

Ascending elvers, *Anguilla anguilla*, from five European localities. Analyses of pigmentation stages, condition, chemical composition and energy reserves

Inge Boëtius & Jan Boëtius

The Danish Institute for Fisheries and Marine Research, Charlottenlund Castle,
DK-2920 Charlottenlund, Denmark

Abstract

Elvers from five European localities (32 samples, about 29,000 specimens) were determined for stage of pigmentation, total length and body weight. The greater part of the material was analysed for elementary chemical composition (water, lipid, protein, ash). Pigmentation studies indicated separate waves of invasion. Length/weight-relations combined with the chemical analyses enabled us to evaluate the total energy reserve per elver in the different areas of ascent.

Keywords: *Anguilla anguilla*, elvers, pigmentation, condition, chemical composition, energy.

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Material

Origin of samples. Ascending elvers (1984-87) were received from 5 European localities (areas). They are indicated on the map, Fig.1.

DENMARK, sample symbols: D1-D18. All samples were taken at Vidå-slusen, the sluice of Vidå, a small river flowing into the Waddensea a few kms north of the frontier between Denmark and Western Germany. (The Vidå sluice has replaced the elder sluice by Højer from where elver ascent was analysed by Boëtius (1976)).

SCOTLAND, sample symbol: Sc. Sample from river Laxford, NW Scotland.

ENGLAND, sample symbols: E1-E6. All samples originate from the Bristol Channel/river Severn ascent.

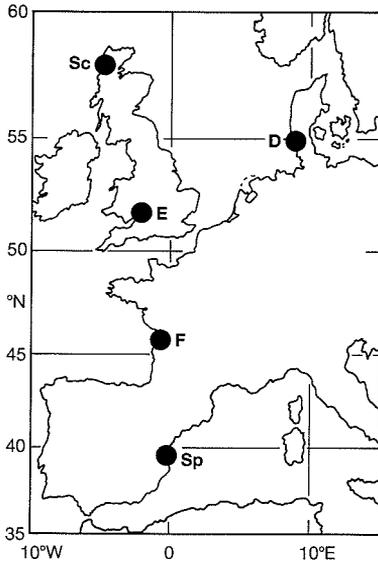


Fig. 1. Localities of samples.

FRANCE, sample symbols: F1-F6. All samples are from the central part of the French Atlantic area of ascent: Rochefort and Royan, river Seudre.

SPAIN, sample symbol: Sp. Elvers caught in the outflow from a lake about 5 kms south of Valencia.

Date of sampling. Samples D1-D18, Sc and E5 were frozen immediately after catch while the remaining samples were shipped live. They were caught 2 to 5 days ahead and at their arrival in the laboratory they were frozen immediately. In Table 1 the time of collection of the samples is given by year and the number of the week in which the catch took place.

Methods

The elvers were kept frozen for a maximum of 3 months before length/weight determinations were made soon after thawing of the material.

Total length was measured '1 mm below'. Weight was determined of each mm class. The index of condition (k) was calculated as $k = w/l^3 \cdot 10^3$, where w is the body weight (g) and l is the total length (cm). Mean indices of condition of the samples are given in Table 1.

Pigmentation. Stages of integumental pigmentation were determined according to the simplified principle described by Boëtius (1976) where the stages A-E include the development from the unpigmented glass eel to the fully pigmented elver. The percentual distributions of stages of the individual samples are given in Table 1.

Chemical analyses. Proximate analyses were made on homogenates of 20-50 g eels to which 50-100% water was added. Samples of approximately 2 g of homogenate

Table 1. Overview of samples, measurements and distribution of pigmentation stages.

Sample	Year	Week no.	N, nos of elvers	Total length, mm			Mean body wt, mg	Condition, <i>k</i>	Pigmentation stages [*] , %				
				mean	SE	range			A	B	C	D	E
D1	84	15	188	71.72	0.21	63-79	223	0.61	5.3	30.9	63.8	-	-
D2	84	16	112	70.77	0.26	64-76	212	0.60	-	0.9	83.0	16.1	-
D3	84	17	169	71.12	0.21	61-78	195	0.54	-	0.6	68.0	31.4	-
D4	84	18	184	71.30	0.23	59-78	202	0.56	-	1.6	64.7	33.7	-
D5	84	19	132	71.85	0.23	65-78	204	0.55	3.8	18.9	68.2	9.1	-
D6	84	20	284	71.61	0.17	63-81	196	0.53	-	-	10.2	86.3	3.5
D7	84	21	309	71.10	0.16	62-79	185	0.52	-	-	7.4	87.1	5.5
D8	84	22	285	71.96	0.17	63-79	204	0.55	0.4	2.1	54.7	42.8	-
D9	85	20	993	71.98	0.08	62-81	116	0.31	-	-	3.0	92.5	4.4
D10	86	18	808	71.96	0.10	63-83	175	0.47	-	-	13.0	87.0	-
D11	86	20	785	72.21	0.10	63-82	192	0.51	-	-	15.3	84.7	-
D12	86	21	1474	71.05	0.07	62-80	180	0.50	2.6	6.2	68.0	23.2	-
D13	87	17	795	70.37	0.10	60-79	207	0.59	-	-	15.8	84.2	-
D14	87	18	777	70.48	0.11	61-78	206	0.59	2.2	7.3	68.7	21.8	-
D15	87	19	946	70.14	0.09	62-79	195	0.57	0.1	0.7	28.5	70.6	-
D16	87	20	689	69.92	0.11	61-78	196	0.57	0.3	1.5	79.7	18.6	-
D17	87	21	985	70.21	0.09	61-78	204	0.59	3.3	6.4	66.4	24.0	-
D18	87	22	870	70.88	0.10	59-79	199	0.57	0.7	1.5	64.4	33.4	-
Sc	86	26	695	69.10	0.12	58-79	225	0.68	-	-	-	29.4	70.6
E1	85	17	509	68.56	0.17	59-77	258	0.80	-	0.5	84.1	15.3	-
E2	85	24	3442	68.05	0.05	57-78	214	0.68	-	-	45.5	54.5	-
E3	86	13	729	68.96	0.14	57-80	284	0.87	35.5	28.0	36.5	-	-
E4	86	16	825	72.46	0.13	60-84	324	0.85	41.9	25.3	32.4	0.4	-
E5	86	22	864	69.50	0.11	59-81	183	0.55	-	-	16.8	83.1	-
E6	87	15	1659	69.33	0.09	58-80	240	0.72	0.1	1.0	82.8	16.2	-
F1	84	51	544	68.02	0.15	57-77	310	0.99	-	0.6	97.3	2.1	-
F2	85	7	484	69.57	0.18	56-80	259	0.77	53.6	18.1	28.2	-	-
F3	85	51	917	68.17	0.13	55-80	295	0.93	84.2	11.2	4.6	-	-
F4	86	2	416	70.01	0.21	55-81	313	0.91	85.6	10.6	3.8	-	-
F5	86	50	2280	68.77	0.07	56-82	288	0.89	74.3	11.8	13.9	-	-
F6	87	2	1680	68.77	0.09	57-80	317	0.97	97.5	1.8	0.7	-	-
Sp	84	49	3025	68.15	0.06	55-79	316	1.00	48.5	40.6	10.8	0.1	-

* the number of elvers used for determination of pigmentation stages are given in column N except for the samples E1, E2, F1, F2 and Sc where the numbers are 1049, 719, 1356, 1314 and 1955 respectively.

were used for determinations of dry matter, lipid (L), total nitrogen (N), non-protein nitrogen (NPN) and ash.

Samples for dry matter determinations were placed for 24 hrs in an incubator (40-50°C) and afterwards for 24 hrs in a vacuum desiccator. Lipid analyses were made by a slightly modified Bligh & Dyer (1959) method (water:methanol:chloroform extraction). N was determined by the Kjeldahl method using a Kjeltex System I equipment. NPN was determined by Kjeldahl after precipitation of the proteins by a 15% solution of trichloroacetic acid. Samples for ash determinations were treated for 24 hrs in an incubator at 105°C and afterwards for 4 hrs at 600°C in a muffle furnace.

All the data are expressed as percentage of wet body weight. Protein, P, is calculated as (N-NPN) 6.025, the conversion factor is adopted from Love (1970), footnote p. 238.

Primary data of length/weight, pigmentation stages and chemical composition are given in Boëtius & Boëtius (1989).

Indication of 'waves' of ascent based on pigmentation stages

Danish material

Introductorily is given (in Fig. 2) the daily catches of the years 1984-87. They were made by night from the Vidå sluice by means of horizontal nets and by artificial light. As is seen great fluctuations occur and the ascent in 1985 is almost negligible.

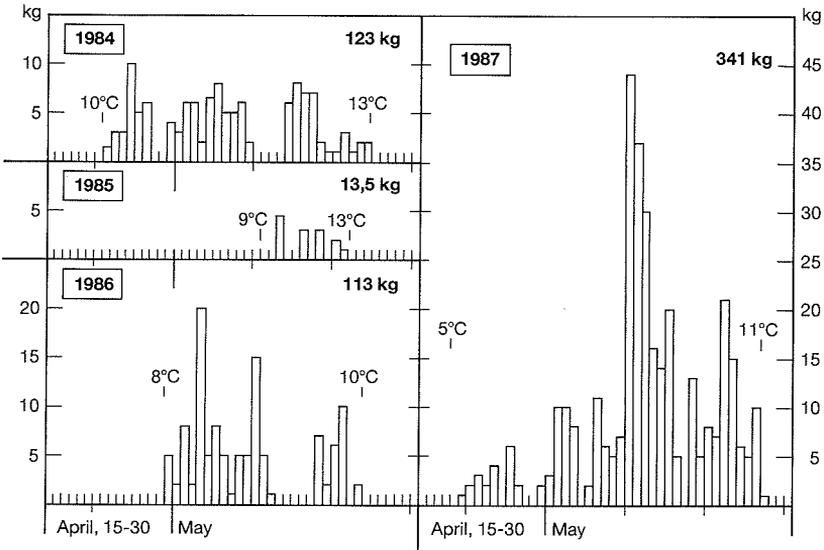


Fig. 2. Denmark, the Vidå Sluice. Daily catches of elvers 1984-87. Total catch of the season is given in the upper right corner of each diagram. Water temperatures of start and end of the period of ascent are indicated.

In Fig. 3 the distributions of pigmentation stages of the individual D-samples are placed against time of sampling (week no.).

Stage C is present in all samples. A 'wave of invasion' is indicated when younger stages (A+B) appear or increase when compared with the previous sample. According to this principle 'waves' are indicated between the following samples:

1984	D4/D5	weeks	18/19
1986	D11/D12	-	20/21
1987	D13/D14	-	17/18
-	D16/D17	-	20/21

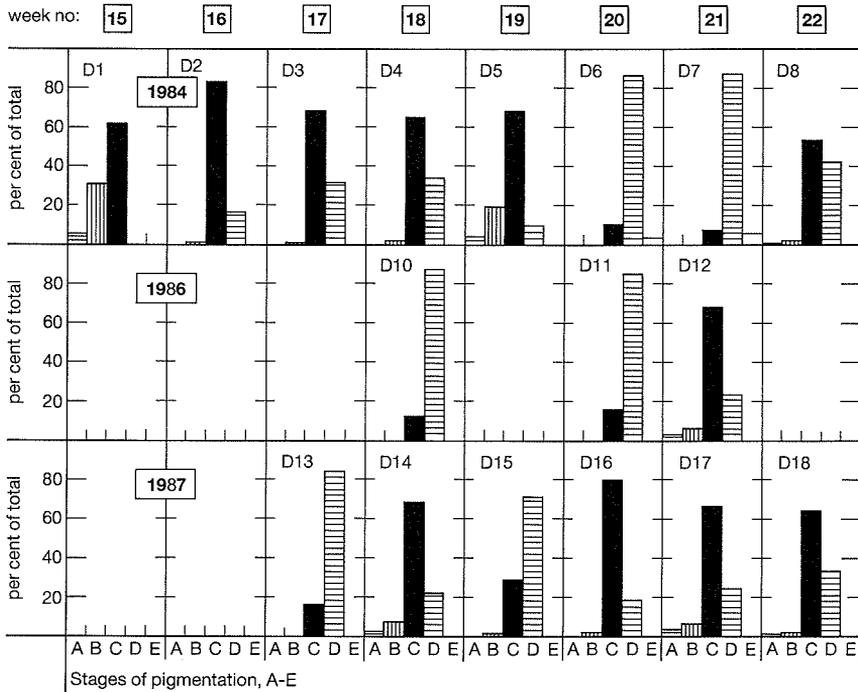


Fig. 3. Denmark. Distribution of pigmentation stages A-E per sample.

An analysis of the elver ascent in 1972 at the mouth of the river Vidå was made by Boëtius (1976). From a statistical evaluation of this material Harding (1985) was able to conclude: 'It is found that the material can be represented as a mixture of at least two, possibly three, distinct groups, each with its own distribution of length and TNV.' (TNV = total number of vertebrae). The present findings based on pigmentation stages are in agreement with the above cited results of Harding's.

French and English material

This material is presented in Fig. 4. For indication of invasion waves this material is rather poor. The French material, however, indicates that during the 1984-85 ascent, an invasion has taken place between samples F1 and F2 (weeks 51 and 6) and most likely also during the 1986-87 ascent, between samples F5 and F6 (weeks 50 and 2). In the English material only samples E3 and E4 indicate an intermediate invasion.

Total lengths of pigmentation stages

The total lengths of pigmentation stages are given in Table 2. 86 of the subsamples comprise 10 or more elvers. Based on these the following general view can be given according to the number of subsamples in which total lengths have either increased or decreased when the elvers develop from one stage of pigmentation to the next.

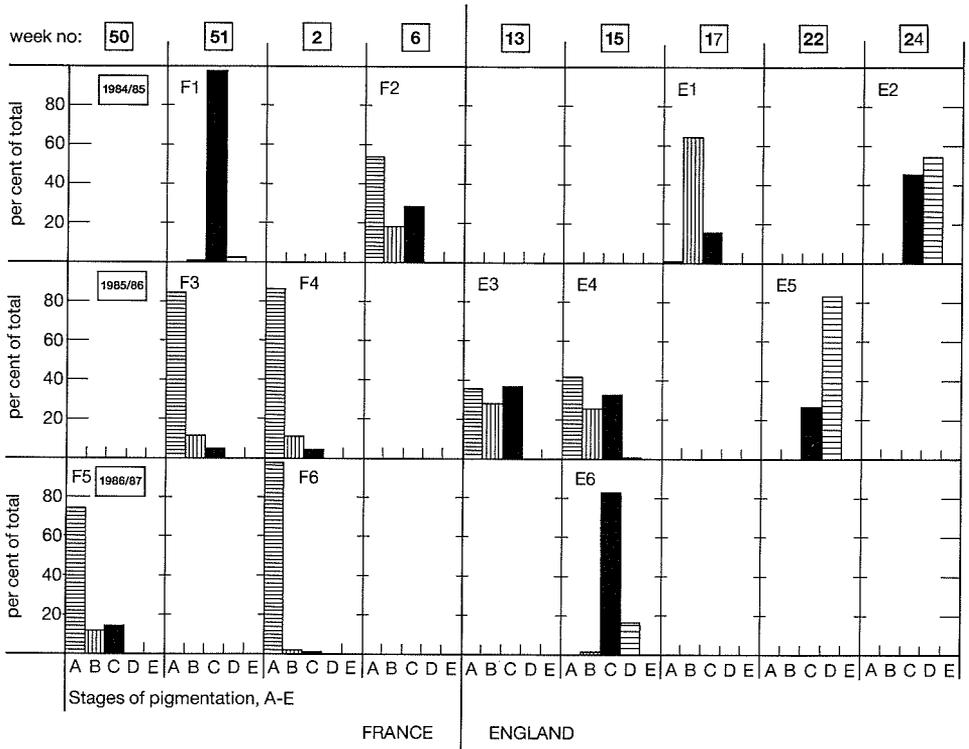


Fig. 4. France, England. Distribution of pigmentation stages A-E per sample.

	A-B	B-C	C-D	D-E
Increase	10	7	11	4
Decrease	2	9	11	0

Except for a rather clear increase from stage A to B and D to E total lengths remain almost unaltered during development.

From Table 2 it is seen that the stage C is represented in all samples investigated except for the Scottish (Sc). Keeping to stage C, the mean of means of total lengths from the 18 Danish samples (71.16 ± 0.16 (SE) mm) surpass that of the 13 samples from England, France and Spain (69.21 ± 0.36 (SE) mm) by about 2 mm.

Length/weight relations

Denmark. Length/weight data are presented in Fig. 5, each year of sampling given separately.

The samples from 1984, 86 and 87 show great similarity. With reference to Table 1 the indices of condition (k) of these samples range from 0.47 to 0.61.

The 1985 sample (D9, $k = 0.31$), however, forms a special case. Referring to Fig. 2 in this year the ascent at the Vidå was very poor and the D9-sample was taken late in the season. It is not included in the summarizing diagram Fig. 7.

Table 2. Total lengths of pigmentation stages A-E.

Sam- ple	Stage A total length,mm		Stage B total length,mm		Stage C total length,mm		Stage D total length,mm		Stage E total length, mm	
	n	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE
D1	10	69.70±0.87	58	71.21±0.37	120	72.14±0.26	-	-	-	-
D2	-	-	1	68	93	70.73±0.28	18	71.11±0.73	-	-
D3	-	-	1	70	115	70.84±0.28	53	71.73±0.28	-	-
D4	-	-	3	75.0	119	71.27±0.27	62	71.16±0.41	-	-
D5	5	71.2	25	71.82±0.46	90	71.90±0.29	12	71.58±0.77	-	-
D6	-	-	-	-	29	71.74±0.60	245	71.59±0.18	10	71.80±1.02
D7	-	-	-	-	23	71.59±0.48	269	71.05±0.18	17	71.21±0.59
D8	1	74	6	70.5	156	71.64±0.23	122	72.36±0.25	-	-
D9	-	-	-	-	30	71.93±0.65	919	71.98±0.09	44	72.18±0.32
D10	-	-	-	-	105	71.59±0.28	703	72.02±0.11	-	-
D11	-	-	-	-	120	71.94±0.27	665	72.25±0.11	-	-
D12	38	70.53±0.40	92	71.32±0.28	1002	71.01±0.09	342	71.18±0.16	-	-
D13	-	-	-	-	126	70.94±0.24	669	70.34±0.11	-	-
D14	17	69.79±0.53	57	70.24±0.37	534	70.54±0.13	169	70.42±0.24	-	-
D15	1	74	7	71.0	270	70.13±0.18	668	70.12±0.11	-	-
D16	2	69.5	10	69.40±0.82	549	69.86±0.12	128	70.20±0.25	-	-
D17	32	70.00±0.44	63	70.63±0.35	654	70.23±0.11	236	70.07±0.19	-	-
D18	6	70.5	13	71.35±0.79	560	70.82±0.11	291	70.96±0.19	-	-
Sc	-	-	-	-	-	-	204	68.92±0.22	491	69.18±0.15
E1	1	73	3	68.7	435	68.69±0.17	70	67.60±0.42	-	-
E2	-	-	-	-	327	68.14±0.16	392	68.61±0.16	-	-
E3	259	68.52±0.23	204	69.48±0.25	266	69.00±0.23	-	-	-	-
E4	346	72.78±0.19	209	72.65±0.25	267	71.93±0.25	3	69.0	-	-
E5	-	-	-	-	145	68.85±0.26	718	69.64±0.12	1	65
E6	2	65.0	16	69.56±1.06	1373	69.38±0.10	268	69.11±0.22	-	-
F1	-	-	3	69.0	529	68.04±0.15	12	67.00±1.29	-	-
F2	279	69.29±0.24	82	69.77±0.46	123	70.09±0.34	-	-	-	-
F3	772	68.23±0.14	103	67.87±0.39	42	67.59±0.57	-	-	-	-
F4	356	69.83±0.23	44	70.93±0.50	16	71.44±1.40	-	-	-	-
F5	1695	68.70±0.09	269	69.17±0.19	316	68.81±0.19	-	-	-	-
F6	1638	68.74±0.09	31	70.31±0.54	11	69.41±0.56	-	-	-	-
Sp	275	67.50±0.19	225	68.10±0.23	61	68.40±0.34	-	-	-	-

Scotland/England and France/Spain. In the double diagram, Fig. 6, the total of determinations are kept together regardless of the year of sampling.

The English material represents elvers with indices of condition ranging from 0.72 to 0.87, in the French material the corresponding range is 0.89 to 0.99.

Two samples, E5 and F2, are given separately. Both are 'late samples' with low indices of condition (0.55 and 0.77 respectively). Like sample D9 they are not included in Fig. 7.

Note from Fig. 6 that the Scottish sample ($k = 0.68$) takes up a low position when compared with the English material, while the Spanish ($k = 1.00$) is found at the top of the French.

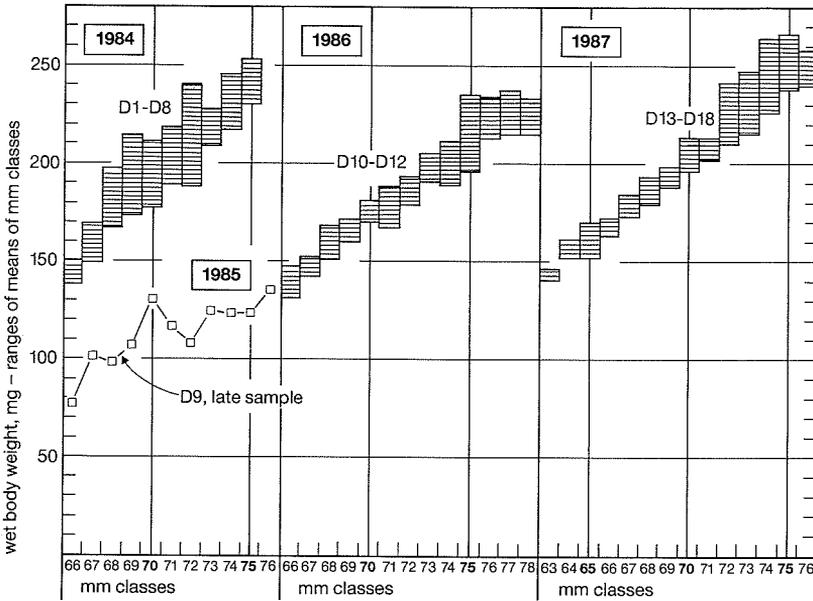


Fig. 5. Denmark. Length/weight relations in separate years.

General. In Fig. 7 the total amount of length/weight data (except the samples D9, E5 and F2) is presented. E + Sc and F + Sp samples have been pooled.

The figure demonstrates markedly differences in condition between the areas Denmark, UK and France/Spain.

Chemical constitution, energy

An outline of the 'proximate analyses' is given in Table 3. Water and protein contents do not vary much between the different samples. Lipid contents, however, are increasing remarkably from the Danish 1.50% via the English 2.65% and up to the French 3.82%. Scotland and Spain only represented by one sample each fit nicely in between the English and French values. The continuous decline in ash contents from Danish to Spanish samples (2.55% to 1.50%) is inversely proportional to the indices of condition.

A clearer picture of the geographical distribution of the conditions at which elvers ascend is achieved at, when the body weight data from Table 1 are combined with the chemical data from Table 3. This is shown in Table 4 where the chemical determinations are converted into energy reserves using the conversion factors from Kleiber (1975): 1 g lipid 9.5 Cal, 1 g protein 5.7 Cal.

From the last column in Table 4 it is evident that an elver ascending in the so called target area of the European ascent (French Atlantic area) represents a total amount of energy per elver twice as big as that of an elver ascending at the western coast of Denmark.

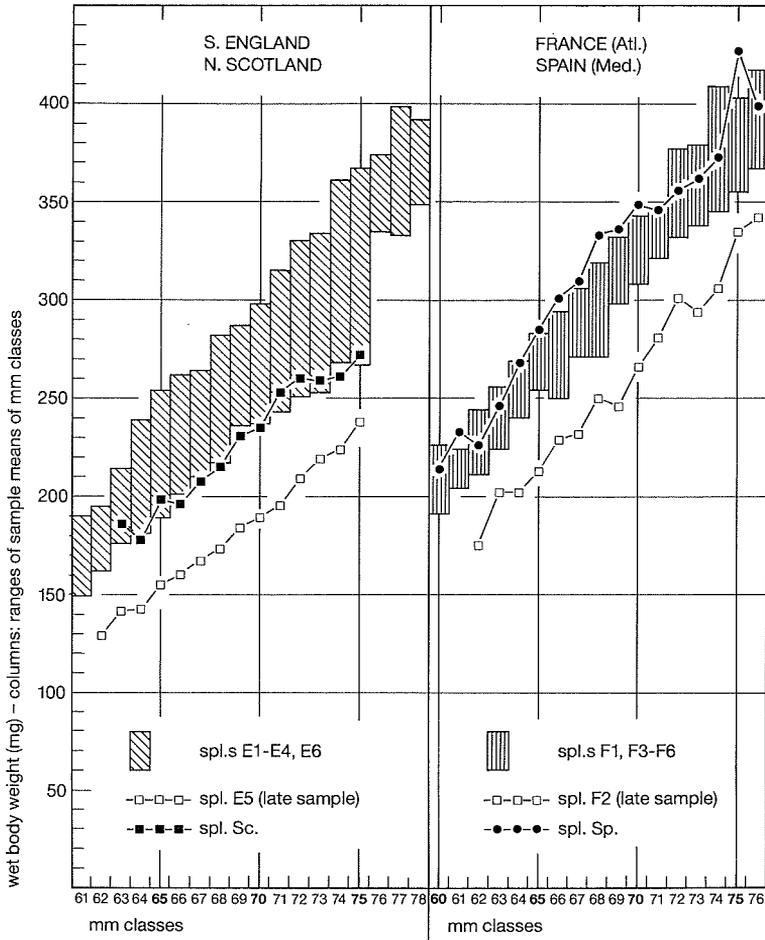


Fig. 6. England/Scotland and France/Spain. Length/weight relations of total material.

Discussion

It is not known if the condition of the metamorphosing eel larvae is the same in the southern and the northern part of their distribution. Even if all newly metamorphosed glass eels are in the same condition, the time passing until their ascent will differ much. In the southern part of the distribution area the glass eels will be able to ascend at any time of the year. Thus in Portugal Weber (1985) has recorded glass eels all year round although in very varying quantities.

Ascent of elvers will normally take place at water temperatures 7-9°C. In France and England the main ascent will take place from December to April while the ascent in Denmark normally starts in late April or the beginning of May. This means that elvers arriving here are forced to stay off-shore, where they are supposed to starve. When water temperatures allow the ascent, the elvers will be in a poor con-

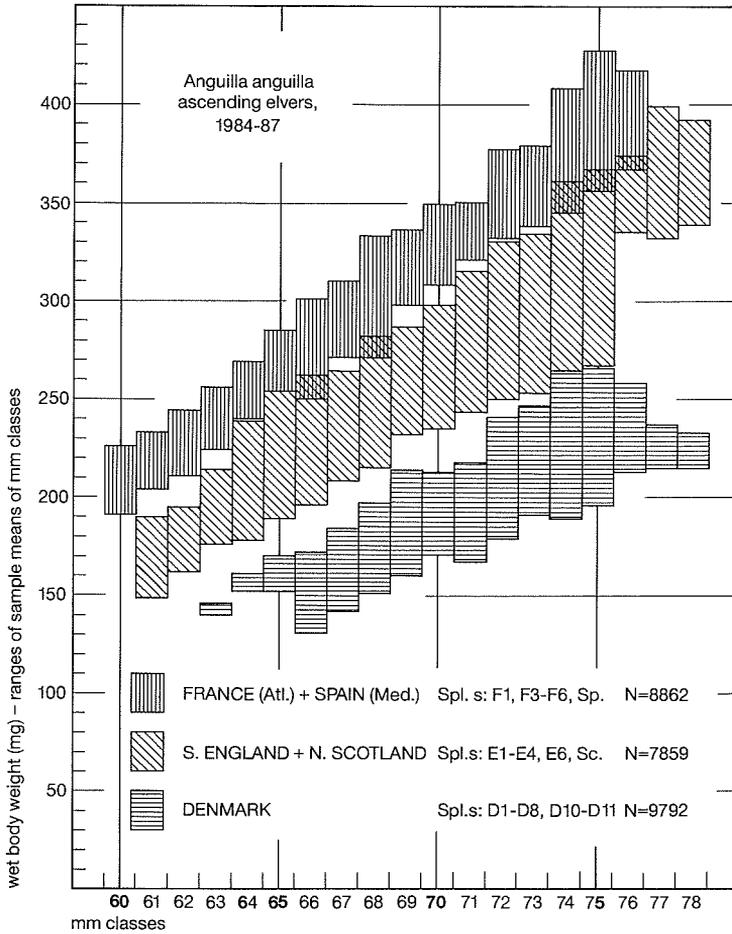


Fig. 7. Length/weight relations of total material from all five localities exclusive of samples D9, E5 and F2.

dition. The decline in condition from France/Spain over England/Scotland to Denmark as shown in Fig. 7 could be explained by the time the glass eels have to spend off-shore. The higher percentage of A-stages (true glass eels) in the France/Spain samples also indicate an ascent soon after metamorphosis.

Table 3. Outline of 'proximate analyses'.

	Country	Nos of elver spl.s	Nos of homo-gen.s	Determinations			
				N	Mean	SE	Range
Water	Denmark	18	51	305	77.96	0.10	75.5-82.6
	Scotland	1	4	24	77.55	0.14	76.7-79.1
	England	6	22	132	78.47	0.14	75.5-81.0
	France, Atl.	6	23	138	75.93	0.15	73.0-79.4
	Spain, Med.	1	6	36	78.90	0.14	77.8-81.0
Lipid	Denmark	17	51	196	1.50	0.03	0.75-2.11
	Scotland	1	4	16	2.93	0.05	2.53-3.31
	England	6	23	88	2.65	0.04	1.63-3.27
	France, Atl.	6	20	75	3.82	0.10	2.56-4.43
	Spain, Med.	1	6	27	2.72	0.10	1.77-3.56
Protein	Denmark	18	52	155	13.66	0.08	11.7-16.9
	Scotland	1	4	12	13.80	0.10	13.4-14.4
	England	6	23	69	13.11	0.14	10.9-15.3
	France, Atl.	6	23	68	14.29	0.15	12.0-16.4
	Spain, Med.	1	6	17	12.28	0.08	11.9-12.9
Ash	Denmark	16	48	286	2.55	0.03	2.06-3.13
	Scotland	1	4	24	2.15	0.03	1.96-2.39
	England	6	23	135	1.85	0.04	0.96-2.67
	France, Atl.	6	23	136	1.74	0.03	1.39-2.10
	Spain, Med.	1	6	35	1.50	0.03	1.26-1.72

Table 4. Estimates of total energy (lipid + protein) of ascending elvers.

	Mean body weight [*] , mg	mg lipid per elver ^{**}	mg protein per elver ^{**}	Energy J/elver
Denmark	199	2.99	27.18	767
Scotland	225	6.59	31.05	1003
England	264	7.00	34.61	1104
France, Atl.	307	11.73	43.87	1513
Spain, Med.	316	8.60	38.80	1267

* mean of means from Table 1 (excl. of spl.s D9, E5 and F2)

** calculated from means given in Table 3.

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References

- Bligh, E.G. & W.J. Dyer, 1959: A rapid method of total lipid extraction and purification. – Can. J. Biochem. Physiol. 37: 911-917.
- Boëtius, I. & J. Boëtius, 1989: Primary data of length/weight, pigmentation stages and chemical composition in ascending elvers, *Anguilla anguilla*. – DFH-rapport nr. 360.
- Boëtius, J., 1976: Elvers, *Anguilla anguilla* and *Anguilla rostrata* from two Danish localities. Size, body weight, developmental stage and number of vertebrae related to time of ascent. – Meddr Danm. Fisk.- og Havunders. N.S. 7: 199-220.
- Harding, E.F., 1985: On the homogeneity of the European Eel population (*Anguilla anguilla*). – Dana 4: 49-66.
- Kleiber, M., 1975: The fire of life. – R.E. Krieger Publ. Comp. New York.
- Love, R.M., 1970: The chemical biology of fishes (vol. 1). – Academic Press, London and New York.
- Weber, M., 1985: Catching method and seasonal occurrence of glass eels in the Rio Minho. – European Inland Fisheries Advisory Commission (FAO) Eel Working Group, Perpignan, France 1985.