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VIE ET MILIEU, 1986, 36 (4)

SOMMAIRE — *SUMMARY*

Les référés suivants ont examiné les manuscrits publiés dans le tome 36. La rédaction leur exprime sa reconnaissance pour leurs analyses et leurs critiques.

The following persons have reviewed manuscripts published in volume 36. Their constructive comments have been valuable for the authors and are gratly appreciated by the editorial board.

G. Bachelet, Bordeaux; A. Baudière, Toulouse, C. Berger, Hambourg; Ph. Bodin, Brest; J.Y. Bodiou, Banyuls-sur-Mer; C.F. Boudouresque, Marseille; P.R. Boyle, Aberdeen; L.D. Brongersma, Leiden; C. Combes, Perpignan; H. Descimon, Marseille; J.M. Demange, Paris; R. Duguy, La Rochelle; A. Fournier, Perpignan; M. Gennesseaux, Paris; B.M. Gilchrist, Londres; Ph. Gros, Brest; H. Kunz, Bischmisheim, RFA; L. Laubier, Paris; R. Lecomte, Perpignan; R.H. Millar, Oban Argyll; C. Moriarty, Dublin; R.C. Newell, Plymouth; J. Nielsen, Copenhague; R.K. O'Dor, Halifax; D. Prieur, Brest; R. Prodon, Banyuls-sur-Mer; A. Saliot, Paris; T.W. Snell, Tampa; A. Tamisier, Arles; C. Thiriot, Villefranche-sur-Mer; F.W. Tesch, Hamburg; H. Wickström, Drottningholm.

AVANT-PROPOS — FOREWORD

The fourth issue of Volume 36 of Vie et Milieu *contains papers presented during the Working Party on Eel of the EIFAC (FAO). The W. P. was held from September 17th to 19th, 1986 in Perpignan. It was attended by 60 scientists and experts from 15 European countries, Israel, Canada and P.R. China. In conjunction with the W. P., a Workshop on Eel Aquaculture took place from September 20th to 21st, 1986 which was convened by J. Hodal, Denmark.*

Since 1975, a working-party, working group or workshop on eel has taken place nearly every year either under the auspices of EIFAC or ICES or both organisations joint. Hardly any published information on these meetings is available, even though many valuable contributions were submitted. The high level of participation in the 1986 Working Party and the quality of the papers submitted called for a publication of the major part of these contributions, and the participants extend their gratitude to the editor of Vie et Milieu for offering his journal as publication organ.

The contributions of this issue comprise complete papers or summaries of papers not quite to the purpose of this issue or otherwise published elsewhere. Most of the summaries refer to the poster presentations. They comprise, in the main, the last six contributions and were prepared by participants of the Laboratoire de Biologie Marine in Perpignan; they demonstrate, for the major part, problems relevant to the Workshop on Eel Aquaculture.

For some years, one of the main subjects of the W. P. has been the recruitment of the European-African continent with larvae and glass eels. The first six contributions are concerned with these problems. They reflect the recent decline of recruitment in the central and northern parts of Europe.

The following 13 papers and summaries cover the large field which is generally designed « resource management and stock assessment ». Aging problems, which provided the start of this Working Party under its recent Chairman C. J. McGrath, are also included. Methods of tagging are considered, but only in summary as the paper on this subject needed more extensive and cooperative studies.

The third section of the W. P. with three papers is introduced by a paper on fishing techniques, which was the topic of the very first EIFAC meeting on Eel in 1970. Other topics on problems of the eel, such as damage to the eel by turbines, and ecology studies on outer European eel species are included in this section.

The participants of the W. P. are indebted to the organizer of the meeting in Parc Ducup in Perpignan, Prof. J. Truslé, Director of the Laboratoire de Biologie Marine of the University in Perpignan, and his staff. Special thanks are due to Mme R. Lecomte Finiger who was involved full time for many days in the organization of the W. P. She also assisted in the preparation of the French texts.

Three referees contributed to the preparation of this issue : C. Moriarty, Ireland, J. Nielsen, Denmark, and H. Wickström, Sweden. They also presided at the meetings of the three sections of the W.P. C. Moriarty, Ireland and C. Berger, Hamburg, revised the English texts.

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VIE MILIEU, 1986, 36 (4) : 233-235

VARIATIONS IN ELVER ABUNDANCE AT EUROPEAN CATCHING STATIONS FROM 1938 TO 1985

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A. ANGUILLA
ELVERS
ABUNDANCE
ANNUAL FLUCTUATIONS

ABSTRACT. — Annual figures are presented for total catch or abundance of glass eels, elvers and young eels from nine countries. The dominant feature and the only one in which the data from all participating countries agree is a severe decline in abundance during the years 1981 to 1985 inclusive. A similar decline was observed in the Netherlands from 1946 to 1950 but no data are available for this period from the other countries. Close agreement is reported between fluctuations in catch in the River Ems in Germany and the abundance of larval eels off the western coast of Europe but in other cases the results are remarkable in the absence of correlation in annual abundance between catching stations.

A. ANGUILLA
CIVELLES
ABONDANCE
VARIATIONS ANNUELLES

RESUMÉ. — Les prises totales ou abondance de civelles et d'anguillettes concernant 9 pays sont présentées. La caractéristique principale commune à tous ces pays consiste en une diminution d'abondance de 1981 jusqu'à fin 1985. La même diminution a été observée aux Pays-Bas de 1946 à 1950 mais il n'existe pas de données disponibles dans les autres pays pour la même période. Une étroite correspondance, entre les variations des captures dans la rivière Ems en Allemagne et l'abondance des larves sur les côtes européennes occidentales a été mise en évidence, mais dans les autres cas on note une absence de relation d'abondance annuelle entre les divers sites de capture.

INTRODUCTION

In an attempt to study the fluctuations in the numbers of ascending glass eels and elvers *Anguilla anguilla* in Europe and Africa, the Working Party on Eel of the European Inland Fisheries Advisory Commission (FAO) has gathered data from different countries and localities. At the present stage of collection it seems reasonable to publish these data. This is especially desirable because many locations have shown a downward trend in numbers of ascending young eels during the past few years.

This report gives results from nine countries not only on glass eels and elvers but also on young eels. For one country, the Netherlands, they go back as far as 1938. The other time series are rather shorter. In the case of the Netherlands, the catches given are the geometric means (as recommended by Dekker, this issue), of sample catches. The other figures represent total catches made either by commercial fisheries or at research stations. The term "elver" is used to include both glass eels and O+ elvers.

RESULTS

Localities and general trends of young eel ascent

Norway. On the River Imsa in the south-west all ascending eels are collected at an eel ladder and the quantities have been measured by volume annually since 1975.

Small eels, presumably elvers, were not measured separately until 1983. The data given in Table I show poor catches in 1978/79 and again 1983/84.

Table I. — Catch of ascending eels in River Imsa.

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Litres	20.5	23.2	13.6	5.8	1.2	16.6	7.4	20.85	7.0	3.2
Litres of "small eels"									4.5	1.32

In his study of the details of the figures Hvidsten (1985) was able to show a good correlation between water temperature in June and July and size of catch, the best catches coinciding with the warmest summers.

Sweden. Recent data are given in Table II for five localities. The 1984 catch in the River Viskan (Fig. 1) was the lowest since records began in 1971 and the other stations also showed a decline.

The dramatic fall in catch in the Viskan from 1983 to 1984 was reflected in a reduction in the numbers of glass eels caught in the Skaggerak and Cattegaut in the month of February.

Table II. — Annual catch (kg) of elvers in Swedish rivers

	1982	1983	1984
South coast (Baltic) Lagan	47.4	2.9	17
West coast (Kattegat) Nissan	2.7	27	2.5
Morupsan	14.6	11	1.5
Tvaakers kanal	7.2	10.4	0
Viskan	472	308.4	20.7
Total	543.9	359.7	41.7

Denmark. Elver catches at the Vida/Hojer sluice in southwest Jutland (Fig. 1) were exceptionally low in

Table III. — Catches of young eels (kg) at Danish trapping stations.

	W Stadil Fjord West Jylland	Holstebro Power Station West Jylland	Kattinge-vaerk North Sjaelland	Frederiks-vaerk North Sjaelland	Ballum Sluice SW Jylland
1967			1 292	10 720	
1968		170	1 500	6 202	
1969	350	258	1 470	2 376	
1970	298		3 290	12 248	
1971	134		4 066	8 090	
1972	170		2 843	10 266	
1973	157		1 648	10 998	
1974	65	386	744	9 414	
1975	107	213	1 183	8 249	
1976	300	622	1 135	6 393	
1977	530	425	2 187	10 630	
1978	70	274	1 675	6 418	
1979		104	3 304	6 371	
1980	27	320	3 527	6 378	635
1981	200	135	1 778	5 872	756
1982	47	140	3 048	5 899	450
1983	0	63	905	4 392	1 668
1984	132	58	2 721	2 996	706

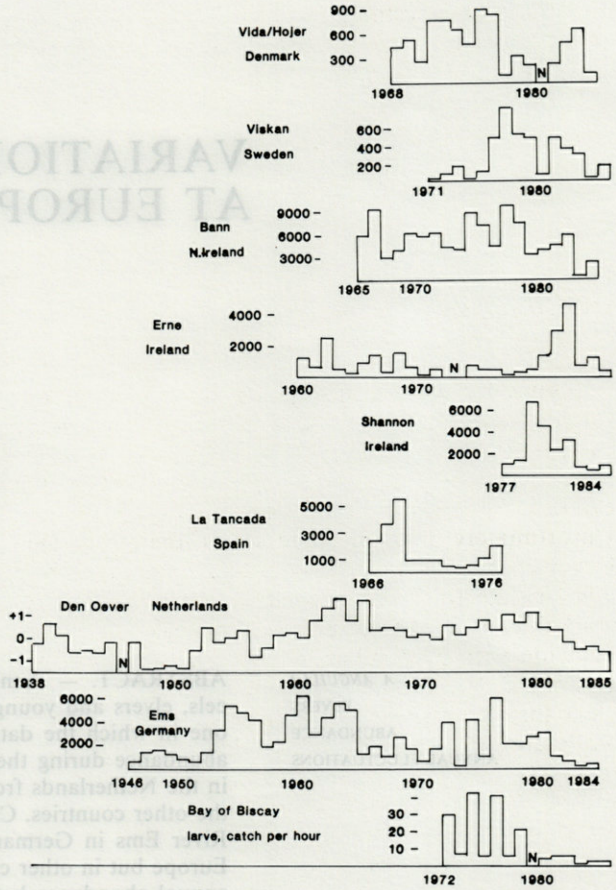

Fig. 1. — Catch per hour of larval eels in Bay of Biscay; "year effect" on glass eel sampling at Den Oever; catch (kg) of glass eels and elvers at other sites.

1977 and in 1984. Catches of young eels from five localities (Table III) show marked but apparently independent fluctuations.

Germany. Catches in the River Ems at Hebrum, near Aschendorf, (Fig. 1) have been abnormally low since 1981. Fluctuations in catch follow closely fluctuations in larval catch in the eastern Atlantic (Fig. 1).

Netherlands. Data accumulated since 1938 at Den Oever on the north coast (Fig. 1) have shown two periods of decline : the current one and one lasting from 1946 to 1950.

Ireland. Data from three stations are given in Fig. 1 : River Bann (north coast), River Erne (northwest coast), both giving complete catches of elvers and River Shannon (west coast) with incomplete catch of elvers. Poor catches in general have been observed over the past few years.

England. Estimated catch from the River Severn (west coast) was high in 1979, medium 1980-82 and extremely low 1983-85 inclusive.

France. Catch per unit effort in the Loire and Vilaine (west coast) declined steadily and severely from 1978 to 1984 (Guérault *et al.,* 1985).

Spain. Glass eel catches from Tancada lagoon in the Ebro delta on the east coast (Fig. 1) were obtained from Demestre *et al.,* (1977).

DISCUSSION

Figure 1 gives a graph of the variations in elver catch in seven fisheries and in larval eel catch in the eastern Atlantic from Tesch *et al.,* (this issue). Two features are of particular interest. The first is that catches have been even worse than at present. Unfortunately only one time series, that from Den Oever in the Netherlands, goes back long enough to demonstrate this. The second is perhaps more remarkable. It is the failure of the peak catches to coincide with each other. Even within the confines of Ireland where three series are available, it is quite clear that one fishery can experience a record catch while another, less than 100 km farther south, has a relatively low one. Dekker (this issue) has shown within the Netherlands annual fluctuations which are similar to one anoter at four stations but significantly different from a fifth.

Considering the fact that past records have shown low periods of as long as six years, five-year total catches were calculated where possible with results shown in Table IV.

Table IV. — Total quantities (kg) of elvers caught in five year periods by constant method.

	Den Oever	Ems	Bann	Erne
1940-44	19.2			
1945-49				
1950-54	34.38	11,754		
1955-59	52.08	17,735		
1960-64	67.03	24,440	46,500	4,954
1965-69	39.59	8,776	27,700	4,782
1970-74	37.07	10,805	29,150	
1975-79	55.18	14,019	31,684	1,723
1980-84	34.90	5,308	16,700	10,701

This gives the surprising result that only two of the four stations for which data are available have shown their lowest elver run.

Tesch *et al.,* (this issue) have provided data since 1972 on the results of larval sampling in the Bay of Biscay. The annual variations coincide remarkably well with the catch in the River Ems in the following year. However, similar relationships cannot be established between the Bay of Biscay figures and the elver catches in other countries (Fig. 1).

CONCLUSIONS

The only definite conclusion is that more extensive observations are required and that they must be continued for many years. There are strong indications that recruitment in the course of the years 1982 — 1985 has been very poor, starting with a decline at nearly all stations in 1979, and that this may be associated with low stocks of larval eels in front of the respective coastal areas. All correspondents have remarked on the effects of physical conditions such as weather, temperature and water flow on the recruitment of elvers. This reduces the reliability of elver catches as indicators of breeding success or of survival in the course of the oceanic migration of the larvae. From this point of view oceanic sampling of larvae has much to recommend it even though it, too, must be influenced by variations the areas sampled.

ACKNOWLEDGMENTS. — These results have been compiled from data kindly supplied by the following correspondents : Denmark : J. Dahl, England : A.S. Churchward and V. Ingram, Germany : F.-W. Tesch, Ireland : O. Kennedy, Norway : N.A. Hvidsten, S.V. Mehli, L.A. Volestad, Netherlands : W. Dekker, Spain : J. Saludes, Sweden : H. Wickstrom. I would like to thank Mr Russel Poole for assistance in analysing the data.

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VARIATIONS DE L'ABONDANCE DE LA CIVELLE AU TRAVERS DES DONNÉES DE PRODUCTION SECTEURS LOIRE ET VILAINE

Variations in glass eel abundance from catch data Loire and Vilaine regions

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ANGUILLE
CIVELLE
PRISE/EFFORT
PÊCHERIES D'ESTUAIRES

RÉSUMÉ. — L'exploitation de la civelle d'Anguille est d'une importance primordiale pour un grand nombre de pêcheurs de la façade atlantique, mais les chiffres officiels de production font état d'une baisse importante de 1976 à 1984. L'étude des données commerciales enregistrées pendant cette période fournit une série d'indices sur les variations récentes des captures, de l'effort de pêche et de la prise par unité d'effort dans l'estuaire de la Loire et de la Vilaine. L'évolution des prises par unité d'effort, interprétées comme des indices d'abondance, est la même dans les deux secteurs. Elle permet de conclure à une très nette diminution de la ressource.

ANGUILLA A.
ELVERS
CATCH/EFFORT
ESTUARINE FISHERIES

ABSTRACT. — Glass-eel fisheries are of great importance for many fishermen along the Atlantic coast, but administration data show a strong decrease in production from 1976 to 1984. The analysis of commercial data for this period provides estimates of the fluctuations of catches, fishing effort and c.p.u.e. in the Loire and Vilaine estuaries. The evolution of c.p.u.e., which reflects the variation of abundance, is the same in both estuaries. The conclusion is a severe decrease of the glass-eel resource.

INTRODUCTION

L'importance de l'exploitation de la civelle d'Anguille par les pêcheurs côtiers et fluviaux de la façade atlantique est parfaitement exprimée par les estimations les plus récentes. Elles placent la France au 1er rang des pays producteurs européens (1 400 à 2 000 t pour la saison 76/77). Elles situent la civelle au 4^{e} rang des productions spécifiques du golfe de Gascogne en valeur économique (84 millions de francs pour la saison 82/83) et parmi les rares espèces dont la balance commerciale est excédentaire. Elles montrent que cette activité est un des constituants essentiels de la pêche côtière et estuarienne, en particulier dans les estuaires de la Loire et de la Vilaine. Il est en effet couramment estimé qu'elle procure 40 à 60 % du revenu annuel des professionnels qui exploitent la civelle de décembre à avril et qui débarquent 70 à 80 % de la production nationale.

Cette importance économique n'est actuellement maintenue que par la croissance exceptionnelle du prix de la civelle (de 20 F/kg en 1975 à 130 F/kg en

Tabl. I. — Production de civelles par saison (en tonne) et prix au kilo (d'après Affaires Maritimes, secteurs Loire et Vilaine).
Glass eels catches per year (metric tons) and price per kilo (from Affaires Maritimes, Loire and Vilaine regions)

Saison de pêche	Quartiers Maritimes: Vannes	Quartiers Maritimes: Nantes	Quartiers Maritimes: St-Nazaire	Loire + Vilaine	Prix d'achat F/kg
1975-76	200	660	353	1 213	20
1976-77	52	287	388	727	30
1977-78	105	161	353	619	32
1978-79	206	183	439	828	37
1979-80	93	196	313	602	38
1980-81	58	111	177	336	70
1981-82	98	80	186	364	91
1982-83	69	75	164	308	130
1983-84	36	39	129	204	72

1983) car les données brutes de production font état d'une baisse importante en Loire et en Vilaine entre 1975 et 1984 (Tabl. I). Il est dès lors apparu nécessaire de faire un bilan de l'évolution de l'abondance de la ressource sur la base d'une série chronologique d'indices constitués par les prises par unité d'effort dans les 2 secteurs étudiés.

I. DÉMARCHES, MATÉRIELS ET MÉTHODES

Cette étude repose sur l'hypothèse que les prises par unité d'effort sont proportionnelles à l'abondance de la ressource et reprend le travail important effectué par Elie (1979) de 1977 à 1979.

L'emploi du même critère de sélection a permis d'isoler les captures et l'effort de pêche des pêcheurs professionnels maritimes pour lesquels on disposait d'au moins 25 jours de vente au cours de la saison, au sein des données commerciales qui regroupent les achats effectués à différentes catégories de pêcheurs (engins et secteurs différents). Cette première sélection (sélection 1 dite des « pêcheurs assidus ») nous a ainsi fourni une série de résultats directement comparables entre eux de 1977 à 1984.

Ces résultats pouvaient cependant ne représenter que l'évolution moyenne des ventes par pêcheur et par sortie à certains acheteurs pour différentes raisons (faiblesse du seuil de sélection, évolution mensuelle des rendements, déplacement des pêcheries).

On a alors opéré au sein de la population précédente une deuxième sélection (sélection 2 dite des « pêcheurs assidus et constants », basée sur la constance au cours de la période considérée et sur un nombre de sorties par pêcheur plus élevé (40 pour la Loire et 70 pour la Vilaine) réparties sur toute la saison de pêche. Elle a permis d'isoler pour chaque secteur un lot témoin de dix pêcheurs fondant toute leur activité hivernale sur la pêche de la civelle et dont on disposait de toutes les captures de 1977 à 1984 pour la Loire et de 1979 à 1984 pour la Vilaine. Les résultats dépassent le stade précédent et il devient dès lors possible de parler de captures totales, d'effort de pêche et de prises par unité d'effort. Ils constituent une série chronologique d'indices qui contrôlent les données de la première sélection et qui permettent une analyse plus fine de l'évolution récente de la pêche et de l'abondance de la ressource.

Ces deux sélections n'ont en aucun cas valeur d'échantillon et les résultats ne se prêtent à aucune extrapolation.

II. RÉSULTATS

L'effort de pêche est mesuré par le nombre de ventes assimilé au nombre de sorties effectuées au cours de la saison ou du mois. La sortie a été choisie et non le jour de pêche car plusieurs sorties peuvent être effectuées par jour. En toute rigueur, l'unité d'effort devrait être la durée de la pêche et devrait être pondérée par la puissance de pêche individuelle. La prise par unité d'effort est exprimée en kg de civelles par sortie, à l'échelle de la saison de pêche ou au niveau mensuel.

A. *Etude globale de l'évolution des indices d'effort de pêche et de prise par unité d'effort*

a) Evolution de l'effort de pêche

L'effort moyen par pêcheur (nombre de ventes ou de sorties par pêcheur) est exprimé par secteur à partir des données des 2 sélections (Tabl. II et III).

Estuaire de la Loire : L'effort de pêche, d'abord stable et peut-être même légèrement décroissant de 1977 à 1979 subit une soudaine augmentation en 1980 et demeure à un niveau élevé de 1981 à 1983

Tabl. II. — Evolution de l'effort de pêche, de la production et de la p.u.e. en Loire (1977-1984). Sélections 1 et 2.
Evolution of fishing effort, catches and cpue Loire

	1976-1977		1977-1978		1978-1979		1979-1980		1980-1981		1981-1982		1982-1983		1983-1984	
	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)
Nombre de pêcheurs sélectionnés	38	10	48	10	49	10	15	10	15	10	13	10	69	10	68	10
Effort de pêche																
● total	2 185	832	2 573	754	2 831	712	1 513	1 077	1 367	1 025	1 277	1 057	5 060	1 090	4 856	908
● moyens	57	83	54	75	58	71	100	107	91	102	77	105	73	109	71	90
Production																
● totale	58 562	25 885	81 393	27 038	74 898	22 640	31 750	23 093	22 075	16 220	17 445	14 069	49 598	12 619	43 924	9 953
● moyenne	1 541	2 588	1 695	2 703	1 528	2 264	2 105	2 309	1 471	1 622	1 341	1 406	718	1 261	646	995
Prise par unité d'effort	26,8	31,1	31,6	35,8	26,4	31,8	20,8	21,4	16,1	15,8	13,6	13,3	9,8	11,5	9,0	10,9

Tabl. III. — Evolution de l'effort de pêche, de la production et de la p.u.e. en Vilaine (1977-1984). Sélection 1 et 2.
Evolution of fishing effort, catches and cpue Vilaine

	1976-1977		1977-1978		1978-1979		1979-1980		1980-1981		1981-1982		1982-1983		1983-1984	
	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)	Sel (1)	Sel (2)
Nombre de pêcheurs sélectionnés	49	—	48	—	52	10	38	10	64	10	48	10	54	10	48	10
Effort de pêche																
● total	3 175	—	2 518	—	2 804	1 215	3 229	1 277	4 844	1 336	3 506	1 238	4 657	1 266	3 667	906
● moyens	68	—	53	—	64	121	85	127	75	133	73	123	86	126	76	90
Production																
● totale	36 223	—	49 268	—	50 863	20 354	28 569	10 376	27 660	7 321	29 880	9 232	24 094	6 747	24 745	6 109
● moyenne	739	—	1 026	—	978	2 035	751	1 037	432	732	622	923	446	674	515	610
Prise par unité d'effort	11,4		19,5	—	15,2	16,7	8,8	8,1	5,7	5,4	8,5	7,4	5,1	5,3	6,7	6,7

pour les plus assidus en particulier, avant de baisser en 1984.

Estuaire de la Vilaine : L'effort, peut-être mal apprécié en 1977 et 1978, augmente en 1980 et plafonne jusqu'en 1983 avant de baisser en 1984 de manière spectaculaire pour les pêcheurs assidus.

Les deux sélections s'accordent pour rendre compte globalement d'une même évolution de l'effort moyen par pêcheur dans les deux secteurs, mais certaines divergences apparaissent suivant l'assiduité des pêcheurs. L'écart affiché par les valeurs absolues des deux sélections illustre parfaitement qu'il est difficile d'apprécier l'effort de pêche global à partir des données commerciales.

b) Evolution des prises par unité d'effort

Les p.u.e. (vente moyenne ou rendement moyen par sortie et par pêcheur) sont, là encore, exprimées par secteur à partir des données des deux sélections (Tabl. II et III).

Estuaire de la Loire : (Fig. 1). La p.u.e. passe par un maximum de l'ordre de 31 à 36 kg en 1978 et décline régulièrement pour être de l'ordre de 9 à 11 kg en fin de période.

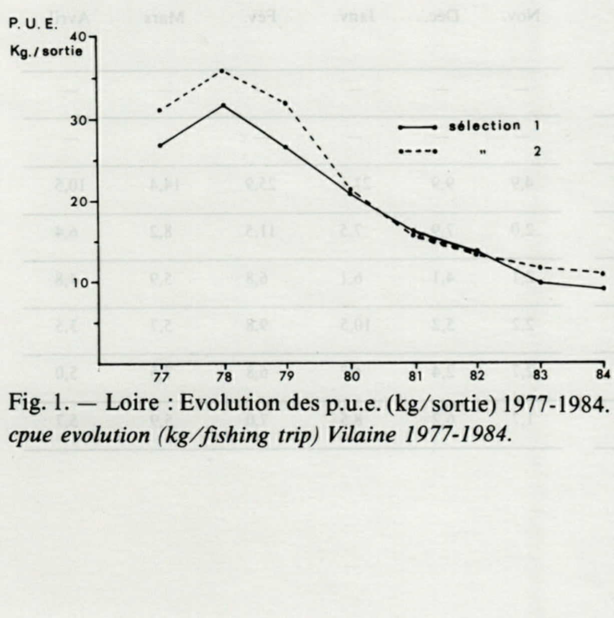

Fig. 1. — Loire : Evolution des p.u.e. (kg/sortie) 1977-1984.
cpue evolution (kg/fishing trip) Vilaine 1977-1984.

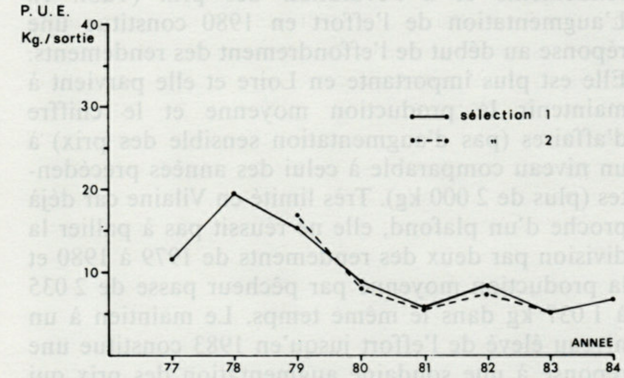

Fig. 2. — Vilaine : Evolution des p.u.e. (kg/sortie) 1977-1984.
cpue evolution (kg/fishing trip) Vilaine 1977-1984.

Estuaire de la Vilaine : (Fig. 2). La p.u.e. passe par un maximum de 19,5 kg en 1978 et diminue rapidement jusqu'en 1980 (8,8 kg) pour osciller ensuite de 5,1 à 8,5 kg de 1981 à 1984.

Les données des deux sélections s'accordent pour retracer la même évolution sensiblement parallèle dans les deux secteurs. Elles n'affichent pas de grandes différences et on peut penser que les données d'ordre commercial permettent une bonne évaluation du rendement moyen par sortie et par pêcheur.

B. *Etude fine de l'évolution de la production, de l'effort et de la prise par unité d'effort de 10 pêcheurs témoins dans les deux secteurs*

Estuaire de la Loire (Tabl. II) : L'effort moyen par pêcheur, relativement stable et même décroissant de 1977 à 1979 (83, 75 et 71 sorties) subit une soudaine augmentation en 1980 (107 sorties) et demeure à un niveau élevé jusqu'en 1983 (102, 105 et 109 sorties) pour décliner en 1984 (90 sorties). Dans le même temps la prise moyenne par unité d'effort passe par un maximum en 1978 (35,8 kg) et diminue régulièrement jusqu'en 1984 (10,9 kg).

Estuaire de la Vilaine (Tabl. III) : L'effort moyen par pêcheur, d'emblée plus élevé qu'en Loire à cause des conditions spécifiques d'exercice de la pêche en Vilaine, ne subit qu'une légère augmentation de 1979 à 1980 (121 à 127 sorties). Il continue d'augmenter en 1981 et reste à un niveau élevé en 1982 et 1983 (133, 123 et 126 sorties), mais chute brusquement en 1984 (90 sorties). Parallèlement, les rendements passent par un maximum en 1978 selon les données de la première sélection (19,5 kg) et s'effondrent de 1979 à 1981 (16,7 kg, 8,7 kg et 5,4 kg). Ils oscillent ensuite et atteignent 7,4 kg en 82, 5,3 kg en 83 et 6,7 kg en 84.

Les variations d'effort sont liées à la baisse des rendements et à l'évolution des prix (Tabl. I). L'augmentation de l'effort en 1980 constitue une réponse au début de l'effondrement des rendements. Elle est plus importante en Loire et elle parvient à maintenir la production moyenne et le chiffre d'affaires (pas d'augmentation sensible des prix) à un niveau comparable à celui des années précédentes (plus de 2 000 kg). Très limité en Vilaine car déjà proche d'un plafond, elle ne réussit pas à pallier la division par deux des rendements de 1979 à 1980 et la production moyenne par pêcheur passe de 2 035 à 1 037 kg dans le même temps. Le maintien à un niveau élevé de l'effort jusqu'en 1983 constitue une réponse à une soudaine augmentation des prix qui compense sans doute la chute de la production moyenne liée à la poursuite de la baisse des rendements.

La production moyenne en Loire ne cesse de diminuer, elle n'est plus que de 1 250 kg en 1983. En Vilaine, elle diminue globalement pour ne plus être que de 674 kg en 1983 (les rendements plus élevés de 1982 entraînent toutefois une production plus importante de 923 kg). La diminution de l'effort en 1984 correspond pour sa part à un certain découragement face au bas niveau simultané des rendements et des prix. Elle fait passer la production moyenne à moins de 1 000 kg en Loire (995 kg) à 610 kg en Vilaine.

Les prises par unité d'effort, largement différentes dans les deux secteurs puisqu'elles varient pratiquement du simple au double au bénéfice de la Loire subissent une évolution globalement parallèle pendant la période considérée.

Les rapports entre les maxima de la saison 77/78 qui atteignaient 35,8 kg en Loire et 19,5 kg en Vilaine (valeur affichée par la première sélection faute de données pour les pêcheurs témoins) et les minima de la saison 83/84 (Loire) et 82/83 (Vilaine) qui ne sont plus que de 10,9 kg en Loire et de 5,3 kg en Vilaine sont comparables. Les p.u.e. de Loire ont été divisées par 3,3. Les p.u.e. de Vilaine ont été divisées par 3,7.

Cette diminution des p.u.e. d'une sélection de pêcheurs ne peut être attribuée ni à une modification importante de l'effort global appliqué aux pêcheries ni à une modification de l'accessibilité.

L'effort global ne peut être apprécié à partir des données existantes. On peut penser qu'il a sans doute d'abord augmenté pour plafonner rapidement au niveau individuel conformément aux données de cette étude, mais on ne peut pas croire qu'il ait pu subir une augmentation de l'ordre de 3,5 en nombre de pêcheurs.

L'étude de la répartition mensuelle des rendements montre que la diminution des p.u.e. s'accompagne d'une modification dans le déroulement des campagnes successives. Les p.u.e. passent par un maximum en février dans les 2 secteurs avant et

Tabl. IV. — Evolution mensuelle de la p.u.e. (Loire et Vilaine 1977-1984).
Monthly evolution of cpue (Loire and Vilaine 1977-1984).

Secteur	LOIRE						VILAINE					
Saison / Mois	Nov.	Déc.	Janv.	Fév.	Mars	Avril	Nov.	Déc.	Janv.	Fév.	Mars	Avril
76/77	3,6	7,9	31,2	40,5	27,9	7,4	—	—	—	—	—	—
77/78		17,2	34,6	48,4	33,6	28,7	—	—	—	—	—	—
78/79		13,6	22,7	43,3	32,7	13,2	4,9	9,9	21,1	25,9	14,4	10,5
79/80		9,9	18	30,9	20,9	12,2	2,0	7,9	7,5	11,5	8,2	6,4
80/81	2,8	8,0	11,5	24,1	16,9	10,5	2,1	4,1	6,1	6,8	5,9	4,8
81/82	5,7	6,0	17,2	17,5	8,8	6,3	2,2	5,2	10,5	9,8	5,7	3,5
82/83		6,0	10,3	14,3	14,1	6,5	2,7	2,4	4,7	6,8	7,5	5,0
83/84		5,3	10,5	11,1	13,2	8,8	1,7	6,2	8,5	7,0	5,9	5,7

pendant la période où s'amorce l'effondrement des rendements annuels (1977-1981 et 1979-1981), mais cette évolution se modifie de 1982 à 1984 (Tabl. IV).

En Loire, le rendement maximum continue d'être enregistré successivement en février 82 et 83, mais seulement en mars 84 alors que des rendements proches du maximum sont réalisés en janvier 82 d'une part et en mars 83 d'autre part. En Vilaine les rendements maxima sont enregistrés successivement en janvier 82, en mars 83 et en janvier 84. Cette modification sans tendance clairement établie ne permet pas de conclure à une modification récente de l'accessibilité.

CONCLUSION

Les différents indices obtenus à partir des données commerciales d'une catégorie donnée de pêcheurs ont permis d'analyser l'évolution récente de la pêche de la civelle dans les 2 secteurs les plus productifs du littoral atlantique de 1977 à 1984. L'évolution des p.u.e. interprétées comme des indices d'abondance est la même dans les 2 secteurs. Elle permet de conclure à une très nette diminution de la ressource car l'abondance des dernières montées n'est plus que de 30 % en Loire et 27 % en Vilaine si l'on compare les maxima de 77/78 (Loire et Vilaine) au minima de 83/84 en Loire et de 82/83 en Vilaine.

De 1971 à 1984, Tesch (1985) met également en évidence une baisse importante de la densité des larves dans le golfe de Gascogne. Cette diminution d'abondance caractérisée globalement par un facteur de 3,5 constitue une variation du recrutement peu importante par rapport à ce que l'on sait d'autres espèces. Elle n'est donc pas obligatoirement déterminante pour le stock d'Anguille (sauf si la chute du recrutement est durable et non pas l'expression d'un phénomène cyclique à long terme) mais elle touche l'exploitation de la civelle.

L'importance économique de cette activité commande la mise en œuvre d'une étude globale des pêcheries qui passe par la mise en place d'un système de collecte de données d'effort et de production pour caractériser la pression exercée sur le « stock civelle » par :

- Les 439 pêcheurs en bateau travaillant en Loire (246 professionnels inscrits maritimes, 48 professionnels fluviaux, 145 amateurs fluviaux selon les pointages effectués en Loire pendant la saison 83/84), les 120 pêcheurs en bateau recensés en Vilaine (professionnels inscrits maritimes) et les nombreux pêcheurs à pied maritimes et fluviaux, clandestins ou non, exerçant plus particulièrement en Loire.

Ces données sont tout à fait indispensables pour assurer le suivi de l'état et de l'évolution de la ressource et pour jeter les bases d'un aménagement des pêcheries dans le sens d'une gestion rationnelle.

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VIE MILIEU, 1986, 36 (4) : 243-250

FISHING METHOD AND SEASONAL OCCURRENCE OF GLASSEELS (*ANGUILLA ANGUILLA L.*) IN THE RIO MINHO, WEST COAST OF THE IBERIAN PENINSULA

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ESTUAIRE DE MINHO
PÊCHE DE CIVELLES
DONNÉES STATISTIQUES
DONNÉES BIOLOGIQUES
MIGRATION

RÉSUMÉ. — La pêche expérimentale des civelles a été entreprise de novembre 1981 à avril 1983 dans l'estuaire du Minho en incluant 2 saisons de pêche régulière au moyen du filet « Hamen ». Les statistiques officielles de l'Espagne et du Portugal sont données mais sont probablement sous-estimées. Les données biologiques de poids et taille, les relations matière sèche et matière organique sèche/poids humide sont discutées en tenant compte des lieux de capture, des phases de la lune et des époques de l'année.

MINHO ESTUARY
GLASSEEL FISHERY
STATISTICS
BIOLOGICAL DATA
MIGRATION

ABSTRACT. — In the Minho estuary experimental fishery of glasseels was carried out between November 1981 and April 1983, including two regular fishing seasons, by means of the locally used "Hamennet". Official statistics of Spain and Portugal are given but are supposed to be underestimates. Biological data on length, weight and relations of dry and organic dry weight to wet weight are discussed with consideration to catchsite, moon's phase and time of the year.

INTRODUCTION

Concerning the fishery of glasseels, the Rio Minho became recently one of the most important rivers of the Iberian Peninsula. An analysis of the glasseel ascent (see e.g. Elie, 1979; Cantrelle, 1981) which provides the natural basis for the fishery, seems therefore necessary. This paper provides results of an experimental glasseel fishery in the estuary of the river and data on the captured glasseels including development stage, length and weight.

THE COMERCIAL FISHERY

With a length of 340 km the Minho has a hydrographic area of 17 081 km^2 and forms over the last 75 km the northern border between Portugal and Spain (fig. 1).

The Portuguese fishery regulations from 26.11.1981 (Dec. Lei 316, Art 55 º) permit the utilization of a "Hamennet" for catching glasseels during the period between 1 November and 1 April with the following maximum dimensions : length of floatlines 2 × 10 m, kept at the surface by means of 10-20 litre buoys, net height 8 m, leadline 15 m, width of the netend 2.5 m, meshsize 2 mm (squaremesh) (fig. 2).

Fishing from the riverbank by means of a dipnet with meshsize of 2 mm and a diameter which should not surpass 1.5 m is limited to the period 1 October to 1 April. Both regulations apply to Spain also.

The glasseel fishery is always performed at night around new moon. The catch extends over a period of three hours from the beginning of the rising tide onwards depending on current speed and yield.

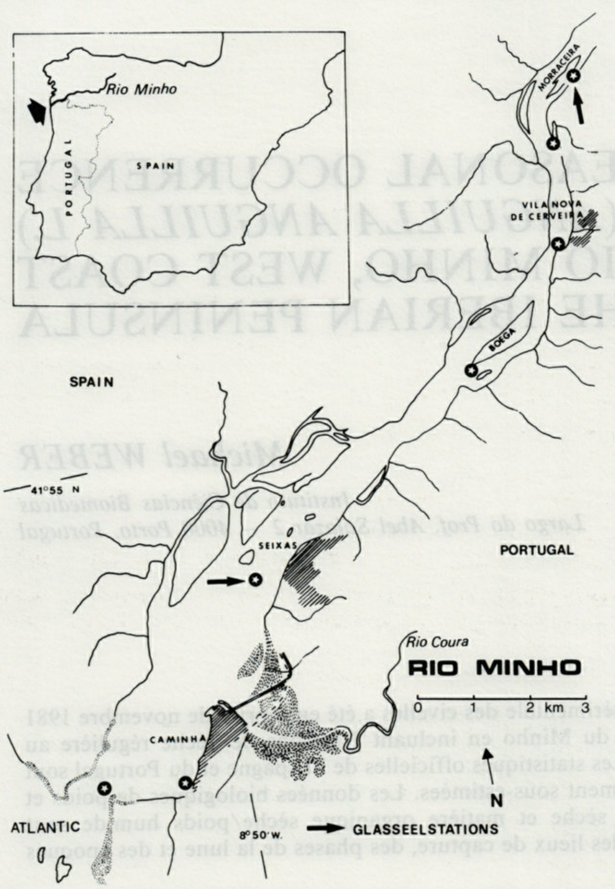

Fig. 1. — The Minho estuary with sampling stations (arrows).

Maximum yield can be up to 40 kg per boat per night within the three hours with a value of 100 000 Escudos (in 1983/1984 the price per kg varied around 2 500 Escudos). Minimum yield was seldom more than 100 g.

When the tide is rising a marked buoy is thrown overboard followed by an anchor belonging to it. Then the boat is moved across the river up to 20-30 m in order to drop a second anchor with a buoy. The net is then released, normally carried by the current, forming a funnel against the now faster flowing tide and held by the two anchors. The end is fastened with two lines to the boat which drifts diagonally to the current. The depth of water at the fishingsite and the location of the anchors determine the opening area of the net (~ 50 m^2).

Using a lamp, the concentration of glasseels, elvers and other organisms is scooped out of the netend with a small dipnet at frequent intervals. The dipnet is emptied into a sieve mounted to a wooden frame with a meshsize of 4-5 mm. Other fish, floating debris and elvers remain on it while the glasseels wind themselves through the meshes to drop into a second sieve of a smaller meshsize (1 mm).

After cleaning the catch, quantities of 4-5 kg are stored in wooden boxes. Back at the riverside the glasseels are delivered to a buying agent who takes care of weighing and further transport. Principal customer of the Portuguese glasseels is Spain where 90 % are provided for human consumption.

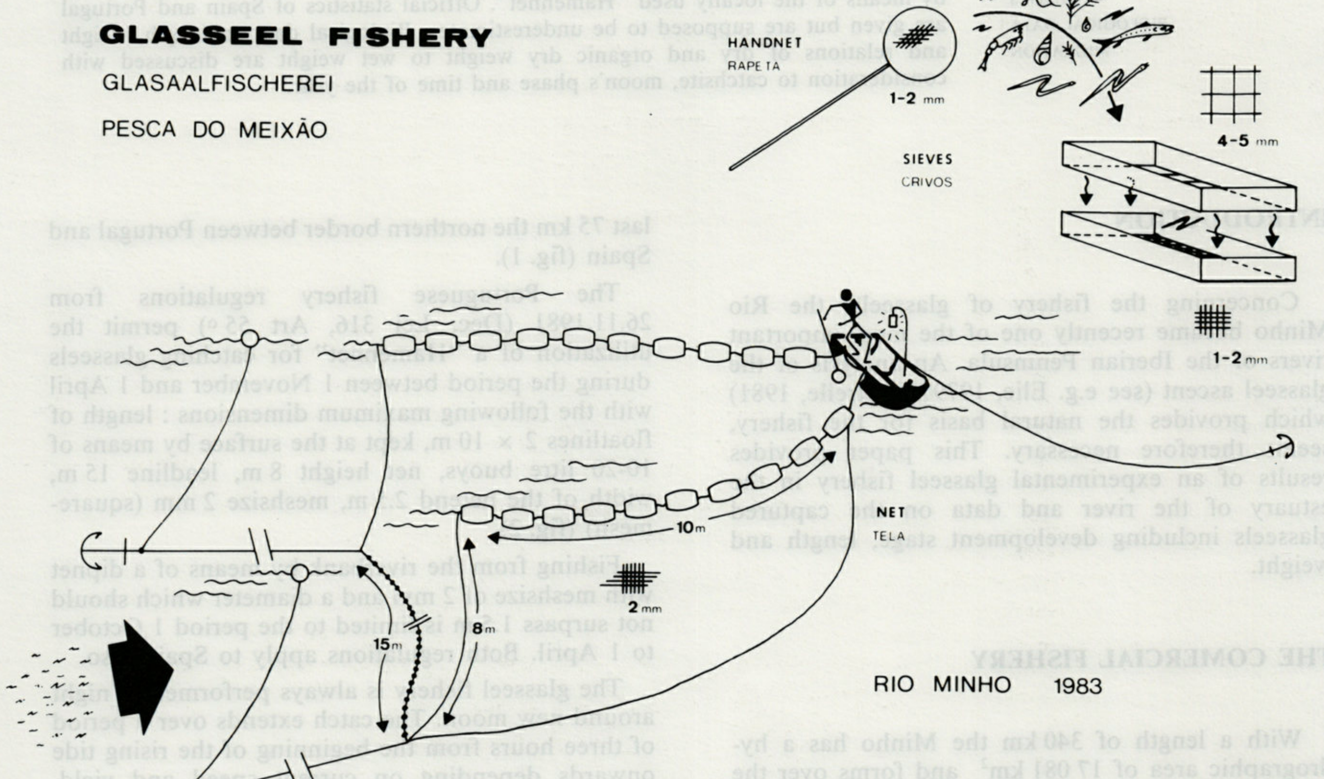

Fig. 2. — Method of fishery "Hamennet".

The by-catch consists mainly of *Atherina presbyter, Palaemon serratus, Bithynia tentaculata* and *Saduriella losadai.* Sometimes juvenile fish like *Alosa fallax, Alosa alosa, Pomatochistus microps, Salmo salar* and *Petromyzon marinus* show up in large quantities. The majority of these organisms die because of exposure to air.

At the end of fishing the boat is set free from the net, one buoy and its anchor are raised, the connecting line is unfastened from the net which then drifts in the current still being held by the second anchor. The floatline, the leadline and the net are hauled in and finally the remaining second anchor.

Since the official beginning of the glasseel fishery in the Minho in 1973, the number of licensed fishermen has increased sharply. Even though this trade can only be pursued during 5 months, the high income is very attractive. Four hundred and fifty licensed fishermen in Spain and seven hundred and fifty in Portugal were registered in 1983, taking into account that the Portuguese number is deduced from the total of license holders distributed over 537 boats. An efficient control is hardly possible due to an uncertain number of amateur fishermen.

According to the statistics given in fig. 3-A, the official catch maximum amounted to a total of 54 tons in 1980/1981. On average 27 tons were caught annually by both countries in the last ten years. The total yield increased by 27.1 % during the periods 1974-1979 and 1979-1984.

In Spain 10 tons, worth 15 Mill. Pesetas, were considered as an official annual mean for the period 1973-1977. The estimation of the actual mean runs up to 50 tons equivalent to 75 Mill. Pesetas (Calviño 1980; in Adega 1981).

MATERIAL & METHODS

From November 1981 to April 1983 glasseels were caught monthly by the method described above at two stations set up in the lower course of the Rio Minho (fig. 1). The fishing was carried out with a small net : floatline length 9.3 m, netheight 5 m, leadline 10 m, netend 0.8 m.

At the upstream site (St. 7), between the Island of Morraçeira and the Portuguese shore, at a distance of 18.7 km from the rivermouth, investigations were carried out over a whole year (November 1981-November 1982). The mean depth was around 3 m. In order to obtain comparable data, as a reference, the same gear was used at St. 3 in the channel of Seixas, 5.2 km away from the rivermouth, in January and February 1982 as well as in the whole season 1982/1983 from November to April. The water depth varied around 6 m.

Fishing took place over the period around new moon and in the summertime at full moon also. Fishing lasted between 30 and 150 minutes depending on the yield. Prior to weighing, the glasseels were cleaned repeatedly in the sieve. After taking subsamples to ascertain data on length and weight the catch was sold. Elvers were taken directly from the first sieve and, like the glasseels preserved in 4 and 10 % buffered formalin. The yield was expressed in terms of catch per hour. The material was classified into 3 size classes or age groups, respectively :

Group I : transparent, unpigmented glasseels
Group II : transparent, pigmented glasseels
Group III : opaque and fully pigmented elvers with palebrown integument.

The individuals were measured in length to the nearest mm and weighed to 1 mg (WW). From each group 20 individuals each month were dried at 80 °C for 24 hours and then incinerated at 550 °C for 3 hours. The organic dry weight (ODW) was obtained by subtracting the ash from the dry weight (DW).

RESULTS

1. Yield

For the whole period of investigation the yield (WW g/h), abundance (N/h) and biomass (ODW g/h) per station and hour of fishing are shown in Table I.

Upriver maximum abundance was recorded in March 1982 and 1983. A slightly lower maximum occured in May 1982. From July onwards the yield decreased conspicuously towards minimal values from August to November. In the estuarine area peak values were recorded in February 1982 and in March 1983. In January and April 1983 abundance was low. In February 1982 extreme variations between the upstream and the downstream station were observed. In the estuary approximately 90 % more glasseels were captured than at a distance of 18.7 km upstream (fig. 3-B). One year later in March 1983 the yields differed only to a small extent.

The percentage of pigmented individuals increased remarkable during the period from March to July. They were almost absent during winter 1981/1982 and then most frequent in April at approximately 40 %. Pigmented glasseels and elvers only were encountered upstream whereas unpigmented individuals exclusively were present in the estuary. Elvers were scarce at less than 1 % and only in spring and summer did they appear more frequently. Towards the end of 1982 they were absent from autumn onwards.

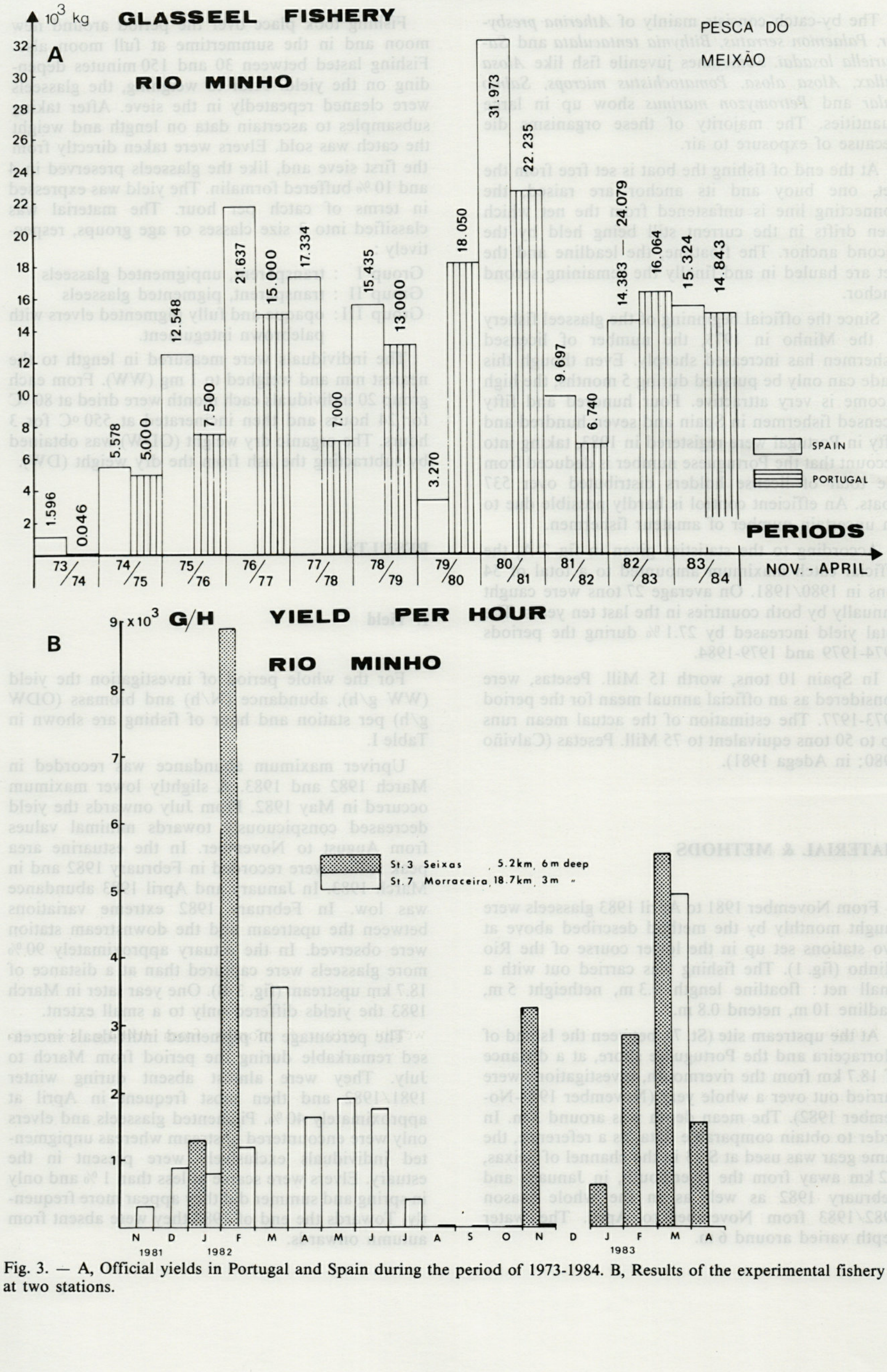

Fig. 3. — A, Official yields in Portugal and Spain during the period of 1973-1984. B, Results of the experimental fishery at two stations.

Table. I. — Yield, abundance and biomass of glasseels and elvers in the Rio Minho. I, unpigmented glasseels; II, pigmented glasseels; III, elvers. WW, wet weight: ODW, organic dry weight; g/h, gram per hour ; N/h, individuals per hour.

date	time (min)	total yield	yield /hour	N/h	ODW (g/h)	N/h	N/h	N/h	WW (g)	ODW (g/h)
		WW/(g)	WW(g/h)	I.+II.	I.+II.	I.	II.	III.		III
Station 7 (18.7 km upstream)										
11.81	145	766	317	1 060	53.6	1 060	—	25	40	8.3
12.81	130	1 908	881	2 360	174.5	2 280	80	37	38	8.6
01.82	60	796	796	2 193	140.3	2 193	—	1	1	0.2
02.82	90	1 528	1 019	3 329	179.7	3 329	—	—	—	—
03.82	90	5 335	3 557	11 075	502.7	10 399	676	45	79	15.7
04.82	90	2 455	1 637	5 469	252.1	3 163	2 306	50	79	15.0
05.82	40	1 271	1 907	5 915	297.9	5 345	571	17	24	4.4
06.82	60	1 744	1 744	5 296	318.5	4 805	491	13	23	4.8
07.82	30	202	404	1 528	64.6	992	536	7	18	3.2
08.82	18	2	7	17	1.0	4	13	—	—	—
9.82	60	1	1	3	0.2	2	1	—	—	—
10.82	75	3	2	6	0.3	4	2	—	—	—
11.82	45	22	29	81	5.0	80	1	—	—	—
13.03.83	120	9 805	4 903	15 838	667.7	13 879	1 959	4	7	1.2
Station 3 (5.2 km estuary)				I.	I.					
01.82	45	955	1 273	4 057	216.3					
02.82	90	13 337	8 891	22 567	1 512.0					
13.11.82	90	769	513	1 147	95.2					
14.11.82	150	5 605	2 242	—	—					
15.11.82	150	8 082	3 233	6 679	594.4					
16.11.82	150	4 752	1 901	4 168	329.3					
17.11.82	120	5 415	2 708	—	—					
18.11.82	90	285	190	—	—					
11.01.83	90	859	573	1 314	107.7					
13.01.83	120	955	478	1 131	88.2					
15.01.83	90	959	639	1 673	117.1					
10.02.83	150	2 386	954	2 334	163.4					
11.02.83	150	1 049	420	938	78.8					
12.02.83	120	1 024	512	1 262	89.6					
13.02.83	115	5 400	2 817	7 205	511.6					
11.03.83	165	5 042	1 831	5 521	247.5					
12.03.83	180	16 490	5 497	14 314	1 016.3					
13.03.83	180	3 527	1 176	3 284	200.3					
13.04.83	120	3 055	1 528	4 163	253.9					
14.04.83	60	381	381	1 125	72.0					

In November 1982 glasseel fishery took place upstream at new moon, two days before and three days after, which resulted in a distinct maximum at new moon with 3233 g/h. The catch two days before and three days after was characterized by an obvious lower yield. The maximum catch per total duration of fishing as well as the yield per hour are given in Table I.

2. Length

The mean length of unpigmented glasseels ranged between 6.5 and 7.3 cm in the course of the year with a maximum in January 1982 and 1983 (Table II). The length of the pigmented individuals were generally smaller than those from group I but showed a slight increase from 6.4 to 6.9 cm within the year, finally surpassing the unpigmented glasseels in October by 0.3 cm. The elvers varied between 9.0 and 11.2 cm (Graphics shown *in* Weber 1985 b).

3. Wet Weight

The mean wet weight deviated between 0.269 and 0.484 g. Upstream within the year 1982 three maxima appeared in January, June and November. Minimum values were predominant in March and July (Table II). The glasseels captured in the estuarine area in the season 1982/1983 were generally heavier than those from upstream but showed a decrease in weight within 5 months from 0.484 g down to 0.339 g.

Towards the beginning of the year the average weight of group II remained distinctly below the values of the size category I, showing a tendency to increase in March and thus surpassing the weight of unpigmented glasseels at around 60 mg in October. The minimum value was recorded in December and the maximum of 0.406 g in October 1982. The mean wet weight of the elvers ranged from 1.0 to 2.6 g, the minimum in December, the maximum in July 1982.

Tabl. II. — Mean length and weight values of glasseels and elvers. L, lenght; WW, wet weight (formalin); ODW, organic dry weight.

date	L (cm)	WW (g)	ODW (g)	L (cm)	WW (g)	ODW (g)	L (cm)	WW (g)	ODW (g)
Station 7		I			II.			III	
11.81	6.8	0.299	0.051	—	—	—	10.2	1.585	0.333
12.81	7.0	0.355	0.075	6.4	0.214	0.044	9.0	1.032	0.232
01.82	7.2	0.363	0.064	—	—	—	—	—	—
02.82	6.6	0.306	0.054	—	—	—	—	—	—
03.82	6.6	0.270	0.046	6.6	0.221	0.036	10.7	1.757	0.349
04.82	6.8	0.325	0.052	6.7	0.258	0.038	10.5	1.587	0.299
05.82	6.8	0.330	0.052	6.7	0.253	0.035	9.7	1.389	0.258
06.82	7.0	0.335	0.062	6.8	0.274	0.042	10.5	1.764	0.371
07.82	6.5	0.269	0.044	6.6	0.255	0.039	11.2	2.596	0.463
08.82	—	—	—	6.9	0.383	0.066			
09.82	6.6	0.314	0.052	—	—	—	—	—	—
10.82	6.7	0.346	0.059	7.0	0.406	0.063	—	—	—
11.82	6.8	0.348	0.061	—	—	—	—	—	—
03.83	7.0	0.325	0.045	6.6	0.200	0.022	10.5	1.664	0.293
Station 3		I							
01.82	6.7	0.338	0.053						
02.82	7.0	0.394	0.067						
13.11.82	7.2	0.447	0.083						
15.11.82	7.3	0.484	0.089						
16.11.82	7.2	0.456	0.079						
11.1.83	7.3	0.436	0.082						
13.01.83	7.2	0.422	0.078						
15.01.83	6.9	0.380	0.070						
10.02.83	7.2	0.409	0.070						
11.02.83	7.2	0.447	0.084						
12.02.83	7.1	0.406	0.071						
13.02.83	7.1	0.391	0.071						
11.03.83	7.0	0.334	0.046						
12.03.83	7.1	0.384	0.071						
13.03.83	7.0	0.358	0.061						
13.04.83	7.0	0.367	0.061						
14.04.83	7.0	0.339	0.064						

4. Organic Dry Weight

The mean organic dry weight of unpigmented glasseels ranged between 0.032 and 0.095 g in the course of the year with a maximum upstream in December 1981 and June 1982. Minimal values were fairly distinct in March and more clearly marked in July (Table II). In the estuary the maximum of group I was registered in November 1982 with 0.095 g.

The weights of group II remained below those of group I, except for a peak of 0.066 g in August. They varied to a slight extent during the period of December 1981 to July 1982 with a mean value of 0.04 g.

In group III, minima were recorded in December 1981 and in May 1982, maxima in November 1981, March and July 1982.

Glasseels from sizegroups I and II were significantly different ($P \leq 0.05$) from the elvers of group III by the ratio of dry weight to wet weight ($F = 14.35$; $F_{(0.05,\ 2,24)} = 3.4$) and organic dry weight to wet weight ($F = 14.65$; $F_{(0.05,\ 2,24)} = 3.4$).

Unpigmented and pigmented glasseels were not significantly different ($t = -1.06$, $t_{(0.05,\ 18)} = 2.1$ for DW % and $t = -0.39$, $t_{(0.05,\ 18)} = 2.1$ for ODW %), indicating that the ash and water content of the tissues was relatively constant. Subsequently their dry weight was 18.19 % of the wet weight and organic dry weight 16.19 % of the wet weight ($n = 385$). Ratios for elvers were 21.86 % (DW to WW) and 19.97 % (ODW to WW).

The unpigmented glasseels ($n = 239$) of the estuarine area differed significantly with 19.25 % (DW to WW) and 17.69 % (ODW to WW) from those individuals of group I caught upstream $t = -4.29$, $t_{(0.05,\ 25)} = 2.06$ for DW % and $t = -4.26$, $t_{(0.05,\ 25)} = 2.06$ for ODW %.

5. Length - Weight Relation

The length-weight relation was calculated separately for each month and for each of the 3 groups according to $W = C \times L^b$. The length-weight data were log-transformed and the factor b determined by regression analysis (Weber 1985 b). It became evi-

Table III. — b and c, values of glasseels and elvers (b, regression coefficient; c, condition factor).

Station 7 (18,7 km upstream)			
		b	c
11.81	I.	4.14	0.011
12.81	I.	3.39	0.049
	III.	3.18	0.094
01.82	I.	3.42	0.042
02.82	I.	3.3	0.061
03.82	I.	2.71	0.163
	II.	3.53	0.028
	III.	2.89	0.187
04.82	I.	3.82	0.021
	II.	4.15	0.01
	III.	2.68	0.294
05.82	I.	3.42	0.047
	II.	2.5	0.218
	III.	3.06	0.133
06.82	I.	2.68	0.183
	II.	3.12	0.07
	III.	3.5	0.047
07.82	I.	3.23	0.064
	II.	3.55	0.031
	III.	3.38	0.073
11.82	I.	2.91	0.132
03.83	I.	3.46	0.039
Station 3 (estuary 5.2 km)			
01.82	I.	3.99	0.017
02.82	I.	3.22	0.075
13.11.82	I.	3.41	0.053
15.11.82	I.	3.83	0.024
11.01.83	I.	2.78	0.174
13.01.83	I.	3.2	0.076
15.01.83	I.	3.17	0.083
10.02.83	I.	2.56	0.261
12.02.83	I.	3.04	0.105
13.02.83	I.	3.33	0.057
11.03.83	I.	3.51	0.036
12.03.83	I.	3.16	0.078
13.03.83	I.	3.0	0.104
13.04.83	I.	3.37	0.052

dent that not only the regression coefficient b but also the condition factor C varied to great extent during the year (Table III).

b ranged from 2.5 to 4.15. Since the main percentage of values was concentrated within the range of > 3 one may draw the conclusion that generally an allometric growth was involved.

The factor C was calculated from the equation above. The unpigmented glasseels from the station upstream showed a range from 0.011 to 0.183 with two distinct maxima in March and June 1982. The minima were recorded 1-2 months before and after, namely in January, April and July. In November 1981 the lowest C-value was recorded with 0.011 (Table III).

In the estuary the factor C increased from 0.024 to 0.261 during the period November 1982 to April 1983. Among the pigmented glasseels a maximum could be recorded in May between two minima in April and July, in contrast to the elvers which showed a peak in April at 0.294 and minimum in June at 0.047.

DISCUSSION

Because of burocratic problems it was not possible to take samples continuously in the estuary, so the investigation was limited to only two samples in spring 1982 (February and March) and the catching season 1982/1983 (5 months). Due to the fact that the lower course of the river was inundated by extreme rainfalls in December 1982 the entire fishery had to be cancelled. Hence to those lacking data it could not to be ascertained whether the peak in frequency of individuals in February 1982 might have caused the maximum upstream in the subsequent month. It has been assumed that glasseels delay their travels upstream, resting for an undeterminable time along the shores, avoiding places with strong currents and resuming their journey only after a while. This assumption is probably confirmed by the feature that a high percentage of already pigmented glasseels was captured in the summermonths upstream.

French experimental fishery stated that the migration is influenced by weather conditions, mainly wind direction and force (Gault, 1979). In the Rio Minho yield maxima were recorded in February and March of both years and at both stations. While the tide became stronger frequently the wind speed rose sharply to a force of BFT 7 mainly from ssw-direction (river mouth). In March during two nights the fishery had to be called off : the net had to be separated from the boat in order to prevent it from capsizing.

Tesch 1973 pointed out a possible dependence of migrating glasseels and the phases of the moon but sufficient quantitative data do not seem to be accumulated yet. Comparing the high yield at new moon in November 1982 with the low number caught during the days before and after gives rise to the presumption that glasseels exhibit a lunar activity.

During 1981/1982, comparing pigmented glasseels with unpigmented, the values for length and weight turned out to be distinctly lower. This is ascribed to the theory that glasseels abstain from feeding while migrating into the estuary. Extensive pigmentation and a higher demand of metabolic energy result in a depletion of body resources for up to two weeks before they start feeding again (Forrest, 1976). Length and weight reduction of glasseels during the initial stage of their anadromous migration and during pigmentation is a well known phenomenon (Elie, 1979, Cantrelle, 1981, Lecomte-Finiger, (1983). According to Lecomte-Finiger (1983) rising water temperatures were hold responsible for the acceleration of the process of pigmentation and an extend dwelling in seawater delayes it but increased the loss of weight (32-54 %) and the reduction of length (4-6 %).

Tarr & Hill (1978) studied biomass relations of South-African elvers and glasseels (*Anguilla mossambica, Anguilla marmorata, Anguilla nebulosa labiata*). Since there was no significant difference between the developmental stages I, II and III, the mean ratios were 17.33 % (DW to WW) and 15.91 % (ODW to WW) which is comparable with the values from the river Minho upstream regarding size groups I and II. The difference, however, to the glasseels from the estuary is more apparent. The same applies to the elvers of sizegroup III.

According to the results of this investigation one may assume that not only seasonal differences with respect to the length-weight relation but also the catch site (distance to the mouth) and the time of fishing (phases of the moon) might exert a qualitative influence on aquaculture experiments.

This assumption was partly checked in a closed circulation system (Weber, 1984), by which it could be shown that glasseels with high C-values, captured upstream in March could adapt themselves to food within a shorter time and that they grew relatively faster (0.64 % towards 0.47 % per feedingday) than individuals caught in the estuary in the previous month. However, they seemed to be more receptive to ectoparasitic infections (*Ichthyophthirius multifiliis*). Further experiments will be necessary to prove that glasseels from certain months and catchsites may be considered more suitable for stocking purposes in aquaculture than individuals from other times and places. However, during the summer one has to reckon with lower numbers and more heterogenous material, containing a higher percentage of already pigmented glasseels and elvers.

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REGIONAL VARIATION IN GLASS EEL CATCHES AN EVALUATION OF MULTIPLE SAMPLE SITES

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GLASS-EELS
NETHERLANDS
SAMPLING

ABSTRACT. — In the Netherlands glass eels are caught for research purposes at various sites. Catches at four sites are compared, using an analysis of variance. It is concluded that three sites basically give the same information, while one, the most southern site, shows independent annual fluctuations. As a side effect of this study, a different indicator for catch sizes is proposed : geometric means reflect more accurately the underlying frequency distribution than common means do.

ANGUILLA ANGUILLA
CIVELLES
ECHANTILLONNAGE
PAYS-BAS

RESUMÉ. — Aux Pays-Bas, des civelles sont échantillonnées dans plusieurs sites. Les captures de 4 points sont comparées par une analyse de variance. Trois sites présentent une même variation tandis qu'une fluctuation annuelle indépendante est remarquée pour le plus méridional. Compte-tenu de ces résultats comparatifs, un nouveau calcul des captures de civelles est proposé : leur distribution statistique est mieux exprimée par les moyens logarithmiques que par les moyennes numériques.

INTRODUCTION

At Den Oever (Fig. 1), the glass eel gathering at the sea side of the sluices is sampled every night in spring at two hourly intervals. In the 1970's additional sampling sites were established at Ijmuiden (1969, 1970 and 1973 onward), Stellendam (1976 onward) and Lauwersoog (1976 onward). Based on the data collected at these four sites, various studies have been published (Deelder, 1960, Heermans, and v. Willigen, 1982) concerning both eel biology and management. Since manpower is limited, the results of the four sampling sites are compared, thereby evaluating the extra research effort of multiple sampling sites within the Netherlands.

METHODS

The sampling method (dipnet, 1 m^2) has been described earlier (Deelder, 1984) and has not been changed among years or between sites. Catches have been made from January through June, at Den

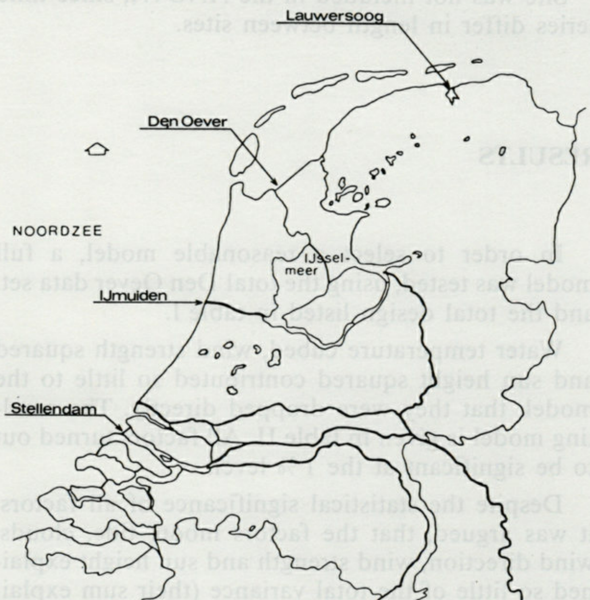

Fig. 1. — Map of the Netherlands, giving the sampling sites.

Table I. — Design used in the analysis of variance

variate	type	remarks
glass eel count	dependent	transformed to Y = log (glass eel count + 1)
year	factor	
month	factor	
hour	factor	two hourly intervals
lunar phase	factor	4 levels
tidal phase	factor	6 levels
cloudiness	factor	5 levels, including fog seperately
wind direction	factor	8 levels
wind strenght	covariate	also squared and cubed, Beaufort
water temperature	covariate	also squared and cubed
sun height	covariate	vertical angle between sun and horizon, also squared.

Oever every night at two hourly intervals; at the other sites at irregular intervals (± twice a month) mostly about two hours after sunset. No effort to concentrate glass eels in the dipnet was made. Glass eels were counted, and a subsample of them measured. Length measurements are recorded elsewhere (Heermans and v. Willigen, 1982).

Analysis of the data was made by a socalled Analysis of Variance (ANOVA).

The design of the ANOVA used is listed in Table I. This design differs from earlier studies based on these data by the transform of the dependent variate : because of the natural count character of this variate, a log-transformation was used : Y = LOG (glass eel count + 1), using Napierian logarithms. A posteriori tests on residuals did not reject this transform.

Site was not included in the ANOVA, since time series differ in length between sites.

RESULTS

In order to select a reasonable model, a full model was tested, using the total Den Oever data set, and the total design listed in table I.

Water temperature cubed, wind strength squared and sun height squared contributed so little to the model, that they were dropped directly. The resulting model is given in table II. All factors turned out to be significant at the 1 % level.

Despite the statistical significance of all factors, it was argued, that the factors moon, tide, clouds, wind direction, wind strength and sun height explained so little of the total variance (their sum explaining only 1.5 %, leaving 43.6 % for temperature, hour, month and year) that their recording cannot be of any practical importance. Therefore, they were dropped from the model. Now it was realized that in the remaining model (water temperature, hour, month and year), water temperature is of a different

Table II. — Percentages of the total variance explained by the full model for Den Oever.

source	% of total variance
year	13 %
month	8 %
hour	1 %
moon	0 %
tide	0 %
clouds	0 %
sun height	1 %
wind direction	0 %
wind strength	0 %
water temperature	4 %
multicollinearity	14 %
total explained	45%
unexplained	55 %
mean square	2.64

nature from the other factors : it is the only one not determined by the sampling scheme. Although water temperature may be readily available for the different parts of the Netherlands, it was preferred to drop water temperature from the model, having only the sampling scheme remain. The fact that just the sampling scheme remains, stresses the necessity of careful analysis of glass eel data.

The results of the remaining small model are given in table III to VI, together with the results for the three other sites.

From inspection of table IV, it can be seen that Lauwersoog-Den Oever show a positive correlation : from 1976 to 1981 both time series give high values; since 1982 both show a rapid decline.

Ijmuiden-Den Oever has an even higher correction : not only is the downward trend from 1981 to 1983 adequately represented, but also temporary decreases in 1970, 1973 and 1976 correspond in both time series.

Stellendam-Den Oever, finally, shows no noteworthy correlation at all : despite a marked decrease in catches at Den Oever in 1980, Stellendam reaches its top record in that year.

Table III. Percentages of the total variance explained by the reduced model for all sites.

source/site	Lauwersoog	Den Oever	Ijmuiden	Stellendam
year	14 %	19 %	25 %	36 %
month	27 %	13 %	14 %	13 %
hour	4 %	5 %	0 %	3 %
multicollinearity	1 %	2 %	13 %	4 %
total explained	47 %	39 %	53 %	56 %
unexplained	53 %	61 %	47 %	44 %
mean square	3.35	2.46	3.45	2.04

Table IV. — Estimated year effects at all sites.

Year/site	Lauwersoog	Den Oever	Ijmuiden	Stellendam
1969		0.01	−2.05	
1970		0.23	−0.02	
1971		0.05		
1972		0.59		
1973		0.07	−0.50	
1974		0.43	1.16	
1975		0.78	1.24	
1976	0.22	0.36	0.20	−0.70
1977	0.46	0.93	0.49	−0.06
1978	0.35	0.68	0.69	0.41
1979	0.03	1.06	0.67	0.17
1980	0.47	0.43	0.87	1.03
1981	0.55	0.37	−0.18	0.29
1982	−0.06	−0.19	−1.10	−0.56
1983	1.16	−0.54	−1.25	−0.55
1984	−0.75	−0.42		
1985		−0.60		

Table V. — Estimated month effects at all sites.

month/site	Lauwersoog	Den Oever	Ijmuiden	Stellendam
February	−1.68	−0.98	−1.87	0.07
March	−0.87	0.21	−0.22	−0.29
April	1.57	1.24	0.48	0.93
May	1.36	0.42	0.47	−0.11
June	−0.38	−0.88	1.14	−0.60

Table VI. — Estimated hour effects at all sites.

hour/site	Lauwersoog	Den Oever	Ijmuiden	Stellendam
17-19		−0.97		−0.82
19-21	0.09	−0.36		−0.37
21-23	0.22	0.38		−0.26
23-01	0.33	0.52	no data	0.32
01-03	0.15	0.52		0.15
03-05	−0.79	0.10		0.52
05-07		−0.19		0.47

DISCUSSION

This study concerns an evaluation of research work. The first point to consider is the appropriateness of the evaluation procedure. Although many aspects of the analysis may be questioned, the discussion will be restricted to the choice of the Y-variate. Basically, an a priori choice was made for the most frequently used transform in case of natural counts : a log transform. Furthermore, a posteriori tests on the distribution of the error terms did not show any significant deviation from the theoretical expectation. However, the choice of a log transform

Table VII. — Results from a bootstrap simulation using the 1952 Den Oever data, to compare year totals and mean log transforms as indicator variables of year class strength. N = number of 'samples', C.V. = coefficient of variation.

'sample' number	year totals		mean log transforms	
N	C.V.	C.V. * sqrt (N)	C.V.	C.V. * sqrt (N)
1	0.54	0.54	0.21	0.21
10	0.31	0.96	0.06	0.18
100	0.08	0.80	0.02	0.19
1 000	0.03	1.05	0.01	0.19
10 000	0.01	0.62	0.00	0.19

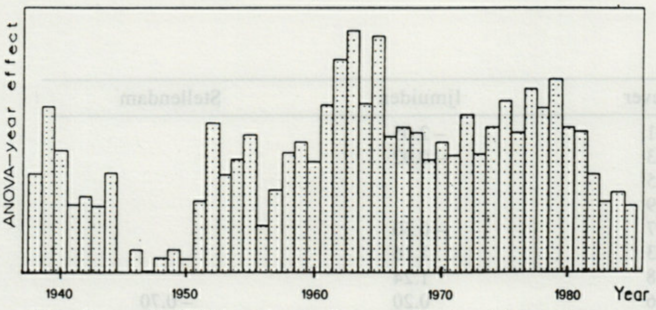

Fig. 2. — ANOVA-estimated year effects at Den Oever.

necessitates a drastic change in accepted views on year class strengths in the Ijsselmeer : figure 2 is definitely different from total year catch figures, as for instance given in Deelder, 1984 : year class 1952 is not a very exceptionally strong year class, and 1958 is average sized instead of top record, while 1963 turns from a moderate year class into the top record. However, long term variations are quite comparable. In order to select a judgement criterion between year totals and mean log transforms, a small bootstrap simulation was set up : table VII lists coefficients of variation (taking 10 runs) of both indices of various numbers of artificial 'samples' taken at random from the 1952 raw sampling data at Den Oever. Furthermore, these coefficients of variation are multiplied by the square root of the number of 'samples', to correct for differences in accuracy induced by the number of 'samples'. From table VII, it can be concluded that year totals heavily depend on the number of samples, and that sample numbers up to 1000 and 10000 are still not enough, while means of log transforms stabilize at sample numbers of 10 to 100. Therefore, means of log transforms are to be preferred.

Secondly, the rationale of this study should be discussed. The primary aim is to stop all work on superfluous sampling sites. It should be stressed that Den Oever is not evaluated, since this sampling site will be continued because of practical considerations. From table IV, it can be concluded that both Lauwersoog and Ijmuiden are superfluous. Sampling is not intense enough to monitor very short term changes, and long term changes do not contradict the Den Oever series. However, Stellendam gives independent information.

Finally, one should have some doubts on the usefullness of these time series to monitor year class strength. Since all four sites discussed concern steep transitions from one water body into another, one can not accept at forehand that instantaneous densities are reliable estimators of the flow of glass eels through some borderline. May be catching devices can fill in this gap at Den Oever.

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DIFFERENCES IN DEVELOPMENT STAGE AND STOCK DENSITY OF LARVAL *ANGUILLA ANGUILLA* OFF THE WEST COAST OF EUROPE

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LARVES
RECRUTEMENT
ANGUILLA ANGUILLA
ATLANTIQUE NORD

RÉSUMÉ. — La présence de larves d'Anguille à différents stades de métamorphose le long du talus continental du Golfe de Gascogne et des régions septentrionales proches du détroit de Gibraltar, est suivie à l'aide de prélèvements effectués à l'IKMT, de nuit et à 25-100 m de profondeur environ. Des prélèvements au MOCNESS ont confirmé leur présence en grande quantité pendant la nuit à cette profondeur. La densité des larves d'Anguille pendant les mois de novembre-décembre 1982-1984, est toujours plus faible dans le Golfe de Gascogne que dans la région occidentale du détroit de Gibraltar. On remarque une chute considérable de la densité moyenne du stock de larves du Golfe de Gascogne pendant la période 1982-1985 comparée à celle de 1971-1977. Le pourcentage de larves en cours de métamorphose est plus faible à l'ouest du détroit de Gibraltar que dans le Golfe de Gascogne. Aussi la longueur des larves du secteur Gibraltar est significativement inférieure à celle des larves du Golfe de Gascogne, confirmant les résultats antérieurs. La discussion porte sur l'interprétation de ces résultats en accord avec l'hypothèse de migration passive des Anguilles.

FISH LARVAE
RECRUITMENT
ANGUILLA ANGUILLA
NORTH ATLANTIC

ABSTRACT. — The occurrence of eel larvae and their stages of metamorphosis along the continental slope from the Bay of Biscay and adjacent northern areas to the entrance of the Mediterranean was investigated with IKMT night hauls at depths of about 25 to 100 m. This was, at night, the main depth of preference of the eel larvae as examined by using MOCNESS hauls. The density of eel larvae in the Bay of Biscay in November/December 1982-1984 was always lower than in the vicinity west of the Straits of Gibraltar. When the density of the larval stock in the Bay of Biscay 1982-1985 is compared with that of the average stock from 1971-1977, a considerable decrease has occurred. Examination of the development stage of the larvae in 1982 to 1984 showed that west of the Straits of Gibraltar the percentage of metamorphosing larvae was much smaller than in the Bay of Biscay. Also the length of the larvae near Gibraltar was significantly smaller than in the Bay of Biscay which is in agreement with earlier investigations. It is discussed how far these results are in agreement with the eel larval drift hypothesis.

INTRODUCTION

A study on the occurrence of fluctuations in the recruitment of eel during arrival of the larvae at the continental slope in the Bay of Biscay and of the glass eels at the coasts has been made for the years 1971 to 1977 (Tesch, 1980). This was repeated only in 1982 (Tesch, Deelder and Niermann, 1983). In the meantime, samples were taken occasionally during Sargasso Sea and other cruises (Kracht and Tesch, 1981; Tesch, 1982a, b; Kracht, 1982) mainly in different areas and seasons. In 1982 we found that the eel larval density in the Bay of Biscay was far below the level registered for the years 1971 to 1977 which corresponded with low glass eel catches at the coasts (Tesch, Deelder, Niermann, 1983). In 1983 and 1984 we continued sampling in the Bay of Biscay and farther south. The results are presented in this paper.

In the 1979 Sargasso Sea cruises, differences in sizes of the eel larvae in the Bay of Biscay and near the entrance of the Mediterranean were observed which threw some doubt on the hypothesis of the mainly passsive drift of the larvae from the Sargasso Sea spawning area to the European coasts (Kracht and Tesch, 1981; Kracht, 1982). We therefore present results on size and development stage of the larvae in the different sampling areas near the European continental slope.

In addition to the horizontal distribution of the larvae, the results of some hauls are given to describe their vertical distribution. This should confirm earlier results (Tesch, 1980; Kracht, 1982) and show that the towing depth used during the surveys met the main depth layer of occurrence.

MATERIALS AND METHODS

For the survey (Table I), an Isaacs Kidd Midwater Trawl (IKMT) with an opening of 6 m^2 and a mesh size of 1 800 µm was mainly used; this concerns especially the surveys from 1982 to 1984 in the Bay of Biscay and around the Iberian Peninsula. The sampling from 1979 to 1981 took place during cruises with only occasional hauls in or north of the Bay of Biscay, with partly other mesh sizes and net openings, or not during the standard season (autumn). At the standard areas and season the collections were carried out generally with three hauls at one position with horizontal towing depths of about 25, 70 and 100 m respectively during darkness.

After Tesch (1980), the depth preference of the "II group" eel larvae is probably within these limits although variations could occur depending on the lunar cycle (Kracht, 1982). We therefore checked the depth preference once more using a Multiple Opening and Closing Net and Environmental Sensing System (Mocness) with a theoretical opening of 1 m^2. This net is obviously rather small for the catch of the "II group" eel larva. In an area of comparably strong larvae concentration, west of the Straits of Gibraltar, 10 Mocness hauls, 8 nets each, were therefore necessary to catch a minimum quantity of larvae. The towing depth of the Ikmt was registered by a time depth recorder and occasionally controlled by a pressure sensing transmitter fixed at the IKMT. The towing time was generally one hour, the speed 2 kn which was controlled by rail log. Flow meter measurements in front of and above the net opening were found to be too variable. For comparison of the larval density in one-hour towing units, night hauls only were used since during the day the larvae occur at greater depths and over a greater depth range (Table II). Length measurements, taken, on freshly caught larvae, were used for evaluation. Measurements on larvae preserved in a 10 % formalin-seawater solution showed 1.5 % shrinkage after one month and negligible additional shrinking one year later. We differentiated between two stages of development, the younger larvae which correspond to development stage I-II (after Schmidt, 1906) and older larvae, corresponding to stages III-V.

Table I. — Type of ship, area and IKMT used for towing.

Date	Ship	Opening of IKMT (m^2)	Mesh size (µm)	Number of hauls	Area	
21.-22.04.79	Friedrich Heincke	2	850	6	Biscay 43°38'N 9°36'W to 56°23'N 7°16'W	1)
07.05.79	Anton Dohrn	6	500	2	Biscay 47°45'N 8°58'W 47°58'N 8°16'W	1)
02.12.79	Anton Dohrn	6	850	1	Biscay 48°23'N 11°50'W	
17.08.-23.08.80	Friedrich Heincke	6	1 000	27	West of Ireland 51°35'N 12°35'W to 56°09'N 9°29'W to 54°06'N 15°56'W	
18.02.-23.04.81	Friedrich Heincke	6	1 800	10	Biscay 45°06'N 8°14'W to 47°19'N 6°24'W	2)
28.10.-21.11.82	Friedrich Heincke	6	1 800	44	from Biscay to Gibraltar	3)
10.11.-11.12.83	Friedrich Heincke	6	1 800	74	from Biscay to Mediterranean to 2°49'W	
15.11.-13.12.84	Friedrich Heincke	6	1 800	29	from Biscay to Gibraltar	
11.11.-14.11.85	Friedrich Heincke	6	1 800	22	Bay of Biscay	

1) Kracht (1982), Tesch (1982a)
2) Tesch (1982b)
3) Tesch *et al.*, 1983)

Table II. — Vertical distribution of leptocephali and metamorphosis stages at about 36°00'N, 6°40'W (west of the Straits of Gibraltar) obtained by 10 MOCNESS hauls and 5 horizontal IKMT (6 m^2) daylight hauls (90 min each) at different depths.

MOCNESS hauls							IKMT hauls		
Depth (m)	Volume of water filtered ($10^4 m^3$) at night	Volume of water filtered ($10^4 m^3$) during daylight	Number of larvae caught (in brackets No./$10^4 m^2$) at night: *A. Anguilla*	at night: Other Anguilliformes	during daylight: *A. Anguilla*	during daylight: Other Anguilliformes	Depth (m)	Number of larvae caught: *A. anguilla*	Congridae
0- 50	2.78	1.05	7 (2.5)	4 (1.4)	0	0			
50-100	2.04	1.41	9 (4.4)	3 (1.5)	0	0			
100-150	1.85	1.04	1 (0.5)	3 (1.6)	0	0	100	0	2
150-200	1.11	0.74	0	3 (2.7)	0	1 (1.3)			
200-250	0.19	0.92	0	0	1 (1.1)	1 (1.1)	200	0	0
250-300	0.19	0.56	0	0	0	0			
300-350	0.37	0.93	0	0	0	0	350	0	1
350-460	0.56	1.11	0	0	1 (0.9)	0	425	16	0
450-560	—	1.11	—	—	1 (0.9)	0	425	5	0

RESULTS

1. Depth occurrence

Table II shows that the highest number of larvae at night occurred between 50 and 100 m with a stronger tendency toward 50 than to 100 m. Compared with the other Anguilliformes (mainly Congridae), they occurred in greater concentration and nearer the surface. The result during daylight is rather poor but confirms that they occur much deeper, as noted in earlier investigations. Horizontal hauls at the same place with the much more powerful IKMT showed that the migration during daylight goes downwards to at least 425 m, which also confirms the earlier results (Tesch, 1980).

2. Density of the stock

Figure 1 shows the mean density of the eel larval stock, combined for three different areas. In all three years, the density was lowest in the Bay of Biscay. It seems to be highest west of the Straits of Gibraltar except for 1982 when the highest density was found west of Portugal. If the catches near the entrance, west of Gibraltar, are compared with those farther out to sea, nearer the southwest corner of Portugal, it is obvious that the density farther out is lower than near Gibraltar and not much different from the other two areas.

The density of the Bay of Biscay stock is compared with the numbers found during earlier investigations (Table III). Because the catch numbers of the years 1971 to 1977 were obtained by an IKMT with 3 times smaller opening these figures were adjusted by multiplying them with three. It is evident that in 1982 to 1985 the density was much smaller than in 1971 to 1977, and even the earlier years with

A

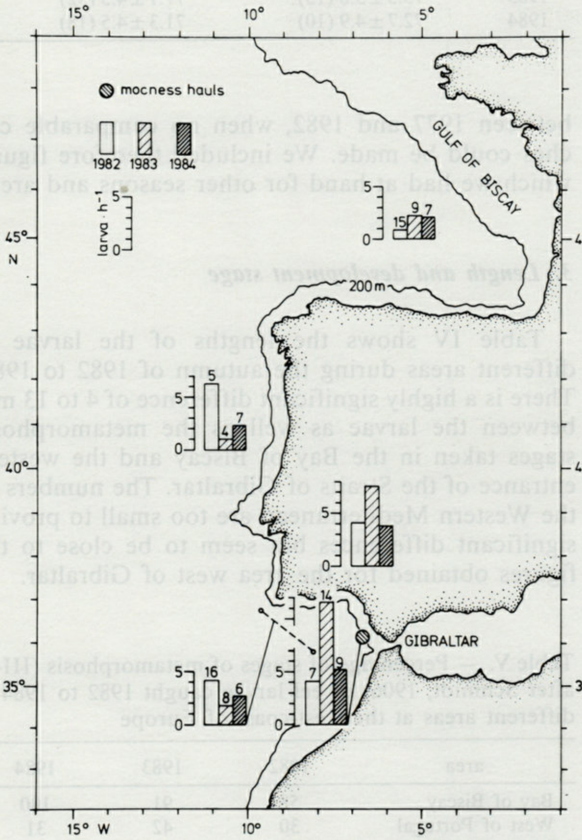

Fig. 1. — Density of eel larvae (n · h^{-1} of towing) in different areas of the European continental slope. West of the Straits of Gibraltar, the data are shown combined for the whole area south of 38°N in the upper arrangement of columns. Below, they are split between 6° and 7°W (right) and the more westerly positions (left, indicated by a stippled line). Number in the columns : number of hauls.

the poorest results (1972, 1974, 1976) yielded two to five times higher catches than the more recent years. It would be interesting to know what occurred

Table III. — Number of eel larvae ($n \cdot h^{-1}$ of towing) 1979-84 in the Bay of Biscay in comparison with results obtained during 1971 to 1977 (Tesch, 1980). The hauls of 1980 are combined data from the northern Bay of Biscay to the area west of Ireland.

year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
spring	30,3	7,4													
autumn		43,5	5,7	42,0	5,1	21,9			5,3		0,9	2,2	2,1	2,7	
spring and autumn									4,2						
number of hauls									9	27	10	15	17	7	22

Table IV. — Length (mm) of eel larvae (L) and their metamorphosis stages (M) in different areas with standard deviation and number of individuals examined (in brackets).

	Biscay, north of 42 °N		West of Gibraltar		West-Mediterranean
	L	M	L	M	L
1982	75.1 ± 3.6 (11)	75.1 ± 5.1 (11)	62.0 ± 3.6 (75)	66.9 ± 4.0 (19)	—
1983	75.5 ± 3.8 (13)	77.1 ± 4.3 (32)	65.8 ± 5.9 (156)	69.7 ± 3.6 (50)	68.0 ± 5.7 (4)
1984	72.7 ± 4.9 (10)	71.3 ± 4.5 (18)	64.7 ± 5.6 (53)	64.5 ± 6.8 (12)	—

between 1977 and 1982, when no comparable catches could be made. We included therefore figures which we had at hand for other seasons and areas.

3. Length and development stage

Table IV shows the lengths of the larvae in different areas during the autumn of 1982 to 1984. There is a highly significant difference of 4 to 13 mm between the larvae as well as the metamorphosis stages taken in the Bay of Biscay and the western entrance of the Straits of Gibraltar. The numbers of the Western Mediterranean are too small to provide significant differences but seem to be close to the figures obtained for the area west of Gibraltar.

Table V. — Percentage of stages of metamorphosis (III-V, after Schmidt, 1906) of eel larvae caught 1982 to 1984 in different areas at the west-coast of Europe

area	1982	1983	1984
Bay of Biscay	58	91	100
West of Portugal	30	42	31
West of the Straits of Gibraltar	18	22	19

The percentage of leptocephalus stages I-II are compared with the more developed metamorphosing stages of three different areas from north to south (Table V). In the Bay of Biscay in all three years the percentage of metamorphosis stages was highest, nearly 100 % in 1983 and 1984, west of Gibraltar about 20 % only, in the area between north and south intermediate.

It seems likely that the density from 1979 to 1981 was average or at least close to the values found for the poorer years from 1971 to 1977.

DISCUSSION

The reliability of our IKMT catch data can be examined when they are compared with the MOCNESS data west of Gibraltar near 6°40'W. 14 IKMT hauls in 1983 at this place yielded 10.9 larvae per one hour of towing. When we assume a 100 % filtration rate, this would correspond to 4.9 larvae/10^4 m^3. The MOCNESS catch yielded 4.4 larvae/10^4 m^3 in the main layer of occurrence (Table II) which is rather similar. In 1982 our catches in addition could be compared with catches obtained by a different ship towing with quite a different net. The results were similar (Tesch, Niermann and Deelder, 1983).

Most striking is the low stock density observed first in 1982 (Tesch, Deelder and Niermann, 1983), and the fact that this low level of larval abundance continued during the following two years. This is in contrast to the rich abundance during the years 1971 to 1977 even though a considerable annual fluctuation also took place here. The poorest year of the earlier period (1976) seems to have more than twice as high a density than the richest from 1982 to 1985 (1983). The average density from 1971 to 1977 (22.4 larvae per one hour of towing of a 6 m^2 IKMT) dropped to an eleventh during 1982 to 1985 (2,0 larvae). The catch was low (4.2 larvae) as in spring/autumn 1979 (Fig. 1; Kracht, 1982) and was probably on a similar level during the following two years; no recovery to peak values, as known from the four years between 1971 to 1977, occurred during the 6 years period after 1978. The question arises, therefore, whether some conditions important for the recruitment have developed negatively. These conditions might not only be connected with the environment in the spawning area in the Sargasso Sea or with the migration from and to the continent but also with the number of individuals or the physiological conditions of the spawners starting for or arriving at the spawning area. A long-term fluctuation caused by natural conditions is also possible, but this possibility should not divert attention from the question of whether damages of anthropogenic origin have occurred.

The higher density of the larvae in the southern areas compared with that in the Bay of Biscay is probably due to a certain stowing or bottleneck effect in the funnel between Europe and Africa which leads to the Straits of Gibraltar. If the density farther outside is considered, there is little or no difference in comparison with that of the Bay of Biscay. Similarly, Kracht (1982) found that the density in the open Atlantic, e.g. west of 15°W was in 1979 much lower than near Gibraltar.

This leads to the question of how the larvae succeed in passing this bottleneck and how they move at all when crossing the Atlantic. If drift is supposed to be the transportation mechanism into the Mediterranean, how might this function ? The current regime in the Straits of Gibraltar is comparatively well known (e.g. Lacombe and Richez, 1982). In the west in front of the sill, a comparatively weak surface current flows to the east (Fig. 2) and a fast deep undercurrent to the west. The vertical distribution samples of the eel larvae shown in Table I are made at 6°40'W, on the left hand side of Figure 2. Beginning at this position, after low speed eastward drifting during the night at the surface they are exposed to a high speed current westward when diving to a depth of 400 m and more. As a result the larvae would have a net westward drift. Compensation would require a swimming speed of at least 20 $cm \cdot s^{-1}$. This struggle against the current is probably an additional factor which produced the accumulation of larvae at the entrance of the Straits.

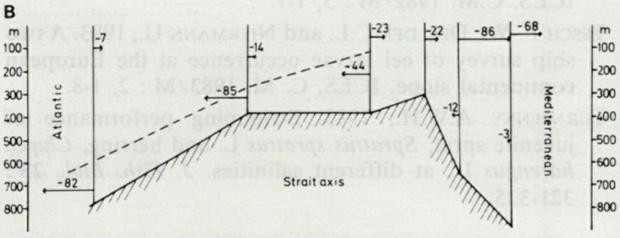

Fig. 2. — Longitudinal section through the Straits of Gibraltar with mean currents (numbers in $cm \cdot sec^{-1}$) in the upper and the lower layer from 6°40'W to the meridian of Gibraltar (after Lacombe and Richez, 1982, modified).

Young herring of about 50 mm TL and young sprat (38 mm TL) sustained a critical swimming speed of 10-12 body length $\cdot s^{-1}$ (Turnpenny, 1983). Applied to the eel larvae with a body length of 65 mm this would produce a swimming speed of about 72 $cm \cdot s^{-1}$. Probably the leptocephalus is not such a fast swimmer. But 20 $cm \cdot s^{-1}$ would require a swimming speed of 3 body lengths only, which seems quite possible.

The problem of orientation remains. This is possible on the basis of a compass course orientation as proposed for the adult eels which have the same problem when migrating in the opposite direction Sargasso Sea (e.g. Tesch, 1978). Also young chum salmon have been found to be oriented by the earth's magnetic field (Quinn and Groot, 1983).

Our results also give rise to doubts on the hypothesis that the eel larvae are mainly drifting when migrating to the continent. We found that the eel larvae as well as the metamorphosing stages near Gibraltar are 4 to 13 mm smaller than in the Bay of Biscay. This confirms earlier results (Kracht and Tesch, 1981; Kracht, 1982) and means that similar differences occurred during all the four years of study. In addition, the larvae in the Bay of Biscay exhibited considerably more stages of advanced development than in the south which could indicate that they are not only longer but also older.

Lower length and earlier development stages in the south than in the north suggest that the larvae are younger in the south. It is therefore unlikely that they are conducted or transported by Gulf Stream and North Atlantic current. This is not the direction to the Mediterranean. In this case, they should be older than the larvae in the Bay of Biscay. That the larvae are mainly transported by the Gulf Stream system is also unlikely considering that the younger larvae are distributed all over the area outside the Gulf Stream and to at least four degrees south of the Azores (Kracht, 1982). This wide distribution is also known from the data of J. Schmidt (Boëtius and Harding, 1985).

A critical light can also be thrown on the drift hypothesis when our density data of the larvae stock near the European continent are compared with those of recent studies obtained further to the west (e.g. Schoth, 1981; Schoth and Tesch, 1982; Kracht, 1982), and a similar comparison is made with the Gulf Stream watermasses reaching Europe. As the density numbers found 1979 to 1981 at the European continental slope are very similar from year to year it does not matter if it is always the same year class which is traced from the Sargasso Sea to Europe. This is also difficult because the conventional year-class classification (0-II) is doubtful (Boetius and Harding, 1985). Night catch data only are used for the small larvae (0-group) in the Sargasso Sea. In 1979 they had a mean TL of 12 mm and a density of 33 per 1 h of towing (= 100 %); between 50°W and Azores, the larvae of a mean TL of 47 mm decreased to 21 per 1 h of towing (= 64 %) and in front of the European continental slope (lengths see Table IV) to about 5 per 1 h of towing (= 15 %). Although these are not the figures of mortality, they are in accordance with the comparatively low mortality calculated for the oceanic stage until the beginning of the glass eel stage (Tesch, 1980). For the percentage of the water masses of the Gulf Stream reaching the European continent the calculation of Dietrich *et al.* (1979) shows that North Atlantic and Portugal Current may be the main contributors to the transport of the larvae. Out of the initial Gulf Stream, south of Newfoundland these two currents carry 17 % of the original water mass. Our calculation showed that the density of the larval stock in the Sargasso Sea decreased to 15 % upon arrival at the European continent which is nearly congruent with the loss of the Gulf Stream. But there is nothing left for the loss of larval stock density by mortality which seems unlikely and speaks for an additional mechanism moving the larvae across the Atlantic.

It is therefore suggested that transportation by currents is a factor which can modify the migratory route, e.g. arrival farther north or south and earlier or with delay. It may be imagined that some larvae are indeed taken by the Gulf Stream and not diverted by one of the various branchings. They could arrive much earlier and then are characterized by an essentially smaller size than the average. The length frequency distribution (Tesch, 1980) observed in the Bay of Biscay in 1975 showed five larvae of a length of 55 to 58 mm only; the average was about 70 mm. The essential factor which moves the larvae across the Atlantic is therefore suggested to be more active swimming. To overcome the direct distance from the central Sargasso Sea spawning area to the coasts of Europe and Africa, a two-year swimming effort of 50 mm long larvae at a speed of two fish lengths $\cdot$ s^{-1} is sufficient. From the east end (50°W) of the spawning area (Schoth and Tesch, 1982) to Gibraltar, the speed could be even lower or the arrival earlier.

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DISTRIBUTION DU PEUPLEMENT D'ANGUILLE (*ANGUILLA ANGUILLA L.*) A L'ÉCHELLE D'UN BASSIN VERSANT : ÉTUDE EN SÈVRE NIORTAISE

*Distribution of eel populations (*Anguilla anguilla L.*) in the watershed area of Sèvre Niortaise*

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ANGUILLA ANGUILLA
DENSITÉ
DISTRIBUTION
EAU DOUCE

RÉSUMÉ. — L'étude de la répartition du peuplement d'Anguille (*Anguilla anguilla* L.) du réseau hydrographique de la Sèvre Niortaise, a été réalisée grâce à des inventaires piscicoles par pêche électrique. Bien que présente dans toutes les zones inventoriées, la distribution de l'Anguille montre une très grande hétérogénéité. Les zones aval du système fluvial sont caractérisées par de fortes densités d'individus de petites tailles (< 450 mm). Dans les zones amont, les densités sont beaucoup plus faibles, mais le spectre de taille est plus large. La distribution de l'Anguille résulte de la colonisation. La grande hétérogénéité observée à l'échelle de ce petit bassin versant, est vraisemblablement liée aux nombreux barrages de ce cours d'eau. Ceux-ci pourraient non seulement influencer l'importance quantitative du peuplement, mais également sa structure.

EEL
DENSITY
DISTRIBUTION
WATERSHED AREA

ABSTRACT. — The distribution of an eel population (*Anguilla anguilla*) has been studied in the watershed area of the Sèvre Niortaise (French atlantic coast) by using electrofishing methods. Although it is present through the whole area, the Eel is to be found heterogeneously. The lower parts of the river system present high densities of small sized eels (< 450 mm long). In upstream sections, the densities are much lower but the length range is wider. The distribution of eel results from the colonization phenomenon. The observed heterogeneity is probably influenced by numbers of small hydraulic dams along the river system. These may influence quantitative importance of the population and its structure too.

L'Anguille européenne (*Anguilla anguilla* L. 1758) représente une part importante du peuplement piscicole des petits fleuves côtiers atlantiques. Cependant, peu d'études se sont intéressées à l'analyse de sa répartition à l'échelle d'un bassin versant. Ceci résulte sans doute de la difficulté d'appréhender à l'échelle d'une vaste zone tous les facteurs pouvant intervenir. En effet, la distribution de l'Anguille est une résultante de nombreux facteurs dont :

— la capacité biotique des différents milieux à recevoir ces animaux.

— la facilité plus ou moins grande pour les individus d'atteindre les différents niveaux du système fluvial.

Cette étude s'inscrit dans le cadre du programme d'étude mené par le Parc Naturel Régional du Marais Poitevin, sur la Biologie et l'Exploitation de l'Anguille dans le bassin versant de la Sèvre Niortaise (Fleuve côtier ouest Atlantique). Elle fait suite aux travaux sur la colonisation par les civelles du Marais Poitevin (Legault, 1984).

Lors de nos études précédentes sur la colonisation de la zone aval du bassin versant et sur le franchissement des obstacles (Ibid) nous avons pu mettre en évidence les difficultés de colonisation, en raison de l'aménagement des rivières (barrages et gestion des niveaux d'eau dans les biefs). Cette étude a pour but d'analyser la répartition du peuplement d'Anguille à l'échelle du réseau hydrographique en mettant notamment en évidence certains facteurs déterminants.

1. MATÉRIEL ET MÉTHODES

La répartition du peuplement d'Anguille à l'échelle de la zone d'étude, a été étudiée par une série d'inventaires par pêche électrique.

1.1. Choix des sites d'inventaire

La Sèvre Niortaise, petit fleuve côtier Atlantique, est située au Nord de La Rochelle, son bassin versant couvre une superficie de 2 880 km^2.

Compte-tenu de l'étendue de la zone d'étude, et de nos possibilités d'intervention limitées, nous avons choisi de privilégier trois axes fluviaux qui présentent entre eux de nombreuses similitudes (géologique et topographique). Cependant, ils se discriminent par la distance à la mer de leurs confluences et par le nombre de barrages situés en aval (Tabl. I).

Après avoir réalisé des observations préliminaires sur chaque rivière, 12 sites d'inventaire à différents niveaux de chacun des axes, ont été sélectionnés (figure 1).

Tabl. I. — Situation des stations d'inventaire.
Description of survey sites.

Rivière	Longève			Autize					Chambon			
Stations	L1	L2	L3	A1	A2	A3	A4	A5	C1	C2	C3	C4
Distance à la mer km	26	30	35	41	44	65	73	95	101	109	119	
Nb de barrages en aval	4	4	4	4	7	10	24	25	37	37	37	38
Altitude m	7	12	22	4	9,5	15	42,5	62	39	50	72	137
Surface m^2	220	270	184	230	350	550	560	350	510	600	330	344

1.2. Protocole d'intervention

Les secteurs ont été pêchés par pêches successives selon la méthode de De Lury (1947), et une estimation de la population d'Anguille la plus probable (Seber et Le Cren, 1967) a été réalisée.

Chaque secteur échantillonné a été préalablement isolé à l'aide de deux filets lestés (mailles de 24 mm étirées). Puis le secteur est pêché à l'électricité, en courant continu (groupe E.P.M.C) avec une ou deux électrodes, et trois épuisettes à maille de 0.8 mm. Le courant continu utilisé a une intensité variant de 2 à 5 ampères pour 300 Volts.

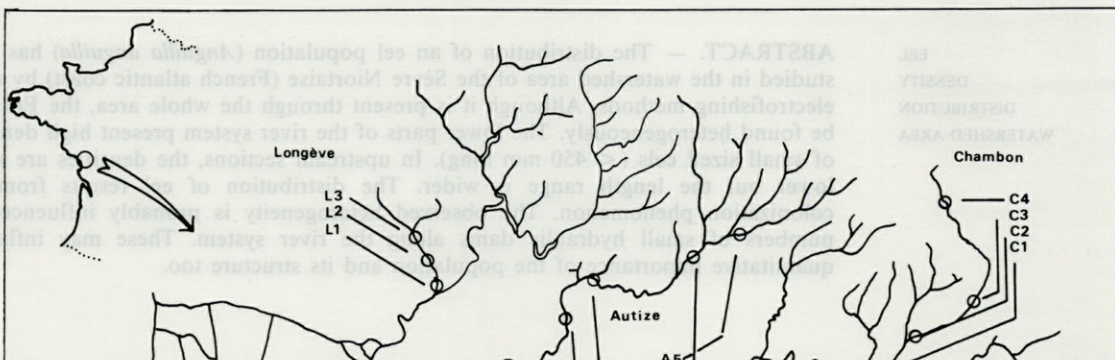

Fig. 1. — Localisation des stations d'inventaire.
Location of survey stations.

Les Anguilles sont mesurées au mm près. Un échantillon est réalisé en prélevant systématiquement une Anguille sur trois par classe de taille de 20 mm, pour acquérir des données biométriques plus complètes au laboratoire.

2. RÉSULTATS

L'Anguille étant l'espèce cible de cette étude, l'efficacité de pêche a été établie pour cette seule espèce.

2.1. Aspect quantitatif du peuplement

L'Anguille est présente dans toutes les stations, toutefois les caractéristiques quantitatives varient fortement sur les différentes stations (Tabl. II).

Tabl. II. — Résultats des inventaires des populations d'Anguille sur trois rivières du bassin versant de la Sèvre Niortaise.
Results (density, biomass, individual mean weight) of eels three tributaries of the Sèvre Niortaise river.

Rivière		Longève			Autize					Chambon			
Nº de la station		1	2	3	1	2	3	4	5	1	2	3	4
Densité Moyenne (Nb d'Anguilles pour 100 m²)	par station	97,7	38,5	35,0	14,8	17,4	19,4	14,8	3,7	3,1	5,3	2,1	0,6
	par rivière (1)		57.0				14.0					2.7	
Biomasse Moyenne (g/100 m²)	par station	3 100	1 050	1 100	300	640	865	740	360	660	1 020	470	240
	par rivière (1)		1 750				581					597	
Poids Individuel	par station (1)	31.7	27.2	31.4	20.3	36.7	44.1	50.0	96.9	214.2	175.5	224.4	410.0
Moyen (g)	par rivière (1)		30.1				49.6					256.0	

(1) Ces valeurs moyennes constituent un indice dont on retiendra l'ordre de grandeur.

Ces résultats mettent en évidence certains aspects de la répartition du peuplement d'Anguille, on note ainsi :

— Une baisse importante des densités moyennes par rivière lorsque l'on s'éloigne de la mer, de 57.0 individus pour 100 m² sur la Longève, elle passe à 2.7 individus sur le Chambon.

— Sur chacune des rivières, une diminution des densités de l'aval vers l'amont, pouvant être masquée sans doute par des caractéristiques particulières des stations.

— Des variations de biomasse, bien qu'elles soient moins nettes que pour la densité. La plus forte biomasse est représentée par la station la plus proche de la mer, 310 kg/hectare, et la plus faible par la plus éloignée, 24 kg/hectare.

— Le poids moyen individuel des Anguilles pour chaque axe fluvial, augmente avec la distance à la mer.

— Sur chacun de ces axes, le poids moyen individuel par station augmente de l'aval vers l'amont, exception faite de la Longève où il paraît constant.

2.2. Structure de taille de la population

Pour analyser la structure de taille à l'échelle de la zone d'étude, les prélèvements par rivière ont été globalisés. Ils mettent en évidence une évolution de la composition entre les différents axes fluviaux (Fig. 2).

— La Longève est caractérisée par un peuplement d'individus de petite taille (inférieurs à 350 mm), une absence d'animaux supérieurs à 450 mm et une chute des fréquences de taille à partir de 300 mm.

— Le Chambon présente une distribution beaucoup plus homogène, avec absence d'animaux de très petite taille (inférieure à 160 mm), et présence des animaux de grande taille (> 600 mm).

— L'Autize occuperait une position intermédiaire, proche de la Longève pour ses stations aval, et du Chambon pour les stations amont. Toutefois des alevinages réguliers ont été effectués sur cette rivière; ils ont pu modifier la structure du peuplement. C'est pourquoi cette rivière n'a pas été prise en compte dans l'analyse.

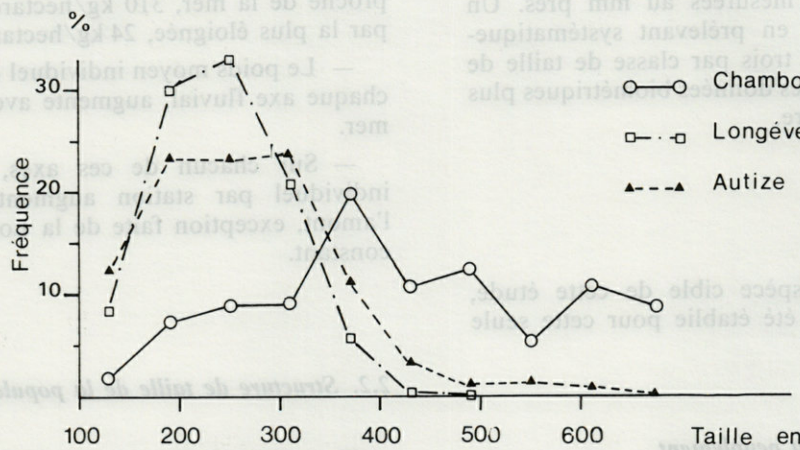

Fig. 2. — Fréquence des tailles des peuplements d'Anguille pour la Longève, l'Autize et le Chambon.
Size distribution of eel caught on the Longeve, the Autize and the Chambon rivers.

3. DISCUSSION

Dans cette étude, limitée à 12 secteurs d'inventaire, nous avons pu mettre en évidence l'hétérogénéité de la distribution de l'Anguille dans le bassin versant de la Sèvre Niortaise. Cette hétérogénéité se traduit par des variations importantes de densité, de biomasse, mais également de la structure du peuplement, en fonction de la localisation géographique des stations.

Sur la Longève, dont la confluence est située à 21 km de la mer, la densité moyenne est importante (57 individus/100 m^2). Elle est très forte pour la station la plus aval (97 individus/100 m^2), et reste élevée dans les stations plus en amont (35 individus/100 m^2). Cette forte densité s'accompagne d'une biomasse importante, toujours supérieure à 1 000 g/100 m^2; le poids individuel moyen est faible.

L'Autize et le Chambon, dont les confluences sont respectivement à 35 et 95 km de l'embouchure, montrent un gradient de densité en fonction de l'éloignement à la mer. Pour l'Autize, la densité moyenne est de 14 individus pour 100 m^2, elle n'est plus que de 2.7 individus pour le Chambon. Ce gradient se retrouve à l'échelle des stations. Corrélativement, le poids moyen individuel augmente; il atteint ainsi les valeurs maximales sur le Chambon, dans les stations les plus amont. Les variations de biomasse restent ainsi limitées.

Ces données confirment les observations réalisées sur le bassin versant de la Vilaine (Boisneau, 1983; Elie et Rigaud, 1985).

Fortes densités et individus de petites tailles dans les zones proches de la mer.

— Faibles densités et individus de grandes tailles dans les zones éloignées.

Dans la zone d'étude, les distances à la mer sont limitées (119 km au maximum). Ces différences de densité semblent donc traduire principalement les difficultés de colonisation liées au nombre important de barrages, qui induirait une colonisation moindre des zones situées à l'amont. Les différences de poids moyen individuel peuvent alors refléter de meilleures conditions de croissance des zones à faibles densités.

La structure de taille par rivière montre également des différences.

Sur la Longève, la distribution des tailles est peu étendue. La présence d'individus de petite taille (inférieures à 160 mm), tend à montrer que les animaux arrivent plus tôt que sur le Chambon. La chute rapide des fréquences de taille à partir de 300 mm indiquerait une émigration plus précoce.

Sur le Chambon, le spectre de taille est plus large, bien que les animaux de petites tailles (> à 160 mm) soient absents. Il n'y a pas de brusques variations des fréquences de taille. Les animaux arrivent sur cette rivière à des tailles plus importantes; l'émigration semble affecter un plus grand nombre de classes de taille.

Les structures de taille des peuplements d'Anguille de ces deux rivières semblent donc principalement affectées par la longueur des animaux à leur immigration et à leur émigration.

La taille moyenne des mâles lors de leur migration de reproduction est plus faible que celle des femelles (Tesch, 1977). La différence de structure pourrait alors provenir d'une différence de composition sexuelle du peuplement de ces deux rivières.

Lors des dissections au laboratoire, la détermination macroscopique du sexe a été réalisée. Bien que ces éléments soient préliminaires, ils paraissent confirmer cette hypothèse. En effet, quand nous comparons la distribution sur la Longève et le Chambon (Tabl. III), bien que sur la Longève la proportion des indéterminés soit importante, on rencontre principalement des mâles. Sur le Cham-

Tabl. III. — Fréquences des sexes pour la Longève et le Chambon.
Sex ratio of eels sampled on the Longeve and Chambon rivers.

Rivière	% mâles	% femelles	% indeter.
Longève	21.5	4.5	74
Chambon	0.	89	11

bon au contraire, il semble n'y avoir que des femelles.

Cette hétérogénéité pourrait traduire :

— Une migration différentielle liée au sexe, les femelles colonisant préférentiellement les zones amont des bassins versant, elles rencontreraient plus de difficultés lors de leur migration anadrome en raison du grand nombre de barrages.

— Des facteurs démographiques, comme la densité pourraient contrôler le déterminisme sexuel, en effet la détermination sexuelle génotypique est très labile chez l'Anguille (Deelder, 1973), la structure du peuplement traduirait alors les conditions de colonisation.

Ces deux hypothèses semblent donc mettre en évidence l'importance de la phase de colonisation, et donc des facteurs pouvant l'affecter, pour la structure du peuplement d'Anguille à l'échelle du bassin versant.

4. CONCLUSION

L'Anguille se distribue dans l'ensemble du réseau hydrographique de la Sèvre Niortaise. Sa répartition montre néanmoins une grande hétérogénéité. Les zones aval sont caractérisées par de fortes densités d'individus de petite taille et l'absence de gros animaux. Dans les zones amont, au contraire, la distribution est plus homogène, mais les densités sont beaucoup plus faibles.

La répartition de l'Anguille résulte de la colonisation. L'aménagement important du bassin versant représente un facteur essentiel de perturbation lors de la migration anadrome. Il risque d'accentuer l'hétérogénéité de la distribution du peuplement, mais aussi de modifier sa structure.

L'étude des animaux migrants à différents niveaux d'un bassin versant, associée à l'étude de la répartition du peuplement, devrait permettre d'analyser les effets des aménagements sur la distribution de cette espèce. En outre, elle contribuera à la compréhension de ces phases biologiques particulièrement importantes pour la distribution de cette espèce dans le domaine continental.

REMERCIEMENTS. — Nous tenons à remercier les fédérations Départementales de Pêche et Pisciculture de Charente-Maritime, des Deux-Sèvres et de Vendée, et les Garderies Départementales pour leur collaboration efficace dans la réalisation de cette étude.

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RIVERINE MIGRATION OF YOUNG EELS *ANGUILLA ANGUILLA* (L.)

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Eels of length 6 cm to 50 cm trapped in the course of upstream migration in the River Shannon have been sampled during ten seasons from 1973 to 1983. Migration normally begins at the end of May at water temperatures of 13 ° or 14 °C but the extreme dates range from 17 May to 24 June. In five out of seven years migration ended between 10 and 19 September, in the other two on 29 July and 6 October. Positive correlations were observed between date of first migration and temperature between 15 and 21 May. No connection between temperature and date of end of migration was apparent. Length measurements of 5 008 eels showed that large individuals (> 15 cm) migrated throughout the season but that the majority of smaller eels (< 10 cm) had a shorter migration period, from mid June to mid August. Ages of 158 specimens were determined. The maximum age was 10 +, the majority ranged from 1 + to 3 +. Elvers of 0 + were scarce or absent early in the season and were never plentiful. Number of eels caught ranged from 131 000 to 417 000 per year. It was concluded that a number of factors influenced migration of the eels, the time of year perhaps the strongest, with water temperature in May being secondary. Migration of the greatest numbers occurred in the year following the greatest immigration of elvers to the river. This suggests that migration may be influenced by population pressure in the lower reaches of the river.

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GROWTH AND PRODUCTION OF FEMALE YELLOW EELS (*ANGUILLA ANGUILLA* L.) FROM BRACKISH WATER IN NORWAY

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GROWTH
MORTALITY
BRACKISH WATER
NORWAY

ABSTRACT. — This paper describes the length distribution, age distribution, growth and production of female yellow eels caught with fyke nets in a small brackish water bight in the Oslo-fjord, Norway. Eels with lengths between 35 and 50 cm and ages between 4 and 7 years of age were most abundant in the catch. An instantaneous rate of total mortality of Z = 0.249, and an instantaneous rate of fishing mortality of F = 0.046 was found. Production was estimated to be from 51.2 to 98.9 kg ha^{-1}, and the production on biomass ratio (P/B) was calculated as 0.23.

ANGUILLA ANGUILLA
CROISSANCE
MORTALITÉ
EAU SAUMÂTRE
NORVÈGE

RESUMÉ. — Cette étude présente la distribution des tailles, l'âge, la croissance et la production d'Anguilles jaunes femelles capturées par verveux dans une petite baie saumâtre du fjord Oslo, en Norvège. Les Anguilles de taille comprise entre 35 et 50 cm et âgées de 4 à 7 ans sont les plus abondantes. Le taux instantané de mortalité totale est estimé à r = 0,249 et le taux instantané de mortalité par pêche à F = 0,046. La production est estimée à 51,2 – 98,9 kg par ha et le rapport production sur biomasse, à 0,28.

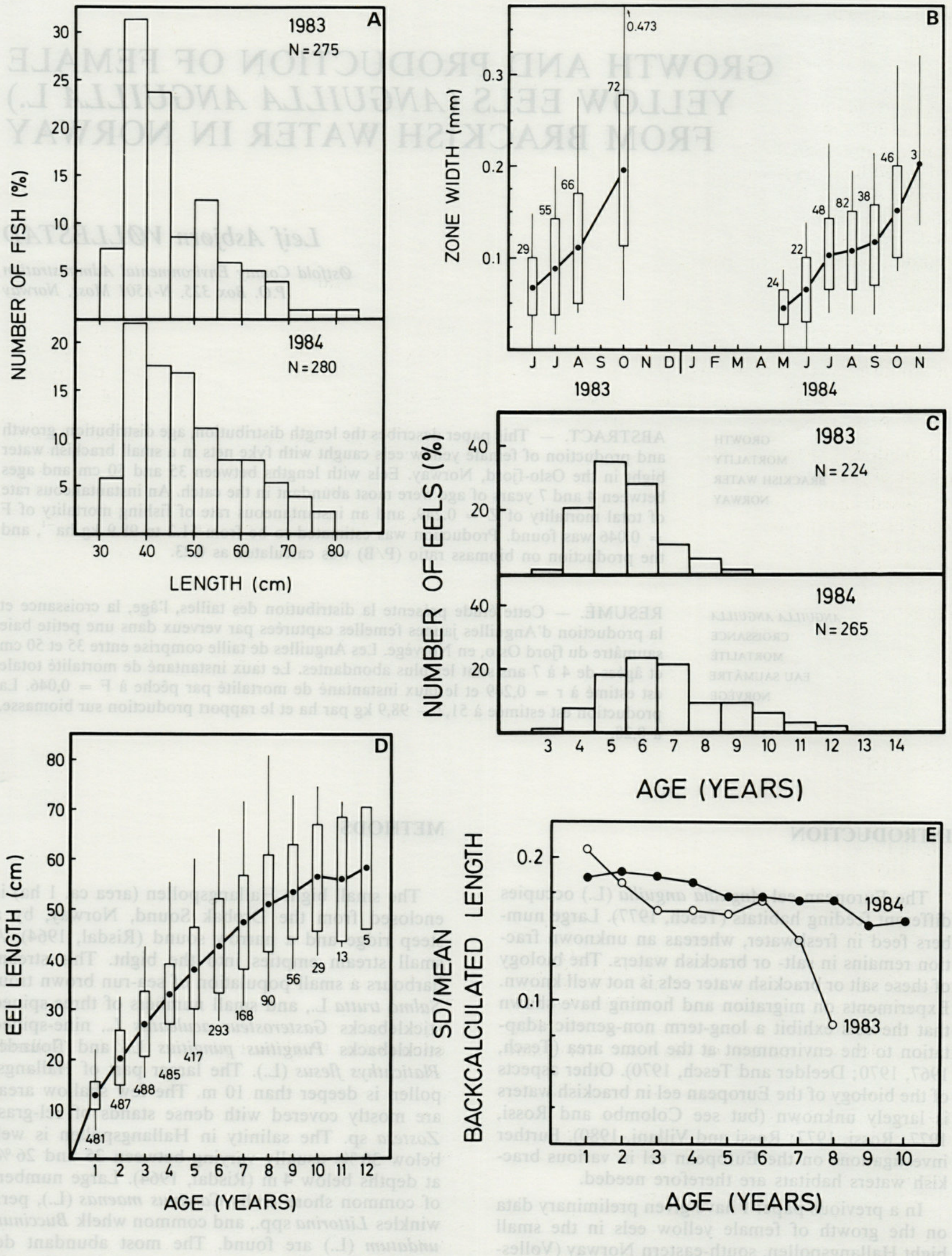
INTRODUCTION

The European eel *Anguilla anguilla* (L.) occupies different feeding habitats (Tesch, 1977). Large numbers feed in freshwater, whereas an unknown fraction remains in salt- or brackish waters. The biology of these salt or brackish water eels is not well known. Experiments on migration and homing have shown that the eels exhibit a long-term non-genetic adaptation to the environment at the home area (Tesch, 1967, 1970; Deelder and Tesch, 1970). Other aspects of the biology of the European eel in brackish waters is largely unknown (but see Colombo and Rossi, 1977; Rossi, 1977; Rossi and Villani, 1980). Further investigations on the European eel in various brackish waters habitats are therefore needed.

In a previous paper I have given preliminary data on the growth of female yellow eels in the small bight Hallangspollen, south-eastern Norway (Vøllestad, 1985).

METHODS

The small bight Hallangspollen (area ca. 1 ha) is enclosed from the Drøbak Sound, Norway, by a steep ridge and a narrow sound (Risdal, 1964). A small stream empties into the bight. This stream harbours a small population of sea-run brown trout *Salmo trutta* L., and small numbers of three-spined sticklebacks *Gasterosteus aculeatus L.*, nine-spined sticklebacks *Pungitius pungitius* L., and flounder *Platichthys flesus* (L.). The larger part of Hallangspollen is deeper than 10 m. The few shallow areas are mostly covered with dense stands of eel-grass *Zostera* sp. The salinity in Hallangspollen is well below 30 ‰ usually varying between 25 and 26 ‰ at depths below 4 m (Risdal, 1964). Large numbers of common shore crabs *Carcinus maenas* (L.), periwinkles *Littorina* spp., and common whelk *Buccinum undatum* (L.) are found. The most abundant demersal fish species present were goldsinny *Ctenola-*


A
1983
N=275
1984
N=280
NUMBER OF FISH (%)
LENGTH (cm)
B
0.473
ZONE WIDTH (mm)
J J A S O N D J F M A M J J A S O N
1983
1984
C
1983
N=224
1984
N=265
NUMBER OF EELS (%)
AGE (YEARS)
D
EEL LENGTH (cm)
AGE (YEARS)
E
1984
1983
BACKCALCULATED LENGTH SD/MEAN
AGE (YEARS)

brus rupestris (L.), black goby *Gobius niger* L., eelpout *Zoarces viviparus* (L.), plaice *Pleuronectes platessa* L., and flounder *platichtys flesus.*

The eels were caught with summer fyke nets (10.5 mm bar mesh) (Moriarty, 1972). These nets catch eels larger than 30 cm (Vøllestad, 1985). The nets were monitored at uneven intervals, varying from every day to once a week. The eels were measured (total length (T.L.; 0.5 cm), weighed (1 g), and sexed by gross macroscopic examination of the gonads. All eels had the typical gonads of female yellow eels (Sinha and Jones, 1966). The eels were aged from sacculus otoliths using the clearing method (Vøllestad, 1985). The caudal otolith radius (Rossi and Villani, 1980; 0.01 mm), gives a relative measure of the body length of the eel. The linear least square regression of total length (*L*, cm; range 30.0 – 78.5 cm, mean = 48.3 cm, SD = 11.5 cm) on otolith radius (*X*, mm) was :

$$L = 2.186 + 25.80\,X,\ N = 274$$
$$R^2 = 0.78,\ F_{1,272} = 929,\ P < 0.001. \quad (1)$$

Equation 1 was used for back-calculating the growth of the eels.

The calculations of biomass and production were made using Allen's method (Allen, 1971; Chapman, 1978). For any age group, the instantaneous rate of increase in weight is $G = (\ln W_2 - \ln W_1)/t_2 - t_1$, where W_1 and W_2 are the average weights at time t_1 and t_2, respectively. Biomass is $B = \hat{N}W$, where $\hat{N}$ is the estimated number of eels in an age group. Average biomass is estimated as $\bar{B} = (B_{t1} + B_{t2})/2$, and production is estimated as $P = G\bar{B}$.

RESULTS

The length distribution of eels caught in the fyke nets did not differ between years (Fig. 1, A; X^2-test, $P > 0.05$). Eels with lengths between 35 and 50 cm were most abundant in the catch both years. Eels below approximately 37 cm in length were not fully vulnerable to the fishing gear.

The eels were aged from otoliths cleared in 96 % ethanol. The accuracy of the method was tested by comparison of the width of the outermost opaque zone during the summers 1983-1984 (Fig. 1, B). The zone width was narrow in May and June, and increased through summer and autumn both years. This indicates that only one hyaline and one opaque zone were counted annually. If supernumerary zones (*sensu* Deelder, 1976) are present they do not occur at specific periods during summer. This further indicates that the ageing technique give a good estimate of the age of the eels.

The age distributions were significantly different for the two years (Fig. 1, C; X^2-test, $P < 0.01$). Year class 1978 was most abundant both in 1983 (age group 5^+) and in 1984 (age group 6^+). A larger number of old eels (> age 9) were caught in 1984 than in 1983.

The growth rate of the eels was rapid, decreasing somewhat with increasing age (Fig. 1, D). The variability in back-calculated length was high in all age groups. Calculations of the coefficient of variation (CV = standard deviation/mean) of the otolith size in each age group show that the relative variability is lower in the older ages (Fig. 1, E). This is probably due to emigration of the larger, maturing individuals in each age group. Back-calculated mean lengths in various age groups did not differ when back-calculation was compared for the individual year classes separately (tested with linear regression models and ANOVA, $P > 0.05$).

Mortality figures from the catch curves are difficult to obtain as emigration cannot be distinguished from the natural and fishing mortalities. Furthermore, the irregular year class strengths make estimation difficult. According to Ricker (1969, p. 10) the best way to reduce the effect of recruitment irregularities is to combine the samples of successive years. By doing this, relative numbers of eels in age groups 3 through 14 were obtained. Since age group, 3, 4 and 5 are not fully vulnerable to the fishery, only eels older than 5 years were used in the calculations. Simple catch curves (Ricker, 1975) were then fitted to the pooled data, giving an instantaneous rate of total mortality of Z = 0.249, and a survival rate of S = 0.78. The instantaneous rate of total loss from a stock is

$$Z' = Z + U = F + M + U,$$

where F is the instantaneous rate of natural mortality, M is the instantaneous rate of natural mortality and U is the instantaneous loss due to other causes (i.e. emigration) (Ricker, 1975). The recapture rate of tagged eels during 1983 was 4.1 %. Thus F can be estimated as $0.041 = F(1 - e^{-Z})/Z$ (cf. Gulland,

Fig. 1. — A, length distribution of female yellow eels *Anguilla anguilla* caught in Hallangspollen, 1983 and 1984. B, seasonal variation in width of the outermost opage otolith zone, standard deviation of the estimate when n > 5, and total range of variation of the measurements of female yellow eel *Anguilla anguilla* caught in Hallangspollen, 1983 and 1984. The number of otoliths measured is indicated. C, age distribution of female yellow eels *Anguilla anguilla* caught in Hallangspollen, 1983 and 1984. D, backcalculated mean lengths in each age group, standard deviation of the estimates, and total range of variation for female yellow eels *Anguilla anguilla* caught in Hallangspollen, 1983 and 1984. Number of eels used in the analysis is indicated for each age group. E, variability in mean otholith size in each age group (expressed as the coefficient of variation, CV = standard deviation of the estimate divided on the mean otolith size in each age group) for female yellow eels *Anguilla anguilla* from Hallangspollen 1983 and 1984.

Tabl. I. — Estimate of biomass (kg/ha) and production (kg/ha) of the eel population in Hallangspollen, Norway. The pooled age-distribution data for 1983 and 1984 and mean weights (g) in each age group is used. The number of eels present is estimated assuming that between 500-1000 eels older than age 5 is present. The number of eels in age group 3 through 5 are estimated using the estimated M_{tot} = 0.22.

Age	W	G	$\hat{N}$	B	$\bar{B}$	P
3	76.7		451-902	35.6-69.2		
		0.10			32.8-64.6	3.3-6.5
4	85.1		351-704	29.9-59.9		
		0.24			29.8-59.7	7.2-14.3
5	108.3		274-549	29.7-59.5		
		0.32			30.8-61.6	9.9-19.7
6	149.1		214-428	31.9-63.8		
		0.39			30.7-61.2	12.0-23.9
7	219.4		134-267	29.4-58.6		
		0.34			27.5-47.1	9.3-16.0
8	307.7		83-116	25.5-35.7		
		0.06			20.5-33.1	1.2-2.0
9	328.2		47-93	15.4-30.5		
		0.42			19.7-29.3	8.3-16.5
> 10	500.4		48-96	24.0-48.0		
				Σ B = 221.4-425.2		Σ P = 51.2-98.9

1969), giving F = 0.046. The instantaneous rate of natural mortality (M) and emigration (U) should therefore be M + U = Z − F = 0.249 − 0.046 = 0.203. It is not possible at this stage to discriminate further between natural mortality and emigration.

Precise information on the density of yellow eels in Hallangspollen was not obtained. In the coastal waters of Bohuslän, Sweden, a mean density of 700-7 000 individuals < 18 cm ha^{-1} was reported (Thorman and Fladvad, 1981). Allowing for mortality, a reasonable estimate may be that between 500 and 1 000 eels older than age 5 are present in Hallangspollen each year (eels older than age 5 are considered fully recruited to the fishery (see Fig. 1, C)). Using these figures, estimated total mortality rates, and mean weights in each age group, estimates of biomass and production for eels older than age 2 can be made (Table I). Total biomass (ΣB_i) was 221.4-425.2 kg ha^{-1}, whereas production (ΣP_i) was 51.2-98,9 kg ha^{-1}. The ratio of production on biomass (P/B) consequently was 0.23.

DISCUSSION

The age determination of eels is a matter of controversy (Deelder, 1976; 1981; Moriarty, 1983; Vøllestad, 1985). No methods for determining the age of eels are at present validated. The precision of the clearing method used in this study is described by Vøllestad (1985). In the present paper I present evidence that supernumerary zones are of no or only small importance. Thus I here present one piece of evidence for the method's validity (Beamish and McFarlane, 1983).

Annual "mortality" rates were calculated from the pooled age distribution. It is not possible to separate the effects of natural mortality and emigration due to maturation of the larger individuals in each age group, whereas fishing mortality can be assessed separately. A very low fishing mortality (F = 0.046) was found. This fishing mortality most probably is identical for all eels exceeding the minimum legal size (40 cm). The instantaneous rate of natural mortality (M) and emigration (U) was calculated to be 0.203. This is much lower than reported for the natural mortality alone for eels from brackish lagoons in Italy (Rossi, 1979). The natural mortality is probably highest in the younger age groups, decreasing for the older age groups. Emigration due to maturation, on the other hand, increases with increasing age and length. In the River Imsa in western Norway few female silver eels with lengths below 50 cm were reported (Haraldstad *et al.,* 1985). The mean length of the yellow eels in age group 6 in Hallangspollen was 44.5-44.7 cm, thus only the larger eels in this age group will be ready to metamorphose. The mortality of eels younger than 6 years is unknown, but little fishing mortality or emigration due to maturation will occur.

Conservative estimates of the population density of eels in Hallangspollen resulted in a rather high estimate of production. A production of 51.2-98.9 kg ha^{-1} is over twice the production reported by Rossi (1979) for brackish water lagoons in Italy. It is in accordance with estimates from a small Danish stream (Rasmussen and Therkildsen, 1979), and is half that reported for small yellow eels (< 18 cm) from the Broälven estuary, Sweden (Thorman and Fladvad, 1981). Hopkins (1971) reported a production of 100-590 kg ha^{-1} of *Anguilla australis schmidtii* Phillipps and *Anguilla dieffenbachii* Gray in two small streams in New Zealand. Both Rossi (1979) and Rasmussen and Therkildsen (1979) reported production on biomass (P/B) ratios considerably higher than in Hallangspollen (0.47-0.57 vs. 0.23).

The P/B ratios in the New Zealand streams were also high (> 0.7) (Hopkins, 1971). Lower P/B ratios would be expected in the cold Norwegian waters compared to warm Italian lagoons and shallow Danish and New Zealand streams. This indicates that the high production in Hallangspollen is due to the high initial density, indicating that this estimate may have been too high. Further studies are necessary to clarify this matter.

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GROWTH OF CULTURED EELS STOCKED IN TWO SWEDISH LAKES

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ANGUILLA ANGUILLA
STOCKING
GROWTH
LAKES
SWEDEN

ABSTRACT. — The downward trend of eel catch on the Baltic coasts has led to studies on the feasibility of eels stocking. Two eel-free lakes (339 ha and 299 ha) in southern Sweden were stocked with cultured yellow eels. The stocking material consisted of glass eels subsequently raised in heated water. Mean weights of the eels stocked in September 1980 in the two lakes were 2.9 g and 4.0 g respectively and stocking densities were 156 eels/ha and 124 eels/ha. Up to and including 1985 about 1.650 eels were caught in the outlet of the more shallow and productive lake, i.e. a recapture rate of 3.2 %. A majority of these (about 90 %) were silver males, about 41 cm in length. Females, both yellow and silver, have also migrated downstream. In 1984, after about four growing seasons, they were about 52 cm in length and in 1985 they were about 54 cm. Test fishing with fyke nets has, despite the stocking density, only yielded a few eels. In the other lake, which is deeper and less productive, very few eels have yet been recaptured. They were roughly 8-10 cm shorter than eels of the same age from the first lake. Of all the eels stocked some 200 were marked subcutaneously with Alcian blue. Only four marked specimens have been recaptured since 1980.

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EMPOISSONNEMENT
CROISSANCE
LACS
SUÈDE

RESUMÉ. — La capture d'Anguilles d'avalaison sur les côtes de la Baltique a conduit à des études sur la faisabilité d'un réempoissonnement en Anguilles. Deux lacs sans populations naturelles (339 ha et 299 ha) situés au Sud de la Suède ont été réempoissonnés en Anguilles jaunes obtenues à partir de civelles élevées en eau réchauffée. Les poids moyens des Anguilles mises en élevage en septembre 1980 dans les 2 lacs étaient respectivement de 2,9 g et de 4,0 g et les densités de 156 et de 124 individus par ha. 1 650 anguillules environ ont été capturées jusqu'à fin 1985 à la sortie du lac le moins profond et le plus productif, soit un taux de recapture de 3,2 %. La majorité (90 %) sont des mâles argentés d'une taille de 41 cm environ. Les femelles, à la fois jaunes et argentées ont également migré vers la mer. En 1984, après 4 saisons de croissance, elles atteignent 52 cm et en 1985, environ 54 cm. Un essai de pêche par verveux n'a permis la capture que de quelques Anguilles, malgré la densité d'empoissonnement. Dans l'autre lac, qui est plus profond et moins productif, très peu d'Anguilles ont été recapturées. Elles sont de 8 à 10 cm plus petites que les Anguilles du même âge en provenance du premier lac. Parmi ce stock d'Anguilles, 200 ont fait l'objet d'un marquage cutané au Bleu d'Alcian. Seuls 4 individus marqués ont été recapturés depuis 1980.

INTRODUCTION

The commercial catch of silver eels in Sweden has decreased considerably since the mid-1960's (Fig. 1). Although the weight of the catch is not so impressive, at present only about 1,000 metric tons per year, it is economically very important. In value, eel ranks fourth after cod, herring and Norway lobster (SCB 1985). The eel fishery is especially important in the Baltic Sea.

Svärdson (1966, 1976) suggested a huge stocking programme, in order to strengthen the recruitment of elvers and subsequently improve the eel stocks.

Stocking experiments were planned, and in 1977 some eel projects commenced at the Institute of Freshwater Research in Drottningholm, with the aim of assessing the value of stocking the Baltic Sea and lakes with eels.

As a part of these investigations some more or less eel-free lakes were chosen as experimental habitats. They were stocked with whatever material was available, viz. elvers, cultured fingerlings and medium-sized yellow eels. The resulting eel stocks have been studied, using different methods, in order to determine growth, sex ratio, size at silvering, feeding habits etc.

In this paper the preliminary results from two of the experimental lakes, which were stocked with cultured fingerlings, are described and discussed.

MATERIAL AND METHODS

The experimental lakes and stocking material were described by Wickström (1984). Briefly, two lakes in southern Sweden, Lake Fardume träsk and Lake Götemaren, were stocked in September 1980 with eels which had been imported as glass eels from France in spring 1980 and subsequently raised in heated water. The lakes are 339 ha and 299 ha respectively, the first one being very shallow and productive. The second one, Lake Götemaren, is deeper and less productive. 53,000 cultured eels were stocked in Lake Fardume träsk and 37,000 in Lake Götemaren, which gives a stocking density of 156 eels/ha and 124 eels/ha. The mean weights of the eels used for the experiments were 2.9 g and 4.0 g respectively.

Small numbers of eels were marked with a spot of Alcian blue on the underside of their bodies in connection with the stocking of the two lakes (Hart and Pitcher, 1969).

In connection with the stocking occasions, test fishing was performed with survey gill nets in order to assess predation on the newly introduced eel fingerlings.

As a rule the outlets of the two lakes have been monitored by fixed wire traps since stocking. There have been some exceptions, essentially during cold periods with ice in winter.

The small mesh size (less than 5×5 mm^2) used in the wire traps should have caught even the smallest of the fingerlings stocked.

In addition to operating the outlet traps, test fishing for eels in the lakes was performed from 1980-85. The gear consisted of paired fyke nets (summer fykes according to Moriarty (1972)) with a mesh size of 10 mm knot to knot at the cod end. Longlines with different hook sizes and different kinds of bait were also used. Electrofishing techniques were also applied in the outlet parts of the lakes.

The eels caught were usually deep-frozen in plastic bags for some months before dissection. They were then measured and weighed when almost thawed. It is obvious that eels shrink a few per cent when deep-frozen (cf. Löwenberg 1979) but the lengths and weights reported in this paper have not been adjusted for shrinkage.

The sex was in most cases determined by the gross morphology of the gonads. However, gonads from males and "undifferentiated" specimens were preserved in Bouin's solution and subsequently made into histological slides (Dolan and Power 1977, Wickström 1984).

Otoliths were sampled from relevant specimens and later on ground while embedded in thermoplastic cement (Charlon 1975). In an attempt to determine the stage of maturity, the colour etc. was noted. When it was difficult to determine whether eels were silver or not, the diameter of the eye was measured, according to Boëtius and Boëtius (1967) and Pankhurst (1982).

RESULTS

The results presented in this paper are up to and including 1985.

Lake Fardume träsk

Since stocking, about 1,650 downstream-migrating eels have been caught in the outlet trap. The numbers are distributed through the years 1980-85 as follows : 11, 11, 66, 163, 1,320 and 79. Since 1980 the total catch has been more than 222 kg.

As shown in Fig. 2 the material has been split into males and females since 1984, when the catches increased. However, in 1982 and 1983 some silver males were caught in the trap. The mean length of males was 415 mm in both 1984 and 1985. Almost all of the males were silver eels.

Among the females, the number of silver eels is not yet known. All of the eye-indices have not yet been calculated, but all stages between yellow and silver occur in the downstream migration. Their mean length was 523 mm in 1984 and 544 mm in 1985.

Despite an effort of about 650 longline-hook-nights from 1980-85 no eels have been caught using this method. The hooks were of different sizes and the bait both small fish of various species and earthworms.

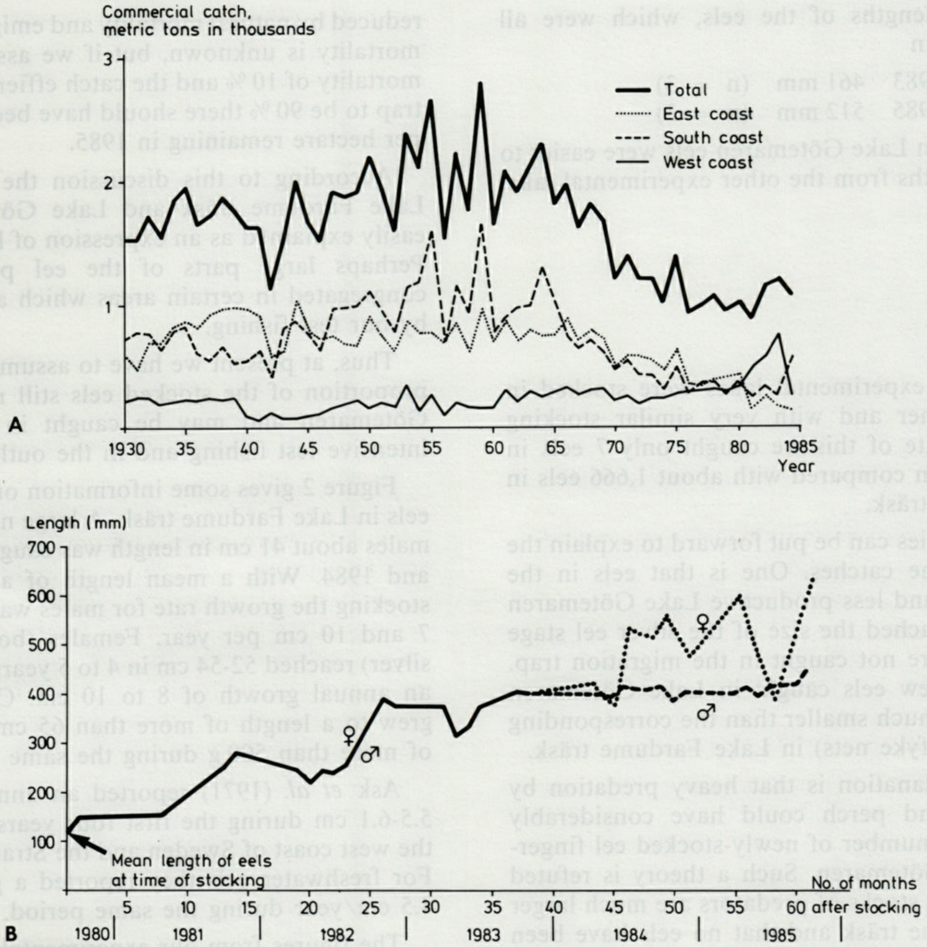

Fig. 1. — A, Commercial catch of silver eels in Sweden 1030-84. B, Monthly mean lengths of downstream-migrating eels in Lake Fardume träsk.

Sampling with fyke nets from 1983-85 also gave very low yields. Only 15 eels were caught during 1,262 fyke-net-nights. This means a CPUE of 0.012 eels or 3.6 g. These are very low figures, especially in comparison with the great number of eels stocked and the numbers of downstream migrants.

The mean lengths of females caught in fyke nets were in

1983	560 mm	(n = 1)
1984	535 mm	(n = 7)
1985	594 mm	(n = 6)

Only one of the 15 eels caught with fyke nets was a male, despite frequency of males of 89 % (1984) and 68 % (1985) in the outlet trap.

Three eels marked with Alcian blue were recaptured among the silver males caught in the outlet trap in 1983 and 1984. As only 86 eels were marked in 1980 the "recapture rate" was in this case 3.5 %. The total recapture rate, expressed as all eels caught/total number stocked was 3.2 %, a very similar figure.

The otoliths sampled show no simple correlation with the known ages. In the zone formed during one growing season (the opaque zone), it was possible to find several checks in the otolith, which were almost as distinct as the true winter ring (the translucent zone).

Lake Götemaren

No eels were ever caught in the outlet trap in Lake Götemaren. On the whole, very few fish of any species were caught, which indicates the poor function of the trap. However, electrofishing in the outlet channel has not yielded any eels either.

As in Lake Fardume träsk the catch on longlines was very small, only one eel during 800 longline-hook-nights. This specimen had been marked with Alcian blue on the stocking occasion (1980) and was recaptured two years later, in 1982 at a length of 392 mm.

Only 6 eels were caught during about 1,050 fyke-net-nights in Lake Götemaren, which means a CPUE of 0.006 eels or 1.1 g.

The mean lengths of the eels, which were all females, were in

1983	461 mm	(n = 3)
1985	512 mm	(n = 3)

Otoliths from Lake Götemaren eels were easier to read than otoliths from the other experimental lake.

DISCUSSION

Both of the experimental lakes were stocked in the same manner and with very similar stocking material. In spite of this we caught only 7 eels in Lake Götemaren compared with about 1,666 eels in Lake Fardume träsk.

Several theories can be put forward to explain the difference in the catches. One is that eels in the deeper, cooler and less productive Lake Götemaren have not yet reached the size of the silver eel stage and are therefore not caught in the migration trap. However, the few eels caught in Lake Götemaren have not been much smaller than the corresponding eels (caught in fyke nets) in Lake Fardume träsk.

Another explanation is that heavy predation by pike, burbot and perch could have considerably diminished the number of newly-stocked eel fingerlings in Lake Götemaren. Such a theory is refuted by the facts that stocks of predators are much larger in Lake Fardume träsk and that no eels have been found in the stomachs of potential predators caught by test fishing close to the stocking sites.

An unknown factor is an increased "natural mortality" of stocked eels caused by poor conditions in the transport tanks etc. However, during sampling and close examination in connection with the marking procedures etc. we could not detect any such damage.

Another unlikely explanation could be that a large number of the stocked eels left the lake during periods when the trap was not in operation.

Even in Lake Fardume träsk, where we know that many eels must have lived and thrived during at least the first four years after stocking, very few eels were caught per unit effort in our fyke nets.

In Lake Mälaren the total commercial catch of silver eels amounts to 0.2 eels per year per hectare of suitable lake area (O-20 m depth). The eels caught are assumed almost solely to originate from stocked yellow eels of about 40 cm in length. Stocking intensities have been about 0.6 eels per year per hectare (defined as above). A very rough estimate of abundance gives about 3 eels per hectare.

In Lake Mälaren our test fishing yields a CPUE of about 0.093 eels or 63.0 g, which is about 8 times the number caught in Lake Fardume träsk. The latter lake should contain the stocked number, 156 eels/ha, reduced by natural mortality and emigration. Natural mortality is unknown, but if we assume an annual mortality of 10 % and the catch effiency of the outlet trap to be 90 % there should have been about 87 eels per hectare remaining in 1985.

According to this discussion the low CPUE in Lake Fardume träsk and Lake Götemaren is not easily explained as an expression of low abundance. Perhaps large parts of the eel populations are congregated in certain areas which are not covered by our test fishing.

Thus, at present we have to assume that a certain proportion of the stocked eels still remain in Lake Götemaren and may be caught in the future by intensive test fishing and in the outlet trap.

Figure 2 gives some information on the growth of eels in Lake Fardume träsk. A large number of silver males about 41 cm in length was caught in both 1983 and 1984. With a mean length of about 12 cm at stocking the growth rate for males was then between 7 and 10 cm per year. Females (both yellow and silver) reached 52-54 cm in 4 to 5 years, which means an annual growth of 8 to 10 cm. Certain females grew to a length of more than 65 cm and a weight of more than 500 g during the same period.

Ask *et al.* (1971) reported an annual growth of 5.5-6.1 cm during the first four years for eels from the west coast of Sweden and the Straits of Öresund. For freshwater eels they reported a growth rate of 4.5 cm/year during the same period.

The figures from our experimental lakes indicate a very good growth, even in comparison with more southerly European countries (cf. Tesch 1983). Tesch (1983) states that the length of female eels in natural waters rarely exceeds 37 cm by the end of their fourth year of life. This means an annual growth of about 7 cm at the most. Hacker and Meisriemler (1978) report even better growth from the heavily stocked Austrian (and Hungarian) Lake Neusiedlersee, 8 cm annually during the first four and five years after stocking.

However, it is important to remember that in our case the lakes have been stocked only once. Such experiments often result in good growth (Dahl 1967), probably due to a relatively low abundance and a simplified population structure among the introduced eels.

The growth of the few yellow females captured in Lake Götemaren seems to be slower than in Lake Fardume träsk. This is consistent with the lower productivity of the former lake.

Under natural conditions our Swedish waters, with the exception of the sea at the West Coast, are recruited by yellow eels which are probably already sex differentiated as females. As the ratio of males usually seems to be very high in eel culture, at least in the final stage (Egusa 1970, 1979) we have expected that the use of cultured fingerlings for stocking purposes should result in higher male ratios. This would also include, at least partly, the use of glass eels as stocking material.

As traditional fishing practices and gear used in the Swedish eel fishery are not aimed towards catching small silver males, a high ratio of males resulting from stocking operations could be considered a failure.

In Lake Fardume träsk males have indeed dominated the catch (a weighted mean of 88 % in 1984-85) in the outlet trap. However, it is too early to determine if this is a characteristic of the whole introduced population or if it is the effect of good growth in males combined with their smaller size at silvering.

The decrease in the ratio of males in 1985 may perhaps support the latter explanation.

The few recaptured eels in Lake Götemaren were all females, but disregarding the fact that fyke nets seem to catch almost only yellow females, the low numbers do not allow any interpretation.

We are well aware of the limitation to studies of "over-simplified eel populations" introduced as a single year class. We could not correctly assess the "natural" growth rate, mortality, etc. but the results from our experimental lakes will probably suggest how well stocking effort could pay off both in ecological and economical terms.

The lakes will probably be stocked again in the future, with the aim of building up a more complex and natural population structure. In order to distinguish eels from different introduced year classes easily from each other, several years have to pass between stocking occasions.

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OBSERVATIONS ON THE EELS OF MEELICK BAY, LOUGH DERG, 1981-1984

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POPULATION
TAGGING
MIGRATION
ANGUILLA ANGUILLA
EEL

ABSTRACT. — Monthly samples totalling 4493 yellow eels were caught by fyke net in a bay, approximately 1 km square in a lake of area 116 km^2. Catch per unit effort figures showed that population density varied between months and between specific areas of the bay. Most of the eels sampled (80 %) measured between 34 cm and 54 cm. Ages of a sample of 74 specimens ranged from 7 to 25 years and a value of 86.3 cm for L-infinity was computed from back calculations. Length frequencies showed changes between months, larger eels being caught in April. Recapture rate for 3,602 eels was extremely low at 1,2 %. The results showed that (1) when eel populations are being assessed it is essential to define exactly positions and dates of sampling and (2) the eel population in this bay was not resident but appeared to be undergoing changes throughout the warmer months of the year.

ANGUILLE
POPULATION
MARQUAGE
MIGRATION
ANGUILLA ANGUILLA

RESUMÉ. — Un échantillonnage portant sur 4 493 Anguilles jaunes a été effectué par verveux, dans une baie de 1 km^2 environ, située sur un lac de 116 km^2. Les valeurs des prises par unité d'effort indiquent que la densité de population présente des variations mensuelles ainsi que des différences entre sites de pêche. La plupart des Anguilles (80 %) mesurent entre 34 et 54 cm. L'âge d'un échantillon de 74 Anguilles varie de 7 à 25 ans et L-infinité est estimé par la méthode du rétrocalcul à 86,3 cm. Les moyennes de taille indiquent des variations mensuelles. Les Anguilles les plus grandes sont capturées en avril. Le pourcentage de recapture à partir de 3 602 Anguilles a été faible, de l'ordre de 1,2 %. Les résultats montrent que (1) pour l'estimation des populations d'Anguilles, il est essentiel de définir exactement les lieux et dates d'échantillonnage; (2) la population de cette baie n'est pas sédentaire et semble varier au cours des mois chauds de l'année.

INTRODUCTION

An extensive study of the eels on the lakes of the Shannon river system was made in 1969 and 1970 (Moriarty, 1974). This has been followed by periodical sampling which is still in progress. Lough Derg is the largest and most downstream of a number of lakes through which the Shannon and its tributaries flow. Considerable variation in the eel population structure within the lake had been observed between months, between years and between sampling locations. It was therefore decided to concentrate the major effort over a period of many years in a small area of the lake over an extended period in each year. This work began in July 1981 and has run for three full seasons to 1984.

Although a number of studies of eels in lakes have been made (Tesch 1977) very few have been concerned with behaviour patterns of yellow eels. In the case of *A. anguilla* it appears that no reports on tagging have been published nor have any detailed studies been made of eel populations within a restricted area. Lake studies of *A. rostrata* have been made by Hurley (1972) and Labar (1982) and of *A. australis* and *A. reinhardtii* by Beumer (1979). These dealt with exploited eel populations while the present work is based on an unexploited population in which all the fishing has been conducted by the author. Changes in catch per unit effort and tag recoveries therefore reflected natural behaviour patterns and were not influenced by fishing mortality.

By the end of 1982 the results had indicated that even within the limited area of the bay, the eel population was unevenly distributed (Moriarty 1983a). Furthermore, an extremely low rate of tagging recovery together with marked fluctuations in numbers and lengths of eels between months suggested that the population of the bay was a migratory one. The results of work in the subsequent two seasons have supported this theory. This paper describes these preliminary conclusions from an ongoing project.

SITE, MATERIALS AND METHODS

Lough Derg has an area of 11,635 ha, pH range 7.7 to 8.2 and conductivity 420 uS/cm (Flanagan and Toner 1975). Its outlet lies 20 km from tidal water. Meelick Bay (Fig. 1) lies on the northern side of Scarriff Bay and opens towards the south.

Sampling procedure was to set trains of ten fyke nets to fish overnight in two or three of the stations

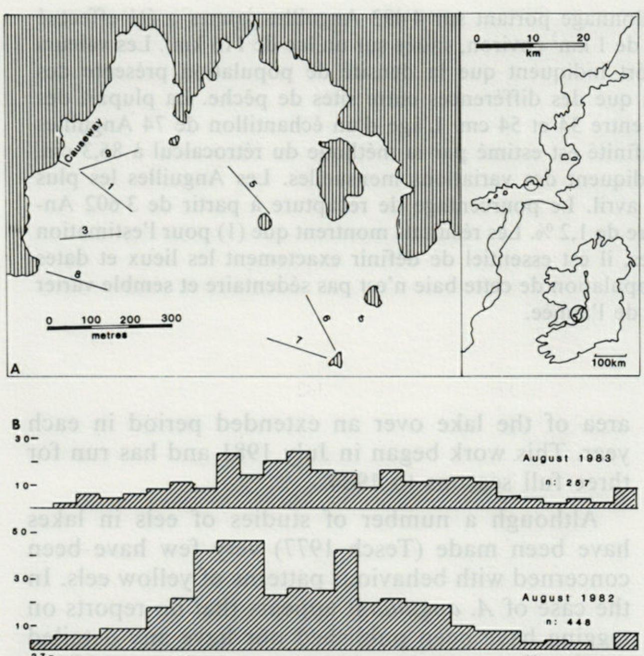

Fig. 1. A, Meelick Bay, showing positions of trains of ten nets (left). Lough Derg with Meelick Bay encircled (right, upper). Ireland, showing main River Shannon with Lough Derg encircled (right, lower). B, length frequencies (percentage in cm rounded downwards) of Meelick Bay eels sampled in August 1982 and 1983.

shown in Figure 1. In this way each month's sample was taken within one week. Each net consisted of a pair of funnels of length 3.2 m and maximum diameter 0.4 m joined mouth to mouth by a leader of length 8 m. Cod end mesh was 12 mm knot to knot. The water in all stations was between 2 m and 4 m in depth. The netting stations were selected to achieve random coverage of the bay, but each was chosen so that the placing of the nets could be repeated accurately by reference to conspicuous landmarks. The unit of effort was defined as the catch per train of ten nets. Two stations, 2 and 4, were abandoned after the 1981 season.

All eels captured were anaesthetised with chlorbutol and measured to nearest mm. One or two specimens from each sample were retained for age determination and stomach analysis. All the other eels were marked with Floy tags inserted just in front of the origin of the dorsal fin and allowed to recover from the anaesthetic in a bucket of water. They were then released at the Causeway (Fig. 1). Ages were determined from photographs of burned otoliths as described by Moriarty (1983b).

RESULTS

Variations in catch

The nets were set once in February and twice in December. No eels were caught in February 1982 or December 1983. In December 1984, however, 16 eels were caught at a water temperature of 7°C. Small catches were made every year at the end of March and in October 1982 and 1984. In 1983 substantial catches were made in October and small catches in November. No fishing has taken place in January.

The figures in Table I show variations in catch between months for a total fishing effort of 70 nets fished overnight at the same seven stations. The catch was relatively high in May and low in June, increasing again in July or August.

Tabl. I. — Mean catch per ten nets from once monthly settings at Stations 1, 3, 5, 6, 7, 8, 9. Blanks indicate incomplete series.

	April	May	June	Aug	Sep	Oct	
1982	—	—	—	27.2	45.7	—	—
1983	15.8	34.3	20.5	21.7	30.0	—	—
1984	—	17.2	13.8	26.7	15.0	—	4.3

Variations in catch between stations within months became apparent in the first year of the experiment. The three stations 1, 3 and 9 on the western side of the bay generally yielded poor

Tabl. II. — Mean catch per ten nets from once-monthly settings May to August inclusive.

	West side (1, 3, 9)		East side (5, 6, 7, 8)		
	1983	1984	1982	1983	1984
Mean	13.9	10.8	38.4	34.2	22.7
99 % limits	10.9	8.2	34.1	30.2	19.4
	16.9	13.4	42.7	38.3	26.0

catches while stations on the eastern side or at the outer edge of the study area had good catches. The mean catches in the western part (Table II) were less than half those for the other stations, the difference being highly significant ($P < 0.01$).

Lengths

The lengths of eels caught showed no significant variation between stations. However, it was found that the mean lengths in April were always significantly higher ($P < 0.05$) than in July or August and were usually higher than in May and June.

Length frequencies for August 1982 and 1983 are shown in Figure B. The greater part of the catch in both years lay between 34 cm and 49 cm and eels of more than 50 cm were scarce. Larger eels were more plentiful in deeper water adjacent to the bay.

Tagging results

A total of 3,602 eels were tagged in the four seasons and 44 were recovered, a recovery rate of 1.2 % Details of the 24 eels recaptured at a greater time interval than 14 days after tagging are given in Table III. Tags with brown sleeves and white print were used in 1981 and up to the end of May 1982. A number of these became illegible with time, so that the exact date of tagging could not be determined.

Periods up to three years between tagging and recapture were recorded and there were five cases in which full details were available for eels recaptured after about one year. Two of these showed no appreciable growth, two had increased in length by about 2 cm and one by 14 cm. The latter had been tagged in June 1983 and was recovered in October 1984 so that it had been absent for the greater part of two summers. It was one of few broad-headed eels in the samples. The specimen recaptured after three summers had increased in length by only 3 cm.

The recapture rate calculated on the numbers tagged and recaptured within months showed little variation, usually being close to the overall figure of 1.2 %. Although the number of eels tagged and released in the bay was increasing throughout the year and, indeed, over the whole period since 1981, the numbers of recaptures remained low.

Tabl. III. — Tag and recapture data for eels recovered after more than two days absence. L1 and L2 are lengths (mm) at tagging and recapture. "Market" signifies silver eels reported from processing factories. In some "illegible" cases the final digits only were obscured so that an approximate tagging date could be given.

	Date tagged	Date recovered	Days absent	L1	L2	Remarks
1981	23.7	14. 8.81	22	355	392	
	23.7	15. 8.81	23	373	395	
	16.8	21. 7.83	714	?	427	illegible
	16.8	26. 7.84	1074	391	422	
	23.8	26. 1.82	?	491	48 cm	market
	23.8	5.82	?	481	?	market
	15.9	21. 8.82	340	?	illegible	
1982	8.4	4.83	?	445	48 cm	market
	14.7	5. 5.83	295	475	476	
	16.7	21. 8.82	36	378	382	
	?	13. 4.83	> 250	?	515	illegible
	?	16. 7.83	> 413	?	438	illegible
1983	13.4	25. 6.83	42	701	705	
	4.5	4. 8.63	92	372	375	
	25.6	26.10.84	488	439	579	
	19.7	2. 8.83	24	356	358	
	20.7	28. 7.84	374	452	472	
	21.7	4. 8.83	14	465	465	
	21.7	29. 7.84	374	456	480	
	4.8	24. 8.84	385	333	337	
	21.8	autumn 83	?	476	49 cm	market
	4.10	21. 3.84	168	392	395	
	4.10	29. 7.84	374	456	480	
1984	21.8	28.05.84	85	414	430	

Age

The ages of 74 specimens caught in 1981 and 1982 were determined and back-calculations of growth rate were made. Variations in length at age of capture were considerable. In 1981 the oldest and youngest eels in the sample, 18 and 7 years respectively, both measured 50 cm. The oldest in the entire sample measured only 53 cm at 25 years. The longest, 73 cm, was 22 years old and the shortest, 30 cm, was 13. Values of 86.3 cm for L-infinity and 0.048 for K were computed from the regression L_{t+1} on L_t using the means of the back calculated lengths for the entire sample.

DISCUSSION

The validity of fyke net samples of eels in stock assessment exercises has been discussed by Moriarty (1975). He showed that the net is capable of catching eels of all sizes above the minima which are able to escape through the meshes. The scarcity of eels of greater than 45 cm in the samples is thus an indication of a scarcity of such eels in the population within Meelick Bay. Within the same river system, very such larger eels are found. For ex, in Lough Key which lies 150 km upstream of Meelick Bay, 75 % of a large July sample were greater than 45 cm (Moriarty 1974).

The majority of the eels in the Bay can be considered as relatively young, less than 12 years, as compared with the population in Lough Key where more than half the sample of 256 specimens ranged from 12 to 25 years.

The catch per unit of effort figures for all four seasons showed clearly the existence of some areas within the Bay which are more favoured by the eels than others. A dredging study of the benthos carried out in 1983 (Moriarty and Moriarty, 1985) showed that the areas favoured by the eels had a substrate of filamentous algae with large numbers of *Asellus aquaticus* while the poor areas had a substrate of fine sand with *Zanicellia* sp. the predominant plant and relatively small numbers of *Asellus. Asellus* was the dominant food organism throughout the season in eels of all sizes.

The small size of the eels in the Bay compared with the sizes observed in other parts of the Shannon system suggests that the population must be subject to regular emigration of immature individuals. Changes in the population between months were also apparent, judged both on relative length frequencies and on the catch per unit of effort. Moriarty (1983) showed that retention of Floy tags by yellow eels lasted up to four years and that tagged eels grew and metamorphosed to silver eels after tagging. In New Zealand P.R. Todd (pers. comm.) has used the tags extensively and over five seasons had 2,747 recaptures of which several were of eels caught more than once. One was caught and released six times. Although tag loss remains a possibility it seems unreasonable to suppose that it occurs at such a high rate it could explain the very low rate of tag recovery recorded in the present study.

The rate of recapture, 1.2 %, is extremely low when compared with other work on the eel. LaBar (1982) for example, in Lake Champlain, Vermont, USA, observed recaptures of 32 out of 373 *Anguilla rostrata* tagged in 1980, over 8 %. In Australia, Beumer (1979) recorded a recapture rate of 18.5 % of eels in Macleods Morass, a shallow water body of 423 hectares. Relatively high rates in recapture were also recorded by Hurley (1972) in Lake Ontario : 5.5 % in an experiment in which eels were displaced from the point of capture. However, when eels were replaced at the points of tagging in the long and winding Bay of Quinte in that lake, 8.9 % were recaptured from a point near its upstream end while only 0.9 % were recovered from a tagging location nearer the downstream end. This observation may be comparable to the results of the present study which show rapid emigration from a relatively downstream position in a lake system.

From the point of view of eel stock assessment, the most important results to date have been to show that significant differences in population density of eels may be observed not only between months but also between areas of a small water body. Survey sampling should therefore take account of the nature of the substrate as well as of the more obvious parameters of depth and time of year.

In the course of the first four seasons of this investigations variations in overall catch by a constant effort have been observed. There have also been marked changes between years in catch for particular stations. Few patterns have been discovered and the need for a long-term study is clearly demonstrated.

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FIELD STUDIES ON EEL *(ANGUILLA ANGUILLA)* IN LAKE CONSTANCE : TAGGING EFFECTS CAUSING RETARDATION OF GROWTH

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MARQUAGE
CROISSANCE
ANGUILLA
EAUX CONTINENTALES

RÉSUMÉ. — Les otolithes d'Anguilles recapturées 7 ans après leur marquage, sont utilisés pour calculer la croissance annuelle. Le ralentissement de croissance causé par le marquage s'élève approximativement à 50 %. Par rapport à la croissance moyenne annuelle qui est de 48 mm pour les Anguilles non marquées, celle des Anguilles marquées est estimée à 24 mm. En relation avec les différents types de réactions dûs à la pose d'une marque sur l'opercule, les données de croissance varient largement. Dans certains cas, il n'y a pas de retard de croissance, dans d'autres, le retard de croissance dure un temps limité, suivi d'une croissance non perturbée, et dans un troisième cas, on observe une réduction de croissance pendant toute la période du marquage. Ces résultats démontrent clairement que la fiabilité d'une étude de croissance par marquage se révèle limitée.

TAGGING
GROWTH
ANGUILLA
INLAND WATERS

ABSTRACT. — Otoliths of eels recaptured up to 7 years after tagging were used for the calculation of the annual growth of tagged eels. The growth reduction caused by the tagging runs to approximately 50 %. In contrast to the mean annual length increments of about 48 mm for untagged eels the average annual growth of tagged eels was calculated to 24 mm. Resulting from different types of reaction to the jaw-tags the growth data of eels varied widely. In some cases there was no distinguishable growth retardation, in other cases the growth retardation lasted a limited time followed by undisturbed growth and in a third type the tagging led to growth reduction over the whole tagging period. In these results the limited relability of growth data derived from tagging experiments is clearly shown.

In the course of an extensive study based on tagged eels in Lake Constance (Bodensee) the reduction of growth was observed. There is practically no information about the extend of growth to be one of the effects of tagging retardation on eel (*Anguilla anguilla* L.) effected by marking with jaw tags.

The study was made on a total of 8.726 tagged eels in Lake Constance, a large prealpine lake with two major basins : Lake Obersee (476 km^2) a deep, cool and mesotrophic lake and the eutrophic Lake Untersee (63 km^2) with a mean depth of 13 m and large shallows covering an area of 44 km^2. The eels were caught by various methods adjusted to the different habitats with the aim of taking a random sample. By using a special pair of tongs to fix the jaw-tags in the corner of the mouth tagging was effected with a minimum of handling. Most of the tagged eels lived in Lake Constance for 3 to 7 years until their final capture.

As a first step the annual growth was measured *in-situ* on eels which were recaptured several times. Plotted against the period of liberty in the lake an average annual increment of 2.4 cm was found for time intervals up to 1.000 days (figure 1). There have been no significant changes with higher periods of liberty. In contrast to the mean annual length incre-

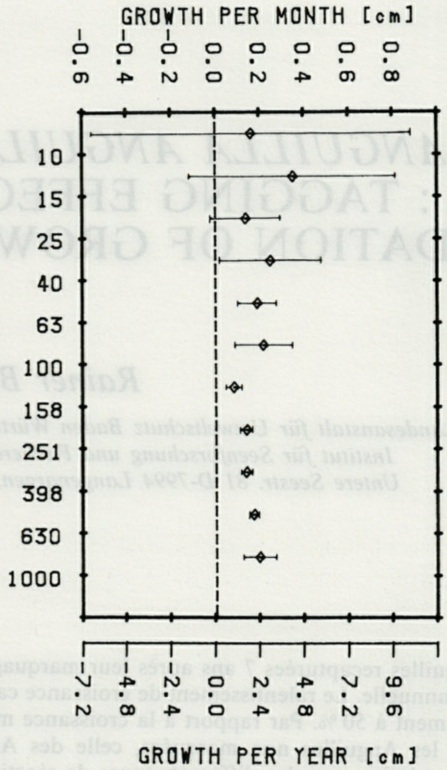

Fig. 1. — *In-situ* growth of tagged eels against the time of liberty in Lake Constance. Vertical lines : 95 % confidence limits.

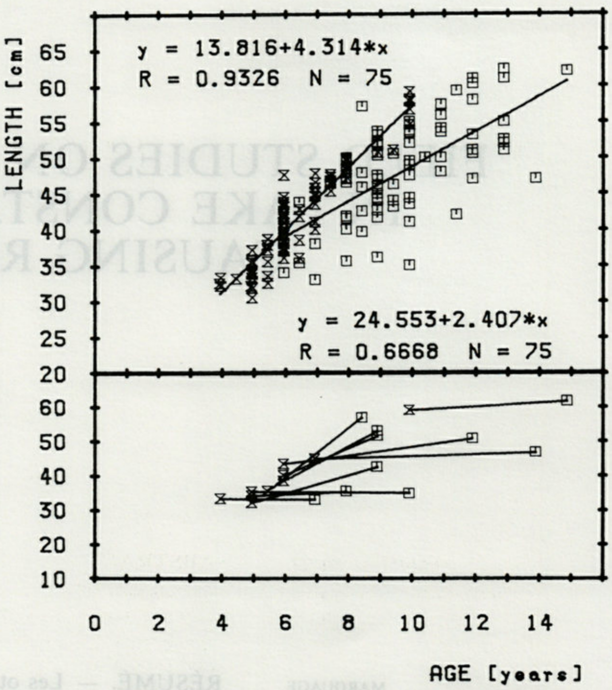

Fig. 2. — Length-age-relation data of tagged and untagged eels. X : Data representing age at time of tagging. □ : Data after final capture of the tagged eels. Below : Different patterns of growth between the time of tagging and the final capture.

ments of 48 mm for untagged eels (Berg, 1985), the average annual growth of tagged eels was reduced to approximately 50 %. Resulting from different types of reaction to the jaw-tagging the growth datas of the eels were widely spread : in some cases there was no distinguishable growth retardation, in other cases the growth retardation lasted a limited time followed by undisturbed growth and in a third type of case the tagging led to growth reduction over the whole tagging period.

By assuming the location of false annuli caused by the tagging procedure it was possible to show the time of first tagging in a thin section of the otolith (Berg 1985). Supported by this method, the length on age relation at the time of tagging and after final capture if plotted in figure 2. The values of the length on age relation after final capture are much lower.

All things considered the jaw tagging led to a considerable reduction of growth. However, using the changed relations in otolith ring pattern it became possible to made allowance for the changed growth situations.

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EEL ESCAPEMENT FROM SMALL FOREST LAKES

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ANGUILLA ANGUILLA
DOWNSTREAM-MIGRATION
FINLAND

ABSTRACT. — Eel populations in Finnish fresh waters are almost completely dependant on introductions and stockings, which have been carried out in many small lakes in southern Finland. This report deals with factors affecting eel escapement from these forest lakes. The material was collected between 1974-1984 in the Evo area (61°12'N; 25°50'E) from five separate, small rivers and brooks. The eel escapement period continues throughout the whole icefree period of the year. Moon phases have visible effect on the escapement, but the main factor seems to be the water discharge in the rivers and brooks. The annual spring and autumn floods clearly encourage the escapement. Occasional heavy rains in summer may rapidly increase the discharge in small rivers, which also leads to active downstream migration.

ANGUILLA ANGUILLA
MIGRATION
AVALAISON
FINLANDE

RESUMÉ. — Les populations d'Anguilles des eaux continentales finlandaises sont entièrement dépendantes de leur introduction et du réempoissonnement, ce qui a été entrepris dans plusieurs petits lacs situés au Sud. Ce travail présente les facteurs affectant la fuite des Anguilles de ces lacs forestiers. Le matériel a été récolté entre 1974 et 1984 dans la région Evo, (61°12'N; 25°50'E), dans 5 petites rivières et ruisseaux indépendants. La fuite des Anguilles se prolonge pendant toute la période chaude de l'année. Les phases de la lune ont un effet certain sur la fuite; mais le facteur le plus important semble être le niveau d'eau dans les rivières et les ruisseaux. Les inondations annuelles de printemps et d'automne provoquent la fuite. Les fortes pluies occasionnelles d'été peuvent entraîner une montée rapide des eaux dans les petites rivières, ce qui conduit à activer la migration d'avalaison.

1. INTRODUCTION

Eel populations in Finnish inland waters depend almost completely depending on introductions and stockings (Pursiainen and Toivonen, 1984). Stockings have been made in more than 250 lakes. Introductions ceased in 1979 because of the possibility of elvers being carriers of viral fish diseases (Anon., 1984). For this reason it was considered best to continue with stockings only with fingerlings reared in careful quarantine.

Most of the previous stockings took place in small inland waters in Souther Finland. In many cases these forest lakes are not efficiently fished and may also have relatively low production. However, the eel can be a rather productive fish in these lakes when compared with the native species, because of its low mortality (Pursiainen and Toivonen 1984). Under Finnish conditions one eel stocking can produce a catch for more than 10-15 years; but the problem of low yearly production making, remains ordinary lake fisheries unprofitable. Therefore, the only eel catch worth considering is the final product, silver eels, taken by traps in the rivers as they escape from their feeding areas.

Eel escapement in Central European circumstances has been discussed by Deelder (1984); and Haraldstadt *et al.* (1985) have presented results from Norway. The general conclusion is that seaward migration occurs in the autumn as water temperature decreases. Eels escaping from Finnish forest lakes seem to behave differently, at least to a certain degree. Therefore in this paper eel escapement and some factors affecting it are further discussed in order to obtain a better understanding of how and when a catch should be taken, with a view to encouraging the utilization of small inland waters for fisheries.

2. DESCRIPTION OF THE LAKES AND RIVERS

The material was collected in the Evo area in Southern Finland (61°12'N; 25°50'E) from five small rivers and brooks (Table I). Catching sites 1-4 are parts of the same water course. The water course can be characterized as typical, oligotrophic forest lakes with a low pH and brownish water. Catching site 5 is of a different type, with almost neutral pH and relatively eutrophic water; and the lakes are partly surrounded by fields. The most common fish species are perch, roach and pike. In some lakes, there are also stocked whitefish. Eels have been stocked in the lakes above catching sites 1 and 2 several times, especially in 1966-1968. Above sites 3 and 4, the stockings were made in 1978; and above site 5 in 1967.

Table I. — Some characteristics of the rivers and brooks containing catching gear, and of the lakes above them.

	Catching sites				
	1	2	3	4	5
River width (m)	3	5	1	0.5	1.5
Number of lakes	17	17	2	2	2
Area of lakes (ha)	150	170	20	8	23
Max. depth (m)	13	11	5	3	5
pH (mean)	5.2	5.9	5.7	5.8	6.6
Colour (Pt mg/l)	92	115	134	160	70
Conductivity	29	42	31	33	110

3. FISHING METHODS AND HANDLING OF THE CATCH

In the Majajoki River (catching site 1), there has been a fixed eel box since 1974. In the Evojoki River (2), eel fishing has been done since the summer 1979 with a fyke net which completely spans the river. In the other catching sites, the eel boxes have been installed in 1981-1982. Problems in the efficiency of the catching gears have sometimes occurred during the spring floods, when part of the water has flowed over the box dams. At this time, part of the eels may have avoided the gears. Except during peak floods the catching systems have functioned well.

The gears were checked almost daily during the entire icefree period of the year. The length, weight, and sex were determined for the eels taken; and otholiths were also collected for age and growth determinations.

Table II. — Total catch of the eels from catching sites and from the lakes above them taken during the study period.

Site	Years	Rivers			Lakes		
		No. of eels	Total weight kg	Mean weight g	No. of eels	Total weight kg	Mean weight g
1	74-84	409	403	985	269	139	517
2	79-84	39	29	743	—	—	—
3	82-84	25	3	120	49	11	224
4	82-84	32	8	250	61	17	278
5	81-84	117	61	521	96	41	427
Total		622	504	810	475	208	438

4. THE EELS CAUGHT

The total catch of the different catching sites have been collated in Table II. The same table also shows eel catches from the above lakes which were taken as by catches from fyke nets and pound nets, and with the eel long-line fishing. The size of the catch from a lake depends of course of the catch effort, but according to the results it is clear that the mean weight of the catch from the rivers is almost double that taken from lakes.

The sum of the daily eel catches according to the time of the year is given in Figure 1, which shows that eel escapement continues through the entire ice-free period. The mean temperature at the time the season's first eel is caught has been 3.8 °C; and at the last eel correspondingly 5.4 °C. The Figure also shows the two peaks of the catch : the active spring migration in May, the quiet summer period and the active autumn migration. Of the total of 622 eels, 28 % were caught during the spring floods

Table III. — The monthly eel catch from all catching sites according to the phases of the moon.

Month		New moon	First quarter	Full moon	Third quarter	Total catch
April	N	3	0	3	0	6
	%	50	—	50	—	
May	N	31	85	33	19	168
	%	18	51	20	11	
June	N	6	5	10	4	25
	%	24	20	40	16	
July	N	37	8	3	35	83
	%	45	10	4	42	
August	N	25	14	21	25	85
	%	29	16	25	29	
September	N	82	31	6	45	164
	%	50	19	4	27	
October	N	12	32	11	31	86
	%	14	37	13	36	
November	N	2	2	0	1	5
	%	40	40	—	20	
Total	N	198	177	87	160	622
	%	32	28	14	26	

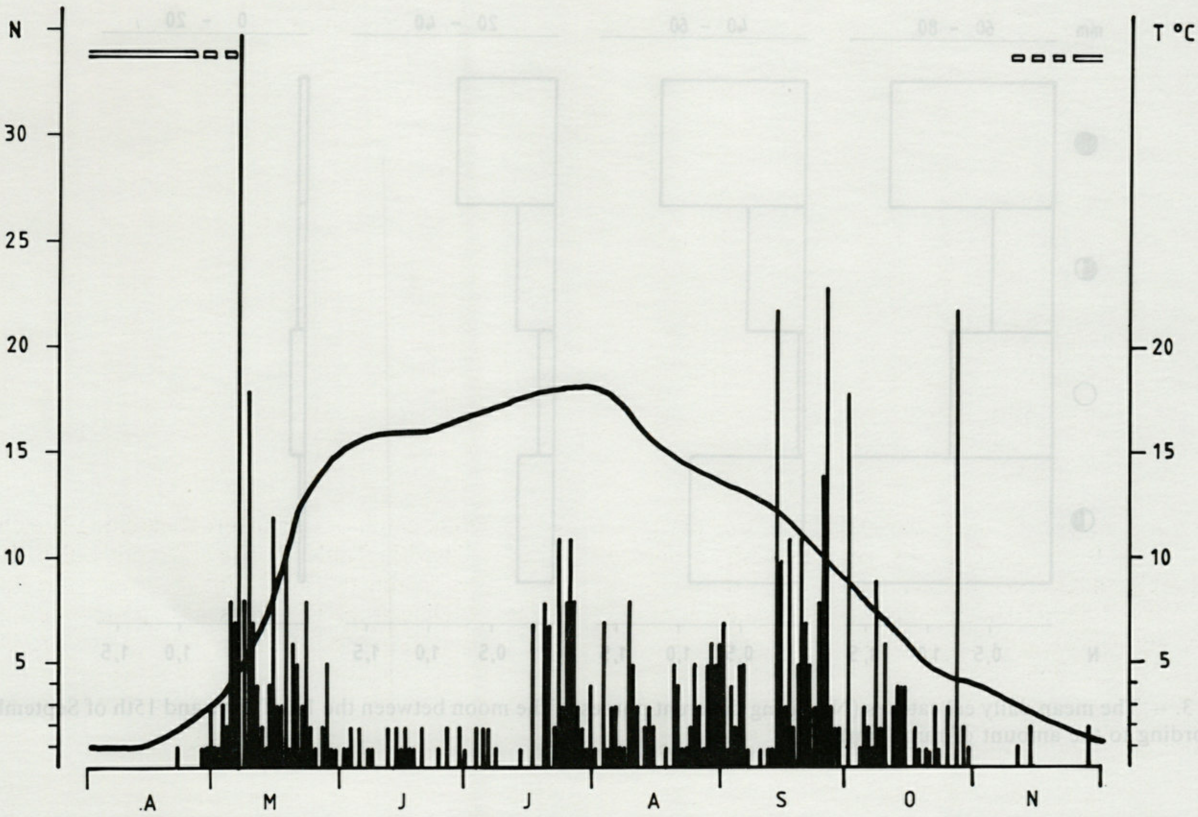

Fig. 1. — Total sum of the daily silver eel catches. The solid line is the mean water temperature. Ice cover is indicated by horizontal bars.

caused by melting snow in late April-May; 31 % during the three summer months; and 41 % during the autumn rains (Table III).

The yearly catch accumulation in this study clearly differs from the data presented by Deelder (1984) and Haraldstadt *et al.* (1985). The spring floods seem to be an important factor affecting the eel escapement in small Finnish lakes, while in more southern or western areas such a spring migration does not seem to occur at all.

5. THE EFFECTS OF THE LUNAR CYCLE AND OF DISCHARGE

The lunar cycle has been said to have remarkable effects on silver eel migration (Deelder 1984), and this does seem to hold true with forest lake eel escapement, too. During the full moon the eel box catches are at their minimum, and during the new moon at their maximum (Table III). From May to mid-July the effect is not very clear, propably because of the very bright nights.

The effects of spring and autumn floods on eel escapement are already mentioned, but in Finland Järvi (1934) has documented the increased silver eel migration activity brought about by heavy summer rains. In small water systems occasional heavy rains also rapidly increase the discharge. Figure 2 shows the mean daily eel catch from 1st of June to 15th of September in relation to the amount of rain. The

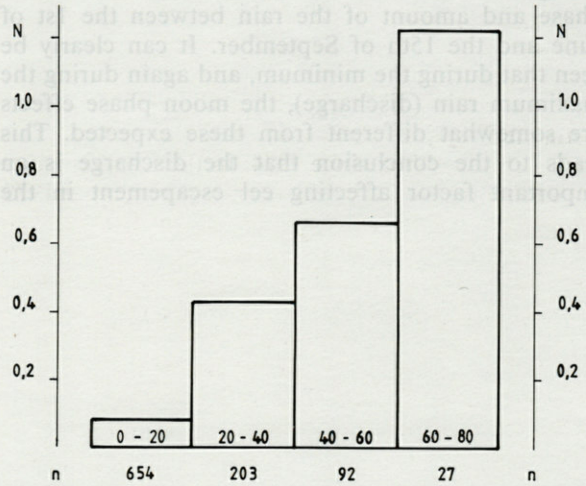

Fig. 2. — The mean daily eel catch between the 1st of June and the 15th of September, according to the amount of rain. Numbers in the columns represent the amount of rain in mm, and n is the number of days.

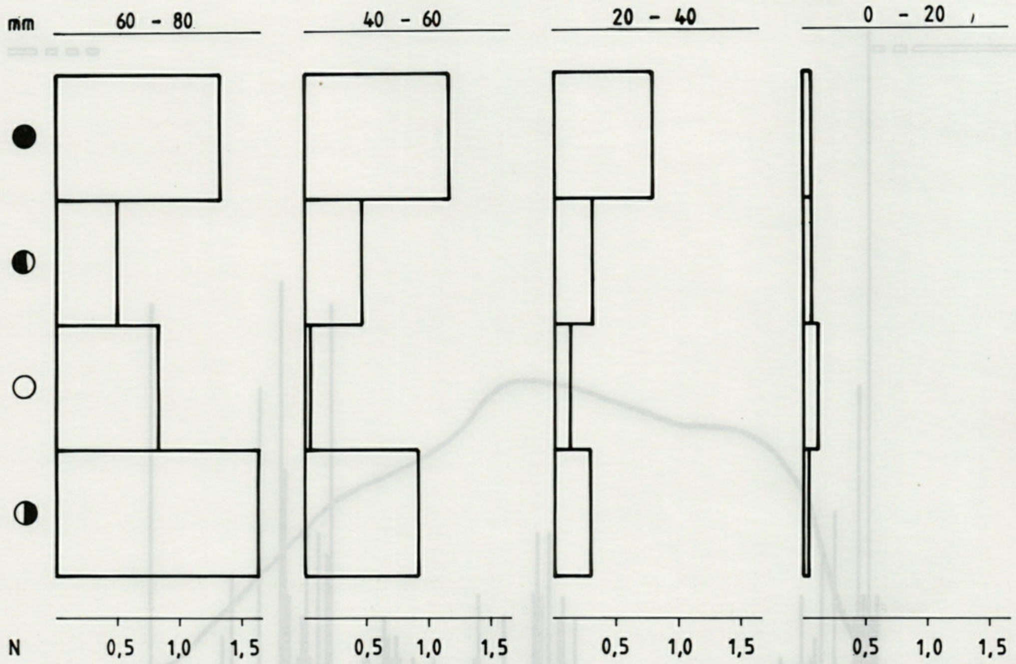

Fig. 3. — The mean daily eel catches (N) during different phases of the moon between the 1st of June and 15th of September according to the amount of rain (mm).

amount of rain is the sum for seven days : the day of the eel catch and the six preceding days. When the amount of rain increases from 0-20 mm to 60-80 mm per 7-days period, the eel catch increases by a factor of fourteen. During the summer the daily mean catch of 0.27 eels per day is very significantly higher than the mean of 0.08 eels per day at minimum rain (Student Test $P < 0.001$). When the amount of rain is more than 20 mm per 7-days period, the catch is fairly significantly greater than the whole summer's mean ($P < 0.1$).

Figure 3 shows the combined effects of the moon phase and amount of the rain between the 1st of June and the 15th of September. It can clearly be seen that during the minimum, and again during the maximum rain (discharge), the moon phase effects are somewhat different from these expected. This leads to the conclusion that the discharge is an important factor affecting eel escapement in the summertime as well, although spring and autumn floods have the most important influence on silver eel escapement from small forest lakes in Finland.

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PROBLEMS OF ANALYSING EFFECTIVENESS OF EEL STOCKING IN INTERCONNECTED LAKES

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ANGUILLA ANGUILLA
LACS RELIÉS
ALEVINAGE
CORRÉLATION MULTIPLE

RÉSUMÉ. — Les études de pêches et d'alevinage d'Anguilles dans cinq groupes de lacs reliés entre eux, ont été réalisées d'après des relevés portant sur de longues années. La méthode d'alevinage s'est montrée très efficace. Par contre, l'analyse de la réussite de l'alevinage dans des lacs particulièrement complexes est fort difficile. Une méthode d'étude sur l'efficacité de l'alevinage dans ces lacs, basée sur des corrélations multiples, est présentée.

ANGUILLA ANGUILLA
INTERCONNECTED LAKES
FISH STOCKING
MULTIPLE CORRELATION

ABSTRACT. — Long-term data on eel stocking and catches from five lake complexes forming an interconnected system were analysed. Eel stocking was highly effective in the whole system. However, analyses of the effectiveness in particular lake complexes proved to be very difficult. The paper presents a method of analysing the effectiveness of stocking in interconnected lakes, based on multiple correlation studies.

INTRODUCTION

Studies on the effectiveness of eel stocking in Polish lakes (Leopold, 1986) practically paid no attention to the possible effect of eel migration between the lakes, especially migration of the stocking material. This was partly due to the fact that dependencies between eel stocking and catches were anyway very strict, highly significant statistically, and as such fulfilled cognitive and practical objectives.

However, as eel management in Poland is becoming more and more important, efforts to optimize this management are being made, and the respective studies have been enlarged to embrace this problem as well. The matter became of special importance when the Department of Fishery Economics, Inland Fisheries Institute, undertook complex studies on the state of the environment and fishery management in the so-called Great Mazurian Lake System, and it appeared that the methods used so far are not satisfactory. This paper presents a new method of analysing the effectiveness of eel stocking in interconnected lakes.

MATERIALS AND METHODS

Analyses embraced materials from the Great Mazurian Lake System. The System consists of 32 interconnected lakes of a total area of over 35 thousand ha. Within the system, 5 more or less integrated lake complexes can be distinguished. These are : Mamry, Niegocin, Mikołajki, Sniardwy and Roś. The complexes Mamry and Roś are peripheral and, thus, connected with only one other lake complex, while the remaining three are located centrally and each is connected with others two (Fig. 1).

The materials consisted of detailed records of eel stocking and commercial catches for each lake over the period 1961-1983. Statistical methods were used to determine the relationship between rate of eel

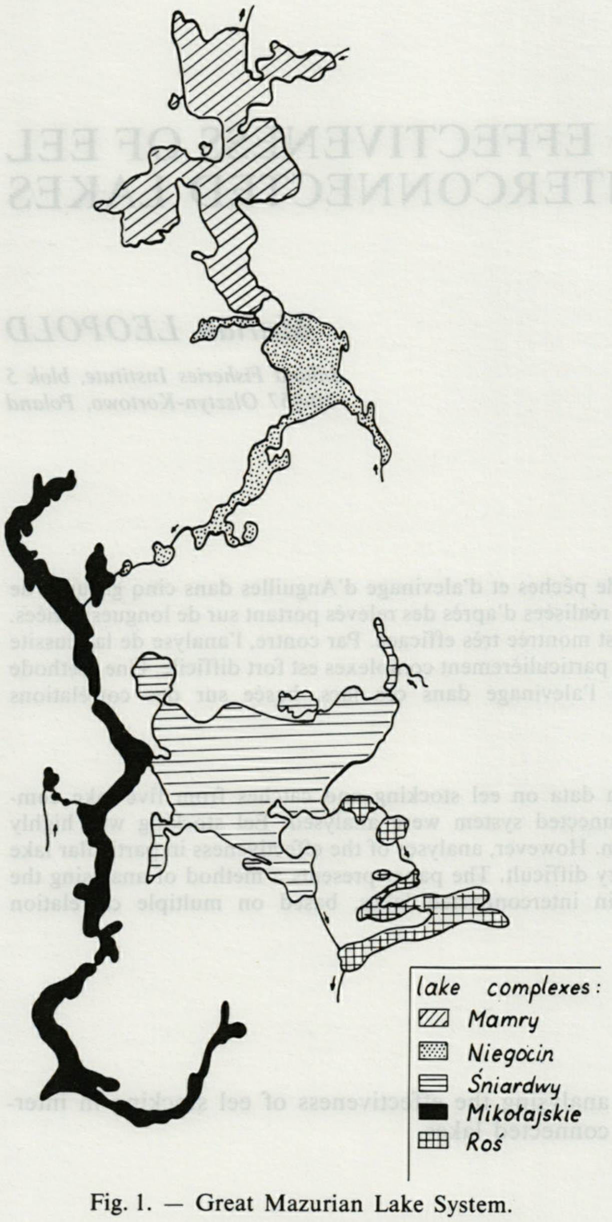

Fig. 1. — Great Mazurian Lake System.

stocking and level of eel catches, especially simple and multiple correlation.

In the first step, simple correlations were calculated between eel stockings and catches in the whole system and in particular lake complexes. In the second step, a totally different approach was adopted. It was assumed that the total eel catch in the whole system depended on the "input" represented by stocking in particular lake complexes. In this way, the obtained relationship could be used as an illustration of possible eel migrations within the whole system. To achieve this aim, multiple correlation and determination were used, with the eel catch in the Great Mazurian Lake System as the dependent variable (y), and the independent variables represented by eel stocking in particular lake complexes (x — complex Mamry, z — complex Niegocin, u — complex Mikołajki, w — complex Sniardwy, p — complex Roś).

It was also established that in the period under study the fishing effort in particular lake complexes did not undergo any major changes.

RESULTS

Table I contains a characteristic of the eel management in the lake system as a whole, in the distinguished lake complexes, and the dependencies between eel stockings in 1961-1978 and eel catches in 1966-1983.

When the Great Mazurian Lakes are considered as a whole, the dependence between stocking rate and level of eel catches seems very simple and unequivocal. The coefficient of correlation $r = 0.7806$ is highly significant and points to very strict dependency between the two variables.

The matter becomes more complicated when particular lake complexes are taken into account. It appears that the greatest lake complex, viz. Sniardwy, which represents 35.5 % of the total are of GML, is characterized by practically insignificant correlation between eel stocking and catch ($p = 0.10$), whereas eel catches are fairly high, and the relation "stocking-catch" very favourable. Moreover, the most obvious conclusion would be that eel stocking in Mikołajki complex should be limited, whereas rate of stocking in other complexes, and in

Table I. — Basic parameters of the eel management in the Great Mazurian Lake System /GML/.

Lake complex	Area (ha)	Average eel stocking (elvers/ha/year)	Average eel yield (kg/ha/year)	Average number of elvers per 1 kg of catch	Coefficient of correlation between stocking and catch (r)	Level of significance
Mamry	10 376.0	58.5	2.13	27.4	0.7217	0.001
Niegocin	4 270.4	63.1	3.99	15.8	0.6282	0.001
Mikołajki	5 632.2	96.4	2.29	42.2	0.6780	0.01
Sniardwy	12 475.0	50.7	3.72	18.6	0.4201	0.10
Roś	2 429.4	63.5	2.01	31.5	0.6171	0.01
Totally GML	35 183.0	62.7	2.58	24.3	0.7805	0.001

Niegocin in the first place, should be increased. The latter complex is characterized by the highest level of catches and the lowest expense in terms of stocking material used to obtain a catch of 1 kg. These conclusions — apparently well founded — do not take into account the fact that the lakes are interconnected and in reality do not constitute isolated objects.

A somewhat different picture was obtained with the second approach. Multiple correlation between eel catch in the whole system and stockings in particular lake complexes was very highly significant : $R_{y.xzuwp} = 0.8579$, at $p < 0.0001$. Value of $R^2 = 0.736$ reveals that variation in eel catch in the whole system is in 73.6 % explained by the stocking rates in particular lake complexes. This multiple determination is composed of « partial » determinations, connected with eel stocking rates in the lake complexes. Their values are as follows :

Mamry complex	+ 25.3 %
Niegocin complex	− 11.2 %
Mikołajki complex	+ 42.4 %
Sniardwy complex	+ 0.1 %
Rós complex	+ 17.0 %

Conclusions resulting from these values are totally different from those derived from a general approach, and suggest that stocking rates in Mikołajki complex should be increased at the expense of limited stockings in the Sniardwy and Niegocin complexes.

DISCUSSION

The two approaches used to determine the effectiveness of eel stocking in the Great Masurian Lake System gave totally different results. Interpretation and explanation of the apparently contradicting conclusions is neither easy nor univocal. Conclusive statements cannot be made without further studies. Nevertheless, it is highly probable that the results can be explained by eel migrations between particular lake complexes of the Great Masurian Lake System, both of the introduced stocking material and of the catchable stocks.

This statement is confirmed by the fact that the greatest « anomalies » in the results obtained with the two methods are observed in the case of the three centrally located complexes : Niegocin, Mikołajki and Sniardwy. Without doubt the fishes have much more chance to migrate between these complexes than between the other two.

Eel catches from the Mikołajki complex constitute only 14.2 % of the total eel catch in the system. Stockings in this complex explain 42 % of the variation in total catch. Hence, it is obvious that eels stocked into this complex are caught elsewhere, most of all in the neighbouring complexes Sniardwy and Niegocin. This explains spuriously low use of the stocking material per 1 kg of catch in these two complexes.

Low determination of total eel catch by stockings in Sniardwy complex can also result from migration of the stocking material to other lake complexes and/or immigration of the catchable eel into Sniardwy complex. In other words, eels caught in Sniardwy complex most probably originate mainly from the stockings made in other complexes.

Special attention should be given to the Niegocin complex. Negative coefficient of determination suggests that eel stocking in this complex decreased the total eel catch in the system. On the other hand, highly significant correlation was found between eel stocking and catch in this complex, and eel yield was high (Table I). The greater part of this complex is highly polluted with untreated domestic sewage. Negative effect of stocking into Niegocin upon total eel catch in the system can probably be explained by the fact that water pollution affects elvers, possibly causing high losses. Eels of catchable size are very resistant and not affected by the sewage, and even a beneficial effect is possible. Hence, high yields in Niegocin complex are probably caused by immigration of catchable eel into this complex.

Significant simple correlation between eel stocking and catch found in the latter complex might also be spurious because the high significance results from the fact that stocking rates were more or less similar in all lake complexes. The matter necessitates further studies.

Obviously, not everything is known as yet. Nevertheless, the results obtained with the two methods clearly show that there is no simple and universal approach to the studies on the effectiveness of stocking in interconnected lakes, even if the results seem to be quite adequate. Consideration of one approach only may lead to erratic conclusions and wrong management decisions.

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THE EFFECT OF EEL STOCKING ON STOCKING WITH OTHER FISH SPECIES

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ALEVINAGE
EAUX CONTINENTALES

RÉSUMÉ. — L'analyse de l'efficacité de l'alevinage en Anguille et en diverses espèces de Poissons, pour 31 lacs d'une surface totale de 5 300 ha, a été effectuée à partir d'échantillons obtenus durant plusieurs années. On a déterminé l'impact de l'alevinage intensif en Anguille sur la réussite de l'alevinage sur diverses espèces de Poissons. L'influence positive des Anguilles sur l'efficacité de l'alevinage des lacs avec *Coregonus albula, C. lavaretus + C. peled, Stizostedion lucioperca* et *Tinca tinca,* a été constatée. Par contre, aucune influence sur l'efficacité de l'alevinage de *Cyprinus carpio* et *Carassius carassius* n'a pu être décelée.

ANGUILLA ANGUILLA
FISH STOCKING
INLAND WATERS

ABSTRACT. — Long-term data on fish stocking and commercial catches from 31 lakes of a total area of 5.300 ha were used to analyse the effect of stocking with eel on other fish species. The effect of stocking at high rates with eel upon the effects of stocking with other fish species was determined. It was found that high rates of stocking with eel affected the effectiveness of stocking with vendace, whitefish + peled, pikeperch and tench positively, whilst no effect was found as regards stocking with carp and crucian carp.

INTRODUCTION

Eel stocking into Polish lakes has been a common practice since many years, carried out on a large scale. Area of lakes with no eel stocking in very small. Average eel landings (commercial and recreational) in lakes stocked with this species amount to 7.0 kg/ha annually on a national scale, compared to less than 0.5 kg/ha in lakes with no eel stocking. Consequently, eel management is of considerable economic significance in Poland and constitutes a subject of both theoretical and applied studies. In all cases significant correlation was found between eel stocking and catches.

This paper deals with one State Fish Farm which manages 52 lakes of total area 5 828 ha. Lakes stocked with eel represent 59.6 % of the total lake number (31 lakes) and 91 % of the total lake area.

At present, lake fishery management is changing its character and becoming more like aquaculture and less and less like traditional fishery. Artificial stocking of many species has become a popular measure treated as a method of counteracting unfavourable changes taking place in the fish stocks (and catches) in lakes under the effect of man-made influences, and especially under the effect of accelerated eutrophication. During the period 1952-1982 only 4 lakes (of total area 50.4 ha) belonging to the farm under study were not stocked with any fish species. All other lakes were artificially stocked although with varying rates. The farm used 13 fish species and 1 crayfish species.

Many earlier studies (e.g. Leopold, 1975) revealed significant positive correlation between eel catches and catches of other fishes. This dependence was looked upon as resulting from lake trophy. According to the interpretations given so far, lakes of a higher eutrophication were stocked with eel at a higher rate, hence its fishery production was higher. At the same time, higher catches of other fish species were considered as being caused by the higher trophy of these lakes.

This view, although quite logical, implied that there was no significant effect of increasing eel population (due to increasing stocking) upon the lake biocenoses, and especially upon their ichthyocenoses. However, eel catches at present are much higher than they used to be with natural recruitement; so density of eel stocks must have also increased. Possible effects of these dense stocks on the stocks of other fish species therefore cannot be disregarded and necessitate proper studies. Special attention should certainly be devoted to the effect of intensive eel management on the management with other fish species.

SPECIES USED AND METHODS OF ANALYSIS

Analysis presented in this paper embrace stockings with 7 fish species i.e. : vendace *Coregonus albula L.*, whitefish + peled *C. lavaretus L. + C. peled* Gmel., tench *Tinca tinca L.;* pikeperch *Stizostedion lucioperca L.*, common carp *Cyprinus carpio L.* and crucian carp *Carassius carassius L.* Stockings with these species were analysed in lakes which were also stocked with eel.

Analysis were performed taking advantage of the linear correlation / regression /. In each case a selection was made of all lakes stocked with eel and the given fish species , with no attention paid to other species. In this way, groups of lakes were distinguished, for which studies were made on a long-term scale of 31 years, each group being treated as a whole. Successive steps of the analysis embraced the following determinations : (1) dependence between rate of stocking with the given species and level of its catches (2); dependence between rate of stocking with eel and level of eel catches (3), dependence between rate of stocking with eel and the effectiveness of stocking with the given fish species. The latter dependance was analysed in two ways, i.e. vertically (n represented the number of years, and the variables — level of stocking and catches in particular years) and horizontally (n represented the number of lakes, and the variables — mean annual stocking and catch in particular lakes). Effectiveness of stocking with the given fish species was expressed in financial terms (cost of the stocking per 1 kg of the catch). In order to eleminate accidental variations, the time series were smoothed using moving averages, so as to expose the trends of a more general character.

No attention was given to the fishing intensity. In the Fish Farm under study the managing team, the fishermen, and the management have not changed for many years, and cannot have any significant effect on the results obtained.

RESULTS

Overall results of the analysis are presented in Table I.

A. *Lakes stocked with eel and vendace*

The dependence between stocking with vendace and vendace catches one year later was highly significant so that, obviously, the measure was effective. The dependence between eel stocking and catches was also very highly significant. Highly significant negative correlation was found between the effectiveness of stocking with vendace and rates of stocking with eel. Hence, the higher the rate of stocking with eel, the lower the cost of vendace stocking needed to obtain 1 kg of vendace catch.

B. *Lakes stocked with eel, whitefish and peled*

Whitefish and peled were analysed together because the fishermen are frequently unable to

Table I. — Relationship between stocking with eel and eel catch as well as with stocking of other fish in 52 Polish lakes. The effect of stocking is expressed by the coefficient of correlation (r). p = significance, f = degrees of freedom, n = number of lakes stoked with the given species and eel, in parenthesis — total number of lakes stocked with the given species, ha = area of lakes stocked with the given species and eel, in parenthesis — total area of lakes stocked with the given species, years = years of stocking/catch.

Species	Species stocking — species catch						Eel stocking-eel catch			Effect of eel stocking on effectiveness stocking of species				
	r	p	f	years	n	ha	r***	p	f	n	ha	r***	p	f
Coregonus albula	0.6710	0.001	28	52-81/53-82	11	3340.2	0.7600	0.001	25	11	3340.2	– 0.7519*	< 0.001	25
Coregonus lavaretus + C. peled	0.8641	0.001	25	53-79/56-82	22 (24)	(4754.6)	0.7635	0.001	25	22	4706.9	– 0.5495*	< 0.01	19
Stizostedion lucioperca	0.4458*	0.02	24	52-81/53-82	13 (15)	(1892.1)	0.6617	0.001	24	13	1844.5	– 0.5571*	< 0.01	24
Tinca tinca	0.8358*	0.001	22	55-82/55-82	26 (38)	(5295.5)	0.7770	0.001	25	26	4862.2	– 0.6469*	< 0.001	22
Carassius carassius	0.5976*	0.001	25	52-82/52-82	18 (26)	(2761.7)	0.7435	0.001	24	18	2396.7	no dependence		
Cyprinus carpio	0.7976**	0.001	23	53-81/54-82	13 (18)	(2111.2)	0.6305	0.001	24	13	1881.7	no dependence		

* 5-year moving averages; ** 3-year moving averages; *** years : 52 or 53-78/56 or 57-82.

distinguish between the two species. The dependance between whitefish + peled stockings and catches was very highly significant, indicating a strict dependence of the catch on artificial stocking. The rate of eel stocking and effectiveness of stocking with whitefish and peled were significantly negatively correlated. Thus, stocking with eel had a beneficial effect on the effectiveness of stocking with the two coregonids, just as in case of the vendace.

C. *Lakes stocked with eel and tench*

The dependence between tench stocking and catches was very highly significant. Strict correlation was also found between eel stockings and catches. Finally, a significant negative correlation was found between the rate of eel stocking and the cost of tench stocking. Hence, eel stocking influenced positively also the effectiveness of stocking with tench.

D. *Lakes stocked with eel and pikeperch*

Dependence between pikeperch stocking and catch was noticeable and a relation between eel stocking and catches in the same lakes was also significant. Stocking with eel correlates negatively with the effectiveness of stocking with pikeperch. Consequently, it seems that eel has similarily a beneficial effect on the effects of stocking with pikeperch.

E. *Lakes stocked with eel and carp*

A strict dependence was found between carp stocking and carp catches. No statistically significant dependence was found between rate of eel stocking and effectiveness of stocking with carp, the latter being expressed by various different methods. This fact suggests that the eel has no effect whatsoever on the effects of stocking the lakes with carp.

F. *Lakes stocked with eel and crucian carp*

A strict dependence was found between crucian carp stocking and catches. As in the case of common carp, no dependence was found between rate of stocking with eel and the effectiveness of stocking with crucian carp. This fact allows us to state that the eel has no negative effect on the effectiveness of stocking with crucian carp.

G. *Horizontal approach*

When the average effectiveness of stocking (over the 31-year period) with particular fish species was related to the respective average rate of stocking with eel, significant negative correlation was found, the correlation coefficient being $r = -0.4944$ at $p < 0.001$. Hence, a horizontal approach also revealed that in each of the 31 lakes stocked with eel, relatively higher rates of stocking with eel were coupled with lower cost of stocking with other fish species to obtain the same catch, i.e. with higher effectiveness of stocking with these species.

DISCUSSION

In the 31 lakes under study, no negative effect of eel stocking on other fish species was noted. On the contrary, it was found that with the exception of carp and crucian carp, stocking with eel improved effects of stocking with other species. This statement applies even to vendace, contradicting common opinion that eel and vendace are unable to coexist. As regards carp and crucian carp, intensive stocking with eel had no effect on the two species.

The relationship between the rate of stocking with eel and the effectiveness of stocking with other fish species does not contradict earlier suggestions that this might be the result of a higher trophical condition of the lake. However, an opposite hypothesis is also possible. It can certainly by assumed that fishery production in lakes (in this case production of other fish species) increased due to the beneficial effect of eel stocking, or of the rather intensive eel management upon the lake ecosystems and their ichthyocenoses. This effect is probably of complex and multiple character, as reflected by the fact that it is noted for a variety of fish species differing as regards their requirements and role played in the ecosystems, such as the coregonids, tench and pikeperch. The conclusion is based on suggestions that eel can act as an ameliorator of the fish stocks in lakes. In the course of eutrophication the predatory species gradually disappear from the lake environment. It is well known that these species are beneficial for the lake biocenosis and the maintenance of the fish stock balance. Moreover, lake eutrophication usually induces excessive development of less valuable species, which are as a rule characterized by higher resistance : they develop at the expense of more valuable species, which are biologically less resistant. Hence, it may be concluded that eel gradually takes over the part of predatory species and becomes a regulator of the environmental balance and of the fishery production in eutrophic lakes.

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MARKING AND TAGGING METHODS APPLIED TO EEL (*ANGUILLA ANGUILLA* L.)

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ABSTRACT. — Tagging or marking of eels often results in tag loss, infection, stunted growth or mortality. The main reason for this is considered caused by the ecology of the eel, hiding in bottom material etc. Most experiments have been performed *in situ*, thus making final conclusions on tag loss, growth and survival difficult.

Marking of eels are reported using different methods :

Submersion in colour bath (Nile blue sulphate, Alizarin, Methylen blue, Trypan blue, Gentiana violet, Janus green, Lithium-carmin, Neutral red and Bismarck brown).
Submersion in tetracycline bath.
Injections of tetracycline, rubber latex, acrylic paint, Alcianblue and Indian Ink.
Cauterization using silver nitrate and concentrated sulphuric acid.
Freezing using liquid nitrogen.
Burning using a red hot piece of metal.
Fin clipping.
Labelling with radionucleotides.

Tagging of eels were done using :

External tags (Carlin tags, Floy tags, other related tags, jaw tags, plastic arrow tags, gill tags).
Internal tags introduced to the body cavity.

All methods tested affect the eel, especially the tagging methods. Some methods have proven unfit for use, but as tagging and marking of fish are valuable tools in fisheries investigations the following methods can be recommended to be tested further :

Tagging methods :

Carlin tags (including different types of wire), Floy tags, Jaw tags, internal tags.

Marking methods :

Submersion in coulour bath, Injection of rubber latex, Injections of alcianblue, Cauterization using silver nitrate pencils, Freezing, Fin removal.

Testing should not involve silver eels.

OTOLITHS OF EELS OF KNOWN AGE

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ABSTRACT. Otolith photos of eels ranging from leptocephali to 18 months eels (after glaseel stage) are presented. The otoliths of glasseels from four European localities were of nearly equal size. Eels of known age from an eel farm showed that the otoliths continue their growth even if the fish itself does not grow at all. This is also true during the metamorphosis from leptocephalus into glasseel, where the body length is reduced. The farmed eels, which were of known age showed in their otoliths a number of rings which indicate a much higher "age" than the actual age.

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A REVIEW ON THE COMPETITIVE SITUATION OF THE EEL IN RELATION TO OTHER SPECIES

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A. ANGUILLA
COMPÉTITION INTERSPÉCIFIQUE

RÉSUMÉ. — L'auteur présente le recensement des dangers (Poissons, Oiseaux, Mammifères) encourus par l'Anguille *A. anguilla* pendant sa vie océanique et continentale. La compétition pour la nourriture et l'espace, ainsi que la prédation sur les Ecrevisses et les Poissons sont considérées, ainsi que l'influence de l'Anguille sur ces groupes. Les effets sur divers Salmonidés et Cyprinidés sont possibles quand la densité de population d'Anguilles est forte ou quand les conditions de l'environnement sont extrêmes. L'espèce la plus affectée est l'Ecrevisse *A. astacus*. Une concurrence cruciale avec d'autres espèces comme *Lota lota* est plus théorique, et il semble que l'Anguille, dans les conditions naturelles, a trouvé sa niche. Considérant que l'Anguille européenne doit supporter les effets négatifs de l'environnement causant une baisse possible du recrutement, des mesures restrictives sur l'unique stock doivent être prises seulement sous conditions exceptionnelles.

A. ANGUILLA
INTERSPECIFIC COMPETITION

ABSTRACT. — Endangerment of all stages of the eel during its life in oceanic and continental waters by fish, bird and mammals is reviewed. Competition for food, space, and predation of freshwater crustacean and fish are reported, and influence of the eel on these species considered. Effects on various Salmonids and Cyprinids are possible when eel stock density is high or under other extreme environmental conditions. More easily affected is the crayfish *Astacus astacus*. Crucial competition with other species such as e.g. *Lota lota* is more speculative and it seems that the eel under natural conditions and with respect to native species has found its niche. Considering the fact that the European eel stock has to endure many negative environmental effects with possible decline of the recruitment, restrictive measures on single stocks should be undertaken only under exceptional circumstances.

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STUDY OF THE STOCK OF EXPLOITED EELS IN THE LAGOON OF BAGES-SIGEAN

Gulf of Lion, Southern France

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Among the exploited stocks in the lagoon of Bages-Sigean, eels *(Anguilla anguilla)* constitute the main species. Their exploitation was highly developed in the course of the last two decades and is now representative of more than the half of fish catches.

The eels of Bages-Sigean caught by fyke nets show a polymodal distribution due to the existence of several age groups.

The highest frequency is found in the 24-36 cm length class which corresponds to the 2nd, 3rd and 4th age classes.

Growth in length is fast during the first four years of their life, from 20 cm average size in the first year, to 33 cm at the end of 4th year (from 11 cm to 34 cm by back-calculation). The length of the smallest and greatest eels in our captures were 15 and 86 cm (10 and 1100 g weight respectively), for eels from 1 year to 11 years.

Growth in weight shows a typical sigmoid form. Yearly growth rate in weight increases until four years and the maximum yearly growth-rate (30 g) occurs between 3 (W = 39,36 g) and 4 years (W = 52,8 g). Value of b ($W = aL^b$) is significantly different from 3 (P = 0,975) indicating a non-proportional length-weight relationship. Because b < 3 (b = 2.8253), the growth rate is lower in weight than in length.

This study demonstrates a wide distribution in length and in weight of individuals of the same age group.

DIFFICULTIES IN DETERMINATION OF PARAMETERS IN EEL STOCK ASSESSMENT

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The assessment on eels using methods in which age determination is essential, for example the virtual population analysis, seems impossible at the time being.

A new method described by Pauly (1984) has been developed for fish population dynamics in tropical waters. With this "length-structured" method several of the limitations of earlier methods might be avoided. If this method is useful for eels, new aspects of stock assessment on eel could be realized.

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VIE MILIEU, 1986, 36 (4) : 301-305

MECHANICAL IMPROVEMENTS TO KILLALOE EEL WEIR IRELAND

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A. ANGUILLA
CATCHING METHODS
RUNNING WATERS
POWER-STATIONS

ABSTRACT. — This paper describes some specially designed eel — catching equipment for Killaloe Weir, operated by the Electricity Supply Board, Ireland. By the use of hydraulic power, which enables heavy frames to be lifted, the difficulty of catching eels at the Navigation opening has been overcome. There is also a description of the conversion of hand-operated nets at another part of the weir, to frames raised and lowered by hydraulic power also.

A. ANGUILLA
MÉTHODES DE CAPTURES
EAUX FLUVIALES
BARRAGE ÉLECTRIQUE

RESUMÉ. — Cette étude décrit quelques engins destinés à la capture des Anguilles au barrage électrique de Killaloe en Irlande. La difficulté de capture des Anguilles dans le canal de navigation a été surmontée par l'utilisation de la force hydraulique qui permet de soulever de lourds cadres. La transformation de filets manœuvrés à la main, à un autre endroit dù barrage, en cadres qui se lèvent et s'abaissent par un procédé hydraulique, est décrite.

INTRODUCTION

Killaloe Eel Weir on the River Shannon is at its present location following its construction by the Electricity Supply Board of Ireland in 1940. The River Shannon fisheries came under the control of E.S.B. after the river had been developed to produce hydro-electric power in 1928. Experimental work and improvements at Killaloe weir have been described by D.P. O'Leary *et al.* in previous papers to EIFAC.

The writer has been associated with the provision of Engineering assistance to the E.S.B. Fisheries Management since 1979 and has designed the equipment described in this paper. Due to the present financial restrictions, there remains much to be done to complete the mechanisation of all the weir.

The paper sets out the work done as an example which may encourage the development of new sites for eel catching or the improvement of existing weirs, especially where labour is scarce or costs are high.

THE NAVIGATION SPAN

The first part of Killaloe Eel Weir selected for mechanisation was at the bridge opening of 9.6 m whidth, which is called the Navigation span.

Because of river boat traffic, this water channel could not be impeded with any permanent fixtures for eel nets, and even when eel nets were set it would be necessary to allow for the passage of boats above them.

To avoid environmental objections when the catching gear was out of the water, it was necessary to store the frame at a height to allow the passage of boats underneath, and not to be visible above the road bridge parapet walls (Fig. 1).

These objectives were achieved by using a specially strengthened steel frame of 8.7 m × 1.7 m to withstand the maximum water velocity of 1.9 m/sec. at this location. The frame size allowed 3 nets of 9.2 m perimeter at the mouth to be attached, and generally allowed about 1.7 m depth of water over the frame when in catching position. The weight of the frame without nets is approx. 580 kg. The res-

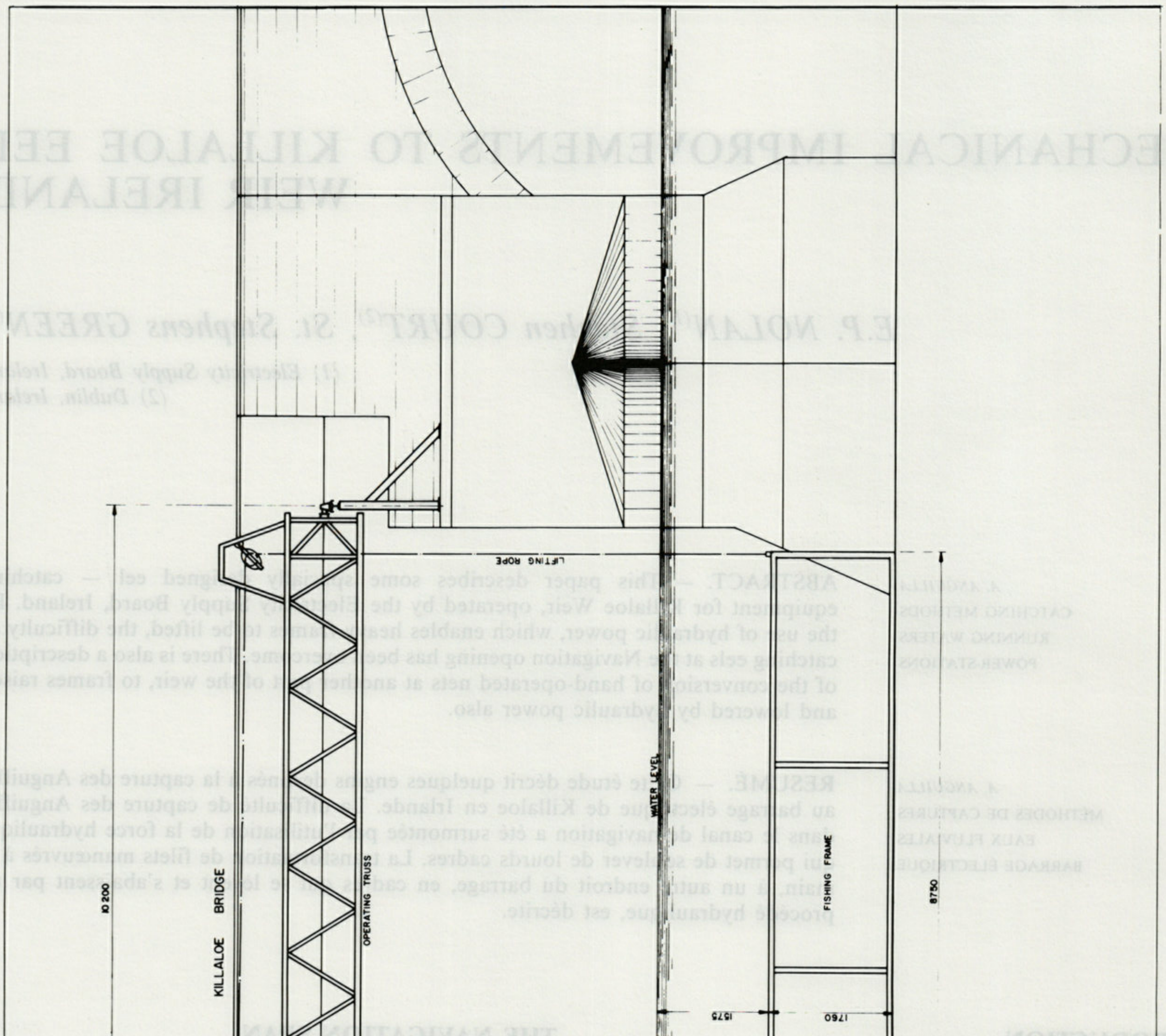
KILLALOE BRIDGE
10 200
OPERATING TRUSS
LIFTING ROPE
LIFTING ROPE
WINCH
WATER LEVEL
1575
1760
FISHING FRAME
8750

Fig. 1.

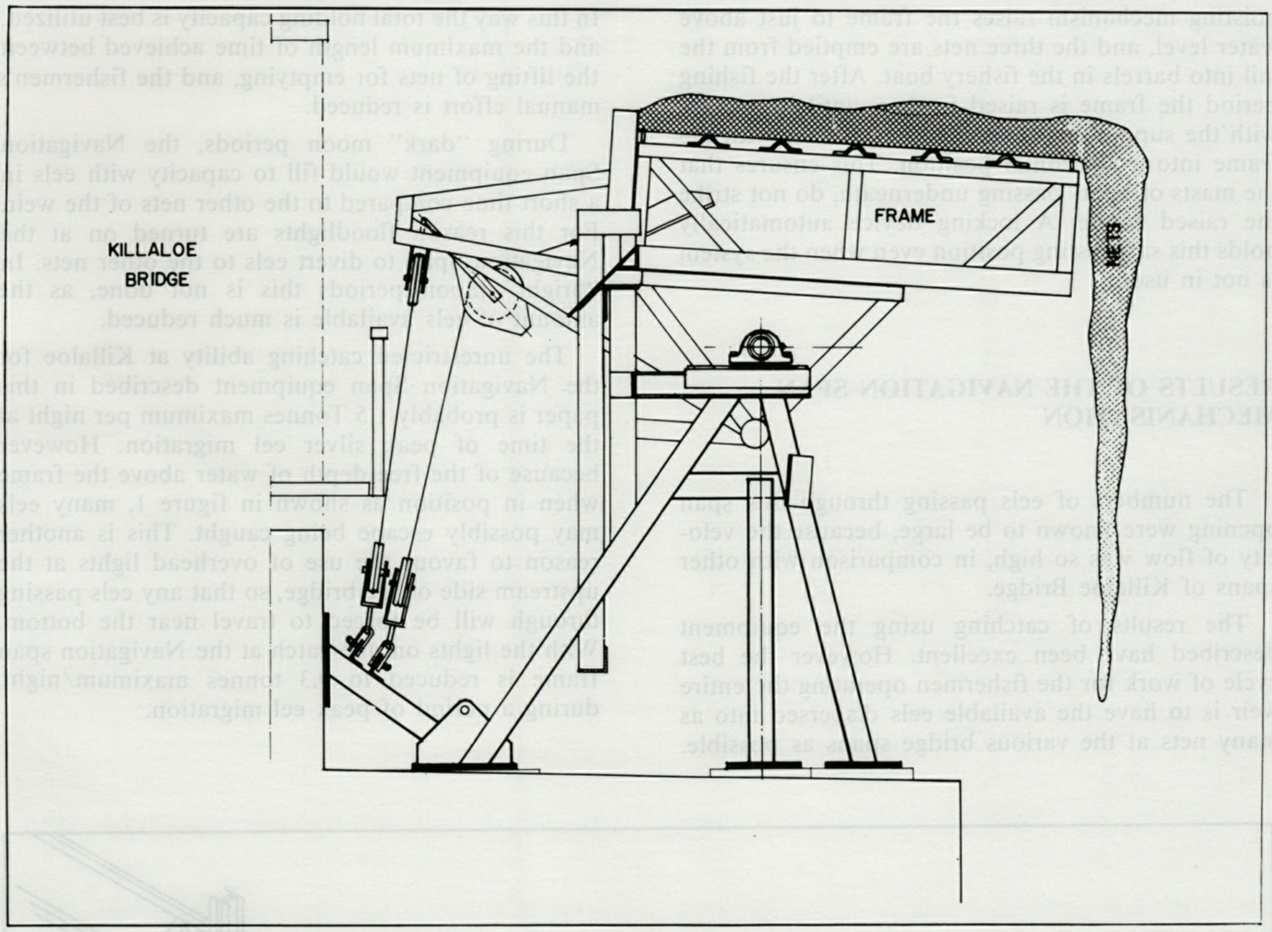

Fig. 2.

traint to hold the frame in position against water flow is provided by wire rope cables anchored to the upstream side of the bridge piers. The frame can be raised or lowered to any position by means of the controls at the side of the span, so that the operator has full fiew. The time taken for raising fully from river bottom to storage position is 50 seconds approximately. The net tails are then tied-in to the steelwork to secure them against wind. The end view of the truss support to the frame is shown in the parked, or storage position on figure 2 without the net tails tied-in to the steelwork.

POWER UNIT

The energy for operating the navigation span fishing gear is from a high pressure hydraulic power unit driven by a 3 phase electric motor of 7.5 kW. This was chosen (a) because of the reliability of hydraulic powered equipment, especially under bad Winter conditions. (b) because of the ease with which further equipment may be added into a hydraulic powered system which will continue to be energised by the original power unit. This is because only one frame at a time is being lifted or lowered. At Killaloe we also have a device for loading barrels on to road transport which also is powered from the hydraulic circuit. The power unit is located in the fishermen store and workshop building, which is on the West bank of the river, and about 123 metres distant from the winch operating at the Navigation span. This has required special attention to the viscosity of the hydraulic oil so that the power would be transmitted at temperatures down to -20^{o}C in a severe Winter. The working pressure of the hydraulic pipelines is 150 bar.

OPERATION OF THE CATCHING GEAR

On movement of the control lever the support to the frame slowly rotates to approx. a vertical position and the frame descends to the water below. On immersion into the water flow the frame is pulled with the flow and the side cables restrain this movement. Lowering is continued until the frame rests on the river bed. To remove the catch, the hoisting mechanism raises the frame to just above water level, and the three nets are emptied from the tail into barrels in the fishery boat. After the fishing period the frame is raised further, until it engages with the support cradle which then rotates with the frame into a horizontal position. This ensures that the masts of boats passing underneath, do not strike the raised frame. A locking device automatically holds this safe resting position even when the system is not in use.

RESULTS OF THE NAVIGATION SPAN MECHANISATION

The numbers of eels passing through this span opening were known to be large, because the velocity of flow was so high, in comparison with other spans of Killaloe Bridge.

The results of catching using the equipment described have been excellent. However the best cycle of work for the fishermen operating the entire weir is to have the available eels dispersed into as many nets at the various bridge spans as possible. In this way the total holding capacity is best utilized, and the maximum length of time achieved between the lifting of nets for emptying, and the fishermen's manual effort is reduced.

During "dark" moon periods, the Navigation Span equipment would fill to capacity with eels in a short time compared to the other nets of the weir. For this reason floodlights are turned on at the Navigation Span to divert eels to the other nets. In "bright" moon periods this is not done, as the amount of eels available is much reduced.

The unrestricted catching ability at Killaloe for the Navigation Span equipment described in this paper is probably 1.5 Tonnes maximum per night at the time of peak silver eel migration. However because of the free depth of water above the frame when in position as shown in figure 1, many eels may possibly escape being caught. This is another reason to favour the use of overhead lights at the upstream side of the bridge, so that any eels passing through will be forced to travel near the bottom. With the lights on, the catch at the Navigation span frame is reduced to 0.3 tonnes maximum/night, during a period of peak eel migration.

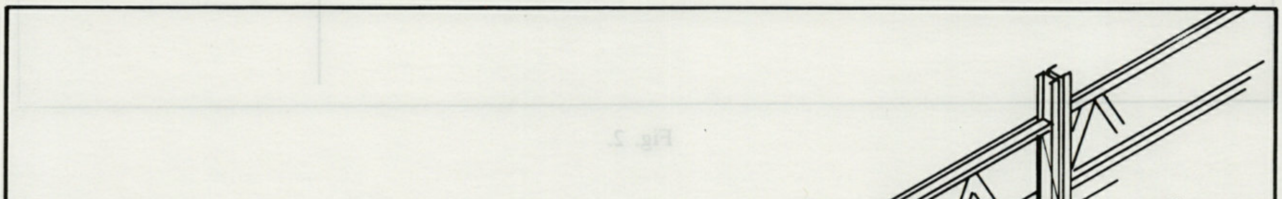

Fig. 3.

THE NO. 4 ARCH MECHANISATION

This mechanisation is expected to be the initial stage of work which can be continued throughout the weir in future time. Three adjoining fyke nets operated by hand lifting of side poles which slide on steel supports were selected for conversion to mechanical frame operation. These were located on the downstream side of No. 4 arch of the Killaloe road bridge which runs parallel to the weir. A three — dimensional view of the mechanisation may be seen on figure 3.

The work was done to examine the possibility of further mechanisation of the weir in order to reduce the fatigue of hand lifting the nets during fishing activity. In order to keep costs to a minimum the existing footbridge used by the fishermen was used to support the winches which were specially designed by E.S.B.

These winches had to fit below the footbridge deck, in a space only 300 mm high and to be of durable construction. A hydraulic cylinder was used to provide the lifting force, and the required height of lift was arranged by using the principle of two attached drums, i.e. the hydraulic cylinder pulling rope from a small diameter drum which at the same time is turning a large diameter drum which is lifting the frame.

The steel supports of the footbridge were not suitable to guide the frames, as they had become somewhat twisted. Instead new guides were fabricated for the three frames and this allowed rollers at the sides of each frame to run smoothly when lifting and lowering. The net mouths were attached to the frames and were approximately 2 400 × 2 700 mm each.

Very smooth operation has been obtained using mechanical frames. The control valves for raising and lowering were positioned on the guide steelwork at a location which allowed the fishermen to operate the system from their boat. However it has been found that when the nets are in the fully raised position during daytime, when no fishing is taking place, that any winds blowing up-river tend to blow the dry nets on to the control valve handles and enmesh them. It is planned to raise the level of the valves soon.

RESULTS OF THE NO. 4 ARCH MECHANISATION

The principal results of No. 4 arch mechanisation has been the reduction in the men's fatigue and consequently a raising of catching efficiency. Since eels tend to travel in large quantity on a small proportion of nights when meteorological conditions are favourable, the existence of powered frame lifting equipment allows potential catches to be more nearly achieved. This can be by shortening the cycle time for lifting and emptying the nets compared with human effort, especially after many such operations during the night of an abnormal eel run.

The catching ability of each frame at this part of the weir is much less than the nets close to the Navigation span. At peak migration of silver eels, approx. 65 kg per frame per night would be the maximum catch achieved.

O'Leary (1979) makes reference to the escape of eels under the sole ropes of the hand-operated nets. The use of the rigid frames at the mouths of these nets is expected to be a contribution to efficiency, although this will not be fully realised until the conversion to frame operation of all the nets along the weir.

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FISH PASSAGE THROUGH KAPLAN TURBINES AT A POWER PLANT ON THE RIVER NECKAR AND SUBSEQUENT EEL INJURIES

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ANGUILLA ANGUILLA
MIGRATION
POWER PLANTS
INJURIES

ABSTRACT. — The percentage of fish, injured during the passage through a Kaplan turbine, was analysed. The investigations were carried out on the river power plant of Neckarzimmern. During the time of investigations the waterflow of the river Neckar varied between 40 m^3/sec and 80 m^3/sec. To avoid misleading results the analyses were carried out under natural conditions without any transplantation, marking or tagging of fish. All fish which passed the power plant were caught with a special fishing net, adapted to the outlet of the Kaplan turbine. The most affected species was the eel, *Anguilla anguilla L.* At a relatively low waterflow in autumn the rate of lethal injuries reached up to 50 %. Eel migration took place during the night, so that the running of the adjoining sluice-gate was without any influence. To stop further injuries of eels by power plant activities a by-pass streaming of the turbine area is proposed.

ANGUILLA ANGUILLA
MIGRATION
CENTRALE ÉLECTRIQUE
BLESSURES

RESUMÉ. — Le taux des Poissons blessés au passage d'une turbine « Kaplan » a été estimé au cours d'études effectuées à l'usine hydro-électrique de Neckarzimmern (RFA). Le débit du Neckar a oscillé entre 40 et 80 m^3/s pendant la période des expériences. Pour éviter de fausser les résultats, l'étude a été effectuée dans des conditions naturelles, sans aucun marquage ou étiquetage des Poissons et sans introduction d'individus étrangers. Tous les Poissons qui sont passés par la centrale hydro-électrique, ont été repêchés à l'aide d'un filet spécial adapté sur l'orifice de la turbine « Kaplan ». L'espèce la plus touchée était l'Anguille, *Anguilla anguilla L.*. Pour un débit relativement faible en automne, le taux des blessures mortelles a atteint 50 %. A cause de leur non-fonctionnement, les écluses du barrage étaient sans influence sur la migration qui se faisait la nuit. Afin d'éviter à l'avenir les blessures des Anguilles par l'usine hydro-électrique, il est proposé de construire une échelle à Poissons.

I. INTRODUCTION

The general problem of injuries to migrating fish by turbines of river power plants has been well known for many decades. By the first half of our century investigations on this topic had already been carried out (Lundbeck, 1927; Schmassmann, 1928). The investigations were developed in Europe and Northern America during the fifties and sixties (Muir, 1959; Cramer and Oligher, 1960; Cramer, 1961a, b, c; Montén, 1964; Munro, 1965; Oligher and Donaldson, 1966). Montén (1985) gave an extensive compilation on the results of research carried out by him and others up to the end of the sixties.

The reasons for our investigations were the changes of the environment caused by hydraulic architecture, eutrophication and pollution in most of the rivers in highly industrialized and densely populated areas of Central Europe. On the one hand many of the older Francis runners were replaced by

Kaplan turbines with adjustable runner blades and smaller Kaplan runners were replaced by bigger ones, on the other hand water pollution increased and caused changes in fish settlement during the nineteen-sixties. In many waters a last chance for profitable fishery management was seen in an intensive eel stocking.

In river sections where power plants used up to 100 % of the drainage water to run their turbines, the problem of fish injuries is enhanced.

Most of the earlier investigations were based on a limited number of tagged fish, which were recaptured after passage through the turbines.

The investigations carried out on the power plant of Neckarzimmern, River Neckar, were based on a new analytical approach which eliminated artificial effects caused by tags and the tagging procedure. All fish which naturally passed the turbine and the draft tube were caught and analysed. This approach led to representative results concerning the total spectrum and quantity of fish species occurring in the turbine passage.

II. MATERIAL AND METHODS

To date our investigations have been limited to one power plant at River Neckar in the southwest of F.R. Germany, which has one Kaplan turbine only. A concentrated fish migration through the single turbine was the basis for our investigations.

The technical characteristics of the Kaplan turbine investigated are : a five blade runner of 4.2 m in diameter and a specific revolution speed of 83.4 rpm. During our investigations the water flow changed between 40 m^3/sec and 80 m^3/sec with an average head of water of 5.3 m. The clearance width of the inlet grid was 48 mm.

The most difficult analytic part of our investigations was the total catch of all fish which had passed the turbine. A special fishing net with an opening of 6.9 m × 15 m was adapted to the outlet of the power station. This covered the outlet of the draft tube completely. This type of fishing net was similar to a stownet or anchor hamen. Possible injuries to fish caused by the net were minimized by the extraordinary net length of 76 m.

Due to the graduation of the mesh openings with 80 mm, 60 mm and 40 mm the fishing net resisted a high water pressure and could catch small fish and fingerlings. In our investigations the chosen graduation worked well. Even small species like *Alburnus alburnus* were captured.

The net was routinely emptied three times a day : in the late afternoon, at night after the shut-down of the sluice-gates and in the early morning. By this timing the changes in intensity of fish migration during day and night as well as influences of the sluice-gates were taken into consideration.

Two categories of injuries were observed :

— Cut eels : In this case the eels had been squeezed between runner blades and the wall of the draft tube.

— Eels with vertebral fractures : Eels without external injuries but with extraordinarily slow movements were found very often. In these cases the dissection of the fish often showed several fractures of the vertebrae. This type of lethal injury is probably caused by the collision with the runner blade edges.

Both types of lethal injuries were evaluated on the base of the total number of eels investigated. The slight injuries were disregarded.

To study seasonal effects, i.e. changes in water flow or seasonal fish migrations, these investigations were carried out at different times of the year : from the end of April to the beginning of May, in August, in September and in October. A single investigation period lasted 6 to 8 days.

III. RESULTS

In the neighbourhood of power plants damage within fish populations not only depends on the technical specification of the turbine, but also has a biological factor. For instance the type of fish community is of some importance, because different types of migratory activities of single fish species result in different influence of the power plant on the fish.

During our investigations a total number of 2.368 individuals belonging to 23 fish species were analysed (Figure 1A). 89 % of the individuals belonged to the five most important species *Rutilus rutilus* (35. 6 %), *Blicca bjoerkna* (20.8 %), *Anguilla anguilla* (11.5 %), *Alburnus alburnus* (10.9 %) and *Stizostedion lucioperca* (10.2 %). Four species reached less than four per cent each (7.6 % in total), fourteen species less than one per cent of the individuals each (3.4 % in total).

The different fish species showed completely different rates of injuries. In the following the analytical results are discussed with special emphasis on the injuries of eels, which are of economical importance.

The relationship between the relative inflow angle of the runner blades and the rate of fish injuries is shown in Figure 1B. There was a definite correlation between the relative inflow angle and the rate of injuries. The unfavourable low inflow angles were caused by low water-flow. Two values, plotted in brackets, were determined in periods with several untypical changes of the waterflow and have not been used for the calculation of the regression line.

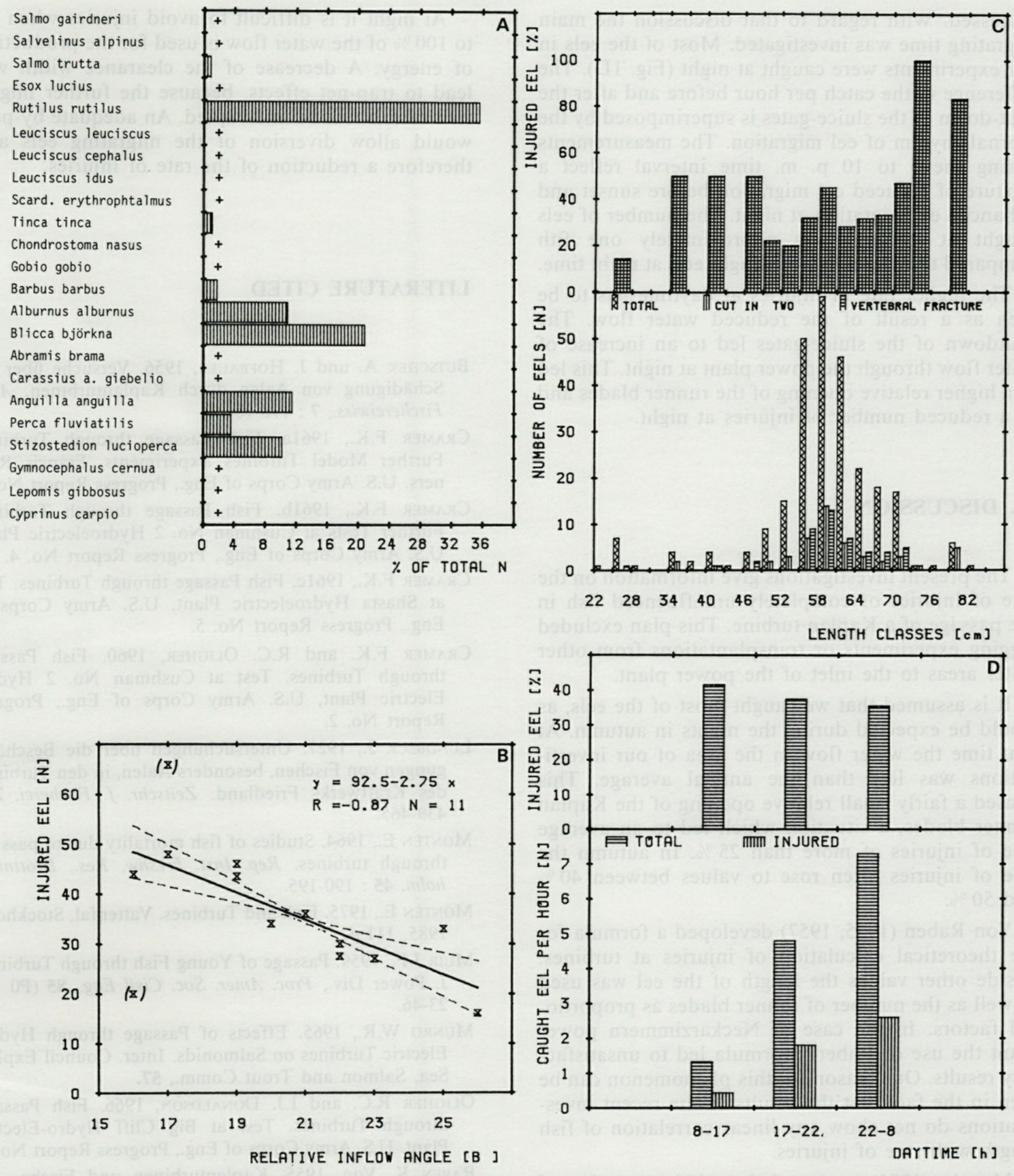

Fig. 1. — A, Fish species found during the investigations at the river power plant Neckarzimmern; + : Values less than 1 % of total N. B, Relation between the relative inflow angle of the Kaplan runner blades and injured eels. (x) : Values determined in periods with untypical changes in the waterflow not used for the calculation of the regression line. C, Total catch, eels cut in two and eels with fractures of vertebrae in relation to the total length. Above : Percentage of injuries. D, Catch of eels . hour^{-1}, injured eels . hour^{-1} and the percentage of injured eels at different times of the day.

The high numbers of eels with fractures of the vertebrae and without visible injuries outside are shown beside the numbers of eels cut in two (Fig. 1C). The total rate of injuries showed no clear positive correlation with the length of the eels (Fig. 1, C). This result does not agree fully with the results of other authors (Von Raben, 1955; Montén, 1985).

The possibility of an alternative migration of fish through the neighbouring sluice-gates was often discussed. With regard to that discussion the main migrating time was investigated. Most of the eels in our experiments were caught at night (Fig. 1D). The difference in the catch per hour before and after the shut-down of the sluice-gates is superimposed by the diurnal rhythm of eel migration. The measurements during the 5 to 10 p. m. time interval reflect a mixture of reduced eel migration before sunset and enhanced eel migration at night. The number of eels caught at daytime was approximately one fith compared to the number of caught eels at night time.

The higher rate of injuries at daytime has to be seen as a result of the reduced water flow. The shutdown of the sluice-gates led to an increase of water flow through the power plant at night. This led to a higher relative opening of the runner blades and to a reduced number of injuries at night.

IV. DISCUSSION

The present investigations give information on the rate of injuries of completely uninfluenced fish in the passage of a Kaplan turbine. This plan excluded tagging experiments or transplantations from other water areas to the inlet of the power plant.

It is assumed that we caught most of the eels, as would be expected during the nights in autumn. At that time the water flow in the area of our investigations was less than the annual average. This caused a fairly small relative opening of the Kaplan runner blades, a situation which led to an average rate of injuries of more than 25 %. In autumn the rate of injuries often rose to values between 40 % and 50 %.

Von Raben (1955, 1957) developed a formula for the theoretical calculation of injuries at turbines. Beside other values the length of the eel was used as well as the number of runner blades as proportional factors. In the case of Neckarzimmern power plant the use of Raben's formula led to unsatisfactory results. One reason for this phenomenon can be seen in the fact that the results of the recent investigations do not show any linear correlation of fish length with rate of injuries.

Montén (1985) suggested the relative opening of the runner blades to be a crucial factor which agrees with our results.

The catch at nigh time was about five times bigger than the catch during day time. At night there was no significant difference in the frequency of eel before and after shut-down of the sluice-gates. Eels orientation in river areas is exclusively bound to continuous streaming of the river, that guided — in this case — directly to the turbines.

At night it is difficult to avoid injuries when up to 100 % of the water flow is used for the production of energy. A decrease of the clearance width will lead to trap-net effects, because the further migration of eels will be interrupted. An adequate by-pass would allow diversion of the migrating eels and therefore a reduction of the rate of injuries.

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VIE MILIEU, 1986, 36 (4) : 311-315

ACQUISITIONS RÉCENTES SUR LA BIOLOGIE DES ANGUILLES DE TAHITI ET DE MOOREA (POLYNÉSIE FRANÇAISE) : *A. marmorata, A. megastoma, A. obscura*

Recent data on eel biology of Tahiti and Moorea islands (French Polynesia) : A. marmorata, A. megastoma, A. obscura

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ANGUILLIDAE
TAHITI
CYCLE BIOLOGIQUE
ESTIMATION DE STOCK

RÉSUMÉ. — Résultats partiels d'une étude entreprise en 1982 sur les 3 espèces d'Anguilles de Tahiti et de Mooréa : *A. marmorata, A. megastoma, A. obscura.* Renseignements fournis sur la systématique, l'écologie, le régime alimentaire, le stock, la croissance et la migration.

ANGUILLIDAE
TAHITI
LIFE HISTORY
STOCK ASSESSMENT

ABSTRACT. — Some data of a study undertaken in 1982 on the three eel *A. marmorata, A. megastoma, A. obscura,* of Tahiti and Moorea islands, are presented. Data include systematics, ecology, diet, stock, growth and migration.

1. INTRODUCTION

Les premiers renseignements sur les Anguilles de Tahiti et de Moorea ont été fournis par Darwin en 1835, à la suite de l'expédition du Beagle (Darwin, 1875). C'est ensuite celle du Challenger entre 1872 et 1876 qui apporte de nouveaux éléments (Anon., 1895), puis celle de Schmidt (1927). Mais ces travaux, ainsi que les plus récents comme ceux de Fowler (1932), de Seurat (1934), de Ege (1939) et de Randall (1973) concernent surtout la systématique et peu la biologie des Anguilles. Il était donc justifié de combler les lacunes.

Par ailleurs, du fait de l'augmentation de la population et du développement industriel, les cours d'eau de Tahiti et de Moorea subissent un certain nombre d'agressions : pollutions organiques, barrages de retenue, prises de gravier en rivière, augmentation de la turbidité, susceptibles de modifier les équilibres écologiques. Il convenait donc de faire le point de la situation avant qu'elle ne soit devenue irréversible.

C'est à partir de 1982 que cette étude a débuté. Elle porte sur l'ensemble des constituants de la flore et de la faune des eaux douces, dont les Anguilles font l'objet du présent travail. Il n'en fournit, toutefois, que quelques résultats.

2. MATÉRIEL ET MÉTHODES

Les Anguilles ont été pêchées sur des périodes réparties tout au long de l'année, à la ligne, au harpon tahitien, à l'épuisette, à la nasse et à l'électricité, dans des plans d'eau jugés représentatifs des conditions existant à Tahiti. Au total 1 300 Anguilles de 10 à 165 cm, et 400 Anguillettes de 5 à 10 cm ont été capturées.

Les civelles ont fait l'objet de captures systématiques 2 fois par semaine, pendant un an, dans la rivière Hamuta, à l'épuisette et en maintenant l'effort de pêche constant, afin d'en étudier le recrutement.

Pour les études de systématique, les données de Ege (1939) ont été utilisées, mais alors que celui-ci avait utilisé des dissections partielles et des radiographies pour compter les vertèbres, dans ce travail, les Anguilles ont été entièrement disséquées.

En matière d'estimation de stocks, la méthode Leslie-Delury (Delury, 1947) a été employée, avec la pêche à l'électricité pratiquée 2 fois de suite sur un même parcours. Etant donné la forte efficacité de la pêche obtenue sur les Anguilles, deux pêches, voire une seule, étaient suffisantes pour fournir une valeur de stock crédible.

Ces estimations ont été faites dans une dizaine de cours d'eau subdivisés en secteurs d'étude, et dans le lac Vaihiria.

3. RÉSULTATS

3.1. *Description des biotopes à Anguilles*

Eaux courantes

Il existe à Tahiti et à Moorea plus de 200 rivières et ruisseaux, tous peuplés d'Anguilles.

L'île de Tahiti mesure une trentaine de km de diamètre et son altitude dépasse 2 000 m : les cours d'eau sont courts et caractérisés par une forte torrentialité provoquant des crues violentes, mais de brève durée. Leur parcours est interrompu par des cascades abruptes, parfois très hautes, qui, agissant comme des obstacles, règlent la composition spécifique en limitant les possibilités de migration vers l'amont.

La largeur des cours d'eau à l'étiage est en général inférieure à 10 m, (2 m à 50 m pour la Papeeno), la profondeur en général inférieure à 40 cm.

L'eau est claire, bien oxygénée et le courant rapide.

Les roches, basaltiques, fournissent une faible minéralisation à l'eau (conductivité : de 80 à 120 µS/cm), mais probablement bien équilibrée en sels minéraux, ce qui permet une forte production de biomasse, tant végétale qu'animale.

Le pH est compris entre 7 et 8, plus proche de 8 que de 7.

La température de l'eau, dans les zones prospectées se situe entre 20 et 25 °C.

La végétation aquatique est essentiellement constituée de Diatomées et de Rhodophycées qui recouvrent les cailloux, auxquelles s'ajoutent des Algues vertes filamenteuses dans les parties à courant lent. Ces Algues constituent la nourriture des consommateurs primaires que sont les *Gobiidae* (5 espèces) et les Crevettes (4 espèces de *Macrobrachium* et 2 espèces d'*Atya*).

Eaux dormantes

A Tahiti, on en trouve deux types :

— au niveau de la mer, une zone plus ou moins marécageuse d'eau douce, alimentée par les débordements de crues, peu importante en surface. C'est le domaine d'*Anguilla obscura.*

— à 470 m d'altitude, un lac d'effondrement : le lac Vaihiria. C'est un lac isolé dont le niveau est maintenu par des apports d'eau venus de l'amont et qui ne communique avec l'aval que par les infiltrations. Ce lac héberge un petit peuplement de grosses Anguilles de l'espèce *Anguilla megastoma.* Sa superficie est d'une quinzaine d'ha.

A Moorea, il existe un lac fortement saumâtre : le lac Temae, d'une superficie d'une vingtaine d'ha, mais dont la population d'*Anguilla* n'a pas encore fait l'objet d'études.

3.2. *Systématique et localisation des Anguilles de Tahiti*

Trois espèces ont été identifiées :

— *Anguilla marmorata* (Quoy et Gaimard, 1824)
— *Anguilla megastoma* (Kaup, 1856)
— *Anguilla obscura* (Gunther, 1871).

A première vue, ces espèces peuvent ainsi se caractériser :

— *A. marmorata :* robe marbrée, mais dont la pigmentation s'efface avec l'altitude.
— *A. megastoma :* robe non tachée, Anguille très souple et très nerveuse, d'allure septentiforme.
— *A. obscura :* robe foncée, Anguille « lourde », peu mobile.

Cependant, il existe des individus d'allure intermédiaire qui nécessitent des critères systématiques de différenciation.

Dans sa classification des Anguilles appartenant au genre *Anguilla* Shaw, Ege (1939) utilise de nombreuses mesures biométriques telles que le nombre de vertèbres préhémales ou le nombre total de vertèbres, les caractéristiques de la dentition, la distance entre les verticales passant par l'anus et l'origine de la nageoire dorsale exprimée en pourcentage de la longueur totale.

Tous ces critères ont été redéterminés sur des lots importants d'Anguilles, et les valeurs trouvées très voisines de celles qu'Ege avait fournies.

Cependant, parmi des critères, 2 seulement sont utilisables pour différencier les 3 espèces de Tahiti : le nombre total de vertèbres et la distance entre les verticales passant par l'anus et l'origine de la nageoire dorsale exprimée en pourcentage de la longueur totale.

Les nombres moyens de vertèbres sont, à P = 0,95 :

A. marmorata : 106,15 ± 2,18 (245 Anguilles)
A. megastoma : 112,95 ± 2,35 (146 Anguilles)
A. obscura : 103,77 ± 2,10 (312 Anguilles)

Il y a chevauchement des limites de confiance supérieure pour *obscura* et inférieure pour *marmorata.* On ne peut donc séparer ces 2 espèces par ce critère avec une sécurité de 0,95.

Par contre, à ce niveau de probabilité, les moyennes des distances anus-origine dorsale, en pourcentage de la longueur totale le permettent. Ces valeurs sont :

A. marmorata : 15,99 ± 1,76 (607 Anguilles)
A. megastoma : 11,22 ± 1,91 (160 Anguilles)
A. obscura : 4,01 ± 2,35 (393 Anguilles)

et pour séparer les 3 espèces :

A. obscura : < 6,36
A. megastoma : de 9,31 à 13,13
A. marmorata : > 14,23

Les 3 espèces peuvent atteindre de fortes dimensions et dépasser le m et les 4 kg.

A. marmorata vit dans les eaux courantes depuis les estuaires jusqu'aux premières grandes cascades.

A. megastoma remonte au-dessus des plus hautes cascades (100 m) à travers la forêt, mais est absente des estuaires.

A. obscura se cantonne dans les eaux douces dormantes du littoral.

Enfin, *A. marmorata* et *A. megastoma* peuvent cohabiter dans les eaux courantes d'altitude moyenne, mais dans le lac Vaihiria on ne trouve que *A. megastoma.*

Tabl. I. — Relations poids-longueur et coefficients de condition mesurés sur les trois espèces dans trois rivières.
Weight-length relationships and condition factors measured for the three species in three rivers.

Espèce et provenance	Relation poids-longueur $W = aL^b$			Coefficient de condition $K_c = 100\ W/L^3$
	a	b	r	
A. marmorata				
R. Opunohu Moorea (80 anguilles)	$7{,}05.10^4$	3,30	0,98	0,210 ± 0,010
A. megastoma				
R. PK 14,5 Tahiti (67 anguilles)	$6{,}86.10^4$	3,13	0,98	0,113 ± 0,005
A. obscura				
Pointe Vénus Tahiti (65 anguilles)	$2{,}98.10^4$	3,48	0,98	0,219 ± 0,010

3.3. *Relations poids-longueur et coefficients de condition*

Leurs valeurs ont été calculées pour les 3 espèces et pour 6 rivières. Le tableau I les fournit, à titre d'exemple, pour 3 d'entre elles.

Les valeurs de a, de b, et de Kc varient en fonction de la saison, de la rivière et de l'espèce.

Dans tous les cas, la valeur de Kc est plus faible pour *A. megastoma* que pour les 2 autres espèces, ce qui se traduit par une forme plus allongée et une grande souplesse, lui permettant de « grimper » le long des cascades.

3.4. *Migrations*

Civelles

Les périodes de recrutement ont été étudiées sur un total de 1 237 civelles, dont 373 transparentes.

Il a été possible de séparer les 3 espèces d'après la forme de la pigmentation de la partie postérieure de la queue.

Pour les 3 espèces, le recrutement commence en octobre et se poursuit jusqu'en avril, avec 2 pics : en janvier et en avril.

Relativement à l'espèce *A. anguilla,* le recrutement semble très peu important, mais il se peut que le mode de pêche, exclusivement diurne, l'ait minimisé. Il semble en tout cas plus faible pour *A. megastoma* que pour les 2 autres espèces.

La taille des civelles transparentes demeure constante au cours des diverses arrivées. Elle est de l'ordre de 50 mm ce qui paraît faible pour des Anguilles de grande taille à l'état adulte, mais le phénomène a déjà été signalé.

La diminution de longueur et de poids des civelles en cours de pigmentation reste faible : de l'ordre de 2 mm pour les 3 espèces, et de 30 mg pour *A. marmorata* et *A. obscura,* mais seulement de 10 mg pour *A. megastoma.*

Anguilles argentées

Bien que Schmidt (1927) ait signalé l'existence de mâles argentés de l'espèce *marmorata* (83 et 71 cm) à Tahiti, aucun individu mâle ou femelle n'a été capturé depuis 1982.

D'après 6 femelles argentées de l'espèce *megastoma,* dont 5 ont été capturées dans le lac Vaihiria et une dans un cours d'eau, et d'après 2 mâles capturés dans un cours d'eau, les Anguilles argentées de cette espèce se caractérisent ainsi : dos uniformément brun-gris, ventre blanc argent, tête très effilée, yeux élargis et pectorales particulièrement développées justifiant l'appellation locale d'Anguille à oreilles. Les femelles du lac Vaihiria mesuraient de 134 à 147 cm tandis que celle provenant de ruisseau ne mesurait que 106,5 cm. Les 2 mâles mesuraient respectivement 44 et 48,5 cm.

Les 5 femelles de l'espèces *obscura* présentaient les mêmes caractérisitiques, mais avec des nageoires pectorales moins développées. Elles mesuraient de 76 à 98,5 cm.

Le petit nombre d'Anguilles argentées capturées, en comparaison du grand nombre d'adultes pose un problème à résoudre.

L'époque d'avalaison n'a pu être déterminée. Elle pourrait débuter en novembre.

Cas particulier du lac Vaihiria

Il n'y a pas de recrutement dans ce lac. Au mois de mai, époque de l'étude de son peuplement, toutes les Anguilles observées ou capturées étaient argentées ou préargentées avec des gonades en cours de formation bien conformées, comme l'a montré la dissection d'une *megastoma* préargentée qui présentait un rapport gonadosomatique de 3,1. Toutes celles qui ont été capturées ou observées dépassaient le mètre et un poids de 4 kg. Toutes étaient des femelles, mais un mâle argenté de 40 à 50 cm a été observé, mais non capturé.

Comme ces Anguilles sont prisonnières, elles ne migrent pas et il est probable que chaque année la formation des gonades soit suivie d'une régression, comme l'ont signalé Moriarty et Hacket (1976) pour l'espèce *Anguilla*.

Comme la première mention de ces Anguilles a été faite lors de l'expédition du Challenger (1872-1876), il est possible qu'elles soient très âgées, ce qui expliquerait la différence de taille entre les Anguilles argentées du lac et celle qui a été capturée en rivière.

Reste enfin le problème de leur introduction. Il se peut qu'elle ait été volontaire et en relation avec l'introduction de *Poecilia* dans le lac pour leur servir de nourriture, celle-ci ayant été antérieure à 1929 (Fowler, 1932). Il se peut aussi qu'elles aient été introduites sous forme d'Anguillettes par des Oiseaux.

3.5. *Régime alimentaire*

Civelles

Leur alimentation débute au stade VI A3 (classification d'Elie *et al.*, 1982). Elles se nourrissent essentiellement de larves de *Macrobrachium* spp.

Anguilles

Le régime alimentaire a été étudié sur 534 contenus stomacaux d'*A. marmorata*, 187 d'*A. megastoma*, 423 d'*A. obscura*, par la méthode des présences (nombre d'individus d'une espèce/nombre total d'individus).

Tabl. II. — Régime alimentaire des trois espèces d'Anguilles (Indices de Présence en %).
Diet of the three eel species (Frequency Occurrence in %).

Espèces	Annelides	Mollusques	Insectes	Crustacés *Macrob.* spp	Crustacés *Atya* spp	Crustacés Crabes	Poissons *Eleotris fusca*	Poissons *Anguilla mar*	Poissons Gobiidae	Rats
A. marmorata	1,5	9,0	1,5	59,0	5,0	1,5	—	3,0	18,0	1,5
A. megastoma	3,5	10,7	—	53,6	7,1	—	—	—	25,0	—
A. obscura	4,0	44,0	40,0	—	—	4,0	8,0	—	—	—

MOLLUSQUES : *Physa, Helisoma, Veronicella*
ANNELIDES : *Perichetes*
INSECTES : Larves aquatiques de diptères, lepidoptères, odonates

Le tableau II fournit la composition alimentaire pour les 3 espèces. Elle varie en fonction des proies disponibles dans les biotopes respectivement occupés par les 3 espèces. Le régime est de type opportuniste.

A. marmorata fait preuve de cannibalisme.

3.6. *Croissance*

On ne dispose pas encore de suffisamment de données pour fournir des valeurs sûres. Toutefois, une première analyse des histogrammes de fréquence des tailles semble montrer qu'un poids individuel moyen de 130 g est atteint à la fin de la première année de rivière et un poids de 300 g à la fin de la seconde.

Des particuliers qui se sont intéressés à leur élevage dans des eaux closes font mention d'un régime omnivore et d'une croissance très rapide. Il s'agit probablement des espèces *obscura* et *marmorata*.

3.7. *Stocks*

Ruisseaux et rivières

Ils ont été déterminés dans une quinzaine de secteurs de 100 à 500 m^2 répartis sur une dizaine de cours d'eau.

En fonction des caractéristiques des biotopes (profondeur, abris), les stocks varient dans d'importantes proportions.

Pour *A. marmorata* : de 23 à 1 583 kg/ha, avec une moyenne de 321 kg pour les 10 cours d'eau.

Pour *A. megastoma* : de 6 à 1 057 kg avec une moyenne de 365 kg.

Pour *A. obscura*, ils n'ont pas encore été estimés.

La précision des mesures est médiocre pour les Anguilles de moins de 100 g, très bonne pour les autres (d'après l'échelle de Robson et Regier, 1964).

Les Anguilles *marmorata* et *megastoma* représentent respectivement 43 % de la zoobiomasse, Insectes et Mollusques exclus, mais il ne s'agit que d'un ordre de grandeur.

Lac Vaihiria

Les Anguilles *megastoma,* qui peuplent le lac ne peuvent vivre que dans sa périphérie sous des abris rocheux peu nombreux, le fond du lac étant totalement privé d'oxygène par la végétation en décomposition. De ce fait leur nombre ne doit guère dépasser une trentaine d'individus.

3.8. *Exploitation des stocks*

Les Anguilles sont très peu exploitées par les Polynésiens, en raison semble-t-il, de croyances ancestrales.

En se basant sur une productivité de 100 à 200 kg/ha, la production par pêche pourrait se situer entre 30 et 60 t/an, pour les 300 ha que représentent les cours d'eau de Tahiti et de Moorea.

Une exploitation rationnelle des Anguilles permettrait de diminuer la pression qu'elles exercent sur les *Macrobrachium lar* (Chevrettes), principale richesse des rivières tahitiennes.

3.9. *Elevage*

Aucune tentative rationnelle d'élevage n'a encore eu lieu, mais elle devrait être tentée car son succès serait certain. Cependant, on se heurte à la faiblesse de l'approvisionnement en civelles. Avant donc de démarrer un élevage d'une certaine importance, il est nécessaire d'approfondir la question du recrutement des civelles.

4. CONCLUSION ET DISCUSSION

Quelques résultats synthétiques ont été présentés pour Tahiti et Moorea, mais ils sont encore loin d'être suffisants.

Il faut notamment approfondir la question du recrutement des civelles en utilisant la pêche à l'électricité de nuit.

Il faut comprendre pourquoi les Anguilles argentées sont si peu nombreuses en rivière. Si de nouvelles prospections n'apportent pas de réponses, leur élevage devrait fournir des éléments d'appréciation.

Les estuaires n'ont encore été que peu prospectés et les lagunes saumâtres pas du tout.

L'âge des *megastoma* du lac Vaihiria devrait être étudié par comparaison d'otolithes provenant d'Anguilles argentées du lac avec celles de rivières, mais cela implique qu'on puisse en capturer suffisamment en rivière.

Débordant le cadre de Tahiti et de Moorea, la distribution des Anguilles des 3 espèces devrait être étudiée sur l'ensemble des îles de la Polynésie française, en y incluant les atolls, pour lesquels il a été avancé qu'on y trouvait des Anguilles.

Il convient enfin de signaler qu'en raison des facilités de capture et d'accès aux divers biotopes, Tahiti constituerait un intéressant « laboratoire naturel » pour y conduire des recherches à caractère plus fondamental tant biologiques que physiologiques sur les Anguilles.

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AN ACCOUNT OF EXPERIMENTAL EEL CULTURE IN SOUTHERN FRANCE

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The eel *Anguilla anguilla* represents one of the most exploited fish and an important resource in all the lagoons of the Gulf of Lions. The eel production has decreased since 1978, probably due to increasing fishing effort and perhaps owing to a diminution of recruitment (Lecomte et Bruslé, 1984).

Several studies of eel culture were consequently carried out in field conditions, in the « Méditerranée-Pisciculture » fish farm (sea-bass production), with the aim of using beneficient thermal waters (from a karst resurgence) and proteins locally available (slaughter offal such as beef liver).

Young yellow eels (20 g), caught in natural waters, were reared in cages immersed in cement ponds provided with water of low salinity (1,2-1,6 ‰), medium temperature (17-18.5 °C) and optimum oxygen rate (6-7 mg/l).

When compared to classifical artificial food (commercial paste), feeding on liver offers several advantages such as : lower mortality, reduced pollution and pathogenicity, best growth rate (in biomass) and higher conversion factor (Affandi, 1983; Roche, 1983; Vassal et Bruslé, 1984).

This should be condensed and presented by Roche and Lecomte (this issue).

When results are expressed on the basis of biomass values, liver feeding offers better results, owing to growth homogeneity and higher survival (90 %).

Adoption of cages separated into three rearing levels (by two grading bars systems made of aluminium and wood tubes) fed by three supply channels, allowed a natural sorting of eels inside the cage, that reduced competition, cannibalism and probably social stress.

Owing the expense of storage of liver by freezing, a cheaper preserving process was adopted : acid silage used at a rate of 40 % in the eel food (Affandi, this issue).

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UTILIZATION OF SILAGE AS FOOD IN EEL CULTURE

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— Silage is one of the available methods of conservation of food material. It is of great economic value because it does not require energy during storage.

— Utilization of silage as a source of proteins from non-marketable fish, fish offal or slaughter offal was justified in the past with Salmonid fish and with carp.

— Incorporation of silage in artificial food for eel feeding was investigated in the present work.

— Conservation of fish (Clupeid) and beef liver with 1,5 % of mixture propionic acid + formic acid (1 : 1) was achieved for periods 2-6 months (20°C) without bacteria or mould spoilage and keeping most of the nutritional value of initial feed-stuffs (with a loss of tryptophan and histidine).

— Incorporation of 40 % fish silage or beef silage in eel food was first carried out without previous neutralization. It gave unsatisfactory results due to low pH (5.2) : eels lost appetite and weight decreased during the first month of the experiment. Later, after eels have adapted to this new food, nearly normal growth and high rate of survival (94-98 %) were observed. Conversion rate was high (6.8-23.3) due to uneaten food of low acceptability for fish.

Incorporation of neutralized silage (pH : 6) in the eel food shows greatest attractiveness and ingestion and consequently, probably higher performance of growth.

Silage production of cheap material appears as a partial solution for the future in valorizing by — products and reducing the costs of production in eel culture.

EXPERIMENTAL EFFECTS OF CADMIUM ON GLASS-EELS *(ANGUILLA ANGUILLA)*

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This report* deals with exposure of glass-eels *(Anguilla anguilla)* to 2 µg/l of cadmium nitrate in laboratory conditions. Prior to the experiment, these larvae were acclimated for one week in aerated brackish water (salinity 10 ‰) in 50 l aquaria. They were divided into 2 groups :

— 50 glass-eels in a control tank

— 50 experimental glass-eels treated with 2 µg/l of cadmium nitrate.

After 27 days'contamination, the treated glass-eels were replaced in non-contaminated water in order to analyse the probable reversibility of organ alterations.

Some individuals were used for histo- and cytopathological studies after 1 day of toxification and then after 23 days'decontamination.

Disturbances occurred related to the timing and probably the mechanisms of pigmentation. After 12 days'contamination, we observed an hypermelanization of the caudal part and a lack of pigmentation of the anterior part of the glass-eels.

The glass-eels exposed (at short term 1 day) to 2 µg/l of cadmium showed extensive gill, liver and integument lesions :

— *Gills* : vascular congestion, oedema, epithelial bulbing and rupture, lamellar fusion and respiratory epithelium necrosis.

(*) Subvention n° 84240 du Ministère de l'Environnement (SRETIE).

— *Liver* : extensive fibrosis mainly located in the perisinusoïdal areas, hepatocytic alterations, portal hypertension (dilated sinusoïds). Such a fibrosis may end, at long term, in acute cirrhosis (degenerated cirrhotic nodules observed even after 23 days'detoxication).

— *Integument* : increase in size and number of mucous-cells (Reversible feature when glass-eels are replaced in non-contaminated water).

Cadmium concentrations measured in field studies (coastal marine ecosystems : Thornton *et al.*, 1975; Amiard *et al.*, 1982; Henry *et al.*, 1984) are similar to the dose used in the present experiment. Thus, it gives informations on the impact of environmental contamination by cadmium.

As such a cadmium pollution is generally detected in all the European estuaries, it might influence the recruitment, the larval survival, the eel stocks and thus the future of the species.

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EXPÉRIENCE DE GROSSISSEMENT D'ANGUILLETTES : Comparaison de deux régimes alimentaires et mise au point d'un système de tri comportemental

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Une expérience d'élevage d'Anguillettes (poids moyen 15 g) a été réalisée dans la pisciculture de Salses (Roussillon-France). Les cages (1 m^3) étaient immergées dans des bassins cimentés et alimentés en eau tiède (15-20°C) et faiblement salée (2 ‰) ayant pour origine une résurgence karstique.

Deux types d'aliments ont été comparés : l'un naturel, le foie de bœuf parasité (sous-produit d'abattoirs), l'autre, artificiel, un composé commercial (Aqualim) distribué sous forme de pâte.

Deux grilles de calibrage disposées à l'intérieur des cages sont destinées à permettre une répartition par **tri comportemental** des Anguilles en 3 lots de taille assez homogène. Le tri naturel favorise une meilleure croissance globale, permet un gain de main-d'œuvre par rapport au tri manuel, réduit les manipulations génératrices de blessures et limite les effets de stress social.

Les performances de survie et de croissances sont différentes et apparemment contradictoires selon que l'on considère l'évolution pondérale (le poids moyen des Anguillettes) et la croissance globale (biomasse de l'élevage). En effet, compte tenu de la forte mortalité (50 %) avec l'alimentation artificielle, les valeurs de croissance individuelle des survivants nourris avec la pâte artificielle sont supérieures à celles obtenues avec l'aliment foie. Par contre, en terme de biomasse, la croissance globale est plus favorable avec l'aliment foie en raison du taux élevé (90 %) de survie et d'un développement plus homogène au sein de la population (histogrammes de distribution des tailles et des poids). Le bilan de l'élevage doit être considéré **en terme de biomasse** plutôt que de poids moyen; il plaide **en faveur** de l'emploi de déchets d'abattoirs tels que le **foie de bœuf en anguilliculture.**

THE FRENCH EEL GROUP ANALYSIS OF KNOWLEDGE AND RECOMMANDATIONS

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SUMMARY. — The Eel stock is considered as an important element of the national patrimony and as a high value resource. But, alarming signs have been appearing for few years : for example, the french catches of glass eels, declined from 1 500 tons in 1975-76 to 297 tons in 1984-85 (declared catches). So, three Ministries (Agriculture — Sea — Environment) asked the french experts to create a working group on eel. This group was mandated for examining the whole acquired knowledge, for giving an opinion on the present state of the stock and of its exploitation and for formulating recommandations.

The results are : the production of *thematic reports* about six selected topics (biology, exploitation, regulation of the exploitation, breeding, pathology, socio-economy); the production of a *synthetic report* including the conclusions of the group : a list of urgent steps; a quinquennial program of research with actions on regional, national and international levels.

The reports include extensive bibliographies with 350 references altogether.

Finally, it is important to say that the national working group on eel will be, probably, the first committee of *the national group of Amphihaline fishes* which will be created later.

VIE MILIEU, 1986, 36 (4) : 319

EXPERIMENTAL STUDY OF THE GROWTH OF GLASS-EELS *(ANGUILLA ANGUILLA)*

The effects of salinity, feeding and grading

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A rearing of glass eels in controlled conditions was carried out in aquaria for 3 or 9 months. The study consisted of an analysis of the effects of salinity (S = 2.5 to 30 ‰), of feeding on growth of elvers and juvenile eels. Grading was carried out after the first two months. The results are as follows :

1) No correlation was observed between pigmentation and salinity.

2) The salinity produced conspicuous effects on feeding and growth, in favour of a low salinity (2.5 to 3.5 %).

3) Food was a major influence on elver development; the best results were obtained with a natural food *(Carcinus).*

4) A wide length and weight distribution of eel population was observed; such heterogeneity needs selective grading. When separated from large sized individuals, the small-sized juvenile eels became capable of higher growth performances.

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