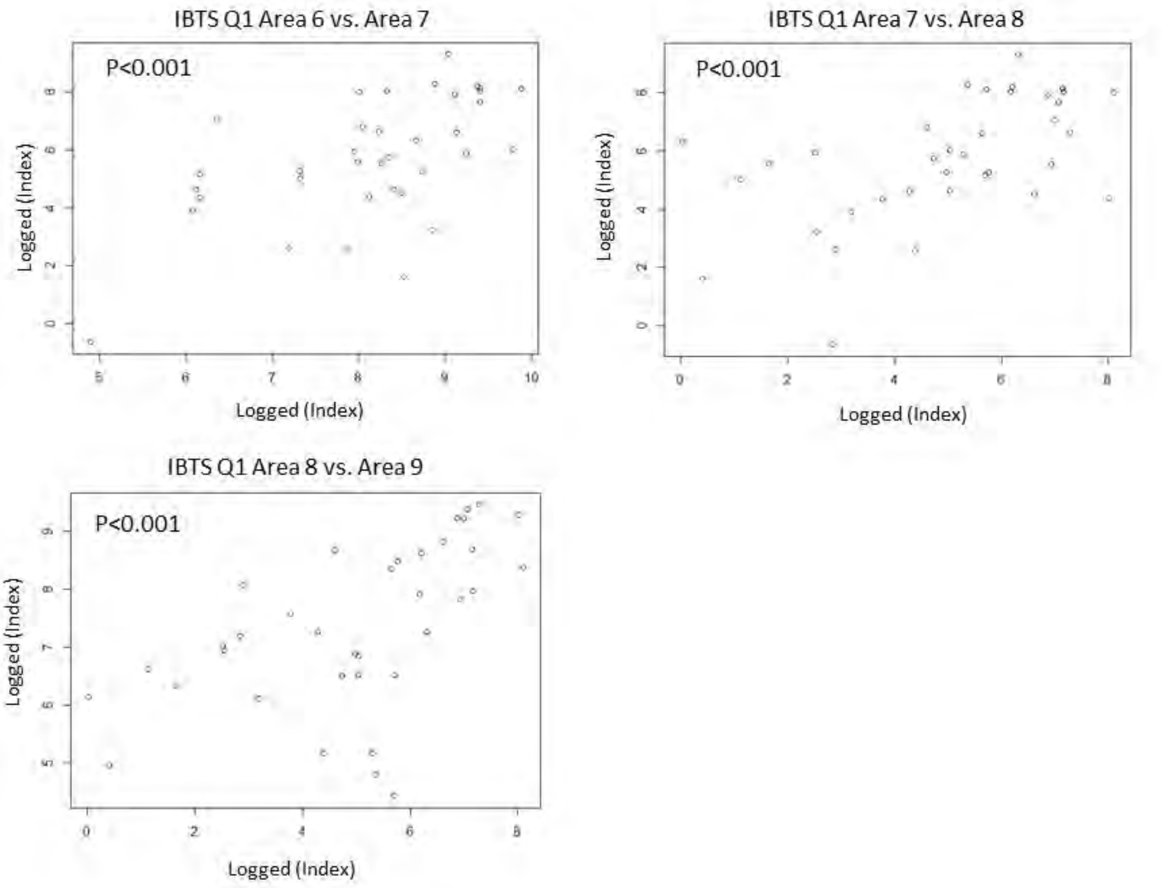


Figure 2. External consistency in IBTS Q1 indices between roundfish areas (see the main text for details).

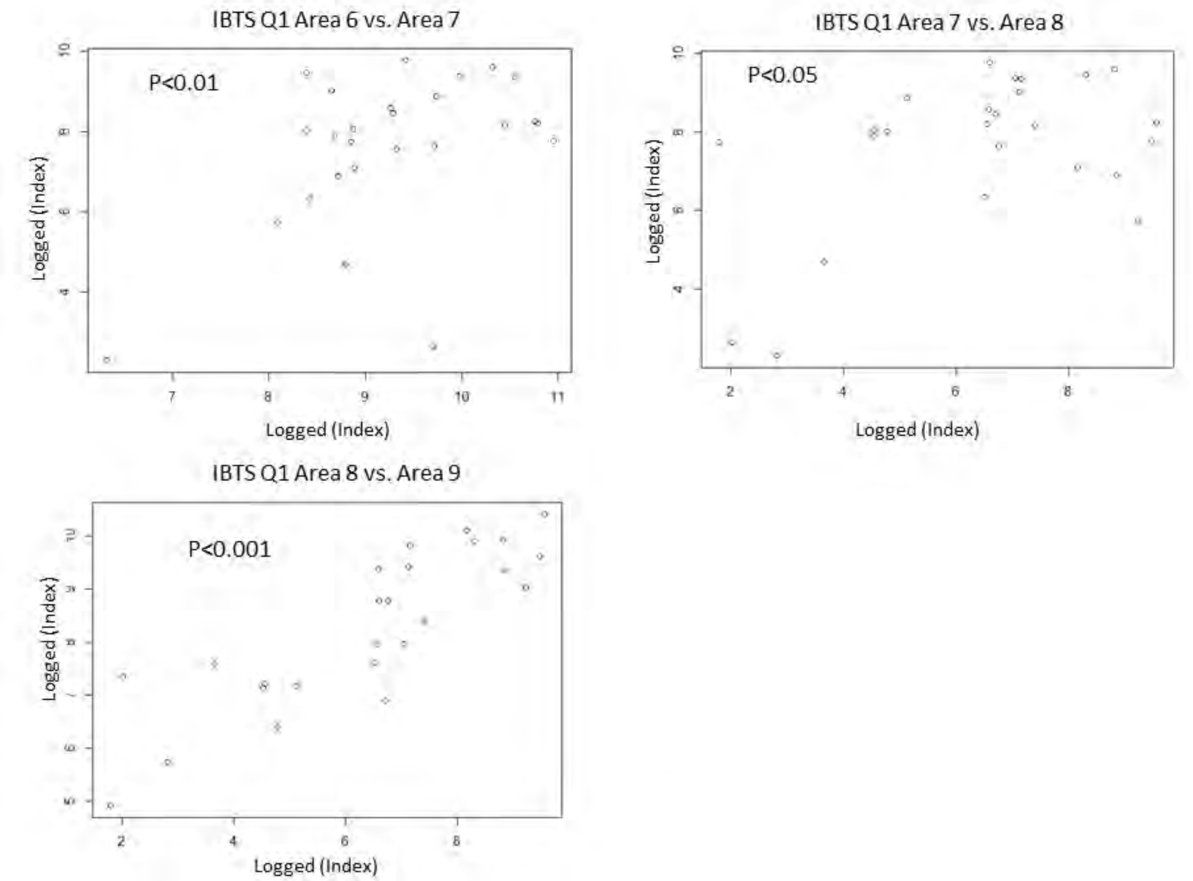


Figure 3. External consistency in IBTS Q3 indices between roundfish areas (see the main text for details).

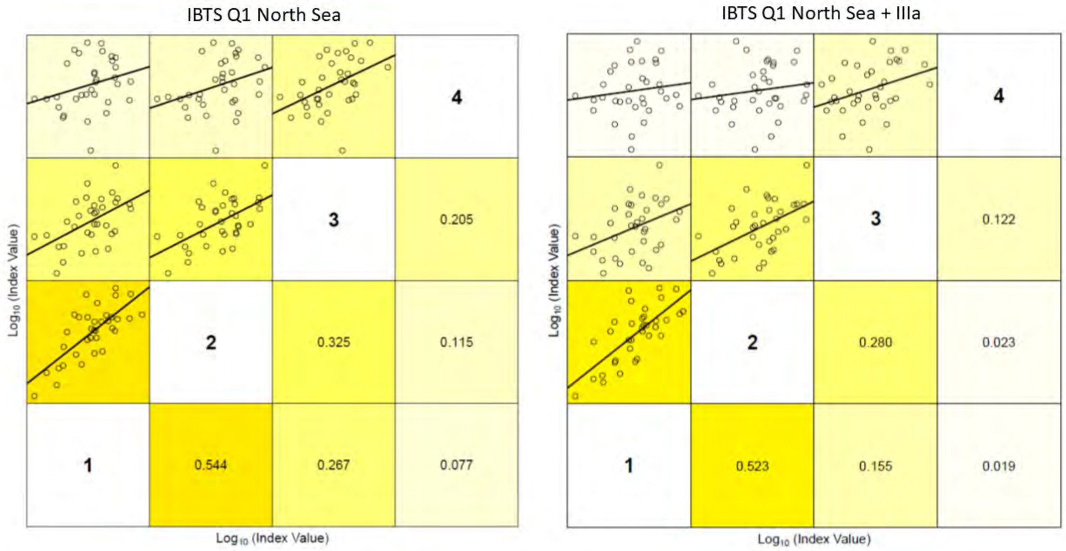


Figure 4. Internal consistency in delta GAM sprat indices (Q1) with and without the inclusion of IIIa data (see the main text for details).

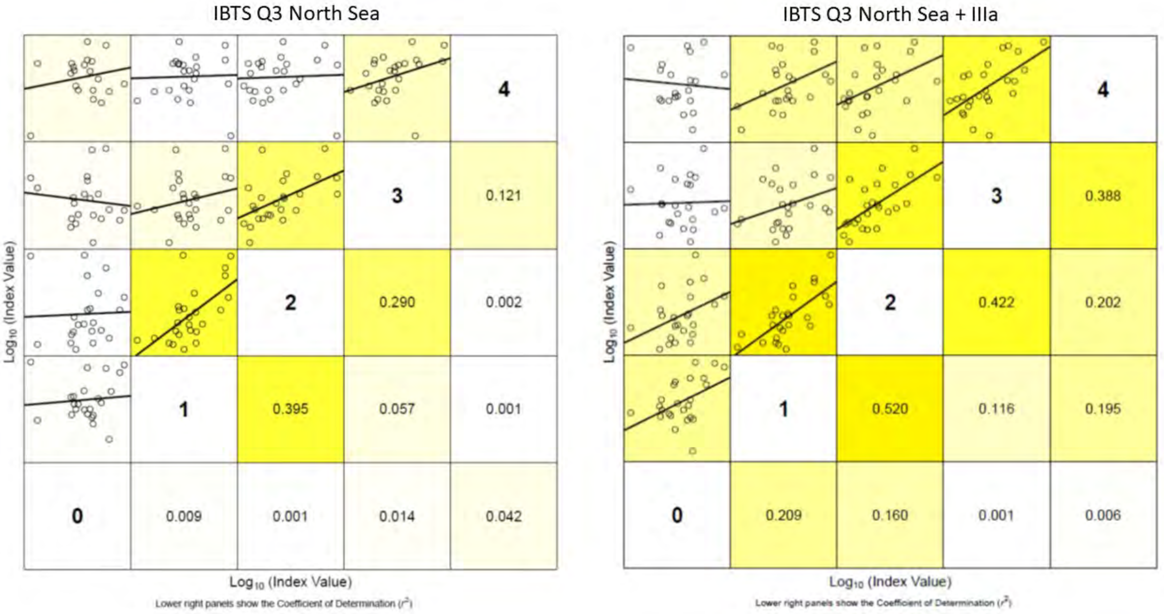
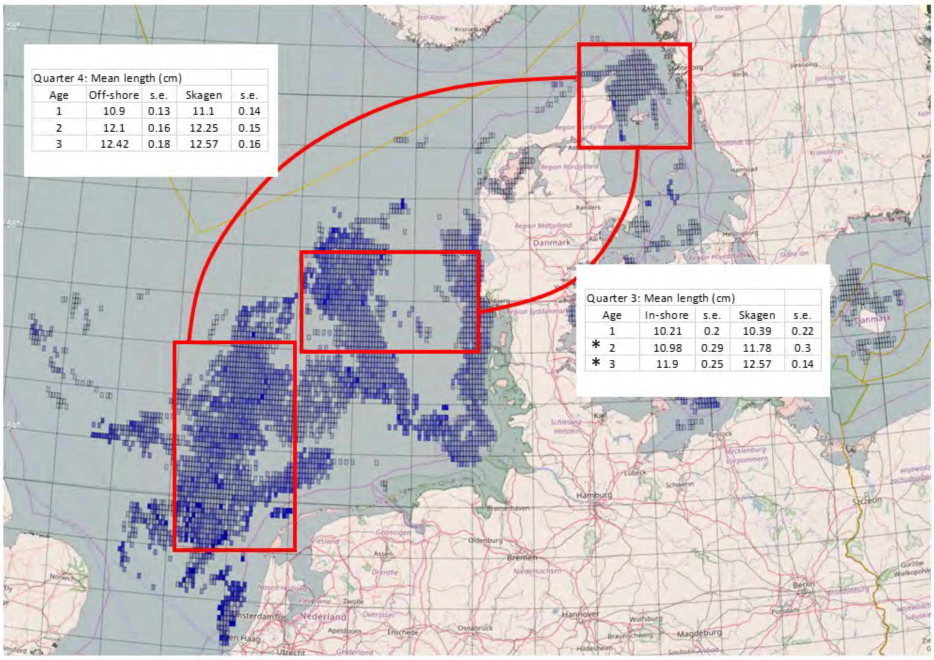


Figure 5. Internal consistency in delta GAM sprat indices (Q3) with and without the inclusion of IIIa data (see the main text for details).



Quarter 4: Mean length (cm)				
Age	Off-shore	s.e.	Skagen	s.e.
1	10.9	0.13	11.1	0.14
2	12.1	0.16	12.25	0.15
3	12.42	0.18	12.57	0.16

Quarter 3: Mean length (cm)				
Age	In-shore	s.e.	Skagen	s.e.
1	10.21	0.2	10.39	0.22
* 2	10.98	0.29	11.78	0.3
* 3	11.9	0.25	12.57	0.14

Figure 6. Map of catch distribution from a representative year and length at age in commercial catches (see the main text for details).

Acknowledgement: EMFF project BEBRIS - Bevarelse af et bæredygtigt industrifiskeri

Bilag 2. Explorative assessment runs

Working document

WKSPRAT 2018
Mikael van Deurs

Explorative assessment runs

Description of work:

A number of explorative assessment runs were carried out during the benchmark meeting. These runs provided a basis, together with additional materials (see other working documents), for reaching a conclusion regarding the settings in the final assessment model. All explorative runs were carried out in the SMS model (see technical description in SMS working document). In the present working document, diagnostics from each explorative run were compared to the diagnostics from a base run, the settings of which was decided on the first day of the benchmark meeting. Selected diagnostics included catch and survey CVs (see for example figure 1a), retrospective patterns for the last five years and Mohn´s Rho (see for example figure 1b), survey residuals (see for example figure 1c), and catch residuals (see for example figure 1d).

The base run differed from the assessment model, used since the last sprat benchmark, on the following aspects:

- North Sea and IIIa is combined
- No break point (i.e. fixed exploitation pattern throughout the time series)
- IBTS survey indices modelled using a delta GAM model described in a different working doc
- Density dependent catchability (power function with one parameter) is estimated for age-0 IBTS Q1

Each explorative run represented a single change made to the base run. The following list summarizes all explorative runs and tells you where to find the associated results:

- No density dependence catchability on IBTS Q1 age-0 (Figure 1a-d)
- Using data for age-0 also in IBTS Q3 survey (and not only in IBTS Q1) (Figure 2)
- Inserting a break point in 1996 (according to an AIC comparison, 1996 seemed like a good place to insert a break point, see figure 3a) (Figure 3a-e)
- Removing the HERAS survey; keeping just IBTS Q1 and Q3 (Figure 4a-d)
- Removing IBTS Q3 survey; keeping just IBTS Q1 and HERAS (Figure 5a-d)
- Shortening of the time series to 1983 and onward (Figure 6a-d)
- Moving all catches in season 4 into season 1 in the following year (Figure 7a-d). Catches in season 4 are in general very small (<10% of all catches) and they are caught late in season 4, when the sandeel season is over (note that the model runs with 4 annual seasons and the model year runs from 1/1 to 30/6)
- Using IBTS indices based on stratified means (i.e. as used in the old model) (Figure 8a-d)

Main results and conclusions:

Describing density dependent catchability in the model as a power function resulted in an increase in the Mohn´s Rho that describes the retrospective pattern (Mohn´s Rho should be as small as possible) (see figure 1b).

The survey CV of age-0 in IBTS Q3 was very high (CVs should be low; down to a limit). Hence, we concluded that no improvement of the model was made by including this index (see figure 2).

Adding a breakpoint in 1996 improved AIC relative to not having a break point (see figure 3a). However, it also increased Mohn´s substantially (see figure 3a).

Removing the HERAS survey did not make much of a difference (see figure 4a-d) and removing IBTS Q3 increased Mohn´s Rho considerably (see figure 5b).

Shortening the time-series increased the catch CVs a bit (note that catch CV should be low). Except for that, not much changed (see figure 6a).

Moving catches in season 4 to season 1 in the following year, improved the retrospective pattern notably (see figure 7b).

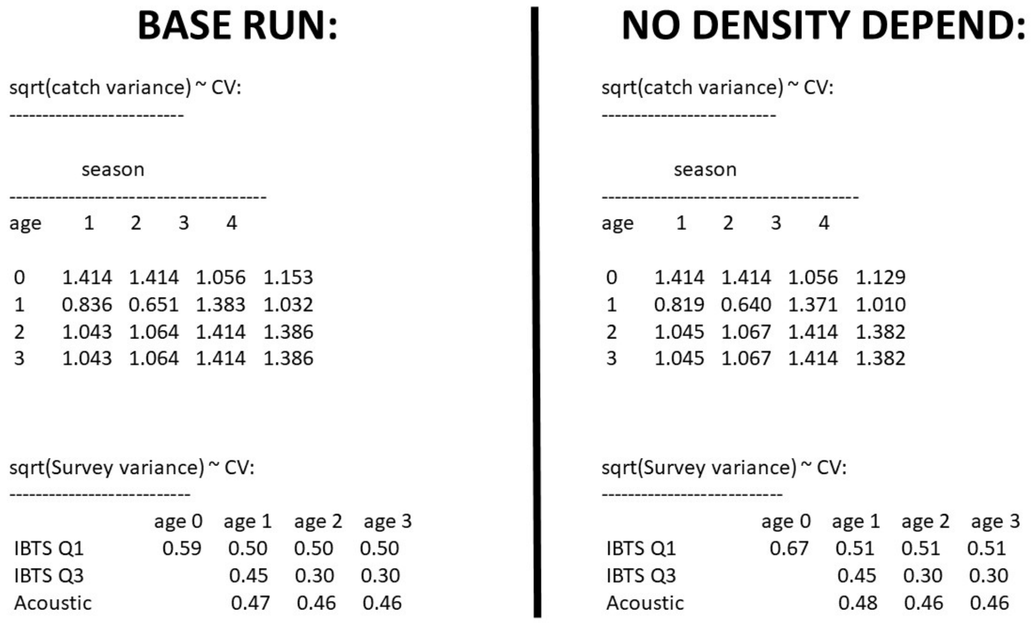
Using indices based on stratified means, instead of the delta GAM indices, increased both catch and survey CVs. Note that the base run used in this comparison is different. The IBTS Q1 index time-series that we got from ICES was considerably shorter than the delta GAM time-series. We therefore decided to shorten the time series in the base run to match that of the explorative run.

Overall, the model was found to be rather robust. Irrespective of the changes made to the model, diagnostics (shown here) and the estimated stock size (not shown here) only changed slightly.

Based on these results and additional information (see other working documents) we concluded that the final assessment model should:

- Area 4 (the North Sea) and 3a (Skagerrak and Kattegat) should be combined
- IBTS survey indices should be modeled using the delta GAM method (see working document on new method for calculating IBTS sprat indices)
- Density dependent survey catchability should be used for for age-0 in IBTS Q1.
- All three surveys, IBTS Q1, IBTS Q3, and the acoustic HERAS survey should be included in the final model (i.e. same as in the previous SMS model setup for area 4).
- Catches in season 4 should be moved into season 1 in the following model year.
- No break points should be inserted (i.e. the exploitation pattern was fixed throughout the time period) and historical catches should not be removed.
- Age-0 indices from IBTS Q3 should not be included (i.e. same as in the previous SMS model setup for area 4).

It should be noted that the natural mortalities used in the final assessment differs from the natural mortalities used here. The difference was only in the last two years and only in Q3 and Q4, where the Ms were wrongly calculated and therefore 2-3 times smaller than what they should have been. The Ms have been corrected in the final assessment run (see working document on the final assessment run)



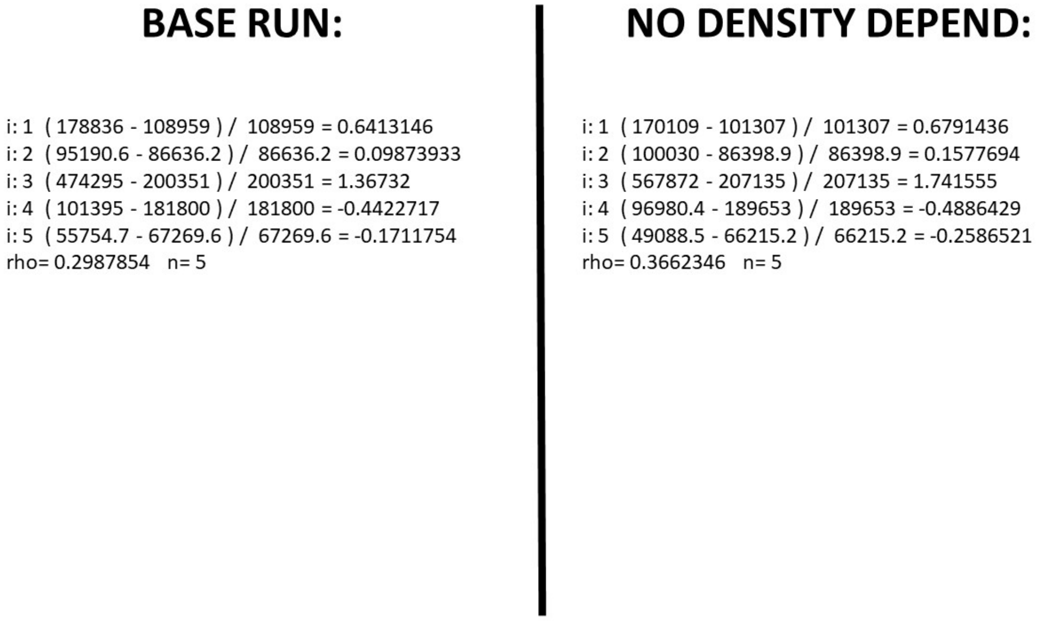
BASE RUN:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
--------------------------------------
age       1      2      3      4

 0      1.414  1.414  1.056  1.153
 1      0.836  0.651  1.383  1.032
 2      1.043  1.064  1.414  1.386
 3      1.043  1.064  1.414  1.386



sqrt(Survey variance) ~ CV:
---------------------------
                    age 0   age 1   age 2   age 3
 IBTS Q1             0.59    0.50    0.50    0.50
 IBTS Q3                     0.45    0.30    0.30
 Acoustic                    0.47    0.46    0.46
```

NO DENSITY DEPEND:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
--------------------------------------
age       1      2      3      4

 0      1.414  1.414  1.056  1.129
 1      0.819  0.640  1.371  1.010
 2      1.045  1.067  1.414  1.382
 3      1.045  1.067  1.414  1.382



sqrt(Survey variance) ~ CV:
---------------------------
                    age 0   age 1   age 2   age 3
 IBTS Q1             0.67    0.51    0.51    0.51
 IBTS Q3                     0.45    0.30    0.30
 Acoustic                    0.48    0.46    0.46
```

Figure 1a



BASE RUN:

```
i: 1  ( 178836 - 108959 ) /  108959 = 0.6413146
i: 2  ( 95190.6 - 86636.2 ) /  86636.2 = 0.09873933
i: 3  ( 474295 - 200351 ) /  200351 = 1.36732
i: 4  ( 101395 - 181800 ) /  181800 = -0.4422717
i: 5  ( 55754.7 - 67269.6 ) /  67269.6 = -0.1711754
rho= 0.2987854    n= 5
```

NO DENSITY DEPEND:

```
i: 1  ( 170109 - 101307 ) /  101307 = 0.6791436
i: 2  ( 100030 - 86398.9 ) /  86398.9 = 0.1577694
i: 3  ( 567872 - 207135 ) /  207135 = 1.741555
i: 4  ( 96980.4 - 189653 ) /  189653 = -0.4886429
i: 5  ( 49088.5 - 66215.2 ) /  66215.2 = -0.2586521
rho= 0.3662346    n= 5
```

Figure 1b

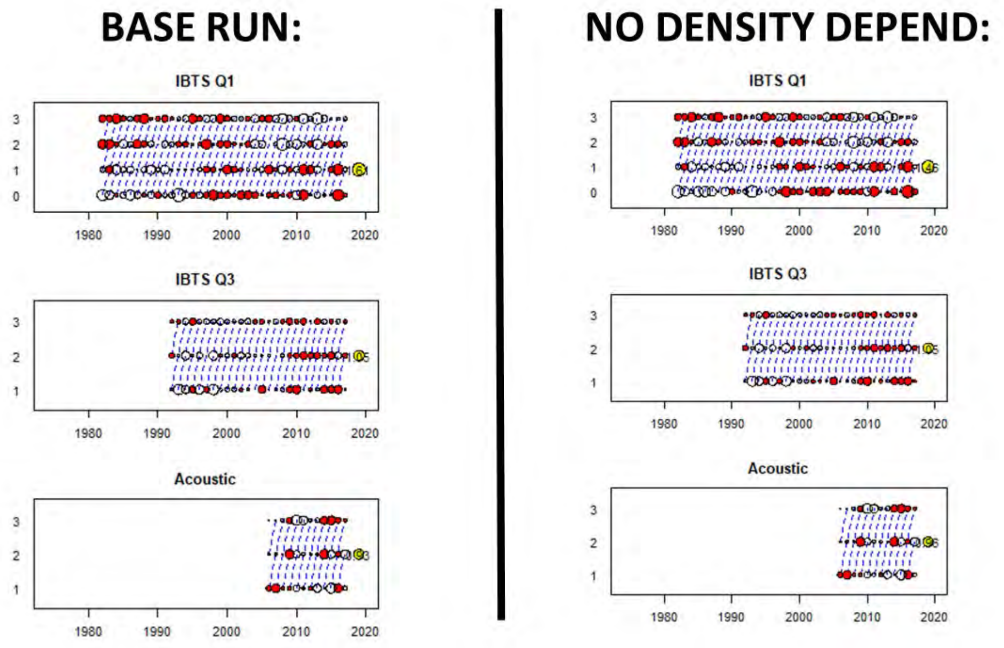


Figure 1c

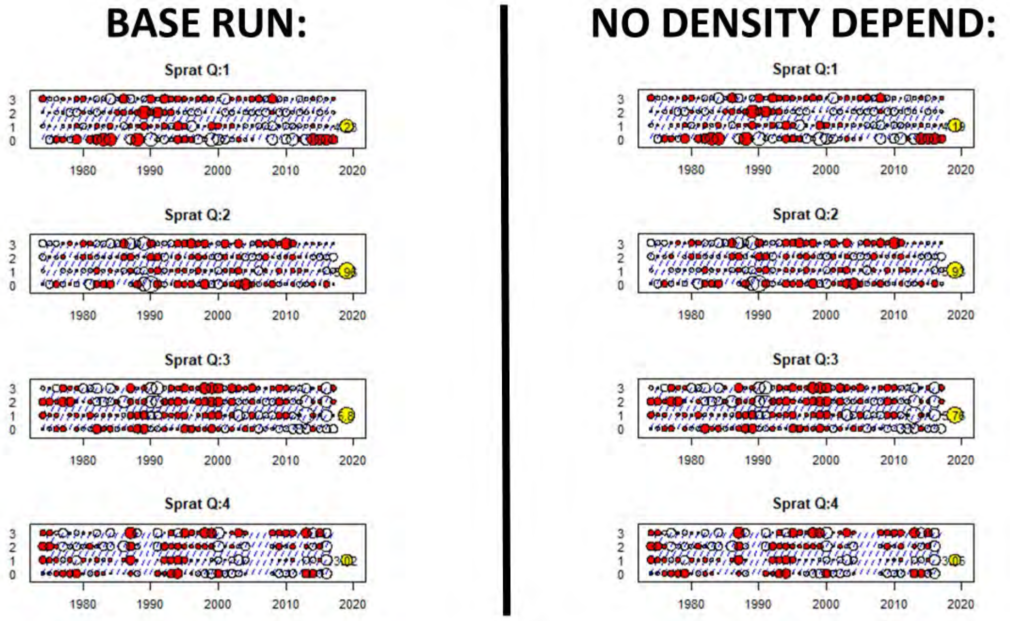
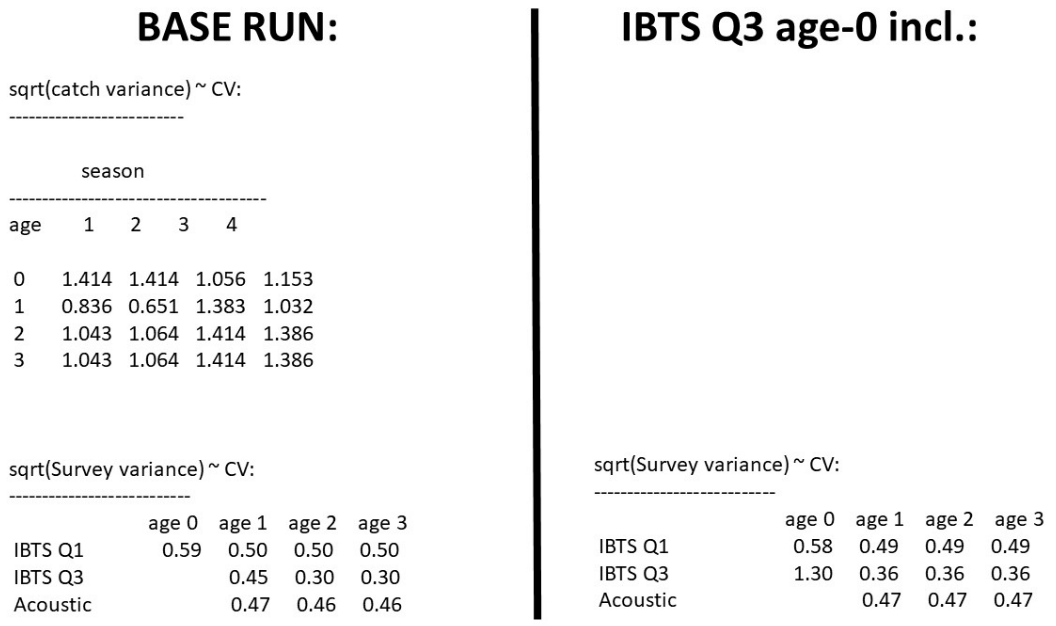


Figure 1d



BASE RUN:

sqrt(catch variance) ~ CV:

----

age	season 1	2	3	4
0	1.414	1.414	1.056	1.153
1	0.836	0.651	1.383	1.032
2	1.043	1.064	1.414	1.386
3	1.043	1.064	1.414	1.386

sqrt(Survey variance) ~ CV:

----

	age 0	age 1	age 2	age 3
IBTS Q1	0.59	0.50	0.50	0.50
IBTS Q3		0.45	0.30	0.30
Acoustic		0.47	0.46	0.46

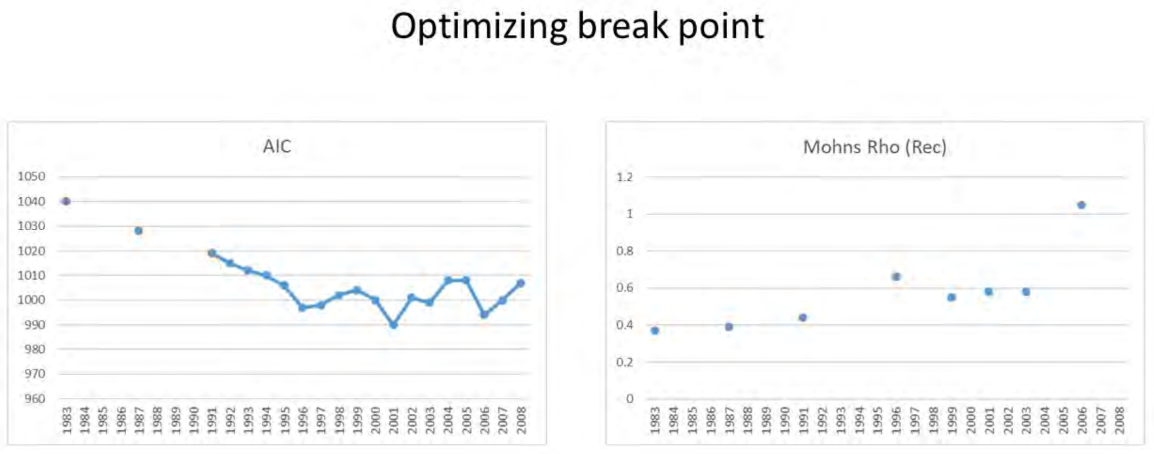
IBTS Q3 age-0 incl.:

sqrt(Survey variance) ~ CV:

----

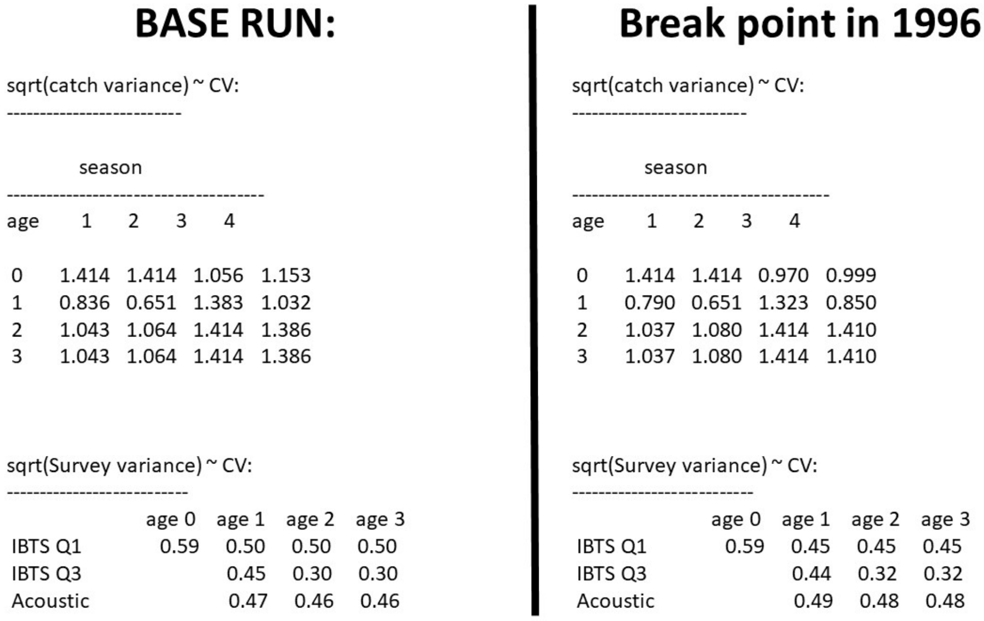
	age 0	age 1	age 2	age 3
IBTS Q1	0.58	0.49	0.49	0.49
IBTS Q3	1.30	0.36	0.36	0.36
Acoustic		0.47	0.47	0.47

Figure 2



Optimizing break point

Figure 3a



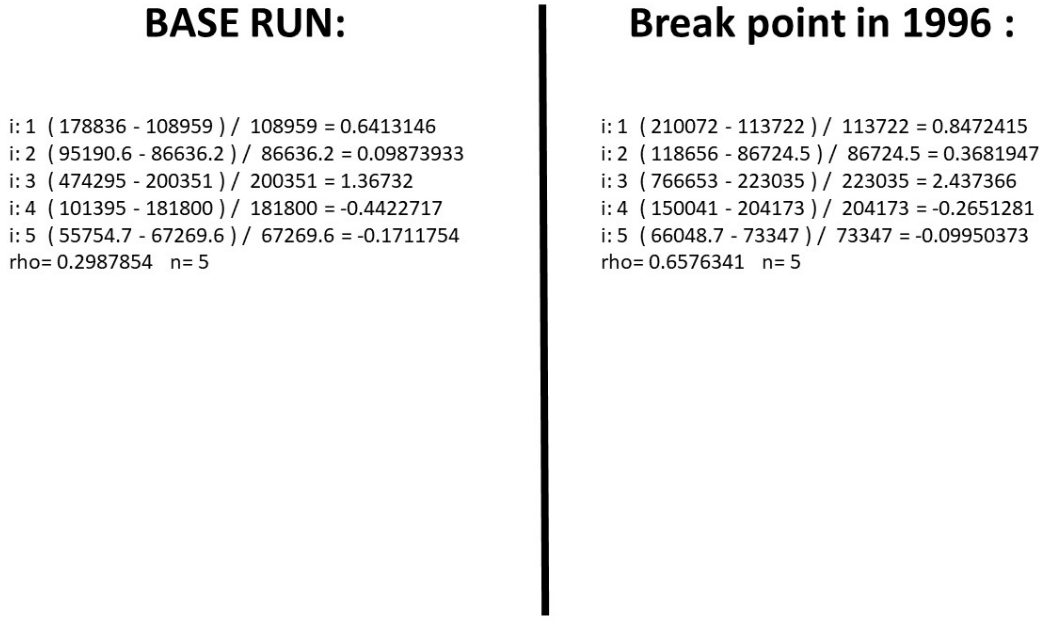
BASE RUN:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
--------------------------------------
age      1     2     3     4

 0     1.414  1.414  1.056  1.153
 1     0.836  0.651  1.383  1.032
 2     1.043  1.064  1.414  1.386
 3     1.043  1.064  1.414  1.386


sqrt(Survey variance) ~ CV:
---------------------------
                   age 0   age 1   age 2   age 3
 IBTS Q1            0.59    0.50    0.50    0.50
 IBTS Q3                    0.45    0.30    0.30
 Acoustic                   0.47    0.46    0.46
```

Break point in 1996:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
--------------------------------------
age      1     2     3     4

 0     1.414  1.414  0.970  0.999
 1     0.790  0.651  1.323  0.850
 2     1.037  1.080  1.414  1.410
 3     1.037  1.080  1.414  1.410


sqrt(Survey variance) ~ CV:
---------------------------
                   age 0   age 1   age 2   age 3
 IBTS Q1            0.59    0.45    0.45    0.45
 IBTS Q3                    0.44    0.32    0.32
 Acoustic                   0.49    0.48    0.48
```

Figure 3b



BASE RUN:

```
i: 1  ( 178836 - 108959 ) /  108959 = 0.6413146
i: 2  ( 95190.6 - 86636.2 ) /  86636.2 = 0.09873933
i: 3  ( 474295 - 200351 ) /  200351 = 1.36732
i: 4  ( 101395 - 181800 ) /  181800 = -0.4422717
i: 5  ( 55754.7 - 67269.6 ) /  67269.6 = -0.1711754
rho= 0.2987854   n= 5
```

Break point in 1996 :

```
i: 1  ( 210072 - 113722 ) /  113722 = 0.8472415
i: 2  ( 118656 - 86724.5 ) /  86724.5 = 0.3681947
i: 3  ( 766653 - 223035 ) /  223035 = 2.437366
i: 4  ( 150041 - 204173 ) /  204173 = -0.2651281
i: 5  ( 66048.7 - 73347 ) /  73347 = -0.09950373
rho= 0.6576341   n= 5
```

Figure 3c

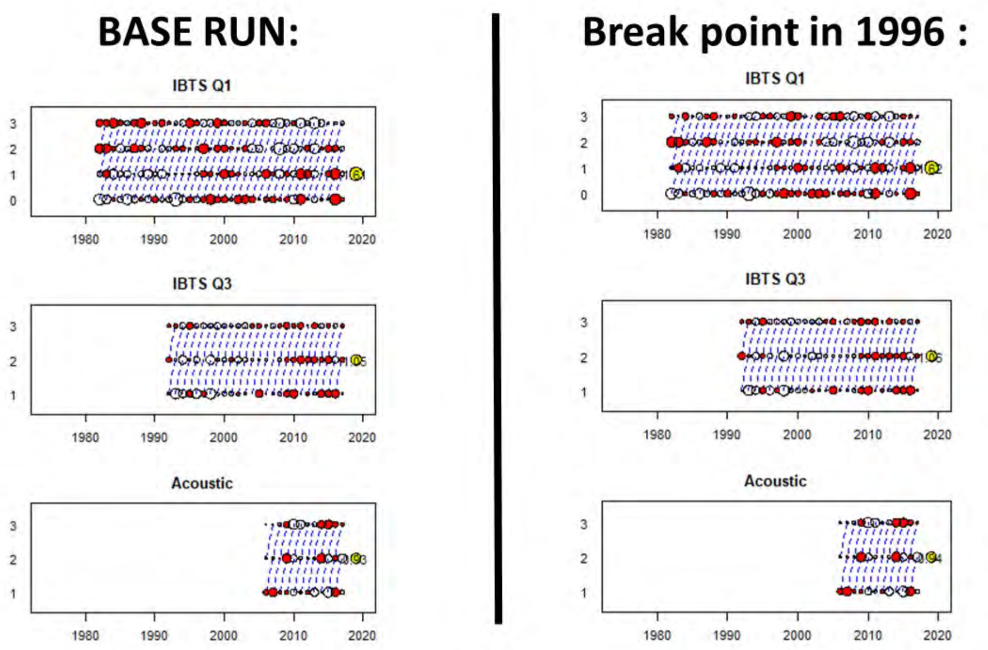


Figure 3d

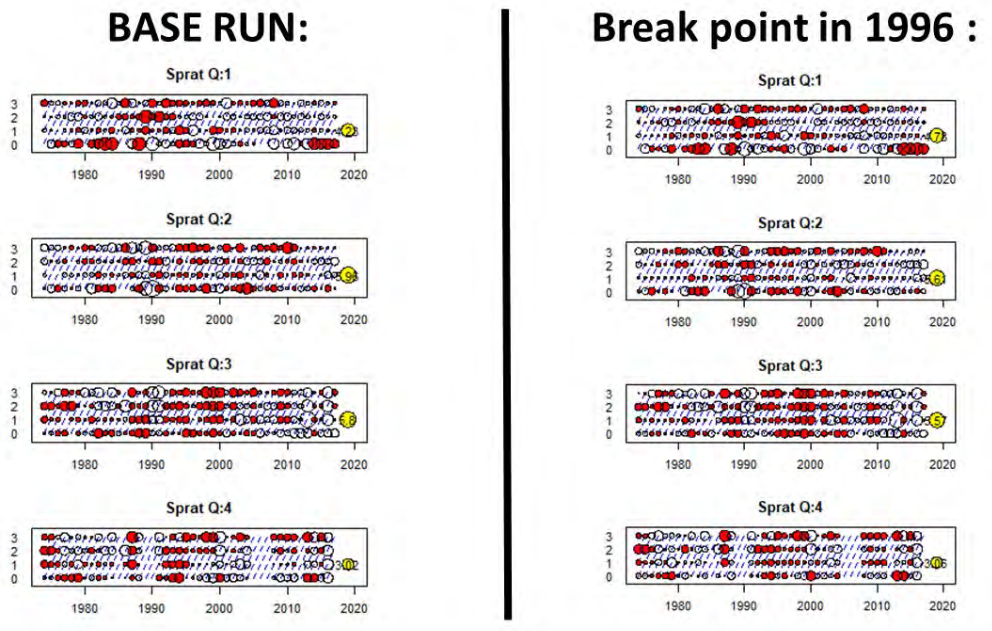
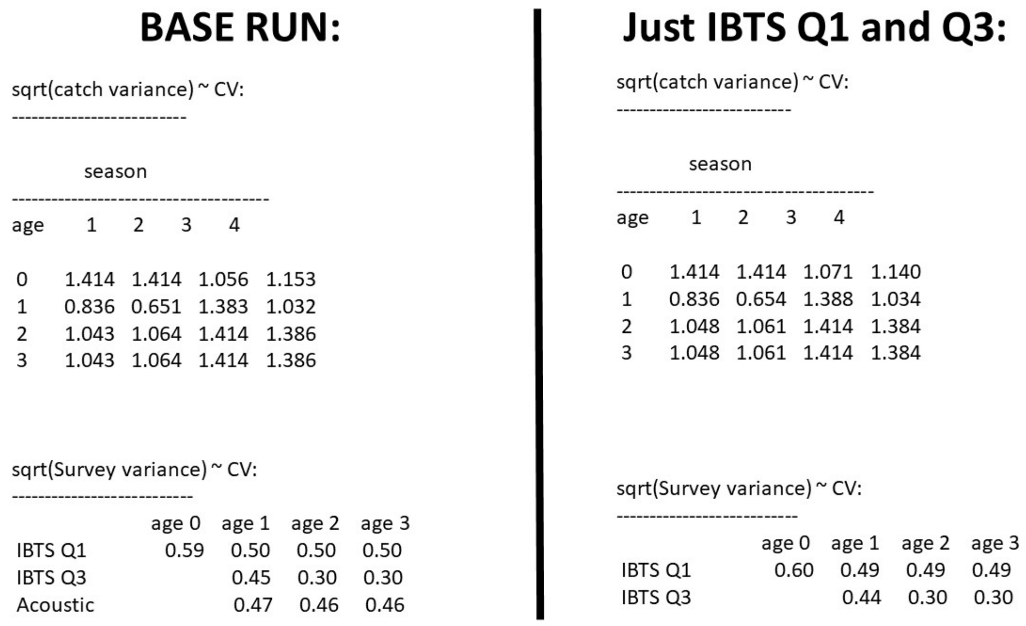


Figure 3e



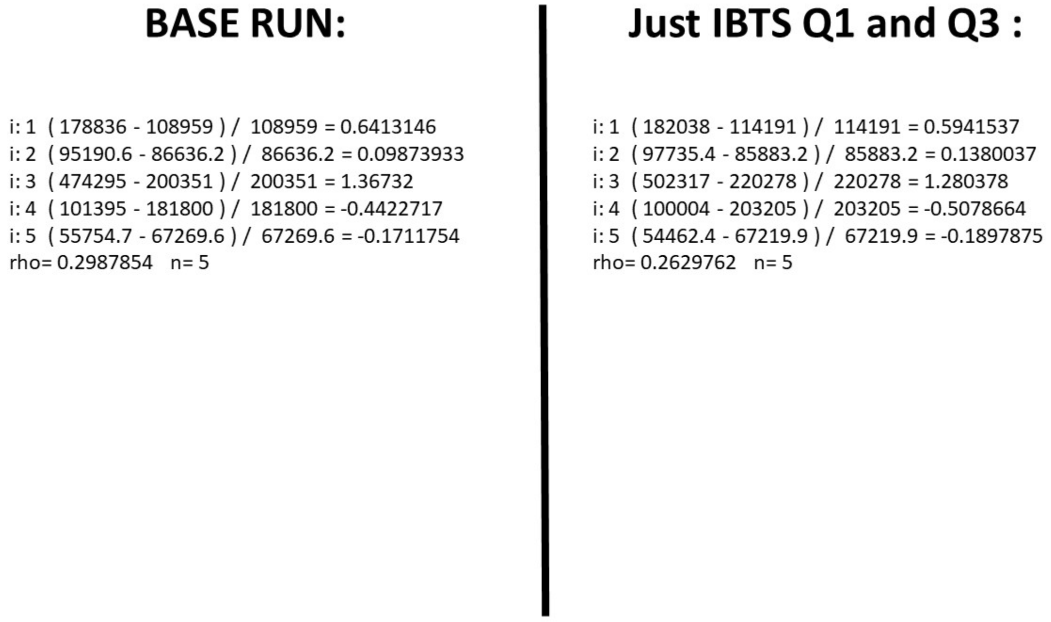
BASE RUN:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
---------------------------------------
age      1      2      3      4

 0     1.414  1.414  1.056  1.153
 1     0.836  0.651  1.383  1.032
 2     1.043  1.064  1.414  1.386
 3     1.043  1.064  1.414  1.386


sqrt(Survey variance) ~ CV:
---------------------------
                    age 0   age 1   age 2   age 3
 IBTS Q1             0.59    0.50    0.50    0.50
 IBTS Q3                     0.45    0.30    0.30
 Acoustic                    0.47    0.46    0.46
```

Just IBTS Q1 and Q3:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
---------------------------------------
age      1      2      3      4

 0     1.414  1.414  1.071  1.140
 1     0.836  0.654  1.388  1.034
 2     1.048  1.061  1.414  1.384
 3     1.048  1.061  1.414  1.384


sqrt(Survey variance) ~ CV:
---------------------------
                    age 0   age 1   age 2   age 3
 IBTS Q1             0.60    0.49    0.49    0.49
 IBTS Q3                     0.44    0.30    0.30
```

Figure 4a



BASE RUN:

```
i: 1  ( 178836 - 108959 ) /  108959 = 0.6413146
i: 2  ( 95190.6 - 86636.2 ) /  86636.2 = 0.09873933
i: 3  ( 474295 - 200351 ) /  200351 = 1.36732
i: 4  ( 101395 - 181800 ) /  181800 = -0.4422717
i: 5  ( 55754.7 - 67269.6 ) /  67269.6 = -0.1711754
rho= 0.2987854   n= 5
```

Just IBTS Q1 and Q3 :

```
i: 1  ( 182038 - 114191 ) /  114191 = 0.5941537
i: 2  ( 97735.4 - 85883.2 ) /  85883.2 = 0.1380037
i: 3  ( 502317 - 220278 ) /  220278 = 1.280378
i: 4  ( 100004 - 203205 ) /  203205 = -0.5078664
i: 5  ( 54462.4 - 67219.9 ) /  67219.9 = -0.1897875
rho= 0.2629762   n= 5
```

Figure 4b

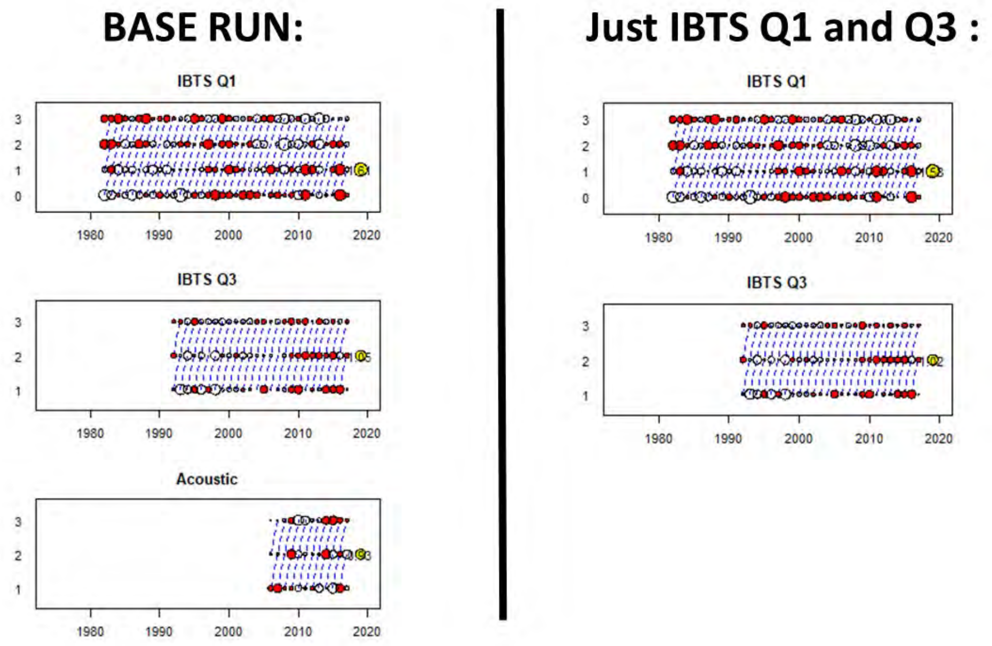


Figure 4c

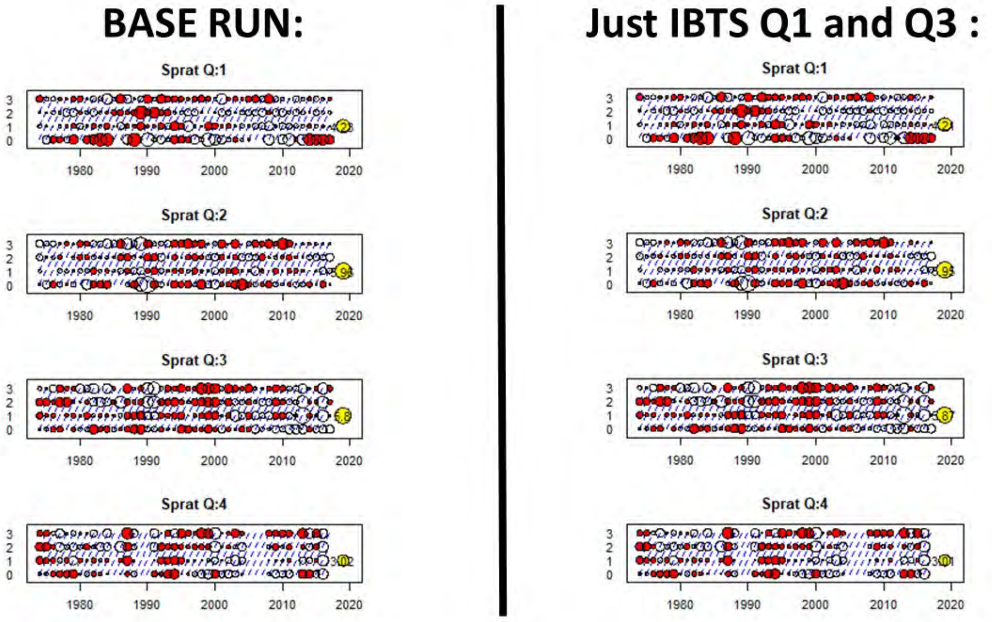
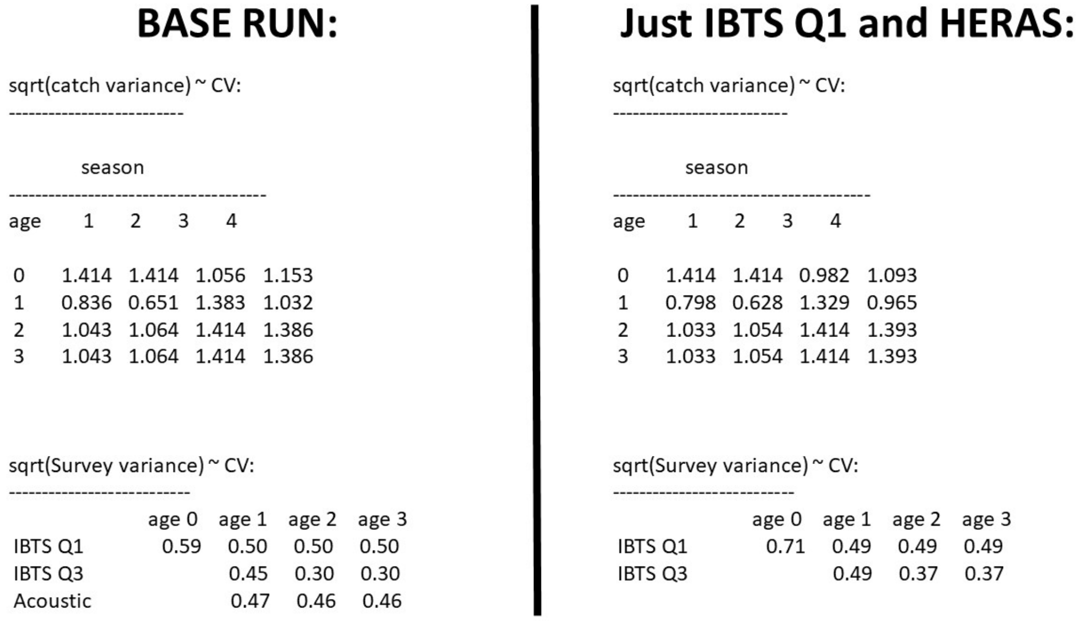


Figure 4d



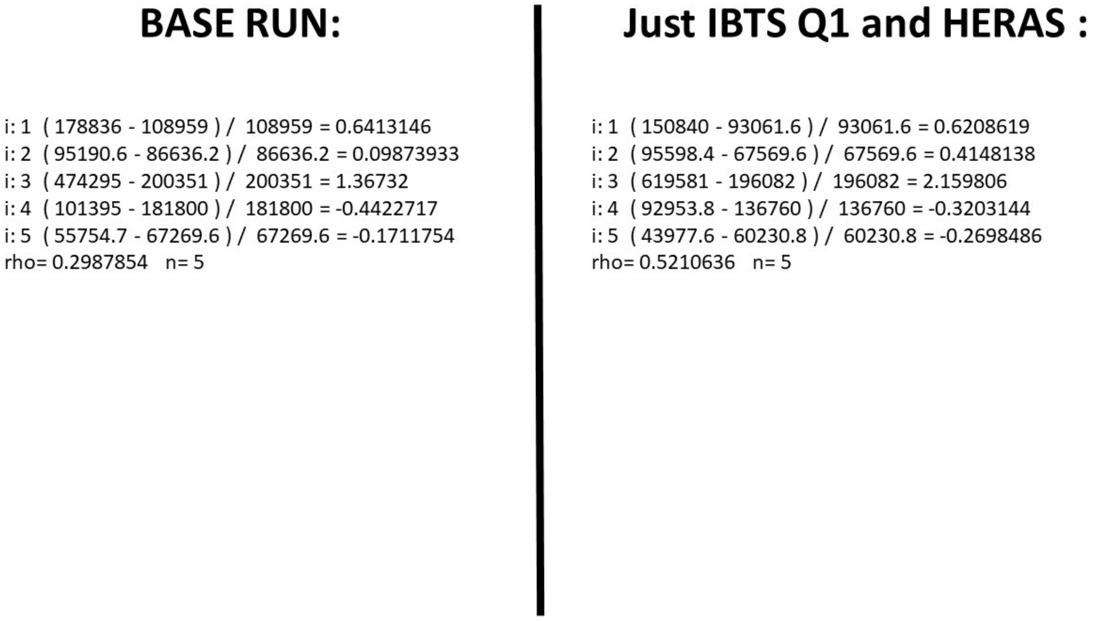
BASE RUN:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
--------------------------------------
age      1     2     3     4

 0     1.414  1.414  1.056  1.153
 1     0.836  0.651  1.383  1.032
 2     1.043  1.064  1.414  1.386
 3     1.043  1.064  1.414  1.386



sqrt(Survey variance) ~ CV:
---------------------------
                    age 0   age 1   age 2   age 3
 IBTS Q1             0.59    0.50    0.50    0.50
 IBTS Q3                     0.45    0.30    0.30
 Acoustic                    0.47    0.46    0.46
```

Just IBTS Q1 and HERAS:

```
sqrt(catch variance) ~ CV:
--------------------------

          season
--------------------------------------
age      1     2     3     4

 0     1.414  1.414  0.982  1.093
 1     0.798  0.628  1.329  0.965
 2     1.033  1.054  1.414  1.393
 3     1.033  1.054  1.414  1.393



sqrt(Survey variance) ~ CV:
---------------------------
                    age 0   age 1   age 2   age 3
 IBTS Q1             0.71    0.49    0.49    0.49
 IBTS Q3                     0.49    0.37    0.37
```

Figure 5a



BASE RUN:

```
i: 1  ( 178836 - 108959 ) /  108959 = 0.6413146
i: 2  ( 95190.6 - 86636.2 ) /  86636.2 = 0.09873933
i: 3  ( 474295 - 200351 ) /  200351 = 1.36732
i: 4  ( 101395 - 181800 ) /  181800 = -0.4422717
i: 5  ( 55754.7 - 67269.6 ) /  67269.6 = -0.1711754
rho= 0.2987854   n= 5
```

Just IBTS Q1 and HERAS :

```
i: 1  ( 150840 - 93061.6 ) /  93061.6 = 0.6208619
i: 2  ( 95598.4 - 67569.6 ) /  67569.6 = 0.4148138
i: 3  ( 619581 - 196082 ) /  196082 = 2.159806
i: 4  ( 92953.8 - 136760 ) /  136760 = -0.3203144
i: 5  ( 43977.6 - 60230.8 ) /  60230.8 = -0.2698486
rho= 0.5210636   n= 5
```

Figure 5b

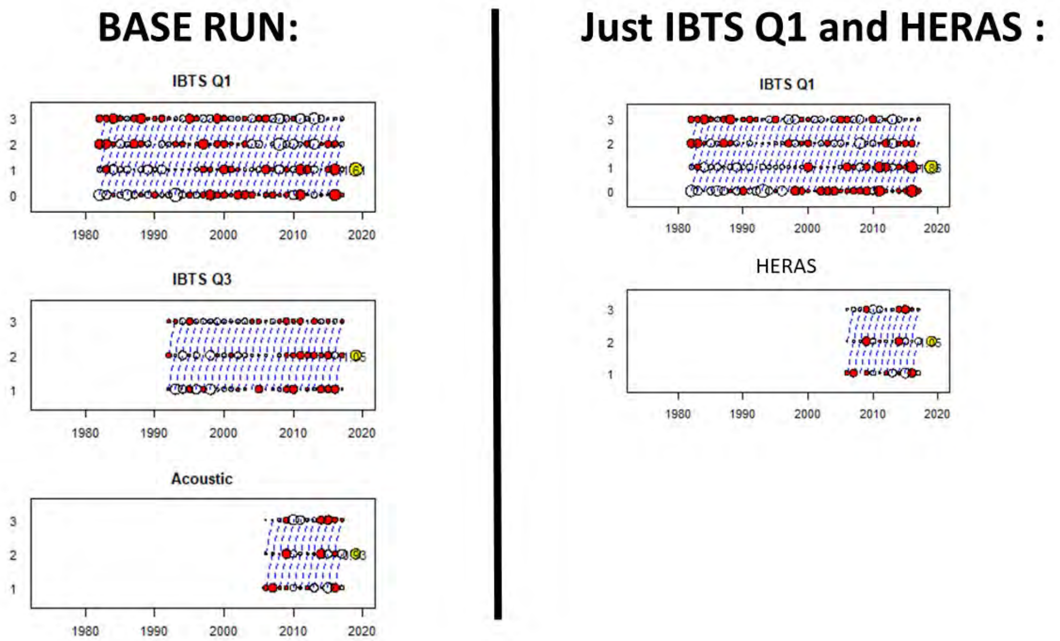


Figure 5c

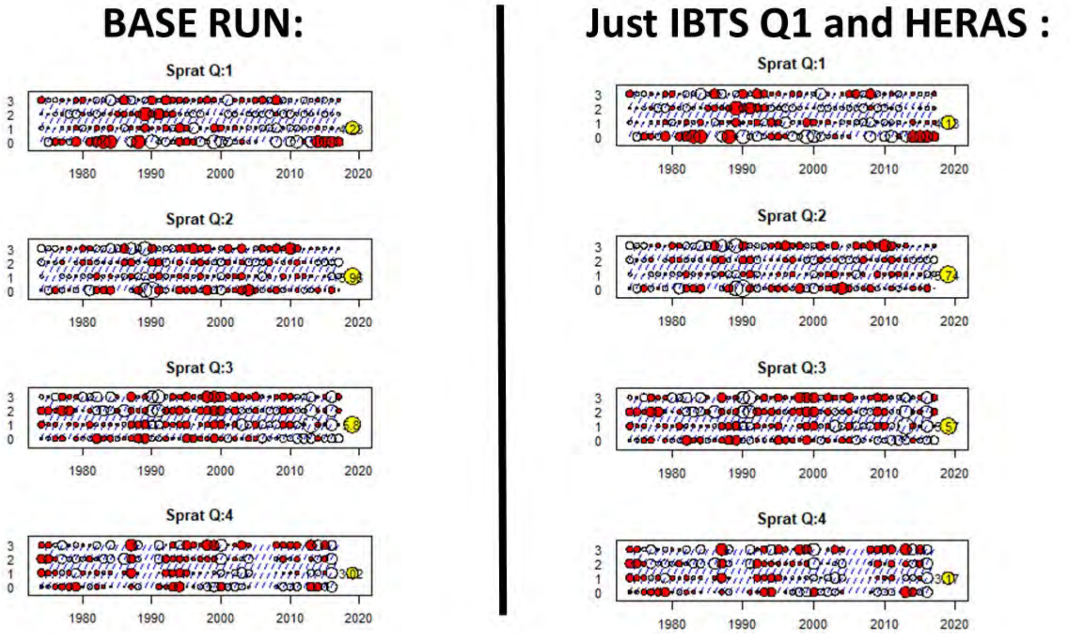
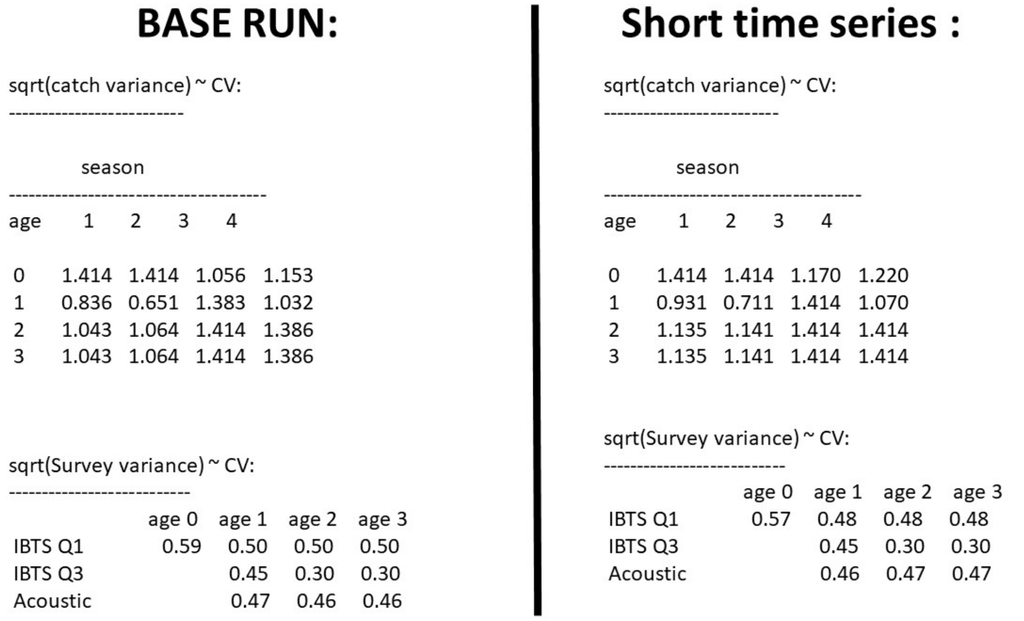


Figure 5d



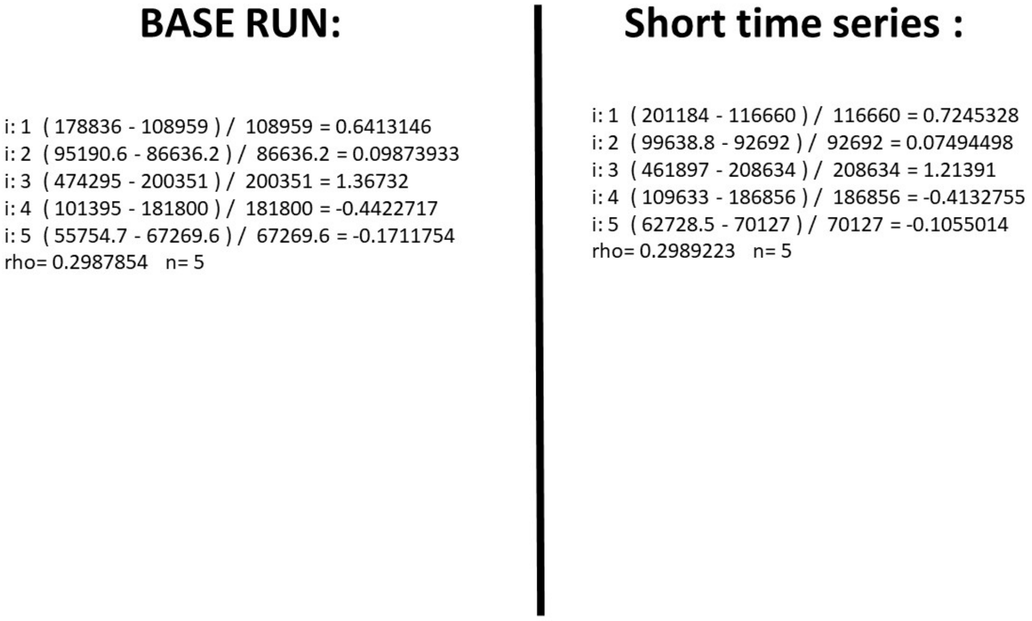
BASE RUN:

```
sqrt(catch variance) ~ CV:
-------------------------

         season
--------------------------------------
age      1     2     3     4

 0     1.414  1.414  1.056  1.153
 1     0.836  0.651  1.383  1.032
 2     1.043  1.064  1.414  1.386
 3     1.043  1.064  1.414  1.386



sqrt(Survey variance) ~ CV:
--------------------------
                  age 0   age 1   age 2   age 3
 IBTS Q1           0.59    0.50    0.50    0.50
 IBTS Q3                   0.45    0.30    0.30
 Acoustic                  0.47    0.46    0.46
```

Short time series :

```
sqrt(catch variance) ~ CV:
-------------------------

         season
--------------------------------------
age      1     2     3     4

 0     1.414  1.414  1.170  1.220
 1     0.931  0.711  1.414  1.070
 2     1.135  1.141  1.414  1.414
 3     1.135  1.141  1.414  1.414


sqrt(Survey variance) ~ CV:
--------------------------
                  age 0   age 1   age 2   age 3
 IBTS Q1           0.57    0.48    0.48    0.48
 IBTS Q3                   0.45    0.30    0.30
 Acoustic                  0.46    0.47    0.47
```

Figure 6a



BASE RUN:

```
i: 1  ( 178836 - 108959 ) /  108959 = 0.6413146
i: 2  ( 95190.6 - 86636.2 ) /  86636.2 = 0.09873933
i: 3  ( 474295 - 200351 ) /  200351 = 1.36732
i: 4  ( 101395 - 181800 ) /  181800 = -0.4422717
i: 5  ( 55754.7 - 67269.6 ) /  67269.6 = -0.1711754
rho= 0.2987854    n= 5
```

Short time series :

```
i: 1  ( 201184 - 116660 ) /  116660 = 0.7245328
i: 2  ( 99638.8 - 92692 ) /  92692 = 0.07494498
i: 3  ( 461897 - 208634 ) /  208634 = 1.21391
i: 4  ( 109633 - 186856 ) /  186856 = -0.4132755
i: 5  ( 62728.5 - 70127 ) /  70127 = -0.1055014
rho= 0.2989223    n= 5
```

Figure 6b

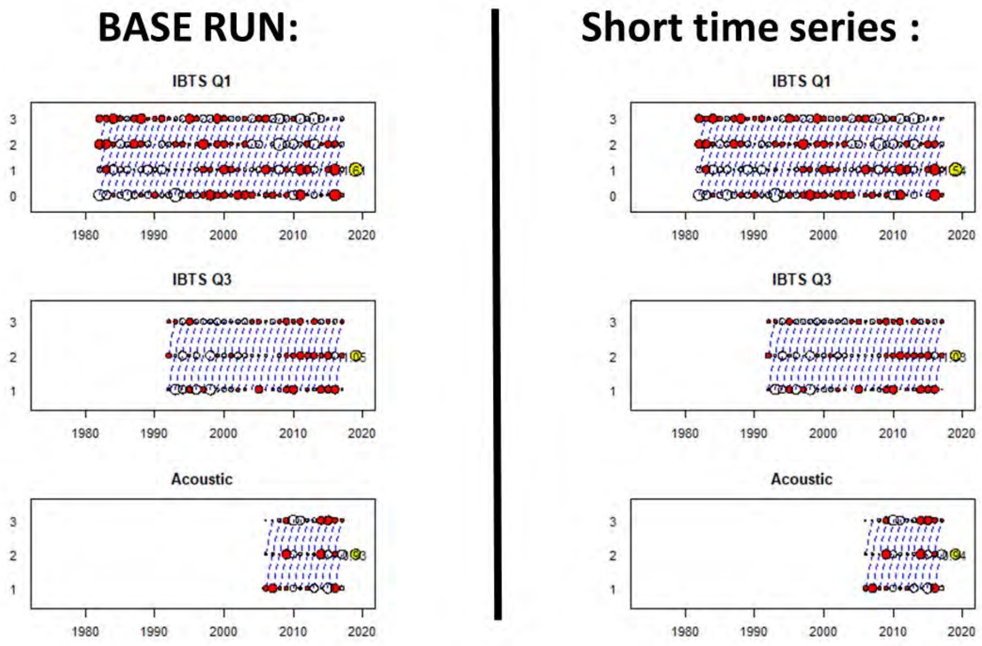


Figure 6c

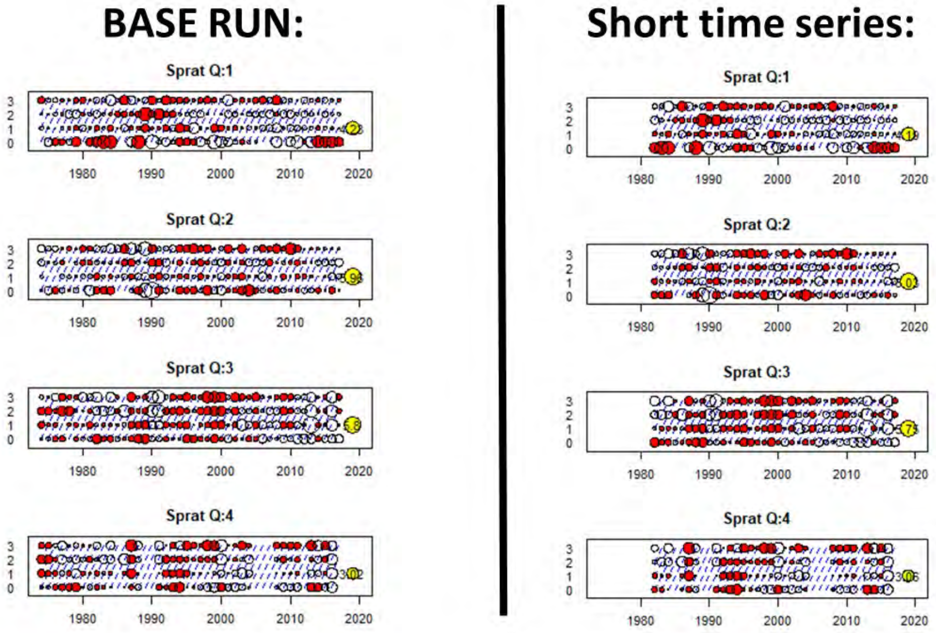
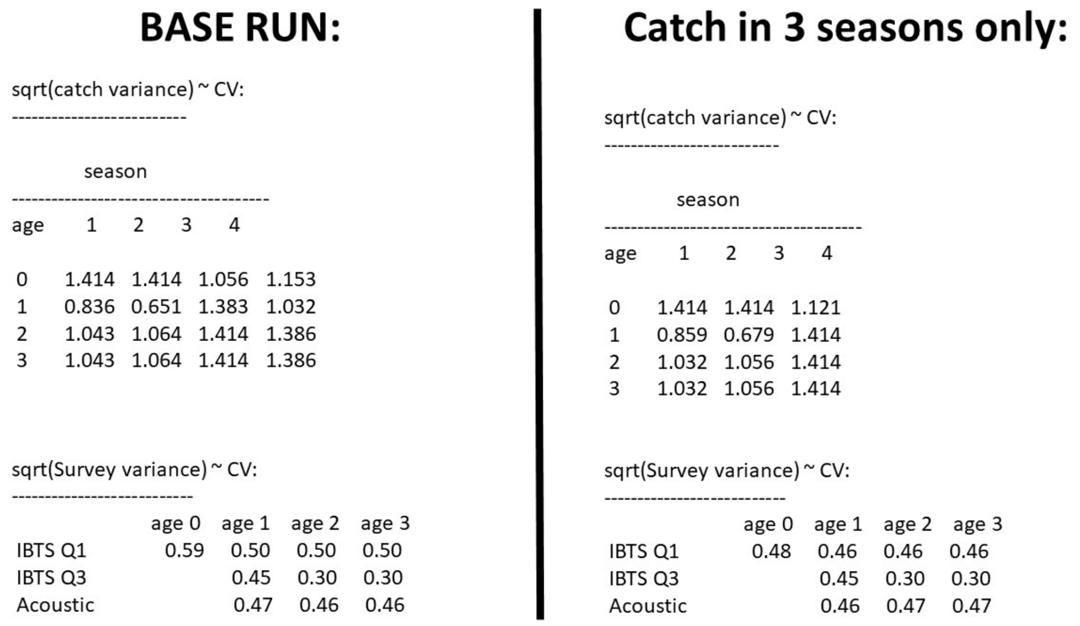


Figure 6d



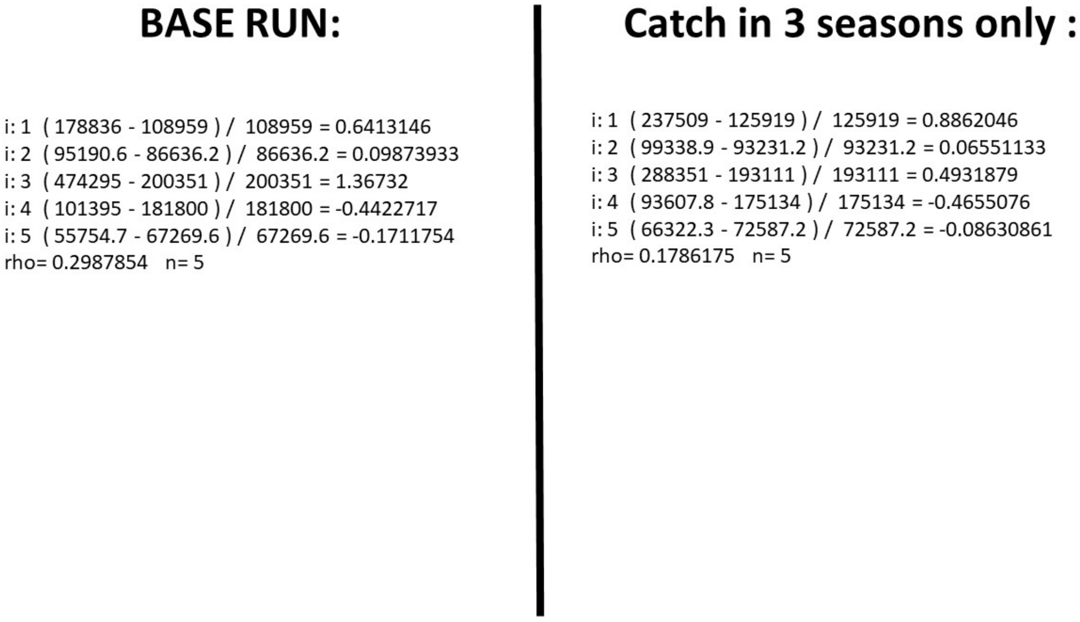
BASE RUN:

```
sqrt(catch variance) ~ CV:
--------------------------

        season
--------------------------------------
age     1     2     3     4

 0     1.414  1.414  1.056  1.153
 1     0.836  0.651  1.383  1.032
 2     1.043  1.064  1.414  1.386
 3     1.043  1.064  1.414  1.386


sqrt(Survey variance) ~ CV:
---------------------------
                  age 0   age 1   age 2   age 3
 IBTS Q1           0.59    0.50    0.50    0.50
 IBTS Q3                   0.45    0.30    0.30
 Acoustic                  0.47    0.46    0.46
```

Catch in 3 seasons only:

```
sqrt(catch variance) ~ CV:
--------------------------

        season
--------------------------------------
age     1     2     3     4

 0     1.414  1.414  1.121
 1     0.859  0.679  1.414
 2     1.032  1.056  1.414
 3     1.032  1.056  1.414


sqrt(Survey variance) ~ CV:
---------------------------
                  age 0   age 1   age 2   age 3
 IBTS Q1           0.48    0.46    0.46    0.46
 IBTS Q3                   0.45    0.30    0.30
 Acoustic                  0.46    0.47    0.47
```

Figure 7a



BASE RUN:

```
i: 1  ( 178836 - 108959 ) /  108959 = 0.6413146
i: 2  ( 95190.6 - 86636.2 ) /  86636.2 = 0.09873933
i: 3  ( 474295 - 200351 ) /  200351 = 1.36732
i: 4  ( 101395 - 181800 ) /  181800 = -0.4422717
i: 5  ( 55754.7 - 67269.6 ) /  67269.6 = -0.1711754
rho= 0.2987854   n= 5
```

Catch in 3 seasons only :

```
i: 1  ( 237509 - 125919 ) /  125919 = 0.8862046
i: 2  ( 99338.9 - 93231.2 ) /  93231.2 = 0.06551133
i: 3  ( 288351 - 193111 ) /  193111 = 0.4931879
i: 4  ( 93607.8 - 175134 ) /  175134 = -0.4655076
i: 5  ( 66322.3 - 72587.2 ) /  72587.2 = -0.08630861
rho= 0.1786175   n= 5
```

Figure 7b

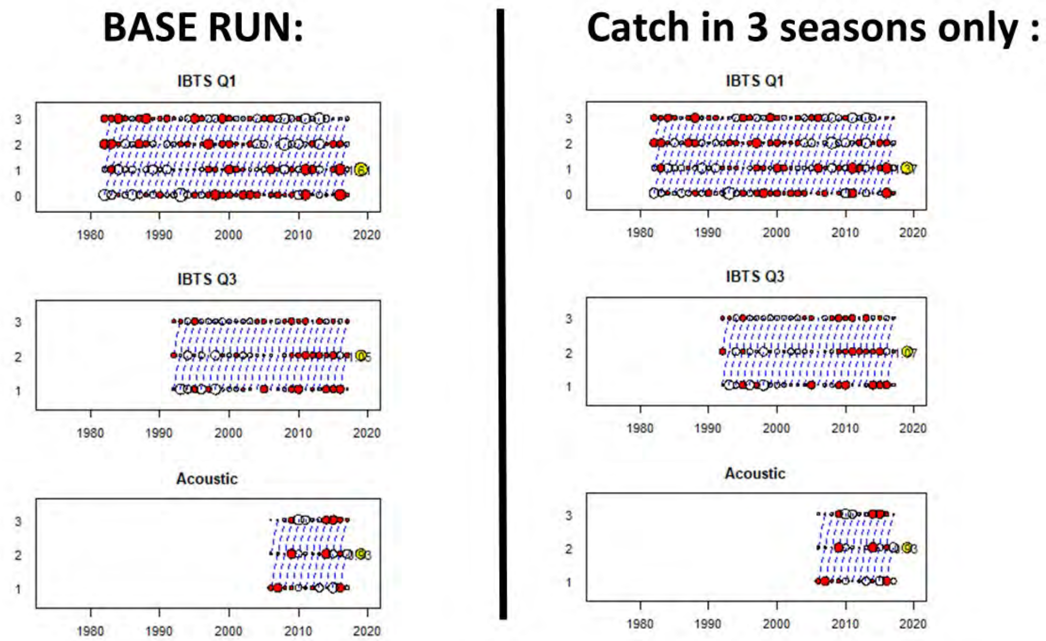


Figure 7c

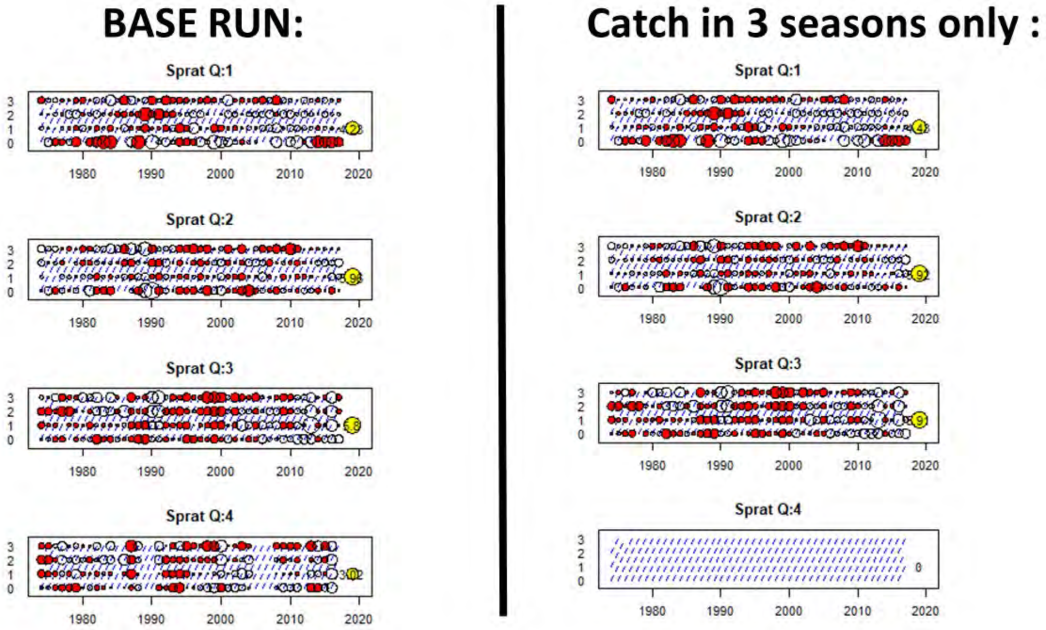
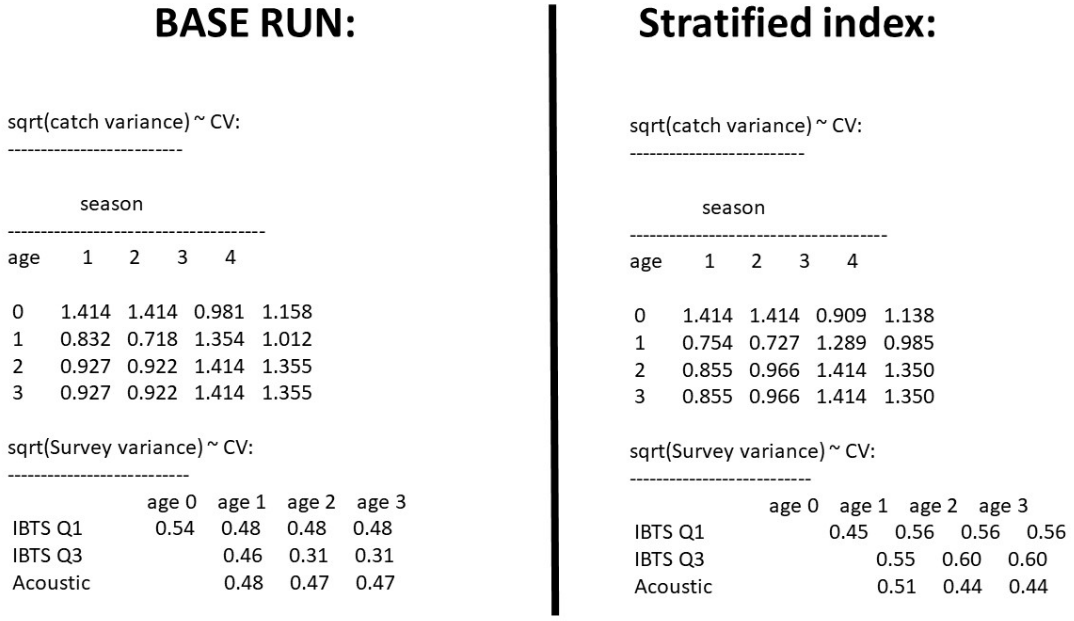


Figure 7d



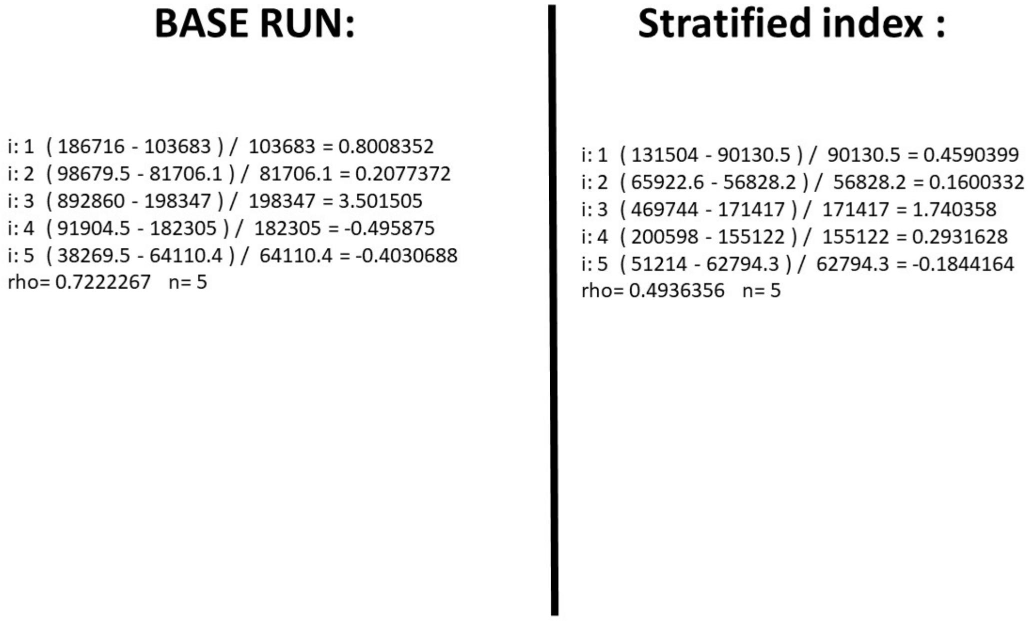
BASE RUN:

```
sqrt(catch variance) ~ CV:
--------------------------

         season
--------------------------------------
age      1     2     3     4

0      1.414  1.414  0.981  1.158
1      0.832  0.718  1.354  1.012
2      0.927  0.922  1.414  1.355
3      0.927  0.922  1.414  1.355

sqrt(Survey variance) ~ CV:
---------------------------
                  age 0   age 1   age 2   age 3
IBTS Q1            0.54    0.48    0.48    0.48
IBTS Q3                    0.46    0.31    0.31
Acoustic                   0.48    0.47    0.47
```

Stratified index:

```
sqrt(catch variance) ~ CV:
--------------------------

         season
--------------------------------------
age      1     2     3     4

0      1.414  1.414  0.909  1.138
1      0.754  0.727  1.289  0.985
2      0.855  0.966  1.414  1.350
3      0.855  0.966  1.414  1.350

sqrt(Survey variance) ~ CV:
---------------------------
                  age 0   age 1   age 2   age 3
IBTS Q1                 0.45    0.56    0.56    0.56
IBTS Q3                         0.55    0.60    0.60
Acoustic                        0.51    0.44    0.44
```

Figure 8a



BASE RUN:

```
i: 1  ( 186716 - 103683 ) /  103683 = 0.8008352
i: 2  ( 98679.5 - 81706.1 ) /  81706.1 = 0.2077372
i: 3  ( 892860 - 198347 ) /  198347 = 3.501505
i: 4  ( 91904.5 - 182305 ) /  182305 = -0.495875
i: 5  ( 38269.5 - 64110.4 ) /  64110.4 = -0.4030688
rho= 0.7222267   n= 5
```

Stratified index :

```
i: 1  ( 131504 - 90130.5 ) /  90130.5 = 0.4590399
i: 2  ( 65922.6 - 56828.2 ) /  56828.2 = 0.1600332
i: 3  ( 469744 - 171417 ) /  171417 = 1.740358
i: 4  ( 200598 - 155122 ) /  155122 = 0.2931628
i: 5  ( 51214 - 62794.3 ) /  62794.3 = -0.1844164
rho= 0.4936356   n= 5
```

Figure 8b

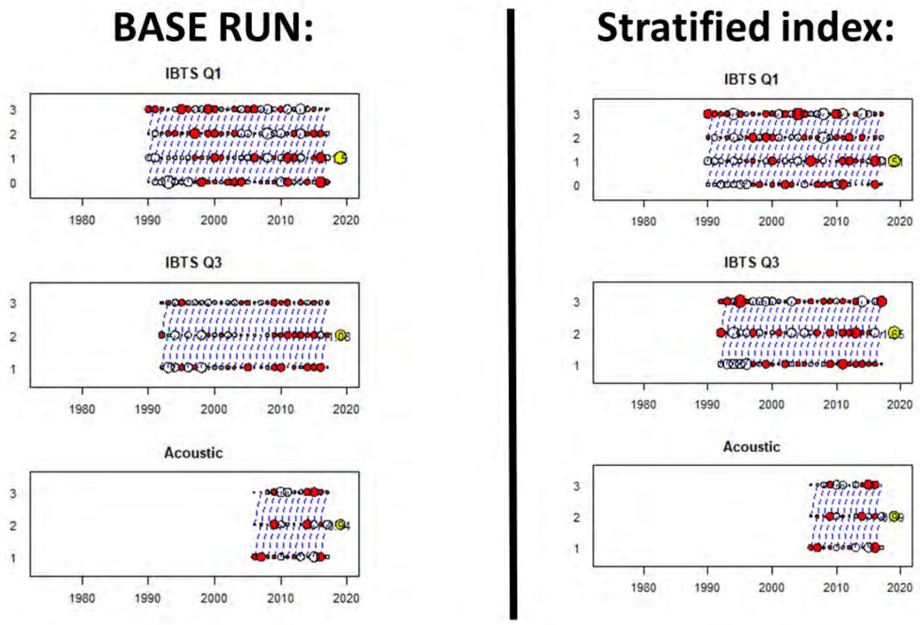


Figure 8c

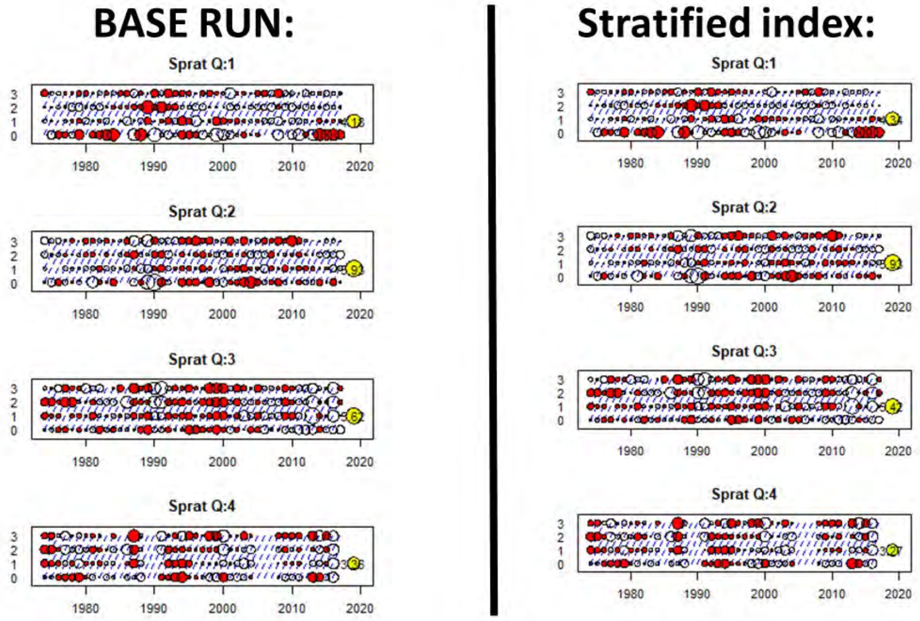


Figure 8d

Acknowledgement: EMFF project BEBRIS - Bevarelse af et bæredygtigt industrifiskeri

HAV & FISK

UDENRIGSMINISTERIET
Fiskeristyrelsen

Bilag 3. Modelling the effect of weather on commercial catch rates of sprat in the North Sea

Modelling the effect of weather on commercial catch rates of sprat in the North Sea

Input for the BEBRIS project report

Christoffer Moesgaard Albertsen

Method

To investigate the effect of weather on commercial catches of sprat, a state-space biomass model was fitted to commercial landings, survey catches and acoustic survey observations. The state-space biomass model consisted of two parts: a population model, describing the available abundance of sprat, and an observation model describing the expected catch for a given available abundance. Besides catch data, oceanographic and atmosphere data was included as covariates. Commercial logbook recorded landings were divided into vessels targeting sprat and vessels targeting other species. Further, daily landings were combined with VMS signals to obtain approximate locations and effort per location. For simplicity, catches without corresponding VMS signals or not available in the Danish database were assumed to be negligible.

Population model

Total log-biomass was modelled by the stochastic differential equation used by Pedersen and Berg (2017),

$$dZ_t = \left(\frac{\gamma m}{K} - \frac{\gamma m}{K} \left(\frac{\exp(Z_t)}{K} \right)^{n-1} - F_t - \frac{1}{2}\sigma^2 \right) dt + \sigma dW_t,$$

where $Z_t = \log(B_t)$ is the log-biomass at time t. In the equation above,

$$\gamma = n^{n/(n-1)}/(n-1)$$

and

$$m = \frac{rK}{n^{n/(n-1)}}.$$

For this application, n was set to 2. In the population model, K is the carrying capacity of the system, r is a population growth rate, F_t is the instantaneous fishing mortality rate, and σ is a variance parameter. For this application, F_t was calculated by the sum of $C_i \cdot \Delta_t^{-1} \cdot B_t^{-1}$ over all observations corresponding to time t, where Δ_t is the time difference between time t and time $t-1$. Further, r was restricted to the interval $(0,2.5)$ and was allowed to vary over time by a periodic B-spline. The spatial component, S_g, of the population model was modelled by a linear combination of physical and biogeochemical covariates on a grid representing the North Sea, Skagerrak, and Kattegat. The linear combination was transformed such that the value for each grid cell was between 0 and 1 and the total sum over grid cells was 1, thereby, representing the fraction of total biomass allocated to each cell.

Effort model

Commercial effort targeting sprat was assumed to depend on the available biomass. Therefore, commercial effort for vessels targeting sprat was modelled by a negative binomial distribution with mean determined by

$$\log E(e_i) = X_{i,e,1}\alpha_e + \exp\left(X_{i,e,2}\beta_e\right)\left(log(S_{g(i)}) + Z_{t(i)}\right)$$

and variance

$$\mathrm{Var}(e_i) = E(e_i) \cdot (1 + \phi)$$

where e_i is effort of the ith observation, $\phi > 0$ is an overdispersion parameter, $X_{e,1}$ and $X_{e,2}$ are row vectors of covariates, α_e and β_e are column vectors of covariates, $S_{g(i)}$ is the spatial biomass fraction at the grid cell corresponding to the observation, and $Z_{t(i)}$ is the total biomass at the time corresponding to the observation.

Commercial effort not targeting sprat as well as survey effort were assumed to be independent of sprat biomass. Therefore, these were not included in the model.

Catch model

Given the available biomass, non-negative trawl catches were assumed to follow a normal distribution on log-scale such that

$$E(\log C_i) = \mu_i = X_{i,C,1}\alpha_C + \exp\left(X_{i,C,2}\gamma_C\right)log(e_i) + \exp\left(X_{i,e,2}\beta_e\right)\left(log(S_{g(i)}) + Z_{t(i)}\right).$$

For acoustic surveys, observed biomass was assumed to reflect available biomass directly:

$$E(\log C_i) = \mu_i = log(S_{g(i)}) + Z_{t(i)}$$

Note that this is a special case of the equation above. Observed biomass was calculated from the Nautical Area Scattering Coefficient (reported at acoustic.ices.dk) using a target strength of -30. Using a different target strength will produce observed biomasses that are proportional to those used in this study.

The probability of a zero observation was modelled by

$$P(C_i = 0) = \Phi\left(\frac{\eta_{f(i)} - \mu_i}{\sigma_{fl(i)}}\right)$$

For surveys only recording presence or absence of sprat, the probability of presence was modelled by

$$P(C_i > 0) = 1 - P(C_i = 0)$$

Model cases

Table 1: Short names for covariates used in the analysis

Short Name	Description
BoatSize	Overall ship length in m
KW	Engine power in KW
MeshSize	Mesh size in mm
wav_VHM0	Wave height in m (center of grid cell)
WindSpeed	Wind speed in m/s (center of grid cell)
WindDirection	Wind direction in degrees (0: North, 90: East) (center of grid cell)
atm2_sp	Air pressure at surface in Pa (center of grid cell)
atm2_r	Relative humidity (center of grid cell)
atm2_tcc	Total cloud cover (center of grid cell)
depth	Depth (center of grid cell)
isBottomTrawl	Yes/No indicator for bottom trawls

A total of 14 model cases were considered. The model cases consisted of combinations sub-cases for the effort model and catch models considering different degrees of including weather data.

For the effort model two cases were considered corresponding to no inclusion and a full inclusion of weather data. Using `R` language syntax, that is,

```
~ Gear + bs(BoatSize,3) + bs(KW,3) + bs(MeshSize,3) +
  bs(depth,3):isBottomTrawl
```

and

```
 ~ Gear + bs(BoatSize,3) + bs(KW,3) + bs(MeshSize,3) +
    bs(wav_VHM0,3) +
    bs(WindSpeed,3) + pbs(WindDirection,3, Boundary.knots=c(0,360))
+
    bs(atm2_sp,3) + bs(atm2_r,3) + bs(atm2_tcc,3) +
    bs(depth,3):isBottomTrawl
```

respectively. Table 1 contains a description of the covariates.

For trawl catches seven subcases were considered. The first subcase was a full inclusion of weather data. That is,

```
~ Gear + bs(BoatSize,3) + bs(KW,3) + bs(MeshSize,3) +
    bs(wav_VHM0,3) +
    bs(WindSpeed,3) + pbs(WindDirection,3, Boundary.knots=c(0,360))
+
    bs(atm2_sp,3) + bs(atm2_r,3) + bs(atm2_tcc,3) +
  bs(depth,3):isBottomTrawl
```

for each commercial data source, and

```
Gear +
        bs(wav_VHM0,3) +
        bs(WindSpeed,3) + pbs(WindDirection,3, Boundary.knots=c(0,360))
+
        bs(atm2_sp,3) + bs(atm2_r,3) +  bs(atm2_tcc,3) +
        bs(depth,3):isBottomTrawl
```

for surveys. The second subcase was similar to the first. However, the weather effect parameters were forced to be identical for targeted and other commercial catches. In the third subcase, weather effect parameters were forced to be identical for all commercial and survey catches. The fourth subcase was similar to the first; however, the model for targeted commercial catches was changed to

```
~ Gear + bs(BoatSize,3) + bs(KW,3) + bs(MeshSize,3) +
        bs(depth,3):isBottomTrawl
```

thereby excluding weather effects. The fifth subcase was similar to the first; however, the survey catch model was changed to only include the gear. The sixth subcase was similar to the fifth; however, weather effect parameters were forced to be identical for targeted and other commercial catches. Finally, the seventh subcase did not include weather effects for any of the catches.

All 14 cases were fitted to data from 2019. Further, case two was fitted to data from 2017-2019 and 2018-2019 for comparison.

Results

The model fit for the 14 cases were compared through AIC. The best model fit was achieved for case 2 where weather data was fully incorporated as covariates for effort and catches. Following closely, the second best fit was achieved for the case where weather data was incorporated for effort and commercial catches but not for surveys. Further, incorporating weather data as covariates for catch data reduced the estimated residual variation.

In general, the results indicate an effect of weather on commercial effort and catch rates. Further, the results indicate that the effect is different for targeted commercial, other commercial, and survey catch rates. Figures below show the estimated effects for case 2 using data for 2019, 2018-2019, and 2017-2019, respectively.

For most cases the model converged with a non-positive definite Hessian matrix. This indicates an issue with identifiability. In particular the combination of K and r was problematic. This can have had an influence on the estimated effects and, in particular, confidence intervals. Therefore, further research is warranted to develop the model.

Tables

Table 2: AIC relative to the best model (where ΔAIC=0) for the 14 cases. A model with a better fit has lower ΔAIC.

Case	Effort	Catch	ΔAIC
1	No	Full	3005.0
2	Yes	Full	0.0
3	No	Same effect for commercial	3618.3
4	Yes	Same effect for commercial	85.5
5	No	Same effect for all	287.9
6	Yes	Same effect for all	107.5
7	No	No effect for targeted	3064.8
8	Yes	No effect for targeted	36.0
9	No	No effect for survey	3070.9
10	Yes	No effect for survey	4.3
11	No	Same effect for commercial, no effect for survey	3278.6
12	Yes	Same effect for commercial, no effect for survey	91.3
13	No	No effect	337.9
14	Yes	No effect	151.9

Table 3: Estimated coefficient of variation for trawl catches (2019).

Fleet	No weather effect	Best fit	Reduction
Targeted commercial	2.7	1.9	29.8%
Other commercial	425.2	114.6	73.0%
Survey	64.3	35.1	45.4%

Figures

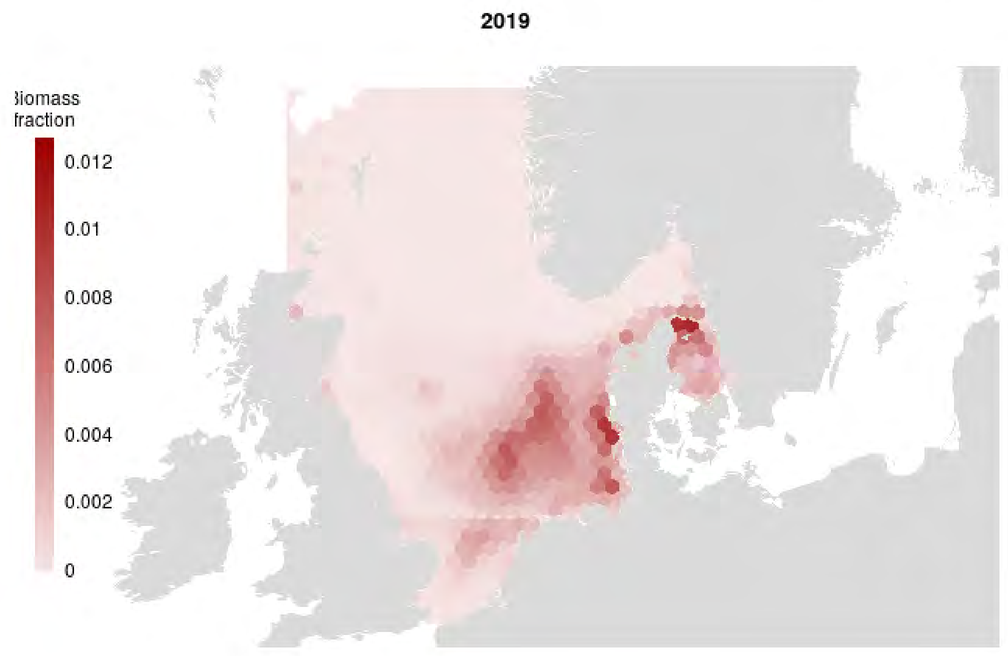


Figure 1: Estimated spatial component of the population model based on data from 2019.

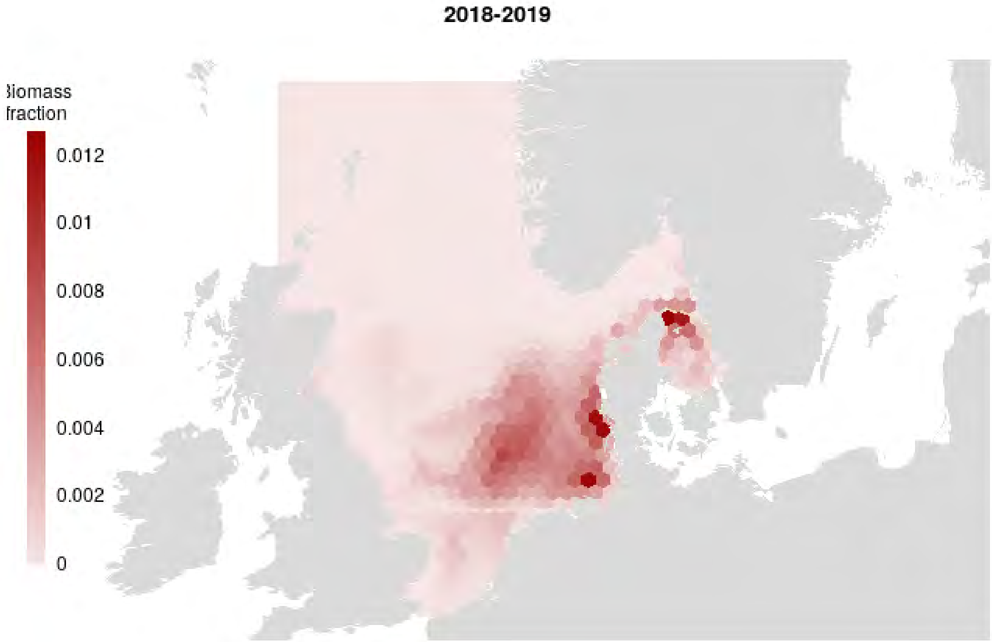


Figure 2: Estimated spatial component of the population model based on data from 2018-2019.

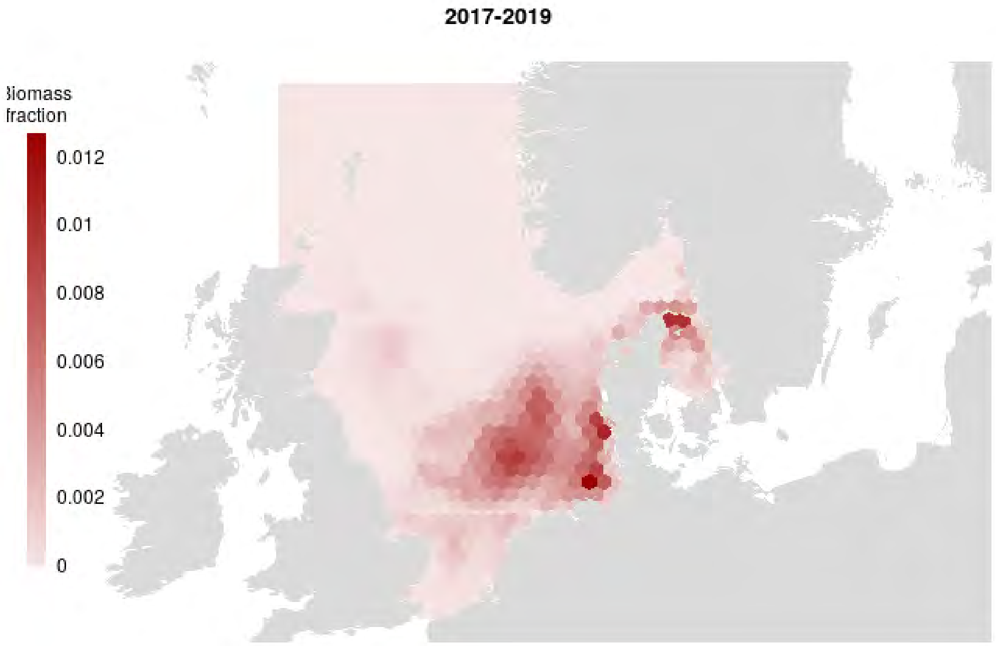


Figure 3: Estimated spatial component of the population model based on data from 2017-2019.

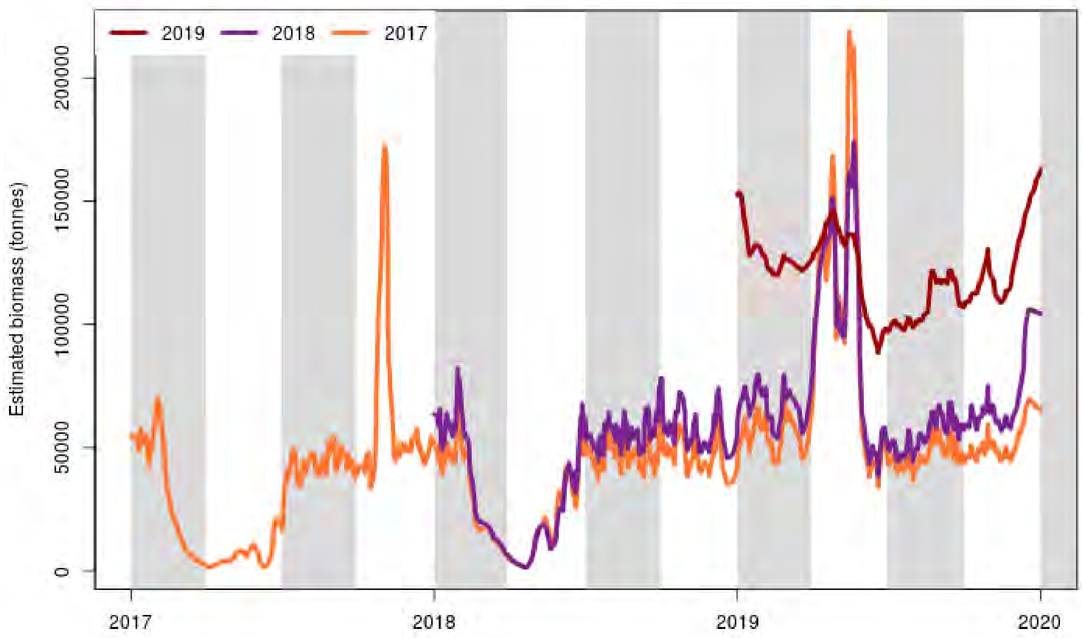


Figure 4: Estimated total abundance. First and third quarter are marked by a grey background.

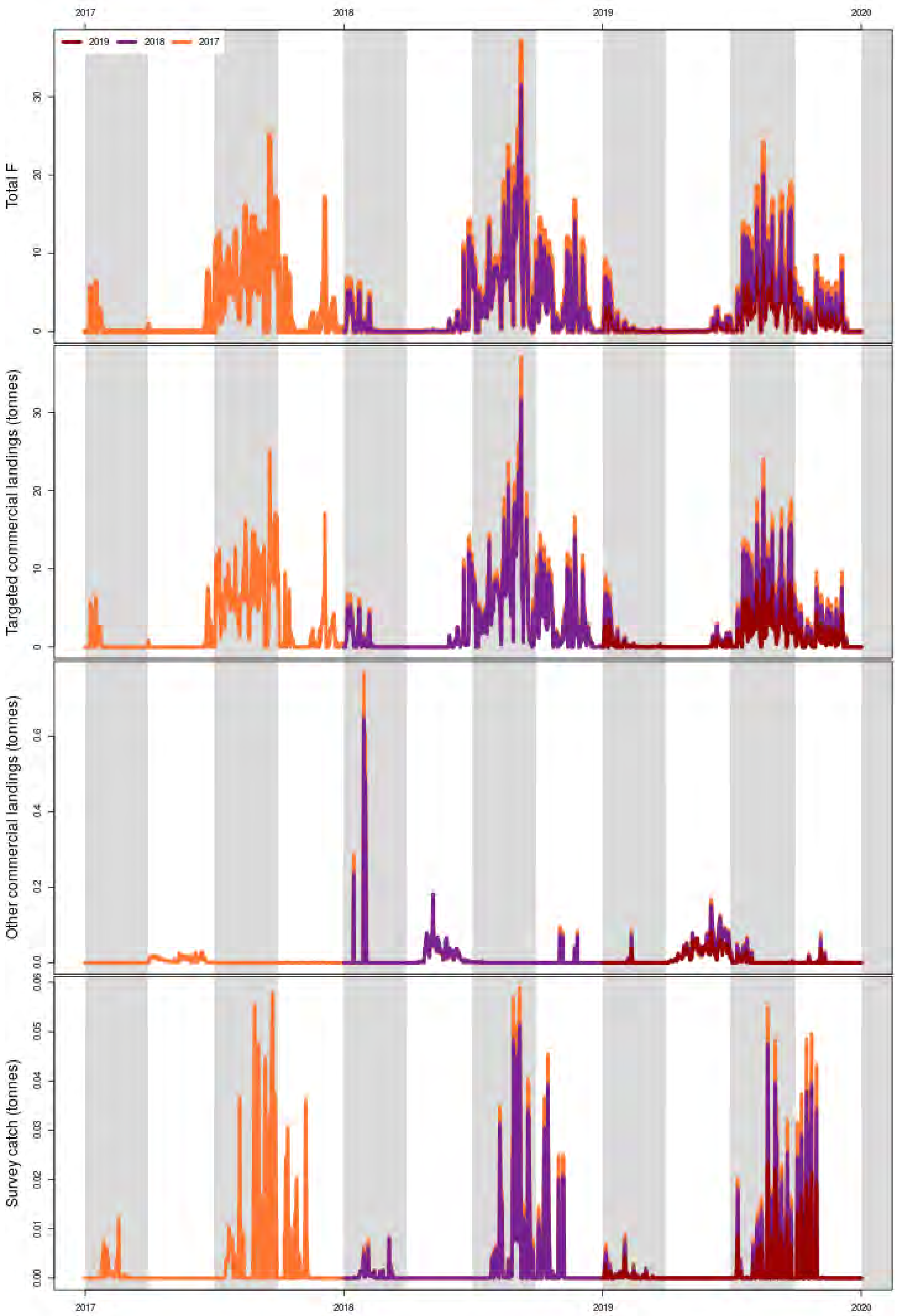


Figure 5: Estimated fishing mortality rate. First and third quarter are marked by a grey background.

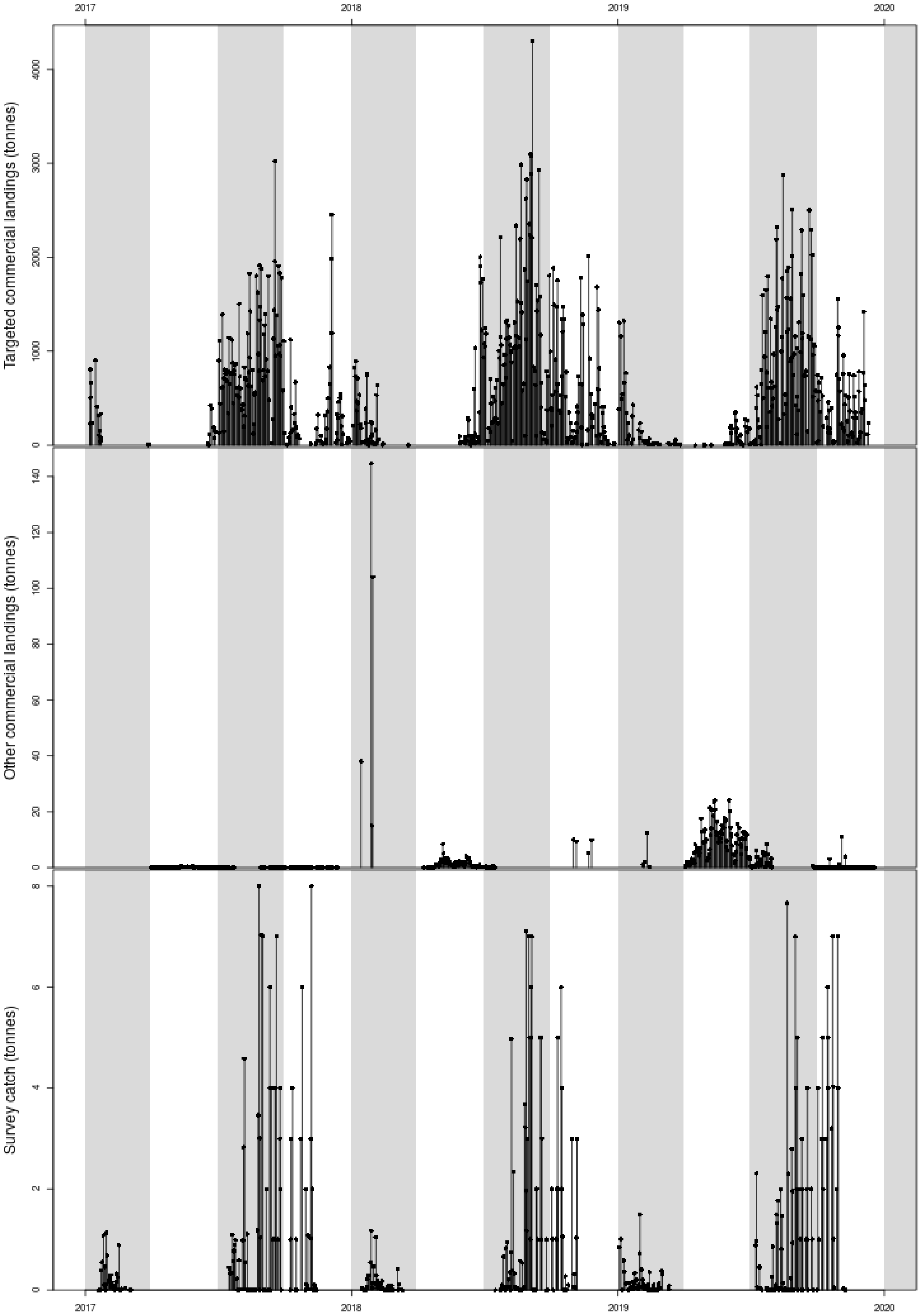


Figure 6: Observed catch per day. First and third quarter are marked by a grey background.

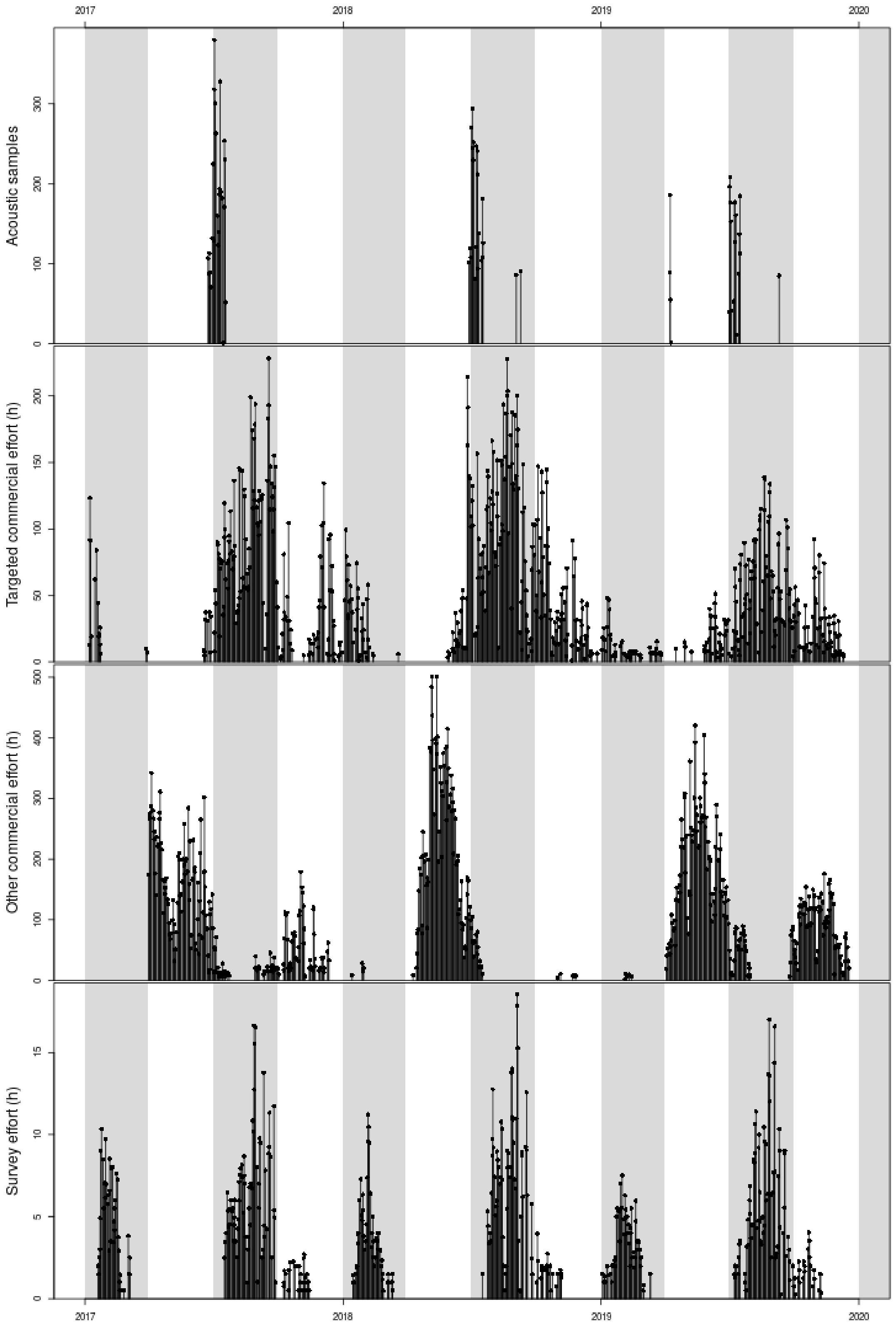


Figure 7: Observed effort per day. First and third quarter are marked by a grey background.

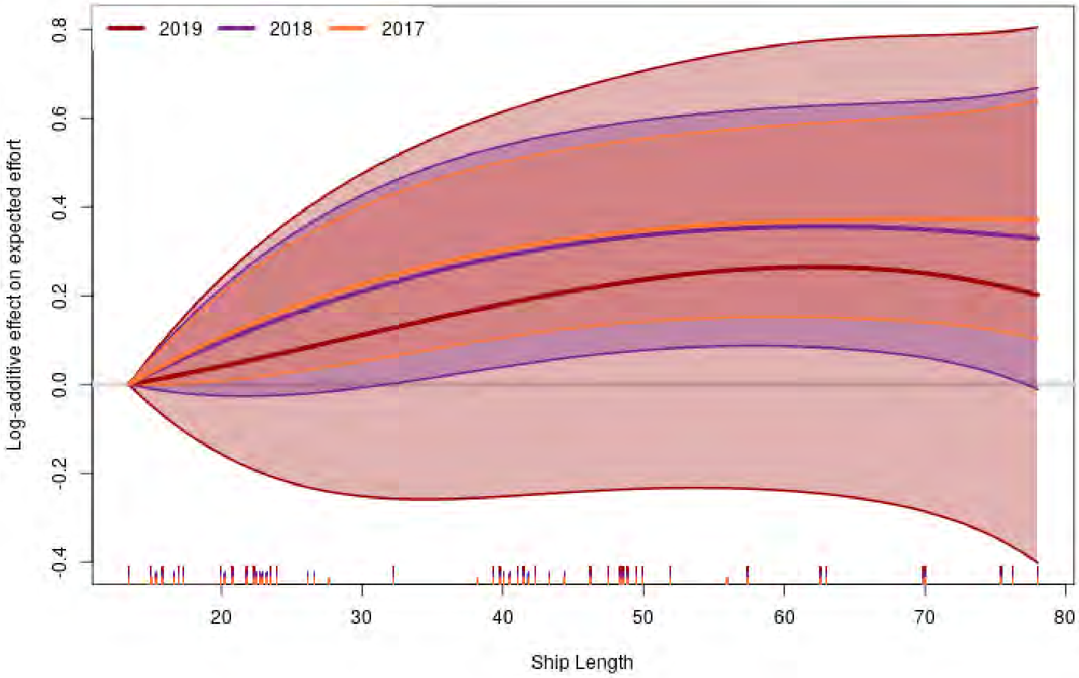


Figure 8: Estimated effect of ship length on commercial effort targeting sprat.

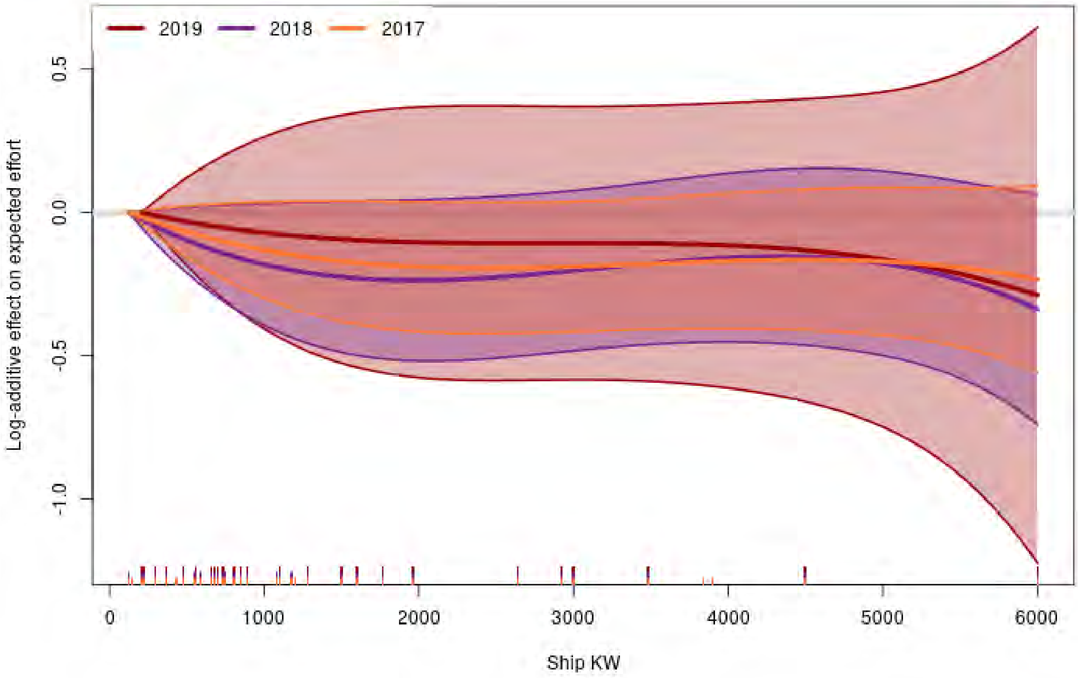


Figure 9: Estimated effect of engine power on commercial effort targeting sprat.

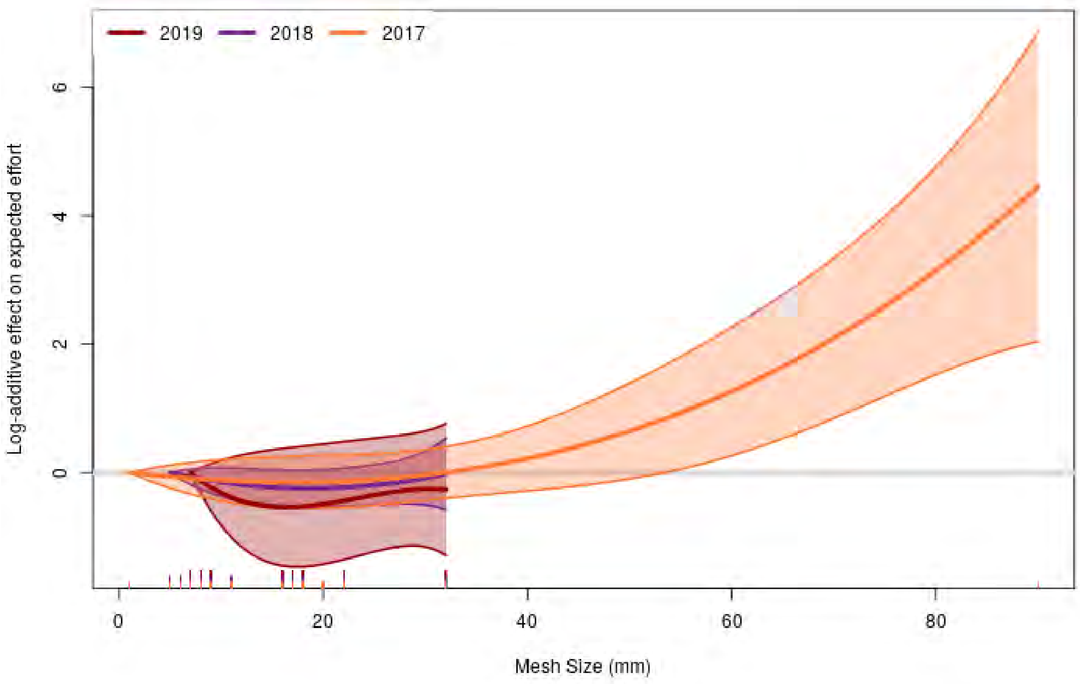


Figure 10: Estimated effect of mesh size on commercial effort targeting sprat.

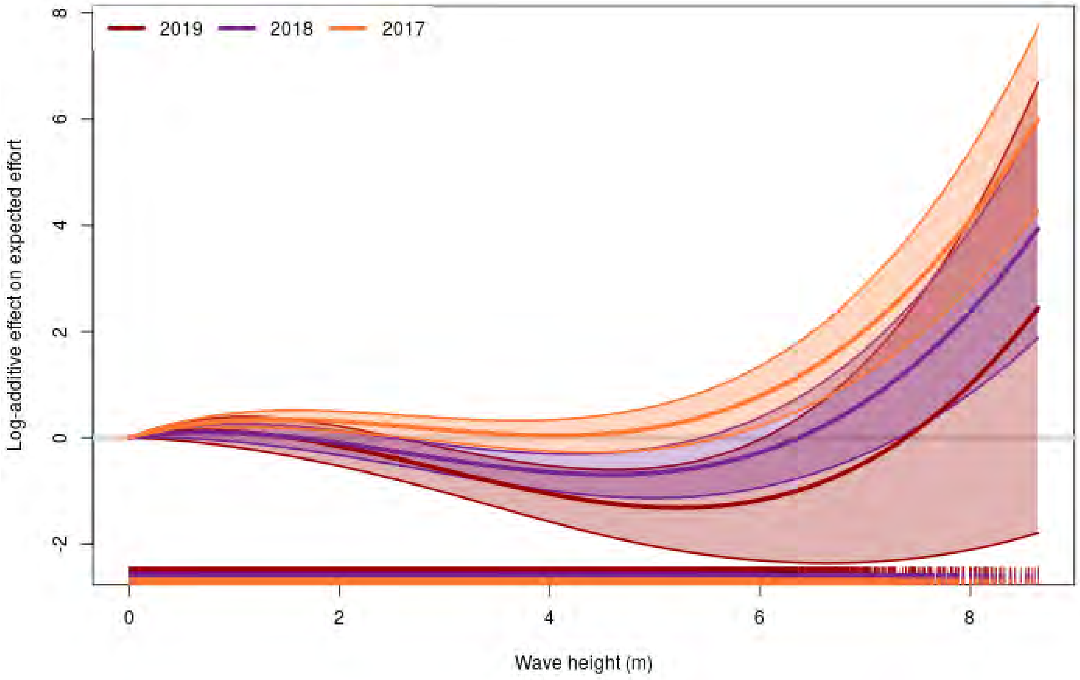


Figure 11: Estimated effect of wave height on commercial effort targeting sprat.

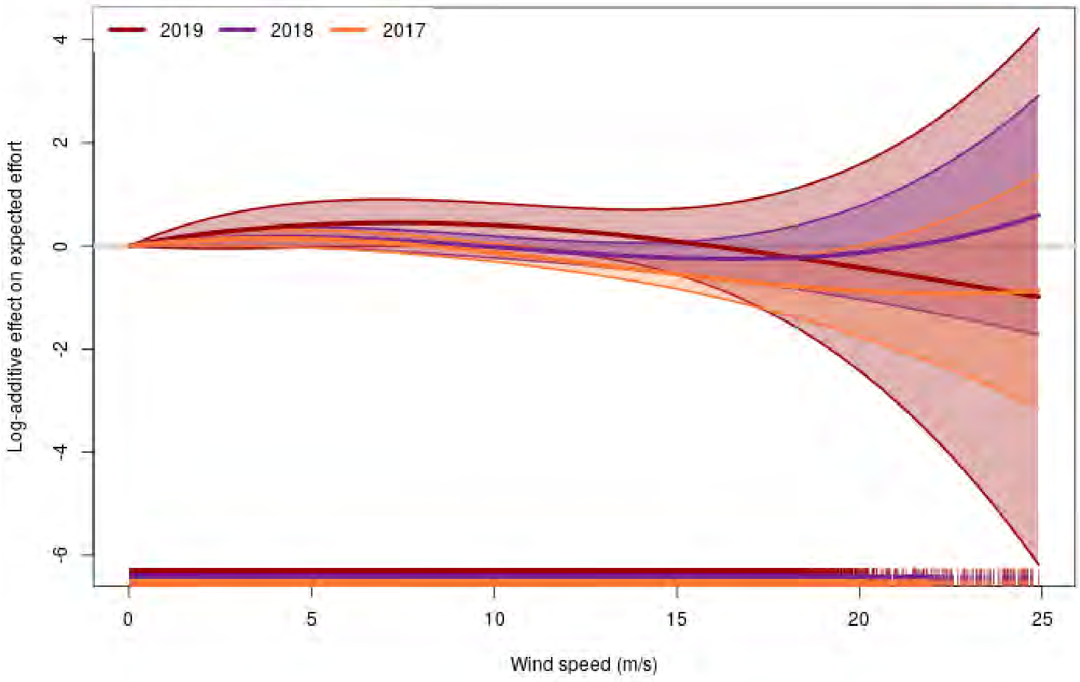


Figure 12: Estimated effect of wind speed on commercial effort targeting sprat.

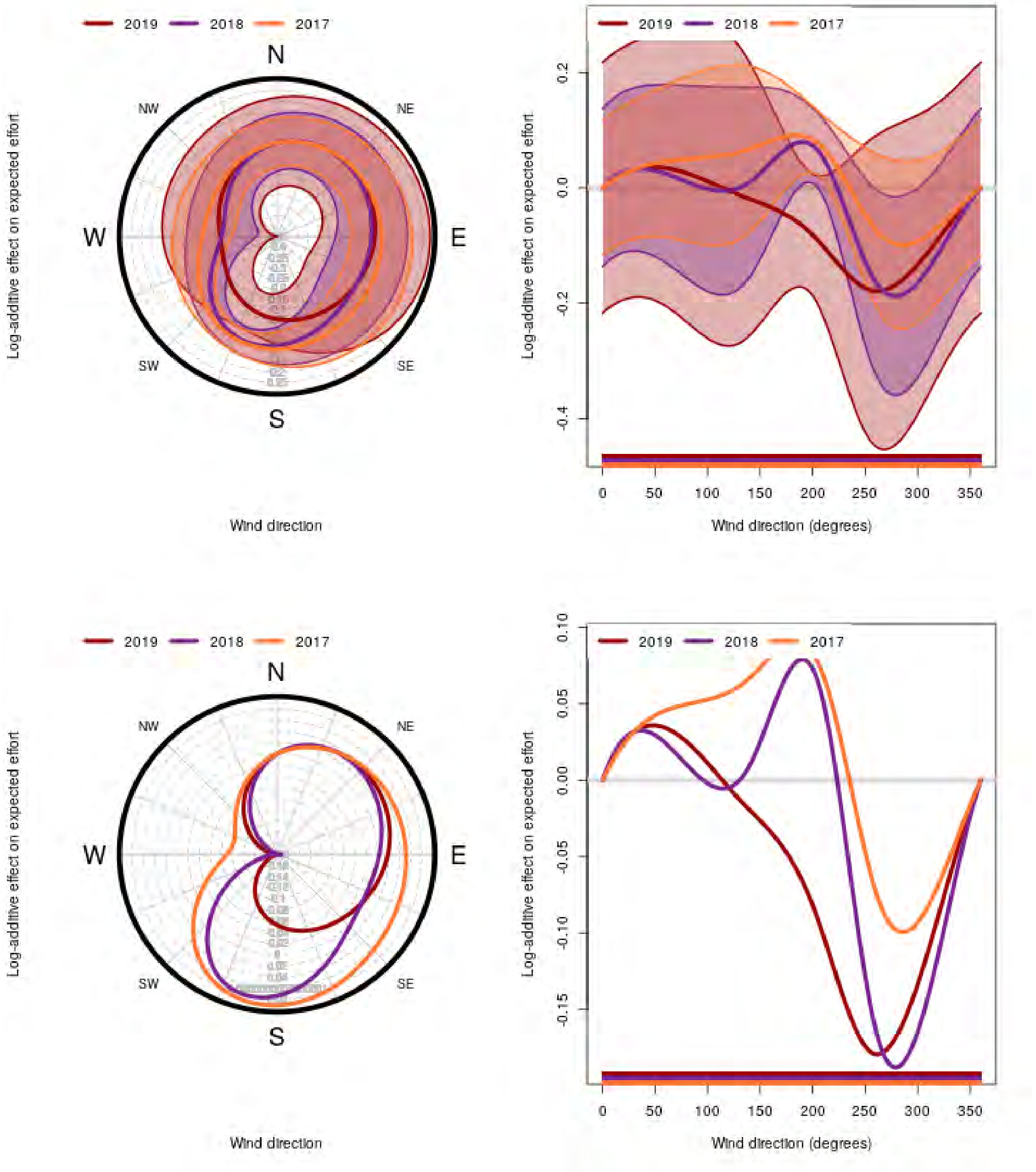


Figure 13: Estimated effect of wind direction on commercial effort targeting sprat. Estimated effects are shown with and without confidence intervals for illustration

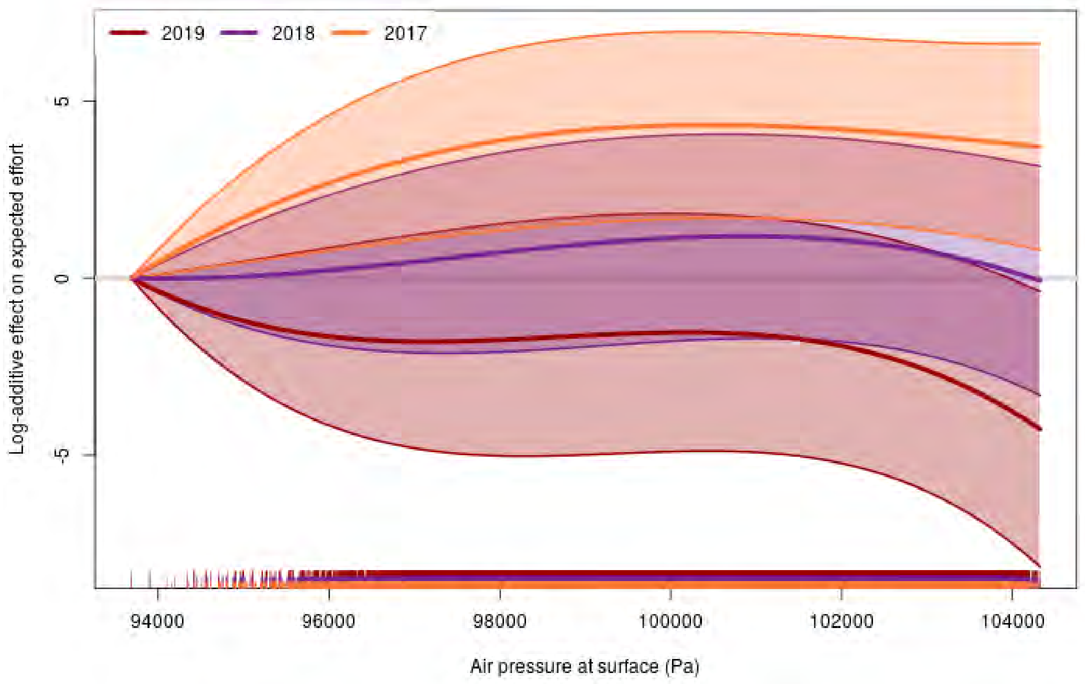


Figure 14: Estimated effect of air pressure at surface on commercial effort targeting sprat.

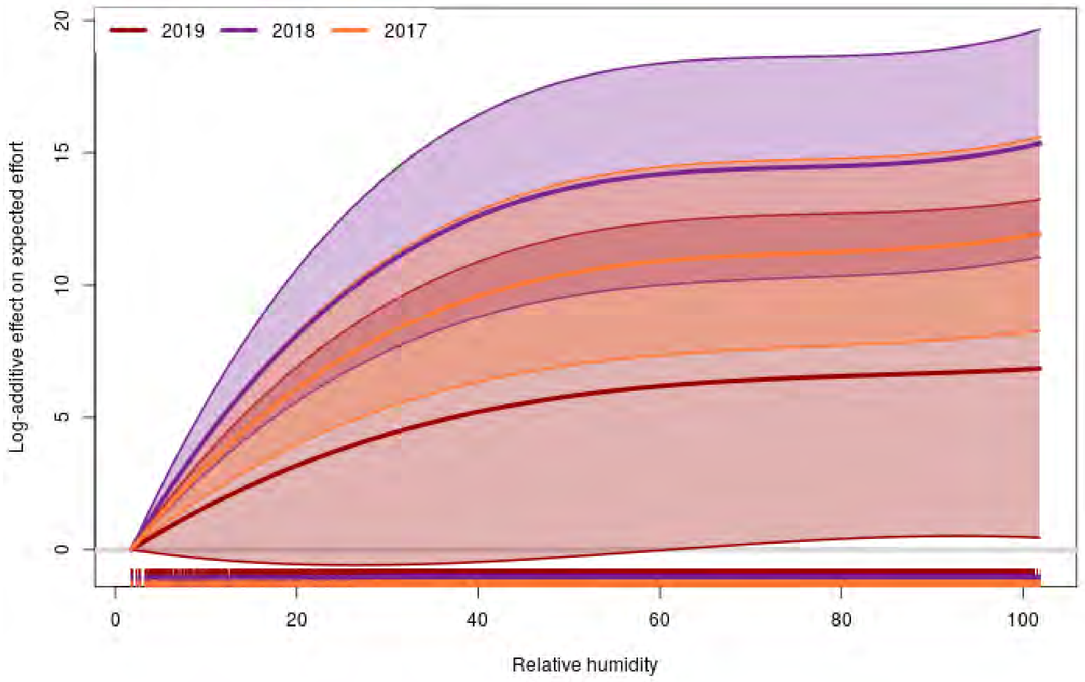


Figure 15: Estimated effect of relative humidity on commercial effort targeting sprat.

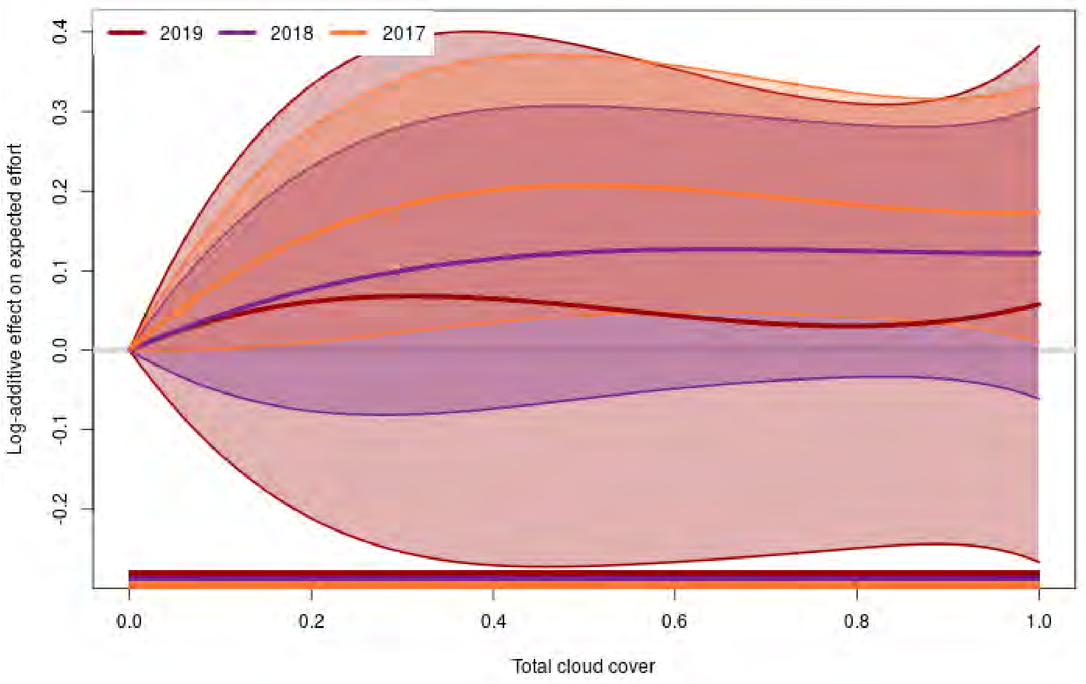


Figure 16: Estimated effect of total cloud cover on commercial effort targeting sprat.

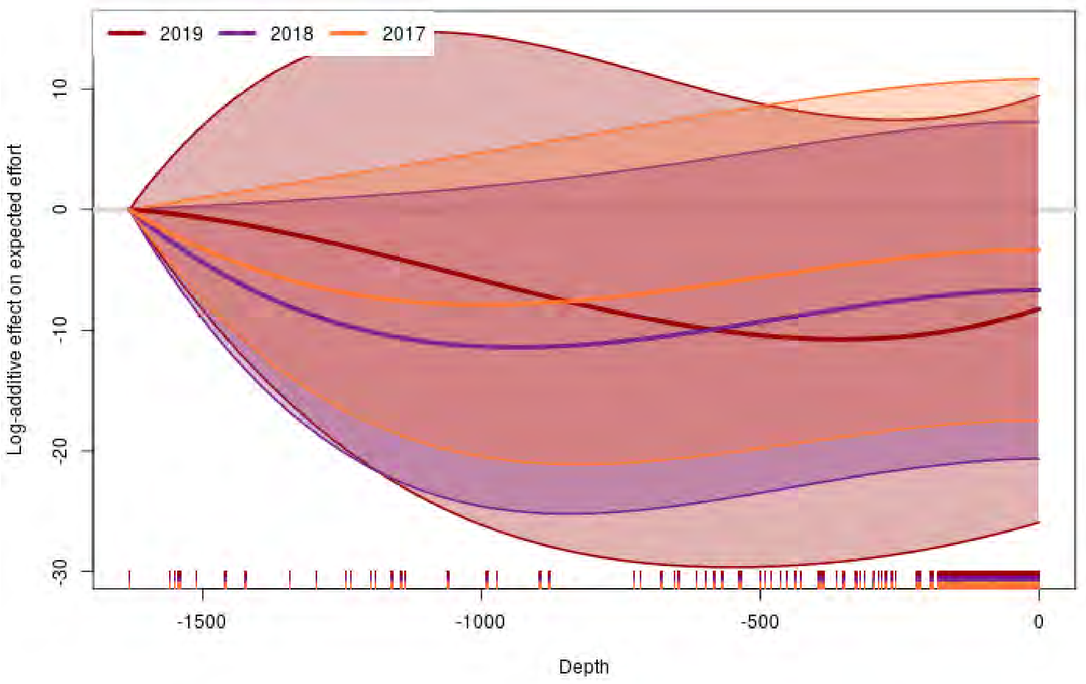


Figure 17: Estimated effect of depth on commercial effort targeting sprat.

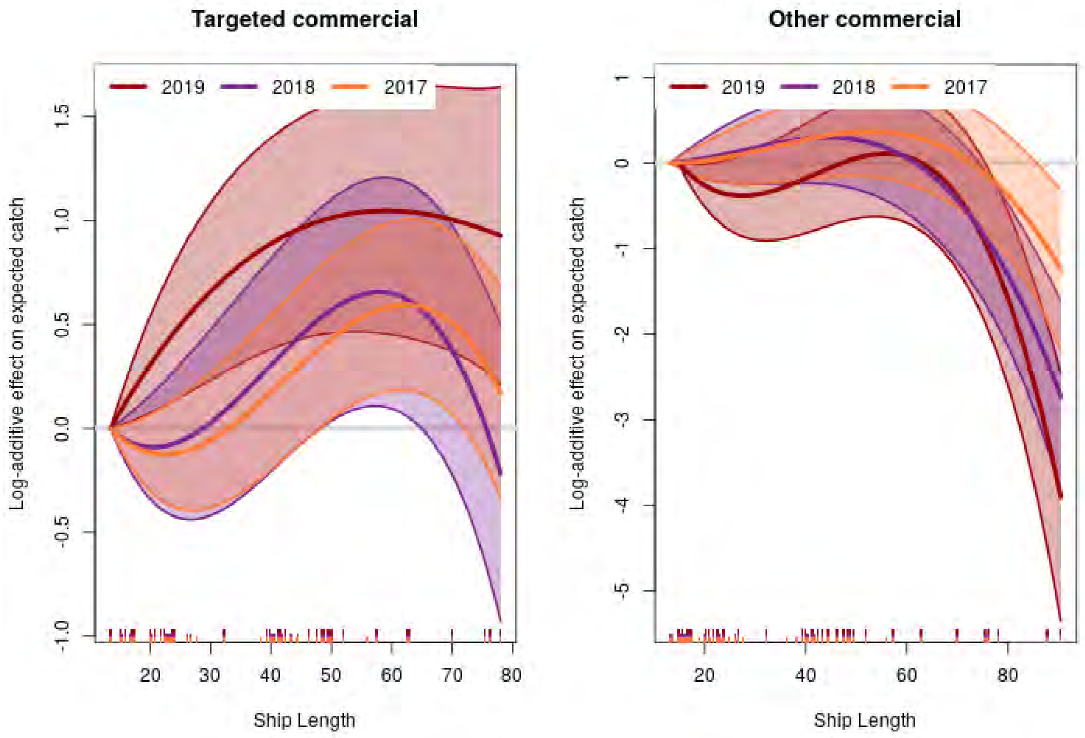


Figure 18: Estimated effect of ship length on catch rates.

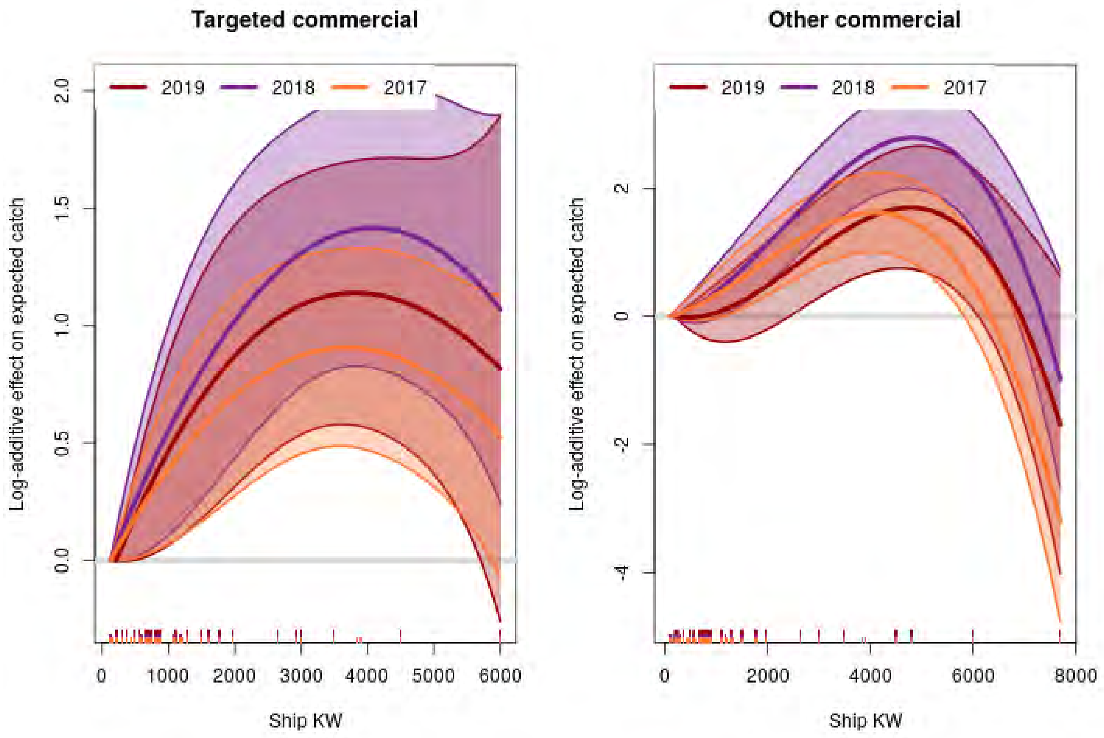


Figure 19: Estimated effect of engine power on catch rates.

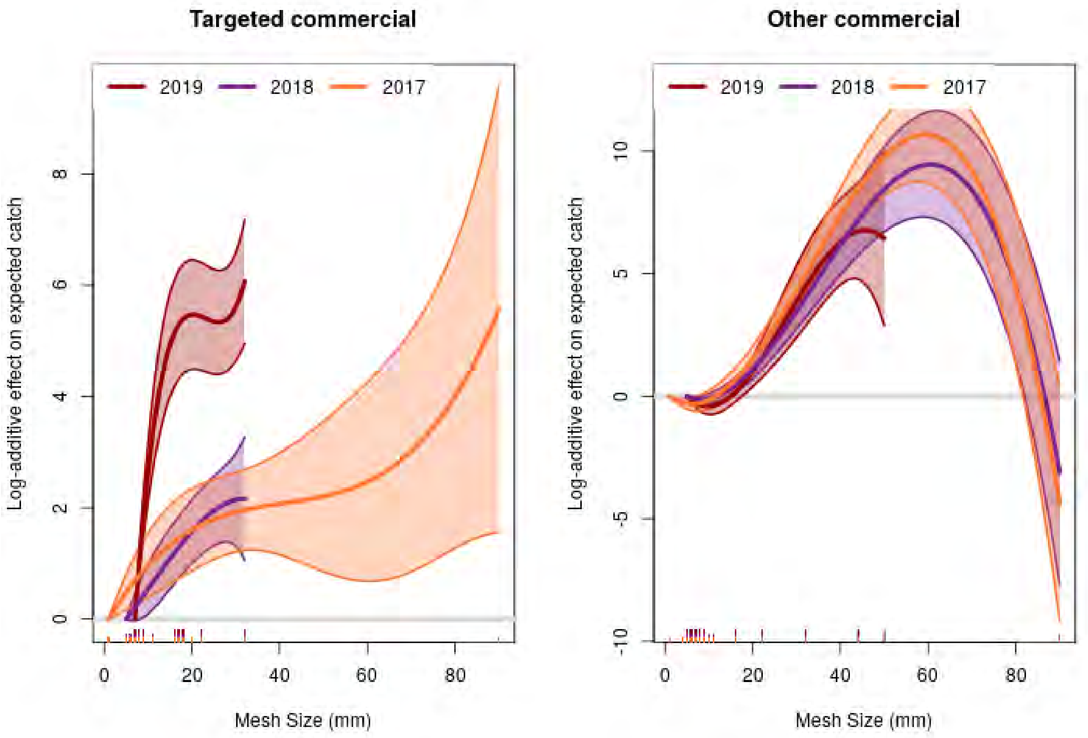


Figure 20: Estimated effect of mesh size on catch rates.

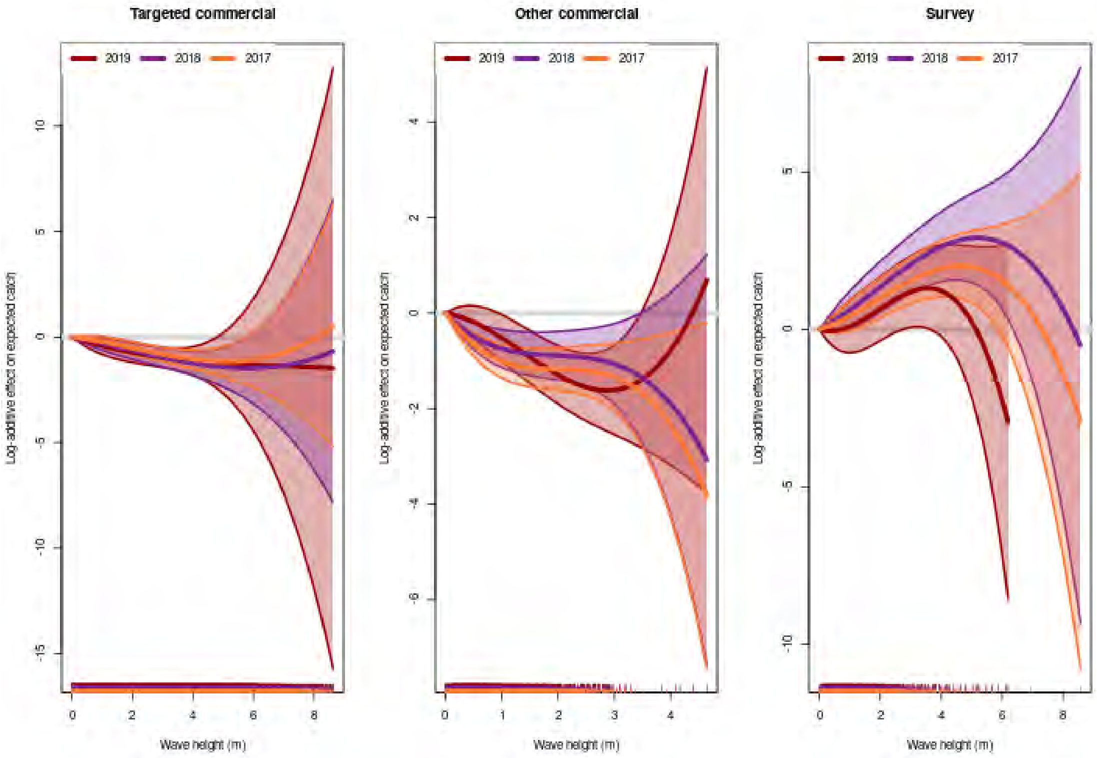


Figure 21: Estimated effect of wave height on catch rates.

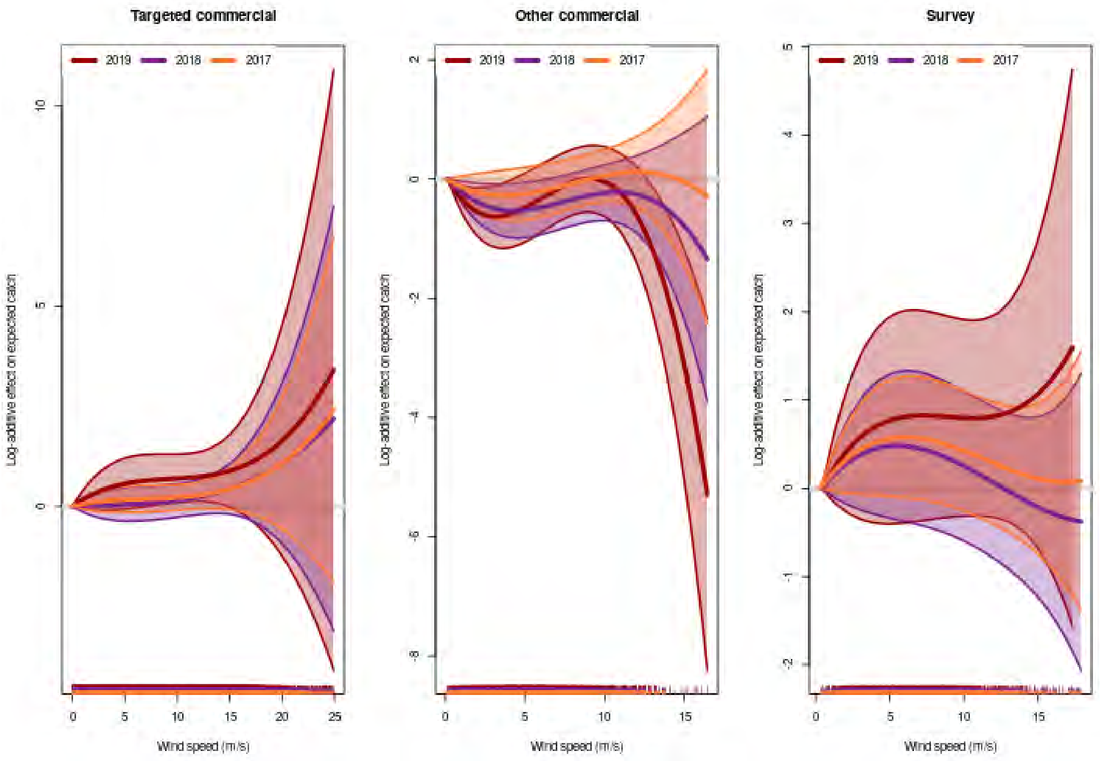


Figure 22: Estimated effect of wind speed on catch rates.

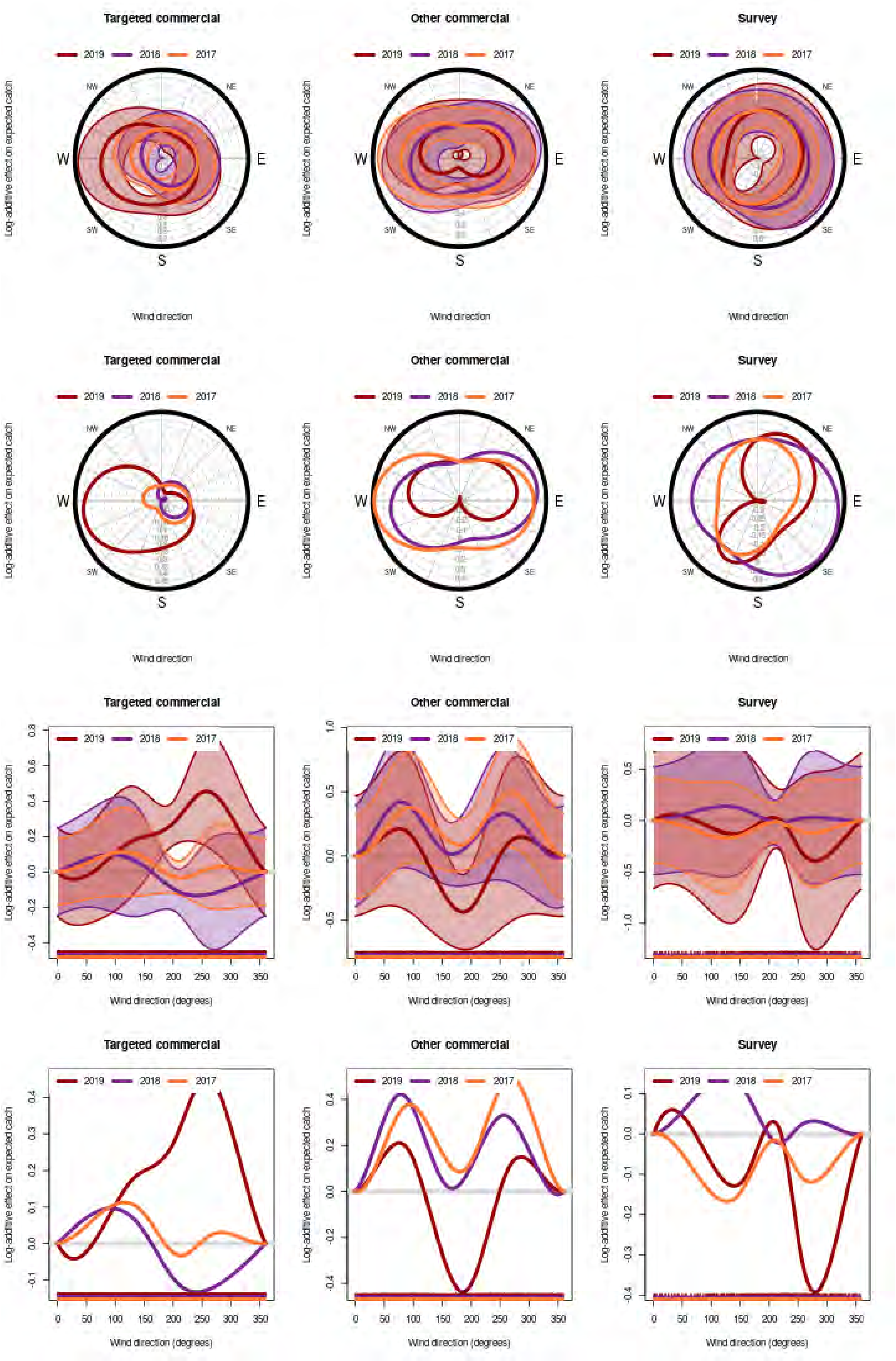


Figure 23: Estimated effect of wind direction on catch rates. Estimated effects are show with and without confidence intervals for illustration.

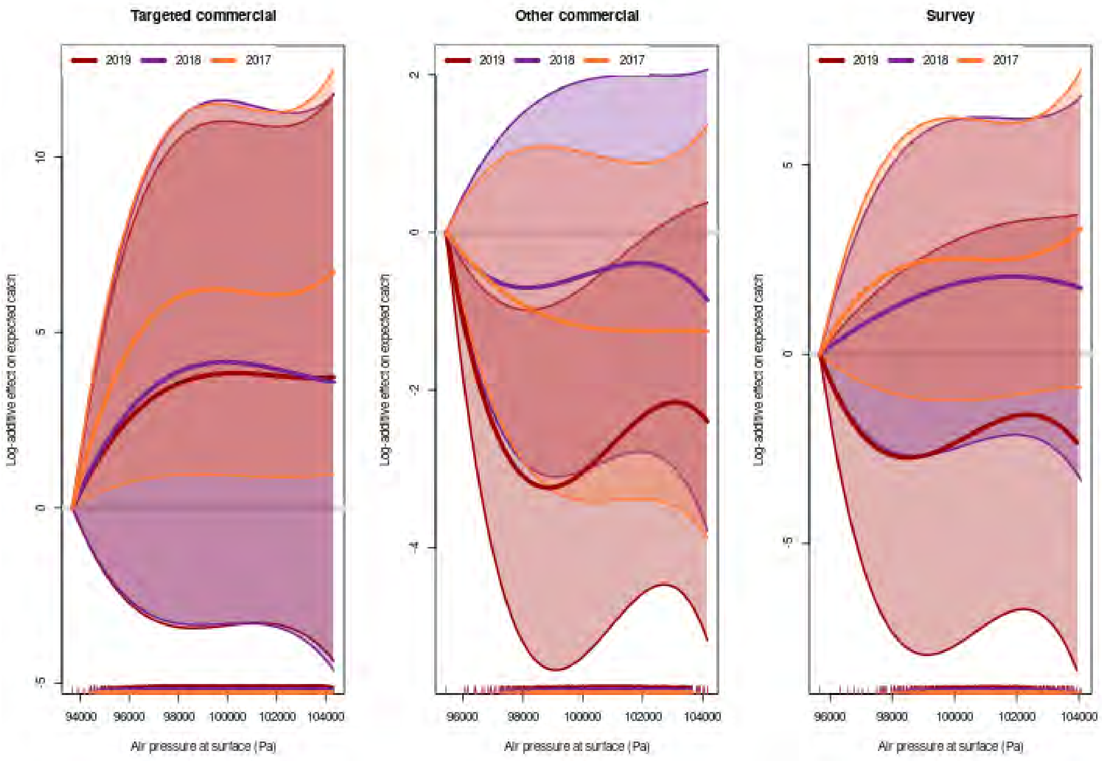


Figure 24: Estimated effect of air pressure at surface on catch rates.

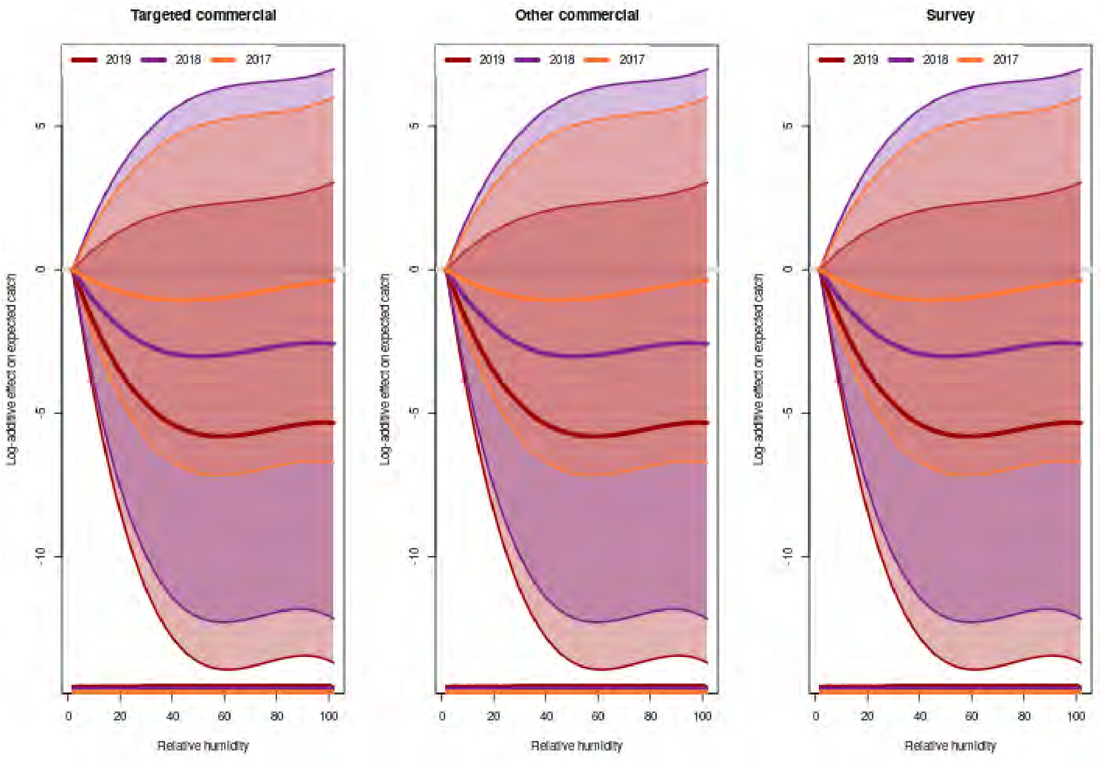


Figure 25: Estimated effect of relative humidity on catch rates.

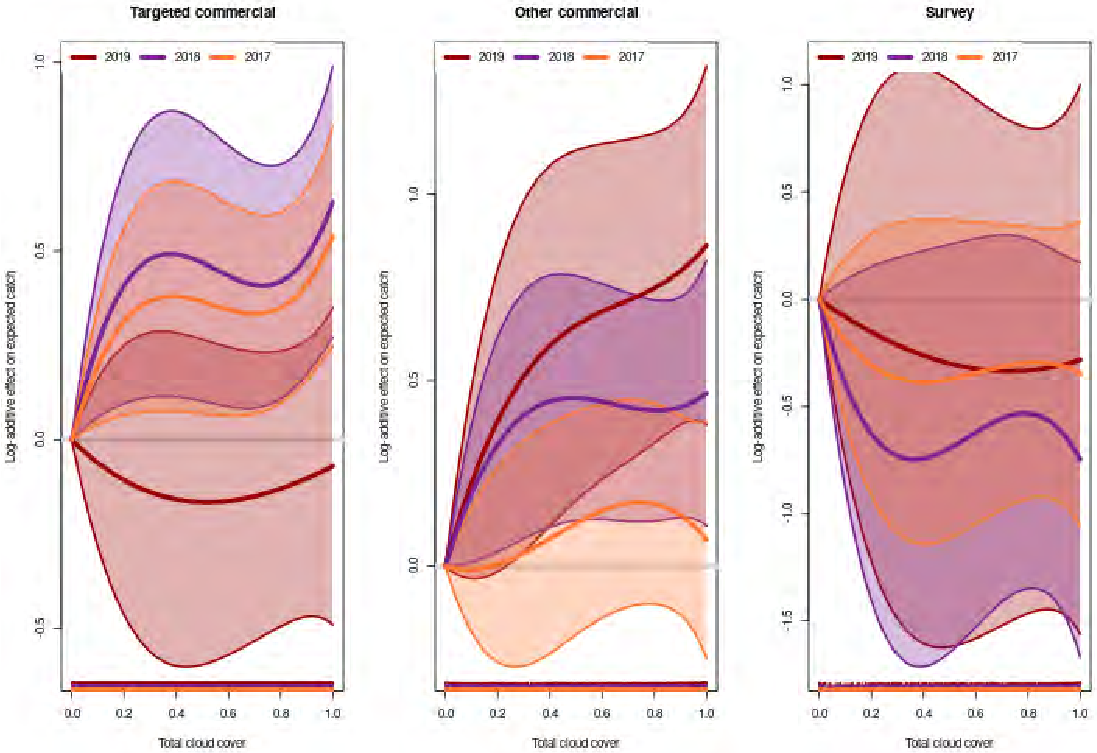


Figure 26: Estimated effect of total cloud cover on catch rates.

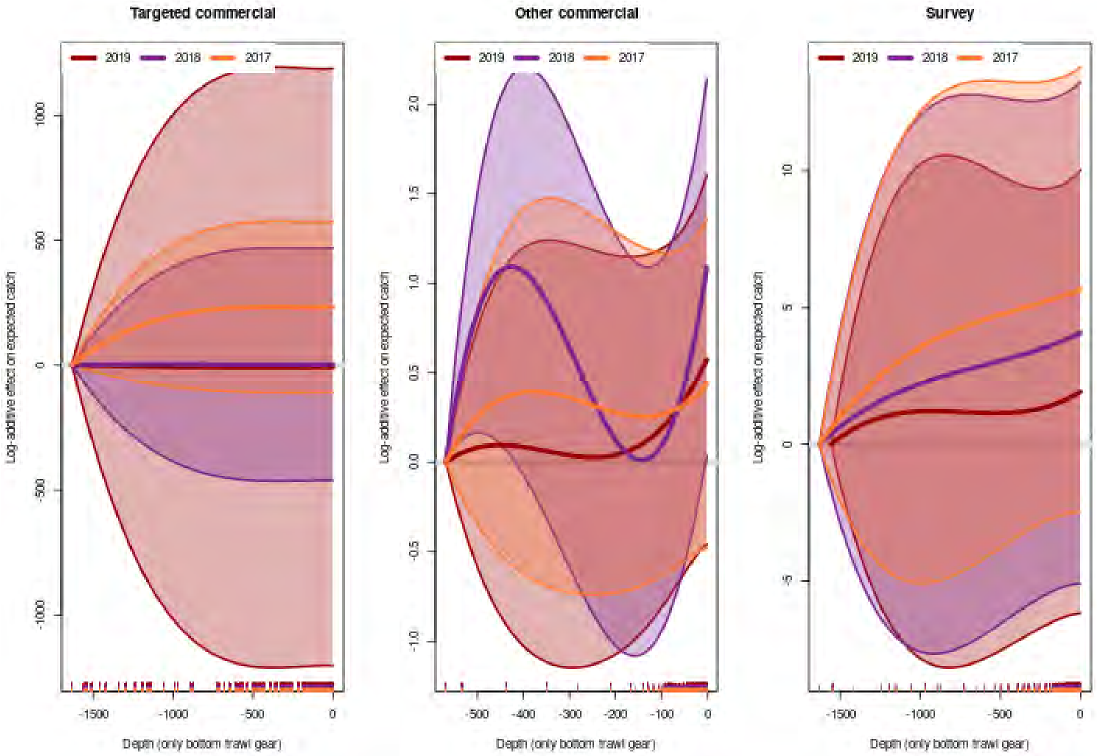


Figure 27: Estimated effect of depth on catch rates.

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Pedersen, Martin W, and Casper W Berg. 2017. “A Stochastic Surplus Production Model in Continuous Time.” *Fish and Fisheries* 18 (2): 226–43. https://doi.org/https://doi.org/10.1111/faf.12174.

Bilag 4. Spatial separation of larval sprat (*Sprattus sprattus*) and sardine (*Sardina pilchardus*) across the North Sea, linkage to hydrography

Spatial separation of larval sprat (*Sprattus sprattus*) and sardine (*Sardina pilchardus*) across the North Sea, linkage to hydrography.

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Abstract

Clupeoid fish species are widely distributed and locally of very high stock sizes. In the North Sea the herring and sprat are the common clupeoid species, but during recent decades the generally more southerly distributed sardine are sporadically observed. North Sea information on nursery area characteristics are limited for the sprat and sardine, and we here investigate relative abundances and distributional patterns of their larvae, hypothesizing separate spatial niches linked to hydrography. Larvae were sampled during standard surveys in August 2018 and 2019 by a large ring-net, and the two clupeoid species were distinguished by systematic myomeer counts. Sprat larvae were found widespread across the area of investigation, with highest concentration in the central North Sea, off the eastern and northern flanks of the Dogger Bank, where abundances could reach 20 m^{-2}. Sardine larvae, on the other hand, showed their highest abundances in the Southern and German Bights. Larval distributions appeared complementary, pointing to separate niches of the species where the sardines predominantly reside in warmer and fresher water. The proportion of sardines versus sprat was ten times higher during our observations on larval stages than during surveys of adult stages in the following years, a discrepancy possibly related to catchability differences and/or juvenile migratory behavior.

Introduction

Small pelagic clupeoid fishes are widespread in all oceans and contribute about 25% to the annual world fisheries (Alheit et al. 2009). In a given ecosystem, these fish often constitute relatively few species, but make up some of the largest fish biomasses. They function as energy conveyers from the primary producers to higher trophic levels, grazing extensively on the secondary production while suffering high predation mortality at the same time (Cury et al. 2000). These species are often relatively short-lived and highly sensitive to environmental changes, leading to extremely variable stock sizes and shifts in range of distribution. Different species of small pelagic fish often show asynchronous population dynamics, appearing to facilitate relative stability of the total biomass of all small pelagic fish, this referred to as functional complementarity (Lindegren et al. 2016). This raises the question whether one flourishing species prevent other species from booming in population numbers because of competition for a common resource, or whether the asynchronous dynamics are merely driven be contrasting environmental optimums driving asynchronous shifts in distributions? If the latter case, co-existence by a number of species would be more likely in ecosystems characterized by distinct gradients in the physical oceanography.

Systems involving sardine and anchovy are generally well-studied and important for our understanding of co-existence of small pelagic species. Other multi-species systems, such as those involving sprat-herring or sprat-sardine are less studied, except for the sprat-herring system in the Baltic Sea (Möllmann et al.

2004). Furthermore, the majority of such system studies have focused on dynamic patterns in the adult stage, whereas competition and environmental preferences during the larval phase have been largely ignored in comparative studies. Thus there are a need for further insight involving a larger part of the life cycles of the species.

In the North Sea the small pelagic species herring and sprat dominate, but also specimen of the generally more southerly distributed clupeoid species, sardine and anchovy, are frequently observed in the North Sea area. The North Sea herring, spawning off the coasts of UK in the early autumn, is the overall most abundant of the species, and the one of main fishery interest. In recent decades the catch is primarily used for direct human consumption. The North Sea sprat is of less interest for human consumption, but is important for the industrial fishery (ICES 2020). During the last decade, the sprat stock has increased significantly, and currently it is fluctuating around two million tons (ICES 2020). Contrary to the demersal spawning of herring, sprat spawns pelagic eggs, mainly during the period May-June, Sprat eggs and larvae have been observed during a range of surveys in the German and Southern Bights, as well as off the Dogger Bank (van Damme et al. 2011).

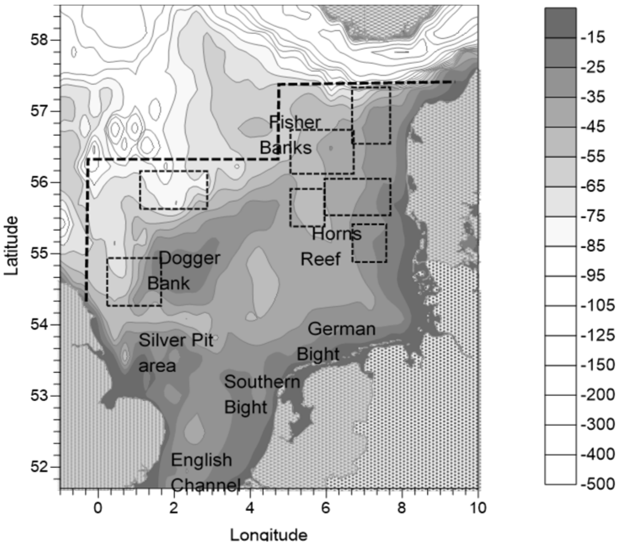

Figure 1. Bottom topography of the North Sea, with indication of specific areas. Present survey area covers area north of 51°40’N and south of heavy hatched line. Specific subareas for 2018-2019 comparison are indicated by rectangles of light hatched lines.

The abundances of the sardines and anchovy in the North Sea is much lower than those of herring and sprat, and historically abundances have been fluctuating at decadal intervals (Alheit et al. 2012). The latest period of enhanced abundances started around 1995 for anchovy and 2003 for sardine, where abundances were peaking during 2005-2009, followed by another decline. While the species generally were observed as adult specimen during fisheries and scientific trawl surveys, the latest reappearance of the two species was also evident from observations during eggs and larvae surveys during these years, predominantly in surveys covering the southern parts of the North Sea (Greve et al. 2005, Kanstinger and Peck 2009).

In order to provide information for spawning stock size and on recruitment to the herring stock, there has been intense sampling of newly hatched larvae (IHLS surveys, ICES 2020) and ½ year old recruiting larvae (MIK-survey, ICES 2020) during the last 40-50 years. Thus extensive information is available on this species for analysis of its spawning and larval distributions. Information on spawning and larvae of North Sea sprat stock is more limited. While some sprat juveniles were found in the early years of the MIK-surveys (before 1986), these have not been present during the last decades. Some information on larval distributions and early life characteristics are available from a series of historical investigations at specific spawning sites in the North Sea (e.g. Munk 1991, Huwer 2004), but a coherent picture of the entire spawning and nursery areas of the North Sea sprat population is lacking.

While sardine and sprat are ecologically and morphologically very similar and both species reproduce in summer, the apparent re-introduction of sardine in the North Sea raises the question whether sardine and sprat is likely to compete for resources in a new scenario. If this is the case, a possible prediction could be that the "warm water" sardine would replace sprat in certain North Sea areas as sea temperature continues to rise. However, if sprat and sardine display different hydrographical preferences at given stages, they could co-occur within the North Sea area. Thus, beside the general need for further information on the spawning and larval distributions of the species, it is also of great interest to ascertain their respective characteristics and the potential linkage to specific environmental cues.

Based on North Sea wide observations of nursery areas for sardine and sprat, we in the present study investigated the hypothesis that sprat and sardine larvae distribution are spatially displaced from each other and that the displacement is driven by specific hydrographical characteristics. Information were obtained during IBTS3 surveys in 2018 and 2019. During these two surveys significant parts of the central and southern North Sea were covered by ring-net hauls, and a varied number of fish larvae were sampled, these predominantly from fish species spawning during late spring-early summer.

Materials and Methods

Salinity and temperature measurements

The hydrographic information was obtained from CTD casts made from surface to 2 m above bottom, available for a range of research vessels working in the North Sea, information available in a common database at ICES (https://ocean.ices.dk/HydChem). For the present study we used all available casts carried out between July 1st to 31st of August in 2018 and 2019 for the area north of 51°40'N and south of 58°50'N (Fig.1). In 2019 a Seabird SBE 25plus CTD was mounted on the ring-net, and supplementary temperature and salinity information from the ring net tow was this year included to the used standard CTD series. In total 711 casts were available for 2018 and 386 casts available for 2019.

Gear and sampling

The area of sampling covered a large part of the central and southern North Sea, a relatively shallow area (depths < 40 m), with a number of characteristic banks (Fig. 1). This area was surveyed between x and y in 2018 and x and y in 2019. The path of the survey was directed by the requests of the daytime trawling, and during the period available for larvae sampling (22:00 – 5:00) 4-5 stations were distributed as widely as possible within the given constraints. At station, a 13 m long ring-net of a mesh size of 1 mm and a 2 meter opening (MIK) and was towed in an oblique path from surface to 5 m above bottom. A mounted depth-sounder availed depth information, and a flow-meter in center of opening registered flow of water into the net. The ships speed was 3 knots, and the wire was paid at 25 m min^{-1} and retrieved at 15 m min^{-1}.

After the haul the hindmost part of the net (which had a 500 µm mesh insert) was washed into a bucket, and the sample was immediately sorted for all fish larvae using a light-board. Larvae were preserved in 96% ethanol, kept separate as clupeoid and "other" larvae.

Processing of larvae

Clupeoid larvae were length measured and identified to species in the laboratory. Due to the morphological resemblance of the sprat and sardine larvae in the present stages, the species identification had to include systematic myomeere counting of larvae. For samples with less than 50 clupeoid larvae all these were length measured and for those larger than 20 mm, the species were identified by the position of the anus respective to the anal find (fin 5 myomeers posterior to the anus for sardine). For those smaller than x mm, all myomeers of the trunk were counted by stereolup examination. If number of clupeoid larvae in the sample were above 50, only 50 were picked randomly in the sample.

The myomeere counts of the species differed systematically, with a slight overlap among species, the average for both species declined during ontogeny (Suppl. Figure 1).

Data treatment

In order test the hypothesis that the number of larvae of given species is related to hydrographic characteristics, we used the following linear mixed effect model: Ln(Y + 1) = X + r(lat) + r(lon) + r(y), where Y is larvae abundance (numbers m^{-2}), X is the environmental driver, and r(lat) + r(lon) + r(y) are the additive random effects of latitude, longitude, and sampling year. Sprat and sardine data was analyzed in separate models. Special focus was on the potential effect of sigma-t which depends on temperature, salinity, and depth, and we produced a separate model for each environmental driver and compared models to determine if sigma-t performed better that other drivers. Models were compared based on AIC, slope coefficient, and the p-value associated with estimated slope coefficient.

The spatial patterns in salinity and temperature at surface (3m depth) and bottom (2 m above bottom) were contoured for the North Sea area, using the “inverse distance” procedure and four search areas in the program “Surfer®”

Results

Hydrography

The surface temperatures were at their highest close to the continental coasts, about 20°C in 2018 and 19°C in 2019, and they declined gradually towards the northwest reaching 15°C in the most northwestern areas (Fig. 2 a-b). Overall the 2018 surface temperatures were 1-2°C higher than in 2019. The bottom temperatures showed strong horizontal stratification, marking a series of fronts (Fig 2 c-d). As for surface temperature, the general magnitudes were 1-2°C higher in 2018, while the patterns of stratification showed strong resemblances between the years. In both years a hydrographic front is indicated north of and to some extent also south of Dogger Bank, when another front is apparent some distance off the continental coast. This pattern basically follows the bottom depth contours (Fig 2 c-d, see also Fig. 1). While the hydrographic measurements are not synoptic and some temporal variability is to be expected at given locations, the interpolation leads to some “smearing” of gradients and actual gradients could be spatially narrower.

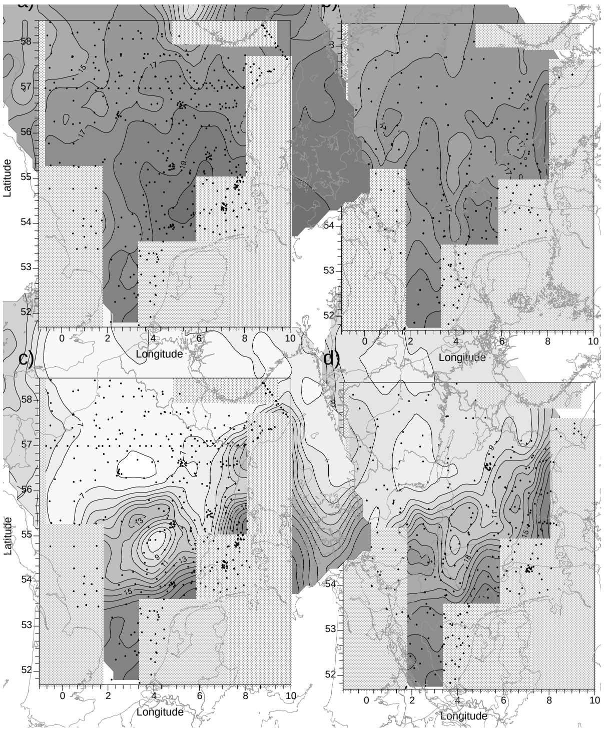

Figure 2. Hydrographic conditions in the North Sea during August 2018 and 2019. a-b) Surface temperature, 2018 and 2019 respectively, c-d) bottom temperature, 2018 and 2019, respectively. Dots indicate positions of measurement, contour lines temperature in °C.

The salinity showed strong horizontal gradients both at the surface and at the bottom (Fig. 3 a-d). Salinity

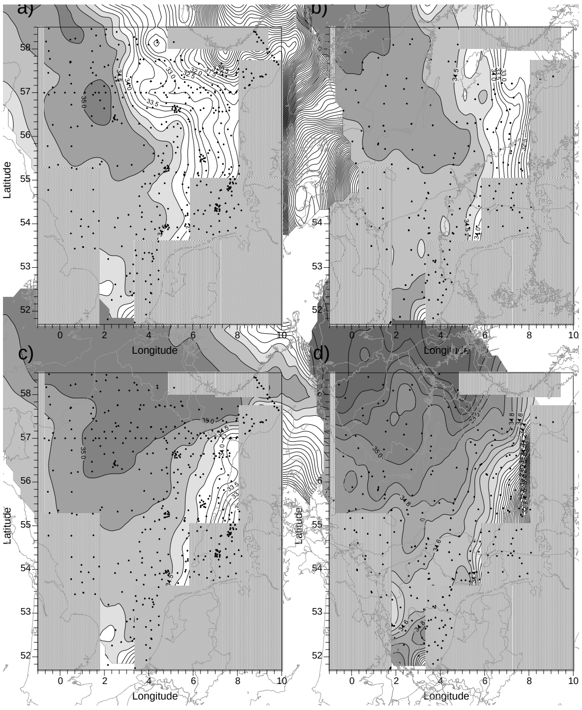

Figure 3. Hydrographic conditions in the North Sea during August 2018 and 2019. a-b) Surface salinity, 2018 and 2019 respectively, c-d) bottom salinity, 2018 and 2019, respectively. Dots indicate positions of measurement, contour lines salinity in psu.

is strongly influenced by the freshwater outflow from rivers, predominantly the Rhine and Elbe in the southeast, and Thames in the southwest; these outflows are apparent both at surface and bottom (Fig. 3 a-d). In the northeastern part of the investigation area the Baltic outflow of fresher surface water is apparent in surface salinity pattern, especially in 2018 this water spreads far out in the North Sea (Fig. 3 a-b). Salinity gradients are generally stronger and closer to the coast in 2019 than in 2018.

The vertical stratification and the positioning of hydrographic fronts are illustrated for a single offshore transect of CTD measurements, for stations within a range of +- 10 minutes along 56°10’N (Fig. 4). A thermocline is seen at about 30 m in offshore areas, while this raise to about 12 m depth closer to the coast (Fig. 4a). The salinity is relatively homogeneous through the water column in offshore areas, but outward-flowing coastal fresher water leads to a more or less marked halocline between 18 and 25 m (Fig. 4b).

Tidal mixing results in bottom front formation around water depths of 30-40 m.

Sprat and sardine larvae

Sprat larvae were caught in large numbers, their abundance estimates at stations reaching 20 m^{-2} (Fig 5 a-b). Abundances were generally higher in the northern parts of the investigation area. In 2018 significant concentrations were seen at the northern and eastern slopes of Dogger Bank in vicinity of the apparent fronts in this area, while in 2019 the highest abundances were seen around the Fisher Banks in the northeastern area (Fig. 5a-b). Observations indicated that the generally high abundances in the northernmost areas would decline sharply further to the north; there was low abundances at the northernmost stations in 2018 and along all south-north oriented sampling transects in 2019 the abundances declined northwards.

Sardine larvae showed their highest abundances in southern and eastern areas. In 2018 significant abundances were seen in the Horns Reef area, when they

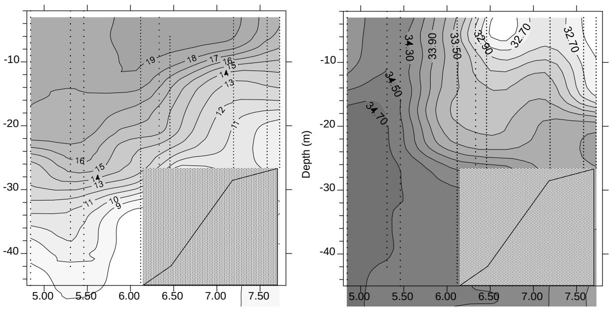

Figure 4. Vertical sections of hydrography off the Danish coast in 2018, along latitude 56°N. a) section of temperature in °C and b) section of salinity in ppm. Dots indicate vertical measurements.

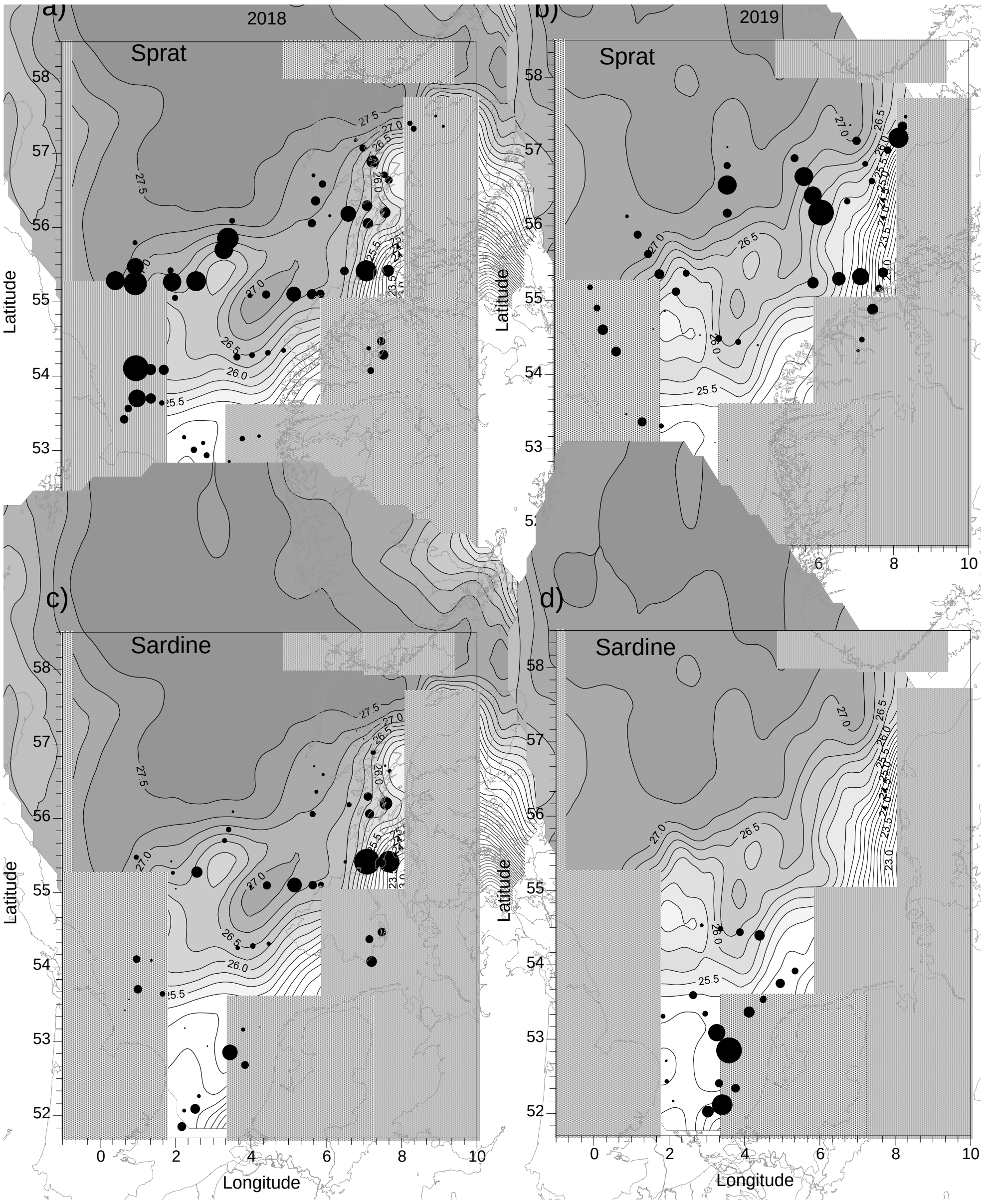

Figure 5. Distribution of sprat and sardine larvae during surveys in August. a-b) abundances of sprat larvae, 2018 and 2019, respectively, c-d) abundances of sardine larvae, 2018 and 2019, respectively. Relative abundance per area illustrated by bubble sizes on map of bottom water density (as sigma-t, kg m^{-3}).

were less abundant in the German and Southern Bights. In 2019, on the other hand, the most significant larval abundances were found in the Southern Bight. However, the sampling in the potentially important German Bight area was limited, see discussion below.

A comparison of absolute abundances between species and between years is hampered by the patchy sampling scheme, and the differences between area coverages. Thus, we here compare specific subareas which have been covered during both years of sampling (these are indicated in Fig 1). An average of relative abundances within these areas reveals a decline from 2018 to 2019. The 2019 abundances where about 64% and 14% of 2018 abundances, for sprat and sardine respectively, and abundances of sardine larvae were about 57% and 13% of sprat abundances in 2018 and 2019, respectively.

Differences among species and relation to hydrography

Larvae of the two species, sprat and sardine, were distributed in different areas of the North Sea. Their distribution showed generally little overlap, equal

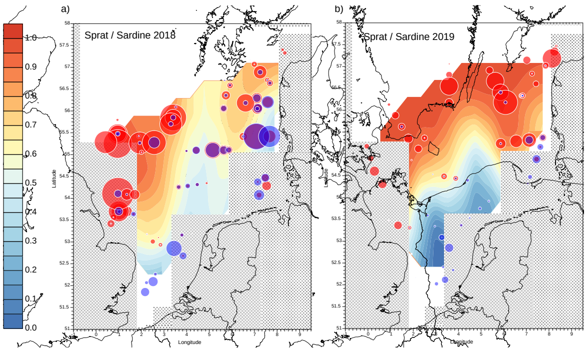

Figure 6. Illustration of relative abundances of sprat and sardine larvae. a) observations in 2018, b) observations in 2019. Red bubbles indicate sprat abundances, blue bubbles indicate sardine abundances, contouring illustrate proportion of sprat relative to sum of both species as in legend bar, e.g. 0.5 = equal abun-

amount of the species were only seen at stations in the Horns reef area, mostly the catch at stations showed high dominance of either sprat or sardine (Fig. 6). As described above the sprat larvae was predominantly in northern parts of the investigation area, while sardine dominated in the southernmost areas. This characteristic appears linked to hydrographical features. Basically sardine were found in the fresher, warmer water off the Dutch, German and Danish coasts. This watermass is bordered by the ROFI front, in our study approximately following the path of the 1026 kg m^{-3} bottom density contour (Figs. 5, 6). Enhanced abundances of the sprat larvae appeared linked to the e ROFI front off the Danish coast, and in the tidal mixing front off the northern and eastern flanks of Dogger Bank (Figs. 5, 6).

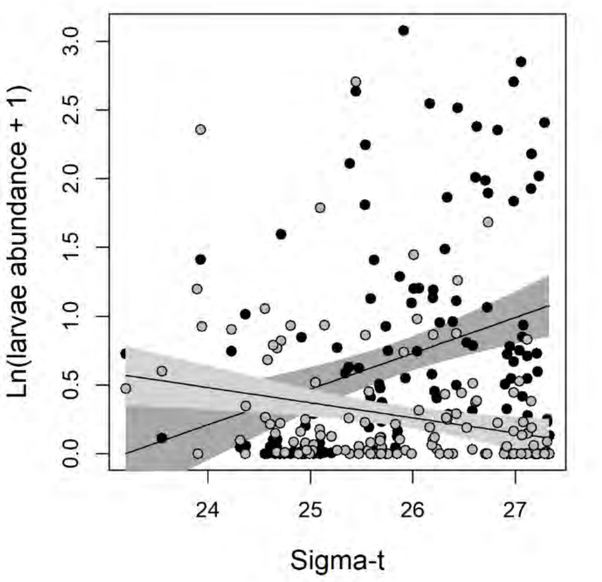

Figure 7. Ln-transformed abundance (numbers m^{-2}) of sprat (black) and sardine (grey) larvae as function of Sigma T (kgm^{-3} -1000) at the bottom. The lines are produced from simple linear regression analysis and the shadings represent 95% confidence intervals (dark grey shading represent sprat and light grey shading represent sardine).

The relationships between sigma t and larvae abundance supported the hypothesis posed in the introduction. The abundance of both species correlated significantly with sigma t ($p < 0.001$ for both species) and the slopes of the relationship were opposite. Sprat were abundant when sigma t was high, whereas, sardine were most abundant in areas of low sigma t (Table 1 and Fig. 7). Overall, sigma t performed consistently better than other environmental drivers, when considering the species together. For example, sigma t was the only driver that yielded highly significant p-values ($p < 0.001$) for both species. However, the difference in performance between sigma t and bottom temperature was marginal.

Larval lengths

Across the sampling area we observed characteristic distributional patterns in observations of larval mean lengths (Fig. 8). The patterns showed some resemblance among the species, but they differed to some extent between years. During both years of investigation, the central-eastern North Sea, i.e, in areas of Little Horns Reef, Jutland Reef and Little Fisher Bank, showed clear minima in mean lengths, while other minima were indicated off the northwestern Dogger Bank. This minimum off Dogger Bank was however not as apparent for sprat in 2019, and contrary to the preceding year we in 2019 sampled quite small larvae of both species in the southernmost part of the Southern Bight. (Fig 8. c,d). Generally, the stations with the smallest specimen were also stations of relatively high larval abundances. In order to ascertain differences in lengths between years of sampling, we compared average lengths for subareas that were covered during both years. Mean lengths within these areas

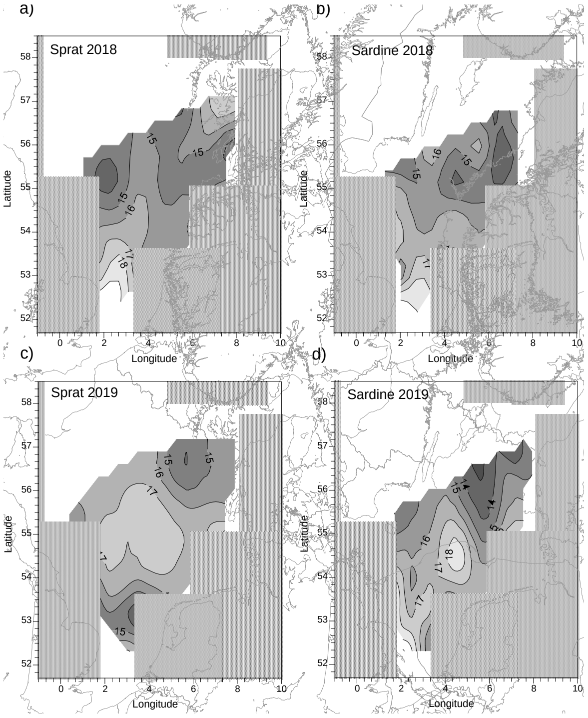

Figure 8. Contouring of larval mean lengths. a-d) Sprat and sardine in 2018 and 2019. Areas of shortest mean lengths are of darkest shading, contour lines for each mm.

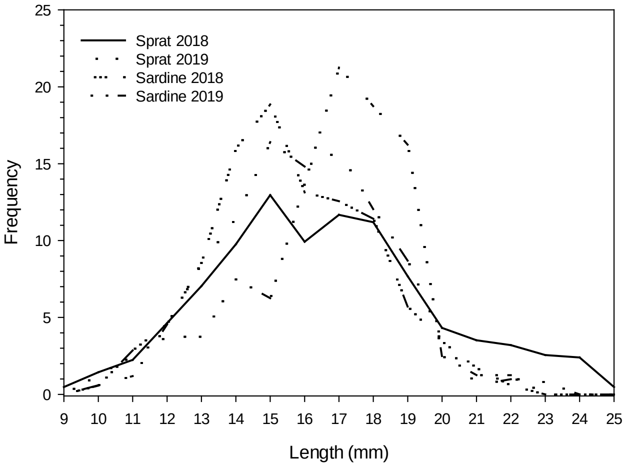

Figure 9. Length distributions of sprat and sardine larvae caught within selected areas in 2018 and 2019.

differed between species and years, but differences between length distributions aggregated for all areas are less prominent, only sprat larvae in 2019 might be outstandingly larger (Fig. 9).

Discussion.

The changes in relative populations sizes of clupeoid species into the North Sea has been discussed intensively (Alheit et al 2012 and ref. herein), and while earlier observations in the North Sea and adjacent waters have mostly been sporadic and within restricted areas, the present observations of widespread and relatively abundant sardine larvae in the southern North Sea indicate significant presence of this species. While the adult sardines are also of increasing abundance in recent years there is however, a marked difference between relative abundance of sprat and sardine in catches of adult specimen, and our catches of the species in larval stages. An inspection of the survey trawl catches of the 2018 and 2019 yearclasses in the ICES trawl database (ICES DATRAS 2020) reveals only an abundance of sardine (one year old and older) 2% relative to sprat of same ages, while we in the present study caught about 20% sardine larvae compared to sprat larvae. This discrepancy points to a need for better monitoring and further understanding of the species changes within the North Sea area. Our study indicate that specific life-cycle patterns related to hydrographic characteristics exert could be the background of population changes in general and specifically the present instruction of warmer water species.

The present study pointed to characteristic patterns in the larval distribution of the abundant clupeid species, sprat and sardine, during the late summer. Sprat larvae were obviously the more abundant of the two species, but especially in 2018 also the sardine showed significant abundances. The observations of these species supplements earlier studies that have observed concentrations of clupeid larvae in specific areas. For example the German Bight area has in earlier studies been identified as an nursery area of both sprat, sardine and anchovy (Aurich 1954, Huwer 2004), and here enhanced abundances of the species have been linked to the hydrographic fronts transversing this area (Kanstinger and Peck 2009). Likewise concentrations of sprat larvae showed strong linkage to the path of hydrographic fronts north of German Bight, over Horns Reef, (Munk 1993) and north of Dogger Bank (Munk and Nielsen 1994).

In favor of the hypothesis posed in the introduction and in contrast to earlier studies (e.g. Kanstinger and Peck 2009), indicating overlapping distributions of sprat and sardine larvae in the southern North Sea, our observations pointed to a geographical separation of sprat and sardine larvae distributions, strongly related to hydrographical characteristics. The sardine were generally found in higher abundance in relatively warm water and low salinity (at shallower depth), in accordance with the more southerly and coastal distributions of the species, which has previously been reported (Alheit et al. 2012). The reason why such spatial separation was not evident in the study by Kanstinger and Peck (2009) might relate to the extent of the study areas, which was much wider in the present study.

A study of sardine and anchovy in the bay of Biscay showed similar spatial segregations, but of adults, concluding that the segregation was driven by other than the affiliations to certain types of food organism (Chouvelon et al. 2015). In contrast, the anchovy and sardines inhabiting the Peruvian waters show strong affiliation with the physical oceanography (Schwartzman et al. 2008). The anchovy and sardines inhabiting the Peruvian waters show strong affiliation with the physical oceanography, facilitating niche segregation temporally and spatially (Schwartzman et al. 2008, Ayón et al. 2011), while the anchovy-sardine dynamics in the Benguela current appears to be trophodynamically controlled (Van der Lingen et al. 2006). In the Baltic Sea, population dynamics of herring and sprat also show contrasting cycles, which appears to be driven by changes in the zooplankton species composition and density-dependent competition (Möllmann et al. 2004).

Observations of high abundances of relatively small larvae are likely indicators of main spawning centers. Sprat larvae are at hatching 3.5 mm (Munk and Nielsen 2005), and while the smallest larvae in the present study were about 12 mm, our sampling obviously took place somewhat past peak spawning time. Preliminary examination of the otoliths of sprat of average size 20 mm from the present study, point to an age from hatching of about 18 days (R. Lundgreen, pers. comm.). The egg development from spawning to hatching would be expected to be 5 days at the temperature of 15 °C (Petereit et al. 2008), thus duration of drift is likely in the order of 23 days, from spawning to our observations sprat eggs and larvae. With the prevalent current directions in the North Sea (Otto 1983) our observations of relatively small larvae of high abundances in areas North of central Dogger Bank and north of Horns Reef, point to main spawning predominantly taking place northwest of Dogger Bank and in the Southern Bight/German Bight areas. Especially the German Bight has earlier been identified as an important spawning area to sprat (Munk 1993, Re at al. 1993), but newly hatched larvae have been found also in the Horns Reef area (Munk 1993). An egg survey carried out in 2010-11 pointed to a relatively wide area of sprat egg distribution, along the 30 m depth contour from the Southern Bight to the Fisher Banks (van Damme et al 2011).

The present study is the first to describe a wider distribution of larvae across a large part of the southern North Sea. The observations of smallest sardine larvae in the same areas where also the smallest sprat larvae were found, i.e. Horns Reef, north of Dogger Bank, indicate that these larvae are not drifting into the North Sea from the southernmost parts. The concentrations of sardine larvae in the Southern and German Bights are relatively large, and when considering the prevalent current directions these are likely from other spawning events than those larvae further to the north. Thus these observations indicate that sardine perform separate spawnings across the southern North Sea and potentially have established local spawning populations. While sardine is a batch spawner with a protracted spawning period (Munk and Nielsen 2010) the pattern could alternatively stem from temporally displaced spawnings from the same population.

Comparison between the two years of sampling is constrained by limitations in detail and overlap of information. However, when data from the two years are spatially compared (using comparable section) they for each of the species basically show the same pattern and distributional linkages to hydrography. The summer of 2018 was outstanding warm (and dry), which is clearly reflected in our surface measurements of temperature, while less influence is seen at the bottom. Whether this have resulted in an outstanding spawning and growth season remains to be identified. We are only able to compare observations from two years, which cannot lead to any conclusion. Apparently the distributional patterns and the distributions of smallest larvae where large-by-large the same for the two years, while there was somewhat fewer larvae (especially of sardine) in 2019. Longer time series of abundance and corresponding environmental data would be necessary to evaluate effects of specific outstanding weather and/or long term trends in abundances and distributions.

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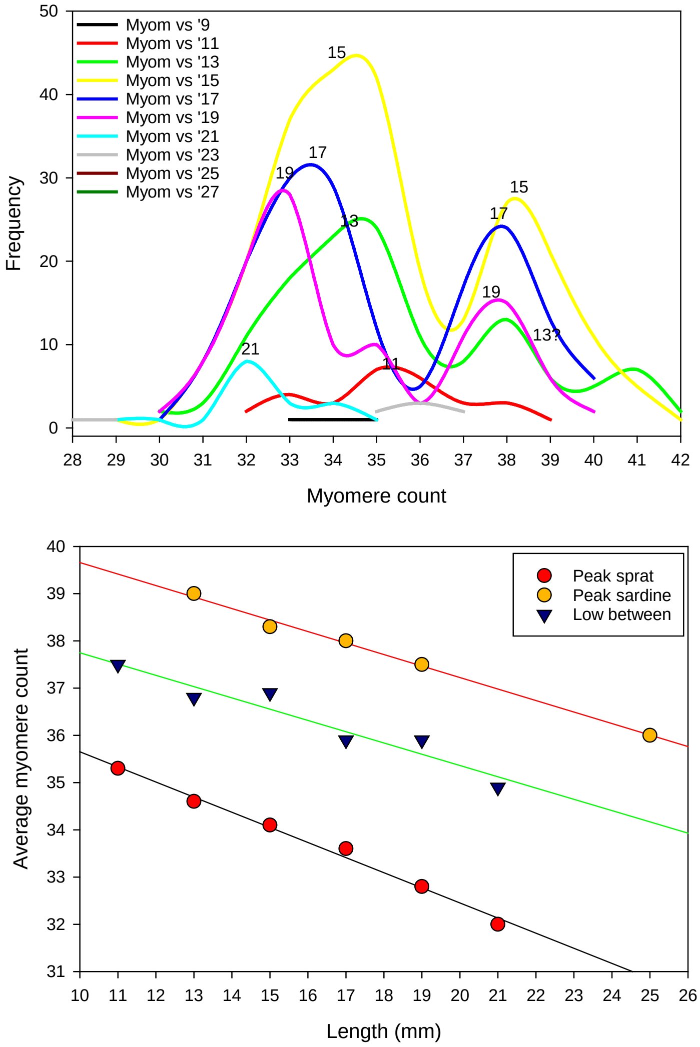
Appendix Table 1. Results from mixed effect models on the form Ln(Y + 1) = X + r(lat) + r(lon), where Y is larvae abundance (numbers m^{-2}), X is the environmental driver, and r(lat) + r(lon) are the additive random effects of latitude and longitude. Slope coeffcients, p-value for the environmental driver and AIC is shown.

Environmental driver	est. coeff.	p-value	AIC
Sprat:			
Sigma T	0.25	< 0.001	312.7
Depth	0.01	0.06	323.6
Surface temperature	-0.13	0.02	319.4
Bottom temperature	-0.07	<0.001	308.4
Surface salinity	0.07	0.37	322.6
Bottom salinity	0.06	0.62	326.9
Sardine:			
Sigma T	-0.14	<0.001	165
Depth	-0.01	<0.001	162.7
Surface temperature	0.12	<0.001	164.3
Bottom temperature	0.02	0.01	172.3
Surface salinity	-0.07	0.08	172.9
Bottom salinity	-0.29	<0.001	160



Appendix figure 1

Separation of myomeer numbers for sprat and sardine larvae. a) Frequency of myomeer observations for 2 mm length groups, b) estimated myomeer maxima and in-between low for the two species, as funktion of larval length.

Bilag 5. Presentation on retrospective bias in three North Sea case studies, sprat, sandeel1r and sandeel2r

Retrospective bias in three North Sea case studies, sprat, sandeel1r and sandeel2r

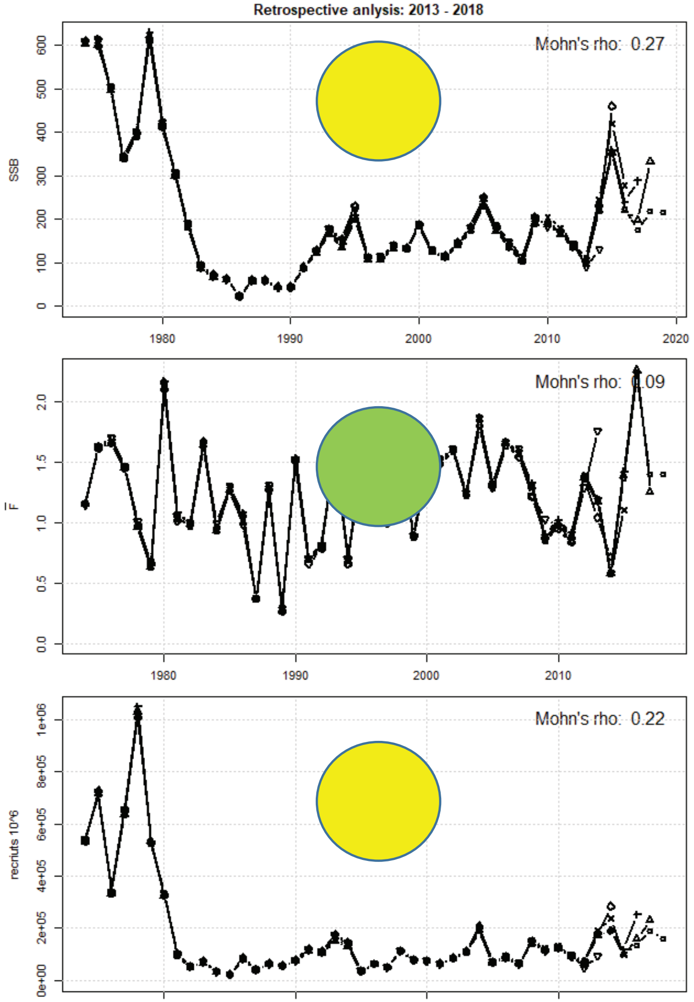
Mikael van Deurs
DTU Aqua

HAV & FISK
UDENRIGSMINISTERIET
Fiskeristyrelsen

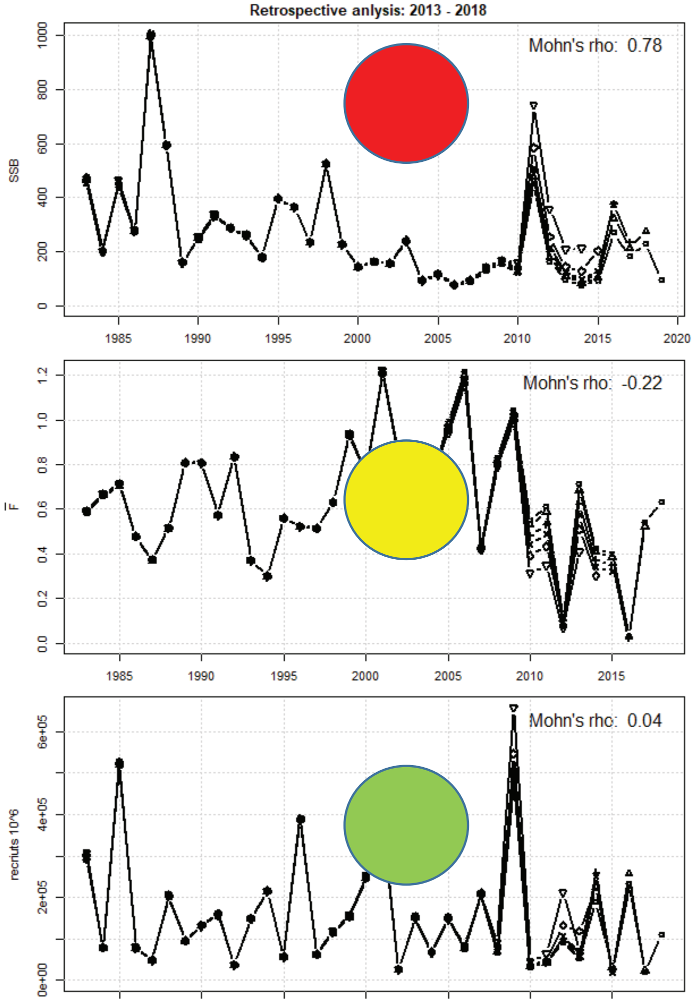
What if we look at a suite of diagnostica, instead of just Mohn´s Rho - will that change the perception of the retrospective pattern?

Mohn´s Rho

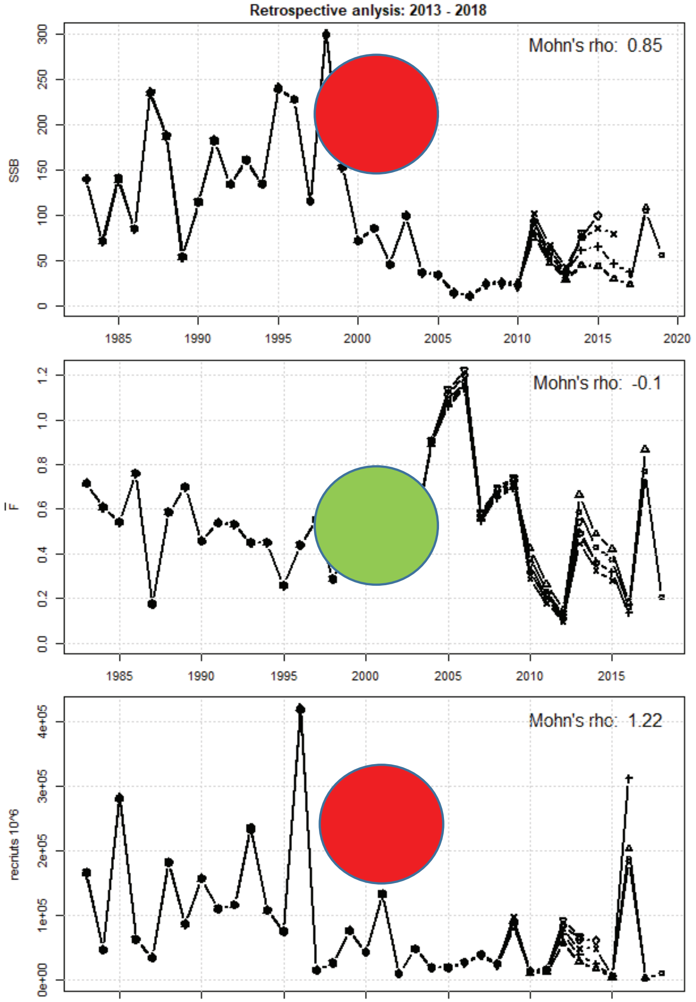
Sprat



Sandeel 1r

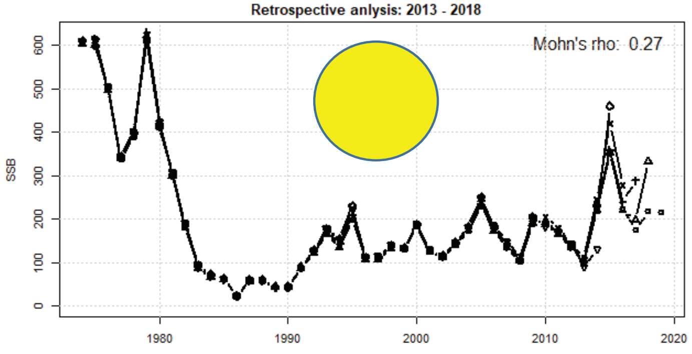


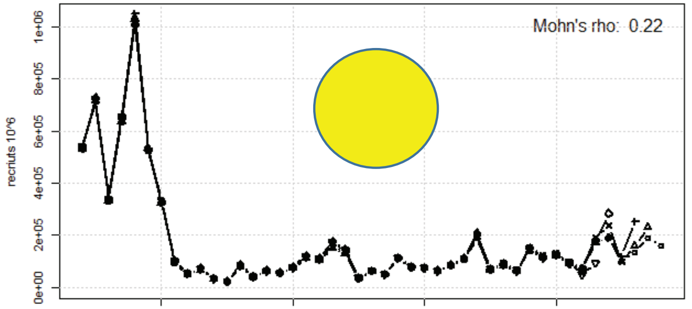
Sandeel 2r



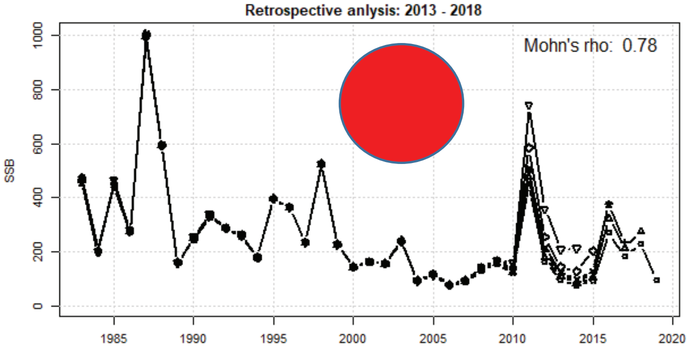
Mohn´s Rho

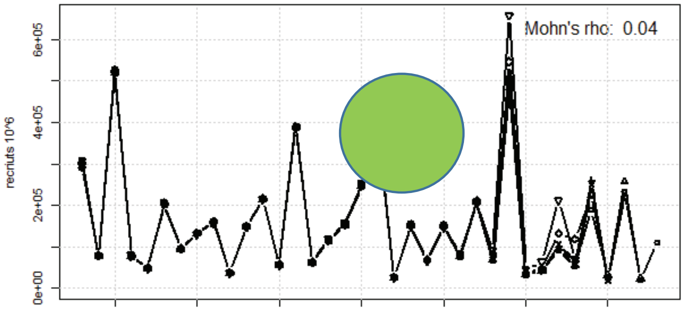
Sprat



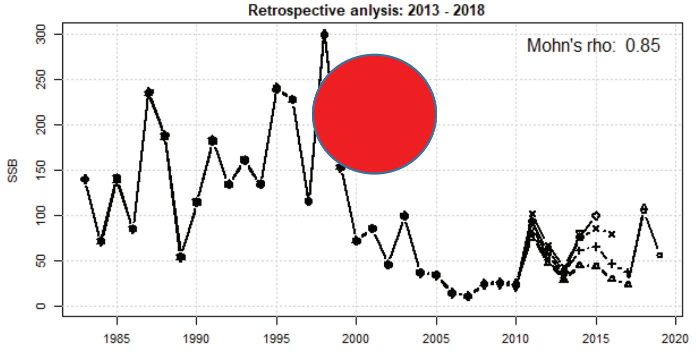


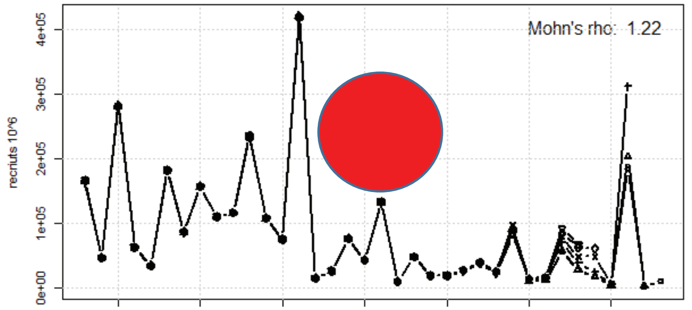
Sandeel 1r



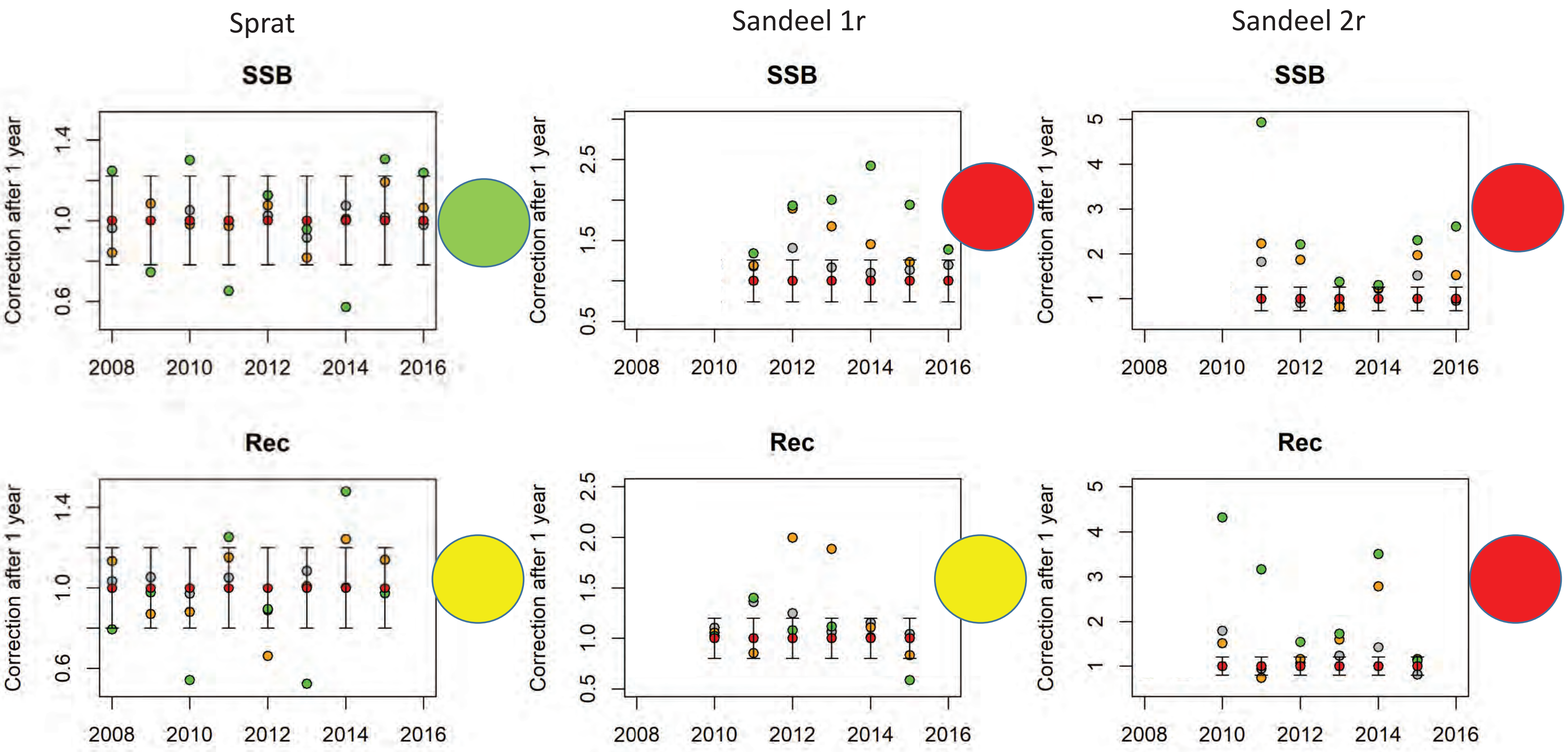


Sandeel 2r



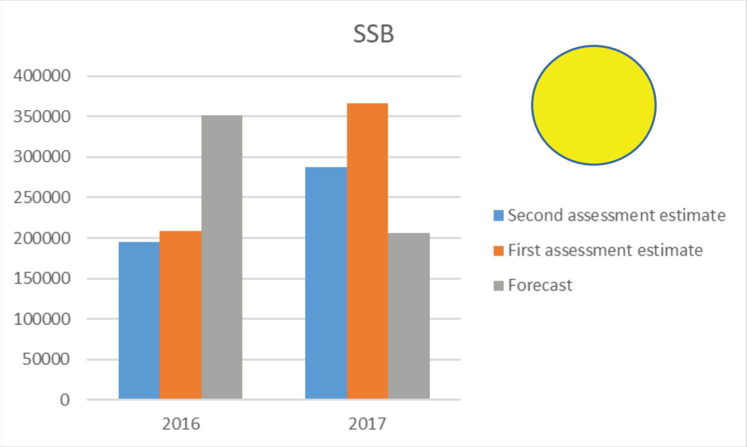


GRADUAL CORRECTIONS (i.e. looking into the retro-adjustments year-by-year)

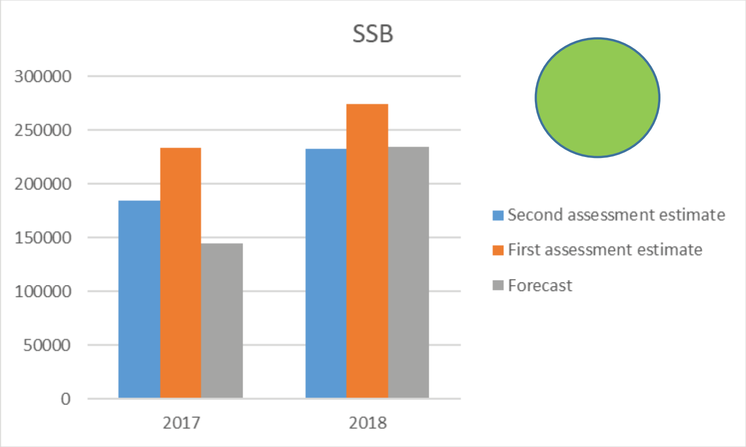


Forecast

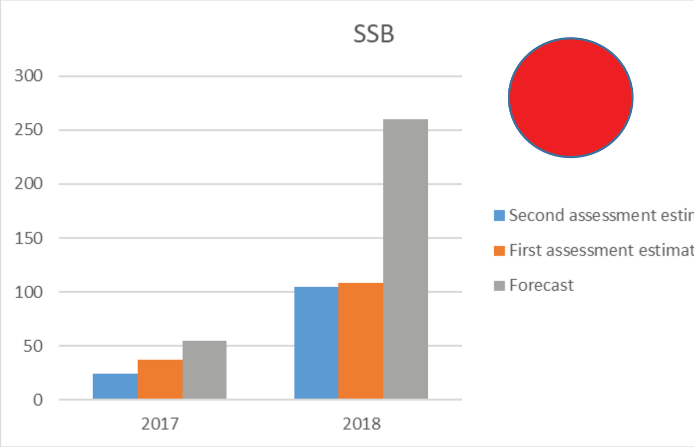
Sprat



Sandeel 1r

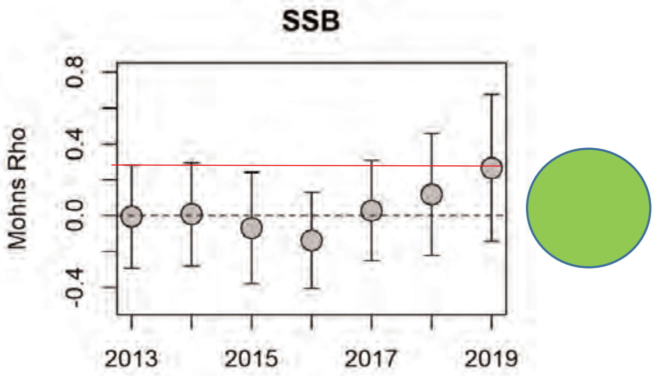


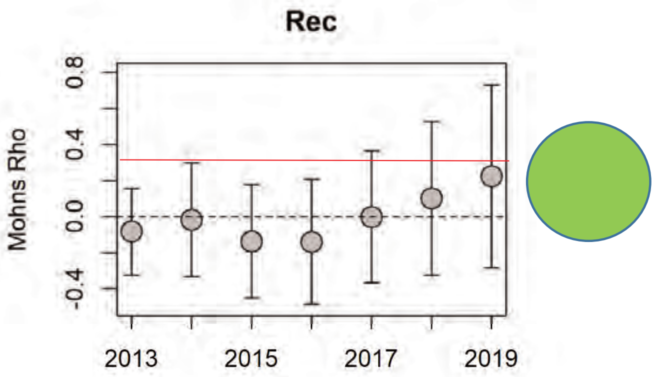
Sandeel 2r



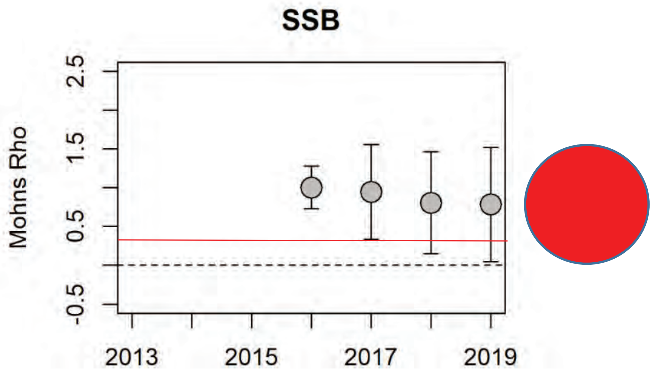
Moving window approach

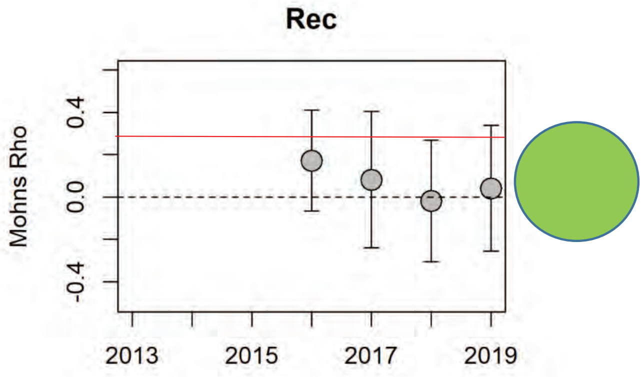
Sprat



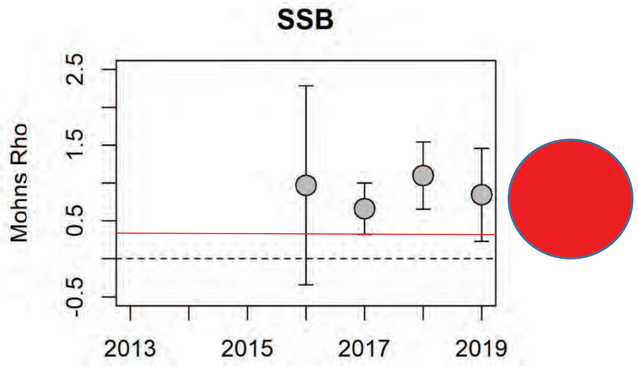


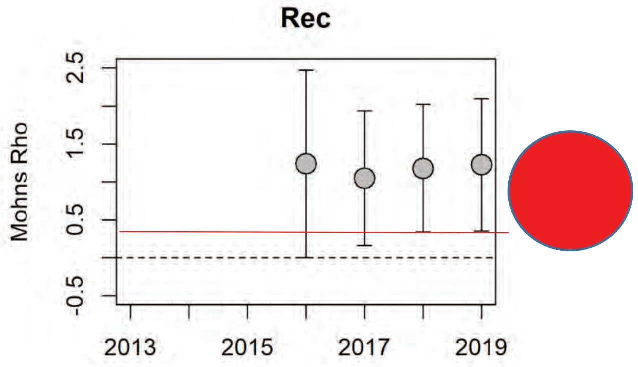
Sandeel 1r





Sandeel 2r





FIRST YEAR ADJUSTMENT

	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
2006	172	172	177	182	182	186	189	192	191	184	197	195
2007	135	134	137	139	142	149	147	144	150	141	146	155
2008	103	103	104	106	107	112	111	110	109	105	92	136
2009	188	191	195	206	204	204	211	212	212	230	158	
2010	188	188	192	205	193	183	190	200	186	247		
2011	167	166	169	180	174	172	172	168	112			
2012	135	134	136	142	139	143	150	157				
2013	108	107	109	110	101	90	106					
2014	220	221	228	245	230	131						
2015	350	352	358	420	460							
2016	225	220	239	278								
2017	174	199	289									
2018	218	332										
2019	216											

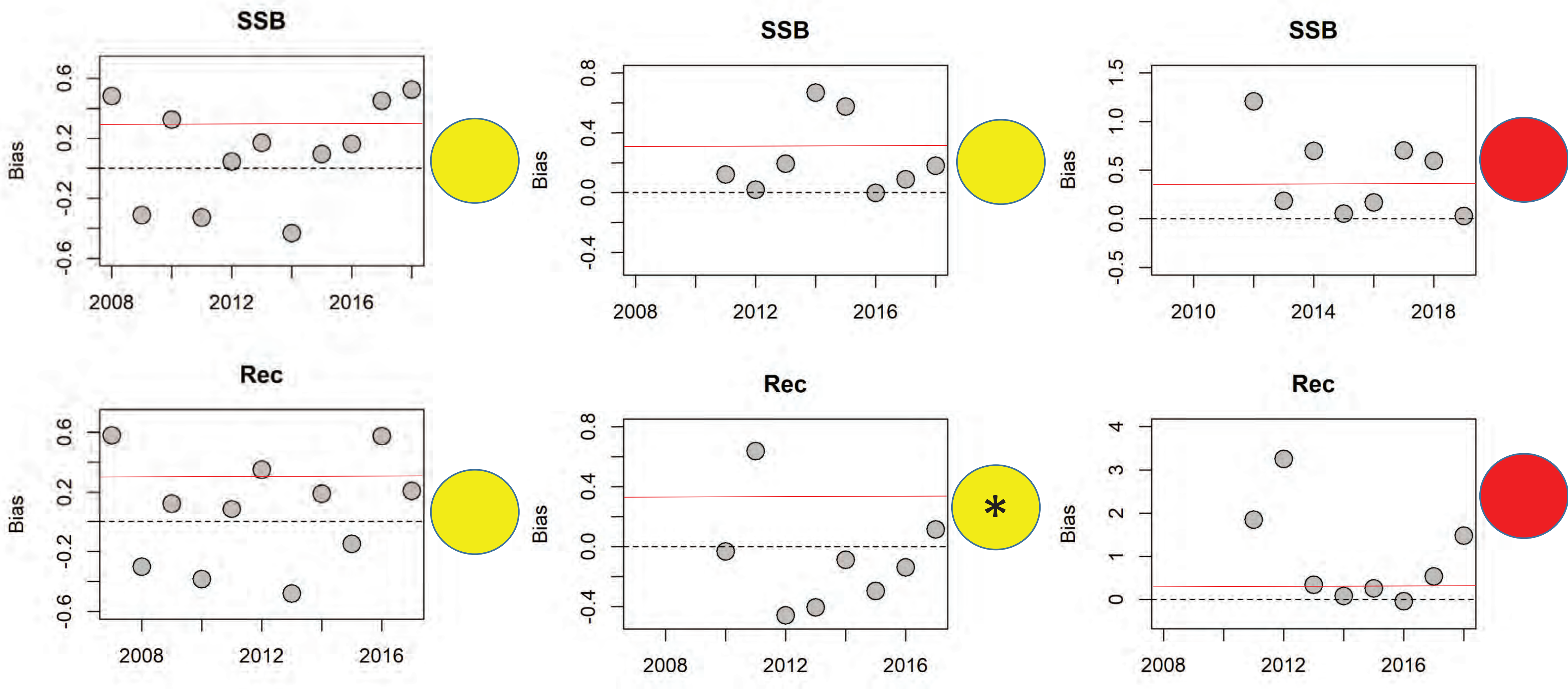
BIAS: (🟩 — 🟥) / 🟥

FIRST YEAR CORRECTIONS

Sprat

Sandeel 1r

Sandeel 2r



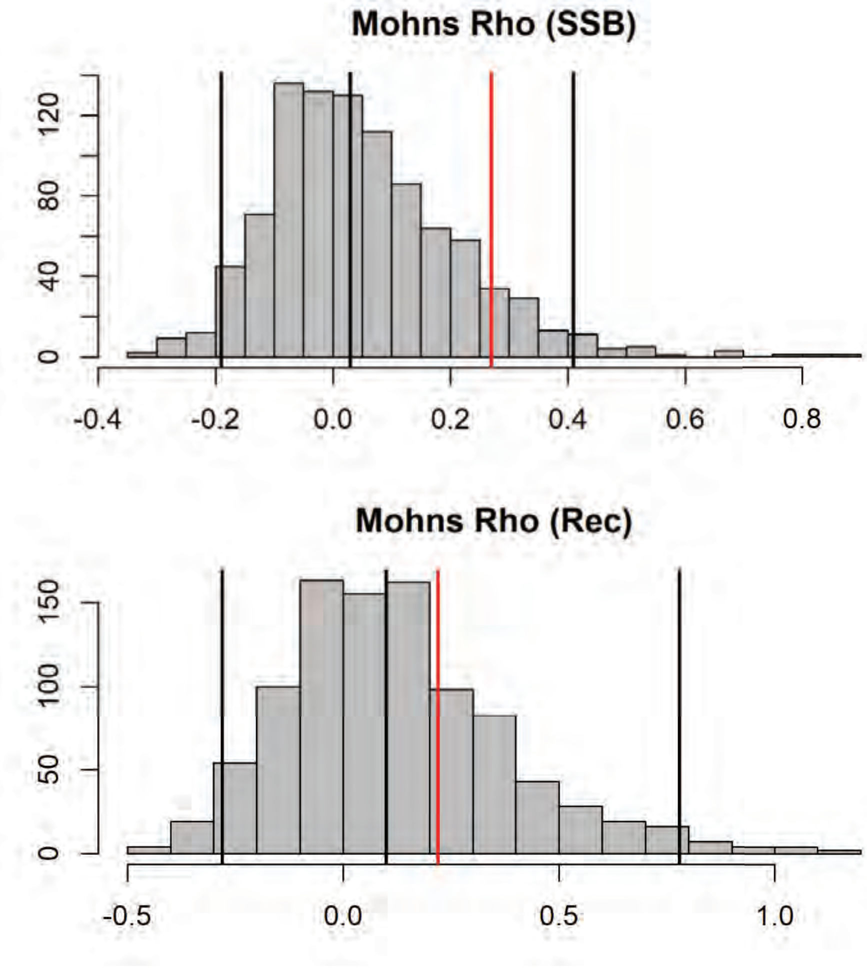
SSB	Sprat	Sandeel 1r	Sandeel 2r
Mohns Rho	🟨	🟥	🟥
Forecast	🟨	🟩	🟥
Moving window approach	🟩	🟥	🟥
Gradual corrections	🟩	🟥	🟥
First year correction	🟨	🟨	🟥

Recruitment	Sprat	Sandeel 1r	Sandeel 2r
Mohns Rho	🟨	🟩	🟥
Forecast	🟨	🟩	🟥
Moving window approach	🟩	🟩	🟥
Gradual corrections	🟨	🟨	🟥
First year correction	🟨	🟨 *	🟥

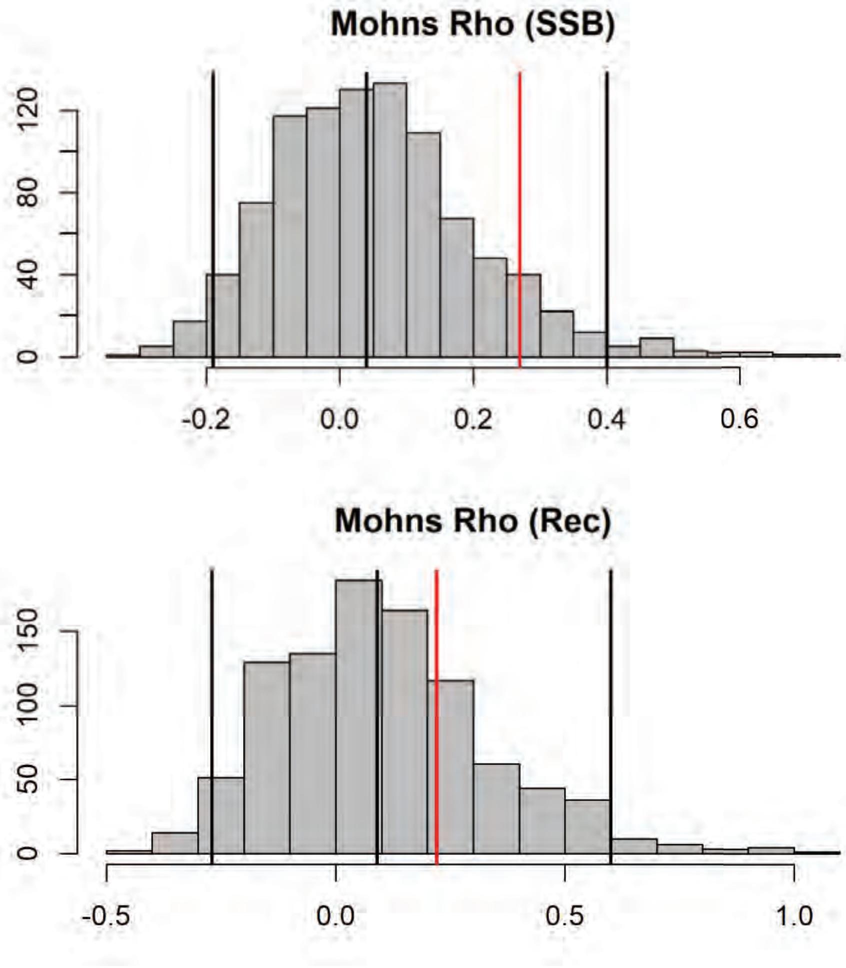
But does it matter if the stock is ”green”, ”yellow”, or ”red” if the it is accounted for in the management strategy?

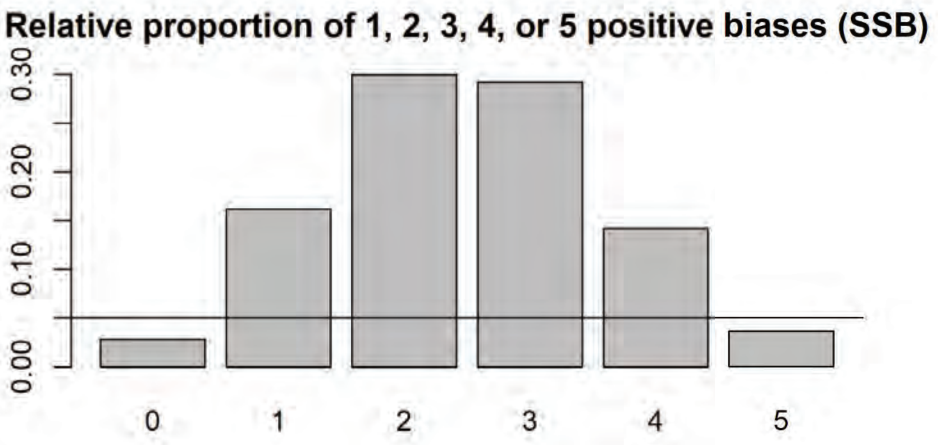
Analyzing retrospective bias in the MSE-output for North Sea sprat

2019-2024

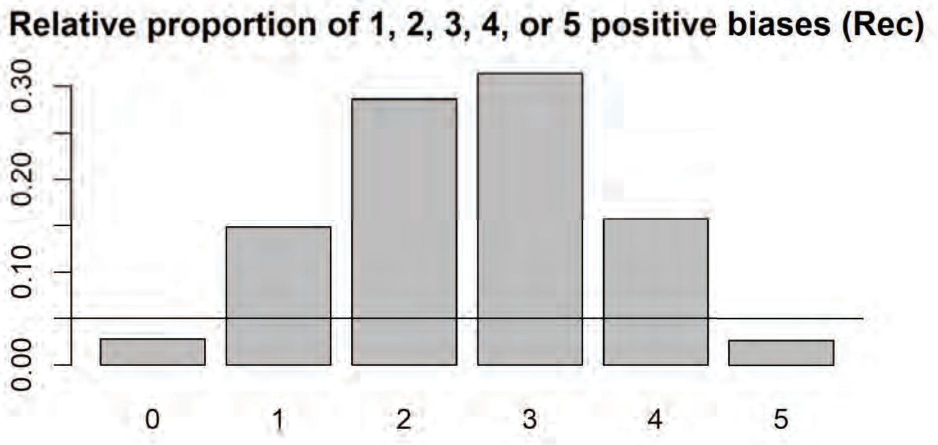


2040-2045

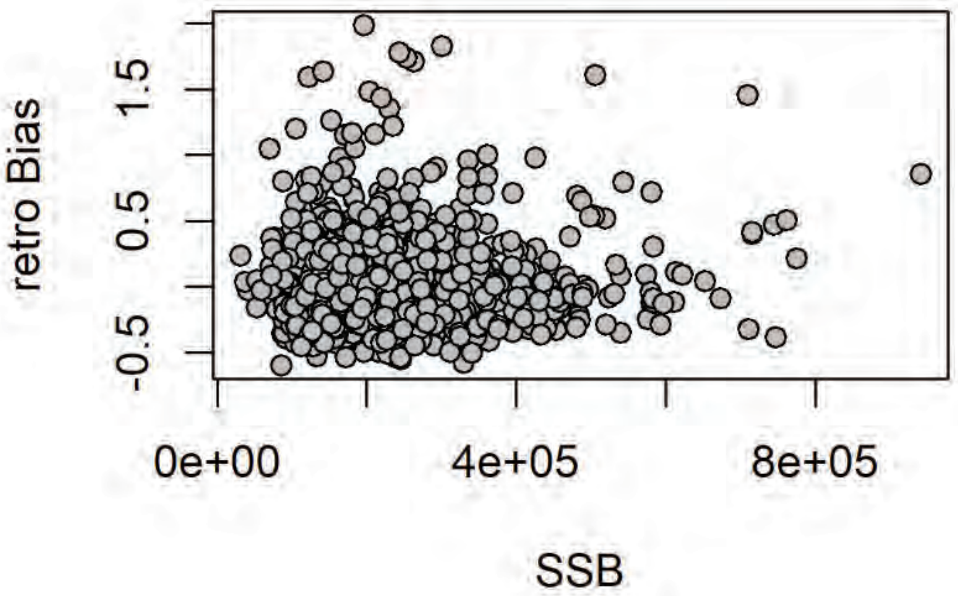


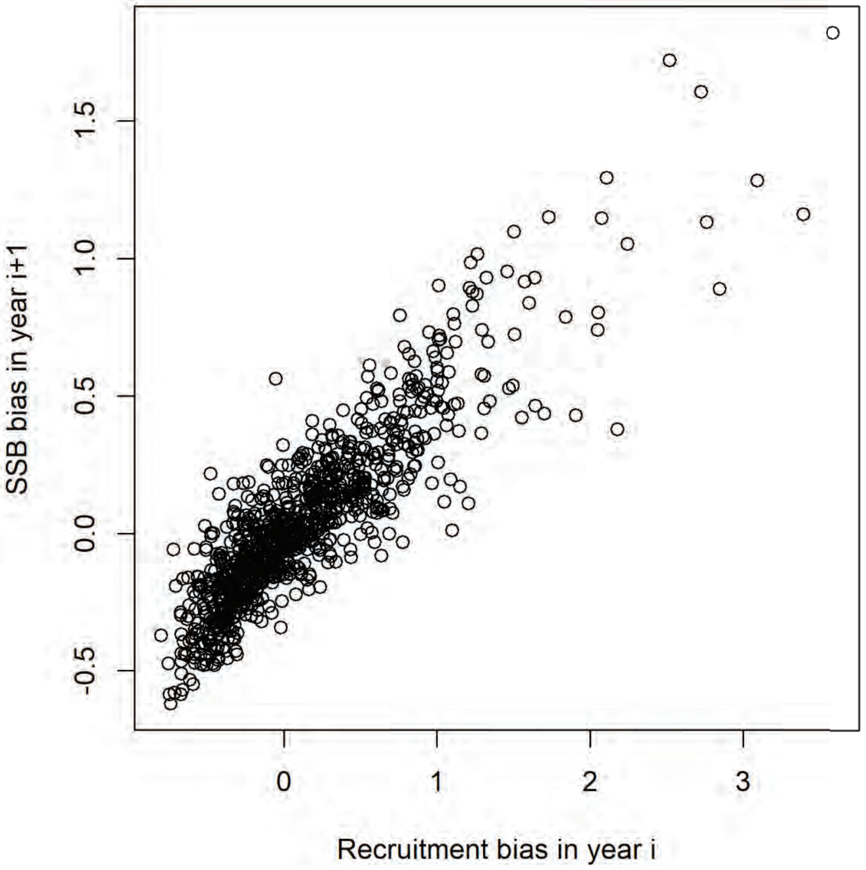


Relative proportion of 1, 2, 3, 4, or 5 positive biases (SSB)



Relative proportion of 1, 2, 3, 4, or 5 positive biases (Rec)


retro Bias
-0.5
0.5
1.5
0e+00
4e+05
8e+05
SSB


SSB bias in year i+1
-0.5
0.0
0.5
1.0
1.5
Recruitment bias in year i
0
1
2
3

Ideas for recommendations:

- Don´t judge based on Mohn´s Rho alone. As we saw for sandeel 1r we can have a very bad Mohn´s Rho, while other diagnostica looks fine.

- Use the MSE to determine if your Mohn´s Rho is too large. If it´s within what we see in the MSE it should already be accounted for… or if it´s within the unceratinty envelope of the assessment model

- Decide on a suite of useful diagnostic plots for the assessment working group to base their decisions on.

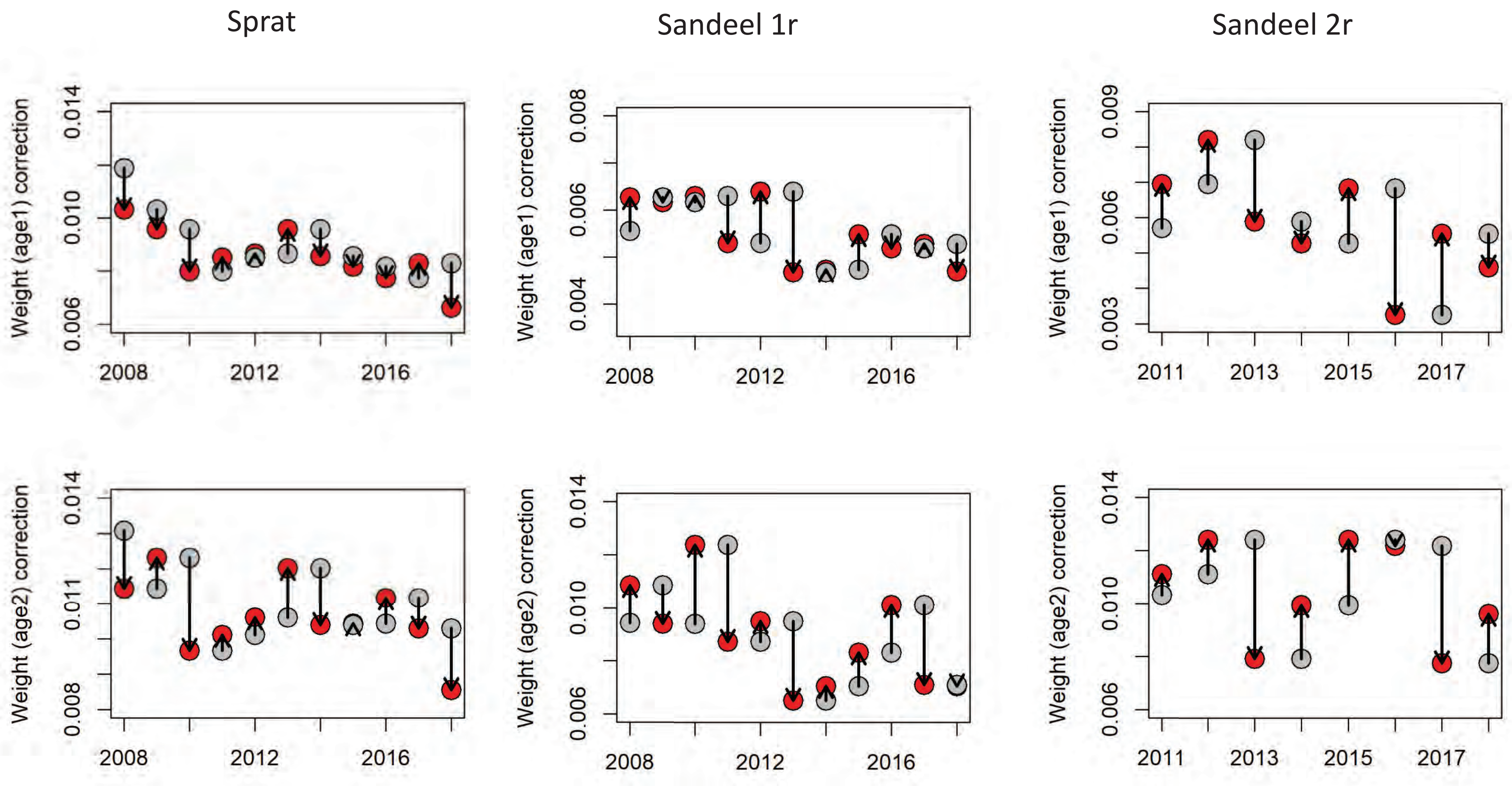
- Sometimes Mohn´s Rho is changing over time. So maybe be careful about adjusting with Mohn´s Rho (which trach past patterns), when forecasting the future.

- Could category-2 be used for those analytical assessment where retro-patterns is so bad, that the choice stands between degrading to cat-3 or adjust SSB/advice?

A bias issue may be related to very low stock stock size? Forecasting that the stock is 5000 and a very small or no TAC was given, when it is only 2500 is maybe less problemativ compared to a situation where the stock is forecasted to 500000 and it turns out to be 250000 and a huge TAC was given (this could be the problem for sandeel 2r).

Variation in weight at age and natural mortality….

If the source to retro can be many different things we can not solve it in one single way as with SSB adj….



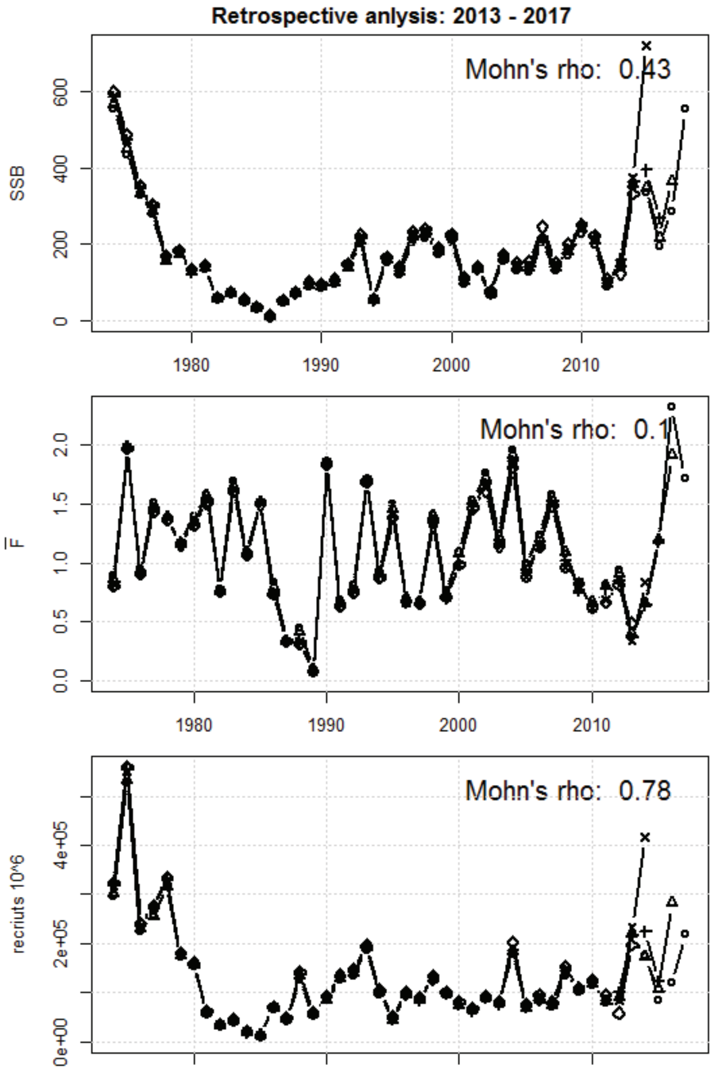
! I expected failure to predict weight-at-age was a major part of the problem, but that was not the case

Sprat before and after benchmark

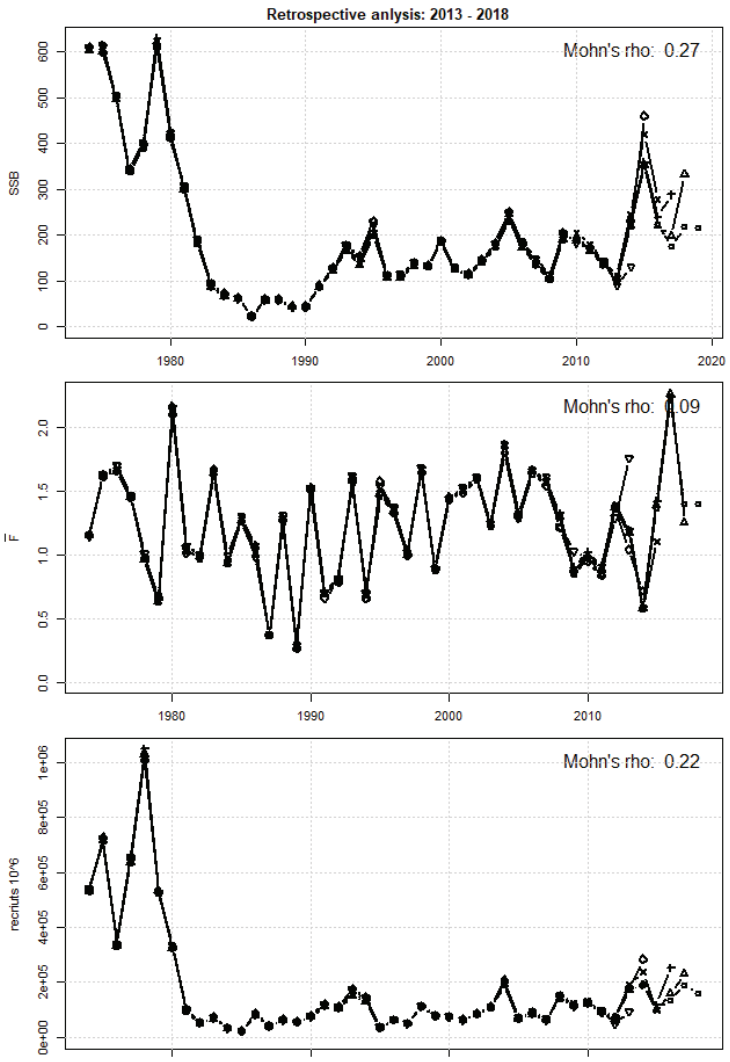
- Among other changes, we introduced a power model to describe the relationship between the recruitment index and recruitment

Sprat
before and after benchmark

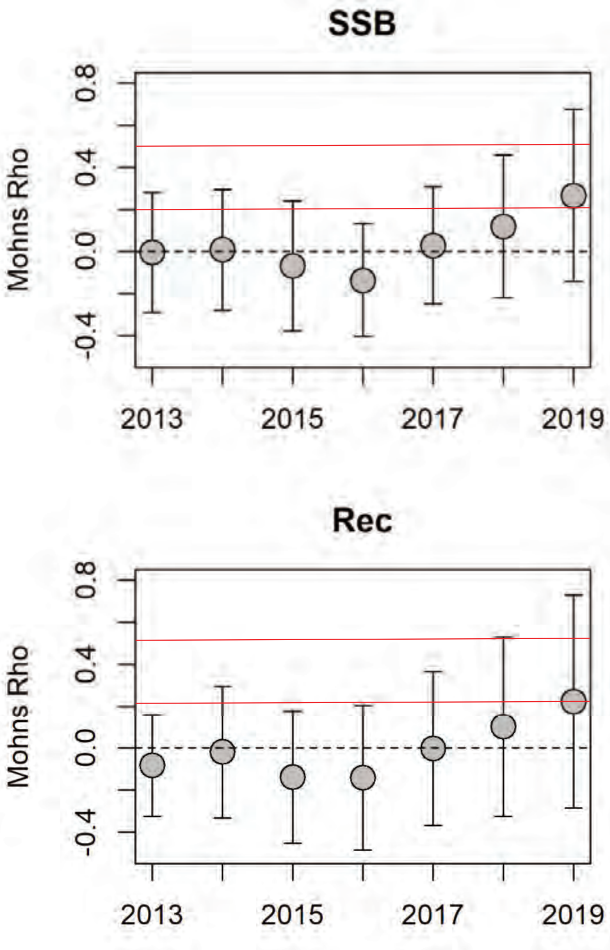
BEFORE:



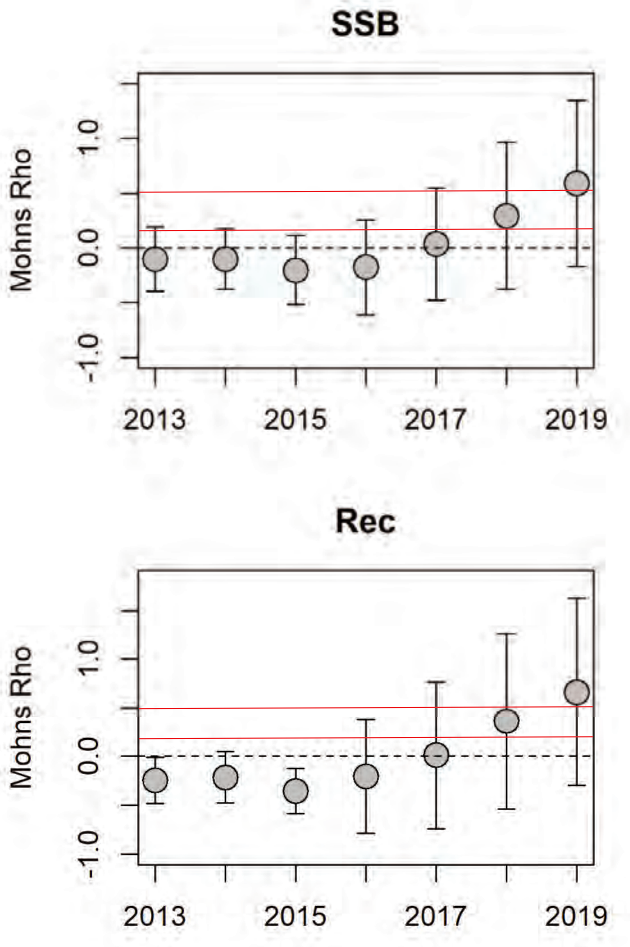
AFTER:



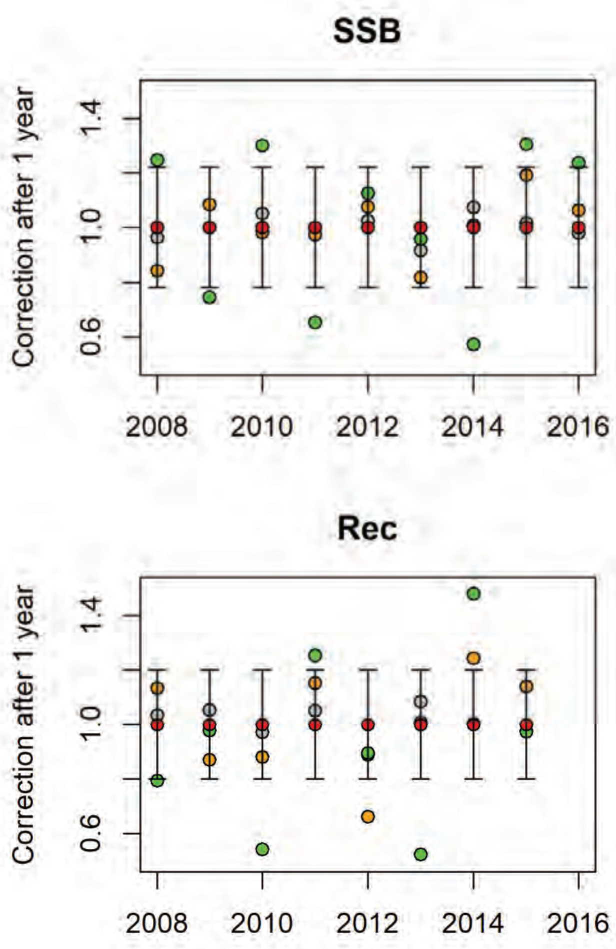
With Power Model



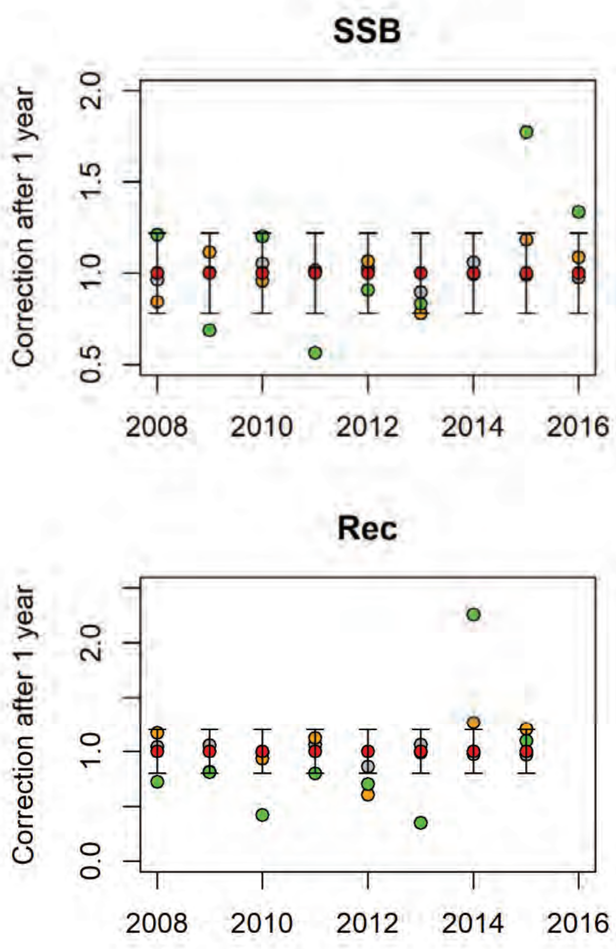
Without Power Model



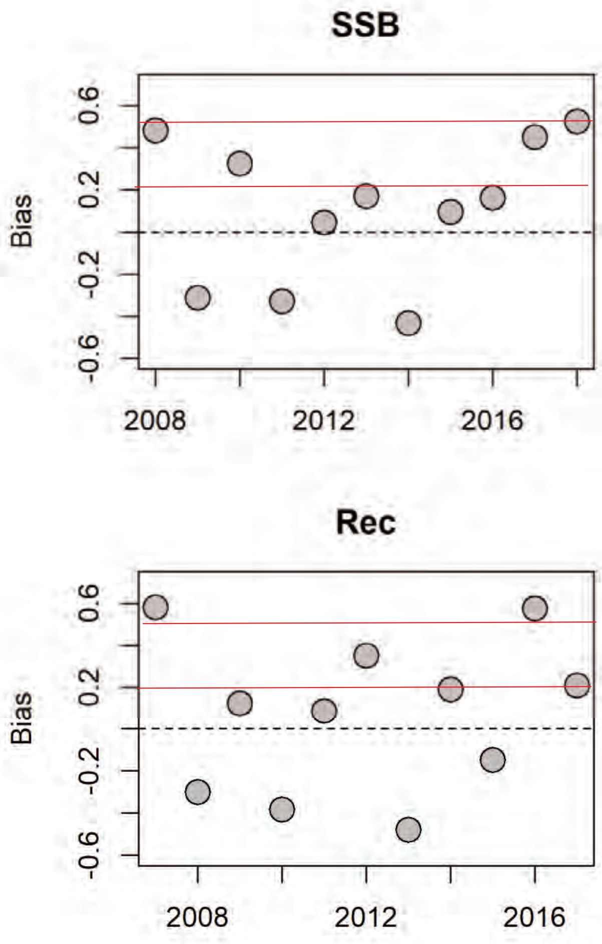
Sprat with Power Model

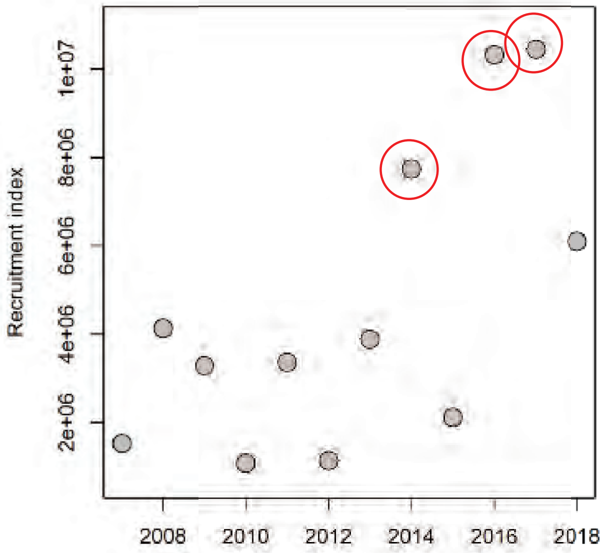


Sprat without Power Model

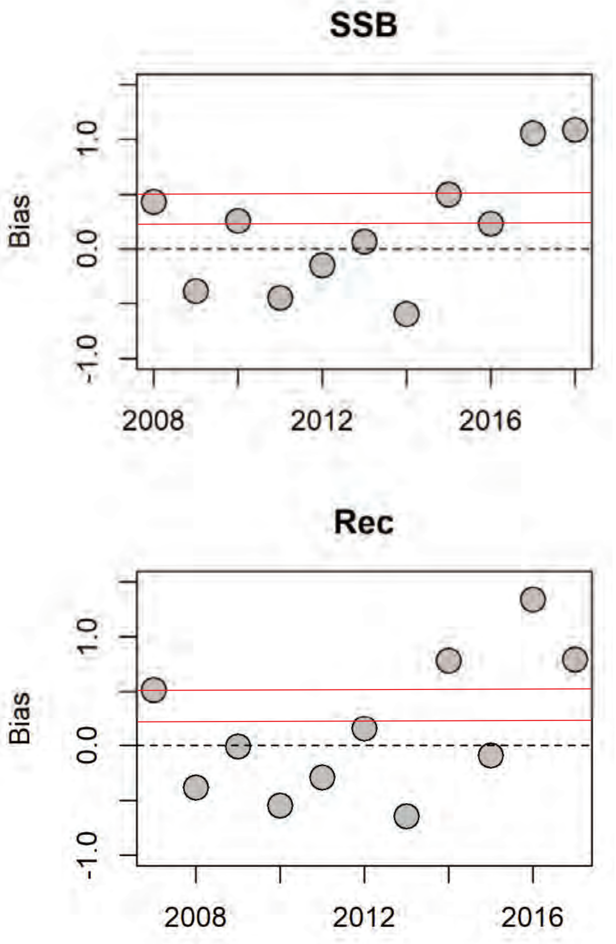


Sprat with Power Model





Sprat without Power Model



Thanks for listening

HAV & FISK

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