Documents presented at the symposium on stock enhancement in the management of freshwater fish

Documents présentés au symposium sur l'amélioration des stocks dans le cadre de l'aménagement des pêcheries d'eau douce

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PREPARATION OF THIS DOCUMENT

This collection of papers represents the Proceedings of the Symposium on Stock Enhancement in the Management of Freshwater Fisheries, held in conjunction with the Twelfth Session of EIFAC (Budapest, Hungary, 31 May – 2 June 1982).

The Proceedings are in two volumes, which are supplementary to the Report of the Symposium issued in 1982 as EIFAC Technical Paper No. 42.

PREPARATION DE CE DOCUMENT

Cette ensemble de documents represente les actes du Symposium sur l'amélioration des stocks dans le cadre de l'aménagement des pêcheries d'eau douce, tenu à Budapest (Hongrie) du 31 mai au 2 juin 1982 à l'occasion de la douzième session de la CECPI.

Les actes sont presentés en deux volumes complémentaires au Rapport du Symposium émis par la CECPI en 1982 sous forme de document technique № 42.

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ABSTRACT

Volume One of these Proceedings groups together the 22 papers presented at the Symposium on Stock Enhancement in the Management of Freshwater Fisheries, which dealt with the advantages and disadvantages of stockings with native species into European waters.

RESUME

Le volume un de ces actes regroupe 22 documents presentés au Symposium sur l'amélioration des stocks dans le cadre de l'aménagement des pêcheries d'eau douce, qui traitait des avantages et desavantages du repeuplement avec des espèces autochtones des eaux européennes.

CONTENTS

TABLE DES MATIERES

INTRODUCTION

Following the recommendations of the International Consultation on Fishery Resources Allocation (Vichy, France, 1980) and its own discussions during its Eleventh Session (Stavanger, Norway, May 1980), EIFAC felt that subsequent sessions should examine closely the current situation for managing stocks of fish in European inland waters. Because the whole topic of management is too large for coverage during any one symposium, it was recommended by the Commission that the subject be covered in two symposia - one on biotic aspects of management to be held in conjunction with the Twelfth Session of EIFAC and one on abiotic aspects to be held with the Thirteenth Session of EIFAC.

There has been a long-standing concern with the effects of introduction of exotic species into European rivers and lakes. Furthermore, whilst stocking with native or introduced species is common management practice, there is very little evidence for or against its biological or economic effectiveness. Therefore, the first Symposium on management addressed the twin problems of introductions and stockings in an effort to define guidelines for both practices in European waters.

The Symposium considered these two specific aspects of stock manipulation in seven sessions as follows:

Session 1	Stocking with non-salmonids
Session 2	Stocking with brown trout
Session 3	Stocking with salmon
Session 4	Introductions and transplantations - case histories and experience with some species
Session 5	Introductions - country reviews and Lake Kinneret case
Session 6	Introductions - ecological and practical aspects
Session 7	Summary, conclusions and recommendations

This document is a compilation of the papers presented at the Symposium, which are grouped into two volumes as follows:

Volume 1: Stocking - contained those papers considered under Sessions 1, 2 and 3 of the Symposium

Volume 2: Introductions and Transplantations - contains those papers considered under Sessions 4, 5 and 6 of the Symposium

The conclusions and recommendations of the Symposium are presented in EIFAC Technical Paper No. 42 - Report of the Symposium on Stock Enhnacement in the Management of Freshwater Fisheries.

INTRODUCTION

Conformément aux recommandations de la Consultation technique sur la répartition des ressources ichtyologiques (Vichy, France, 1980), la CECPI a estimé, à sa onzième session (Stavanger, Norvège, mai 1980), qu'il était nécessaire d'examiner de près la situation actuelle pour l'aménagement des stocks dans les eaux intérieures européennes. Le sujet était trop vaste pour pouvoir être traité en une seule réunion. La Commission a donc recommandé que l'on organise deux symposiums, l'un sur les aspects biotiques de l'aménagement à l'occasion de sa douzième session, l'autre sur les aspects abiotiques à l'occasion de sa treizième session.

On s'intéresse depuis longtemps déjà aux conséquences de l'introduction d'espèces exotiques dans les cours d'eau et lacs européens. Par ailleurs, il est courant de ne peupler les eaux intérieures avec des espèces locales ou exotiques mais, en définitive, on sait très peu de choses des avantages et inconvénients de cette pratique sur le plan biologique et économique. Le premier symposium s'est donc intéressé à ces deux problèmes en vue d'établir des directives pour les eaux intérieures européennes.

Le Symposium a examiné ces deux aspects de la manipulation des stocks au cours de sept sessions:

Session 1	Repeuplement - les non-salmonidés
Session 2	Repeuplement - la truite de mer
Session 3	Repeuplement - le saumon
Session 4	Introductions et transplantations - résultats obtenus avec certaines espèces
Session 5	Introductions - examen pays par pays et cas du lac Kinneret
Session 6	Introductions - aspects écologiques et pratiques
Session 7	Résumé, conclusions et recommandations

Ce recueil regroupe les documents presentés au symposium qui sont répartis dans les deux volumes de la façon suivante:

Volume 1: Repeuplement - contient les documents traités par les sessions 1, 2 et 3 du symposium.
Volume 2: Introductions et transplantations - contient les documents traités par les sessions 4, 5 et 6 du symposium.

Les conclusions et recommandations du symposium sont presentées dans le document technique N^{o} 42 de la CECPI - Rapport du Symposium sur l'amélioration des stocks dans le cadre de l'aménagement des pêcheries d'eau douce (1983).

REGULATION OF BIOMASS OF SMALL (LESS THAN 41 cm) NORTHERN PIKE (*Esox lucius* L.) WITH SPECIAL REFERENCE TO THE CONTRIBUTIONS OF INDIVIDUALS STOCKED AS FINGERLINGS (4–6 cm)

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CONTENTS

ABSTRACT

The composition and abundance of four northern pike (Esox lucius L.) populations were monitored in the period from 1974 to 1982.

The biomass of 0+ pike, pike less than 35 cm and pike less than 41 cm were negatively correlated with biomass of larger individuals following an exponential relationship.

It is argued that this density-dependent relation is the result of a regulation in which intraspecific predation may play a major role.

The standing stock of pike less than 54 cm related to the pike habitat available, was very similar both among sites within years and among years within sites.

This stock is tied to a maximum per unit of vegetated area. Within this maximum the biomass of pike less than 41 cm is determined by the biomass of larger individuals. Therefore stocked pike did not contribute extra biomass to the population.

RESUME

La composition et l'abondance de quatre populations de brochet ont été determinées pendant l'époque 1974–82. Les biomasses de classes: 0+ longeur moins de 35 cm; moins de 41 cm étaient correlées negativement suivant une fonction exponentielle, avec les biomass d'individus de tailles plus grandes.

Des arguments ont presentés que cette relation "densité-dependente" est influencée notamment par la prédation intraspécifique. Pourvu que les biomasses soient liées à l'habitat de brochet, les densitées de la population moins de 54 cm parâmes comparable entre les années dans une site où entre les sites.

Dans une unité de végétation ces densités sont liées à une valeur maximale. Aussi dans cette espace la biomasse de brochet moins de 41 cm est determinée par celle d'individues de plus grandes tailles. Ainsi les individues introduits ne rendent pas une augmentation de stock de brochet.

1. INTRODUCTION

From 1953, the year the Organization for the Improvement of Inland Fisheries was founded, until 1966, the demand for artificially propagated northern pike fingerlings (4–6 cm) increased from 300 thousand to 1.2 million and stabilized thereafter at a level of 1–1.5 million. Stocking success was evaluated in drainable ponds (Grimm and Riemens, 1975; Grimm, 1981a) and from 1974 until 1979 in four "natural" waters. The recruitment of 0+ pike was found to be governed by the density of the population of older individuals and by the size of the habitat for pike (Grimm, 1981).

Based on the composition of four pike populations during the period 1974–82 the factors governing the abundance of pike of less than 41 cm forklength and especially of 0+ pike are further analysed. Also the conclusion that stocking of pike fingerlings would not lead to an increase in the population density (Grimm, 1981) was further elaborated.

2. METHODS

2.1 The experimental waters

The pike populations in four sites: the "Jan Verhoefgracht" (JV), the "Fortgracht" (FN), the "Kleine Wielen" (KW) and the "Parkeerterreinsloot" (PS), that were fenced off from surrounding waters either by natural or artificial barriers, have been studied. The geographical situation and morphological characteristics have been described by Grimm (1981). Additional information on vegetation, fish stocks and dimensions is presented in Table 1 and Fig. 1.

2.2 Sampling techniques, estimate procedures

Sampling was by electrofishing, seining and trawling. The numbers in the populations were estimated using a mark-recapture technique (Petersen) corrected for selectivity of the sampling gear. The biomasses were calculated using yearly determined length-weight relationships. They were related to the area of pike habitat available. Therefore, the vegetated area was calculated. Detailed descriptions of the methods and techniques are presented in Grimm (1981).

All lengths quoted in this article are forklength unless otherwise indicated.

2.3 Subdivision of the populations

Pike populations were classified into the following length classes: 0+; 0+ -34 cm; 35 – 40 cm; 41 – 47 cm; 48 – 53 cm; 54+ cm (Grimm, 1981). The 0+ class (the delimitation of this class was described earlier (Grimm, 1981) was distinguished to quantify the numbers recruited to the population after one growing season, from naturally reproduced individuals as well as those individuals originally stocked as fingerlings.

The sub-groups 0+ - 30 cm and 30 – 35 cm were distinguished because the habitat preference of these length classes, as established from their distribution in the sampling period (October–March), was similar to that of 0+ pike. The lengths attained by 0+ pike in different years at the different sites fell within these ranges (Table 6).

Pike of less than 41 cm were found to be confined to vegetated areas. Pike equal to or greater than 41 cm had less defined habitat preferences, between 41 and 54 cm long, although most frequently caught within vegetated areas, were also found outside these. Pike of 54 cm and over appeared to inhabit vegetated as well as non-vegetated areas.

To differentiate between legal-sized (48 cm) and sublegal-sized pike the 41–54 cm group was subdivided into the 41–47 cm class and the 48–54 cm class.

2.4 Stocking of pike

The records of stocking with artificially propagated pike-fingerlings (4–6 cm) marked by a fin-pulling technique (Patrick and Haas, 1971) are given in Table 2.

As far as pike were concerned, the winter kill of 1978–79 affected mainly the larger individuals in the site JV and KW (see footnote Table 1). Mortality at the latter site was judged so severe that 27 pike of over 75 cm length (117 kg) were stocked to ensure the presence of a spawning stock.

To study the effect of alterations in the composition and the abundance of pike populations, part of the PS population was removed in 1977 and 1978 (Grimm, 1981). In 1979 these factors were influenced by stocking 25 pike of between 18 and 23 cm and 16 pike of over 60 cm (27 kg), which were marked by a fin clip and a subcutaneous injection with Alcian blue (Hart and Pitcher, 1969).

2.5 Relationship between biomass of adjacent subgroups

Assuming a linear relationship, Grimm (1981, 1981a) demonstrated a negative correlation between the biomasses of smaller (less than 41 cm) and larger pike. However, the data presented here, and especially those of the JV population, clearly suggest a curvilinear relationship (Figs. 5 and 6). The relationship between biomasses of pike smaller than 41 cm and those of larger individuals was tested by correlation analysis, using an exponential model, $y = e^{-ax}$. The relationship between other subgroups was tested as $y = e^{\pm ax}$.

3. RESULTS

In Table 3 we give the total surface vegetated area and the biomasses related to them. In the KW population the biomasses of pike of over 41 cm were related not only to the vegetated area but also to 2 ha of broken bottom (Grimm, 1981). The contribution of the pike originally stocked as fingerlings to the subgroups less than 41 cm are listed in Tables 4 and 5. The contribution of pike stocked between 18 and 23 cm length to the PS population proved to be nil (not listed in these tables), while 90 percent of the biomass of pike of over 54 cm consisted of stocked individuals of over 60 cm.

3.1 Influence of abundance of aquatic vegetation on biomass of pike less than 54 cm

Probably due to the disappearance of a population of common carp, the surface vegetated area in site JV increased from ± 1 ha before 1979 to ± 1.5 ha thereafter (Tables 1 and 3). At the same time the biomass of pike of less than 54 cm increased from about 100 kg to about 160 kg. The relative biomass remained the same - about 110 kg/ha vegetated surface.

Fluctuations in total biomass caused by changes in the abundance of vegetation may influence the results of the correlation analysis. This is demonstrated by the relation of the absolute and relative biomasses in JV (Figs. 4 and 5). Therefore, only the results of correlation analysis of relative biomasses of the subgroups are listed (Table 6).

4. DISCUSSION

4.1 Relation between biomass of pike and vegetated area

Grimm (1981) showed that the wide variations in the biomass of pike of less than 54 cm among the four sites were much reduced when the biomasses were related to the availability of pike habitat, the vegetated area. He also pointed out that the decrease in the numbers of 0+ pike coincided with the reduction of submersed/emersed vegetation. It was argued that the same cause could have played a role in the reduction of the numbers of small pike in Murphy Flowage (Beard, 1973; Snow, 1974) and in bodies of water that are subject to heavy eutrophication.

The relationship between the standing stock of pike and the vegetated area is accentuated by the effects (reported under section 3.1) at site JV.

After the winter kill of 1978/79 the density of the prey-fish population was reduced to an estimated 20 percent of its former level in the sites KW and JV. These differences were not reflected in the relative biomasses of pike. Also the difference in the composition and abundance of the fish stocks among the sites (Table 1) do not seem to be reflected in the density of the pike population. A possible explanation for this phenomenon is discussed later. It is apparent that the unit of vegetated area is only indicative of the three-dimensional space that is available. The volume of water in which plants or obstacles are present provides for: spawning substrate; food for all life stages of pike and cover both to stalk the prey from and to shelter from predators. In Dutch waters, perch are generally the most important predators on pike of less than 10 cm and larger pike are the major predators of pike of less than 41 cm. Within the space available to northern pike not all areas are accessible to pike of all sizes. The depth of the water column and the width of vegetation belts are, below a certain limit, physical barriers for pike of a given length. Dense stands of emergent vegetation might also prove impenetrable.

In drainable ponds containing prey fish and 0+ pike, a part of the pike population resident in unvegetated areas or used large pebbles for cover (pers.obs.). In the site JV in years with low densities of pike of more than 41 cm (1979, 1980, 1981), pike of less than 30 cm were found within emersed/submersed, submerged and, occasionally, floating vegetation.

In the period 1974–79, however, pike of less than 30 cm were caught only within emersed/submersed vegetation. This indicates that the availability of potentially accessible areas is also determined by the species itself but is also influenced by the distribution of the prey-fish of swallowable size. Grimm (1981) emphasized that the hunting behaviour and the habitus (colour and pigmentation pattern) of pike further illustrates the importance of available cover. However, the differences in distribution suggest that the function of shelter from intraspecific predation (Grimm, 1981) may be of equal importance.

4.2 Mechanisms causing negative correlation between biomasses of adjacent subgroups

In all experimental waters the biomasses of the subgroups of pike less than 41 cm per unit vegetated area are negatively correlated with those of longer fish (Table 6; Figs. 2–8). These exponential relationships assumed to be density dependent (Ricker, 1975) and could be direct (intraspecific predation) as well as indirect (competition for food and/or cover).

Differences in prey-fish abundance are not reflected in the standing stock of pike of less than 54 cm. Furthermore, the bream and white bream populations of FN and KW covered as a rule the length range 0–30 cm, indicating a maximum recruitment of bream greater than 10 cm, and thus a relatively low predation level. Although the abundance of prey-fish could be supposed to influence the density of pike populations, this is apparently not so within natural waters.

It can be supposed that here pike is confronted with a shortage of food during prolonged periods. For individuals that inhabit vegetated areas, this may arise in July–August when most young-of-the-year cyprinids and percids can be found as planktivores/benthivores outside the vegetated areas. Another period of October–March when prey-fish become unavailable by concentrating in deeper unvegetated areas. As was determined from the catches during the sampling period pike of less than 54 cm stay within the vegetated areas even during prolonged periods of food shortage. It may be anticipated that starvation will lead to a higher level of activity (searching) and thus to a higher vulnerability to intraspecific behaviour. This, in turn, is more liable to occur at the lower value of the autopredatory threshold induced by starvation. The frequency of occurence of pike as a food item in pike was reported by Frost (1954 and Lawler (1965) as highest in December, and Willemsen (1967) supported this view. These similarities in (a) food shortages, and (b) inaccessibility of the areas where food is to be found, explain the uniformity of the biomasses of pike of less than 54 cm per hectare vegetated area.

Thus, the negative correlations in Table 6 and Figs. 2–8 are most probably caused by direct density-dependent intraspecific predation. Within the four populations negative as well as positive correlations have been found. The pattern of interdependence between the subgroup biomasses also differs to some extent. These phenomena are discussed by Grimm (1983).

4.3 Interdependence of density of small pike (less than 41 cm) and that of larger individuals. Contributions of introduced fish

The density of pike of less than 41 cm and especially that of 0+ pike is limited to a maximum determined by the density of larger individuals up to 54 cm. The exponential relationships presented in Figs. 2–8 show that with increasing density of larger individuals the decrease in density of smaller individuals becomes progressively slower, thus “protecting” continuity in the recruitment of 0+ pike. In this respect it is worth noting that the introduction of pike of over 54 cm in site PS, which increased the total biomass of pike above the supposed carrying capacity, did not lead to the total failure of the recruitment to the 0+ class (Table 3). Moreover the 0+ pike in 1979 recorded the smallest average length (12 cm) ever observed at this site (Table 4). Thus the relatively low biomass comprised the highest number recorded. This suggests that individuals of less than 15 cm can occupy an area within the vegetation which is inaccessible to larger pike, a supposition that agrees with results from experiments in drainable 0.2-ha ponds (Grimm, in prep.).

In view of the interdependences of the biomasses of length classes and the relationships between the surface vegetated area and the biomass of pike of less than 54 cm it is evident that stocking pike of less than 41 cm and especially of fingerlings will not lead to higher densities of pike below this size. This is illustrated in Figs. 2–8 (the data can be read from Tables 3, 4 and 5) and accentuated by the fact that the numbers stocked (Table 2) are neither reflected in their frequency of occurrence nor in the magnitude of the 0+ class.

The varying frequency of occurrence in the 0+ class (4–85 percent, Table 4) is explained by the fact that the individuals stocked were, at the date of stocking, either developmentally ahead or behind the naturally reproduced individuals. They could thus either have been intraspecific predators or themselves preyed upon within the same year-class.

The results of Forney (1968) and Franklin and Smith (1963) also demonstrate this effect as do the results of the consecutive stocking of two batches of fingerlings (4–6 cm) with a 20-day interval in 0.2 ha drainable ponds; the first and last stocked individuals comprised 96 percent and 4 percent of the biomass of the 0+ class, respectively (Grimm, in prep.).

The failure of yearling pike of between 18 and 23 cm stocked into site PS illustrates that the stocking of larger individuals is equally useless. The survival of about 45 percent of the autochthonous 0+ pike (12–22 cm in 1978) during the same growing season indicates the extreme vulnerability of the individuals introduced.

4.4 Management measures leading to higher densities of pike

Grimm (1981a) proposed that the availability of cover could influence the number of pike of over 54 cm in unvegetated areas, and postulated therefore that the potential density of pike populations in natural waters were limited.

In view of this postulate and the relationships demonstrated here it is argued that habitat-engineering rather than stocking may be the answer to the problem of maximizing of pike populations. The creation or enlargement of areas covered with emersed types of vegetation, the remnants of which persist throughout the winter and the construction of obstacles in open/deeper waters may increase the number and biomass of pike.

The maximum sustainable yield (MSY), as may be apparent from the results reported here, can only be calculated if possible changes in the interactions between the biomasses of the various length classes arising from management measures can be predicted quantitatively as well as qualitatively.

The failure to increase the numbers of pike greater than 56 cm total length, a size limit based on a MSY calculation with mortality and growth assumed to be constant (Kempinger and Carline, 1978) illustrates this.

5. ACKNOWLEDGEMENTS

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Table 1 The dominant vegetation and fish species

Vegetation.	Site FN	JV[1]	KW[1]	PS
dominant species	Glyceria-, Phragmites-, Salix-, Typha sp.	Glyceria-, Nuphar-, Nymphoides-, Phragmites-, Salix-, Sparganium-, Typha sp.	Phragmites-, Salix-, Typha sp.	Elodes sp.
Wildth (m) of emersed/submersed				
vegetation in general	0,3 – 0,8	1–2	1–6	±2
ingrowing in general	4 – 15	4–10	4–10	
floating in general		20–40		
average width total vegetated area	±2	±4	±3	±2
changes/cause	marked decrease of Salix sp. due to clearance operations september 1977	marked increase of Nymphoides sp.possibly due to disappearance of carp winter 1978/1979	slight decrease due to succession to terrestial stages	permanent reduction to minimum level by mechanical means.
<u>Fish: (kg ≥ 10 cm/ha)</u>				
Bream (<u>Abramis brama</u> (L.))				
White bream (<u>Blicca bjoerkna</u> (L.))	{ 200–250	{ --[2]	{ 100–150	--[2]
Common carp (<u>Cyprinis carpio</u>)	±150	±150	100–150	0
Roach (<u>Rutilus rutilus</u> (L.))	--[2]	{ ±600	±25	±170
Rudd (<u>Scardinius erythrophtalmus</u> (L.))	1–2		--	--
Tench (<u>Tinca tinca</u> (L.))	--	±170	--	--
Eel (<u>Anguilla anguilla</u> (L.))	25(--)[3]	--	--(5–10)[3]	--
Perch (<u>Perca fluviatilis</u> (L.))	--	?[4]	?	--
Pike-perch (<u>Stizostedion lucioperca</u> (L.))	±40	0	5	0
Pike (<u>Esox lucius</u> L.)	7–12-	50–75	±10	50[5] – 110

1. heavily affected by winterkill in 1978–1979
2. neglectable = - -
3. abundance after 1976
4. no estimates available = ?
5. due to experimental culling (Grimm 1981a)

Table 2 Stocking records of pike fingerlings (numbers)

Date of stocking	Site FN	JV	KW	PS
2/3-5-1974	1050	1350		
3/7-5-1975	350	none		
11-5-1975			4,416	803
3-5-1976	405	999		
12-5-1976			2,761	372
17-5-1977	none	none	1,369	372
17-5-1978	none	none	1,369	
30-5-1978				372
30-5-1979	none	900	1,400	327

Table 3 The estimated biomasses (B) per ha aquatic vegetation, the minimum value, ≥ cumulative catch, (L) and the maximum value (H) of the accuracy interval. The surface vegetated area

Site	Year	o^+ p(ike)			o^+ <p<30			30 ≤ p<35			35 ≤ p<41			41 ≤ p<48			48 ≤ p<54			p ≥ 54		
ha.vegetated		L	B	H	L	B	H	L	B	H	L	B	H	L	B	H	L	B	H	L	B	H
FN																						
0.345	1974	8.1	9.0	11.2	-	-	-	7.0	7.0	7.0	5.5	5.5	5.5	41.4	41.4	41.4	67.2	67.2	67.2	68.1	68.1	68.1
0.330	75	6.2	7.3	8.9	-	-	-	4.5	4.5	4.5	9.4	9.4	9.4	50.9	51.5	54.2	63.9	63.9	65.2	88.6	96.6	114.3
0.310	76	5.7	5.8	6.2	-	-	-	2.9	2.9	2.9	6.2	7.4	12.6	41.7	42.9	46.7	60.7	61.0	70.3	103.8	115.2	137.9
0.281	77	11.1	13.9	16.7	-	-	-	1.8	1.8	1.8	8.5	8.5	8.5	22.6	26.7	35.8	48.1	50.5	58.2	48.2	54.1	80.4
0.297	78	28.9	33.0	37.1	-	-	-	6.5	7.1	9.0	14.1	14.1	14.1	16.9	17.8	20.0	26.9	29.0	37.7	71.1	81.5	110.8
0.319	79	14.4	16.9	19.4	1.5	3.1	7.0	15.1	15.1	15.1	19.0	22.6	29.8	22.3	22.3	22.3	42.3	42.3	42.3	68.9	68.9	68.9
JV																						
0.962	1974	10.6	13.2	15.8	-	-	-	-	-	-	6.5	9.7	14.7	25.2	27.4	35.0	40.3	58.9	81.3		-	
0.959	75	6.5	9.0	11.6	-	-	-	-	-	-	8.5	12.6	19.1	28.4	30.3	33.6	46.4	56.5	68.5		-	
0.979	76	16.9	19.0	21.1	-	-	-	-	-	-	14.9	15.4	17.4	20.6	21.6	23.8	31.5	33.9	39.1	142.0	255.4	385.1
0.989	77	4.1	5.3	7.1	-	-	-	-	-	-	10.1	12.1	16.4	30.0	35.0	45.5	46.6	65.6	94.1	157.2	199.7	262.0
1.034	78	14.8	18.0	21.2	-	-	-	-	-	-	7.7	9.6	12.6	13.7	15.6	19.3	43.9	46.0	55.4	92.4	212.3	332.2
1.067	79	48.0	52.5	57.0	2.1	2.2	3.6	9.4	10.6	12.4	11.5	14.3	19.5	8.5	11.7	15.1	15.0	16.9	31.9	51.6	71.4	119.0
1.558	80	1.1	1.5	1.9	30.0	32.4	34.8	21.5	26.3	31.1	17.9	20.2	24.2	13.2	13.2	16.3	9.9	12.5	19.1	45.4	72.7	121.2
1.459	81	0.8	1.2	1.8	6.1	9.3	12.5	18.0	20.9	23.8	23.9	33.4	42.9	18.2	36.7	56.6	5.7	10.2	16.6		-	
KW																						
1.330	1975	16.3	18.7	21.1	4.4	5.0	6.1	17.7	18.3	19.6	37.3	38.1	41.0	32.4	35.8	39.2	24.2	34.4	44.4	35.5	52.6	69.7
1.330	76	21.5	24.0	26.5	-	-	-	17.9	22.4	26.9	33.5	34.6	37.7	33.0	37.0	41.0	27.0	34.5	42.0	36.9	41.3	47.9
1.350	77	3.3	4.4	5.5	5.5	6.1	6.9	18.4	23.0	27.6	24.5	38.0	51.5	21.4	28.2	35.0	20.8	38.5	56.2	20.7	27.8	37.4
1.131	78	14.3	17.3	20.3	1.9	2.4	3.5	7.6	10.7	14.0	24.3	31.9	39.5	22.6	30.9	39.2	21.4	38.4	55.6		-	
1.226	79	43.7	50.7	57.7	-	-	-	9.3	14.3	19.4	29.4	40.9	52.4	5.1	7.5	10.8	4.4	6.9	11.9	34.9	60.4	100.4
1.231	81	4.8	8.5	12.2	4.2	5.8	8.2	15.9	19.3	24.1	39.8	53.5	67.2	32.7	41.8	49.3	36.7	48.9	61.1	35.3	73.7	112.1
PS																						
0.185	1975	43.0	50.2	57.5	-	-	-	5.0	7.6	18.2	8.1	8.1	8.1	32.4	32.4	32.4	21.1	23.8	38.8	27.5	27.5	27.5
0.185	76	11.6	12.4	13.6	35.2	35.6	37.7	25.2	25.9	28.2	5.9	5.9	5.9	16.2	16.2	16.2	11.3	15.1	36.5	44.3	44.3	44.3
0.185	77	8.1	9.2	11.7	11.1	13.5	18.5	19.1	23.2	33.1	15.6	16.7	22.1	6.1	7.0	12.1	5.9	5.9	5.9	26.5	26.5	26.5
0.185	78	13.0	16.2	19.4	4.8	7.0	14.2	15.6	19.4	28.8	20.5	30.8	52.5	2.7	2.7	2.7	4.9	4.9	4.9	7.0	7.0	7.0
0.185	79	10.8	13.0	15.1	13.1	16.7	21.6	4.3	4.3	4.3	7.0	7.0	7.0	7.0	7.0	7.0	10.8	10.8	10.8	102.6	122.0	183.8

Table 4 The length-range (L in cm), the estimated numbers (N) and biomasses (kg) of $\circ^{+}$ pike. Between brackets the frequency of occurrence (%) of the $\circ^{+}$ pike, originally stocked as fingerlings

Year	FN			JV			KW			PS		
	L	N	Kg	L	N	Kg	L	N	Kg	L	N	Kg
1974	0–30	35[59]	3.1[50]	0–35	88[80]	12.7[72]		+			+	
1975	0–30	36[70]	2.4[85]	0–35	62[x]	8.6[x] (1)	0–26	389[16]	24.8[17]	0–30	169[59]	9.3[63]
1976	0–27	23[87]	1.8[82]	0–35	118[84]	18.6[81]	0–29	452[46]	31.9[46]	0–22	64[38]	2.3[41]
1977	0–27	75[x]	3.9[x]	0–35	54[x]	5.2[x]	0–25	122[28]	5.9[28]	0–22	48[71]	1.7[73]
1978	0–30	117[x]	9.8[x]	0–35	122[x]	18.6[x]	0–27	366[24]	22.6[31]	0–26	89[77]	3.0[74]
1979	0–30	114[x]	5.4[x]	0–28	1182[6]	56.0[4]	0–30	749[45]	62.2[66]	0–15	203[26]	2.4[29]
1980		+ (2)		0–21	68[x]	2.4[x]		+			+	
1981		+		0–21	46[x]	1.8[x]	0–25	194[x]	10.5[x]		+	

1. no fingerlings stocked. 2. no sampling executed.

Table 5 The estimated biomasses of pike <35 cm and pike <41 cm in the site KW and other experimental waters, respectively. Between brackets the contribution in percentage of individuals originally stocked as fingerlings.

Site	Year							
	1974	1975	1976	1977	1978	1979	1980	1981
<u>FN</u>	7.4	7.0	5.0	6.8	16.1	18.4	-	-
	[21]	[62]	[53]	[43]	[3]	[2]		
<u>JV</u>	22.0	20.7	33.7	17.2	28.5	85.0	125.3	94.6
	[41]	[20]	[45]	[44]	[6]	[3]	[4]	[5]
<u>KW</u>	-	56.7	61.7	43.5	40.3	65.0	-	33.6
		[7]	[30]	[26]	[22]	[67]		[3]
<u>PS</u>	-	12.2	14.8	11.6	13.6	7.6	-	-
		[48]	[54]	[43]	[53]	[51]		

Table 6 The correlation of the relative biomasses (kg/ha vegetated area) of adjacent subgroups (in cm):
(a) the FN population (df = 4)
(b) the JV population (df = 6)
(c) the KW population (df = 4)[1]
(d) the PS population (df = 3)

a)	$o^+<p<54$	$p>o^+$	$30 \le p <54$	$p \ge 30$	$35 \le p <54$	$p \ge 35$	$41 \le p <48$	$41 \le p <54$	$p \ge 41$	$p \ge 48$
o^+p(ike)	$-0,8719^{xx(2)}$	$-0,8438^{xx}$								
$p <30$			$-0,8605^{xx}$	$-0,8386^{xx}$						
$p <35$					$-0,8386^{xx}$	$-0,7994^{x}$				
$p <41$		$\boxed{48<p<54}$					$-0,8343^{xx}$	$-0,8738^{xx}$	$-0,7919^{x}$	
$35 \le p <48$										
$41 \le p <48$		$0,9558^{++}$								$0,8411^{+}$

b)	$o^+ + <p <41$	$o^+ <p <48$	$o^+<p <54$	$35 \le p <54$	$41 \le p <54$	$48 \le p <54$
o^+p(ike)	$-0,7484^{xx}$	$-0,8932^{xxxx}$	$-0,8537^{xxxx}$			
$p <35$				$-0,9486^{xxxx}$		
$p <41$					$-0,9621^{xxxx}$	
$p <48$						$-0,8916^{xxxx}$

c)	$o^+ <p <35$	$30 \le p <54$	$35 \le p <54$	$48 \le p <54$
o^+ p(ike)	$-0,7693^{x}$			
$p <30$		$-0,7827^{x}$		
$p <35$			$-0,7763^{+}$	
$30 \le p <48$				$0,9273^{+++}$
$35 \le p <48$				$0,9426^{+++}$
$41 \le p <48$				$0,9320^{+++}$

d)	p(ike) ≥ 35	$p \ge 41$	$p \ge 48$	$48 \le p < 54$
$30 \le p <35$	$-0,8557^{x}$			
$30 \le p<41$		$-0,9380^{xxx}$		
$30 \le p<48$			$-0,9419^{++}$	
$35 \le p<41$		$-0,8263^{x}$		
$41 \le p<48$				$0,9398^{++}$

1. relative biomasses expressed as kg/ha vegetated area + 2 ha broken bottom

2.+/x = two-/one tailed test 0.05 >p>0.02

++/xx = two-/one tailed test 0.02 >p>0.01

+++/xxx = two-/one tailed test 0.01 >p>0.005

++++/xxxx = two-/one tailed test p<0.005

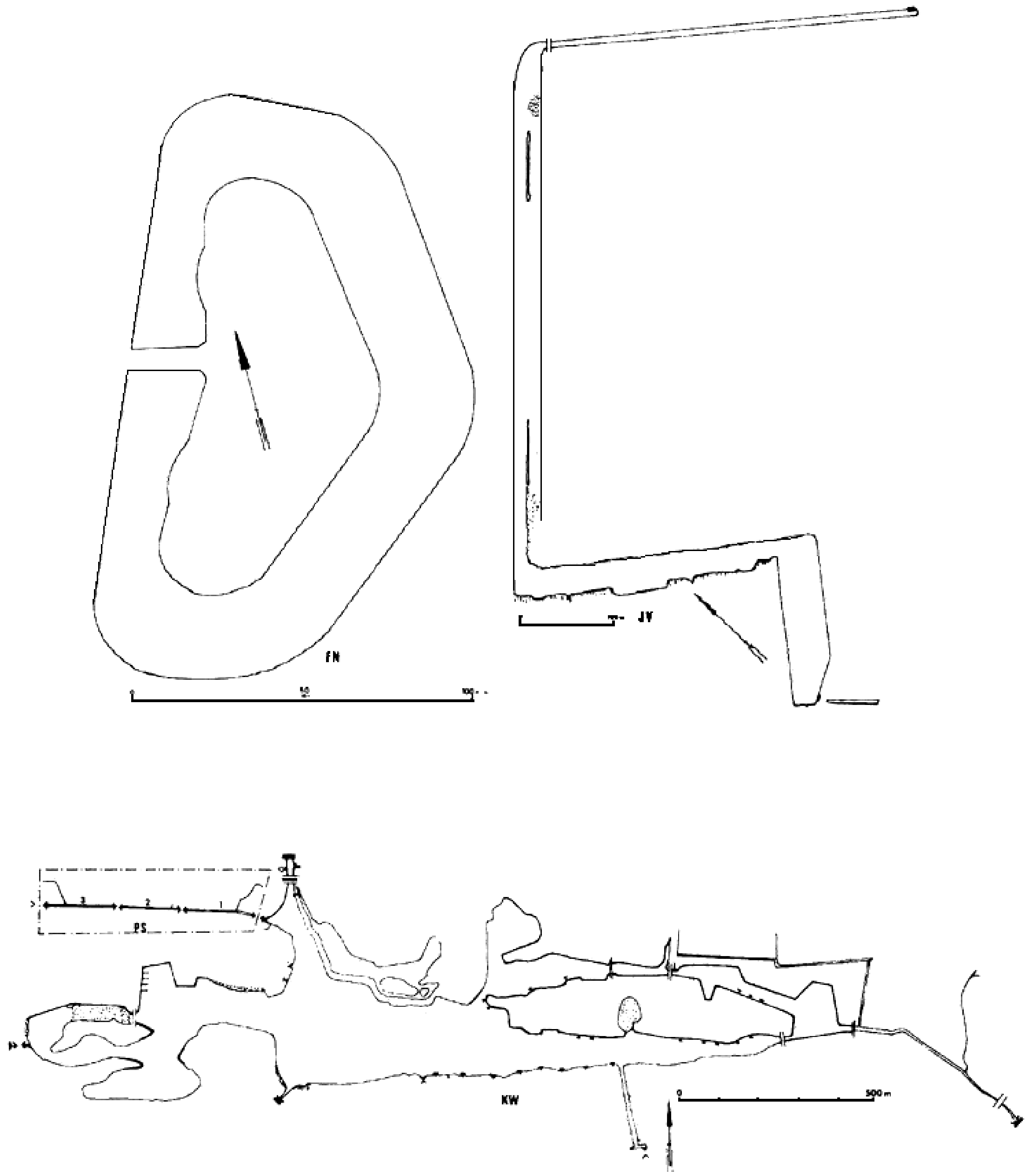

Fig.1 Schematical plans of the four sites

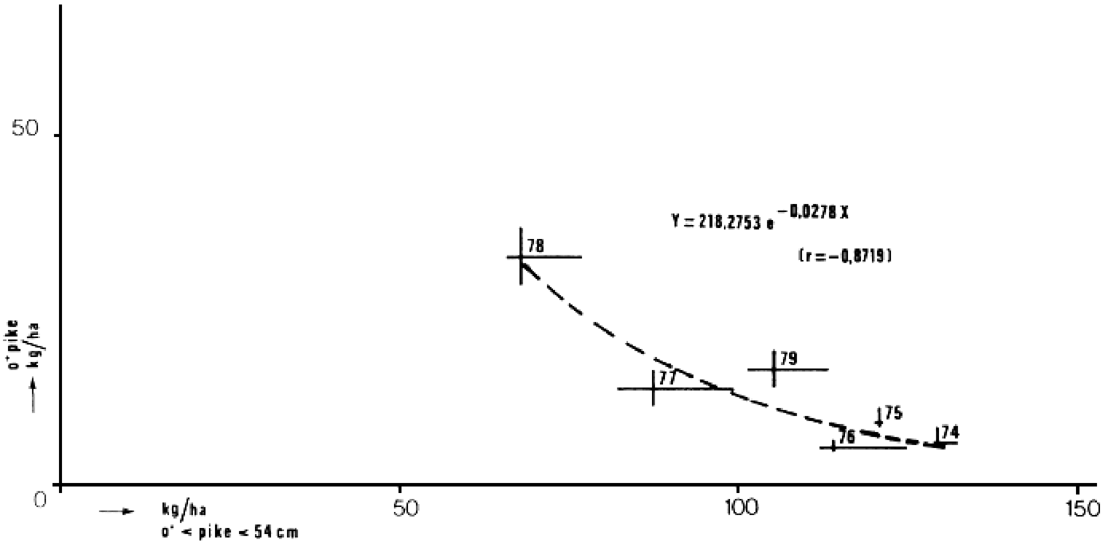

Fig. 2 The relationship between the relative biomasses (kg/ha vegatation) of o^+ pike and the relative biomasses of o^+ **<** pike **<** 54 cm in the FN population (years indicated)

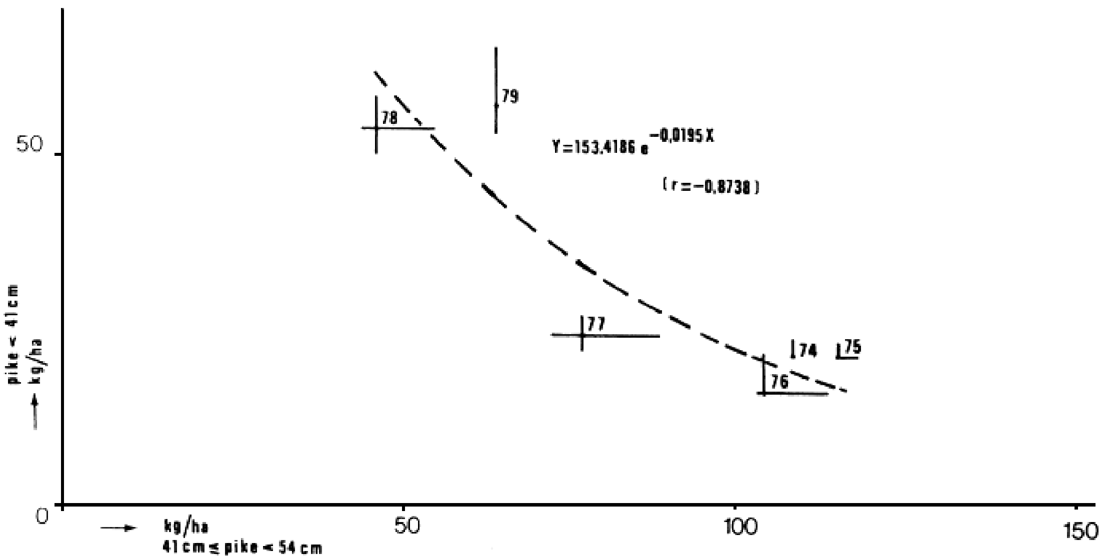

Fig. 3 The relationship between the relative biomasses (kg/ha vegetation) of the pike < 41 cm and the relative biomasses of 41 cm ≤ pike < 54 cm in the FN population (years indicated)

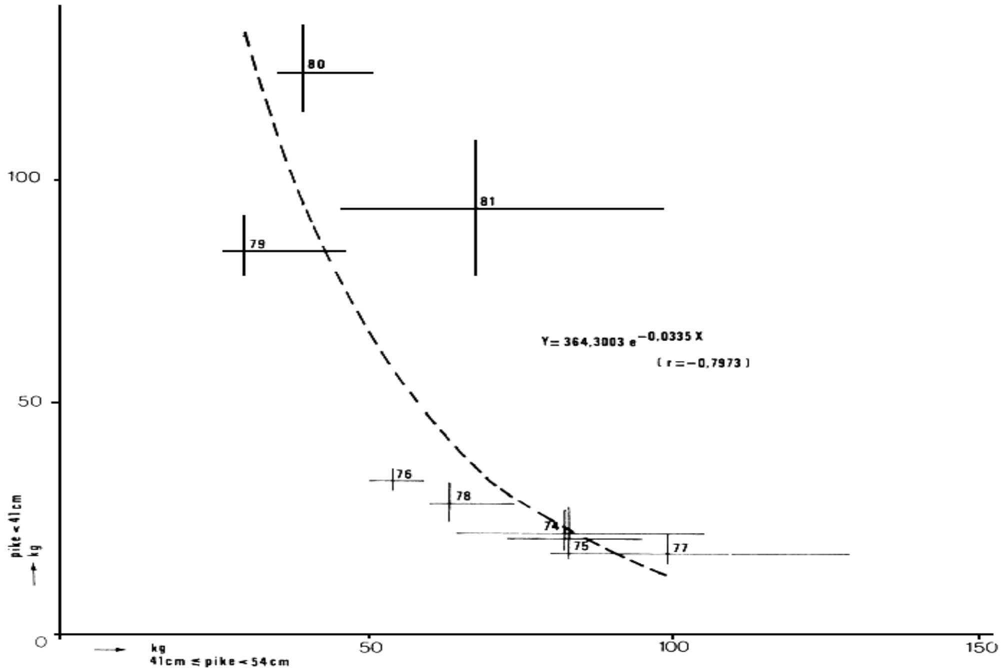

Fig. 4 The relationship between the absolute biomasses (kg) of pike < 41 cm and the absolute biomasses of 41 cm ≤ pike < 54 cm in the JV population (years indicated)

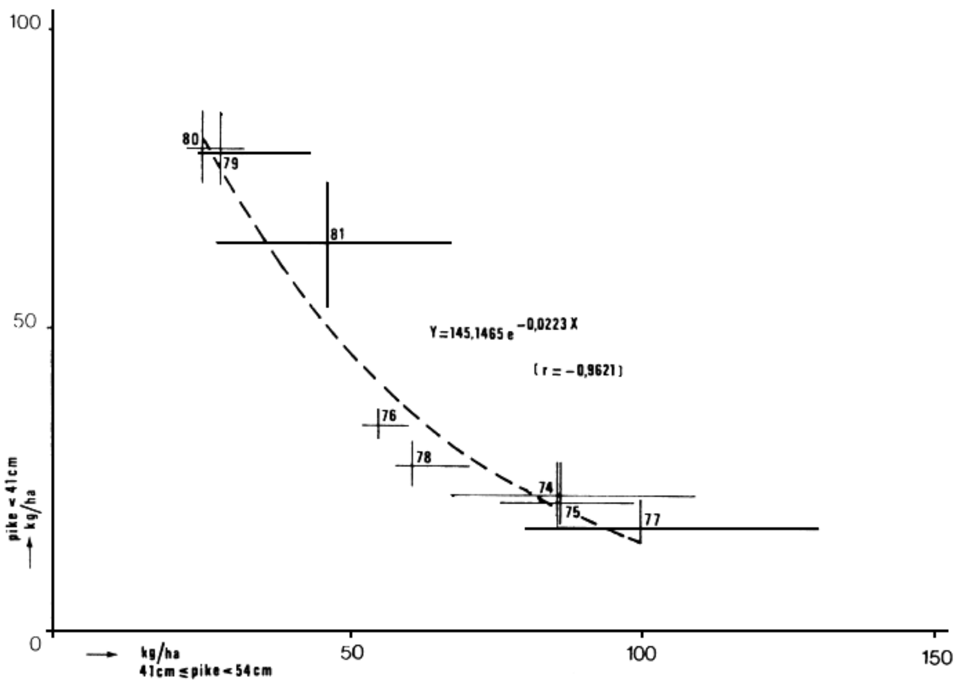

Fig. 5 The relationship between the relative biomasses (kg/ha vegetation) of pike < 41 cm and the relative biomasses of 41 cm ≤ pike < 54 cm in the JV population (years indicated)

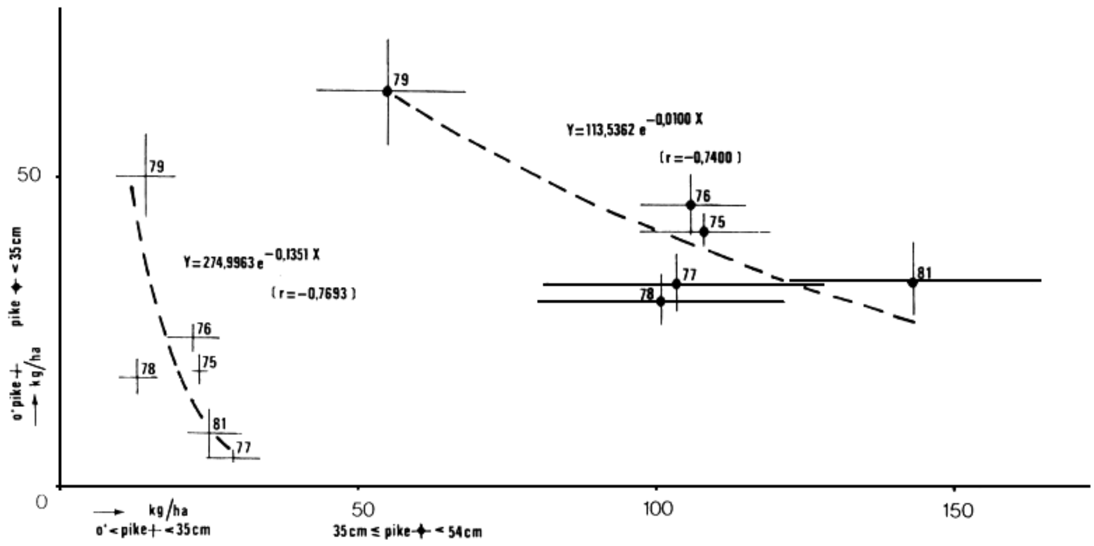

Fig. 6 The relationship between the relative biomasses (kg/ha vegetation) of o$^+$ pike and the relative biomasses of o$^+$ **<** pike **<** 54 cm in the JV population (years indicated)

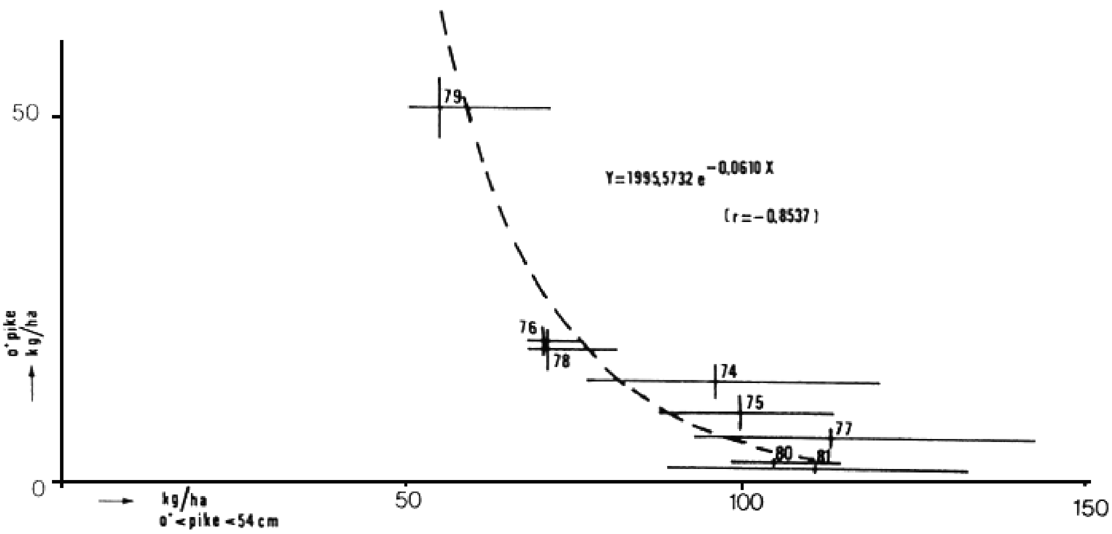

Fig. 7 The relationship between the relative biomasses (kg/ha vegetation) of o+ pike and the relative biomasses of o+ < pike < 35 cm (+), and of the relative biomasses of pike 35 cm and the relative biomasses of 35 cm ≤ pike < 54 cm (o) in the KW population. The biomasses of pike ≥ 41 cm were related also to 2 ha of broken bottom, see text (years indicated)

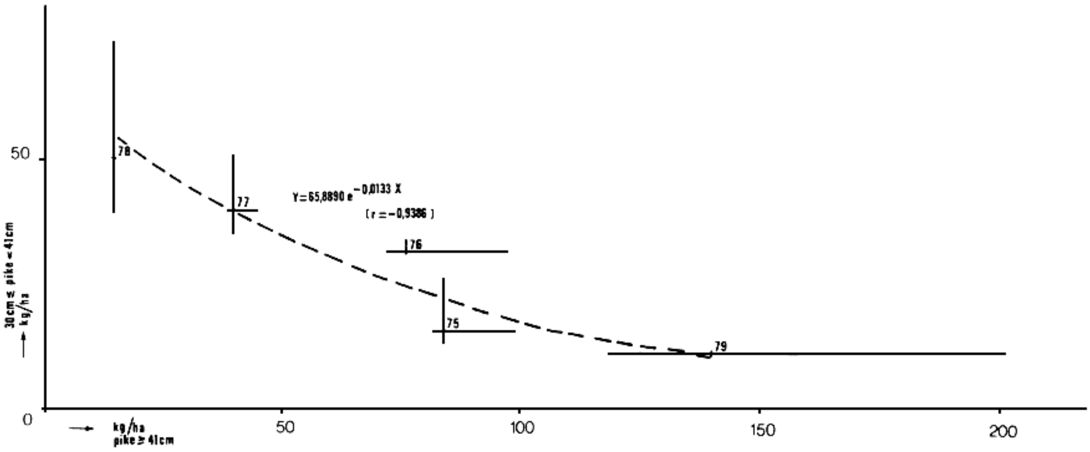

Fig. 8 The relationship between the relative biomasses (kg/ha vegetation) of 30 cm ≤ pike < 41 cm and the relative biomasses of pike ≥ 41 cm in the PS population (years indicated)

GROWTH POTENTIAL OF POORLY GROWN BREAM (Abramis brama L.) REVEALED BY TRANSPLANTATION TO ANOTHER ENVIRONMENT

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CONTENTS

ABSTRACT

Bream grows very slowly in some Dutch waterbodies. In normal practice, stimulation of growth rate is attempted by removing part of such populations. The results are mostly poor, not durable and this type of management is very expensive. Alternative management measures have to be found by research.

In some cases bream even seem to lack the ability to increase their growth rate. By transplantation of very slowly-grown bream from a poor to a rich environment, it was established that even old bream could raise their growth rate to a remarkable extent.

The influence of the environment on growth and population density are discussed as well as the implications for such regulation of bream populations as thinning and stocking.

RESUME

Dans le cadre de recherches sur la régulation des populations de brèmes on a prélevé un échantillon de ces poissons dans un petit lac situé près de Langeraar, où, depuis au moins 60 ans, leur croissance est très médiocre, pour les transplanter dans un autre petit lac, Oude Veer, où leur croissance est à l'inverse très rapide. Dans le premier lac, la longueur totale des brèmes à l'âge de neuf ans est de l'ordre de 30 cm en moyenne alors qu'elle est de 50 cm environ dans le second, les poids correspondants se situant aux alentours de 300 et 1 500 g.

En l'éspace de trois ans, on a recapturé, sur un total de 1 517 brèmes marquées et transplantées, 440 individus. On a constaté que leur croissance avait été très bonne durant cette période et même supérieure à celle des brèmes autochtones. Leur état s'était également amélioré de façon remarquable.

La faible croissance des brèmes dans le lac de Langeraar pendant une longue période n'avait donc en rien réduit leur potentiel de croissance rapide. Il semble même que les brèmes habituées à une nourriture insuffisante aient un métabolisme ou un comportement alimentaire qui leur permet, après transplantation dans un milieu plus favorable, de se développer mieux que les autres.

Il est presque certain que l'accélération de la croissance des brèmes transplantées est due essentiellement à des différences d'alimentation d'un lac à l'autre. A Oude Veer, la biomasse benthique est beaucoup plus importante que dans l'autre lac, dans lequel la population de brèmes est nettement plus dense.

L'exploitation ou la régulation artificielle des stocks de brèmes ne peut pas être à l'origine de la différence de densité observée d'une pièce d'eau à l'autre. Selon toute probabilité, la régulation est due à des mécanismes indépendants de la densité. L'auteur examine ces mécanismes et souligne qu'il est capital de bien les comprendre pour aménager correctement les nombreuses populations de brèmes des Pays-Bas.

1. INTRODUCTION

Adjustments of the population of bream (Abramis brama) by removing a portion of such populations are more and more common in the Netherlands. Such measures are intended to cope with the problems of stunted growth of this species and to decrease competition for food (mainly benthos) with the eel (Anguilla anguilla). Sportfishermen are interested in fast growth of bream and professional fishermen in high yields of their eel fisheries. The ecological mechanisms regulating bream stocks are not well known at the moment. In some water bodies the population density stabilizes at a high level, while in others the density remains low. As far as is known, fishing mortality plays an unimportant role. Most probably the mortality of eggs, larvae and juveniles forms the key factor in this phenomenon.

Opinions of population reductions as a management tool are somewhat divergent because, among other things, results are disappointing in most cases; the effects are not lasting, and the evaluation is mostly rather poor.

An important problem was that in some populations bream appear unable to increase their growth rate, possibly through a lack of appropriate genetic strains in the population. If this does play a role in bream, it is not surprising that lowering the number of fish per hectare, which means an increase of the benthos available per fish, is not always followed by a significant improvement of the growth rate. Therefore an experiment was designed whereby bream from a water body (Langeraarse Plas) having a dense population of fish in which individual growth has been consistently poor for at least 60 years (Redeke, 1923) were transplanted to a water body in which bream growth rate is very high (Oude Veer - Fig. 1). The growth and condition of the transplanted bream were determined over a period of three years, from the autumn of 1978 until April 1981, by examining recaptured specimens.

Sampling fish food-organisms and measuring some chemical and physical parameters was carried out from September 1973 until March 1976 in five water bodies. Fish stock assessments were made in these in March 1975 and in March 1977. This work was done prior to the transplantation of bream, in March 1978. Langeraar and Oude Veer are two of the five water bodies but only the results from these two are discussed in this paper.

Information from the other water bodies as well was published by Cazemier (1975), Cazemier and Van der Heul (1979) and Cazemier (1982).

2. METHODS

In both water bodies a number of physical and chemical parameters were measured during 30 months (14 times) by using normal standard methods. The characteristics of the bottom were determined by direct observations, completed with information from soil maps. Plankton and other small organisms were sampled with nets.

Two surveys were carried out to estimate the population of bream, using a bottom trawl (3.5 m wide), towed by two boats equipped with 25 hp outboard motors (see Backiel and Welcomme, 1980). A number of short hauls (five minutes) were made over measured distances. The efficiency of the trawl was considered equal in both waters, because their characteristics for trawling were to a large extent similar. The actual efficiency was not known but could be estimated as rather high - about 75–90 percent.

To determine the rate of growth, ageing was carried out by counting annual marks in scales and finrays. Back calculations of lengths in successive years were carried out by measuring the distance between the nucleus of scales and the rostral part of the annuli. These data were substituted in a fish length-rostral scale radius relationship, expressed by the following expressions:

$r = 0.0012\, l^{1.4104}$ (bream shorter than 9.7 cm)

$r = -0.5970 + 0.0142\, l$ (bream longer than 9.7 cm total length)

(r = rostral scale radius in mm; l = total fish length in mm)

The condition factor for bream is expressed as a quotient:

$$k = \frac{\text{actual weight}}{\text{expected weight}} \times 100$$

The expected weight corresponds to the mean weight determined for bream from a number of Dutch waters, which can be expressed by the formula:

$g = 0.0053\, l^{3.1997}$

(g = weight in g; l = total length in cm)

An estimate of the average standing crop of benthos was made by regular sampling, 13 times during 26 months. The fresh weights of chironomid larvae (pupae) and oligochaetes only are given here because these organisms are the main food for bream bigger than 20 cm.

The transplanted bream were all caught on one day with a seine net in the Langeraarse Plas. Immediately thereafter they were transported and marked (1 March 1978) by injecting a small quantity of alcian blue in aqueous solution into the skin, with a Panjet Injector. A proportion of these fish was tagged by putting a small (1.4 × 0.3 cm) stainless steel numbered tag through an incision into the body cavity. Both marking methods had been successfully used in former experiments.

3. RESULTS

3.1 Physical and chemical aspects (see Tables 1 and 2)

In Langeraar the turbidity is caused by a permanent bloom of *Oscillatoria agardhii* and in Oude Veer by flagellates, green algae and diatoms.

Chlorinity and total hardness in Oude Veer are very high for fresh water, due to seepage of marine water into the lake.

A reduced oxygen content was found only once when emanations fell to 61 percent saturation on a hot day near the bottom of Langeraar. Otherwise measurements always showed at least 80 percent saturation, and supersaturation was frequently observed.

3.2 Characteristics of bottom and soil

Langeraar: very soft, muddy peat bottom, with a high content of dead plant material. The waterbody originates from peat-cutting activities.

Oude Veer: rather firm clayey mud with only a small amount of vegetable remains, made up of calcareous young sea claysoil. The water body lies in a polder reclaimed from the sea some 200 years ago.

3.3 Plankton sampling

Neomysis integer a small brackishwater shrimp, was estimated to be about five times as numerous in Oude Veer than in Langeraar. The species mostly swims about in dense shoals. Data on the abundance of other planktonic organisms are considered to be less relevant to the problem and therefore omitted here.

3.4 The fish stocks

Fishing with bottom trawls were carried out in the spring of 1975 and 1977 in both water bodies. The figures in Table 3 refer to bream of over 20 cm (total length) and should be considered as minimum estimates of the stocks (see also Figs. 2, 3 and 4).

The number of juveniles, especially one-year old bream, was much higher in Langeraar than in Oude Veer. In 1977, for instance, 562 individuals were caught per 100 m trawl in Langeraar, against only 0.6 per 100 m in Oude Veer.

Bream contributed between 70 and 86 percent of the total catch and compared with the stock of bream the quantity of other benthivorous species was negligible. The only predatory species of importance for the bream population was pike-perch (zander) but is considered to be of minor importance as a factor in bream population-density regulation in these lakes.

The length frequency distribution for cm-classes above 20 cm, of bream caught during the trawl assessment fishery in March 1977, is presented in Figs. 2 and 3.

The growth of bream in Langeraar and Oude Veer was calculated by using data from a number of year-classes (Table 4).

The condition of bream over 20 cm was at the start of the transplantation experiment at an average of 101 in Langeraar and 109 in Oude Veer.

3.5 Zoobenthos

Estimates of average standing crop of chironomid larvae and oligochaetes in the period January 1974–March 1976 are presented in Fig. 4, together with a minimum estimate of that portion of the stocks of bream feeding on benthos.

3.6 The transplantation experiment

The mean length of the transplanted bream was 30.8 cm (s = 3.5) on the day of stocking.

Within the three years after stocking 29.6 percent were recaptured in professional fishing gear, mainly gill nets.

Eighteen bream belonging to the original length group of 30 ± 2 cm (average age nine years) were recaptured in the period between 1 October 1980 and 1 April 1981 having completed three years in Oude Veer. By means of back calculation, the lengths at the end of 1978 and 1979 were determined.

The growth curve of this select group from their ninth year onward, is compared with the growth curves of both autochthonous groups in Fig. 5.

4. DISCUSSION

The ecology of the two bream lakes studied is very different. The water in Oude Veer is more alkaline, contains much more chloride and is much harder than Langeraar water (Table 2). The bottom structure and soil composition are also completely different. Both waters are eutrophic, however, have a low transparency, little aquatic vegetation, the same depth, and surface areas which are of the same magnitude (Table 1). The bream population in Langeraar is very dense and stunted as compared with that of Oude Veer (see Tables 3 and 4 and Figs. 2, 3, 4 and 5). The average standing crop of bottom fauna per kg of bream in Langeraar is only 10 percent of that in Oude Veer (see Fig. 4). The Langeraar bream population has already lived for at least 60 years under circumstances which though apparently favourable for a high density of the stock are not favourable for a high growth rate.

The main purpose of the investigation was to determine whether it would be possible for poorly grown bream to increase their growth rate and condition under more favourable circumstances.

The results show this to occur (see Tables 6 and 7 and Fig. 5). Enhancement of growth rate and condition were very striking and introduced bream, in fact, scored better in Oude Veer than the autochthonous ones in both factors, indicating that introduced fish adapted to poor conditions, could exploit the food supply more effectively than local ones.

The only way to achieve such growth rates and condition in Langeraar itself, would most probably be to reduce the bream population drastically and to keep it on a very low level of density. Increases in growth rate as a result of removing a part of a fish population are described by many authors (e.g., Walter, 1934; Schaperclaus, 1961; Weatherley, 1972; Hofstede, 1974; Bagenal, 1978). On the other hand, bream is a species which flourishes very well in most eutrophic waters (Willemsen, 1980) and managing dense, stunted populations by such adjustment fisheries seems to be rather problematic. Else Nielsen (1977) reports an experiment in Lake Arreso in Denmark in which a bream population was heavily exploited over many years. The growth did not become faster and the number of recruits rose, probably only because cannibalism became less. The total weight of bream per ha was only slightly reduced.

It looks as if there are mechanisms at work, which tend to stabilize the bream population density at a certain level, which is specific for each water body. The food supply seems to be of minor importance for this regulation. It was observed rather frequently, however, that the gonads of lean female bream out of a dense population were poorly developed, with a high percentage of small, white eggs (atretic eggs). In such extreme cases availability of food obviously plays a role in limiting populations.

Possibly, the natural survival rate of bream (especially in its first year) and the productivity of benthos (e.g., Schaperclaus, 1961) should be considered more or less fixed properties for water bodies. The latter is normally higher when the total hardness is higher as established by the author (Cazemier, 1982). Kennedy and Fitzmaurice (1968) also determined that alkalinity was positively correlated with bream growth rate in Irish waters.

It is very difficult to increase the food available to bream in natural waters, thus there is hardly any alternative other than trying to adjust the stock of bream to the food resources to achieve a better growth rate. However, when the density tends to stabilize at a certain level, the removal of part of a dense population (or conversely stocking to make a sparse population numerically denser) has to be repeated at regular intervals to be effective. This conclusion is supported by Backiel and Le Cren (1967), Bennett (1970) and Nielsen (1977) as well as the results of many adjustment fisheries and stockings of fry or older fish in Dutch waters.

The costs of such a regulatory practice (removing dozens of kg of bream per ha each year by seining in winter) are very high and especially so in the case of bream and are generally not acceptable.

In some water bodies there are natural regulatory mechanisms at work, which seem to be lacking in overcrowded waters. It is the aim of further investigations to find out the nature of these mechanisms. Most obviously, the survival rate (and thus mortality) in the first months of life is decisive for the year-class strength (see also the remark in 3.4). Predation by some organisms probably plays an important role. Because Neomysis integer is so numerous in Oude Veer, experiments were carried out to reveal if this small shrimp could be a predator on bream larvae. We found this was indeed the case; the shrimp seems not to chase this prey but predation can follow when it hits a larva. Without any doubt there are other important causes as well (Zuromska, 1966, 1967; Blaxter, 1974). Revealing and quantifying these causes of mortality will be of great use for solving the problem of stunted bream populations in an effective and durable way. In some cases, changing the environment by, for instance, lowering the eutrophication, will obviously be more effective than manipulating the population itself.

5. ACKNOWLEDGEMENTS

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Table 1 Area, depth and transparency in Langeraar and Oude Veer

Water body	Area (ha)	Average depth (m)	Transparency in cm (Secchi-disk) Spring	Summer and autumn
Langeraar	70	2.2	35 – 60	20 – 25
Oude Veer	55	2.1	50 – 55	25 – 30

Table 2 Range and mean of some chemical parameters from 14 samplings during the period September 1973 to February 1976

	Langeraar			Oude Veer		
Parameter	min.	max.	mean	min.	max.	mean
Acidity (pH)	7.6	8.9	8.4	7.9	8.8	8.4
Alkalinity (m. eq)	2.9	4.6	3.5	4.2	6.9	6.0
Chlorinity (mg/l)	131	187	156	536.	2 030	1 472
Total hardness (Ca^{2+} + Mg^{2+}; °D)	15	20	16	40	72	57

Table 3 Results of assessments of bream stock (specimens longer than 20 cm) on two occasions; estimated by numbers and weights (kg) per ha

	March 1975		March 1977		mean	
Water	Number	weight	number	weight	number	weight
Langeraar	1 751	391	1 011	329	1 381	360
Oude Veer	203	251	166	206	185	229

Table 4 Growth rate expressed as mean total length at age (rounded to nearest 0.5 cm)

	Age								
Water	1	2	3	4	5	6	7	8	9
Langeraar	6.5	11.0	15.0	18.5	22	25	27.0	28.5	30.0
Oude Veer	7.0	13.5	20.5	27.5	34	39	43.5	48.0	50.5

Table 5 The numbers of bream stocked (1/3/78) and recaptures (till 1/4/81) in Oude Veer

Mark	Numbers marked and stocked		Numbers recaptured 1/3/78 to 1/4/81	
Blue spots and metal tag	928	61.2 %	267	59.5 %
Blue spots only	589	38.8 %	182	40.5 %
Total	1 517	100.0 %	449	100.0 %

Table 6 The average condition (k) of bream of the three different groups

	Time of sampling			
	1/3/78	Winter 1978	Winter 1979	Winter 1980
Langeraar bream	101	97	95	87
Oude Veer bream	109	110	114	113
Transplanted bream	101	116	116	118

Table 7 Mean length (Δ1) and weight (Δw) increments per original length-group, during three years after the transplantation from Langeraar to Oude Veer

Length group (cm)	Langeraar autochthonous		Oude Veer autochthonous		Transplanted bream	
Feb. 1978	Δ1(cm)	Δw(%)	Δ1(cm)	Δw(%)	Δ1(cm)	Δw(%)
21 – 25	8.5	132	15.6	428	16.3	537
26 – 30	6.0	69	14.2	292	14.0	309
31 – 35	5.3	47	11.4	147	13.0	249
36 – 40	5.7	61	7.2	77	13.7	212

Fig. 1 Map of the Netherlands with the locations of the two lakes mentioned in this contribution

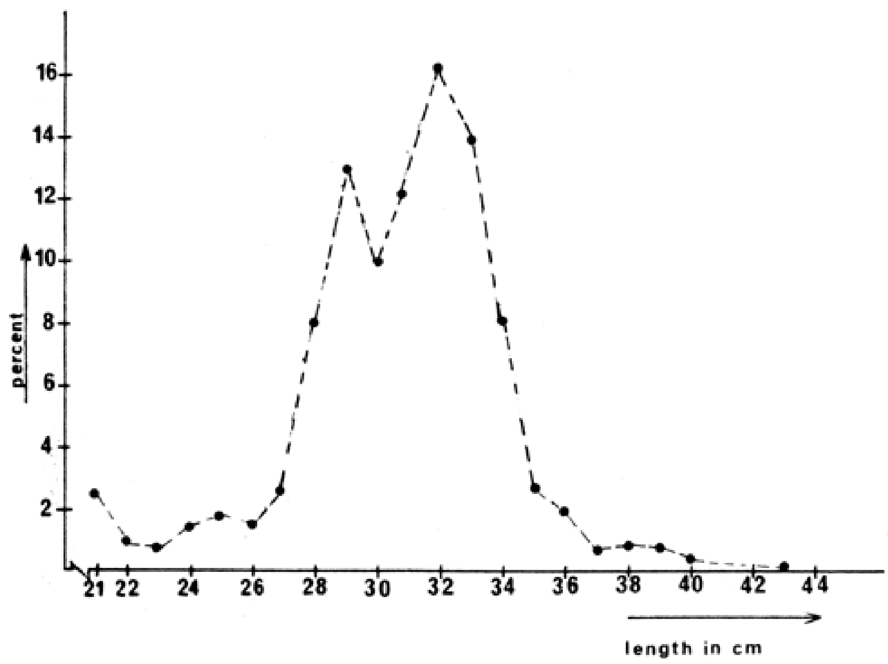

Fig. 2 Length frequency distribution of bream longer than 20 cm caught with bottom trawl in Langeraar, March 1977

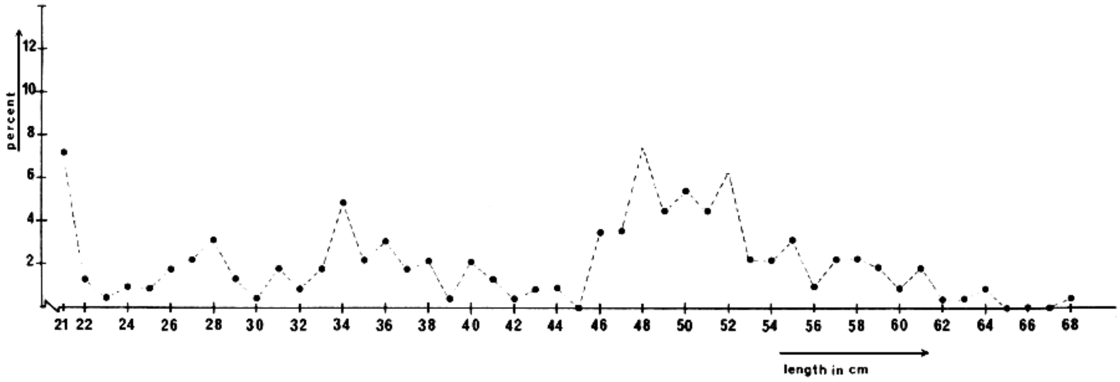

Fig. 3 Length frequency distribution of bream longer than 20 cm caught with the bottom trawl in Oude Veer, March 1977

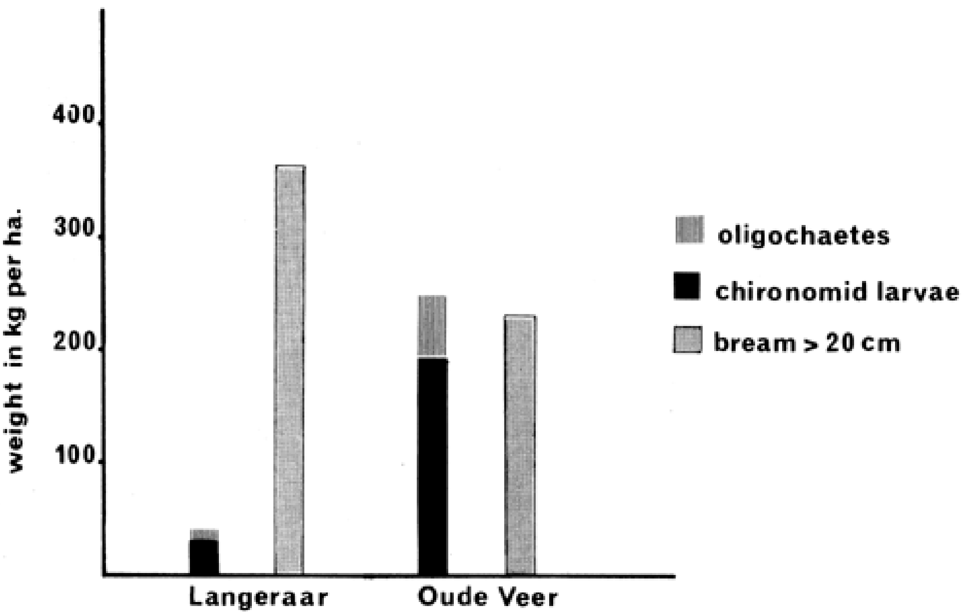

Fig. 4 Average standing crop (fresh weight) of chironomid larvae and oligochaetes (January 1974 – February 1976) and of bream (see Table 3)

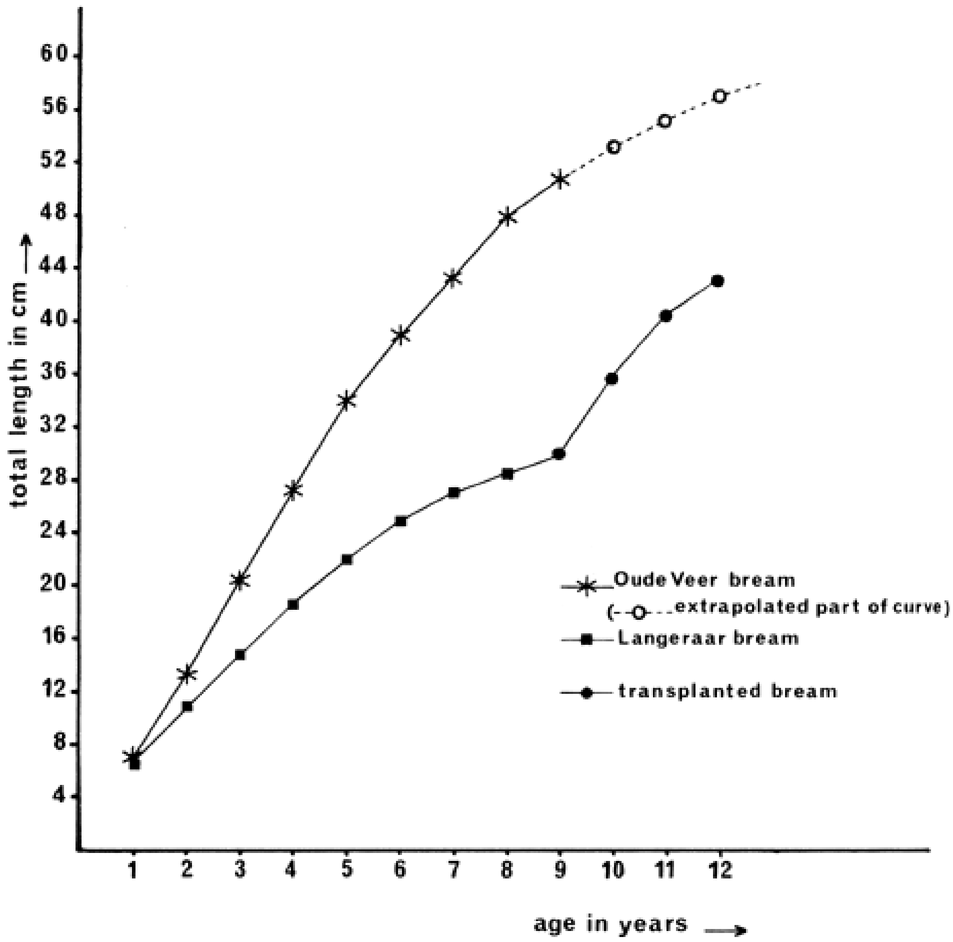

Fig. 5 Growth curves of bream in Langeraar and in Oude Veer and of a group that was transplanted at the average age of nine years from Langeraar to Oude Veer

SURVIVAL OF ROACH CAUGHT WITH A SEINE NET

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CONTENTS

ABSTRACT

In the Netherlands every year more than 200 000 kg of roach (15–25 cm) caught by seine netting, are stocked in sport-fishery waters.

From 1973 to 1980 experiments were carried out in drainable ponds to quantify the survival of these roach.

Experimental ponds (0.05 and 0.1 ha) were stocked in November to March and drained in July of the same year. Survival of roach varied from 0.8 to 67.3 percent with a mean value of 23 percent.

Induced stress seems to be the most critical factor in the overall handling procedure (catch, storage, transport, stocking). Suppressing stress with a tranquillizer (benzocaine) added to the transport medium improved survival up to five times.

RESUME

Aux Pays-Bas, on capture chaque année à la seine plus de 200 000 kg de gardons (15–25 cm) pour repeupler les eaux où se pratique la pêche sportive.

La survie de ces gardons a été étudiée dans des étangs vidangeables de 0,1 ha à la station expérimentale de l'Organisation pour l'amélioration des pêches continentales. Les gardons ont été mis à l'eau de décembre à mars et les étangs ont été vidés en juillet de la même année.

Durant la période 1973–81, le taux de survie des gardons a varié entre 0,8 et 67,3 pour cent, le taux moyen étant de 23 pour cent. Le stress occasionné par les manipulations (capture, stockage, transport) semble être le facteur le plus important. On a constaté qu'en versant un tranquillisant (benzocaïne) dans l'eau des bacs de transport, on pouvait réduire la mortalité de près de 30 pour cent.

1. INTRODUCTION

Every year more than 200 000 kg of roach (Rutilus rutilus (L.)), caught by commercial fishermen by seine netting, are stocked into waters generally managed by sport fishery associations. A greater part of this quantity (nearly 150 000 kg) is stocked into water of managers registered at the Organization for the Improvement of Inland Fisheries (OVB). If stocked into such waters, roach stockings can be subsidized at a maximum of 40 percent of the costs.

At first, quality of roach was evaluated on the basis of injuries and scale losses at stocking and/or the visible mortality immediately after stocking. When the majority of the roach showed no sign of either of these, the quality of roach was assumed to be good, with a corresponding high survival rate. Later, quality of roach was quantified more objectively by determining the post stocking survival in drainable ponds. In view of the low survival rates demonstrated in these, the OVB started an investigation in 1975 to study the possibility of lowering post stocking mortality. The results of this study are reported here.

2. METHODS

2.1 Introduction

During the winter period between 1 November and 31 March, roach for stocking into sport fishing waters of managers registered at the OVB are seined by commercial fishermen in two main areas of the Netherlands. More than 60 percent of the 150 000 kg of roach needed each year, are caught in the lower reaches of the Maas and Waal Rivers (The Biesbosch) situated in the southwestern region of the country. Approximately 35 percent of the roach are caught in the lower reaches of the River IJssel near Lake IJssel (Lake IJssel region) in the eastern part of the country.

After seining, roach (15–30 cm) are usually transported in aluminium tanks to the holding units of fish dealers. During transport, fish density does not exceed 300 kg/m^3. The holding units used by the fish dealers are mainly large keep nets (5–15 m^3). Roach are kept at a density of 60–120 kg/m^3 in these for a 2–7 days period during which quantities large enough for stocking are collected and dead, injured or lethargic individuals are sorted out. Finally, roach are transported (300 kg/m^3) and are stocked into sport fishery waters all over the country.

2.2 Experiments in drainable ponds

2.2.1 General

Survival experiments were carried out in drainable ponds at the OVB Experimental Station, situated in the centre of the Netherlands near Beesd. These experimental ponds (0.05 and 1.0 ha) were of a similar (rectangular) shape with a mean depth of 1.0 m and a bottom consisting of alluvial clay. Ponds were stocked exclusively with roach in order to determine a conditional survival value for the species.

Ponds were stocked between 1 November and 31 March at the same time as the period of normal stocking of sport fishing waters.

Stocking density was standardized at 2 000 roach/ha. In practice, roach are stocked to increase catches or to guarantee angling success in the summer following the closed season (15 March–1 June). Experimental ponds were drained in the first weeks of July to gain an impression of the proportion of stocked roach left from the stocking in the previous winter. At draining, surviving fish were counted and the numbers of fish injured, wounded or ulcerated were determined. Survival was calculated as the percentage of living fish relative to the total number stocked into the ponds. The injury ratio was calculated as a percentage of the number of fish harvested.

2.2.2 Determination of survival of roach provided for stocking in sport fishery waters

Ponds were stocked with roach taken from samples from different batches of roach just prior to being stocked into sport fishing waters. From 1972 to 1980 samples of 70–100 kg of roach were taken each year between 1 November and 31 March from roach deliveries without prior notice to the fish dealers. Only batches of roach originating from the most important fish dealer of the "Biesbosch region" and that of the "Lake IJssel region" were sampled. These two fish dealers were handling nearly 80 percent of the total catch of roach. The samples were transported to the Experimental Station in oxygenated water in glass-fibre tanks. Depending on the place of sampling, transport to the Experimental Station took between two and three hours.

2.2.3 Experiments to determine causes of mortality

In these experiments, started in 1975, three kinds of roach were tested for conditional survival rate:

(a.) roach, sampled as described in 2.2.2;

(b.) roach, harvested by draining experimental ponds in which the fish were hatched and reared. These were subjected to simulated transport and storage at a density of 150 kg/m^3, as practised by the fish dealers.

(c.) roach, sampled as soon as possible after seining by the fishermen (with exclusion of the storage at the fish dealers) and kept in simulated storage. Some of these samples were treated with the tranquillizer benzocaine (10 ppm) during transport from fishing site to Experimental Station and during the simulated transport before stocking.

3. RESULTS

3.1 Survival of roach provided for stocking in sport fishing waters

The survival of different batches of roach, sampled from the deliveries from fish dealers are summarized in Table 1.

Independent of the region of origin, the survival of roach varied from 0.8±67.3 percent with a mean value of 23.0 percent. Mean survival of roach from the Lake IJssel region was 24.4 and 22.0 percent of roach from the Biesbosch survived.

As is shown in Fig. 1, the survival of roach originating from both regions appeared to be negatively correlated to the injury ratio.

3.2 The effect of storage of roach on survival

Roach, sampled directly at the fishing sites and stocked into the experimental ponds without storage, showed considerably better survival than roach sampled from the deliveries from fish dealers, at about the same time (Table 2).

With no storage by the dealer, the survival of roach reached values of more than 90 percent, suggesting that seining and transporting can be done without being harmful to roach. However, low survivals (36.9 percent) were also recorded in batches of roach which were not exposed to storage.

Experiments carried out with artificially reared roach subjected to simulated transport without storage revealed a survival of 93.0 and 96.9 percent. When subjected to storage as well as transport the survival of these roach decreased to 43.5 percent.

The results of experiments with batches of roach sampled at the fishing sites and the same batches kept at the holding units of the fish dealers are shown in Table 3.

This demonstrates that survival decreased sharply from 47.0 to 7.6 percent and from 23.9 to 0.8 percent, respectively. The negative effect of keeping roach seemed most pronounced during the first 24 h of storage. Survival decreased with longer storage but less drastically.

3.3 Effect of benzocaine

The results of treatment with benzocaine administered to the water during the transport of roach before as well as after simulated storage at the Experimental Station is shown in Table 4.

In all samples, the survival after 72 h storage was increased by treatment with benzocaine. The mean survival rate increased from 19.0 to 43.3 percent and when survival of untreated roach was low (11.0 and 20.0 percent respectively) treatment with benzocaine increased survival above these values.

4. DISCUSSION

The results of a seven-year study of the survival of roach after stocking, reveals a generally low survival of about 22.0 to 24.4 percent (mean values) independent of the region of origin of the stocked fish.

If the same situation applies in practice, i.e., when roach are stocked into sport fishing waters, only a small part of the roach stocked just prior to the beginning of the closed season for angling is available at the opening of the season in the beginning of June.

It is apparent that handling, and especially storage, of roach as practised by the fish dealers decreases survival drastically. Similar results are reported for other species, especially salmonids (Hosmer, 1980; Johnson and Metcalf, 1982; Strange and Schreck, 1978). When storage is avoided by taking roach directly from the fishermen, survival can be increased up to 97.3 percent. However, the exclusion of storage by the fish dealers does not always guarantee a high survival of roach. As may be seen from Tables 2, 3 and 4 survival of roach obtained immediately from the fishing sites varies considerably from 97.3 to 11.0 percent and it is supposed that the low survival is connected with storage as practised by the fishermen themselves. If only small quantities of roach are caught, the fishermen keep them in their tanks until sufficiently large quantities are available which are saleable to fish dealers. There is no doubt that the avoidance of storage would be a good way to improve the survival of roach. However, in practice, such a measure seems hard to realize. In general, the batches of roach caught by fishermen are brought to the fish dealer in the afternoon. As a consequence, transport and stocking are not possible during the same day as seining. Furthermore, storage is often necessary to give fish dealers the opportunity to sort the fish and to accumulate small batches until deliverable amounts are obtained. In view of the practical impossibility of avoiding storage, improvement of post stocking survival seems only possible by reducing the metabolic processes (stress) which are induced by handling and keeping the fish, and which affect the survival.

Applying the stress-reducing tranquillizer benzocaine (Laird and Oswald, 1975) during the transport of fish, survival rate has been shown to improve up to and even over five times. Comparable effects are reported for other species, using different tranquillizers or salt (Collins and Hulsey, 1963; Long et al, 1977; Taylor and Solomon, 1979).

The treatment of roach with tranquillizer, however, is restricted to the transport of fish, in view of the impossibility of applying these chemicals through the flowing water systems as used in storage.

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Table 1 Percentage survival of different samples of roach originating from the Biesbosch region or the Lake IJssel region

Stocking season (1 Nov.–31 March)	Biesbosch	Lake IJssel
1972/73	8.5	1.0
1973/74	44.5	39.0; 26.5
1974/75	3.7	25.3
1975/76	32.5; 15.5; 66.8; 34.5	67.3; 24.5
1976/77	23.9	-
1977/78	7.6	11.0; 0.8
1979/80	7.0; 10.0; 10.0	-
Mean value	22.0±19.2	24.4±20.4

Table 2 Percentage survival of different batches of roach caught by seine net sampled at fishing sites and fish from dealers

	Roach from fishermen	Roach from fish dealers
1974/75	81.0	3.7
1975/76	70.5	32.5
1975/76	81.3	15.5
1975/76	58.0	66.8
1975/76	97.3	34.5
1976/77	36.9	23.9

Table 3 Percentage survival of roach sampled at the fishing sites and kept at the fish dealers

Duration of storage			
0 h	24 h	49 h	120 h
47.0	14.1	10.1	7.6
23.9	-	-	0.8

Table 4 Effect of benzocaine (10 ppm) on the percentage survival after stocking of four different batches of roach, sampled at the fishing site and stored for 72 hours before stocking

	Untreated	Storage (72 h)	Storage (72 h) benzocaine during transport
	20.0	23.5	62.5
	48.5	8.5	42.0
	11.0	11.0	27.5
	89.5	33.0	41.0
mean	42.3	19.0	43.3

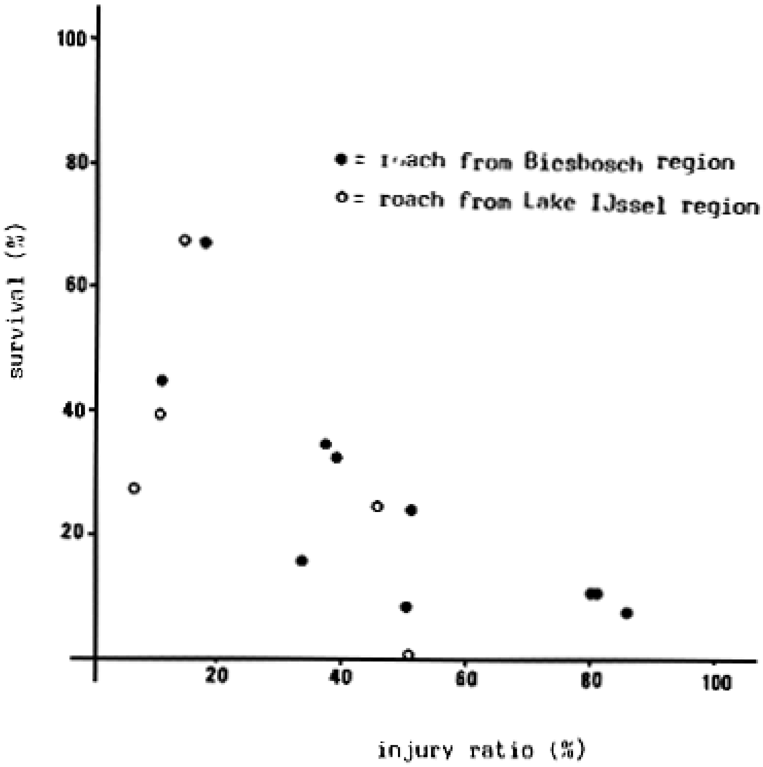

Fig. 1   Relationship between percentage survival and injury ratio

THE EFFECTIVENESS OF EEL STOCKING IN POLISH LAKES

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CONTENTS

ABSTRACT

Polish lakes have been stocked with elvers for many years but since 1950 the practice has intensified and is now a regular measure. This paper examines eel stocking and catches against a background of increasing eutrophication. General data on stocking and catch from all Polish lakes is presented for the 30-year period from 1951 to 1980. More detailed information from 559 lakes is analysed for the past 24 years. An assessment of the effectiveness of stocking is made from both the commercial and recreational catches. The influence of selected factors on stocking effectiveness is pointed out and some suggestions are made as to the types of lake most suitable for stocking.

RESUME

Cela fait quelques dizaines d'années que l'on repeuple les lacs polonais avec des civelles. Depuis 1950, cette pratique s'est intensifiée et est devenue régulière. Les auteurs présentent les captures d'anguilles et les repeuplements effectués dans les lacs polonais sur la base de l'évolution des stocks sous l'effet de l'eutrophisation. L'efficacité du repeuplement est analysée statistiquement dans le temps et dans l'espace.

Dans le premier cas, les auteurs se fondent sur des données générales concernant le repeuplement et les captures d'anguilles dans tous les lacs polonais pendant 30 ans (1951–80); dans le second, sur des données générales concernant le repeuplement et les captures d'anguilles dans tous les lacs polonais pendant 30 ans (1951–80); dans le second, sur des données détaillées concernant un certain nombre de lacs (559) pendant plus de 24 ans. C'est la première fois en Pologne que l'on procède à une évaluation définitive de l'efficacité du repeuplement en anguilles en se fondant à la fois sur les captures de la pêche commerciale et sur celles de la pêche récréative. En outre, les auteurs indiquent certains des facteurs qui ont un effet sur cette efficacité et présentent des suggestions préliminaires touchant le type de lac le mieux adapté au repeuplement.

1. HISTORY OF STOCKING

Polish lakes have been systematically stocked with eels since 1948. Time series analysis shows the trend in stocking to be an approximately straight line (Fig. 1) which fits the equation:

$$z = 0.027 + 1.135\ x$$

where:

z = level of stocking in millions of elvers
x = successive years of the analysed period (1,2,3.......31)

The mean level of stocking was 18.182 million individuals, with a S.D. of 11.86 and a coefficient of variation V% = 65.2.

The average annual increment relative to the mean level of stocking was 6.24 percent for the period 1948 to 1978. This represents a yearly increment of 4 elvers/ha for the 280 000 ha of exploited lakes, with a mean level of stocking of 65 elvers/ha/yr. In recent years the mean level of stocking has risen to over 100 elvers/ha/yr.

2. THE COMMERCIAL FISHERY

Catches of eel by the commercial fisheries of Polish lakes show a continuous increase both in total weight and as a percentage of the catch. The average catch during the 1951 to 1981 period was 432.25 t and the avarage annual increase was 4.15 percent i.e., 18 000 kg annually. Variations in catch are less pronounced than those of stocking as are shown by the S.D. of 167.57 and the coefficient of variation V% = 38,77.

The trend in eel catch is approximately linear represented by the equation:

$$y = 145.51 + 17.92\ x$$

where y = eel catch in metric tons and x = successive years of the analysed period (1,2,3....31). However the trend in catch conforms better to a parabola (Fig. 2) represented by the equation:

$$y = 219.026 + 4.554\ x + 0.418\ x^2$$

The parabolic function has a coefficient of convergence of 0.055, as compared to 0.085 for the straight line. It can therefore be concluded that the increments in eel catch increase with successive years. In the first five years of the period increments amounted to 1 to 2 percent, whereas in the last five years they were as high as 6 to 7 percent, equivalent to 30 000 kg/yr.

3. SIGNIFICANCE OF STOCKING TO THE FISHERY

A comparison between the trends in stocking and catch suggests that the effectiveness of eel stocking into Polish lakes has increased in recent years. The commercial catch of other species from lakes over the past 20 years (1961 to 1980) shows an especially strong tendency for cyprinid landings also to increase (Table 1). This, together with a decline in the catch of percid and littoral fish species (Table 2) clearly points to the progressive eutrophication of Polish lakes. These trends in catch agree with the schemes of eutrophication presented by Colby *et al.* (1972), Hartman (1978) and Leach *et al.* (1977). In the context of these changes in the environment the increase in catch of stocked fish species, and especially of eel, indicates that the effectiveness of eel management in Poland is high.

Statistical analysis of the general data on eel stockings and catches in Polish lakes during the 31-year periods - 1948 to 1978 and 1951 to 1981 showed that the commercial catch of eel was totally dependent on artificial stocking. Linear correlations were calculated between eel stockings in a given year (year y) and the catch of eel in some subsequent year (year y + ..). The correlation was very high between stocking in year y and catch in years between y + 3 and y + 20. This demonstrates the close dependence of catch on stocking but at the same time indicates the difficulty of Interpreting the results in any detail because eel catches in any given year are determined by stockings in several of the preceding years. Furthermore the degree to which catches are influenced by the various preceding years is determined by a variety of physical, chemical and biological factors such as different thermal regimes, variations in water level, differential growth rates, etc. This is confirmed by the slight influence on the results of the removal of years where eel stocking deviated widely from the general trend from the data set. Fig. 3 compares the real catches with those calculated from regression equations for the relationship between stocking and catch 10 to 16 years later. As the figure shows there is very good agreement between real and calculated catches in both cases.

4. SUITABILITY OF LAKES FOR STOCKING

Data from 454 individual lakes were analysed to find out what types of lakes are most suitable for eel management. The data included morphometric and environmental information as well as average values of certain parameters of eel management for the 24-year period 1950 to 1973. From this analysis it was apparent that eel catch was dependent on the level of eel stocking, an index of intensity of exploitation (expressed as average number of months of fishing in the year), the average depth of the lakes, the shoreline development (expressed as length of shore/unit of surface area). This relationship is expressed by the equation:

$$y = -0.70 + 0.0077\,z + 0.381\,x + 0.0119\,u - 0.082\,v$$

where: y = eel catch in kg/ha
z = intensity of eel stocking in number of elvers/ha (z = 82.05)
x = average number of months fishing (x = 3.52)
u = shoreline development in m/ha (u = 65.58)
v = average depth in m (v = 6.17)

The coefficient of multiple correlation was $R_{y.zxuv} = 0.66$. The equation shows clearly that relatively shallow lakes with well developed shorelines are the most suitable for management for eel fisheries. This conclusion is supported by an analysis of the effectiveness of eel stocking into lakes as classified acording to the Polish typology. For instance in vendace lakes, which are usually deep and large with poorly developed shorelines some 64.4 elvers are needed to obtain 1 kg of commercially caught eel. By contrast in pikeperch lakes, which are shallower, smaller and with well developed shorelines, only 45.5 elvers are needed for the same catch. In these two exteme types of lake the intensity of exploitation of eel is about the same: 3.98 months/yr in the vendace lakes and 3.67 months in the pikeperch lakes. The average yield of eel amounts to 1.09 kg/ha and 2.01 kg/ha respectively. In addition to the features of the lakes described above pikeperch lakes tend to be more eutrophicated and hence productive than vendace lakes.

5. INFLUENCE OF RECREATIONAL FISHERY

The above results are based solely on the commercial catch, but in order to define the true effectiveness of eel management in Poland it is necessary to also take into account the catch from the recreational fishery. Angling is extremely popular in Poland with some 800 000 legally registered anglers in 1980. In 1979 studies showed that the eel catch from this fishery was 1 786 t, or 2.6 times higher than the commercial catch. When this additional catch is taken into account it would appear that the real survival of eels from stocking to capture is at least 15 percent, an estimate that includes natural recruitment to the stock. In these circumstances only 11.7 elvers are needed to obtain 1 kg of eel catch and the real yield works out at 4.6 kg/ha.

6. CONCLUSIONS

The continuously increasing catches of eel in Poland and the greater effectiveness of eel stocking are essentially determined by four factors:

(a) An increase in the stocking rate

(b) Increasing fertility of the lakes due to eutrophication

(c) More intensive and effective fisheries

(d) Improvements in the selection of lakes for management.

The last of these particularly can significantly increase production of eel in inland waters because the results of this survey show that eel management is most effective in relatively shallow, fertile lakes with well developed shorelines. Lakes of this type are usually small and have not been utilised properly so far.

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Table 1 Trend of commercial lake fish catches in Poland in the past 20 years

1961–80	Average catch (t)	Annual increase or decrease (t)	% of annual increase or decrease of catches in relation to average
Total fish catch (trout excluded)	7 342.1	+ 88.80	+ 1.21
Eel	508.8	+ 22.60	+ 4.44
Other species:	6 833.3	+ 66.20	+ 0.97
other artificially-stocked species	770.4	+ 30.94	+ 4.02
- coregonids	519.6	+ 9.01	+ 1.73
species based on natural reproduction (no artificial stocking)	6 062.9	+ 35.26	+ 0.58
- cyprinids (littoral species excl.)	4 510.7	+ 87.94	+ 1.95
- small bream and roach	1 932.2	+ 52.50	+ 2.72
- other non-cyprinid species (littoral species excluded)	734.0	- 22.48	- 3.06
- percids	531.0	- 10.69	- 2.01
- littoral fish species	818.2	- 30.17	- 3.69
- pike	480.1	- 19.26	- 4.01

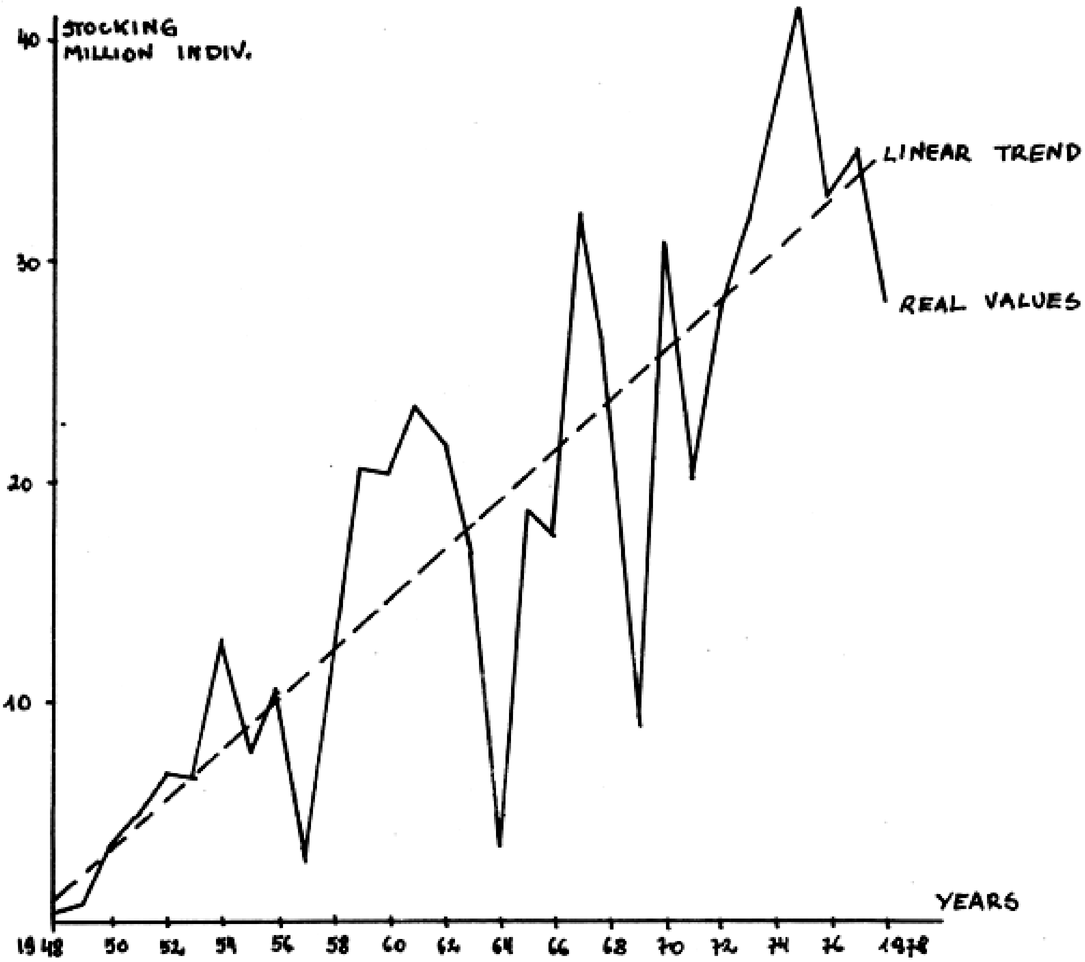

Fig. 1 Trend of eel stocking in Poland

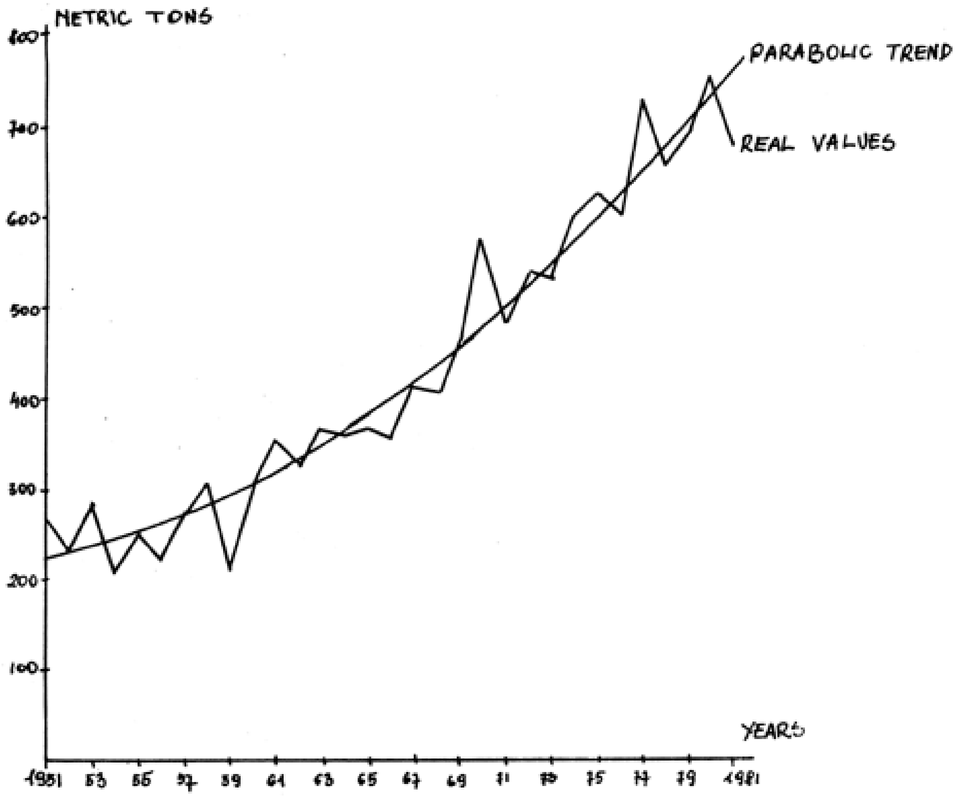

Fig. 2   Trend of eel catches in Poland (commercial catch only)

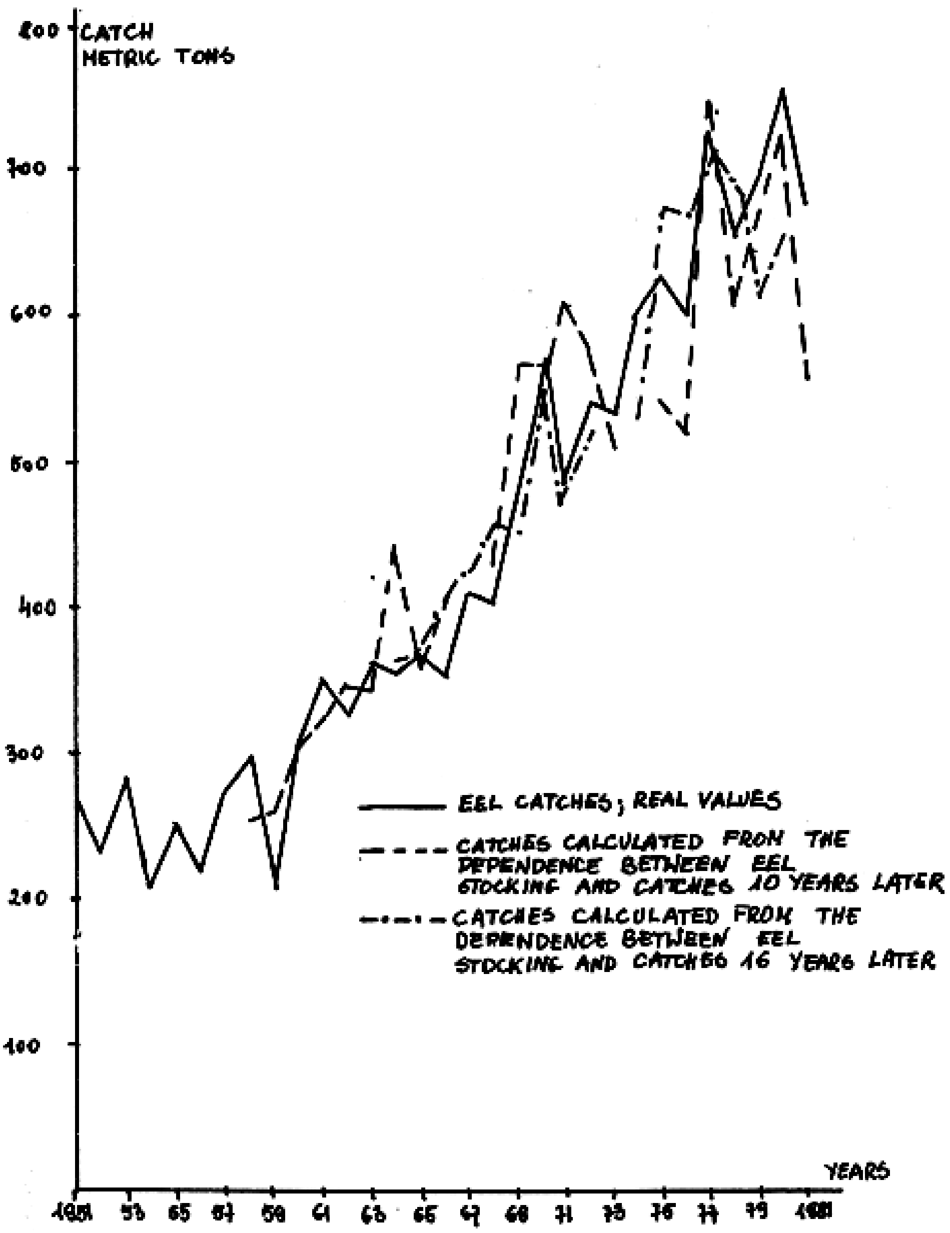

Fig. 3 Relationship between eel catches and eel stockings

STOCK ENHANCEMENT IN THE IRISH EEL (*Anguilla anguilla*) FISHERY

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CONTENTS

ABSTRACT

Data on elver recruitment and eel stocks in Ireland are reviewed. The annual catch of eels in Lough Neagh of the order of 600 to 800 t indicates an exceptionally high yield per unit area by northern European standards. The corresponding yield in the majority of lakes in Ireland is well below the average. Data on eel populations and on elver recruitment in Ireland are reviewed. It is concluded that the low eel yield results from topographical features of the river systems and from disruption of elver ascent by hydro-electric dams. Data on yield per recruit in the Lough Neagh fishery suggest that at least a tenfold increase in catch elsewhere in Ireland could be achieved by augmenting the existing system of elver transportation.

RESUME

C'est en 1959 que l'on a commencé en République d'Irlande à prélever des civelles à l'embouchure du Shannon pour les transporter, par voie terrestre, en amont. L'auteur décrit l'évolution des stocks et des captures (quantités et composition) par suite, en premier lieu, de la construction de barrages hydro-électriques et, en second lieu, du transport des civelles. Il passe en revue les travaux consacrés à l'évaluation des stocks d'anguilles et à leur régime alimentaire dans différentes parties de l'Irlande et aboutit à la conclusion que le transport des civelles devrait permettre de multiplier par 10 les rendements sans nuire aux stocks de poissons destinés à la pêche sportive.

1. INTRODUCTION

The mean annual catch of eels in Ireland (Republic) from 1970 to 1977 was 113 t, while the catch in Northern Ireland was 765 t (FAO, 1979). The eel fishery of Northern Ireland is based on two lakes; Lough Neagh and Lough Erne with by far the greater proportion coming from Lough Neagh (Black, 1981). The total area of lakes in the Republic is considerably greater than the combined area of these two and there are no significant differences in climate between north and south. There is accordingly reason to believe that the yield of eels in the Republic could be enhanced.

Eels have been traditionally caught by long line or by a variety of silver eel traps in rivers. Fyke nets were first used experimentally in 1961 but, in the course of the next 20 years, were adopted by only 15 fishermen in the Republic. The lack of enthusiasm for development by fishermen suggested that stocks were too low to provide a viable fishery in most cases. This suggestion was supported by the results of extensive fyke-netting surveys carried out by the author since 1965.

The major eel fishery in the Republic is based on the River Shannon, which has the most extensive catchment area and the greatest total area of lakes in the country. This fishery is owned by the Electricity Supply Board (ESB), which constructed a major hydro-electric dam at Ardnacrusha in 1928. Even though a flow of water was maintained in the River Shannon, by-passing the dam, it was apparent that the entry of elvers into the lakes had been seriously impeded. An elver pass was constructed at Ardnacrusha in 1958 and overland transport of elvers to Lough Derg began in 1959.

Overland transport of elvers to Lough Neagh has been in progress since 1933, with a break from 1948 to 1959 (Parsons et al., 1977) and to Lough Erne since 1960 (Moriarty, 1981). Elver catch data allow an estimate of yield per recruit to be made. The results of the fyke-netting surveys give evidence of low stocks in most Irish lakes and provide an explanation of the situation. In the light of this explanation and of the yield per recruit data an estimate of the potential yield following a stock enhancement programme is presented.

2. ELVER RECRUITMENT

Comparable data for elver catches are available for Lough Neagh (River Bann system, Fig. 1) and the Shannon Lakes. There is an unknown degree of escapement of elvers in the case of the Bann and the Shannon but it is generally believed that the catches in both cases represent a large proportion of the elver runs. The Bann traps, situated at Coleraine, are operated beside a substantial weir, which is likely to discourage direct ascent by the elvers. The Shannon traps are either situated at weirs or at the hydro dam at Ardnacrusha, which appears to attract the majority of the elvers. The Erne trap, at Ballyshannon, is operated at a hydro dam which controls the entire river. Elvers do not appear to use the salmon pass on this dam.

Mean annual catches for periods between 1960 and 1981 show that similar numbers of elvers enter the rivers Bann and Shannon while recruitment to the Erne is very much less (Table 1).

3. FYKE-NET SURVEY

3.1 Methods

Details of a number of these surveys have been published (Moriarty, 1979) and the fyke-netting technique has been assessed in Moriarty (1975). The results, summarized in Table 2, are based on a standardized effort of one net fished overnight in water between 2 and 3 m in depth. The net consists of a pair of funnel traps joined mouth to mouth by a single leader.

3.2 Results

The catch per unit of effort is taken as a measure of the numbers of eels in the stocks. Within a river system the numbers decrease with increasing distance from the sea. This is shown very clearly in the case of the Corrib system where the three lakes investigated lie on the main river. Eels must travel through the downstream lakes to reach the higher ones.

The decrease in numbers on the Shannon system is not so obvious and the distance from lake to sea in the case of the other three lakes has no apparent effect on numbers. In the case of the two rivers numbers are very much higher than in any of the lakes, with no direct relationship to distance upstream. An increase of 62 percent in numbers with time was recorded in Lough Derg, between 1969 and 1981.

Length frequencies change dramatically from downstream to upstream lakes: small eels are plentiful close to the sea and scarce at increasing distances. Large eels are scarce in the downstream lakes and much more numerous upstream. Age determination confirms that increasing length results from increasing age and shows that the eels in general take a number of years to reach the upper lakes. Small eels are plentiful in Lough Conn at 25 km from the sea and in Lough Gill at 4 km but scarce in Lough Arrow at 24 km while large eels are scarce in Lough Gill and Lough Conn.

The fish eaten are mainly perch, Perca fluviatilis, or cyprinids; salmonids are rarely present in the stomachs. Eels of less than 40 cm rarely eat fish in any case. In the River Blackwater fish become important in the diet of eels of over 40 cm but in the lakes do not appear to any marked extent at lengths of less than 50 cm. Where Asellus is abundant, fish are seldom eaten by eels of any size.

The stomach contents of samples of the eels were analysed with results shown in Table 3.

3.3 Discussion

Compared with the results from the two rivers, the catches in all the lakes are very low. There is no reason to believe that the nets operate any less efficiently in lakes than in rivers and, therefore, it appears that stocks per unit of area in the lakes are much lower than in the rivers. In the case of Lough Corrib and Lough Gill, which are very close to the sea and whose outflowing rivers provide no serious obstruction to the ascent of elvers, it appears that the natural run of elvers is insufficient to populate the available area of lake bed at the maximum possible density. It is possible that similar numbers of elvers enter the two rivers but yield much higher densities of eels since the area of river bed is relatively much smaller than in the lakes.

Even lower numbers of eels are present in the upstream lakes. Comparing the stock density of the rivers with that of the downstream lakes suggests that there is adequate space for many more eels to live in the downstream lakes and therefore no pressure to induce those which have arrived to migrate upstream through the lake system. The downstream lakes thus serve almost as a barrier to the continued migration of the growing eels. There is, in fact, a slow movement through the lakes so that the upstream lakes are not totally devoid of eels.

The low stocks in Lough Derg and Lough Arrow may both be explained by the presence of major obstructions to elver ascent in the firm of the hydro dam at

Ardnacrusha and a high waterfall close to the mouth of the Ballysadare River which drains Lough Arrow. Lough Conn is unusual in the Irish context in lying on a tributary of the River Moy which flows directly to the sea without passing through a lake system. All the other downstream lakes lie on the main rivers.

Lough Derg was first sampled in 1969. Very few of the eels in the samples were aged less than ten years. Elver transport had begun in 1959 and would not, therefore, have influenced the numbers in the samples. By 1981 it was clear that the continuing elver transport had brought about a marked increase in the yellow eel numbers and also had altered the length frequency distribution in favour of smaller eels.

Observations on the food of the eels indicated that neither in lakes nor in rivers were salmonids significant prey species. In many lakes fish of any species were rarely present in eel stomachs. In those where the piscivorous diet was normal, perch, cyprinids and eel were the usual food. Since perch and the cyprinids are prolific breeders, it is considered that there is no danger of enhanced eel stocks reducing the existing fish population by predation. In the lakes where Asellus is the dominant food of the eel there appears to be no risk of competition with salmonids and in the other lakes there was little evidence of eels feeding on the principal salmonid food species. Competition for food with cyprinds cannot be completely ruled out but observations to date have not suggested that this is likely to be serious. The most dense lotic water population of eels observed to date, that of the South Sloblands lagoon on the south coast of Ireland, co-exists with an abundant stock of rudd, Erythrophthalmus scardinius (Moriarty, 1972).

4. STOCKING AND YIELD DATA

In a review of eel stocking practices, Wickstrom (1979) quotes rates from as low as 6 to as high as 1 500 glass eels/ha. Tesch (1977) gives yield figures for market eels ranging from 0.03 to 40 kg/ha and states that average yields are between 3 and 10 kg/ha. Leopold (1980) provides figures for stocking rates and catch in a number of Polish lakes, with variations in stocking rate and in intensity of fishing. The maximum yields result from a combination of higher than average fishing effort and highest stocking rate, giving a mean yield of 2.39 kg/ha at a stocking rate of 128.8 elvers/ha.

In the case of Lough Neagh, the minimum annual catch is 600 t and a record catch of 1 020 t was made in 1979 (Black, 1981). The usual annual range for this lake of 39 000 ha is 600–800 t. The production of eels has remained high for many years and it is particularly interesting to note that the latest available catch statistics give the greatest catch on record both of silver and of yellow eels. This has been achieved in spite of a period marked by a high level of poaching and serious management difficulties. The mean annual number of elvers transported from 1960 to 1974 was 13.8 million (Parsons et al., 1977).

The numbers of elvers transported to Lough Erne are known with a fair degree of accuracy: the mean annual supply from 1960 to 1981 being 3.3 million. The catch of market eels from Lough Erne is reckoned to be up to 49 t per year (Black, 1981). There is an extensive lake system upstream of Lough Erne. The lakes of the River Shannon have a total surface area similar to that of Lough Neagh and have been supplied with eels at a similar, or possibly higher, rate. However, the yield per hectare of eels is very much lower: at approximately 1.4 kg/ha for the years 1976 to 1980, well below the average for German lakes and of a similar order to figures from Poland. Fishing on the Shannon lakes is exclusively for silver eels.

5. CONCLUSIONS

The situation of Lough Neagh has given it certain advantages for an eel production study. Firstly, the lake is a large one and has no outlet to other potential eel-producing waters. Secondly, elvers have been trapped and known quantities introduced to the lake for a considerable period. The catch figures are those which have been officially reported and therefore indicate a minimum. An unknown number of elvers reach the lake by making an unaided ascent of the River Bann but, as the weir at the trapping station forms a considerable obstacle, it is believed that the catch represents a high proportion of the numbers actually entering the system. Figures for production per unit area of lake surface are, therefore, if anything, an underestimate. The fact that they are well above average for northern European lakes therefore suggests that other lakes are producing eels at a level considerably below the maximum possible.

One factor which might contribute to the success of Lough Neagh is the paucity of its fish fauna. Cyprinids are represented by not more than six species and percids by only one. There could, therefore, be considerably less competition for food and less predation than in continental lakes. On the other hand, the water temperature in Lough Neagh rarely rises above 20°C and the number of species of invertebrates available as food is less than on the continent.

Figures relating directly to stock of elvers and yield of eels are very few. Leopold's (1980) data for Polish lakes indicate that yield varies with stocking rate. In his paper both stocking rate and yield are considerably lower than the Lough Neagh figures.

It is possible that, for reasons unknown, conditions in Lough Neagh are ideal for eels and superior to those in other lakes studied. This is hard to accept, particularly when temperature and sparse fauna are considered. The conclusion, therefore, is that the stocking rate in Lough Neagh, of 350 glass eels/ha is the best known figure to be applied to other lake systems. On this assumption, Table 4 has been compiled as a recommended programme for the larger and richer lakes of Ireland.

Since 1959 the Electricity Supply Board has transported elvers to the Shannon lakes at rates ranging from 29 to 770/ha, with a mean of 340/ha. The mean annual catch of silver eels for the years 1961 to 1970, before transplanting would have had any significant effect, was 19 900 kg. Unpublished age determinations by the author indicate that few female eels in the system become silver in less than 15 years and therefore an increased catch resulting from the transportation might be expected about the year 1975. The mean annual catch since then has been 35 000 kg with a record catch of 44 000 kg in 1980. This yield is still no more than 1.4 kg/ha, less than one tenth of the yield in Lough Neagh.

The transportation programme in the Shannon has not yet, therefore, yielded spectacular results. There are several possible explanations. Although the operation began in 1959, stocking at the rate of 350/ha or over was not achieved until 1966 so that considerable improvements in catches may yet take place. The fishing effort may not have been increased at a rate which would be sufficient to harvest the increased stocks efficiently. Finally, ecological factors in the Shannon lakes may prevent the development of eel populations of similar density to those inhabiting Lough Neagh.

The eel fishery of Ireland, therefore, presents two aspects of stock enhancement. In the case of the major fishery in the Shannon transportation of elvers at a rate known to yield excellent results has been in progress for 16 years. The catch has doubled in this period, but appears to be far below the potential value. In the case of the other lakes, a transportation scheme has been planned but has to-date been implemented only at a pilot stage. However, considerable details of the present stock situation in these lakes are available and will enable a very valuable monitoring of future developments to be made.

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Table 1 Mean annual quantities of elvers caught for transport (River Bann data from Parsons <u>et al.</u>, 1977)

	Period	Numbers (millions)	Weight (kg) Mean	SE
River Shannon	1972–81	16.6	5 529	1 053
River Erne	1960–81	2.3	776	135
River Bann	1960–74	13.8	4 613	546

Table 2 Numbers and length frequency of eels caught by fyke net

	Distance from sea (km)	Sampling effort (nets × nights)	Catch/unit effort	% Length Frequency (cm)		
LAKES				40	40–49	50
(1) Shannon System						
Derg (1969)	20	189	1.6	12	54	34
Derg (1981)		188	2.6	42	49	9
Key (1970)	185	208	1.5	7	39	54
(2) Corrib System						
Corrib	4	88	4.4	44	49	5
Mask	40	56	1.2	25	56	18
Carra	50	142	0.5	15	48	35
(3) Other Lakes						
Conn	25	48	1.8	63	29	8
Arrow	24	144	1.2	19	39	42
Gill	4	104	1.2	61	28	11
(4) Rivers						
Barrow	75	16	12.8	12	47	41
Blackwater	40	18	7.8	27	21	52

Table 3 Dominant food organisms

<u>Asellus</u> spp.	Lakes Derg, Key, Mask, Arrow, River Barrow
Chironomidae and fish	Lough Corrib
Trichoptera and fish	Lough Gill
Gastropoda and fish	Lakes Carra, Conn
Ephemeroptera and fish	River Blackwater

Table 4 Eel yield potential at 20 kg/ha and stocking requirements at 350 elvers/ha in Irish lakes of area 500 ha and conductivity 125 us/cm (Physical data from Flanagan and Toner, 1975)

	Area (ha)	Potential Yield (kg)	Stocking Requirement (kg at 3 000 elvers/kg)
Shannon Catchment			
Derg	11 635	233 100	1 396
Derravaragh	1 100	22 000	132
Ennell	1 400	28 000	168
Gara	1 100	22 000	132
Key	900	18 000	108
Owel	950	19 000	114
Ree	10 500	210 000	1 260
Sheelin	1 900	38 000	228
Corrib Catchment			
Carra	1 500	30 000	180
Corrib	17 000	340 000	2 040
Mask	8 000	160 000	960
Other Lakes			
Arrow	1 250	25 000	150
Carrowmore	960	19 200	115
Conn	5 000	100 000	600
Cullin	1 100	22 000	132
Gill	1 400	28 000	168
Gowna	1 100	22 000	132
Oughter	1 300	26 000	156
Ramor	800	16 000	96
Total including smaller lakes	72 223	1 440 000	8 666

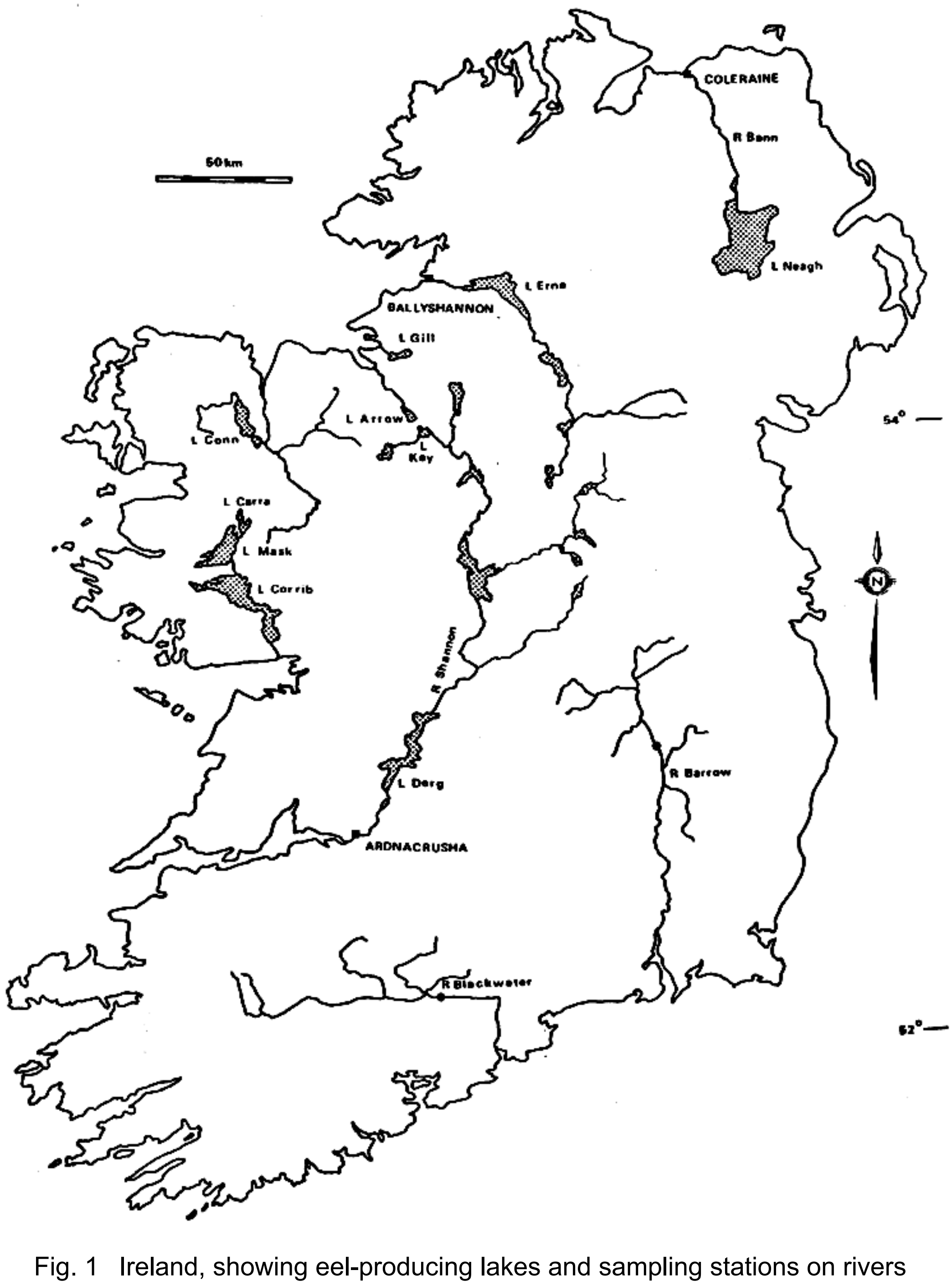

Fig. 1 Ireland, showing eel-producing lakes and sampling stations on rivers

THE ENHANCEMENT OF EEL STOCKS IN FINLAND; A REVIEW OF INTRODUCTION AND STOCKINGS

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CONTENTS

ABSTRACT

Eel populations in Finnish fresh waters have never been dense because of Finland's northern location. Young eels, which in the past migrated up rivers to lakes, are nowadays unable to reach the lakes because most rivers are blocked by dams. Therefore, stocking represents the only possibility for maintaining eel populations in inland waters.

Stocking experiments began on a small scale as early as 1894. During the last 20 years, stocking has been carried out to some degree almost every year. In general, small yellow eels have been used as stocking material; glass eels (elvers) have been stocked only a few times. Most of the stocking has been done in southern Finland.

Stockings have generally been successful: in particular, the results of the relatively large introductions of glass eels (elvers) in the sixties are clearly visible in Finnish catch statistics. The eel catch in inland waters has grown from 9 t in 1976 to 63 t in 1980. In some registered cases, fishermen have caught almost 30 percent of stocked eels with ordinary fishing methods. A survival rate of over 70 percent within nine years following introduction has been recorded using rotenone sampling.

The main difficulties in eel stocking in Finland are the cold weather in March–April during the elver stocking period and the possibility of elvers being carriers of viral fish diseases. Therefore, it has been considered that the stockings should be made with reared fingerlings which can be released during the summer after careful disease control.

RESUME

Les populations d'anguilles n'ont jamais été très denses dans les eaux douces de Finlande, ce qui tient à la position septentrionnale de ce pays. Les jeunes anguillcs qui, autrefois, remontaient les fleuves pour s'installer dans les lacs en sont aujourd'hui empêchées par les barrages que l'on a édifiés sur la plupart des cours d'eau. Le repeuplement est donc le seul moyen de conserver des populations d'anguilles dans les eaux intérieures.

Les premières expériences de repeuplement ont été effectuées, sur une échelle modeste, en 1894. Depuis vingt ans, on repeuple les eaux presque chaque année en employant en général de petites anguilles jaunes. Les civelles transparentes ont rarement été utilisées. On repeuple essentiellement les eaux du sud de la Finlande.

Les opérations de repeuplement ont en général, été couronnées de succès; les statistiques montrent en particulier que les captures se sont nettement améliorées à la suite des introductions relativement importantes de civelles transparentes au cours des années soixante. Les captures d'anguilles dans les eaux intérieures sont passées de 9 t en 1976 à 63 t en 1980. Dans certains cas, les pêcheurs ont capturé, avec des méthodes ordinaires de pêche, près de 30 pour cent des anguilles de repeuplement. Grâce à l'utilisation du roténone, on a réussi à obtenir un taux de survie supérieur à 70 pour cent neuf ans après l'introduction.

Le repeuplement en anguilles des eaux finlandaises se heurte essentiellement à deux problèmes. D'une part, le temps est encore très froid en mars-avril lorsque l'on met à l'eau les civelles et, d'autre part, celles-ci risquent d'être porteuses de virus transmissibles aux autres poissons. Il faudrait donc utiliser des alevins d'élevage qui pourraient être mis à l'eau durant l'été après un examen sanitaire soigneux.

1. INTRODUCTION

Eel populations in Finnish fresh waters have probably never been dense, because of Finland's northerly geographical location and distance from the Atlantic. Young eels have, however, migrated upriver to inland waters previous to the commencement of river damming operations for electric power plants. For instance, some examples of upstream migrating eels have been caught by lamprey fishing. The eels were all females and, as is usual in Finland, were rather large (27–54 cm long) (Nordqvist, 1903; Jarvi, 1909 and 1936).

For these reasons, eel fishing has been of only slight significance in Finland. Nevertheless, in some areas fishing for silver eel took place in rivers and on the Baltic coast (Jarvi, 1932) but this ceased almost entirely after the main rivers were closed in the thirties. The first eel stockings were made as early as 1894 in an attempt to improve eel fishing possibilities (Brofeldt, 1920). Eel introductions and stockings have, however, been rather sporadic and not until the sixties was greater attention given to this practice (Toivonen, 1966).

This report deals with eel introductions and stockings from the year 1960, some individual results from earlier years and especially discusses the present freshwater eel fishery, which is almost totally dependent on stocking.

2. STOCKING

2.1 Origin of the material

The number of eels reaching the Baltic coast of Finland is so small that it is unprofitable to acquire stocking material from the river mouths. Therefore, young yellow eels have been introduced from Denmark, as well as from Germany and in smaller amounts from Sweden. During the last two decades the material for introductions has come mainly from Denmark but these introductions have now ceased because the export of small, under-sized eels from Denmark is forbidden. Glass eels and/or elvers have been introduced three times in the sixties and once in the seventies (see also Table 1).

Small yellow eels for introduction were transported by tank trucks and elvers in moist boxes by air.

2.2 Amounts stocked

The eel stockings carried out in Finland during 1960–79 have been listed in Table 1. This shows that stockings were actively carried out in the sixties, with a mean yearly stocking of 830 000 specimens, of which 781 000 (94 percent) were elvers and 48 500 small yellow eels. During the seventies, the stocking rate dropped to only 57 200 specimens per year, of which 36 800 (64 percent) were elvers and 20 400 yellow eels. The main reason for this decreasing was the risk of transporting communicable fish diseases together with the stocking material.

Stocking material was distributed among the statistical areas used by the Finnish Game and Fisheries Research Institute, as shown in Fig. 1. Most stockings were directed to southern Finland's small inland waters (Area 1) and to the area called Lake Finland (Areas 2, 3 and 4). Stockings of small yellow eels have clearly been concentrated in southern Finland (Areas 1 and 4, see Fig. 1).

The mean size of elvers introduced to Finland has been about 0.3 g, while that of small yellow eels has varied from 3.5 to 56.2 g (see also Table 1). During the sixties it was still possible to obtain very small yellow eels with a mean weight of 8.4 g for introduction but during the seventies the mean weight rose to 44.5 g.

The value of the stocking material in the sixties can be calculated using current eighties prices at 820 000 Finnish marks (FIM), which corresponds to about U.S.$ 200 000. During the seventies this value was about 300 000 FIM (U.S.$ 70 000).

3. RESULTS OF INTRODUCTIONS AND STOCKINGS

Results of stocking in Finland can be examined both on the basis of some individual cases and also by comparing the stockings made in the sixties with the catch in the second half of the seventies.

3.1 Individual cases

Yellow eel stockings in some small forest lakes at the Evo Inland Fisheries and Aquaculture Research Station (61°10'N) in the beginning of this century have given the results shown in Table 2. Fishing for eels in these lakes has been irregular and done using ordinary fishing methods; but because the lakes have no outlets, the calculated survival rates can be considered as relatively reliable. The mean survival rate has been 27.4 percent of stocked eels, and the size of caught specimens about 1 kg (Brofeldt, 1955). This is the equivalent of a catch of approximately 200 kg/1 000 stocked specimens.

Table 2 also shows the results from two lakes in northern Finland near Rovaniemi (66°30'N), which were stocked in 1954 and treated with rotenone in 1963 and 1964 (Toivonen, 1966). In the smaller lake (Pohtimolampi) the stocking rate has probably been too large, taking into consideration the surface area and northern location of the lake, and the very small mean weight of caught specimens, only 60 g. The survival rate in this case has, however, been exceptionally high: 72 percent of stocked eels within nine years. Because of poor growth, the catch in this lake was only 43 kg/1 000 stocked specimens. In the other lake (Pasmajarvi), some of the eels may have escaped for their spawning migration, because in sampling the catch with rotenone only 20 percent of the eels stocked were recovered; the mean weight of specimens caught was 600 g. However, the catch was nonetheless about 120 kg/1 000 stocked specimens.

The results presented here clearly show that the survival rate of young yellow eels is very high, and stockings are therefore rather profitable. For elver stockings such individual results cannot be presented, because the first stockings of this kind were made in the second half of the sixties and all the eels from such stockings have not yet been fished out.

3.2 Catch statistics

Eel has been considered as a separate species only since 1976 in the Finnish Game and Fisheries Research Institute's official fisheries statistics (see Table 3). These statistics can be considered reliable from the year 1977 onward, as the results of non-professional fishermen were used as a basis for assessment from 1975 (Lehtonen and Salojarvi, 1978). The total catch of eel in the marine fishery has been steady but inland catches have grown slightly since 1977.

The catch of eel from inland waters is based almost totally on stocking. From ageing studies it appears that catches made in the second half of the seventies are derived from stockings made in the sixties. Since at that time the yearly amount stocked was about 830 000 specimens, it can be estimated that they have produced a catch of circa 60 t/year in the second half of the seventies. This is equivalent to a catch of approximately 72 kg/1 000 stocked specimens. In Finland fishing and marketing of eel are not effectively organized and, for example, there is almost no fishery for silver eel in rivers. Furthermore, according to catch statistics over 96 percent of the total catch is caught by non-professional fishermen. These estimates are therefore likely to be low.

The best picture of the relationship between stockings and catch can be obtained by examining stockings and eel catches in various statistical areas. The greater part of the eel catch is taken by non-professional fishermen and in 1975 the eel catch was 45 t (Lehtonen and Salojarvi, 1978) and 66 t in 1978 (Lehtonen and Salojarvi, unpublished data). The mean yearly catch divided according to various statistical areas is shown in Fig. 2. The figure clearly shows how stockings (see Fig. 1) in the sixties are mirrored in catches in the second half of the seventies. For example, southern Finland's small inland waters (Area 1) received 18 percent of all eel stockings in the sixties, and the eel catch has been about 24 percent of the yearly total catch of eels. In some areas, eel fishing is rather low compared to the amounts stocked; for example, Area 2 (eastern Finland) received 18 percent of all eels stocked in the sixties, but the eel catch here has been only 9 percent of the annual total. The most important stocking area (4) received 43 percent of the elvers and young yellow eels stocked in the sixties and this is reflected in the area's large share (49 percent) of the whole country's eel catch.

3.3 The profitability of stockings

The result of eel stockings in the sixties was a catch of about 72 kg/1 000 stocked specimens and in some individual cases even over 200 kg. A comparison between the different areas shows the best result to have been obtained in Area 1 (southern Finland), where the catch reached about 90 kg/1 000 stocked specimens. This compares with about 76 kg in Area 4 and only a little over 10 kg/1 000 specimens in northern Finland (Areas 6 and 7). Of course, the size of the catch depends greatly on the intensity of fishing, which is low for eels in those areas where the eel is rather unknown.

It is difficult to come to any conclusions as to differences in the results between stockings of elvers and those of young yellow eels. In Areas 1 and 4, stockings with yellow eels accounted for a relatively great proportion of all stockings (see Fig. 1), which may to some extent also be reflected in the catches. Eel fishing has a long history in these areas and, therefore, catches are relatively better than in other areas. In central Finland (Area 3) stocking with yellow eels has been almost insignificant, but the percentage ratio of catch to stocking is almost the same as in Areas 1 and 4. Therefore, it seems that elver stockings in 1966–68 produced the most important part of the whole country's present eel catch.

By comparing the expenses incurred in stocking with the value of the catch, it is possible to make estimates of the economic profitability of stocking. In the sixties the cost of stocking was about 820 000 FIM, i.e., 82 000 FIM per year, calculated according to 1980 prices. The value of the present yearly eel catch in inland waters is about 600 000 FIM, i.e., about seven times annual stocking expenses. If inflation is taken into account in a comparison with the real stocking expenses incurred in the sixties (Toivonen, 1966), the value of the present catch is more than 50 times that of expenses.

4. PRESENT AND FUTURE ACTIVITIES

Stocking with elvers presents certain difficulties in Finland. Firstly, at the time of year when elvers can be introduced, i.e., in March–April, the lakes are still very cold and under ice cover. Secondly, and more important, is the possibility that elvers can be carriers of viral fish diseases which creates a certain risk, because Finland is, as far as is known, free of such diseases.

Small, under-sized yellow eels can no longer be introduced, due to new legislation by the exporting countries. This type of stocking is also rather expensive, although it still might be economically profitable.

No special negative effects of eel stockings have been found and therefore these activities should be continued. Because of the difficulties mentioned above, it is considered that stockings should be made with reared fingerling eels which can be released into waters during the summer, after a few months of careful control for diseases especially those arising from viruses.

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Table 1 Eel stocking in Finland in 1960–79

Year	Origin*	Elvers Number	Mean Weight (g)	Origin*	Yellow Eels Number	Mean Weight (g)	Total Number
1960							
1961				S	53 000	3.8	53 000
1962				D	143 000	3.5	143 000
1963							
1964				D	83 000	4.7	83 000
1965				D + S	114 000	7.7	114 000
1966	F	1 077 000	0.3	G	53 000	10.8	1 130 000
1967	F	3 935 000	0.3				3 935 000
1968	F	2 803 000	0.3	D	4 000	40.3	2 807 000
1969				D	35 000	39.9	35 000
1960–69		7 815 000	0.3		485 000	8.4	8 300 000
1970				D	30 000	40.0	30 000
1971							
1972							
1973							
1974							
1975				D	38 000	40.3	38 000
1976				D	19 000	40.5	19 000
1977				D	30 000	29.6	30 000
1978	F	368 000	0.3	D	12 000	38.7	380 000
1979				D	75 000	56.2	75 000
1970–79		368 000	0.3		204 000	44.5	572 000
1960–79		8 183 000	0.3		689 000	19.1	8 872 000

* The origin of the material (Denmark = D; France = F; Germany = G; Sweden = S)

Table 2 Eel stockings and their results in some small forest lakes in southern Finland (61°10'N) (Brofelt, 1920 and 1955) and two results from northern Finland (66°30'N) (Toivonen, 1966)

	LAKE	AREA	STOCKING YEAR	NUMBER OF SPECIMENS STOCKED	CATCH AS % OF STOCKED SPECIMENS
Southern Finland					
1.	Opiston Valkjarvi	4.2	1900	75	42.7
2.	Hautajarvi	5.3	1911	1 500	29.9
3.	Valkea-Mustajarvi	13.9	1911	1 100	27.0
4.	Majajarvi	3.9	1911	300	23.7
5.	Mustajarvi	2.9	1911	1 000	20.6
6.	Haaraj Valkjarvi	3.5	1911	500	18.6
Northern Finland					
7.	Pohtimolampi	3.7	1954	1 000	72.0
8.	Pasmajarvi	64.0	1954	1 000	20.0

Table 3 Finland's eel fishing statistics from 1976 to 1980 Statistics from the year 1976 are unreliable Catches given in 1 000 kg

YEAR	SEA FISHERIES	INLAND FISHERIES	TOTAL CATCH
1976	19	9	28
1977	16	47	63
1978	15	62	77
1979	16	61	77
1980	16	63	79

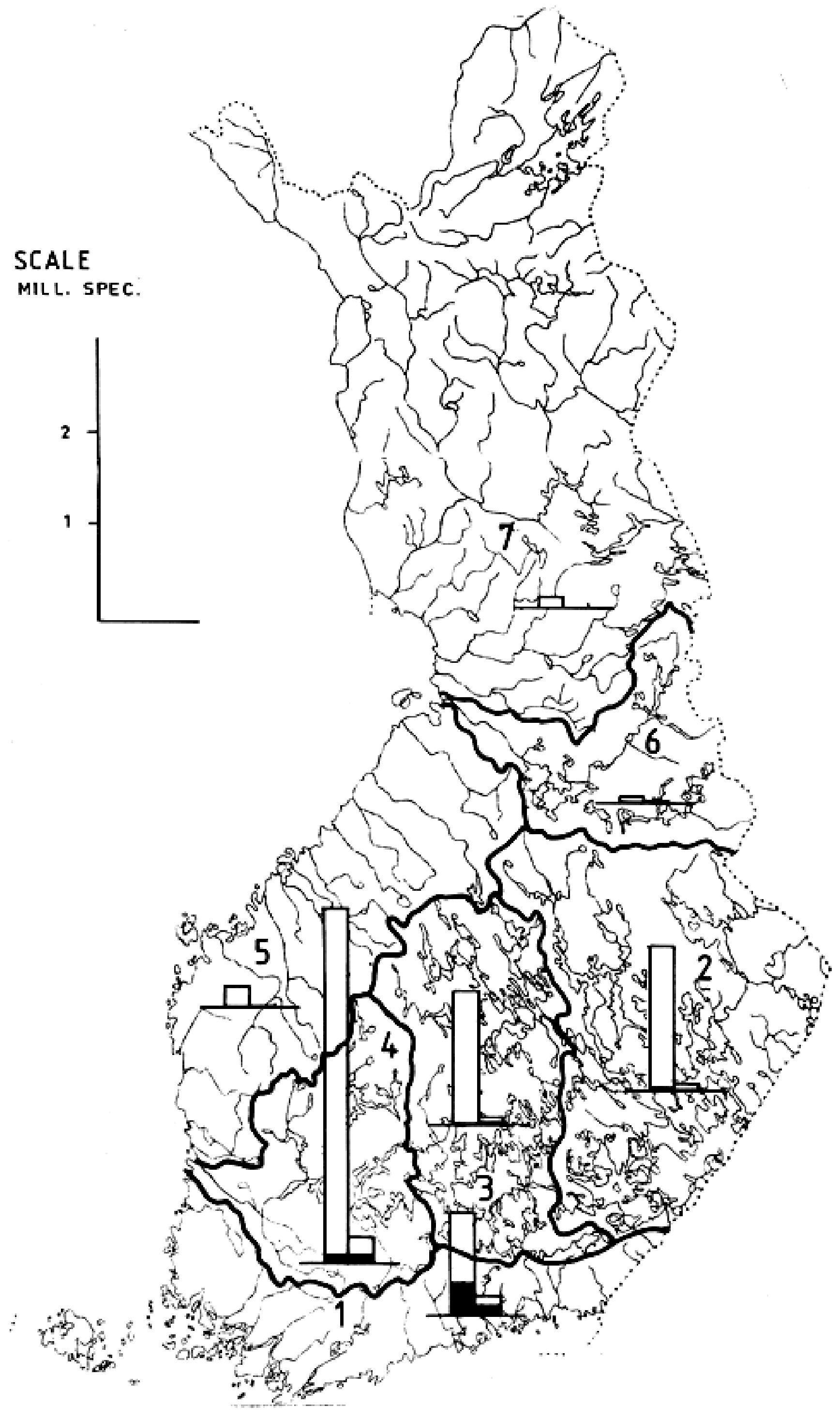

Fig. 1 Eel stockings in Finland in 1960–69 (left columns) and in 1970–79 (right columns) in various statistical areas. Shaded parts represent yellow eel stockings and light parts elver stockings

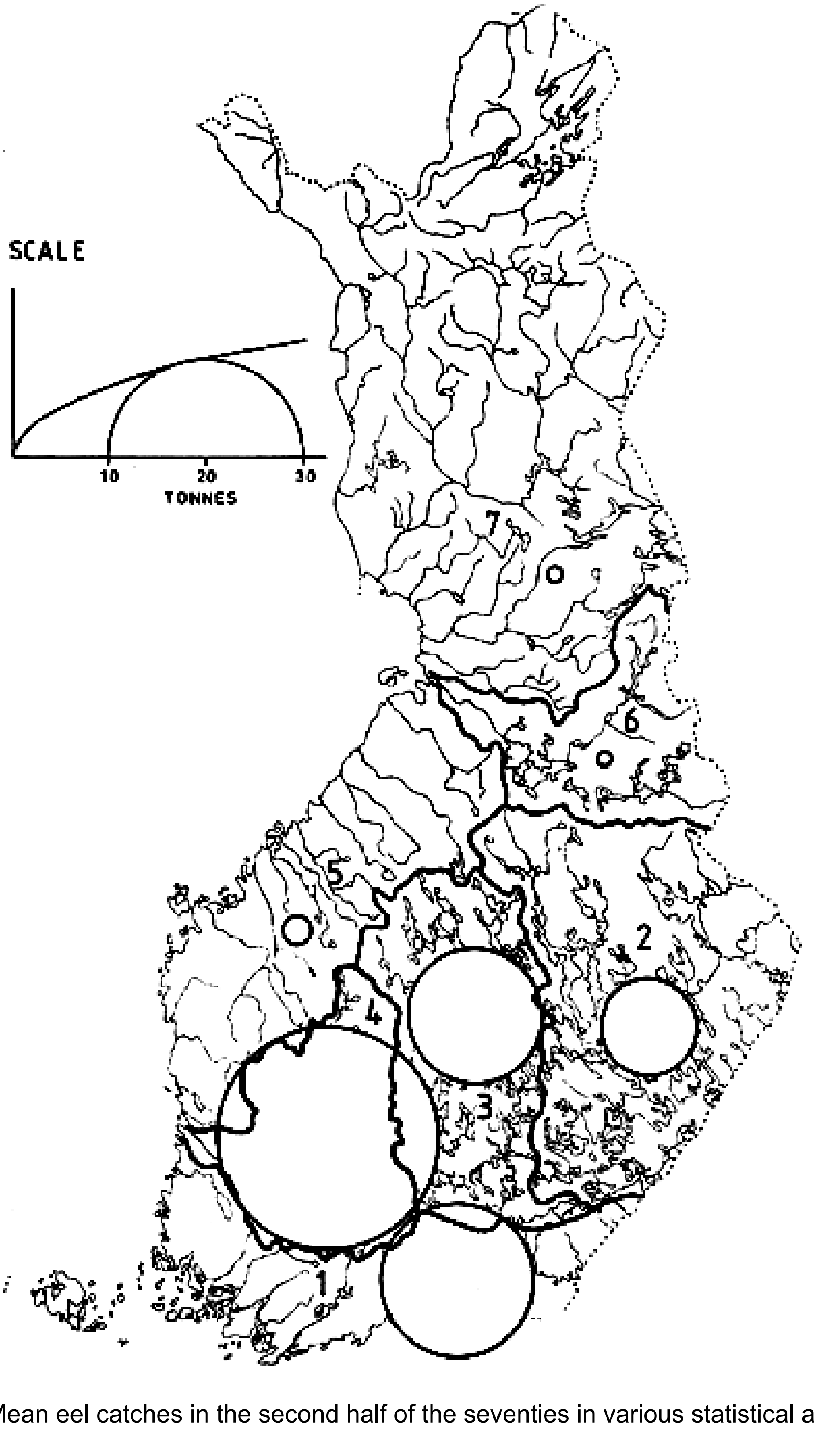

Fig. 2 Mean eel catches in the second half of the seventies in various statistical areas

THE SWEDISH EEL STOCKING PROGRAMME

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CONTENTS

ABSTRACT

The drastic decline in catches of silver eel and in upstream-migrating yellow eel have stressed the need for restocking Swedish waters.

Traditionally, relatively large yellow eel (10–100 g each) caught in the sea or during their migration in rivers are used for stocking. Since 1976 elvers have been imported from France and stocked mostly in lakes and in the Baltic Sea. Some of the elvers have also been grown to a larger size in fish farms and subsequently used as stocking material or as seedfish for further culture.

Despite a long tradition of stocking lakes with eels (at least with the large specimens), the knowledge of stocking density, returns, economics etc., is poor. In order to increase that knowledge and to estimate the importance of eel stocking, a project was begun in 1977 within which the dynamics of a number of yellow eel populations along the Swedish coast and in some rivers were studied in order to determine the influence and effect of stocking. As part of the investigation a few lakes were stocked in 1979–80 with known numbers of large yellow eels, elvers and intermediate-sized eels from a fish farm, respectively. The eel populations of these lakes were then studied with respect to downstream migration, growth, sex ratios, predation on eels, etc.

RESUME

La diminution considérable des captures d'anguilles argentées et d'anguilles jaunes remontant les fleuves a montré qu'il était indispensable de repeupler les eaux suédoises.

La méthode traditionnelle consiste à utiliser des anguilles jaunes d'assez grande taille (10–100 g chacune) capturées en mer ou dans les cours d'eau durant la migration. Depuis 1976, on importe de France des civelles que l'on emploie essentiellement pour repeupler les lacs et la Baltique. Des civelles sont également élevées dans des établissements piscicoles; lorsqu'elles ont atteint une taille suffisante, on s'en sert pour repeupler les eaux ou on les conserve comme géniteurs.

Le repeuplement des lacs en anguilles (du moins, avec de grandes anguilles) est une tradition déjà ancienne mais on manque de données sur la densité, la rentabilité, etc. de ces opérations. Pour remédier à ce problème et évaluer l'importance du repeuplement en anguilles, on a lancé en 1977 un projet consistant à étudier la dynamique d'un certain nombre de populations d'anguilles jaunes, le long des côtes suédoises et dans divers cours d'eau, afin de déterminer l'influence et l'effet du repeuplement. Dans le cadre de ces recherches, on a repeuplé quelques lacs en 1979/80 avec un nombre déterminé de grandes anguilles jaunes, de civelles et d'anguilles de taille intermédiaire provenant d'un établissement piscicole. On a ensuite commencé à étudier les populations d'anguilles de ces lacs: migration vers l'aval, croissance, taux de masculinité, prédateurs, etc.

1. INTRODUCTION

The stocking of lakes with eels is an old tradition in Sweden. As early as the 18th century lakes were stocked with eels (Gyllenborg, 1770). Trybom (1893) recommended trapping and building of eel ladders in order to improve the fishery and to distribute eels into new waters.

The commercial catch of eel in Sweden has decreased rather drastically in the last 15 years (Fig. 1).

The decline of the Baltic eel population has been described in detail by Svardson (1976) and the ultimate cause seems to be a decrease in the immigration of elvers and young yellow eels. Svardson discussed changes in the North Sea as possible reasons for the reduced immigration of glass eels including a lower frequency of westerly winds, lower water temperature and a more Arctic predator fauna. All these factors resulted in more unfavourable conditions for the drifting glass eels. The decrease in immigration, which has become apparent along the coast of Sweden, is shown in Fig. 2. The decline of the Baltic eel population has also appeared as a diminished catch of eels per unit effort, both in Sweden and in Denmark (Hoffman et al., 1979; Neuman and Thoresson, 1981). The average weight of silver eels has increased, probably as an effect of better growth due to decreased intraspecific competition within this smaller population (Hoffman et al., 1979; Neuman and Thoresson, 1979; Neuman and Thoresson 1981).

In order to improve the low catch, large-scale introductions of elvers were proposed by Svärdson (1976) and some introductions of elvers have actually been undertaken since then. Elvers (about 1.5 t) were imported from France 1976–80 and stocked mostly along the coast and in lakes. Yellow eel, generally about 35–45 cm in length, have been sorted out from the commercial catch in the Straits of Öresund and on the west coast for stocking for many years. In laters years also intermediate-sized eels have been cultured for stocking, at a fish farm using heated water. Lake Vanern, the largest lake in Sweden, has been stocked since 1900 with elvers and small yellow eels trapped at the downstream dams of the lake as well as larger yellow eels.

The extent of the total stocking activity for the last three years has been about 250 kg of elvers, 14 t of yellow eels and 150 kg of cultured eel annually.

Since 1979 the Swedish Board of Fisheries has had about Sw.Cr. 425 000 available annually for actual eel stocking experiments. Other funds pay for additional stocking beyond this sum.

Although the stocking of lakes with eel has been practised for many years, not much is known about the economical and ecological results. An evaluation project was started in connexion with the more intensified stocking programme. Hopefully, this project will lead to an increase in knowledge about eels, with special emphasis on stocking and stocking results.

2. MATERIAL AND METHODS

2.1 Size, age and sex ratio

It has been suggested that large-scale stocking of Swedish waters be done with elvers, i.e., more or less pigmented small eels (≤10 cm) with at least outer pigment on the tail (EIFAC, 1981). As the Baltic eel stocks, except in the southernmost parts, are recruited from yellow eels which are larger and older than glass eels, elvers planted along the east coast would form well defined new year-classes in the population. These “artificial” year-classes are believed to change size and age distributions in favour of smaller and younger eels.

Svärdson (1976) suggested that sex ratios in eel populations could be used as an index of abundance. According to Svärdson, females have developed an effective dispersal mechanism but the males often stay and become overcrowded in coastal and estuarine waters. This difference in behaviour is thought to be the evolutionary reproduction strategy of this species, allowing females to grow big and produce high numbers of eggs.

To estimate the value of stocking the Baltic with eel, yellow eels were sampled annually from ten stations. Six of the stations are situated along the coast of Sweden and four of them are traps in rivers (Fig. 3). From each station 100 eels have been sampled annually, since 1977. The eels were delivered deep-frozen to the laboratory and when almost thawed they were analysed for weight, length and sex. Age was determined on ground otoliths in both transmitted and reflected light. Sexing was performed in the traditional way, i.e., gross morphological examination of the gonads. Histological slides were made according to Dolan and Power (1977) from all organs or Syrski and from all undifferentiated specimens longer than 200 mm.

2.2 Trial lakes

As another attempt to increase knowledge on eels and eel stocking, six lakes were stocked with known numbers of the different sized material described earlier. Information about the lakes and the stocking material used are summarized in Table 1 and in Fig. 3. The populations in these lakes were studied with regard to downstream migration, growth, sex ratio, predation, etc.

2.3 Miscellaneous

Sub-cutaneous dye-marking with Alcian blue (Hart and Pitcher, 1969) has been tried in connexion with coast stockings with yellow eels (35–45 cm in length). Observations made by fishermen and from test fishing are expected to give more direct information about both the marking method and value of stocking.

As a very valuable supplement to the more practical work numbers of ascending eels from 22 rivers were collected continuously (Fig. 4).

3. RESULTS

As a preliminary to the evaluation project the literature on eel stocking was studied. Stocking densities used or recommended in Europe as well as the recorded recapture rates have been summarized by Wickström (1979) who recommends annual stocking with about 100 elvers or 20 yellow eel/ha in medium and high productive waters. In waters with poor nutrient supply 25 elvers or five yellow eels/ha/year may be sufficient. Intermediate-sized eel from fish farms or small yellow eel fall about half way between these values. The economics of the various stocking materials was also discussed and it may be concluded on the basis of prices and knowledge in 1979 that stocking with big yellow eels seemed to be the most economic. The difference in time until recapture played an important role in these calculations.

The otoliths sampled and the data on weight, length and sex have not been completely analysed yet. However, the size distributions from each sampling station are summarized in Figs. 5 and 6.

In the trial lakes a few eels have been trapped in the outlets. In Lake Ången, which was stocked with yellow eels (average length 370 mm) in autumn 1979, about 5 percent migrated downstream in the following spring. Of the cultured eels (average length 117 mm) stocked in Lake Fardume marsh in autumn 1980, only a few specimens were caught during 1980 and 1981.

Some results have also been obtained from lakes not directly included in the project. Fig. 7 presents the yield and numbers of eels stocked into three lakes. Important eel fisheries have built up in Lake Mälaren and Hjälmaren, which must be based mainly on stocking. Natural recruitment appears very low from the few ascending eels trapped in nearby rivers. Unfortunately, the stocking material varied much in size (and age) in these lakes and in many others, which makes comparisons and correlations difficult. In an attempt to facilitate comparisons "eel stocking units" were used in Fig. 7. Such units take into account our recommended stocking densities, which, in turn, take expected survival, sex ratio, etc., into consideration (Wickström, 1979). Expressed in these units about 7.5 elvers are comparable to about 2.5 10-g eels which, in turn, are equivalent to one 100-g eel. However, no correlations have been calculated as we do not yet know accurately the age of eels in the commercial catch from these lakes.

4. DISCUSSION

The decline of the Baltic eel population is believed to reflect some climatological changes in the North Sea (Svärdson, 1976). According to Hansen et al. (1981) temperature in the Northern Hemisphere decreased by about 0.5°C between 1940 and 1970 (despite a rapid CO_2 build-up during the same time period). This is coincident with the negative trend in numbers of eels ascending Swedish rivers, reported by Svärdson (1976) (see also Figs. 2 and 9). Hansen et al. (1981) also described an increase in temperature of about 0.2°C since 1970 in the Northern Hemisphere. Whether this will create better conditions for survival of eel larvae and glass eels drifting in the Atlantic Ocean and in the North Sea, will not show up until several years after the inflexion in 1970. If this is indeed the case, immigration of elvers may have slowly increased from 1973 and an increase in commercial catch can be expected in 1983 at the earliest (assuming a silver eel age of ten years). We have no indications of such a development in immigration, possibly due to disturbance from annual fluctuations. Results of our stocking activities, however, could very well be "disturbed" by this climatological change.

As the Swedish eel fishery has already decreased considerably and is expected to decrease even further, recruitment must increase quickly. We must, therefore, use a combination of the different size of eel available for stocking, big yellow eels for recapture some few years later and elvers for a longer-term improvement. With their intermediate size and recapture time, cultured fingerlings play an important role in this plan. Unfortunately, the size (and age) of yellow eels used for stocking coincides with the natural immigrants in the Baltic area (Ask et al., 1971) which creates difficulties in interpretations of sampling results.

The numbers of immigrating elvers and yellow eels have decreased in the River Göta Älv, as depicted in Fig. 2. This is obvious if we, like Svärdson (1976) measure the amounts in kilogrammes. During this period of decline the average weight, calculated from observed numbers/kg, has also decreased (Fig. 8). This can be due to some technical changes of the eel ladder or changes in water-flow regimes, etc., allowing the smallest eels to ascend more easily. If this is the case, one might expect that ascending eels are smaller than but as numerous as formerly. However, in Fig. 9 the calculated numbers are presented and a negative trend is obvious. Thus, ascending eels have decreased in both weight and numbers. The proportion of older eels ought to increase when the inflow of elvers diminishes. Our observations are contradictory so we have to find another explanation. Formerly, when elvers and small yellow eels were more abundant in the River Göta Älv, predation and competition from large eels presumably reduced the proportion of elvers (Moriarty, 1978). Nowadays, the abundance of large eels is lower and the proportion of surviving small yellow eels and elvers can increase. If this is true, the average weight will increase if and when elver immigration increases in the future.

The import of elvers is essential for our stocking programme. Unfortunately, importation has not proceeded as expected, due mainly to a fear of introducing fish diseases.

Infectious pancreas necrosis (IPN) virus has been discovered in elvers both from France and the United Kingdom (Castric and Chastel, 1980; Hudson et al., 1981). Elvers may possibly act as carriers for IPN and may infect salmonids in both culture and natural waters. The former import of elvers from France was, therefore, prohibited by the Swedish authorities in 1981. A quarantine station has now been built in southern Sweden and in 1982 elvers will be imported from the River Severn in the United Kingdom. If the elvers are disease-free, after one month in quarantine and two months in isolation, they can be used for culture and stocking.

This station will simplify import procedures and perhaps elver sources other than the River Severn can be used in future. This will guarantee the supply of elvers and can extend the elver import season considerably. The eel stocking programme can then run without hindrance and if higher proportions of elvers and cultured fingerlings are used, resulting changes in the population will be easier to interpret.

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ble 1 Data on the trial lakes stocked with eel

Name	Angersjon	Angen	Ommen	Frisksjon	Gotemaren	Fardume trask
Locality	63°37'N 19°48'E	58°45'N 17°11'E	58°00'N 16°28'E	57°56'N 16°42'E	57°29'N 16°35'E	57°47'N 18°55'E
Area (ha)	127	240	205	275	305	339
Condition	mesotrophic but acid	mesotrophic	Mesotrophic	mesotrophic	mesotrophic	oligotrophic but shallow & “productive”
Fish species	perch, pike, burbot and roach	perch, ruffe, pike, burbot, bream and eel	perch, roach, bream, rudd tench and eel	perch, ruffe, roach, bream, tench, eel and crayfish	perch, ruffe, roach, bream, white bream, eel and crayfish	perch, ruffe, pike, roach, rudd, tench & crucian carp
Stocking date	29/5/79	14/9/79	27/6/79	27/6/79	16/9/80	2/9/80
Nos. stocked	about 6 000 (elvers)	about 5 000(yellow eels, average length 370 mm)	about 12 000(elvers)	about 28 000(elvers)	about 37 000 (cultured eels, average weight 4 g)	about 53 000 (cultured eels, average length 117 mm)

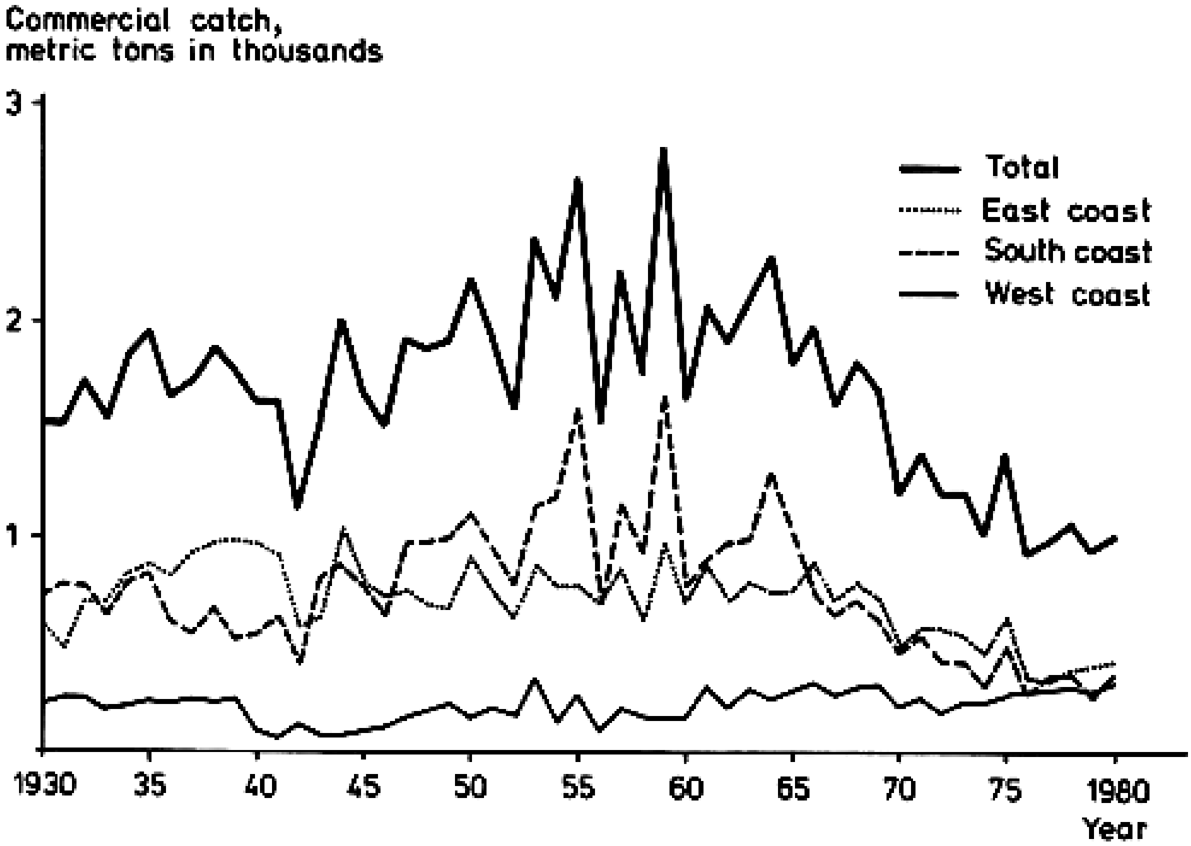

Fig. 1 The commercial eel catch in Sweden 1930–80

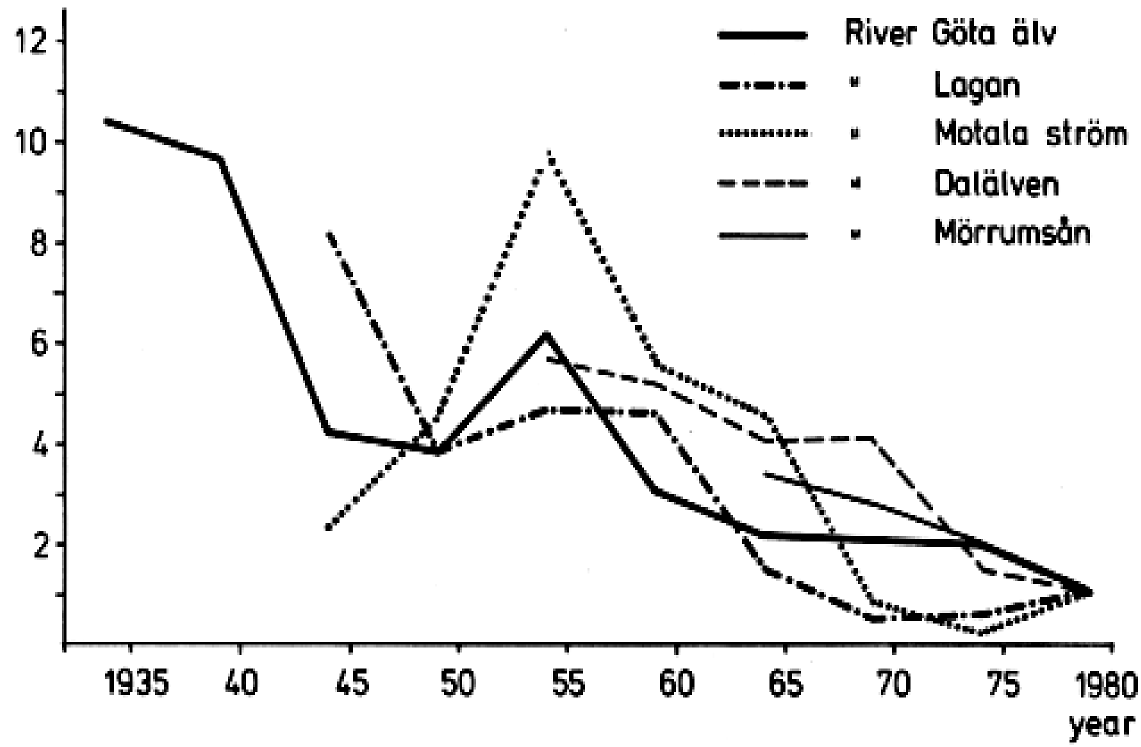

Fig. 2 Ascent of elvers and yellow eels in five Swedish rivers. (Compared with the mean of the period 1977–81 = 1 unit)

SAMPLING STATIONS

1 River Göta älv
2 Ringhals
3 Barsebäck
4 River Mörrumsån
5 Torhamn
6 Simpevarp
7 Comparison area
8 River Motala ström
9 Forsmark
10 River Dalälven

EXPERIMENTAL LAKES

a Ängersjön
b Ången
c Ommen
d Frisksjön
e Götemaren
f Fardume träsk

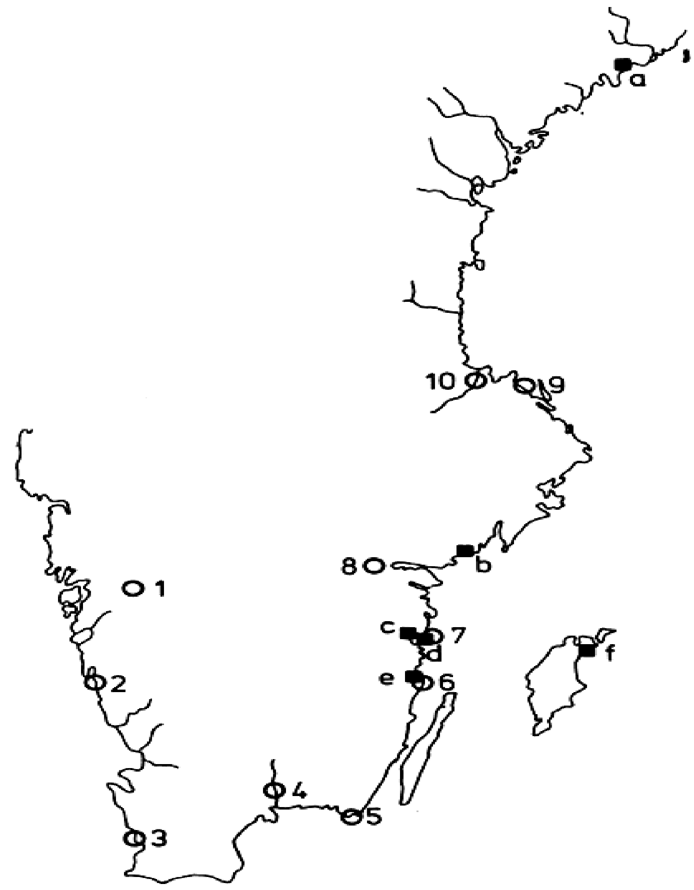

Fig. 3 Locality of eel sampling stations and experimental lakes

RIVERS

1 Ljungan
2 Ljusnan
3 Gavleån
4 Dalälven
5 Nyköpingsån
6 Kilaån
7 Motala ström
8 Botorpsströmmen
9 Emån
10 Alsterån
11 Mörrumsån
12 Skrään
13 Helgeån
14 Rååån
15 Rönneå
16 Lagan
17 Nissan
18 Ätran
19 Morupsån
20 Tvååkers kanal
21 Viskan
22 Göta älv

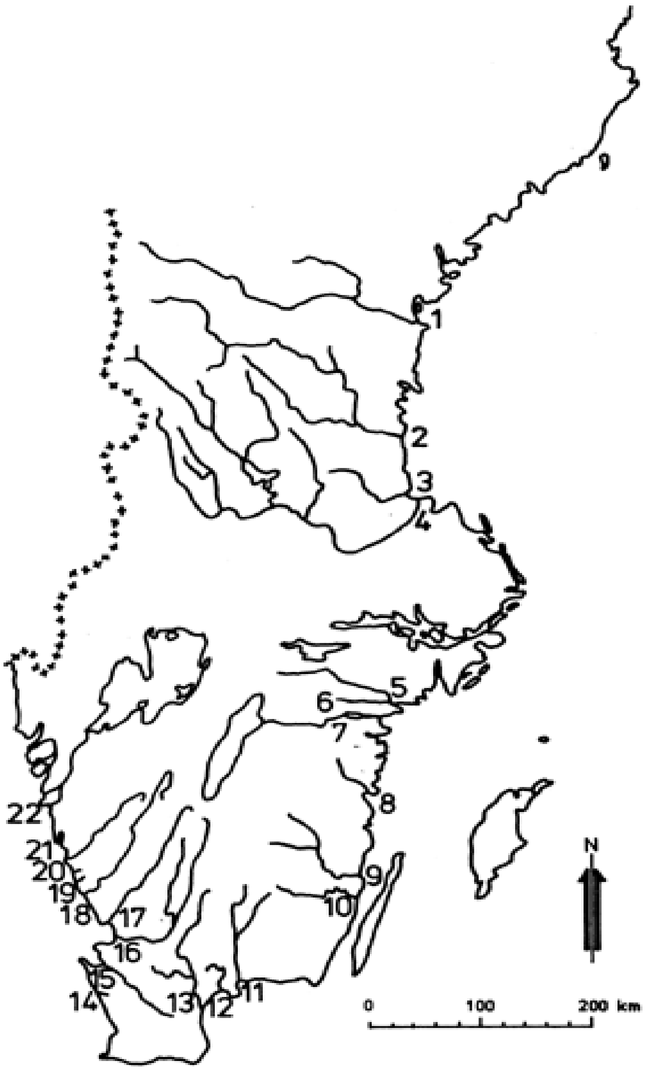

Fig. 4 Swedish rivers where ascending elvers and yellow eels are trapped and recorded annually

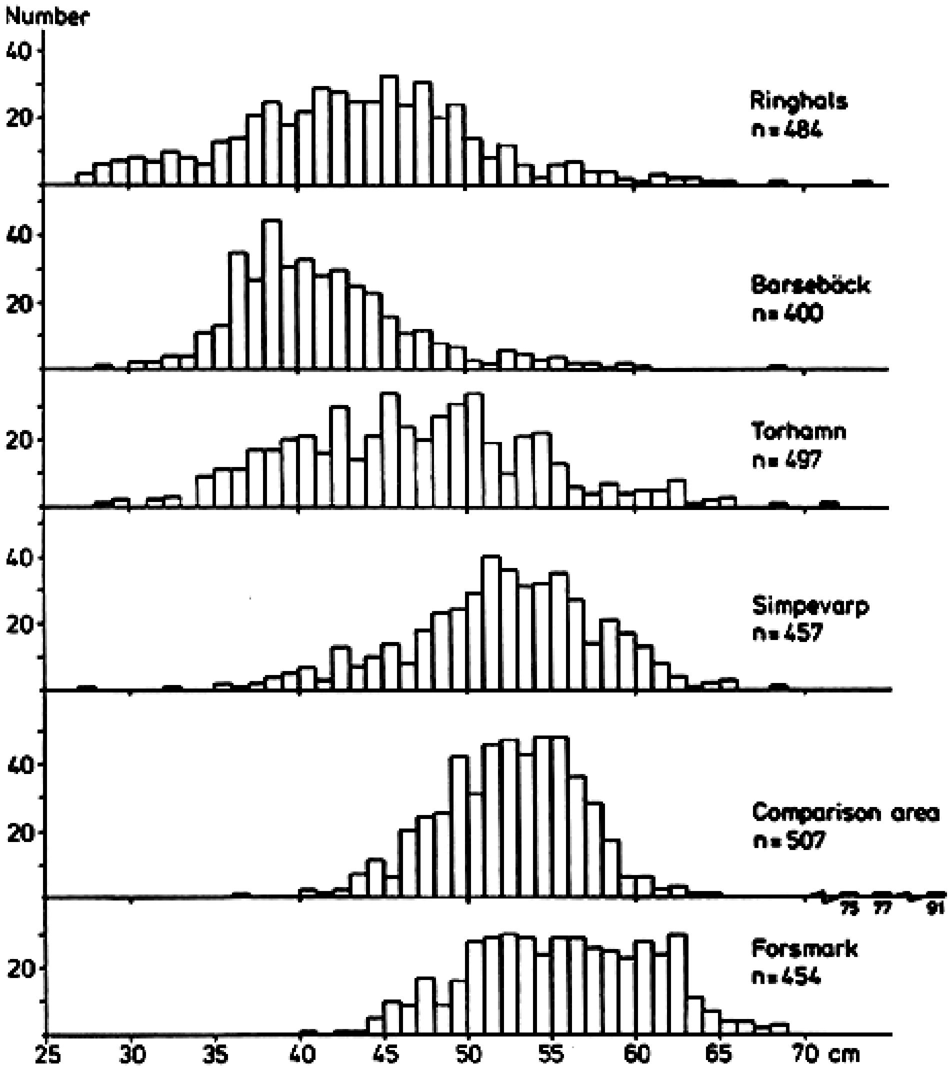

Fig. 5 Size distributions of eels sampled at six coastal localities

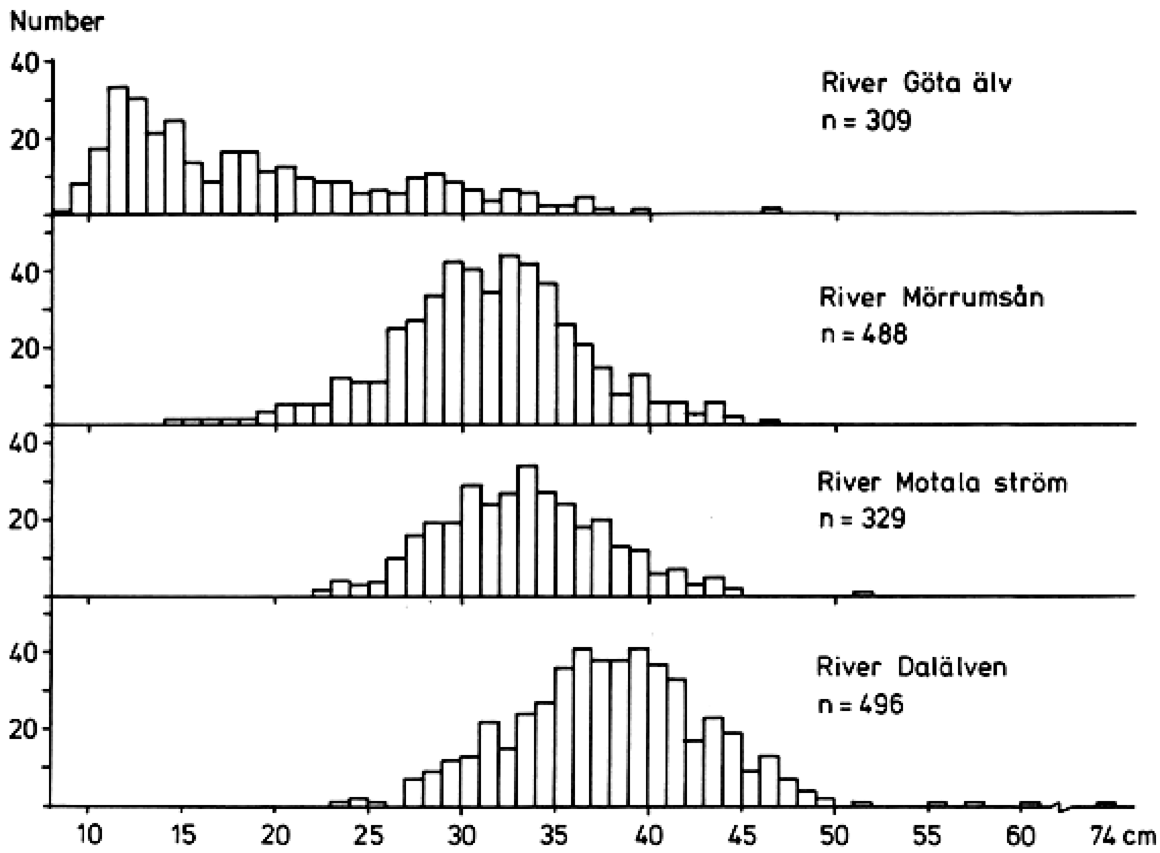

Fig. 6 Size distributions of ascending eels sampled in four rivers

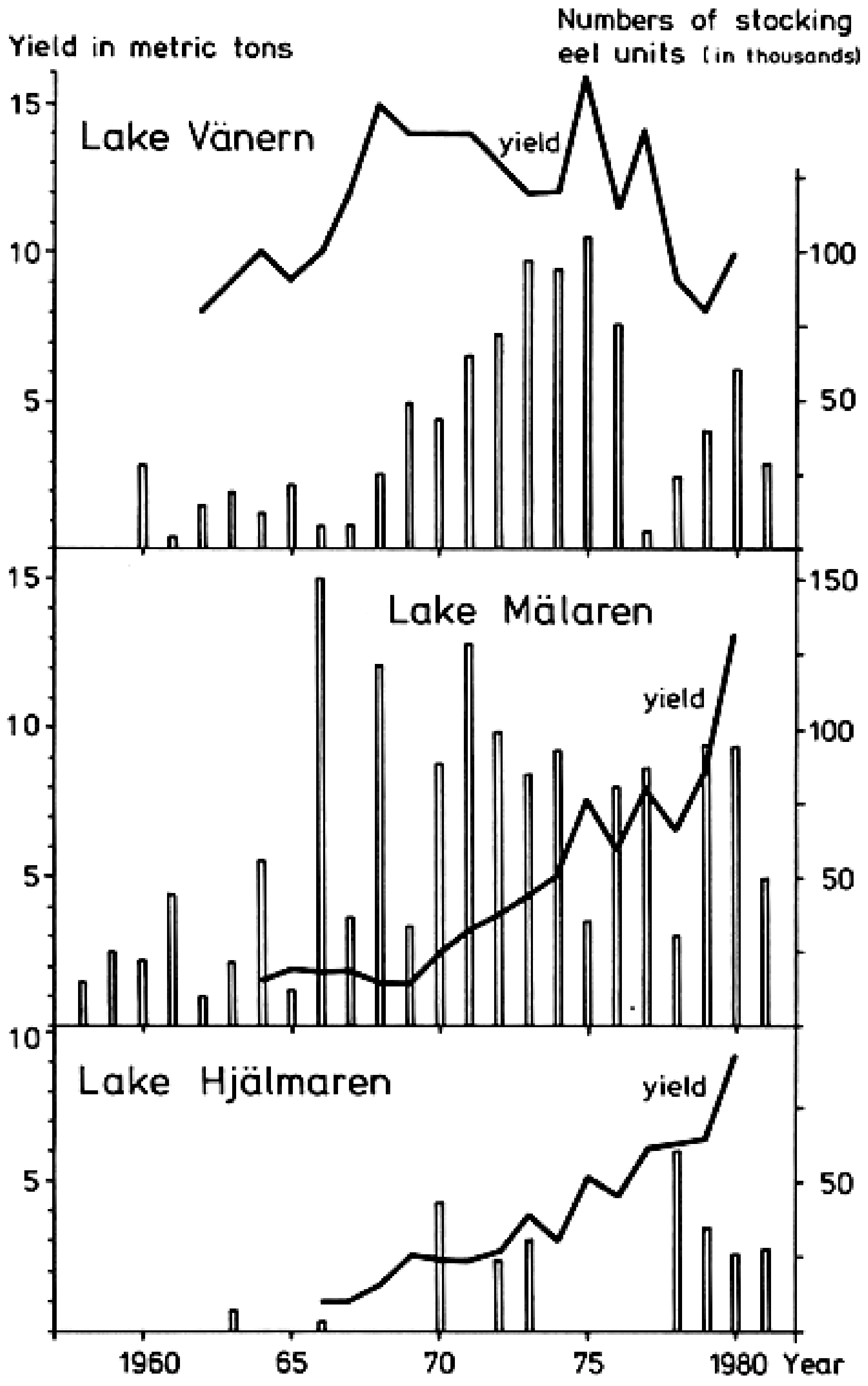

Fig. 7 Yield and numbers of stocked eels in three Swedish lakes

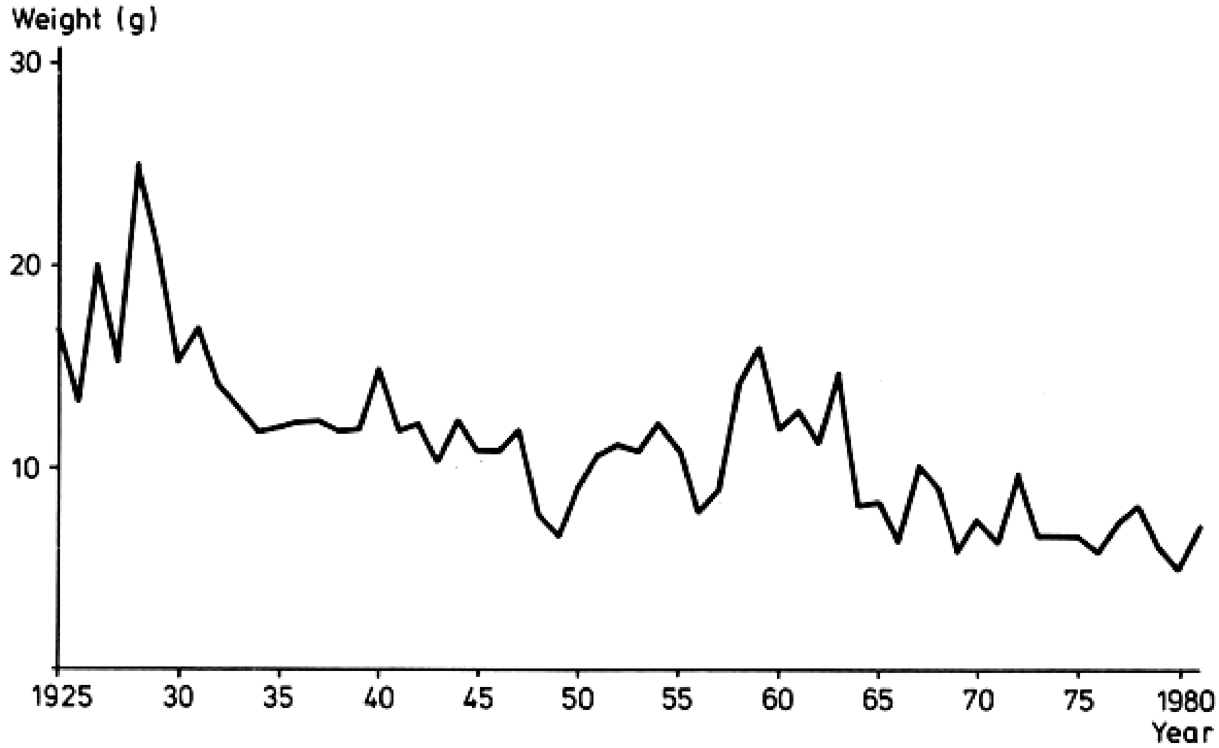

Fig. 8 Calculated average weight of ascending eels in River Göta älv

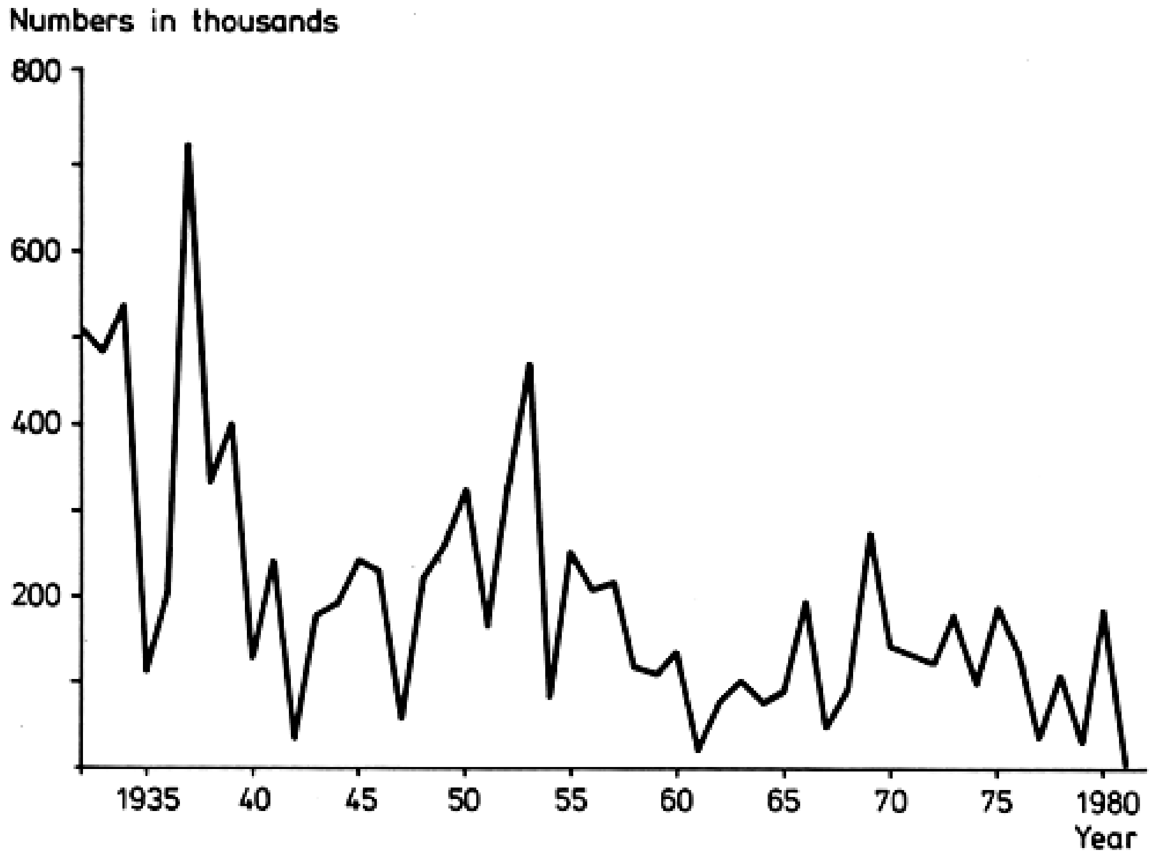

Fig. 9 Calculated numbers of ascending eels in River Göta älv

THE ROLE OF WHITEFISH (Coregonus lavaretus L.) STOCKINGS IN FISHERIES MANAGEMENT IN FINLAND

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CONTENTS

ABSTRACT

Fish stocking plays a central role in fisheries management in Finland. In 1981 the total value of stockings was about 25 million FIM (U.S.$ 6.3 million), of which nearly 5 million (U.S.$ 1.3 million) was spent on stocking with whitefish. Much of the stocking was financed by the State, even though almost all inland fishing waters are privately owned (about 85 percent). The objectives of whitefish stocking have been: to increase the quality and quantity of fish yield, to compensate for the damage caused by hydro-power plant construction, lake water level regulation and pollution, and to create employment opportunities in under-employment areas. Thus, in evaluating the results of whitefish stocking, we must take into consideration that better fish yield has been only one of the objectives.

RESUME

Le repeuplement joue un rôle capital dans l'aménagement des pêches en Finlande. A la fin des années soixante-dix, la valeur totale du repeuplement était de l'ordre de 25 millions de marks (6.3 millions de dollars E.U.) et près de 5 million FIM (1.3 millions de dollars E.U.) étaient consacrée au poisson blanc. L'Etat finance une très grande partie de ces opérations, bien que 85 pour cent environ des eaux de pêche intérieures soient propriété privée. Les objectifs du repeuplement en poisson blanc sont les suivants: améliorer les rendements, en qualité et en quantité; compenser les dommages causés par la construction d'ouvrages hydro-électriques, la régulation du niveau des lacs et la pollution; créer des emplois pour résorber le chômage de certaines zones. L'amélioration des rendements n'était donc qu'un objectif parmi d'autres, ce dont il faut tenir compte lorsque l'on évalue les résultats du repeuplement. Au moment de planifier la stratégie future d'aménagement des pêches, il faudra notamment trouver le moyen le plus efficace de construire et d'utiliser des étangs où l'on élévera avec des aliments naturels des alevins destinés au repeuplement.

1. INTRODUCTION

Mass-rearing of autumn whitefish fingerlings for stocking into natural waters was begun in Finland at the beginning of the sixties; since then, production has steadily increased (Salojarvi, 1982). In 1980 production was nearly 27 million autumn fingerlings (circa 130 t) (Eskelinen and Sumari, 1981).

The whitefish catch in 1980 was 3 502 t, of which catch from fresh waters was 1 325 t and the remaining 2 177 t were caught in the sea off the Finnish coast, mainly in the Gulf of Bothnia (Lehtonen, 1981). The present whitefish catch is larger than it was in the sixties (Sjoblom et al., 1980). It is evident that this is at least partly the result of stockings (Salojarvi, 1982).

This paper deals with goals and objectives, financing and the possible benefits of a large-scale whitefish stocking programme such as that carried out in Finland.

2. ORGANIZATION OF FISHERIES MANAGEMENT

The Finnish judicial system is, in principle, the same as that of the other Scandinavian countries. Most bodies of water are jointly owned, waters within village limits are jointly owned by the landowners of the village; all waters outside village boundaries are owned by the State. Presently about 85 percent of all inland fishing waters are privately owned (Munne, 1980).

Fishing rights in Finland generally belong to the owners of the respective waters. The primary ownership unit is the village; and each landowner's share in the jointly owned water area and fishing rights depends on the size of his estate (Munne, 1980; Sjoblom et al., 1980).

According to the Fisheries Act (which comes into force in the beginning of 1983) the owners of fishing waters are responsible for the conservation and management of the fish stocks and are obliged under the law to form a fishing commune on a village basis for the management of the jointly owned waters. The fishing commune defines the extent of fishing rights for different shareholders. Fishing communes can transfer their obligations concerning fisheries management to a larger administrative unit of fisheries management, the so-called “Fisheries Area”. Fishing communes play an important role in the management of Fisheries Areas.

Government responsibility for both inland and marine fisheries in Finland is vested in the Ministry for Agriculture and Forestry. The majority of state-owned waters fall under the jurisdiction of the National Board of Forestry.

In the field of fisheries and fisheries management, there exist three government-sponsored organizations, the Federation of Finnish Fisheries Associations, the Federation of Finnish Recreational Fishermen's Associations and the Finnish Fish and Game Association.

3. FINANCE OF FISHERIES MANAGEMENT

Fisheries management in Finland is primarily financed by fishing communes (privately owned waters), the State and those (hydro-electric power companies, cities, industry, etc.) who have been ordered by the Water Courts to repair damage they have caused to fish stocks (obligatory stockings).

Much of the fisheries management work undertaken by the water owners cannot be estimated in monetary terms. In 1981 fishing communes spent circa 5.5 million FIM (circa U.S.$ 1.4 million) to buy fish larvae and fingerlings for stocking in natural waters.

The State fisheries budget for 1981 was circa 70 million FIM (U.S.$ 17.5 million). This sum includes inter alia 17 million FIM (U.S.$ 4.3 million) spent for the construction of new fish culture stations and natural food ponds.

In 1981 the Finnish Government spent roughtly 17 million FIM (U.S.$ 4.3 million) for fish culture and related activities (including purchases of stocking material from private fish cultivation companies). In the same year, the Government invested about the same amount in construction of new fish culture facilities. This means that rearing of stocking material for natural lakes and the sea will increase in the years to come.

The rearing of stocking material for obligatory stocking was just beginning in 1981; but obligatory stocking, especially for marine waters, is expected to increase in the next few years.

Estimated expenditures for direct fisheries management in Finland in 1981 were approximately 25 million FIM (U.S.$ 6.3 million), most of it for rearing stocking material. Taking into consideration the operational costs of State-owned natural food ponds and the known production of private whitefish cultivation companies, it can be estimated that roughly 5 million FIM (U.S.$ 1.3 million) was spent in 1981 for rearing whitefish fingerlings in State-owned natural food ponds and for purchases of whitefish stocking material from private fish-rearing companies.

4. GOALS AND OBJECTIVES OF THE WHITEFISH STOCKING PROGRAMME

In Finland, public spending for the management of fisheries exceeds the income received by the State from that sector of the economy. The income from the sale of State fishing licences is too low to cover costs, due to a desire to keep these licences inexpensive. This is justified for many reasons.

Most of the human stresses on naturally reproducing whitefish stocks (Table 1) arise as a result of action taken for the so-called “public benefit”. According to the Water Act, damage to fish stocks will, in principle, be compensated through obligatory stockings but in reality only part of the damage is compensated. Further the greater involvement of the Government in the cost of management is justified by the fact that fishing rights have been broadened in the Fisheries Act 1951 and 1982 to encompass fishermen who own no fishing waters (recreational fishermen). Whitefish stockings are a good method of compensation in this respect, because most of the catch is taken with different kinds of gill nets (Lehtonen and Salojarvi 1978, 1982; Salojarvi and Lehtonen, 1980) and according to the Finnish Fisheries Act gill net fishing is controlled by owners of the waters.

It is also logical that Government would ensure the preservation of the fish stocks that are in danger of extinction. Because the short-term benefit of this preservation is small, it is not generally undertaken by any private enterprise or person, who do not consider it to be in their interest.

In addition to the conservation and compensation for damage to natural fish stocks and public involvement in private ownership, it is possible to achieve many other benefits through stocking (Table 2). These benefits (employment, income, etc.) are not only important for certain special interest groups, they are also important for society as a whole, because they help in maintaining the social infrastructure and social well-being in a given region.

Therefore, in evaluating the usefulness of the whitefish stocking programme, it is necessary to take into consideration that better fish yield has been only one of the objectives although the measurement of benefits presents certain difficulties.

5. PROSPECTS FOR WHITEFISH STOCKINGS

The present Fisheries Act (1982) tends to promote the achievement of as high a productivity of fishing waters as possible on a sustained basis. In allocating fish resources, professional fishing has first priority.

The high investment costs involved in the construction of the natural food ponds used for rearing one-summer old whitefish fingerlings for stocking in natural waters results in a fisheries management strategy based on stocking. In many cases, for example in northern Finland, only restricted possibilities exist for rearing other fish than whitefish in the natural food ponds. In that sense the chosen strategy is rather inflexible. Further, this means that fisheries regulations must be based on whitefish in order to gain as high a yield as possible from stockings.

It has been shown that the stocking programme has increased the whitefish catch in northern Finland (Salojarvi, 1982) but it is possible to achieve an even higher yield. At present, the most important whitefish stocks in northern Finland are over-exploited (Toivonen et al., 1981; Salojarvi, 1982). This is probably also the case in southern Finland and even in the sea (Lehtonen, 1981). Thus, it is possible to achieve a higher yield by restricting the mesh size of gill nets and the fishing season. In multi-species fisheries these measures will also affect the catch of other species, how it is not yet known. This depends on the development of fishing using such gear as different hooks, wire traps, fyke nets, etc.

Professional fishing, especially in inland lakes, is presently in a crisis of profitability. The whitefish stocking programme can help somewhat in this respect, because any additional catch is very valuable as a marginal catch. On the other hand, stocking with whitefish fingerlings can create social pressure on professional fishermen using seine nets. A small amount of juvenile whitefish is caught by the seines which is unacceptable to subsistence and recreational fishermen who use gill nets. At present, the whitefish catch is not very important economically for professional fishermen, with the exception of the Inari region of northern Finland. How much professional whitefish fishing will increase in Finland depends to a large extent on the fishing regulations which will be adopted.

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1981

Table 1 List of human stresses on naturally reproducing whitefish (Coregonus lavaretus) populations in Finland (after Loftus et al., 1980)

1. Fishing
2. Introductions of exotic species
3. Microcontaminants, toxic wastes and biocides, from industry and agriculture
4. Nutrients and eutrophication from sewage plants, agricultural and urban run-off
5. Organic inputs and oxygen demand from pulp and paper mills, factories, sewers, etc.
6. Sediment loading and turbidity from agriculture, construction sites and resuspension
7. Stream modification: dams, channelization and logging, changes in land use
8. Dredging of rivers
9. Water level control for electric power production, wetland management, etc.
10. Ditching and draining of wetlands
11. Weather modification, mostly industrial
12. Acids and toxic chemicals carried in the atmosphere

Table 2 Benefits, benefit groups and units of measurement that can be used in evaluating the significance of natural food ponds used for rearing whitefish autumn fingerlings

Benefit	Benefit group	Units of measurement
Employment	- Pond construction - Professional fishing - Secondary industry and services - Pond management	Number of persons employed
Income	Same groups as in Employment above	Gross sales or earnings and gross amount of money used on services
Food	- Subsistence - Recreational - Purchasers	A reliable source of food and variety of edible fish (kg of fish consumed <u>per caput</u>)
Recreational	Resident fishermen (subsistence and recreational)	A continuous supply and access variety of recreational opportunities (user-days)
Retention of social infrastructure	All residents	Social well-being (healthy society)
Conservation of natural fish stocks	All residents including consumers and non-consumers	Availability or sustained supply of utilizable natural resource

A STUDY OF THE GROWTH AND PRODUCTION OF THE NATIVE WHITEFISH (Coregonus muksun (Pallas)) AND THE INTRODUCED WHITEFISH (C. peled (Gmelin)) STOCKED IN TWO SMALL FOREST LAKES IN SOUTHERN FINLAND

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CONTENTS

ABSTRACT

Over a period of several years the native whitefish (Coregonus muksun (Pallas)) and the introduced Siberian whitefish (C. peled (Gmelin)), were stocked in two small forest lakes in Evo in southern Finland. The stocking density was circa 100 individuals/ha and stocking size was 6–14 cm (one-summer old). In both lakes, natural reproduction of whitefish had not been observed. The evolution of the stocked whitefish populations were followed using catch statistics, trial fishings and marking-recapture.

Coregonus peled grew faster than C. muksun up to three-four years of age. The growth of whitefish stocked after the first stocking deteriorated year by year. The stockings created such a dense whitefish population that the amount of food became a limiting factor for growth.

In both lakes the instantaneous rate of natural mortality (M) was lower for one-four year old whitefish than for other age groups. The considerably higher instantaneous rate of natural mortality (M) for Lake Rahtijarvi (M = 0.5 – 0.8 for one-four year old whitefish) compared to Lake Valkea-Mustajarvi (M = 0.1 – 0.4 for one-four year old whitefish) caused primarily by the large number of predators in Lake Rahtijarvi, especially pike (Esox lucius L.).

After five years the instantaneous rate of natural mortality (M) for whitefish in both lakes was about 1. The rise was evidently due to the attainment of sexual maturity, a too dense population, and a lack of food.

The maximum biomass of the year-class of C. peled stocked in Lake Rahtijarvi was 37 kg/1 000 stocked individuals. The respective maximum biomass for C. muksun was only 16 kg/1 000 stocked individuals, due to the slower growth rate.

The maximum biomass in Lake Valkea-Mustajarvi obtained for C. peled was 307 kg/1 000 stocked individuals and for C. muksun 231 kg/1 000 stocked individuals. These maximum biomasses, in comparison to those in Lake Rahtijarvi, were many times higher, due to better growth and the lower instantaneous rate of natural mortality (M) during the first years.

It is obvious that the value of small lakes in terms of fisheries can be considerably raised by stocking them with whitefish that utilize zooplankton production. Of the whitefish species available, C. peled from the U.S.S.R. provides a serious alternative to the Finnish whitefish species because of its good growth.

RESUME

Pendant plusieurs années, on a utilisé Coregonus muksun, poisson blanc indigène planctophage, et C. peled, poisson blanc sibérien introduit, pour le repeuplement de deux petits lacs forestiers du sud de la Finlande sans rien changer aux sources naturelles de nourriture. La densité du repeuplement était de l'ordre de 100 individus à l'hectare et la taille des poissons de 6 à 13 cm (poissons d'un été). On n'avait observé de reproduction naturelle du poisson blanc dans aucun de ces deux lacs. Les statistiques des captures ainsi que des essais de pêche et des opérations de marquage/recapture ont permis de suivre l'évolution des poissons mis à l'eau.

Dans le lac de Rahtijarvi le poisson blanc sibérien s'est d'abord développé plus vite que le poisson blanc indigène mais on a constaté au bout de cinq ans que ce dernier l'avait dépassé car le taux de croissance du premier cité avait nettement diminué la troisième année. Dans le lac de Valkea-Mustajarvi, au bout de cinq ans le taux annuel de croissance de C. muksun était supérieur à celui de C. peled, mais ce dernier avait

pris une telle avance au cours des toutes premières années qu'il était impossible pour C. muksun de combler son retard.

Le taux de mortalité naturelle instantanée (M) a été assez élevé (environ 0,5) au cours des premières années dans le lac de Rahtijarvi où il existait une forte population de brochets alors qu'il est resté faible (environ 0,1) dans le lac de Valkea-Mustajarvi où il y avait très peu de prédateurs. Au bout de cinq ans, la mortalité des poissons blancs dans les deux lacs était voisine de 1.

Le ralentissement de la croissance et le taux élevé de mortalité naturelle des groupes d'âge les plus vieux indiquent que, dans le lac de Rahtijarvi, la biomasse maximale d'un groupe d'âge a été atteints dès l'âge de 2–3 ans pour C. peled et à l'âge de 3–4 ans pour C. muksun. A ce moment, les possibilités de captures étaient au maximum de 30–450 kg/1 000 unités de repeuplement pour C. peled et de 10–20 1 kg/1 000 unités de repeuplement pour C. muksun. Dans le lac de Valkea-Mustajarvi, pour les deux espèces, un groupe d'âge atteignait sa biomasse maximale à 4–5 ans. A ce moment, les possibilités de captures étaient au maximum de 275–325 kg/1 000 unités de repeuplement pour C. peled et de 200–250 kg/1 000 unités pour C. muksun. Ces résultats sont nettement supérieurs à ceux obtenus dans le premier lac, ce qui tient au fait que le taux de mortalité a été faible les premières années et le taux de croissance plus élevé.

Si l'objectif n'est pas de maximiser les captures mais, plutôt, d'obtenir des poissons d'une taille supérieure à la moyenne, C. muksun donne plus ou moins les mêmes résultats que C. peled.

1. INTRODUCTION

In Finland, the productive capacity and utilization of small waters for fisheries have been studied for a long time (Levander, 1906; Valle, 1924; Toivonen, 1964; Tuunainen, 1970). As Ryhänen (1972) has observed, there are good reasons to assume that in fisheries in dystrophic lakes, those species that feed on zooplankton are to be preferred, which would also be practical from the point of view of energy economics. However, because the fish stock in small Finnish waters generally lacks those species that utilize zooplankton, in recent years we have begun large-scale trials in small waters stocked with whitefish which feed on zooplankton. In the Evo Inland Fisheries and Aquaculture Research Station (located near Lammi in southern Finland) comparative studies have been carried out since 1973 between the native plankton-feeding Coregonus muksun (Pallas) and Coregonus peled (Gmelin), which was imported to Finland from Siberia, to see which species was better suited for management in small waters. In general, neither of these species has been observed to reproduce naturally in small Finnish lakes.

Coregonus peled was first imported to Finland from the U.S.S.R. in 1965 (Toivonen, 1965) where it had been found to survive in waters with little oxygen and low pH. For this reason, it was felt that it might also be suited for many Finnish waters.

In Finland in 1980, 5.2 million one-summer old C. peled and 8.0 million one-summer old C. muksun were stocked (Eskelinen and Sumari, 1981).

The present study follows and compares the growth and estimated production, and factors which affect them, of C. peled and C. muksun stocked in two small forest lakes, Lake Rahtijärvi and Lake Valkea-Mustajärvi, located near the Evo Research Station.

This paper is based on a study by Pruuki (1982) in which the subject has been treated in greater detail.

2. LAKES USED IN THE STUDY

For the stocking trials, two similar sized lakes were chosen near the Evo Inland Fisheries and Aquaculture Research Station, located near Lammi in southern Finland (25°5'E; 61°12'N) (Fig. 1). The surface area of Lake Rahtijärvi (shown in Fig. 2 and hereinafter referred to as Lake R) is 13.2 ha, with a maximum depth of 15 m. The water of the lake has a very high humus content, as shown by its average colour values: 107 mg/Pt 1 at the surface, and 153 mg/Pt 1 at the bottom. The oxygen content of the hypolimnion is poor both at the end of the winter and at the end of the summer. The major species found naturally in Lake R are European perch (Perca fluviatilis (L.)), pike (Esox lucius L.), European bleak (Alburnus alburnus (L.)), and roach (Rutilus rutilus (L.)). The lake has several inlets and one outlet.

The surface area of Lake Valkea-Mustajärvi (shown in Fig. 2 and hereinafter referred to as Lake V-M) is 13.9 ha, with a maximum depth of 10 m. The average colour values for the water were 25 mg/Pt 1 at the surface and 50 mg/Pt 1 at the bottom. The oxygen content of the hypolimnion was poor at the end of winter and the end of summer. The major species occurring naturally in Lake V-M is perch (Perca fluviatillis (L.)). The lake has neither inlets nor outlets.

Fishing in the lakes, except for that in connexion with the experiment and stocking trials, is forbidden.

3. MATERIAL AND METHODS

The whitefish populations in the study came from one-summer old stocked whitefish raised with natural feed, which had been stocked in Lake R since 1974 and in Lake V-M since 1973 (Table 1). The average size of the stocked fish in different years was 6–14 cm. There were no observations of natural reproduction of whitefish.

Monitoring of the whitefish stocking was carried out on the basis of catch records, trial fishing carried out with nets, and marking-recapture trials in 1980 and 1981. The total whitefish catch in Lake R and Lake V-M, on which the results of this study are primarily based, is shown in Table 2.

The age of the whitefish was determined by scale samples taken from between the abdominal fins (Einsele, 1943; Bagenal and Tesch, 1978). Part of the growth data was obtained from back calculation of lengths. The length-weight relationships for whitefish and von Bertalanffy's growth equations (von Bertalanffy, 1938; ref. Ricker, 1975) were calculated using Abramson's (1971) computer programme. The size of the whitefish populations in 1980 and 1981 was determined through marking-recapture using the so-called Petersen method (see e.g., Ricker, 1975).

The mortality and population size development were calculated using virtual population analysis (VPA) (Gulland, 1965), followed by the FPROG 4 programme (Salojärvi et al., 1978) based on a computer simulation population analysis. The instantaneous rates of mortality, population sizes, and recruitment in the simulation were adjusted to correspond with the known total catches, the results of the marking-recapture and the numbers of juveniles stocked. On the basis of the catch data, the rate of natural mortality calculated for both C. peled and C. muksun in the same lake was estimated to be the same (Pruuki, 1982).

The development of the biomass of a year-class as a function of its age was calculated using the FPROG 6 programme (Salojärvi et al., 1978) which was based on population analysis, assuming that mortality due to fishing did not occur. The value of the instantaneous rate of natural mortality (M) used was the average value described above, which was obtained with a computer simulation for the years 1973–81. The net production of a year-class in this method is equal to the peak biomass; and the most efficient catching age is that in which the maximum biomass is achieved. The calculations and evaluations have been made by the senior author of this paper.

4. RESULTS

Table 3 shows von Bertalanffy's growth parameters for the whitefish populations being studied. Figs. 3 and 4 show the growth curves drawn on the basis of the growth equations, and Fig. 5 shows the annual incremental growth for those year-classes in which both C. peled and C. muksun were stocked in the same lake.

The average instantaneous rates of mortality for the years 1973–81 are shown in Table 4. The development of population size and the results of the mark-recapture experiment are shown in Table 5. Figs. 6 and 7 show the development of the size of the whitefish population in the experimental lakes, as a function of the age of the year-classes, assuming mortality due to fishing does not occur.

5. DISCUSSION

5.1 Growth

It can be seen from Table 3 that the asymptotic length (Loo) in von Bertalanffy's equation is on average greater for C. muksun than for C. peled and the Brody growth coefficient (K) is on average greater for C. peled than for C. muksun. In the growth curves (Figs. 3–5) this can be seen in the more rapid growth of C. peled up to 3–4 years of age. The values for the 1975 Rahtijärvi C. muksun, which deviate from those of other year-classes, will evidently approach average values when additional samples are taken in following years. It is evident that C. peled in these conditions grow faster than C. muksun in the first years. C. peled is sexually mature at 2–3 years, while C. muksun reach maturity only at 4–5 years; which may be the reason that the growth of C. peled slows earlier than that of C. muksun.

In both lakes, that year-class which was stocked first in the lake had the best growth (Figs. 3 and 4). The growth of whitefish stocked after that first stocking deterioriated year by year. From this it may be concluded that stocking created such a dense whitefish population that the amount of food became a limiting factor of growth. A corresponding deterioration of growth has been observed, e.g., in the U.S.S.R., in the 67.5-ha Lake Krivogo (Rudenko, 1975). The reasons for this have been given as inter alia increased population density and the large number of other fish species in the lake (Tikhomirova, 1975). The size of the population and growth have been shown to be connected also in larger lakes (Healey, 1975, 1975a and 1980; Kenyon, 1978).

The parameters in the von Bertalanffy's equations for the whitefish populations of Lake R and Lake V-M are on the order of those for the plankton whitefish populations of large lakes in the Oulujoki river system, calculated by Salojärvi (1982). Thus, on the basis of growth, the whitefish species being studied appear to be suitable for stocking also in small lakes.

5.2 Mortality

In both lakes, the instantaneous rates of natural mortality (M) for the autumn of the stocking year was higher than that for the next years (Table 4). This higher mortality rate was evidently due to damage caused during transportation and stocking, the change of the living environment, and predation.

The considerably higher instantaneous rate of natural mortality (M) for Lake R compared to Lake V-M was evidently caused by the large number of predators in Lake R, especially pike (Esox lucius L.). In addition, there were in Lake R along with whitefish, large numbers of cyprinoid fish which competed with whitefish for food and living space, and which were not present at all in Lake V-M. It should also be noted that the quality of the water in the comparatively clear. Lake V-M is evidently more suitable for whitefish than the water in Lake R.

Usually the same instantaneous rate of natural mortality (M) has been shown for all age groups, but in Lake R and Lake V-M at least the instantaneous rate of natural mortality (M) was lower for 1–4 year old whitefish than for other age groups. Spangler (1970) has also observed a rise in natural mortality for older age groups.

In both lakes, the rise in the instantaneous rate of natural mortality (M) at the age of 4–5 years was evidently due to the attainment of sexual maturity, a too dense population, and a lack of food. In both lakes, the fishing mortality was particularly low and the whitefish populations in question were only slightly exploited (Pruuki, 1982).

Healey (1975) has compiled a table of the values of the instantaneous rates of natural mortality (M) for whitefish populations which had not been fished. They varied from 0.2 to 1.2 with an average value of 0.69. Salojärvi (unpublished) has obtained momentary death rates of 0.1–0.2 in a whitefish population stocked in the Oulujoki river system. The population in question has been thoroughly fished.

When comparing with the results presented above the instantaneous rates of natural mortality (M) were common in Lake R and Lake V-M.

5.3 Production

Lake V-M is able to maintain a much larger whitefish population than is Lake R (see Table 5). This is influenced by the structure of the fish species, the production of feed (zooplankton) and the quality of the water. The year-class of C. peled stocked in Lake R reached its biomass peak of 37 kg/1 000 stocked individuals, i.e., a net production of 4 kg/ha/year according to growth, in 1975. The respective maximum biomass for C. muksun was only 16 kg/1 000 stocked individuals, i.e., a net production of 2 kg/ha/year, due to the slower growth rate.

The maximum biomass in Lake V-M were many times higher than those in Lake R, due to better growth and the lower instantaneous rate of natural mortality (M) during the first years. The maximum biomass obtained for C. peled was 307 kg/1 000 stocked individuals, which would correspond to an annual net production of 31 kg/ha. The poorer growth of C. muksun during their first few years resulted in a maximum biomass of 231 kg/1 000 stocked individuals, i.e., a net production of 23 kg/ha/year.

Hakkari et al. (1983) have estimated the zooplankton production utilizable for fish and predatory invertebrates to be more than 400 kg/ha/year in Lake V-M. This estimation corresponds well with the whitefish net production in Lake V-M presented above.

According to the catch statistics complied at the beginning of the century by Brofeldt (1920), the lakes with the Evo Inland Fisheries and Aquaculture Research Station have produced a whitefish catch of circa 20 kg/1 000 stocked one-summer old individuals (Salojärvl, 1980). According to Salojärvi (1980 and unpublished) the average yield obtained from some small Finnish lakes has been 95 kg/1000 one-summer old stocked whitefish, when fishing was intensive.

According to the statistics published by Bell Hanford and Dietz (1977), the whitefish yield from 13 lakes in Alberta with a surface area of less than 1 000 ha has been on average 5.7 kg/ha/year. Titova (1978, ref. Reshetnikov, 1979) has presented data according to which the yield obtained from C. peled stockings has been 24 kg/ha/year in certain waters in the U.S.S.R. In comparison to the above mentioned results, the results from the whitefish stockings in Lake R are fair, and those from Lake V-M good.

The results from Lake R and V-M are, however, only theoretical because the fishing mortalities were low and the whitefish populations slightly exploited. In any case it is obvious that the value of small lakes in terms of fisheries can be considerably raised by stocking them with whitefish that utilize zooplankton production, as Ryhanen (1972) assumed. Of the whitefish species available, C. peled from the U.S.S.R. provides a serious alternative to the Finnish whitefish species because of its good growth.

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Table 1 Stocking of one-summer old C. peled and C. muksun in Lake Rahtijarvi and Lake Valkea-Mustajarvi between 1973–81

Year	Lake Rahtijarvi (13.2 ha) C. peled No. of ind.	Lake Rahtijarvi (13.2 ha) C. muksun No. of ind.	Lake Valkea-Mustajarvi (13.9 ha) C. peled No. of ind.	Lake Valkea-Mustajarvi (13.9 ha) C. muksun No. of ind.
1973	-	-	487	487
1974	1 200	-	-	-
1975	920	1 000	-	700
1976	1 300	-	462	937
1977	1 300	-	463	941
1978	1 300	-	-	1 400
1979	1 300	-	-	1 400
1980	1 320	-	-	1 400
1981	1 000	-	-	1 400

Table 2 Total whitefish catch in Lake Rahtijarvi and Lake Valkea-Mustajarvi from 1974 to 1981

	Lake Rahtijarvi						Lake Valkea-Mustajarvi					
	C. peled			C. muksun			C. peled			C. muksun		
	ind.	kg	kg/ha	ind.	kg	kg/ha	ind.	kg	kg/ha	ind.	kg	kg/ha
1974	-	-	-	-	-	-	71	8.3	0.6	69	4.4	0.3
1975	1	0.1	0.0	-	-	-	29	12.9	0.9	63	15.9	1.1
1976	17	3.5	0.3	-	-	-	-	-	-	33	16.0	1.2
1977	12	3.9	0.3	-	-	-	-	-	-	33	25.1	1.8
1978	43	10.4	0.8	-	-	-	-	-	-	8	6.6	0.5
1979	50	7.0	0.5	-	-	-	15	7.6	0.5	38	16.2	1.2
1980	28	3.3	0.3	2	0.5	0.0	10	5.3	0.4	103	22.3	1.6
1981	164	26.6	2.0	15	6.6	0.5	25	14.4	1.0	161	57.4	4.1

Table 3 The von Bertalanffy growth parameters according to year-class for <u>C. peled</u> and <u>C. muksun</u> stocked in Lake Rahtijarvi and Lake Valkes-Mustajarvi.

Lake	Year class	Species of whitefish	von Bertalanffy's growth parameters Loo/cm	Woo/g	K	To
Rahtijarvi	1974	C. peled	38.8	480	0.5842	0.2332
	1975	C. peled	31.0	243	1.0252	0.3353
	1975	C. muksun	69.9	3 363	0.1078	-0.8947
	1976	C. peled	30.7	235	0.6681	0.1611
	1977	C. peled	33.1	311	0.4863	-0.1431
	1978	C. peled	32.4	290	0.5177	-0.2378
Valkea-Mustajarvi	1973	C. muksun	46.4	908	0.5151	0.0284
	1975	C. muksun	45.7	928	0.5149	0.2071
	1976	C. muksun	43.0	737	0.4821	0.0320
	1976	C. peled	41.1	730	0.6052	0.1070
	1977	C. muksun	37.0	405	0.7341	0.2011
	1977	C. peled	30.0	591	0.7630	0.2291
	1978	C. muksun	37.2	413	0.5430	0.0016

Loo = asymptotic length
Woo = asymptotic weight
K = Brody growth coefficient
To = hypothetical moment at which the fish length is 0

Table 4 The average instantantaneous rates of natural mortality for <u>C. peled</u> in Lake Rahijarvi and for <u>C. muksun</u> in Lake Valkea-Mustajarvi for the period 1974–1981 based on population analysis

Age	Lake Rahtijarvi M	F	Z	Lake Valkea-Mustajarvi M	F	Z
0	0.53	0.00	0.53	0.11	0.00	0.11
1	0.51	0.01	0.52	0.10	0.03	0.13
2	0.53	0.02	0.55	0.08	0.05	0.13
3	0.63	0.10	0.73	0.13	0.05	0.18
4	0.80	0.16	0.96	0.40	0.10	0.50
5	0.90	0.18	1.08	1.13	0.09	1.22
6	1.00	0.40	1.40	1.20	0.17	1.37
mean	0.70	0.12	0.82	0.45	0.07	0.52

M the instantaneous rate of natural mortality

F the instantaneous rate of fishing mortality

Z the instantaneous rate of total mortality

The values in the table are annual values, so that the mortality for 0-year old fish must be multiplied by 4 in order to give the mortality of the first quarter of the year, i.e., the Autumn of the year in which they were stocked

Table 5 Development of the size (number of individuals at the beginning of the year) of the Lake Rahtijarvi C. Peled population and the Lake Valkea-Mustajarvi C. muksun population, calculated using population analysis and the estimated size based on marking-recapture

Lake	1974	1975	1976	1977	1978	1979	1980	1981	Marking-recapture summer 1981
Rahtijarvi	-	846	1 243	1 949	2 172	1 931	1 727	1 726	1 455
Valkea-Mustajarvi	441	340	887	1 616	2 259	3 353	4 019	4 454	4 108

Fig. 1   Location of the lakes used in the study (Evo)

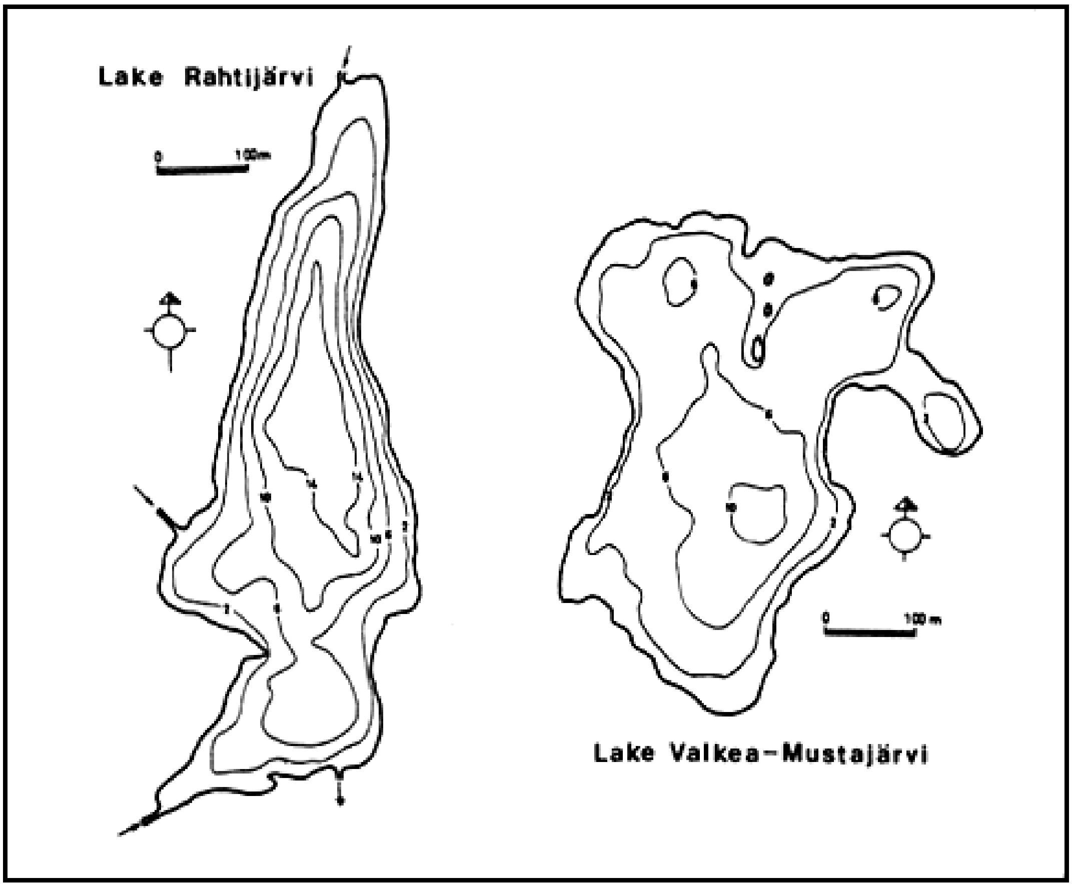

Fig. 2 Lake Rahtijärvi (Lake R) and Lake Valkea-Mustajärvi (Lake V-M)

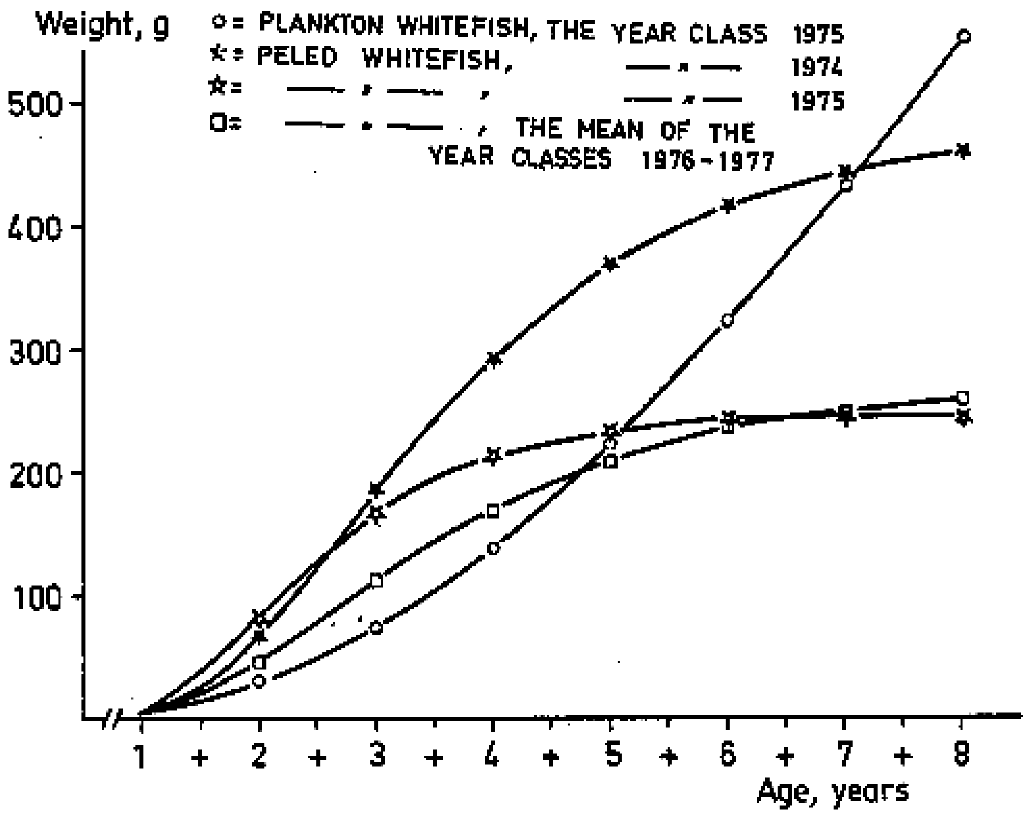

Fig. 3 The average weight at various ages of selected year-classes of C. peled and C. muksun whitefish stocked in Lake Rahtijärvi. Calculated on the basis of von Bertalanffy's growth equations and length-weight relationships. C. muksun were stocked only once, in 1975 (see Table 1)

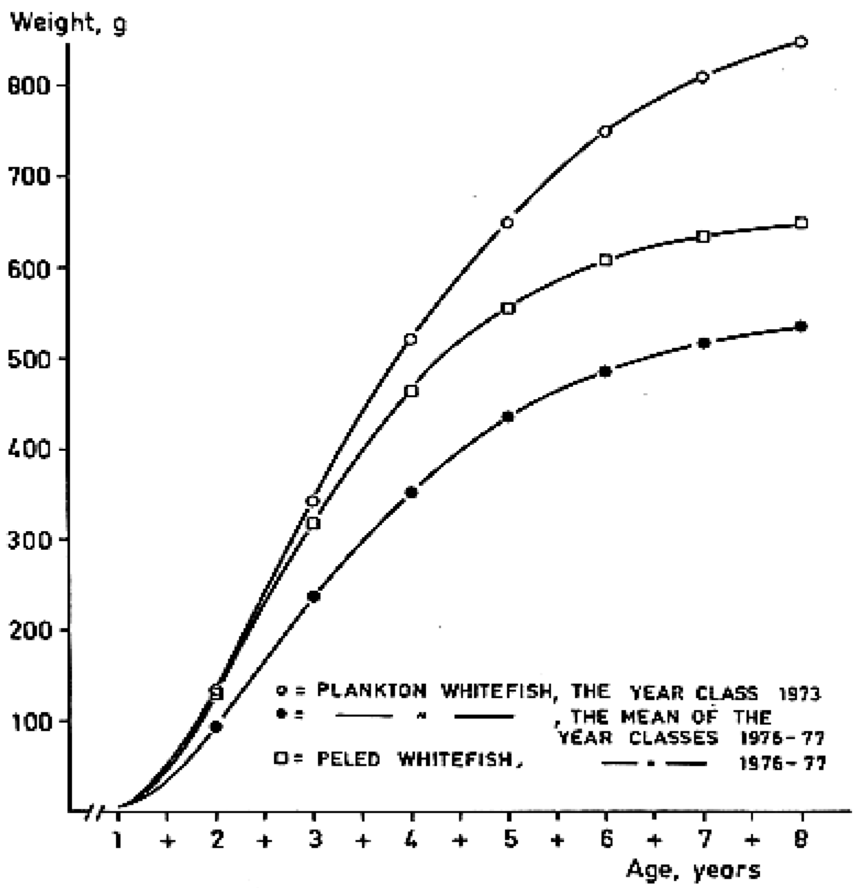

Fig. 4 The average weight at various ages of selected year-classes of <u>C. peled</u> and <u>C. muksun</u> stocked in Lake Valkea-Mustajärvi. Calculated on the basis on von Bertalanffy's growth equations and length-weight relationships

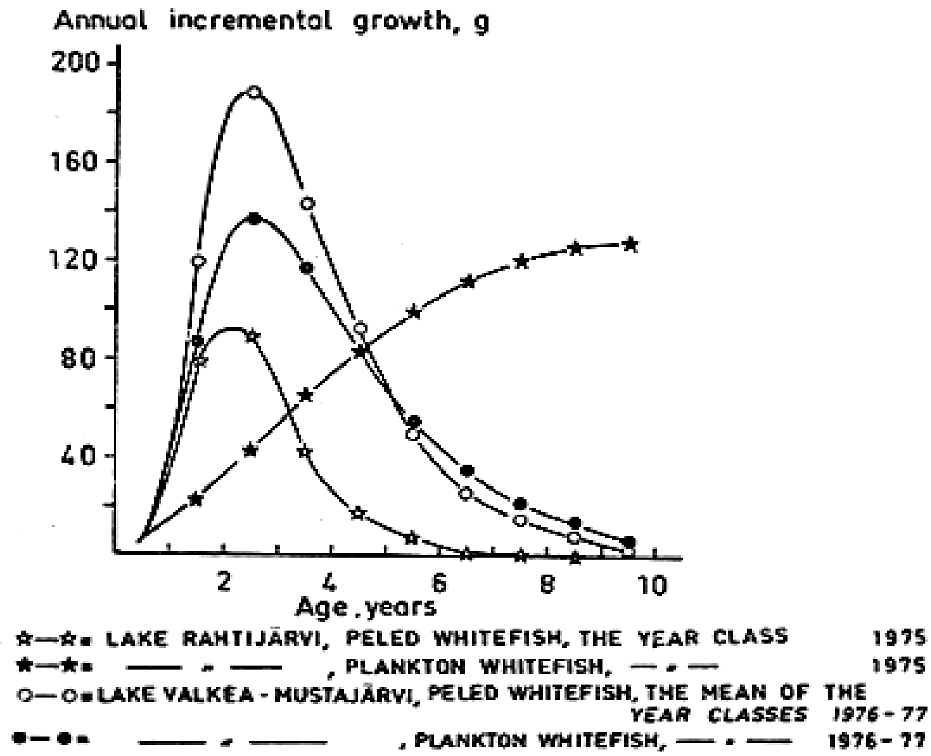

Fig. 5 The annual incremental growth of C. peled and C. muksun stocked in Lakes Rahtijärvi and Valkea-Mustajärvi as a function of the age of fish, calculated on the basis of von Bertalanffy's growth equations, for those year-classes in which year both C. peled and C. muksun were stocked in the same lake

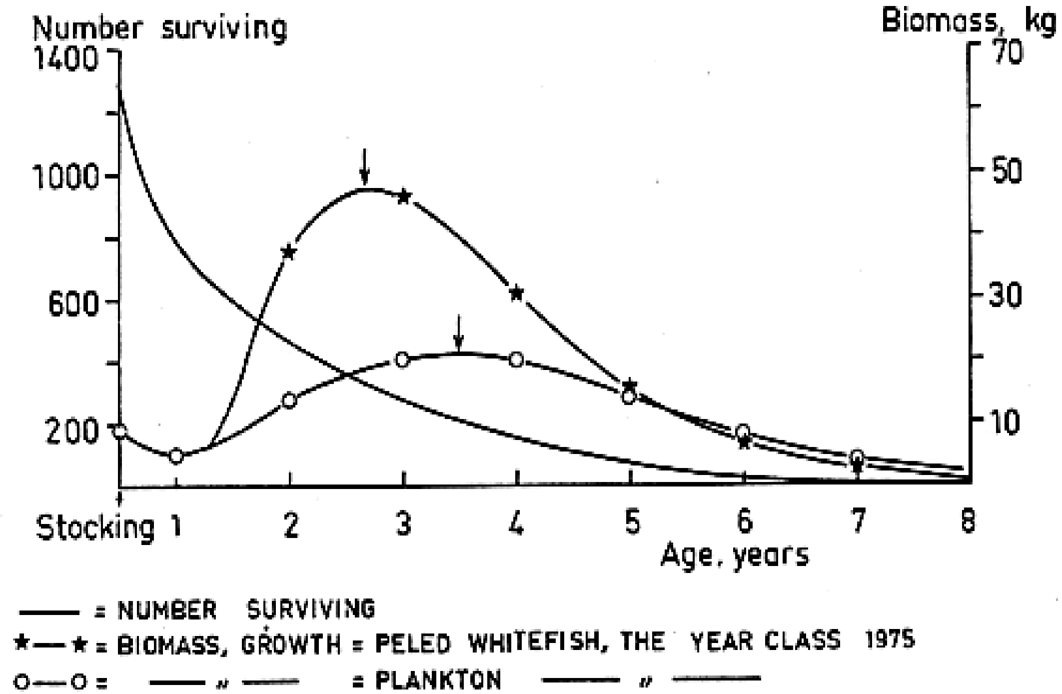

Fig. 6 The development in size and biomass of a year-class for <u>C. peled</u> and <u>C. muksun</u> in Lake Rahtijärvi when the size of the stocking was 1 300 individuals. The instantaneous rate of natural mortality used is the average for 1974–81. The maximum biomass, calculated on the basis of various calculations, is marked with an arrow on the biomass curve

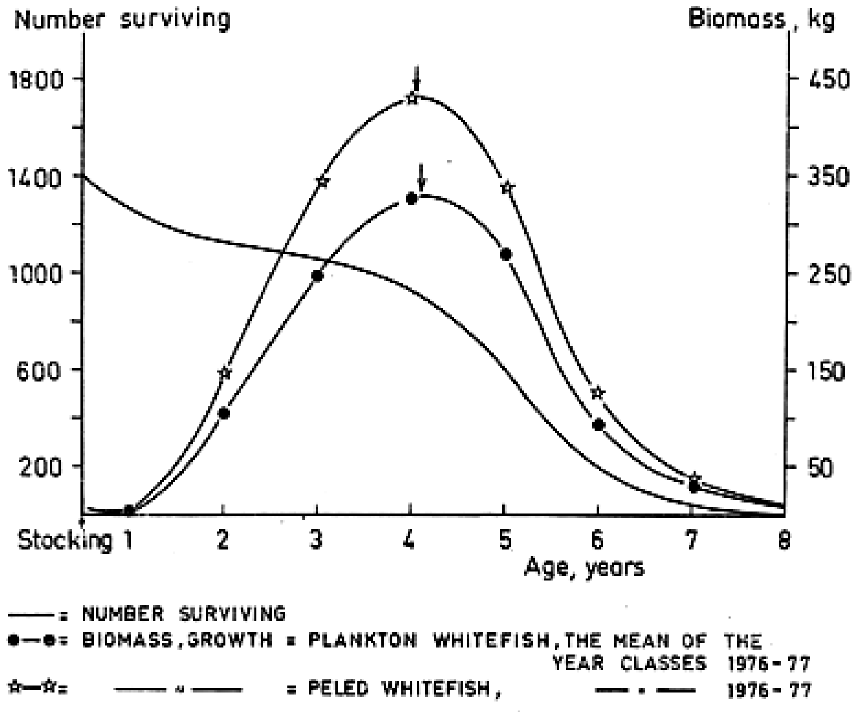

Fig. 7 The development of the size and biomass of a year-class for C. peled and C. muksun in Lake Valkea-Mustajärvi when the size of the stocking was 1 400 individuals. The instantaneous rate of natural mortality used is the average for 1973–81. The maximum biomass is marked with an arrow on the biomass curve

THE FOOD OF THE NATIVE WHITEFISH (Coregonus muksun (Pallas)) AND THE INTRODUCED WHITEFISH (C. peled (Gmelin)) STOCKED IN THE SAME SMALL FOREST LAKES IN SOUTHERN FINLAND

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CONTENTS

ABSTRACT

In 1973, one-summer old whitefish fingerlings were stocked in two small forest lakes: Lake Valkea-Mustajarvi, an oligohumous lake with a surface area of 13.9 ha and a mean depth of 3.3 m; and Lake Majajarvi, a polyhumous lake with a surface area of 3.4 ha and a mean depth of 4.0 m. The stocking density was 35 fingerlings of C. muksun (Pallas) and 35 fingerlings of C. peled (Gmelin) per hectare in both lakes.

The zooplankton biomass (wet weight) was 40.4 kg/ha in Lake Valkea-Mustajarvi and 26.1 kg/ha in Lake Majajarvi in June–September 1974. The amount of the large, preferred plankton species, Heterocope appendiculata and Holopedium gibberum, was less in Lake Majajarvi than in Lake Valkea-Mustajarvi; Daphnia galeata and Leptodora kindti were lacking entirely in Lake Majajarvi. Respectively, small zooplankters, rotifers, Ceriodaphnia quadrangula and Bosmina longirostris were more abundant in Lake Majajarvi.

According to the stomach analyses, cladocerans (Daphnia, Bosmina) and Holopedium usually dominated in the summer and autumn, and copepods (especially Eudiaptomus sometimes Cyclops) in the winter and spring. Bottom fauna (e.g., chironomids, culicids, trichopterids) constituted more than 50 percent of the stomach content in only two of the 29 fish samples.

The similarity index was low (45±4.9 percent) in Lake Valkea-Mustajarvi but quite high (78.3±9.1 percent) in Lake Majajarvi. Effective predation in the latter lake diminished the occurrence of important food species, with the result that Bosmina coregoni and Daphnia cristata became objects of predation.

Thus, both similarity of food items and trophic competition were high in Lake Majajarvi.

The difference between the intensity of competition in the two lakes was observed in the stomach fullness and condition indices as well as in the growth rate. The growth rate of C. muksun was high in Lake Valkea-Mustajarvi: the total length of four-year old C. muksun individuals was 39.4±0.4 cm.

The zooplankton production utilizable by the next trophic level was estimated at circa 400 kg/ha in Lake Valkea-Mustajarvi but only 130 kg/ha in Lake Majajarvi in June–September 1974. Whitefish production in Lake Valkea-Mustajarvi was estimated as accounting for over 60 percent of the theoretical total fish production calculated on the basis of utilizable zooplankton. According to the zooplankton species composition, utilization of zooplankton was higher in Lake Majajarvi than in Lake Valkea-Mustajarvi in 1974. Whitefish numbers in Lake Majajarvi may have decreased during the winter of 1974–75 due to starvation and possibly a low oxygen concentration. Thus, a stocking rate of 70 whitefish fingerlings per hectare was suitable for Lake Valkea-Mustajarvi but too great for Lake Majajarvi.

RESUME

En septembre 1973, on a repeuplé deux petits lacs forestiers du sud de la Finlande (Valkea-Mustajarvi et Majajarvi) avec des juvéniles (un été) appartenant à deux espèces de poisson blanc: Coregonus muksun (espèce indigène planctophage) et Coregonus peled (poisson blanc sibérien, espèce introduite). On a mis 487 unités de chaque espèce dans le premier lac, 119 dans le second. Les deux lacs sont oligotrophes; le premier est oligohumique, le second polyhumique. Leur superificie est respectivement de 13,9 et 3,4 ha et leur profondeur moyenne de 4,0 et 3,3 m.

On a analysé le contenu de l'estomac de ces poissons et on a constaté que leur nourriture se composait essentiellement de cladocères (Daphnia, Bosmina et Holopedium) en été et en automne et de copépodes surtout Eudiaptomus spp. et, occasionnellement, Cyclops spp.) en hiver et au printemps. Seuls deux des 31 estomacs analysés contenaient plus de 50 pour cent (en poids) de faune benthique (par exemple, chironomides, culicides, trichoptérides, hydracariens).

L'indice de similarité alimentaire (cf. Shorygin, 1939) entre les deux espèces de poisson blanc était plus élevé dans le lac de Majajarvi (72 pour cent) que dans celui de Valkea-Mustajarvi (48 pour cent) en 1974. Le pourcentage de faune benthique dans le premier de ces lacs était faible. La biomasse du zooplancton en juin–septembre 1974 (poids humide) était de 26 kg/ha dans le lac de Majajarvi et de 40 kg/ha dans celui de Valkea-Mustajarvi. La production de zooplancton utilisable au stade trophique suivant était estimée à 400 kg/ha environ (en juin/septembre) dans le lac de Valkea-Mustajarvi et à 130 kg/ha seulement dans le lac de Majajarvi. En 1974, le pourcentage de remplissage des estomacs (cf. Windell, 1971) montrait que les poissons étaient insuffisamment nourris. Dans le lac de Valkea-Mustajarvi, ce pourcentage était de 47,5/1 000 pour Coregonus muksun et de 34, 2/1 000 pour Coregonus peled; dans le lac de Majajarvi, il était respectivement de 25,4/1 000 et 30,1/1 000. En outre, le taux de croissance du poisson blanc montrait clairement qu'il y avait une forte concurrence alimentaire dans le lac de Majajarvi. En octobre 1974, le poids moyen de C. muksun dans le lac de Valkea-Mustajarvi était de 108 g, contre 33 g seulement dans le lac de Majajarvi; pour C. peled, il était respectivement de 183 et 66 g.

1. INTRODUCTION

In recent years more attention has been paid in efforts to improve the economic utilization of Finland's numerous small lakes by stocking of whitefish which feed on zooplankton. Such whitefish are generally not found in the natural communities of small Finnish lakes. In 1973 the Evo Inland Fisheries and Aquaculture Station began a comparative study of the suitability of the domestic Coregonus muksun (Pallas) and Coregonus peled (Gmelin), imported from the U.S.S.R. in 1965 for fish cultivation in small waters (Pruuki, Pursiainen and Westman, 1983).

The aim of the present investigation was to study the food and trophic competition between these two whitefish species stocked in 1973 in two small forest lakes in southern Finland, both the property of the Evo Inland Fisheries and Aquaculture Research Station.

Lakes Valkea-Mustajarvi and Majajarvi are situated in Lammi, Evo (25°5'E; 61°12'N). The water in these lakes is quite different (Table 1). Lake Valkea-Mustajarvi is oligohumic and Lake Majajarvi polyhumic. Oxygen loss was observed in March–April in the hypolimnion of both lakes, and in some years also in the epilimnion of Lake Majajarvi.

The growth and production of the whitefish stocked in Lake Valkea-Mustajarvi has been presented elsewhere (Pruuki, Pursiainen and Westman, 1983).

2. MATERIAL AND METHODS

Zooplankton samples were collected with a Sormunen tube sampler and filtered through a 50 um mesh (Hakkari, 1978). Altogether, 64 zooplankton samples were collected between October 1973 and October 1974. The zooplankton biomass was estimated as wet weight using standard volumes (Hakkari, 1978). The production of the most important zooplankton taxa was estimated according to the graphical method of Winberg (1971).

In October 1973, one-summer old whitefish fingerlings were stocked in the lakes, 35 C. muksun and 35 C. peled per hectare. The fish material collected with gill nets and fyke nets in 1974–76 consisted of 300 individuals in 29 samples (of. Table 3). Species, total length (RT-measure), weight and the weight and species composition of the stomach contents were analysed. Samples were preserved frozen. The zooplankton and fish samples were taken by the author Matti Mielonen and the analyses were carried out by the author Pirkko Selin.

3. RESULTS

3.1 Zooplankton

Eudiaptomus spp. (E. gracilis and graciloides), Daphnia cristata and Holopedium gibberum dominated the zooplankton in Lake Valkea-Mustajarvi; and the mean total biomass in this lake was 40.4 kg/ha during the growing season 1974 (Table 2). The mean biomass in Lake Majajarvi was only 65 percent, i.e., 26.1 kg/ha that of Lake Valkea-Mustajarvi. The dominant zooplankton taxa in Lake Majajarvi were Eudiaptomus spp., Cyclops spp., and Daphnia cristata; D. galeata and Leptodora kindti were entirely lacking. On the other hand, the amounts of rotifers, Bosmina longirostris and Ceriodaphnia quadrangula were higher than in Lake Valkea-Mustajarvi.

If the ingestion rate of predatory zooplankton is taken as four times their own production (Winberg et al., 1972) then the useful zooplankton production left for fish and invertebrate predators was at least 400 kg/ha in Lake Valkea-Mustajarvi, and 130 kg/ha in Lake Majajarvi in June–September 1974.

3.2 The food of whitefish

Zooplankton was the main food of both whitefish species (Table 3). Only in two of the 29 fish samples did bottom and surface fauna (e.g., chironomids, culicids, trichopterids, hydracarins) constitute more than 50 percent of the stomach contents. Chironomids and culicids were partly as pupae in the spring. According to Grimas (1961) they are important food for fish at that time.

The stomach contents were clearly simpler in Lake Majajarvi. Coregonus peled and C. muksun fed on almost the same food items. The size of food items changed only slightly in the food contents of one and four-year old whitefish. Asellus aquaticus was only observed in the diet of C. muksun with a length of more than 34 cm.

The similarity index that may have values between 0 and 100 percent (Shorygin, 1939) was low between C. muksun and C. peled (average 45 ± 4.9 percent) in Lake Valkea-Mustajarvi but quite high (average 78.3 ± 9.1 percent) in Lake Majajarvi in 1974. The differences between the lake indices were statistically significant ($t = 3.24$ t_5 percent $= 2.31$; Fig. 1). In 1975 the similarity between the species in Lake Valkea-Mustajarvi seemed to be quite high (cf. Table 3).

The forage ratio (FR) (Zaret, 1980) showed that both species preferred Holopedium in Lake Valkea-Mustajarvi in the summer. In both lakes, C. muksun seemed to prefer Daphnia slightly more intensively than C. peled. Bosmina c. obtusirostris was the only strongly preferred taxon in Lake Majajarvi; however, in Lake Valkea-Mustajarvi it was only slightly preferred in the spring and autumn. The most abundant copepod taxa, Eudiaptomus and Cyclops, were avoided during the summer despite their rather high biomass (Figs. 2 and 3).

The stomach fullness index (Windell, 1971) gives information as to the sufficiency of food. The mean stomach content indices were as follows:

	Lake Valkea-Mustajarvi		Lake Majajarvi
	1974	1975	1974
C. muksun	47.5 %oo	32.1 %oo	25.4 %oo
C. peled	34.2 %oo	18.8 %oo	30.1 %oo

The index values for C. muksun were statistically higher in Lake Valkea-Mustajarvi than in Lake Majajarvi in summer in 1974 ($t = 2.32^{x}$).

3.3 The condition and growth rate of whitefish

The Fulton condition index of C. muksun was significantly higher in Lake Valkea-Mustajarvi than in Lake Majajarvi and slightly significantly higher by C. peled in 1974:

	Lake Valkea-Mustajarvi	Lake Majajarvi	t-test
C. muksun	0.768±0.017	0.678±0.013	4.117^{xx}
C. peled	0.838±0.027	0.748±0.012	3.091^{x}

The results agree well with the stomach content index values. C. muksun and C. peled were highly significantly bigger in Lake Valkea-Mustajarvi than in Lake Majajarvi in the autumn 1974, when whitefish were two years old (C. muksun: $t = 16.41^{xxx}$; C. peled: $t = 15.13^{xxx}$). Respectively, C. peled was highly significantly bigger than C. muksun in

Lake Valkea-Mustajarvi ($t = 8.07^{xxx}$; cf. Pruuki, Pursiainen and Westman, 1983) and in Lake Majajarvi ($t = 7.81^{xxx}$) at that time (Table 4).

4. DISCUSSION

4.1 Whitefish predation and the species composition of zooplankton

Sympatric whitefish species have an ability to segregate into different feeding niches, especially as the gill raker counts are different (Nilsson, 1960; Lindstrom and Nilsson, 1962). In this study the gill raker counts were close to each other, roughly 50. Feeding segregation appeared to take place in Lake Valkea-Mustajarvi where a varied food supply made it easy. The segregation was observed as a low similarity (percentage of overlap in feeding habits) between the species in 1974.

For example, Nilsson (1960, 1965) stated that segregation between whitefish species took place when competition was high. Also, segregation became clearer toward autumn when the food was on the decrease. This was also found by Heikinheimo-Schmid (1982) in some lakes in northern Finland.

In this study no segregation was found in Lake Majajarvi during hard competition for food between C. muksun and C. peled in 1974. In spite of the sparse material, the standard error of the mean of similarity between the food composition of C. muksun and C. peled was small, as seen in Fig. 1. Obviously, the result gave a real picture of the situation in the lake.

Large species, such as Leptodora and Heterocope appendiculata, as well as Holopedium gibberum, were preferred in Lake Valkea-Mustajarvi. Thus the size and visibility of the prey species had an effect on food selection, as pointed out earlier by many authors (e.g., Brooks and Dodson, 1965; Hrbacek and Hrbackova-Esslova, 1966; Reif and Tappa, 1966; Hakkari 1978). Eudiaptomus and Cyclops were avoided in summer, perhaps because of their agility (cf. Dodson, 1974).

The size of fish had no clear effect on the food composition. C. muksun, 30–40 cm in length, fed mainly on small items, e.g., Daphnia, Bosmina and Cyclops (cf. Table 3). Heikinheimo-Schmid (1982) supposed that the size of densely-rakered whitefish does not have as great an effect on the food composition as that of whitefish with a low gill raker count.

Many Scandinavian investigations have shown that among the zooplankters consumed by most species of Coregonus, Bosmina coregoni is by far the most important food item (Nilsson and Pejler, 1973). Its presence in the stomach content indicates a high feeding pressure on zooplankton. The number of large, preferred species is low, and selection becomes intensively concentrated on Bosmina coregoni, as was observed in Lake Majajarvi in 1974.

Fish predation has an effect on the species composition of zooplankton (e.g., Zaret, 1980). The differences in the predation pressure between L. Valkea-Mustajarvi and Majajarvi are seen in the proportions of preferred and avoided species. Rotifers are too small to be food for whitefish. They compete for food with cladocerans and benefit by the predation on cladocerans. This has been shown, e.g., in fish ponds with a natural food supply, where fingerlings of C. peled were raised (Hakkari and Dahlstrom, 1969). The increase of the small cladocerans Bosmina longirostris and Ceriodaphnia quadrangula in Lake Majajarvi agrees well with the results of Nilsson and Pejler (1973) in Swedish whitefish lakes. Respectively, the proportion of the large species Holopedium, Daphnia galeata, Leptodora and Heterocope appendiculata was smaller in

Lake Majajarvi, which also indicates more effective predation in Lake Majajarvi than in Lake Valkea-Mustajarvi.

4.2 Zooplankton production and its consumption by whitefish

The utilizable zooplankton production for fish and predatory invertebrates was more than 400 kg/ha/year in Lake Valkea-Mustajarvi and 130 kg/ha/year in Lake Majajarvi. The abundance of invertebrate predators, e.g., Chaoborus, was low in both plankton and stomachs; and other predators, e.g., Gammarus, were not observed even in the stomach content of whitefish.

The productivity of the natural fish composition of Lake Valke-Mustajarvi has obviously also been higher than that of Lake Majajarvi, because of the greater transparency of the water. Thus, when 70 one-summer old whitefish fingerlings per hectare were introduced, the zooplankton productivity in Lake Valkea-Mustajarvi was able to bear the increased predation but zooplankton production in Lake Majajarvi could not meet the demand for food. Therefore, the final results were:

(i) The whitefish in Lake Valkea-Mustajarvi were in good condition and had a good rate of growth while those in Lake Majajarvi starved and had a lower growth rate; and

(ii) In Lake Majajarvi both the biomass and production of preferred large zooplankton were low because of the effective predation.

The potential fish production based on the zooplankton production in 1974, calculated using a food coefficient of 8 (Phillips, 1972; Winberg et al., 1972) was about 50 kg/ha/year in Lake Valkea-Mustajarvi but only 16 kg/ha/year in Lake Majajarvi. Veijo Pruuki (manuscript) estimated that the maximum biomass of a stocking year-class was 200–300 kg/ha/1 000 whitefish fingerlings in Lake Valkea-Mustajarvi. According to Pruuki, it imparts a net production of 20–30 kg/ha, if stocking density is 100 fingerlings per hectare.

If zooplankton production is assumed to be lowered from the 1974 level because of the increased fish production resulting from the whitefish introduction (cf. Nilsson and Pejler, 1973), fish production based on zooplankton may rise to more than 60 percent of theoretical fish production. According to the zooplankton species composition, utilization of zooplankton was higher in Lake Majajarvi than in Lake Valkea-Mustajarvi in 1974.

Although several trial fishings were made, the catch was only four C. peled in Lake Majajarvi in 1975. The amount of whitefish diminished during the winter of 1974–75 as a result of starvation and, perhaps, because of the low oxygen concentration.

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Table 1 Hydrographical data from Lakes Valkea-Mustajarvi and Majajarvi from 1976 to 1981

	L. Valkea-Mustajarvi		L. Majajarvi	
Depth (m)	1	9	1	9
Oxygen concentration in March–April (mg/l)	8.1–12.3	0.9–1.8	3.7–9.5	0.0–1.3
pH	5.8–7.2	5.8–6.5	5.6–5.7	5.6–6.3
Water colour (mg Pt/l)	10–30	25–50	140–160	140–300
Conductivity (uS)	18–24	18–30	23–26	25–30
Area (ha)	13.9		3.4	
Greatest depth (m)	10.0		12.0	
Mean depth (m)	3.3		4.0	

Table 2 The mean biomass (B) and production (P) of the most important zooplankton taxa in Lakes Valkea-Mustajarvi and Majajarvi in June–September 1974

	L. Valkea-Mustajarvi		L. Majajarvi	
	B(kg/ha)	P(kg/ha)	B(kg/ha)	P(kg/ha)
Rotifera	2.31	30.98	3.04	45.72
Limnosida frontosa	0.01	0.96	-	-
Diaphanosoma brachyurum	0.57	28.50	0.30	19.92
Holopedium gibberum	7.30	200.00	0.89	26.16
Daphnia cristata	8.30	156.00	3.29	63.60
D. galeata	1.10	25.20	-	-
Bosmina coregoni obtusirostris	4.26	60.40	2.80	49.20
B. longirostris	+	+	0.30	3.64
Leptodors kindti	0.18	3.41	-	-
Ceriodaphnia quadrangula	0.01	0.25	0.22	4.09
Heterocope appendiculata	2.71	9.10	0.84	3.20
Eudiaptomus spp.	8.75	71.20	9.50	62.40
Cyclops spp.	4.87	55.40	4.88	32.20
Total	40.37	641.40	26.06	310.10

Table 3 The numbers and total lengths (cm) of the whitefish species in different seasons and the dominant food items in the stomachs (% of biomass)

	Lake Valkea-Mustajarvi					Lake Majajarvi			
C. muksun 1974 No. Size(cm) Main food	Winter (I-III) 8 11.3–12.6 Daphnia(49%) Chironomidae (28%)	Spring (IV-V) 14 11.7–15.0 Culicidae (71%) Chironomidae (11%)	Summer (VI-IX) 25 14.4–24.6 Holopedium (39%) Daphnia(44%) Leptodora (12%)	Autumn (X) 21 20.7–25.6 Daphnia(44%) Holopedium (20%) Bosmina(19%)	C.muksun 1974 No. Size(cm) Main food	Winter (I-III) 8 10.5–14.7 Eudiaptomus (59%) Cyclops(41%)	Spring (IV-V) 3 11.6–13.3 Cyclops(68%) Eudiaptomus (21%)	Summer (VI-IX) 12 11.7–18.7 Bosmina(68%) Daphnia(27%)	Autumn (X) 9 15.5–19.5 Bosmina(39%) Daphnia(35%)
1975 No. Size(cm) Main food	Winter (III) 11 22.8–26.7 Eudiaptomus (91%)	Spring (V) 10 24.3–26.3 Daphnia(46%) Chironomidae (34%)	Summer (VII) 6 28.2–31.3 Daphnia(54%) Cyclops(28%)	Autumn (XII) 14 31.6–34.2 Daphnia(61%) Asellus(16%) Cyclops(13%)					
1976 No. Size(cm) Main food	Winter (I-II) 9 31.8–39.6 Daphnia(46%) Cyclops(32%)	Spring (V) 4 30.8–36.2 Daphnia(46%) Cyclops(16%) Eudiaptomus (13%)	Summer (VI-IX)	Autumn (XII) 14 38.0–41.5 Bosmina(71%) Asellus(14%)					
C.peled 1974 No. Size(cm) Main food	Winter (I-III) 0	Spring (IV-V) 10 12.2–14.9 Cyclops(48%) Eudiaptomus	Summer (VI-IX) 52 14.9–28.1 Daphnia(20%) Cyclops(16%)	Autumn (X) 8 27.0–36.0 Holopedium (27%)	C.peled 1974 No. Size Main food	Winter (I-III) 0	Spring (IV-V) 2 11.6–12.2 Cyclops(74%) Eudiaptomus	Summer (VI-IX) 31 12.4–22.0 Bosmina(80%) Daphnia(12%)	Autumn (X) 12 17.6–22.7 Bosmina(47%) Daphnia(44%)

		(27%) Culicidae (16%)	Holopedium (13%)	Heterocope (22%) Cyclops(14%)			(24%)		
1975 No. Size(cm) Main food	Winter (III) 3 28.0–28.5 Eudiaptomus (75%) Cyclops(21%)	Spring (V) 1 29.6 Daphnia(85%)	Summer (VII) 11 30.5–36.0 Daphnia(54%) Cyclops(25%)	Autumn (XII)	1975 No. Size	Winter (III) 0	Spring (V) 0	Summer (VII) 0	Autumn (XII) 2 27.6–30.2

Table 4 The mean total lengths (cm) of C. muksun and C. peled in Lakes Valkea-Mustajarvi and Majajarvi in the autumn 1973–76

	C. muksun	C. peled
1973		
Valkea-Mustajarvi	10.0	9.4
Majajarvi	10.0	9.4
1974		
Valkea-Mustajarvi	24.1±1.1	28.1±0.3
Majajarvi	17.1±0.4	20.6±0.4
1975		
Valkea-Mustajarvi	34.3±0.6	-
Majajarvi	-	28.6±1.6
1976		
Valkea-Mustajarvi	39.4±0.4	-
Majajarvi	-	-

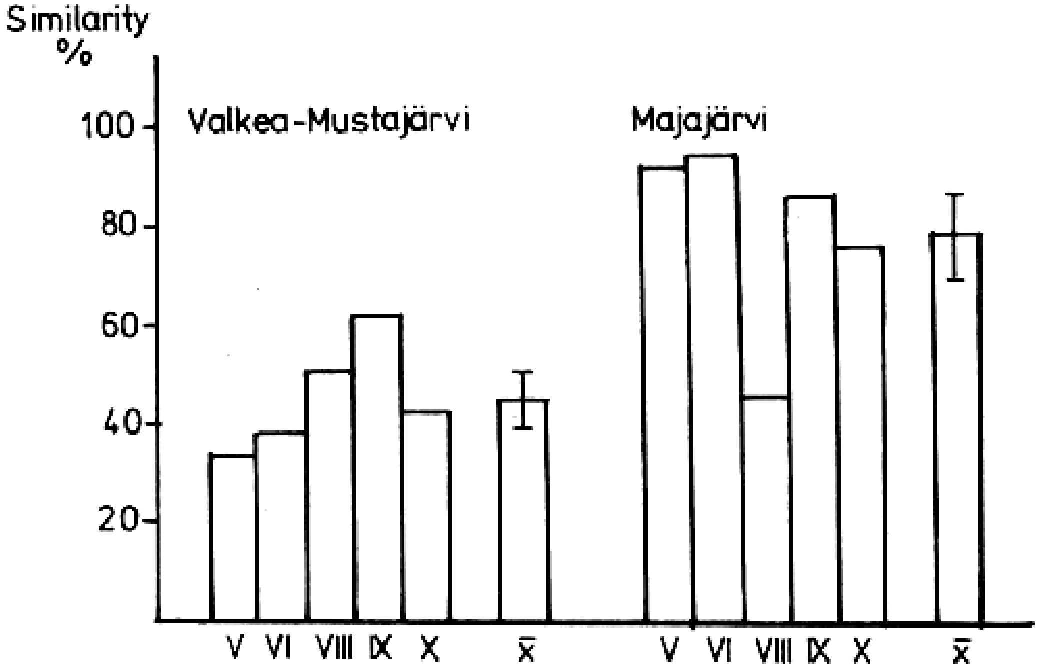

Fig. 1 The similarity index (Shorygin, 1939) between C. muksun and C. peled in L. Valkea-Mustajärvi and L. Majajärvi

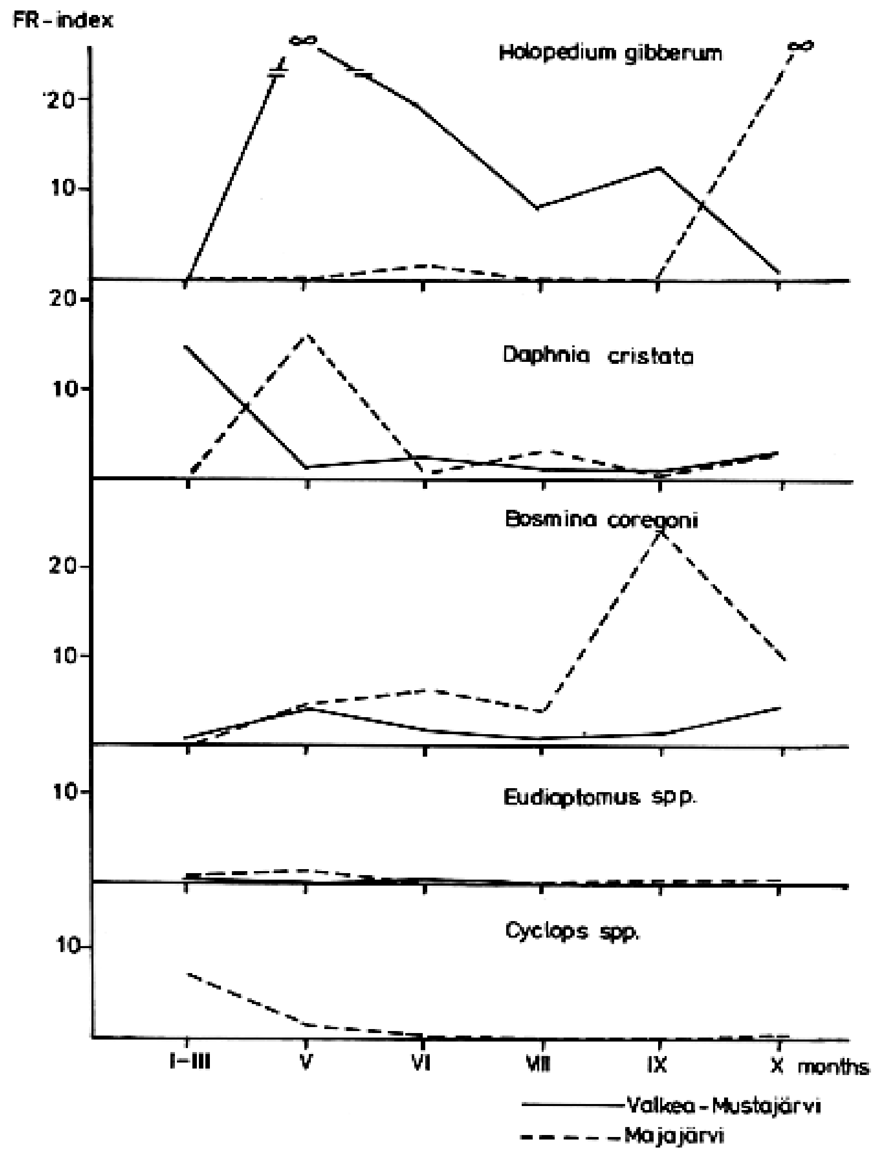

Fig. 2 The forage ratio (FR) index (Zaret, 1980) for C. muksun in L. Valkea-Mustajärvi and L. Majajärvi

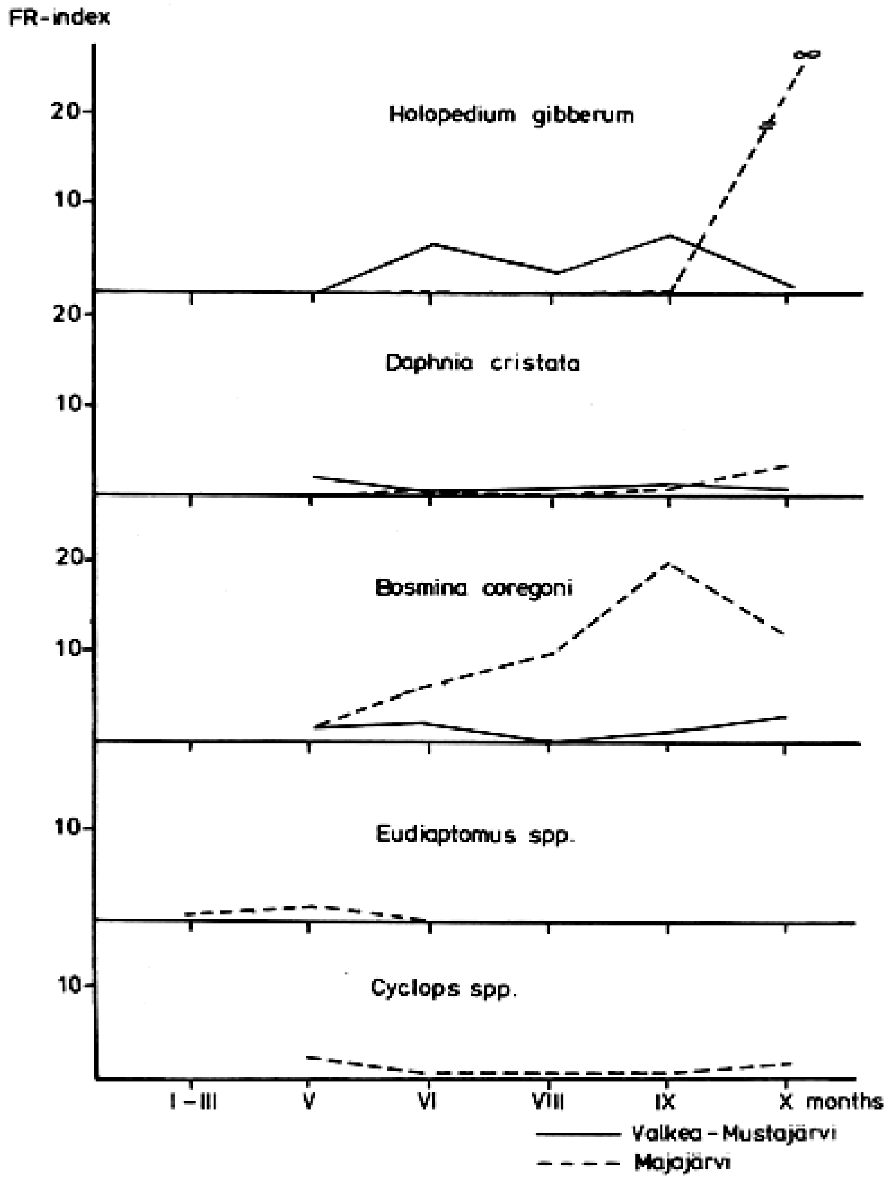

Fig. 3 The forage ratio (FR) index (Zaret, 1980) for C. peled in L. Valkea-Mustajärvi and L. Majajärvi

BROWN TROUT STOCKING IN NORWAY

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CONTENTS

ABSTRACT

The brown trout populations of Norway, especially in the high-lying forest and mountain regions are mainly the result of introductions which go back to the Stone Age and have continued to the present day. As a consequence of the rediscovery of artificial propagation, the Government Inspectorate of Salmon and Inland Fisheries was established in 1855, and introductions and stocking became more organized.

About 3 million brown trout are now released yearly, of which fry and autumn fingerlings comprise the major part. About two thirds of the total number are stocked into hydro-electric reservoirs. The released fish are meant to supplement the natural recruitment, and the stocking density accordingly varies with the local conditions. Ten fingerlings to one hectare is a density often used.

To explore the effects of stocking, experiments now in progress include 2.5 million fin-clipped or tagged young. The work has mainly taken place in hydro-electric reservoirs with severe living conditions.

After some years of stocking with fingerlings, the proportion of released fish in the catches normally varies between 30 and 50 percent but extremes of 5 and 75 percent are recorded. On the basis of total catches and assuming a total rate of exploitation of 75 percent, it is estimated that in most cases less than 10 percent of stocked juveniles survive to catchable size. The number may be as high as 60 percent in lakes where low natural recruitment and high food production are combined. Increasing the size of the stocked fish will also increase efficiency. Depending on local conditions, one two-summer old juvenile is equivalent to 4–12 autumn fingerlings. In sparsely populated lakes this ratio may be smaller, in reservoirs with predators higher. Releases of fish of catchable sizes will normally give a return of 40–60 percent, depending on fishing intensity.

Stocking in spring is more efficient than in autumn and so is stocking directly into the reservoirs compared to release in tributaries. The use of fish-eating trout strains in reservoirs crowded with small pelagic fish may give rise to fast-growing individuals, attaining a maximum weight of 15 kg. Such strains are often used in the control of dwarfed char populations. Good returns are also achieved by releasing two-year old predatory trout into fjord systems without prior adjustment of the fish to brackish water.

At present prices, the value of fish flesh recaptured rarely exceeds the cost of stocking. Only the use of big predatory trout or fry and fingerlings in sparsely populated lakes may be directly profitable. However, good fishing is in many places a basis for the tourist industry. Income by hiring out fishing rights or sale of licences may surpass the purchase sum of the stocked fish. Furthermore, the accomodation of anglers will contribute to making stocking profitable.

RESUME

En Norvège, les populations de truites (Salmo trutta) notamment dans les régions montagneuses et dans les zones forestières d'altitude, résultent essentiellement d'introductions. Celles-ci remontent à l'âge de pierre. En 1855, une fois redécouverte la propagation artificielle, la Norvège a décidé de créer une Inspection des pêches continentales et du saumon et on a commencé à organiser de façon plus systématique les introductions et le repeuplement.

On déverse chaque année dans les eaux intérieurs quelque 3 millions de truites; il s'agit surtout de fretin et d'alevins d'automne. Les deux tiers à peu près de ces truites

servent à repeupler des réservoirs hydro-électriques. Le repeuplement est destiné à compléter le recrutement naturel et sa densité varie donc en fonction des conditions locales. Elle est souvent de dix alevins à l'hectare.

On procède actuellement à des expériences avec 2,5 millions de juvéniles marqués (coupe des nageoires ou autre méthode) pour étudier les effets du repeuplement, principalement dans les réservoirs hydro-électriques où les conditions de vie sont difficiles.

Après quelques années de repeuplement avec des alevins, les poissons qui en sont issus représentent normalement de 30 à 50 pour cent des captures mais on a également observé des minimums de 5 pour cent et des maximums de 75 pour cent. Compte tenu du total des captures et en évaluant à 75 pour cent le taux d'exploitation, on estime que, dans la plupart des cas, moins de 10 pour cent des juvéniles utilisés pour le repueplement atteignent une taille exploitable. Toutefois, cette proportion peut atteindre 60 pour cent dans les lacs où le recrutement naturel est faible et la production alimentaire élevée.

Le repeuplement donne de meilleurs résultats si l'on utilise des poissons de plus grande taille. En fonction des conditions locales, un juvénile de deux étés équivant à 4–12 alevins d'automne. Ce rapport sera sans doute plus faible dans les lacs peu peuplés alors qu'il sera plus élevé dans les réservoirs où il y a des prédateurs. En lâchant des poissons de taille exploitable, on obtiendra normalement un rendement de 40–60 pour cent, en fonction de l'intensité de la pêche.

Il est préférable de mettre les poissons à l'eau au printemps plutôt qu'en automne et de repeupler directement les réservoirs plutôt que leurs affluents. L'utilisation de races de truites piscivores dans des réservoirs très densément peuplés en petits poissons pélagiques permet d'obtenir des individus à croissance rapide, pouvant atteindre un poids maximum de 15 kg. Ces races sont souvent utilisées pour empêcher le développement de populations d'ombres nains. On obtient également de bons résultats en lâchant des truites prédatrices de deux ans dans les fjords sans les adapter au préalable aux eaux saumâtres.

Aux prix actuels, la valeur du poisson recapturé est rarement supérieure au coût du repeuplement. Seule l'utilisation de grandes truites prédatrices ou de frai et d'alevins dans des lacs peu peuplés peut être directement profitable. Toutefois, la pêche est souvent un attrait pour le touriste. Les recettes tirées de l'allocation de droits de pêche ou de la vente de permis peuvent être supérieures aux dépenses faites pour le repeuplement. Le logement des pêcheurs contribuera aussi à rendre le repeuplement rentable.

1. INTRODUCTION

The brown trout (<u>Salmo trutta</u> L.) is the most widespread and important freshwater fish species in Norway. The populations, especially in the high-lying forest and mountain regions are mainly results of introductions which date from as far back as the Stone Age and have continued to the present day. As a consequence of the rediscovery of the artificial propagation, the Government Inspectorate of Salmon and Inland Fisheries was established in 1855, and introductions and stocking became more organized. Recently about 3 million brown trout are released yearly, fry and autumn fingerlings comprising the major part. About two thirds of the total number are stocked into hydro-electric reservoirs. The released fish now mostly supplement the natural recruitment.

To explore the effects, experiments including 2.5 million tagged and fin-cut young have been in progress in southern Norway for the last 20 years. The studies have mainly taken place in hydro-electric reservoirs with severe living conditions. Few results have been published (Aass, 1971, 1973, 1981) and the present paper tries to sum up the knowledge so far.

2. RETURNS OF STOCKED TROUT

The returns depend both on local conditions, such as existing fish populations and food production, and experimental conditions, e.g., time of stocking and fish size and strain. Traditionally, stockings take place in autumn with fingerlings averaging 5 cm and 1.5 g. The stocking density mostly used is 5–10 fingerlings/ha, the reservoir areas measured at maximum water level.

After some years of stocking, the reared fish may constitute 30–50 percent of the trout catch in number. But great deviations from these figures occur with extremes of 5 and 75 percent having been recorded. The variations are due to different ratios of food production to recruitment. Stocking is only imposed when an impoundment is expected to interfere with recruitment. But experience shows that it is difficult to assess the rate of damage in advance. The figures mentioned include several year-classes of reared fish. The return from a single stocking mostly lies between 3 and 7 percent. Generally, the costs of stocking greatly exceed the value of fish flesh produced or harvested. However, the plantings imposed on the hydro-electric companies are not expected to be profitable but are intended to exploit the remaining fish food production. Stocking success may also be achieved. Two successive releases in a mountain lake situated 1 350 m above sea level yielded returns of 55 and 50 percent, respectively. In this case recruitment was reduced proportionally more than the production of bottom organisms. By continued stocking the return dropped to 25 percent. An even bigger decline may occur in the most oligotrophic reservoirs, e.g., Limingen, where the return decreased from 15 to 3 percent after few years of stocking. As frequently demonstrated, the rate of survival is density dependent. Thus, an increase of number planted rarely gives the results expected. By doubling the number of fingerlings released in Lake Tunhovdfjord from 5 to 10 per hectare, the return only rose by 40 percent.

Some of the bigger lakes harbour fast-growing trout strains, feeding entirely on prey fish. To stock such lakes with autumn fingerlings would be in vain, and two-year old trout are used. The return depends on whether the young are planted in the lower sections of adjacent rivers or in the lake itself. River stocking gives a high return in number because the groups are subject to exploitation before moving into the lake. Lake release gives a higher return of adult fish Accordingly, the return in number varies strongly, perhaps between 10 and 50 percent. Plantings of large young contribute 50 percent toward the maintenance of the most famous trout strain in Norway, the Hunder trout of Lake Mjosa.

Recently, fast-growing strains of fish-eating trout have been stocked into fjord systems, mainly the Oslofjord, without prior acclimatization of the young to brackish or salt water. The recorded returns average about 20 percent, but the fishermen are reluctant to report recoveries, and the real number is considerably higher. The fjord plantings are perhaps the most promising stocking project for the time being.

River angling for trout is the most popular recreational fishery in Norway. In many rivers, the demand for sport cannot be met by the local fish production. To enhance the resident river populations, plantings of 0+ and 1+ young seem to be of little use. Stocking with sizable fish is more rewarding both for economic and recreational reasons. Depending on exploitation, a return of about 50 percent may be expected, but the results are also influenced by fish size and time of planting. Put-and-take fishing is not yet common practice in Norway.

All the return figures have been given in percentage of number planted. Returns expressed as a percentage of total weight released may give a better indication of the success of stocking with larger young. The best return from Lake Mjosa is estimated to be about 600 percent and from the Oslofjord to 400 percent of the total weight released.

3. THE IMPORTANCE OF SIZE AND TIME IN STOCKING

For introductions and plantings into tarns and lakes either empty of fish or with small trout stocks, fry is the natural choice. Yet only one experiment with fry has been carried out in Norway. The little Lake Ljosevatn, 1 100 m above sea level, harbouring a small resident stock was stocked every second year with 100 fry/ha. After 17 years, Dahl (1933) estimated the return to be 4.7 percent. The yields of the strengthened year-classes were doubled. When conditions become more complicated, especially in connexion with the development of the water courses for hydro-electric power production, a change to bigger fish is necessary. In Norway, this transition mainly took place in the fifties. The return figures already mentioned show that even fingerlings may be inadequate in places. Consequently 1+ fish have been compared to fingerlings in a series of reservoirs where trout is living sympatrically with char (<u>Salvelinus alpinus</u> L.), whitefish (<u>Coregonus lavaretus</u> L.) or grayling (<u>Thymallus thymallus</u> L.). The two-summer old fish gave 3–12 times better return than fish one-summer old stocked at the same time. Where trout is co-existing with perch or other predatory species the ratio is even more favourable. The higher production and transportation expenses make a return ratio of 1:4 necessary for a change to two-summer old fish to be profitable.

The change from one to two-summer old fish means an increase in average stocking size from 5–6 to 13–16 cm. The significance of size has also been confirmed in experiments with groups of 0+ young differing 2–3 cm in average length. Two-year old fish are used when stocking lakes containing fish species serving as prey for the trout. The minimum size mainly imposed on the hydro-electric companies is 20 cm, and a bonus is given for young exceeding 24 cm. The figures are based on return results from Lake Mjosa where the trout co-exists with about 20 species but mainly feeds on smelt (<u>Osmerus eperlanus</u> L.) and cisco (<u>Coregonus albula</u> L.). The return of adult fish doubled by increasing the size of the young from 17 to 20 cm and doubled again by a further increase to 23 cm. Stocked as untagged fish, the differences might have been less striking but it is assumed that tag shedding and tagging mortality are not the main reasons for the superiority of the bigger young. The greater part of the loss is ascribed to predation and competition. A speeding up of growth in the hatcheries will, however, accelerate maturity and consequently decrease the spawning size.

Also time of release seems to be a factor of major importance to rate of survival and return. Of comparable releases in autumn and spring, the spring-stocked fish always give the highest return. In the mountain lake Skurdalsvann, spring yearlings gave four times better result than autumn fingerlings. Part of the result may be ascribed to a size difference of 3 cm, the average lengths being 6 and 9 cm. As always, strain and hatch were kept the same. But even when the fingerlings and yearlings are of the same size, the spring-stocked fish seem to be superior (Strange and Kennedy, 1979). However, differences in rate of growth make comparisons between Scandinavian and Continental/British experiments difficult.

In Norway hatchery wintering nearly doubles the per-unit production cost of young fish. Therefore, many experiments with stocking fish-eating 1+ young have been made in the autumn. But releases of the same brood as two years old in spring have always given a higher return, in the case of Lake Mjosa 3–6 times higher. The same ratio is achieved if the young are released into the fjords. The results are perhaps not surprising because most Norwegian lakes are ice-covered 6 to 9 months a year. Fish released in autumn may start their free life with a fast lasting half a year. But spring stocked fish also give a higher return when climate is less severe (Kennedy et al., 1982). During a stocking experiment in Lake Mjosa, batches of two year-old young were released every fortnight throughout most of the year. The returns increased from winter to spring and decreased from summer to autumn. The batches giving the highest returns were released in early June. At this time of the year, the behaviour of the fast-growing young very much resembles that of smolts.

Sizable trout, mean lengths of batches 25–35 cm, are mostly planted in the heavily fished rivers of eastern Norway. Releases late in autumn have given a return of 20–25 percent in the next season, whereas spring stocked fish have given a return of 40–60 percent. Most recoveries are made within a few weeks, but early planting may give a more even distribution of returns throughout the season. The winter mortality of the remaining stocked fish exceeds that of the resident trout by 3–4 times. The migrations of the stocked trout are in general very short (Aass, 1978, 1981a).

4. THE IMPORTANCE OF STRAIN IN STOCKING

If bottom food exists in abundance, the strain used in fingerling stocking is of little importance, but if typical trout food is scarce, the survival of different strains may vary considerably. In the oligotrophic Lake Tunhovdfjord domesticated foreign and Norwegian lowland trout have proved inferior to the indigenous strain. When Danish trout were used, their proportion in the catch varied between 0.5 and 3.6 percent in different years. After changing to the local strain stocked fish made up 34–37 percent of the catches. Mountain strains should be used for stocking of high-altitude reservoirs or lakes, but not all mountain strains are fit for stocking. Slow-growing strains mostly give a low recapture (Aass, 1973).

In lakes where smelt, coregonids and cyprinids co-exist with fast-growing trout, the diet of the adult trout consists entirely of prey fish. This situation may have lasted for centuries. But because of damming and impoundments fish-eating trout strains have become more usual in recent years. To compensate for the loss of bottom food, the trout in some reservoirs invade the pelagic zone for their subsistence, predating on small or stunted, plankton-feeding fish species. The development in lake Tunhovdfjord is most illustrative. Twenty-thirty years after the impoundment, char had become the staple food of the adult trout. The change in diet takes place when the trout become about 25 cm long and is accompanied by a change in growth rate. The maximum weight now reaches 13–15 kg against 2–3 kg before impoundment (Aass, 1973). But in some reservoirs the local trout strain is unable to utilize the char resources. Therefore, Tunhovdfjord trout are now stocked in many reservoirs with stunted char populations. The best results are obtained when the length of the mature char do not exceed 20–22 cm. The conditions being favourable, the planted trout may grow to 3–5 kg in 5–6 years. But when stocked into lowland lakes, the Tunhovdfjord strain do not prey on coregonids or cyprinids. On the other hand, the Hunder trout of Lake Mjosa do not forage on char if stocked in char reservoirs. The strains thus seem to prefer certain prey species. But the fish-eating lowland trout strains, accustomed to prey on a multitude of species, have given the best returns in the fjord experiments. The transfer of small wild trout from coastal lakes to the fjords has not been successful. Most re-enter fresh water quickly and even if they stay put their rate of growth is slow.

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FACTORS INFLUENCING THE MOVEMENTS, RECAPTURE AND SURVIVAL OF HATCHERY-REARED TROUT RELEASED INTO FLOWING WATERS AND THEIR MANAGEMENT IMPLICATIONS

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CONTENTS

ABSTRACT

The success of stocking with hatchery-reared trout has been the subject of varied investigations for the past half century. Percentage returns and post-stocking movements are summarized and related to the size and species of trout stocked and to the season of stocking.

Factors influencing the movements, recapture and survival of hatchery-reared brown trout, Salmo trutta L., stocked into rivers in Wales, U.K., were investigated during the period 1975–78. Experiments involved stocking more than 10 000 individually tagged trout, many of which had been acclimated to specific conditions. Information regarding the subsequent distribution of stocked fish was obtained from electro-fishing surveys, trapping and tag returns by anglers.

The majority of stocked trout moved only short distances; generally less than 1 km and principally in a downstream direction. The degree of dispersion after stocking was largely dependent on the character of the receiving river; dispersal was most extensive in fast-flowing rivers and more limited in deeper, more slow-flowing waters. Acclimation to flowing water prior to release had little effect on the distribution of stocked fish but did result in their being recovered in greater numbers. The presence of a resident wild population affected neither stocked fish movement nor their percentage recovery. "Spot-and scatter-planting" caused no difference in post-stocking movements but "spot-planting" did result in a higher percentage recovery.

Tag returns from stocked trout ranged from 10 to 62 percent. More than 65 percent of the stocked fish caught were taken within five weeks of stocking and more than 50 percent by less than 20 percent of the anglers benefiting. Less than 1 percent of the fish stocked contributed to the catch in the season after stocking.

The majority of stocked trout did not begin feeding until several weeks after stocking. The food intake of these fish tended toward that of wild trout as their period of residence in the river increased, but most stocked trout still had a lower food consumption after 40 to 50 days in the river. Many fish lost condition, reducing their chance of survival over the winter period. Hatchery-reared trout retained their distinctive silvery appearance for 2–3 months after stocking, making them more conspicuous to predators.

The implications of these findings are discussed in relation to the expediency, efficiency and cost-effectiveness of future management strategies involving the stocking of hatchery-reared trout.

RESUME

Le succès de l'empoissonnement avec des truites élevées en alevinière a fait l'objet de diverses recherches ces cinquante dernières années. On indique brièvement les rendements et les déplacements après la mise en liberté des alevins (en pourcentage) par dimension et espèce de truites et par saison de peuplement.

On a fait des recherches de 1975 à 1978 sur les facteurs qui influencent les déplacements, la recapture et la survie des truites brunes élevées en alevinières Salmo trutta L. qui peuplent les rivières du pays de Galles en Grande Bretagne. Les expériences comportaient le lâcher de plus de 10 000 truites marquées individuellement, dont un grande nombre avait été acclimatées à certaines conditions. Les renseignements concernant la distribution ultérieure du poisson d'alevinage ont été

obtenus à partir d'enquêtes halieutiques à l'aide d'appareils électriques, de captures dans des nasses ou des marques renvoyées par les pêcheurs à la ligne.

La majeure partie des truites de repeuplement ne se déplacent que sur de courtes distances, en général moins d'un kilomètre et surtout en aval. Le degré de dispersion des alevins après l'empoissonnement dépend en grande partie du type du cours d'eau où le poisson est lâché. Cette dispersion est plus large dans les cours d'eau à débit rapide et plus limitée dans ceux où les eaux sont profondes et le débit lent. L'acclimatation aux eaux courantes avant la remise en liberté du poisson a peu d'effet sur la distribution des sujets mais a permis d'en récuperer un plus grand nombre. La présence d'une population sauvage n'a affecté ni les déplacements du poisson de repeuplement ni le pourcentage de récapture. L'ensemencement sur place et disséminé n'a causé aucune différence dans le déplacement du poisson après l'empoissonnement mais l'ensemencement sur place a permis de récuperer une plus grande proportion de poisson.

Le renvoi des marques des truites de repeuplement a variée entre 10 et 62 pour cent. Plus de 65 pour cent du poisson de repeuplement a été capturé dans les cinq semaines qui suivent sa mise en liberté et plus de 50 pour cent a été pêché par moins de 20 pour cent des pêcheurs à la ligne bénéficiaires. Moins d'un pour cent du poisson de repeuplement entre dans les captures pendant la saison qui a suivi l'empoissonnement.

La plupart des truites de repeuplement n'ont commencé à s'alimenter que plusieurs semaines après leur mise en liberté. Elles ont eu tendance à adopter la même alimentation que les truites sauvages au fur et à mesure que leur permanence dans le cours d'eau augmentait et la plupart d'entre elles avaient encore un niveau d'alimentation plus faible qui la normale 40 ou 50 jours après leur mise en liberté. Un grand nombre de poissons n'étaient plus en bonne santé, ce qui réduisait leur chance de survie pendant l'hiver. Les truites élevées en écloserie conservent leur apparence argentée caractéristique pendant deux à trois mois après leur mise en liberté ce qui permet aux prédateurs de les répêcher plus facilement.

On étudie les incidences de ces facteurs du point de vue de l'opportunité, de l'efficacité et du rapport coût-rentabilité, des futures stratégies d'aménagement concernant l'empoissonnement avec des truites élevées en alevinières.

1. INTRODUCTION

In recent years, native brown trout Salmo trutta L. populations in many rivers have declined as a result of increased exploitation and environmental pressures. In an attempt to maintain the quality of river trout fishing, many fishery managers have become increasingly dependent upon restocking with hatchery-reared trout. With the expense involved it is important that stocking programmes and procedures be designed and implemented so as to ensure the best possible results in terms of angler catch and increased recreational opportunities.

The success of stocking with hatchery-reared trout has been the subject of varied investigations for the past half-century. This paper examines the reported percentage recaptures and post-stocking movements in relation to the species and size of trout stocked and the season of stocking. More recent investigations (Cresswell, 1979) into factors affecting the movements, recapture and survival of brown trout stocked into rivers in South Wales, U.K., are summarized.

2. PERCENTAGE RECAPTURE

Restocking may be achieved by releasing fish of takeable size (in the U.K., usually more than 20 cm) which are immediately available to the angler, or by releasing smaller fish which will only be available for legal capture after a period of growth. The latter option is made attractive by the lower purchase price of small fish and the possibility that they will take on some feral characteristics before attaining takeable size. However, investigations carried out predominantly in the U.S.A. (reviewed by Cresswell, 1981) show that the percentage recapture (in terms of takeable-sized fish) resulting from stockings of small trout (8–14 cm) is generally less than 3 percent. Hence, the effective cost of each trout captured may be increased as many as 30 times, counteracting the apparent economic benefit of this type of stocking policy.

Investigations into the success of stocking with takeable-sized fish of different species and at various times of the year are well documented. Cresswell (1981) pooled data from many of these investigations and showed that brook trout Salvelinus fontinalis Mitchill, brown trout and rainbow trout Salmo gairdneri Richardson stocked in the autumn were caught in considerably lower proportions (4, 14 and 10 percent, respectively) than those stocked during the spring or open (angling) season (37, 23, 32 percent, respectively). As with stockings of fingerling trout, autumn introduction necessitates the exposure of stocked fish to the risk of overwintering mortality before the population is subjected to angling pressure; it is likely that this is responsible for the lower percentage recaptures obtained from these two stocking policies. The overall percentage recaptures for spring, pre-season and in-season stockings of brook, brown and rainbow trout were broadly similar (range 21–39 percent). However, individual authors did obtain considerable differences which were often attributable to specific conditions pertaining to the receiving river at the time of stocking.

3. POST-STOCKING MOVEMENTS

Literature on the post-stocking movements of hatchery-reared trout has been reviewed by Cresswell (1981) who concluded that:

(a.) 90 percent of the reported catch of stocked brown trout were taken within 4.5 km of the stocking site, but that lower proportions of brook and rainbow trout were taken within these limits;

(b.) Brook and rainbow trout showed a greater propensity toward downstream movement than brown trout. A small proportion of this latter species were taken further than 4.5 km from the stocking area principally in a downstream direction;

(c.) Greater dispersion was exhibited by fish of all three species which had overwintered prior to capture or which had been stocked in the smaller upstream reaches of a river.

These conclusions seem to conflict with the assertion so often made by trout fishermen that a large proportion of hatchery-reared fish move off downstream soon after stocking. However, it should be noted that although 90 percent of the reported catch of stocked brown trout were taken within 4.5 km of the stocking site, the reported catch generally represented less than 40 percent of the total number of fish stocked, leaving a large proportion unaccounted for. In the period immediately following an introduction of fish, angling pressure is often concentrated in the vicinity of the stocking point. Under such circumstances the spatial distribution of the catch can be misleading and tends to indicate a lack of movement away from the stocking point. This apparent lack of movement results from a combination of anglers catching fish before they had an opportunity to disperse and a lack of angling effort in areas further from the stocking point (Cresswell and Williams, 1979).

Concern over the large number of stocked trout which remain uncaught and the uncertainty surrounding their fate led to a study on trout stocking carried out during the period 1975–78 (Cresswell, 1979).

4. INVESTIGATIONS INTO FACTORS AFFECTING THE POST-STOCKING MOVEMENTS AND SURVIVAL OF HATCHERY-REARED TROUT

The investigations were carried out on a variety of rivers in Wales (Fig. 1). These rivers have been described by Cresswell (1979) and a summary of their physical parameters is given in Table 1.

All fish stocked during the investigations were of takeable size and were tagged with either Floy fingerling tags, for individual recognition during electro-fishing surveys, or with message-bearing Floy spaghetti tags when a particular investigation relied on anglers' returns.

Investigations into factors affecting the movements and survival generally involved the simultaneous stockings of matched batches of fish, one of which had been acclimated to specific conditions. This procedure eliminated the effects of factors other than those being examined. Several of the investigations were carried out on the Clettwr, a manageable river in terms of electro-fishing and where traps recorded fish moving large distances downstream (Cresswell, 1977; Cresswell and Williams, 1983). A single upstream electro-fishing run was found to be the most economical use of electro-fishing time and was effective in locating large numbers of stocked fish. This method of locating the fish eliminated the problem of uneven fishing effort, thereby allowing the true distributions of fish to be assessed. On larger rivers where the investigations relied on anglers' returns, absolute distributions could not be determined, but comparisons were drawn between the distributions of each batch of fish stocked simultaneously in one river.

4.1 Prior acclimation to flowing water

Hatchery-reared trout inevitably become stressed by transportation procedures associated with stocking (Cotter, 1976) and, in this condition, they are stocked into the relatively strong currents typical of many trout waters. The effects of (a) retaining fish caged in the river for 24 h before release and (b) a period of acclimation to flowing water (up to 0.24 m/sec) in tanks prior to stocking were investigated (Cresswell and Williams, 1983).

In-stream acclimation resulted in a higher percentage recapture and a more limited dispersion of the fish stocked under low river flow conditions, but had no effect on trout stocked into a river where higher water velocities were experienced.

Acclimation, in tanks, to a flow of 0.1 m/sec for 14 days led to higher percentage recaptures, whereas acclimation for only two days resulted in fewer returns than for unacclimated fish. No difference in fish distribution within the rivers could be attributed to these acclimation procedures.

4.2 Resident wild population

Hatchery-reared trout stocked into rivers not only have to adjust to unfamiliar physical conditions but also have to compete for food and space with a resident wild population. To examine the effect of a resident wild population, trout were stocked into two similar stretches of river, one of which had its native population of brown trout removed (Cresswell and Williams, 1984).

Recapture rates ranged from 67 to 76 percent for both stretches. The resident population of wild brown trout had no significant effect on the dispersion of the stocked fish, the majority of which remained close to the point of stocking.

No stocked fish were recovered from the experimental stretches in the year following their introduction. Within one year the depopulated stretch had been recolonized by wild trout.

4.3 Method of stocking

"Spot-planting", almost invariably used in preference to the more laborious "scatter-planting" method, involves liberating large numbers of fish at a few sites. "Scatter-planting" entails releasing a few fish at each of many sites within a river. The relative merits of these two methods were compared (Cresswell and Williams, 1982).

Higher percentage recaptures were recorded for spot-planting (65 and 31 percent) than for "scatter-planting" (16 percent). Neither spot- nor scatter-planting resulted in stocked fish contributing to the catch for an appreciably longer period of time. The majority of trout stocked were caught in the area of stocking irrespective of the method of planting.

4.4 Time of stocking

Previous investigations have shown that higher returns are obtained from stockings made during the spring and open season than from those made in autumn. Spring stockings allow fish to become accustomed to their new environment before being subjected to angling pressure and are, thus, preferred to stockings made during the open season. A further investigation compared the results obtained from spring stockings made at one and four weeks prior to the start of the angling season (Cresswell and Williams, 1982).

Stockings made one week before the start of the angling season yielded better returns (17.1 percent) than those made three weeks earlier (2.2 percent). Most fish were caught in the area of stocking irrespective of the time of their introduction.

4.5 Fish distributions

4.5.1 Distributions determined by electro-fishing

The post-stocking distributions of more than 3 000 fish stocked in six separate experiments on four different streams were determined by electro-fishing (Cresswell, 1979). Recoveries ranged from 35 to 88 percent; higher rates being achieved in the smaller streams where electro-fishing was more efficient. Percentage recovery decreased as the period between stocking and survey lengthened. Despite differences in pre-stocking treatments the distributions were strikingly similar - a prominent peak in the region of stocking and an extended tail downstream. In the majority of experimental stockings, more than 90 percent of recaptures were recorded within 600 m of the stocking site during surveys conducted 5–13 days after stocking. These results emphasize the limited movement shown by the stocked trout in these small streams.

4.5.2 Distributions determined from anglers' returns

Anglers' returns ranged from 10 percent on the Afon Taf in 1978 to 62 percent on the Western Cleddau in 1977.

The distributions of fish stocked into the Taf, Western Cleddau, Dysynni and Teifi are compared (Fig. 2). The extent of these distributions varies from "limited", in the cases of Taf and Teifi, to "extensive" in the case of the Dysynni. In all cases, movements were principally in a downstream direction. Although it might be expected that rivers with high angling pressure would show a limited distribution due to the rapid capture of fish before they moved far from the stocking site, this was not apparent. The Western Cleddau had both the highest percentage recovery and an extensive stocked fish distribution.

The distributions of stocked fish were more limited in the larger, deeper and more slow-flowing rivers (e.g., Taf) and more extensive in faster-flowing rivers offering less cover to stocked fish (e.g., Dysynni). Despite the variability in extent of the stocked fish distributions, all but one exhibited a distinct peak at or close to the stocking point; the exception being the Afon Dysynni where the angling season was suspended for one week immediately after stocking. This suggests that early angling pressure in the vicinity of the stocking point results in a large number of fish being caught in that area, but does not affect the overall extent of the distribution. Hence the distributions shown in Fig. 2 reflect not only the behaviour of stocked fish in each river but also the spatial and temporal distribution of angling pressure.

A detailed analysis of data from the River Sirhowy indicated that the stocked fish distributions were affected by irregularities in both the spatial and temporal distributions of angling pressure (Cresswell and Williams, 1979). Although the overall extent of the stocked fish distributions seems principally dependent upon the characteristics of the receiving river, angling pressure can have a considerable effect on the shape of these distributions.

4.6 Anglers' returns

On all rivers studied, more than 65 percent of the total catch of stocked fish was taken within five weeks of stocking, and on some rivers (Western Cleddau, 1977; Taf, 1977, 1978) more than 80 percent was taken within three weeks (Fig. 3). Less than 1 percent of the fish stocked contributed to the catch in the season following stocking.

More than 50 percent of the declared catch was taken by less than 20 percent of the anglers who made returns (Fig. 4). On the Western Cleddau, 10 percent of the anglers took almost 70 percent of the declared catch.

4.7 Survival of stocked fish

The percentage of stocked fish captured by anglers rarely exceeded 50 percent in these studies and less than 1 percent were recaptured in the year following stocking. This tends to suggest that the survival of stocked fish, particularly over the winter period is poor. During the stocking investigations it was noted that many of the fish lost condition. An investigation was, therefore, carried out to assess the feeding behaviour of stocked fish (Cresswell, 1979).

The majority of stocked fish did not begin feeding until several weeks after stocking and many lost condition. Although the food intake of these fish tended toward that of wild trout as their period of residence in the river increased, most hatchery-reared trout still had a lower food consumption than wild trout 40–50 days after stocking.

Hatchery-reared brown trout are often silvery and without the bright red spots characteristic of most wild trout, and because of this they may be more conspicuous to predators. The silvery appearance of the hatchery fish persisted for 2–3 months after stocking. The relatively slow change to a more wild type coloration was probably related to the limited intake of natural food by the stocked hatchery fish.

5. IMPLICATIONS FOR FUTURE MANAGEMENT POLICIES REGARDING RESTOCKING WITH HATCHERY-REARED TROUT

Effective management is essential to ensure the best use of available trout rivers and where natural production of takeable-sized fish does not satisfy angling demand restocking is a likely solution. Natural production may need augmenting for various reasons:

- angling demand is particularly high, e.g., in areas of high population;
- natural production is low due to poor spawning success or slow growth rate, e.g., in industrial rivers;
- the native population is reduced by a pollution incident.

Restocking after a pollution incident or in rivers where spawning is poor but natural food plentiful may involve the release of fry or fingerlings. In such instances the stocked fry or fingerlings fill a vacant niche, optimum use is made of the natural resource, and the resultant fish have more feral characteristics hence providing better sport. The low percentage recapture, in terms of takeable-sized fish, resulting from stockings of small trout reduces the apparent economic benefit of this type of stocking policy.

Restocking with fish of takeable size is the more usual practice on rivers where the natural growth rate is slow, where a pollution incident has occurred, or where a plentiful supply of large fish is required to satisfy angling demand. Stocking with takeable-sized fish rarely has any long-term benefits; few stocked fish survive to contribute to the catch in the season after stocking, and in view of the loss in condition of many fish their contribution to natural recruitment is likely to be insignificant. Thus, greatest benefit is derived from an introduction of takeable-sized fish by maximizing the return in the season of stocking. This reduces the effective cost of each fish caught and is generally associated with a greater number of anglers contributing to the total catch.

As a result of the findings described in this paper the following proposals are made to improve the efficiency and cost effectiveness of future management strategies involving the stocking of hatchery-reared trout:

(i) Restock with brown trout rather than rainbow or brook trout; rainbow and brook trout have a greater tendency to downstream displacement.

(ii) Fish reared in flowing water in raceway type environments are best suited for stocking in rivers; acclimation to flow confers a survival advantage.

(iii) Stocking should be carried out shortly before or during the early part of the open (angling) season to maximize percentage returns. Stocking early in the year also provides uncaptured fish with a greater opportunity to feed and regain condition before the winter period.

(iv) Fish should be stocked at 3–4 week intervals throughout the season rather than a single major stocking so as to provide a more continuous benefit; the majority of fish caught are taken within 3–4 weeks of stocking.

(v) "Scatter-planting" yields lower returns than "spot-planting" and should only be used if natural dispersion is negligible, e.g., in deep, slow-flowing rivers. If artificial dispersion is necessary, fish should be stocked at intervals along the river in batches of not less than 50.

(vi) The dispersal of stocked fish is usually greatest in fast-flowing rivers with a paucity of cover. In such circumstances consideration should be given to the provision of artificial instream cover.

(vii) Stocking should be confined to stretches of river where it is economical in terms of the effective cost of captured fish. In regions where angling pressure is low and returns are small, the effective cost of captured fish may exceed their recreational value.

6. ACKNOWLEDGEMENTS

We would like to thank the fisheries staff of the Welsh Water Authority, riparian owners and anglers for their valued assistance throughout this study.

The research was based at the University of Wales Institute of Science and Technology and was carried out during the tenure of a CASE award financed by the Natural Environmental Research Council and the Welsh Water Authority.

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Table 1 Physical parameters of study rivers

River	Catchment- Area (km^2)	Catchment- Length/Max. Width	Average Daily flow (cumecs)	Gauging Station (National Grid Reference)	Altitude (m) at source	Altitude (m) at mouth	Average Gradient (m/km)	Gradient at Stocking Points (m/km)
Clettwr	57.8	2.0	1.65	SN 447412	240	82	10.5	9.7
Dysynni	75.1	1.8	1.96	SH 636071	82	0	3.4	7.7
Einon	7.5	2.8	0.19	SN 451427	210	100	24.4	24.6
Sirhowy	76.1	6.1	1.84	ST 205912	472	69	12.4	8–10.7
Taf	244.2	1.4	6.35	SN 238160	213	0	5.5	3.0
Talog	21.9	1.5	0.67	SN 446363	274	114	23.5	14.2
Teifi	554.0	2.4	16.95	SN 433406	440	0	3.4	1.9
Tyweli	49.2	1.0	1.34	SN 411400	245	58	20.1	10.0
Western Cleddau	197.6	1.4	5.15	SM 954177	115	0	4.0	4.5

- Measured to gauging station

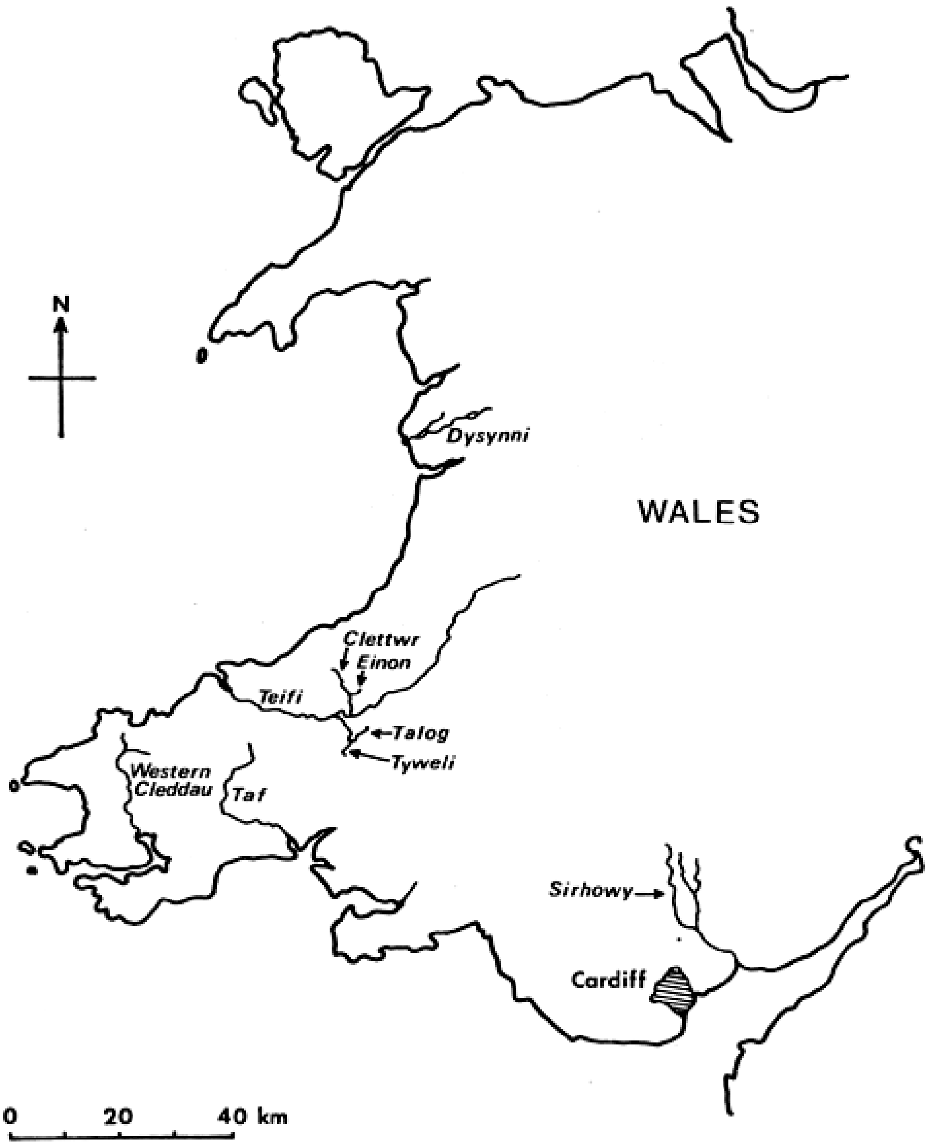

Fig. 1 Study area

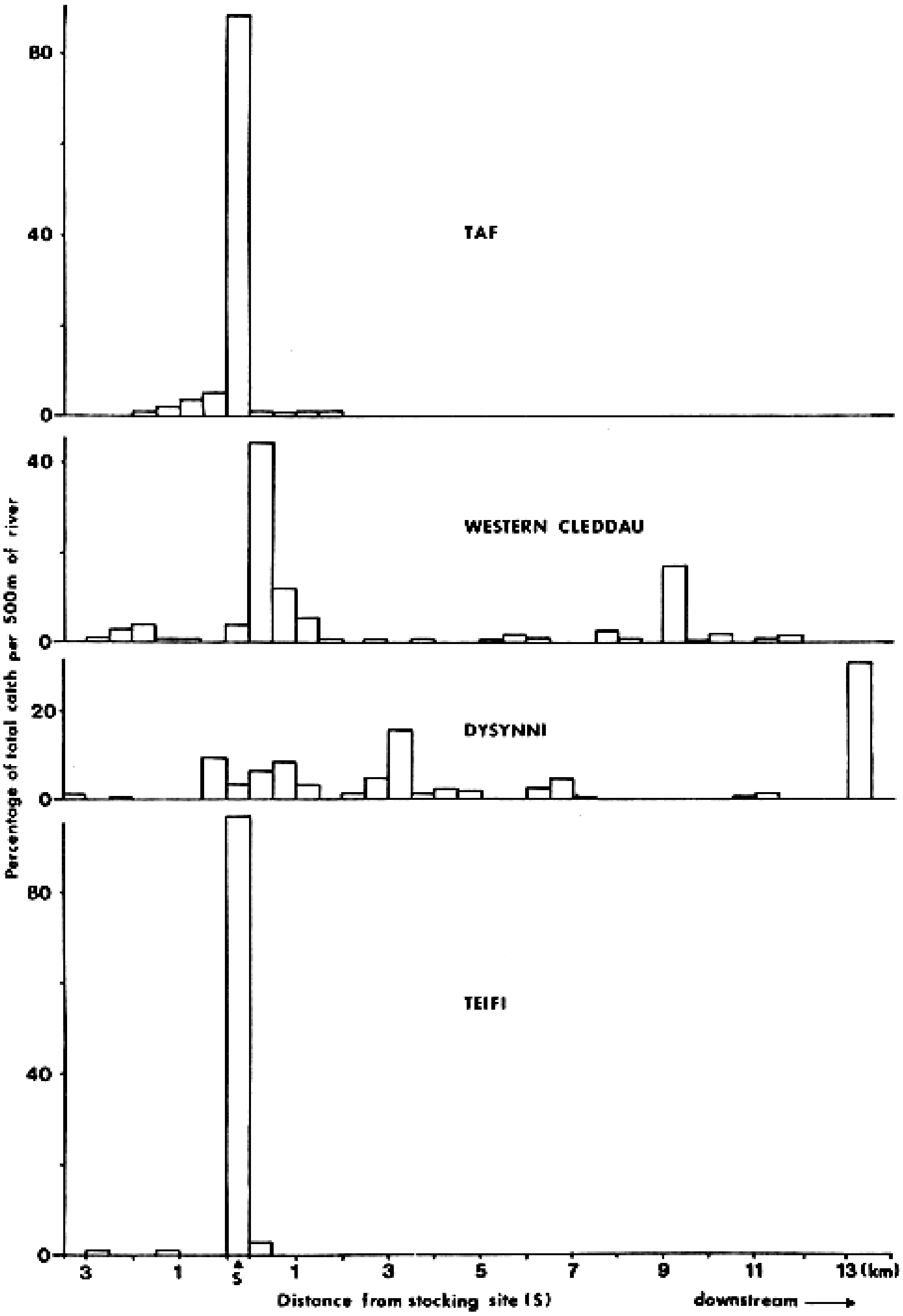

Fig. 2 Distributions of stocked fish as determined by anglers' returns

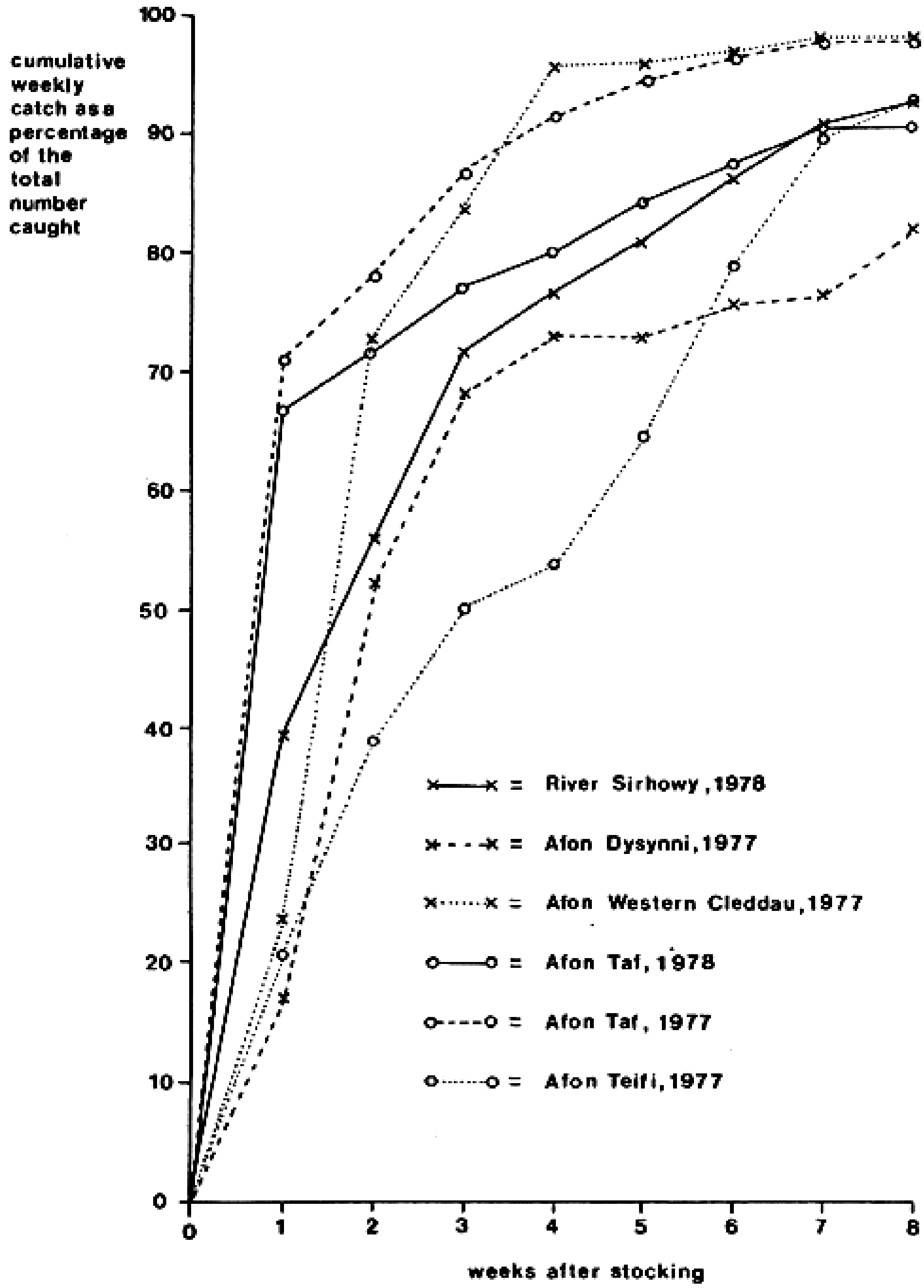

Fig. 3 Rate of capture of stocked fish

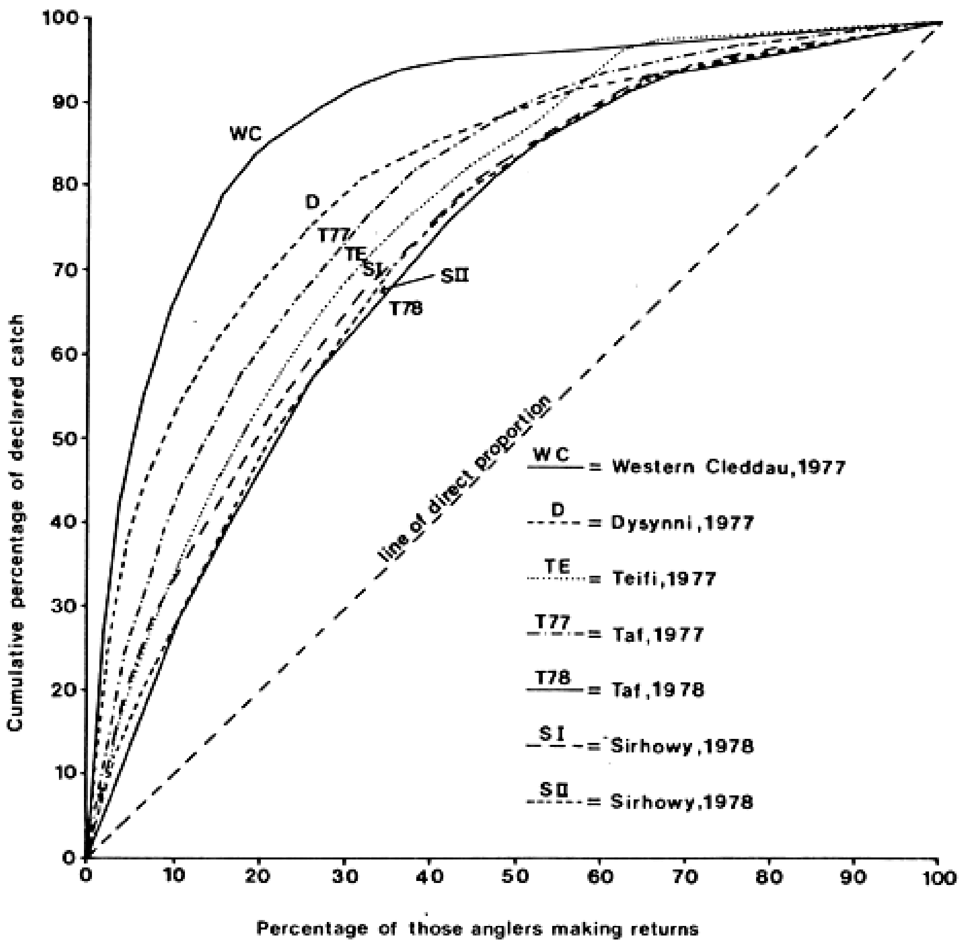

Fig. 4 Cumulative percentage of declared catch plotted against the percentage of those anglers making returns

RESULTS OF STOCKING WITH BROWN TROUT (Salmo trutta m. lacustris) IN FINNISH LAKES AND RIVERS

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CONTENTS

ABSTRACT

The paper deals with the tagging experiments with brown trout (Salmo trutta m. lacustris) in Finnish lakes in the sixties and seventies. These were performed on fish in different kinds of lakes in order to monitor profitability and to find the best fish size and date for stocking. The yield per 1 000 stocked smolts varied between 0 and 600 kg. The recommended minimum size for stocking is 18 cm, and 25 cm in most of the regulated lakes. Stocking in spring has given considerably better results than stocking in autumn. The best results have been obtained in large, clear, oligotrophic lakes with dense stocks of vendace (Coregonus albula).

RESUME

Au cours des années 60 et 70, des expériences de marquage de truites (Salmo trutta m. lacustris) ont été effectuées en Finlande dans différents types de lacs. Il s'agissait de suivre l'évolution des rendements et de déterminer quelles étaient les conditions optimales pour le repeuplement (date et taille des poissons). On a constaté que les rendements variaient entre 0 et 600 kg pour 1 000 juvéniles mis à l'eau et que la taille minimale de ces juvéniles devait être de 18 cm en général et de 25 cm dans la plupart des lacs aux eaux régularisées. Le repeuplement de printemps s'est révélé bien plus efficace que celui d'automne. Les meilleurs résultats ont été obtenus dans de grands lacs oligotrophes, aux eaux claires, où vivaient des populations denses de Coregonus albula.

1. INTRODUCTION

In Finland, stocking with brown trout (Salmo trutta m. lacustris) was started in the fifties in all main waters in order to maintain a fishable stock. Natural reproduction was prevented by power-plant constructions, pollution and dredging for timber floating. In spite of the fact that the price of smolts is quite high and the stocking results are unknown, the number of stocked smolts has increased rapidly. In many cases money is badly invested in such stocking. This paper gives a brief report of the results of brown trout stocking in Finnish lakes in the sixties and seventies based on tagging experiments. Some ideas on fish size and stocking time and place are given.

2. MATERIAL AND METHODS

The material includes tagging experiments in Finnish lakes, rivers and impoundments in 1959–76. The total number of tagged smolts was 211 062 (73 635 in the sixties, 137 427 in the seventies) in 503 experimental groups (210 in the sixties, 293 in the seventies). The mean number of tagged fish in each experimental group was 350 in the sixties and 469 in the seventies. The tag most commonly used was the Carlin tag (Carlin, 1955). The age of the tagged fish was usually two years. The conditions under which the fish were tagged varied considerably.

3. RESULTS

Table 1 gives the poorest, best and mean catches per 1 000 stocked smolts in tagging experiments in the main water courses of Finland. The best result was 538 kg/1 000 stocked smolts in 1966 in Lake Puruvesi, a large, clear, oligotrophic lake in the Vuoksi watercourse. The mean catch was lower in the seventies than in the sixties (Fig. 1).

Figs. 2a–2c show that stocking in spring usually gives better results than stocking in autumn. The same figures also show that bigger smolts have a better chance of survival until fished.

4. DISCUSSION

Tagging results do not represent the results obtained by stocking with untagged fish. It is obvious that untagged fish give much better results than tagged ones. This is due to the higher mortality and slower growth rate of tagged fish, tag losses, unreported tags, etc. Neither are we necessarily comparing the different experimental groups because smolt-rearing conditions, taggers, transporters and other factors differ greatly.

The 1982 price of one brown trout smolt is about 4.6 Finnish marks. The value of the brown trout catch for the fisherman in 1980 was 30 marks/kg. On this basis, a yield of more than 150 kg/1 000 stocked smolts is the limit for the profitability of brown trout stocking. The costs of fishing have not been taken into account in this estimate. They may be as high as 50 percent. However, fishing for brown trout is mainly recreational, which is why it is difficult to evaluate the profitability of stocking. Usually the prospects of catching brown trout are sufficient to start and maintain a recreational fishery.

The trend toward poorer results (Fig. 1) is not very clear but raises many questions. It is not believed that the reporting rate in inland waters has fallen off, because no limitations on fishing (TAC or others) have been imposed. There may be a change in the condition of the stocking material. In Finland most brown trout eggs are produced from hatchery-reared spawners, which may cause severe genetic problems due to inbreeding (Kincaid, 1976). However, a special study is required before this can be verified. There have been no major change in either food or tagging methods.

As may be expected from the need of brown trout, the best results have generally been obtained in large oligotrophic lakes. A dense stock of vendace (Coregonus albula) will further increase the yield. When the brown trout are stocked at a size large enough to eat fish, the result will be better than with smaller fish which have to feed on benthos for a time. This is especially true in lakes where water-level regulation causes a poor bottom fauna in the littoral (Nilsson, 1961). Very good catches have been reported for stocking with a minimum smolt size of 25 cm in regulated lakes (Salojarvi et al., 1981). In unregulated lakes the bottom fauna is better and supplies the smolts with adequate food. Here good results can be obtained even with smaller smolts.

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Table 1 Results of stocking with brown trout of age 1+ to 3+ years in five main watercourses in Finland (kg/1 000 stocked fish)

Stocking	Vuoksi				Kymijoki				Kokemäenjoki				Oulujoki				Kemijoki			
year	worst	best	mean	No.	worst	best	mean	No.	worst	best	mean	No.	worst	best	mean	No.	worst	best	mean	No.
1961	0	228	64	6		-				-			26	26	26	1		-		
1962	3	93	48	10	102	102	102	1		-			30	30	30	1	0.5	0.5	0.5	1
1963		-				-				-			53	53	53	1		-		
1964	4	84	48	6	136	292	204	4		-			11	11	11	1		-		
1965	43	324	184	2	3	496	175	6		-			4	23	14	2	19	120	70	2
1966	538	538	538	1	82	199	130	3	18	262	114	3		-			5	185	81	11
1967	390	448	419	2	31	147	76	7	16	50	32	3	17	17	17	1	1	70	20	35
1968	153	372	278	4	7	78	28	6		-				-			1	32	15	6
1969	1	289	61	10	1	59	24	10	24	24	24	1	1	25	13	2	44	44	44	1
1970	0	126	20	11	0	139	26	21	12	14	13	2	1	139	47	3	0	94	45	4
1971	20	78	50	3	0	67	15	15		-			9	10	9	1	0	37	8	8
1971	28	280	140	6	4	251	124	14	0	45	17	4	5	7	6	2	0	123	33	9
1973	3	101	36	9	52	387	206	4	114	114	114	1	0	15	9	4	39	124	78	9
1974	118	118	118	1	19	105	58	4		-			4	60	17	5	134	134	134	1
1975	103	132	117	3	1	177	60	9		-			0	47	15	12	15	96	43	7
1976		-			0	223	71	11	1	66	34	2	2	2	2	2	159	159	159	1
Mean	100	229	151	74	31	194	93	115	26	82	50	16	12	33	19	39	32	94	56	95

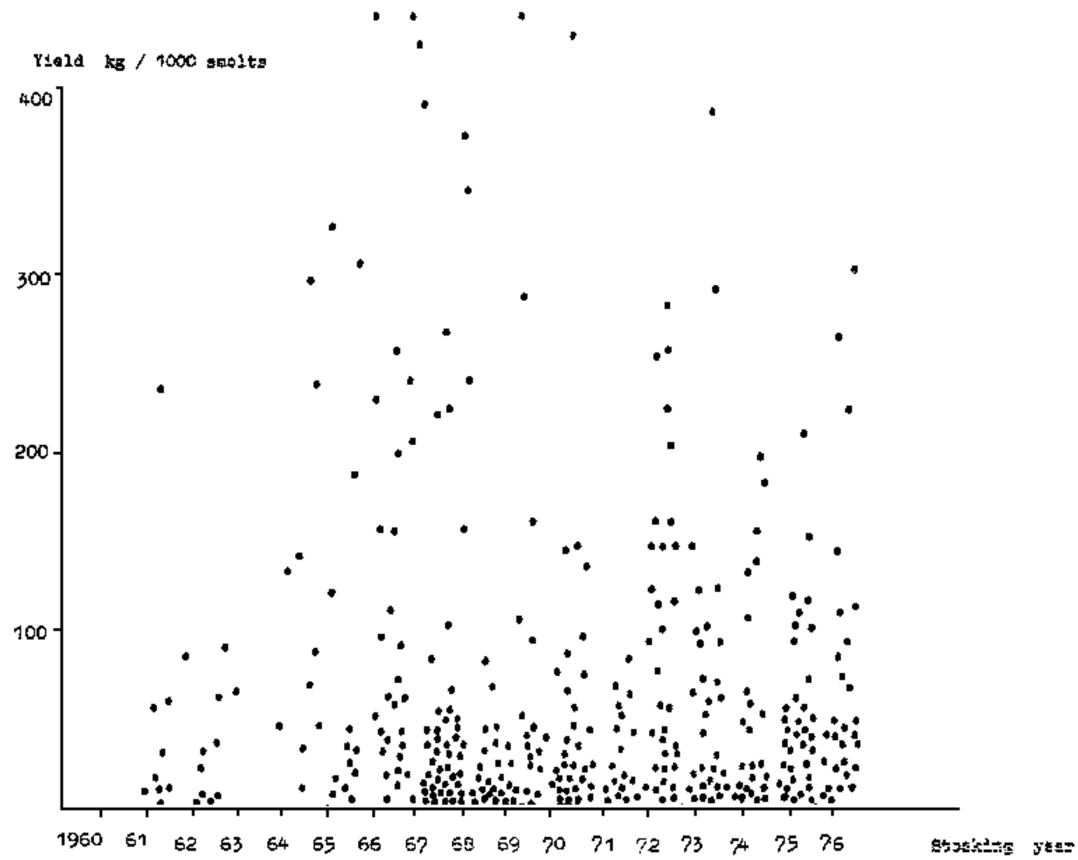
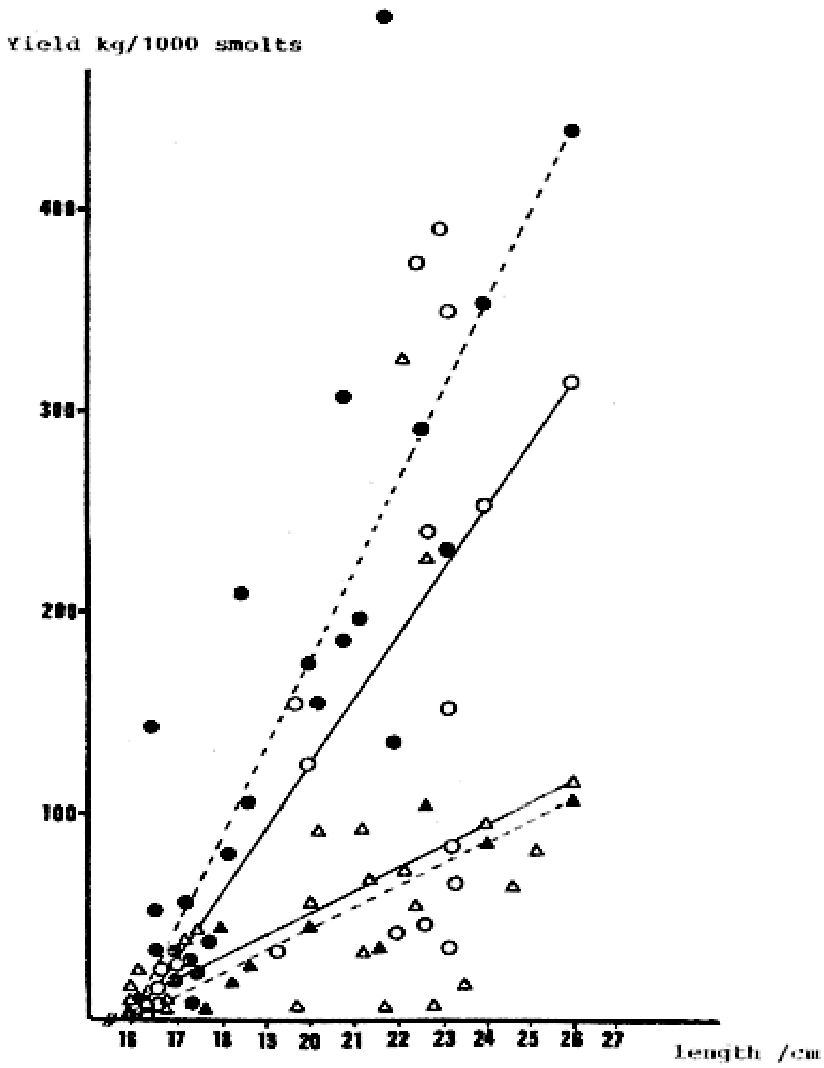


Fig. 1 Results of stocking with brown trout in Finnish lakes in 1960–76



<u>Vuoksi watercourse</u>

—○— spring stocking: y= 32.0x - 513, r= 0.60, n= 23

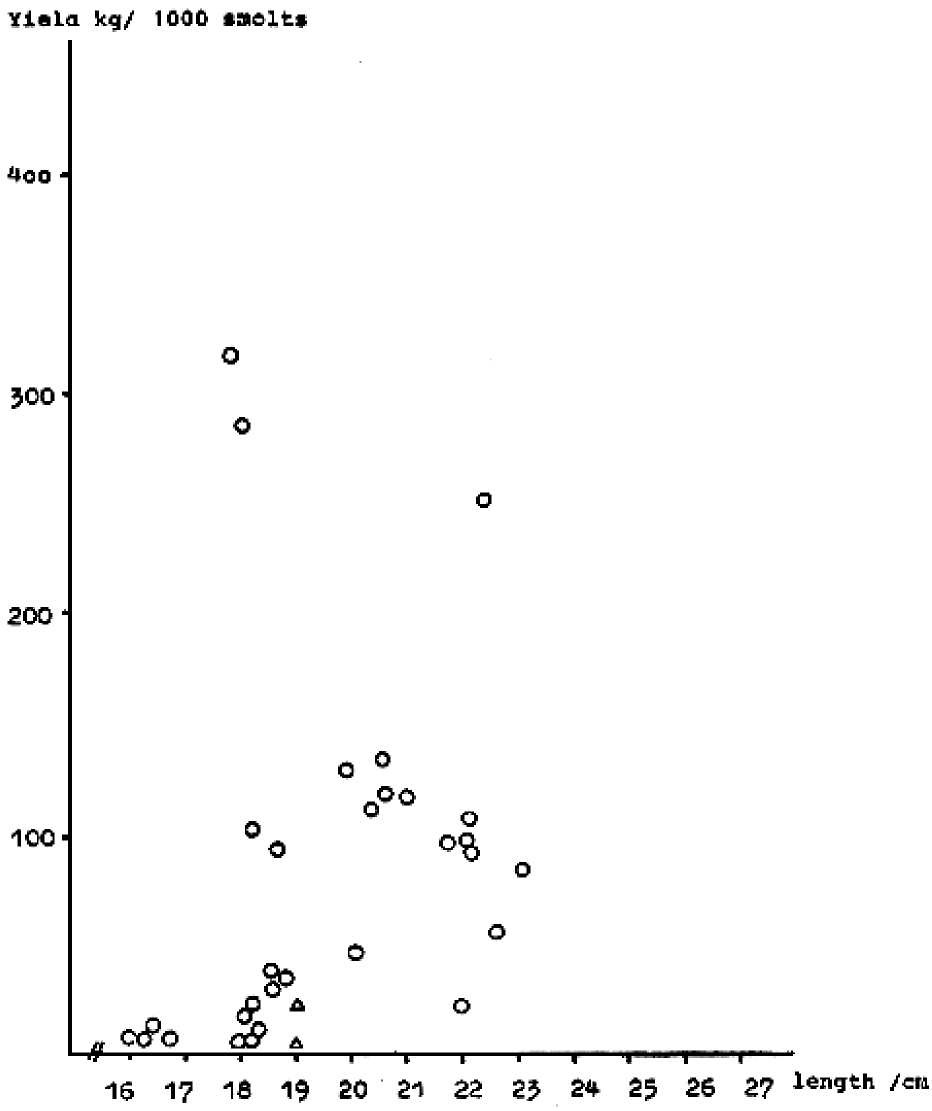
—△— autumn stocking: y= 9.8x - 138, r= 0.30, n= 21

<u>Kymi watercourse</u>

---●--- spring stocking: y= 44.0x - 704, r= 0.78, n= 19

---▲--- autumn stocking: y= 10.4x - 162, r= 0.74, n= 10

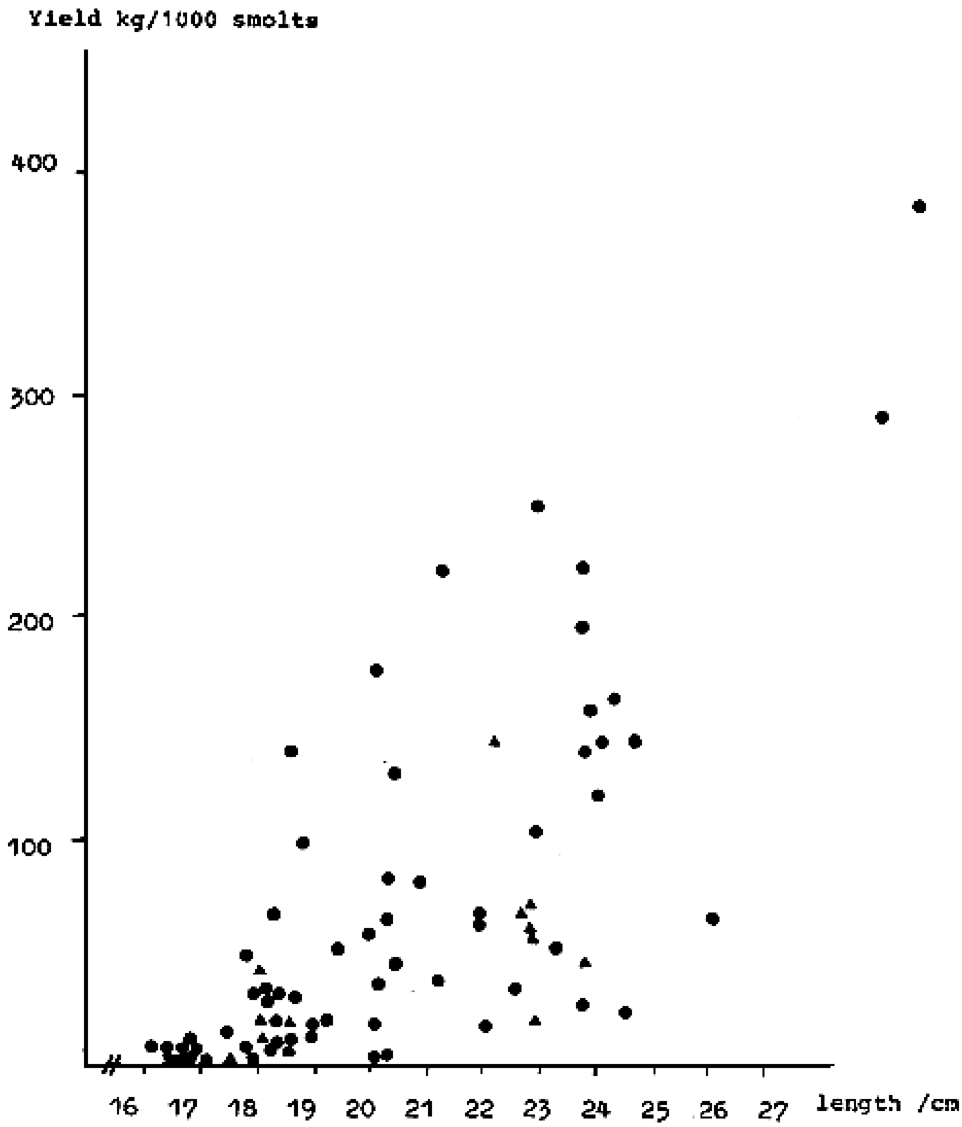
Fig. 2a Comparison of stocking with brown trout in spring and autumn in the sixties



spring stocking ○ n = 30

autumn stocking △ n = 2

Fig. 2b Comparison of stocking with brown trout in spring and autumn in the Vuoksi watercourse in the seventies



spring stocking ● n = 62

autumn stocking ▲ n = 11

Fig. 2c Comparison of stocking with brown trout in spring and autumn in the Kymi watercourse in the seventies

BROWN TROUT (Salmo trutta m. lacustris (L.)) STOCKINGS AS A COMPENSATION METHOD IN A POLLUTED AREA IN CENTRAL FINLAND

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CONTENTS

ABSTRACT

Brown trout parr were incubated in nylon netting cages in an area polluted by pulp and paper mill effluents. Tagged brown trout smolts (average length 18–20 cm) were also stocked in order to examine the suitability of brown trout for compensation stocking.

The catch per 1 000 smolts was 6.2–145.3 kg in spring stockings and 0–37.8 kg in autumn stockings. The percentage of tags returned was 1.6–14.2 and 0.2–6.4, respectively. Fish were found to migrate down the watercourse. About 50 percent of the fish were caught at a distance of 40 km or more from the stocking sites.

Thus, the results show that damages to local fisheries could not be entirely compensated for by stockings with brown trout.

RESUME

On a étudié une partie du cours du Kymijoki dans la province centrale de la Finlande. Le nord de cette zone est pollué par des usines de pâte à papier et par les effluents ménagers.

En 1977–79 on a déversé des truites (Salmo trutta) marquées de deux étés/ans dans trois zones différentes du point de vue de la pollution ou de l'eutrophisation. Fin 1981, on avait recapturé au total 4 pour cent des 4 500 poissons marqués. La plupart de ces captures ont été faites par des pêcheurs de subsistance ou par des amateurs.

La valeur commerciale des captures ne représentait que la moitié environ du coût des alevins. Le repeuplement de printemps a donné de meilleurs résultats que celui d'automne.

Les opérations de repeuplement effectuées en automne dans la zone la plus polluée ont échoué. Dans la zone moins polluée, 20 pour cent seulement des recaptures ont été faites sur les lieux mêmes du repeuplement et certains poissons ont été recapturés jusqu'à 100 km plus en aval. Enfin, dans la zone non polluée, 63 pour cent des recaptures ont été effectuées près du site de repeuplement.

La truite s'est déplacée vers l'aval même lorsqu'il n'y avait pas de pollution. Aussi n'est-il pas recommandé de repeupler avec ce poisson des lacs ouverts si l'objectif est d'améliorer les pêcheries locales.

1. INTRODUCTION

Fish stockings have been the most common method for minimizing damage to fisheries caused by the pulp industry and by domestic sewages in Finland. Brown trout has been one of the most frequently used species. However, it demands good water quality and many strains have the tendency to migrate down the watercourse.

This paper discusses the suitability of brown trout for compensative stocking in a polluted area.

2. STUDY AREA

The study area is part of the Kymijoki watercourse, which is the second largest watercourse in Finland and flows into the Gulf of Finland. There is a pulp and paper mill situated in the northern part of the study area, at Aanekoski, whose effluents are discharges into Lake Kuhnamo (Figs. 1 and 2). Lake Vatianjarvi, Saravesi and Northern Leppavesi are situated further downstream. Southern Leppavesi discharges into Northern Leppavesi but remains uncontaminated by the effluents. N. Leppavesi flows into Lake Paijanne through Vaajakoski, where the mean flow (1961–79) was 155 m^3/sec.

Lake Paijanne is the central lake in the Kymijoki watercourse. Its maximum length is 120 km, maximum depth 104 m, mean depth 17 m (Fig. 3) and its level is regulated by hydroelectric plants. Its northern and central parts are contaminated with pulp and paper mill effluents and domestic wastewaters. Diverse dilution gradients can be found within the lake.

BOD_7 and NaLS analyses indicate the effect of pulp mill effluents on the different water bodies (Granberg, 1977). The effluent load is highest in Lake Kuhnamo and Saravesi (Table 1). A rising trend was observed in the effluent load of the pulp mill in Aanekoski in 1977–79.

The oxygen concentration was usually less than 5 mg/l in the hypolimnion of Lakes Kuhnamo, Vatianjarvi and Saravesi during periods of stagnation as well as in N. Leppavesi during the summers of 1978 and 1979. In S. Leppavesi the oxygen concentration was ca. 8 mg/l.

The degree of damage to the fishery is estimated to be 100 percent above the Kuusankoski rapids (Fig. 1) and between 40 and 70 percent in Lakes Saravesi and N. Leppavesi. Furthermore, the effluents affect the flavour of the fish from this watercourse.

3. MATERIALS AND METHODS

3.1 Cage tests

Brown trout parr of between 11.6 and 16.2 cm length were brought from fish-breeding establishments near the study area and were placed in nylon netting cages. In N. and S. Leppavesi the fish were tested at the depths of 2 and 15 m; in Lake Vatianjarvi at the depth of 2 m only, because of the poor water quality. A test time of seven days was used. The test was carried out in October 1977, and in March and June 1978. Altogether 225 fish were tested (Nyronen and Hakkari, unpubl.).

3.2 Tagging and stocking

In 1977–79 4 493 brown trout smolts of average length 18–20 cm were marked with Carlin tags and stocked in different places in the Aanekoski watercourse. Fish were marked and stocked in groups of about 500 fish. Spring and autumn stockings were made into N. Leppavesi during three successive years but into S. Leppavesi, Lake

Kuhnamo and Lake Saravesi only one autumn stocking was made in 1977 (cf. Fig. 1). Thus 1 500 marked fish were stocked in spring and 2 993 in autumn.

The results of the stockings have been calculated from recaptures that were made up to the end of the year 1981.

4. RESULTS

4.1 Cage tests

The seven day tests of brown trout parr gave the following results expressed in percentages:

	L. Vatianjarvi		N. Leppavesi		S. Leppavesi	
	Alive	Dead	Alive	Dead	Alive	Dead
Autumn 1977	100	0	100	0	90	10
Winter 1978	80	20	100	0	100	0
Summer 1978	73	27	100	0	100	0

The results were examined with the Fisher's exact test (Siegel, 1956). The parr survived slightly significantly better in Lake Leppavesi than in Lake Vatianjarvi. No statistical difference was found between the results of epilimnion and hypolimnion in Lake Leppavesi. It can be stated that the water quality of Lake Vatianjarvi was too poor for young brown trout, but in Lake Leppavesi it was good enough for the survival of these fish.

4.2 Marking results

Fish were found to migrate down the watercourse (Figs. 2 and 3) and the most distant recaptures were made 120 km from the stocking area. These migrations seemed to be much longer than those undertaken by brown trout in Lake Saimaa, eastern Finland or Baltic trout (Salmo trutta m. trutta (L.)) (Toivonen, 1977; Toivonen and Ikonen, 1978; Bertmar, 1979).

Only 28 percent by weight of the recaptured fish were fished in the stocking area between Aanekoski and Vaajakoski, 26 percent in northern Paijanne, 25 percent in central Paijanne and 21 percent in southern Paijanne. Thus, about 50 percent of the catch was captured at a distance of 40 km or more from the stocking sites.

Only 19 percent of the recaptures of fish stocked into polluted areas were made at the stocking sites. By contrast, 63 percent of fish stocked in the autumn into unpolluted areas of S. Leppavesi were recaptured at the stocking site. However, autumn stockings into Lakes Kuhnamo and Saravesi failed. Many fish were either dead or in poor condition when they were found and some marked fish were found dead on the shores of this polluted area.

The catch per 1 000 smolts was 6.2–145.3 kg from spring stockings and 0–37.8 kg from autumn stockings (Table 2). Most recaptures were made during the first three years after tagging. The percentage return by number of marked fish was 1.6–14.2 for spring stockings and 0.2–6.4 percent for autumn stockings.

Regardless of the small sample, correlations between the NaLS concentration (mg/l) at the stocking site during stocking (x) and the recaptures of each marking group (kg/1 000 smolts; y) were as follows:

Spring stockings:

$$y = 209-46.4\,x$$
$$n = 3$$
$$t = -7.02^{x}$$
$$r = -0.99^{xx}$$

Autumn stockings:

$$y = 29.3-4.90\,x$$
$$n = 6$$
$$t = -3.06^{x}$$
$$r = -0.84^{x}$$

The recapture rate increased when the NaLS concentration decreased. The regression lines for spring and autumn stockings were, however, quite different.

No statistically significant differences in growth rate were found between sites or times of stocking, mainly because most of the growth takes place in Lake Paijanne. Growth in this system was similar to that of brown trout in Lake Saimaa (Seppovaara, 1962).

5. DISCUSSION

Pollution and the concentration of dissolved oxygen (DO) were considered to be important factors affecting the success of stocking. Because the annual 50- and 5-percent DO values should be 9 mg/l and 5 mg/l respectively for resident populations of salmonids (EIFAC, 1973), the failure of stockings in Lakes Saravesi and Kuhnamo was probably due to the low oxygen concentration. In these areas only, DO remained below 5 mg/l for longer than the required 5 percent. However, no correlation was found between the DO of the hypolimnion during the winter stagnation and the catch of each marked group.

The toxicity of pulp mill effluents is known to increase as DO decreases. Thus organic and inorganic sulphur and chlorine compounds, resinous acids and slime toxicants connected with the effluents may have affected the environmental conditions of those lakes. For example, Sprague and Drury (1969) noted a moderate avoidance by trout of bleach kraft mill effluent throughout the sublethal range of 10–100 000 ppm. Bleach effluents are also released by Aanekoski pulp and paper mills and the load from the pulp mill was particularly high at the end of 1978 and in 1979. At that time stockings were not successful in N. Leppavesi. It is obvious that if the cage tests had been carried out in 1979, the mortality in N. Leppavesi would have been higher than it was in 1977–78.

Although brown trout do migrate downstream in the watercourse even under natural situations, the avoidance of polluted conditions and movement to areas providing better water quality may partly explain such migrations (Hoglund, 1961). In fact, stocked fish stayed longer near the area of stocking in S. Leppavesi than in N. Leppavesi. The winter oxygen concentration of the former was 2 mg/l higher than that of the latter.

According to studies carried out by the Finnish Game and Fisheries Institute, brown trout stockings give better results in spring than in autumn in Finland - an observation also made in this study. The average catch during the experiment was lower than that usually made from brown trout stockings in central Finland, about 146–263 kg/1 000 smolts (Sumari, 1982, unpublished information), although some further recaptures from the latest stockings can be expected.

The purchase value of the stocked smolts was 16 251 Fmk in 1981. The value of the catch from spring stockings was 3 141 Fmk and from autumn stockings 1 110 Fmk, a total of 4 251 Fmk, at commercial prices. This is only 26 percent of the purchase value of the smolts.

Bias connected with recaptures have been estimated in Finland by Sormunen (1975) and Toivonen (1977), who concluded that the catch of trout has to be multiplied by 1.5–1.7 in order to get the real catch. Thus the real value of the catch may be as much as 40 percent of the purchase value.

These results indicate that damage to local fisheries through pollution cannot be entirely compensated for by stocking with brown trout.

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Table 1 Biological oxygen demand (BOD) and lignin (NaLS) values (mg/l) in Lakes Kuhnamo, Saravesi and N. and S. Leppavesi in spring and autumn 1977–79

	Kuhnamo		Saravesi		N.Leppavesi		S.Leppavesi	
	BOD_7	NaLS	BOD_7	NaLS	BOD_7	NaLS	BOD_7	NaLS
<u>1977</u>								
Spring	3.6	2.3	2.8	0.7	2.5	1.5	-	-
Autumn	3.9	4.0	3.5	3.2	1.3	1.5	-	0.1
<u>1978</u>								
Spring	4.5	6.5	2.3	5.0	1.7	3.0	-	0.1
Autumn	7.3	9.0	5.7	9.5	3.1	7.0	-	-
<u>1979</u>								
Spring	2.4	4.2	2.3	3.8	2.7	4.5	-	-
Autumn	7.8	10.0	3.8	8.1	2.4	4.7	-	-

Table 2 Yearly recaptures in Finnish lakes

Stocking date	Year of recapture	Total catch No.	Total catch kg	Average weight × ± SD (kg)	Average increase of weight (kg)	Kg/1000 smolts	% of recapture
<u>Northern Leppavesi</u>							
6/6/77	1977	11	1.47**	0.16 ± 0.12			
	1978	42	28.94	0.69 ± 0.29	0.56		
	1979	14	25.81	1.84 ± 0.81	1.15		
	1980	2	7.60	3.80	1.96		
	1981	2	8.85	4.43	0.63		
	Total	71	72.67			145.3	14.2
7/9/77	1978	5	2.36	0.47 ± 0.12			
	1979	2	1.68	0.84	0.37		
	1980	2	5.45	2.73	1.89		
	Total	9	9.49			19.0	1.8
10/5/78	1978	12	2.62 **	0.26 ± 0.15			
	1979	22	15.46**	0.77 ± 0.48	0.51		
	1980	6	11.24	1.87 ± 0.79	1.10		
	Total	40	29.32			58.6	8.0
20/10/78	1979	1	0.75	0.75			
	Total	1	0.75			1.5	0.2
6/6/79	1979	4	0.86	0.22 ± 0.18			
	1980	4	2.25	0.56 ± 0.13	0.34		
	Total	8	3.11			6.2	1.6
17/10/79	1980	3	0.93	0.31 ± 0.22			
	1981	2	0.93	0.47	0.16		
	Total	5	1.86			3.8	1.0
		134	117.20				
<u>Southern Leppavesi</u>							
6/9/77	1977	5	0.43	0.09 ± 0.01			
	1978	18	4.05***	0.31 ± 0.24	0.22		
	1979	6	4.43	0.74 ± 0.42	0.43		
	1980	2	6.00	3.00	2.26		
	1981	1	4.00	4.00	1.00		
	Total	32	18.91			37.8	6.4
<u>Lake Kuhnamo</u>							
7/9/77	1977	10	0.76	0.08			
	1978	3	0.71	0.24 ± 0.23	0.16		
	1979	2	0.50*	0.50	0.26		
	1981	1	4.10	4.10			
	Total	16	6.07			12.1	3.2
<u>Lake Saravesi</u>							
7/9/77	1978	1					0.2

* The weight of one fish unknown
** The weight of two fishes unknown
*** The weight of five fishes unknown

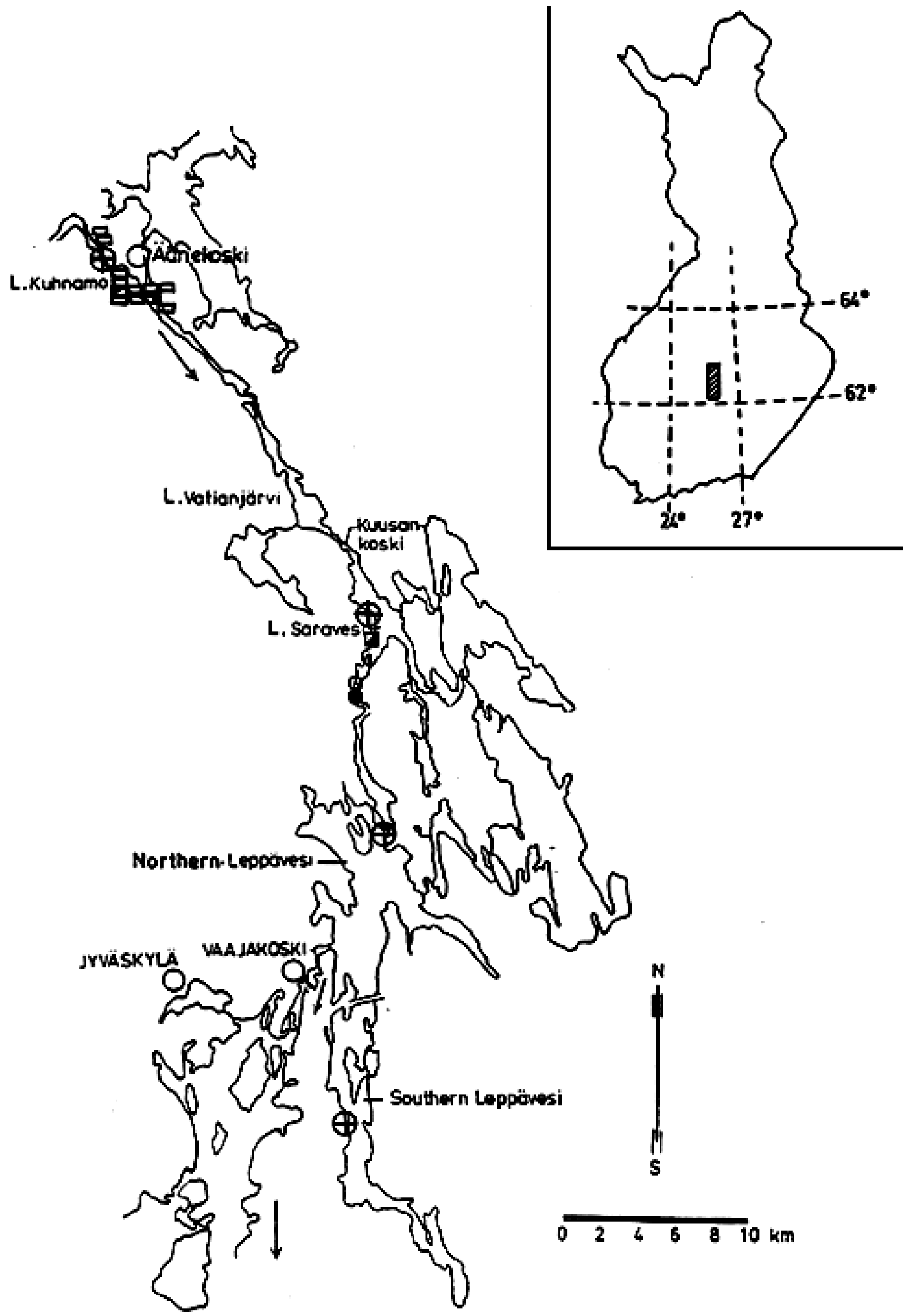

Fig. 1 The study area and stocking sites (⊕) (See Fig. 3)

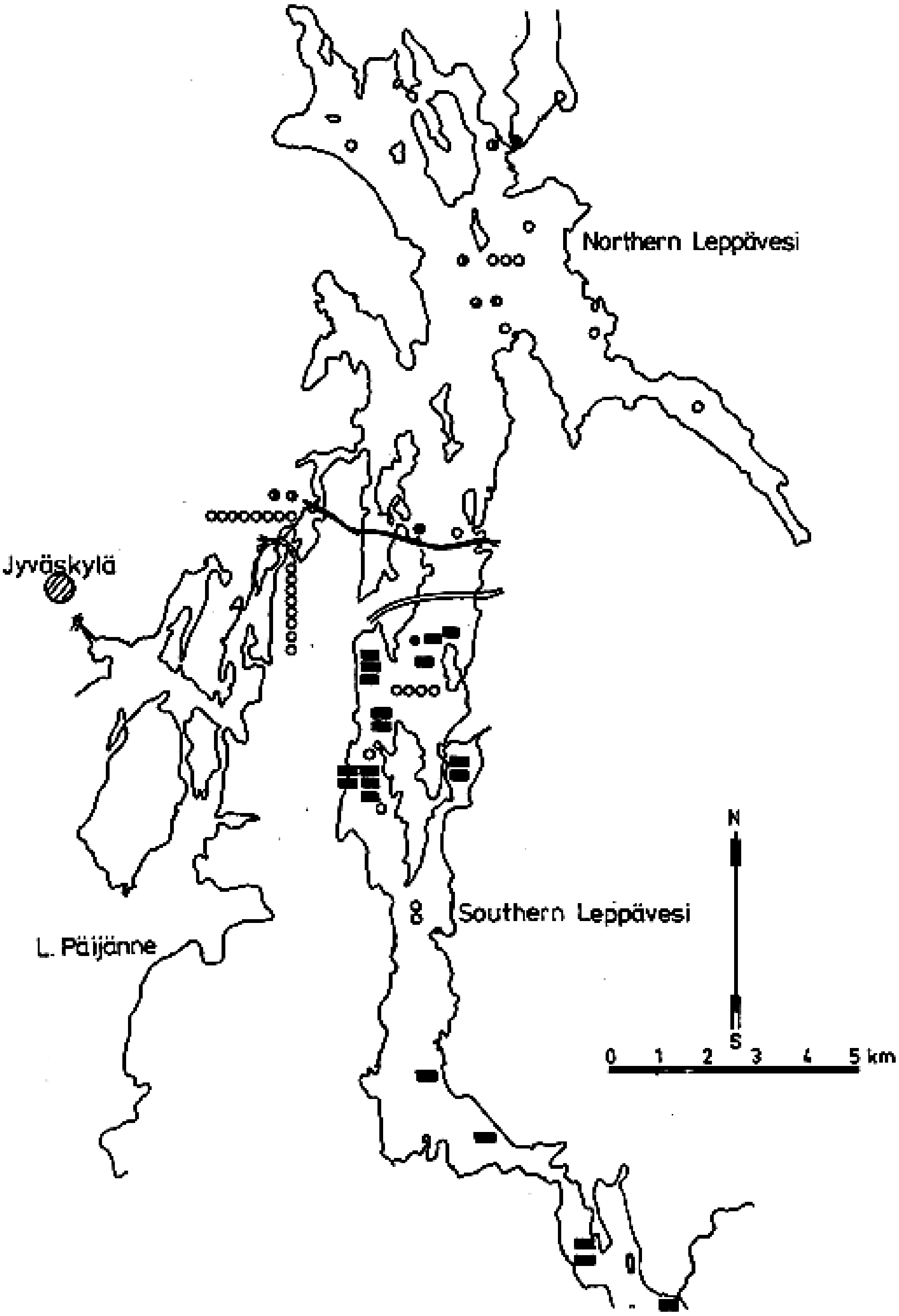

Fig. 2 Sites of recaptures (See Fig. 3)

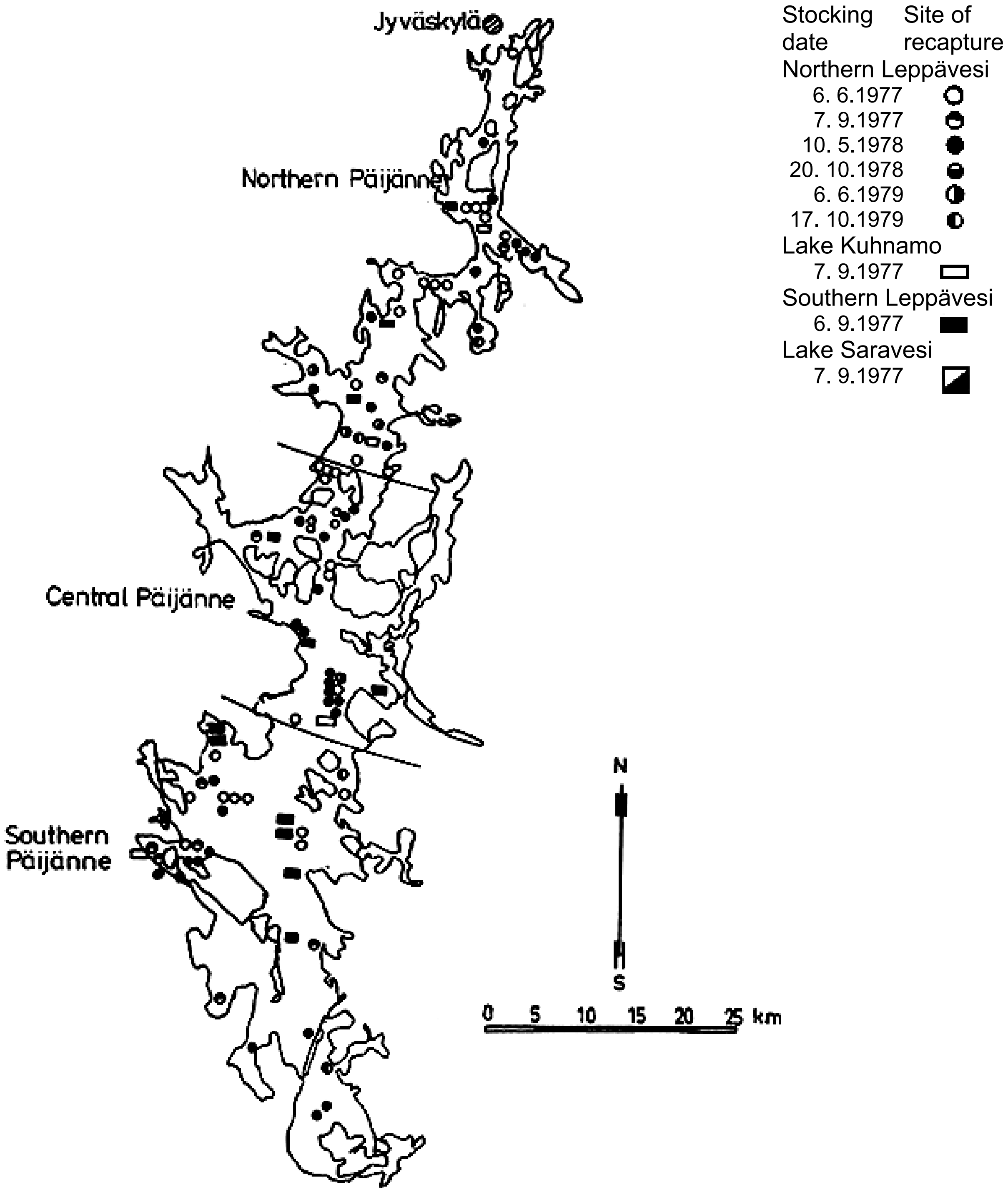

Fig. 3 Sites of recaptures

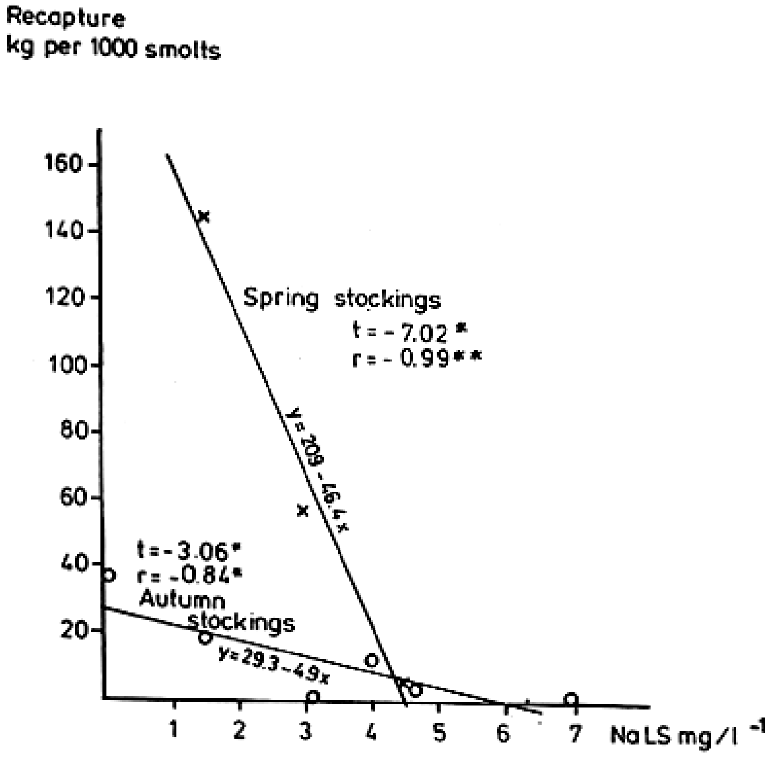

Fig. 4 Correlation between the NaLS concentration of the stocking place during stocking (x) and the recapture of each marking group (y)

LIBERATION OF TROUT (Salmo trutta L.) IN DANISH STREAMS

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CONTENTS

ABSTRACT

During the past century pond-reared trout have been liberated into natural Danish fresh waters in order to compensate for decreasing salmonid production caused by the increasing deterioration of the physical environment. At the beginning of the century such stocking was performed in a very uncritical way without any regard to the biological requirements of the fish and no beneficial effect of these stockings has been demonstrated. From the middle of the thirties, however, stocking of trout fry was systematized with regard to the habitat requirement of this developmental stage. Today, modern stocking schemes operate with fry, half-yearlings, yearlings and two-year old fish (smolts). At present about 56 percent of Danish catchment areas are managed according to such modern schemes, according to which about 1 600 000 fry, 350 000 half-yearlings, 200 000 yearlings and 130 000 two-year old fish are liberated per annum.

The paper discusses the biological and technical principles for these schemes and gives an example of their effects on the trout stocks. The paper finally discusses the actual problems and outlines the work to be done in the future.

RESUME

Au siècle dernier, on a lâché des truites élevées en étang dans les eaux douces naturelles du Danemark pour compenser la diminution de la production de salmonidés, diminution causée par la dégradation de plus en plus marquée de l'environnement. Au début du siècle, ces opérations étaient encore effectuées de façon empirique, sans tenir compte des exigences biologiques du poisson; rien ne permet de dire qu'elles ont été effectivement bénéfiques. C'est vers 1935 qu l'on a commencé à repeupler méthodiquement les eaux avec du frai de truites en tenant dûment compte de l'habitat nécessaire. Aujourd'hui, on déverse chaque année dans les eaux intérieures environ 1 500 000 alevins de moins de six mois, 500 000 alevins de six mois, 300 000 sujets d'un an et 220 000 sujets de deux ans. Environ 56 pour cent des bassins versants du Danemark sont ainsi aménagés.

L'auteur examine ces opérations du point de vue technique et biologique et donne des exemples de leurs effets sur les stocks de truites. Il passe en revue les problèmes qui subsistent et indique brièvement le travail qui reste à accomplir.

1. INTRODUCTION

Denmark is typically lowland with sandy or gravelly soils.

The streams of western Jutland are characteristically cold in summer (maximum 12–15°C), relatively poor in nutrients (150–300 µS/cm) and have a large run-off in summertime (about 7–15 1/sec/km^2). These streams are potentially excellent for spawning and growth of trout (<u>Salmo trutta</u> L.) provided that physical interventions are reduced or can be performed with better environmental understanding.

The streams of eastern Jutland and of the islands rise in morainic soils and in the summer may reach temperatures above the optimum temperature for trout (about 15°C) and even close to lethal temperature (about 25°C). The streams are rich in nutrients (200–600µS/cm) and are today more or less influenced by biologically purified sewage. In critical periods during summer, run-off may reach values as low as 1 l/sec/km^2. Furthermore, the greatly increased extraction of ground water especially in Zealand must be blamed for the disappearance of formerly good trout streams, whereas the streams in eastern Jutland and in Funen are still affected by agro-technical interventions and the presence of obstructions to spawning migration. In these streams, therefore, the possibilities for reproduction are reduced, whereas the conditions for growth are excellent.

When summer run-off exceeds a level of ≥ 1–2 1/sec/km^2, Danish streams are potentially excellent waters for spawning and growth (Larsen, 1955; 1961; 1972).

During the last century agro-technical interventions such as land drainage, culverting of small streams, straightening, canalization and diversion of larger streams changed the hydraulic conditions in the streams, principally by increasing the annual fluctuations between minimum and maximum run-off and the conveyance of suspended material from the fields to and transport in the streams. The discharge of acid ferruginous water was also increased by drainage and lignite mining. Interventions for agricultural improvements of this kind have been followed by increased applications of fertilizers which have resulted in greater weed growth in the streams. To counteract this, intensive weed cutting and stream maintenance are needed with up to three weed cuttings per season and frequent dredging of bottom and bank material, which greatly reduces the areas for spawning and growth of salmonids.

Since the Middle Ages weirs at mills and industrial plants have effectively prevented spawners from reaching the spawning grounds. Water intakes for irrigation and fish farms have not only obstructed the migration of spawners but also the downstream migration of smolts. Because stocking with trout in streams and coastal waters have been undertaken with varying success throughout this period, it is not possible to evaluate the degree to which original trout populations have naturally been reduced to the present level.

The following review describes the past and present practices in Denmark for stocking of trout into natural freshwater areas. Furthermore, it recommends intensified biological investigations of existing natural trout populations, investigations of stocking material, together with a re-examination of policies for future stocking.

1.1 <u>Trout stocking</u>

The history and the biological principles of the Danish trout stocking programme have been described by Otterstr□m (1938) and Larsen (1972). Apart from the comparatively recent introduction of electrical fishing (Larsen, 1955) the present practice has not changed since the middle thirties.

Up to the middle thirties trout stocking was carried out uncritically with no proper consideration of the suitability of the streams for fry or which year-class was to be preferred for stocking. In those cases where it has been possible to check the effect of such stockings (Poulsen, 1935) it has been demonstrated that generally speaking they had been without value.

Today the following year-classes are being used: fry, half-yearlings, yearlings and two-year olds and, if desired, older fish, the latter usually in connexion with "put-and-take" fishery. Stocking is performed according to the following principles:

(i) The stocking material is distributed as widely as possible in the river system in order to make use of its total productive capacity.

(ii) The size of the material stocked must conform to the summer depth of the stream in question.

(iii) The numbers of fish liberated must be adjusted according to the estimated carrying capacity of the locality, minus any natural trout population already present.

(i) and (ii) are relatively easily demonstrated on site, whereas (iii) at least implies a quantitative survey of the trout population by means of electro-fishing over a representative section of the stream, if necessary combined with scale sampling. The carrying capacity of the site for an individual year-class of trout is evaluated first according to (ii), then with respect to the different requirements of the various trout sizes (i.e., year-classes) to the physical conditions of the stream. Thus a high quality biotope for fry will typically be a shallow (depth about 10 cm) small stream with gravel or pebbles, constituting a mosaic of permanent territories on the bottom. Water weeds and overhanging vegetation on the banks may also create territories during the spring and summer, but it is essential that territories are also present during wintertime when weeds normally are sparse. A suitable fry biotope with such characteristics may also be found in the main stream provided that the original structure of the bottom with alternations between shallows and pools is retained. A locality evaluated as potentially suitable for liberation of larger fish requires a greater amount of shelter such as undercut banks, overhanging bank vegetation or alder roots. Localities of this kind are typically found in the greater parts of a river system.

Any site is evaluated according to a "trout biotope scale", which is linear from 0 (i.e., unsuitable because of stagnant water, pollution, total lack of shelter, etc.) up to 5, which typically satisfies a trout population, physically as well as chemically. However, a biotope score of 5 for fry differs in its physical constitution from a level 5 biotope for, for example, two-year old fish.

Following this evaluation, an on-site investigation of the actual need for stocking is undertaken by determining the existing trout population by means of electro-fishing. In practice, the field investigations take place in the autumn, when the young of the year resulting from natural reproduction have reached a size when they may be caught with a reasonable sampling accuracy. As the investigation aims at quantifying the natural reproduction potential of the reach in question, no fry are stocked in the preceding spring. However, releases of older fish are allowed. As half-yearlings are only liberated after electro-fishing it is possible in this way to demonstrate the **natural** breeding of young of the year (half-yearlings), together with breeding of any older fish which have been liberated in the preceding spring, possibly mixed with naturally-hatched trout.

The need for stocking is then worked out on the basis of knowledge gained from previous stockings together with the experimentally determined size and composition of the population, and a knowledge of the obstacles in the stream system. It should be stressed that a stocking programme covers a whole river system and not only a part of it. The exact quantity to be stocked is calculated on the basis of the area of the stream sections and on the demonstrated need for stocking.

A so-called trout stocking scheme is then worked out in the laboratory, which is based on stream descriptions and the results of the electro-fishings, and also makes provision for stockings in the years to come. The scheme is accompanied by a map (Fig. 4) which shows that the localities where fry are found are typically in the headwaters of the tributaries, where the average width of the streams varies between 0.5 to 1.5 m. The localities for half-yearlings are found downstream of the fry localities indicating that young trout gradually move downstream as they grow. This downstream movement of the fry must also be taken into consideration when evaluating the quantity of half-yearling fish to be liberated. The distribution of the localities for stocking one and two-year old fish are determined in a similar way. A stocking scheme also includes suggestions for the liberation of two-year olds (or older) at localities where it has not been possible to electro-fish.

Stockings with fry and one-year old fish takes place in April with densities of up to 200 and 20 fish/100m^2 respectively for the best biotopes, whereas half-yearlings are stocked in October up to a density of 50 fish/100 m^2.

Stockings with older fish normally take place in June or July to avoid excessive migration to the sea. However, contrary to this principle, some two-year old fish (regarded as smolts) are stocked in the mouth of the rivers in April. These fish are expected to leave the stream almost at once, thus not burdening the stocking site with extra fish to compete for territories. The numbers of fish thus stocked depend on the economic possibilities at this time.

Ideally, the principles regulating a stocking scheme should be revised every fifth year, not only because of changes in the state of pollution, obstructions, streams maintenance, etc., but also because self-reproducing trout populations may have arisen as a result of stocking. Alternatively, satisfactory trout populations may not have been created by means of the stocking system adopted, so that a revised scheme may be necessary.

The Inland Fisheries Act states that in a river system where a stocking scheme has been worked out and approved by the fishery authorities trout may only be stocked in accordance with its recommendations. The numbers may, however, be reduced in the case of economic difficulty but the numbers provided for in the scheme are the maximum allowed and correspond to the carrying capacity of the system.

1.2 The extent of Danish trout stocking activities

The percentage of various catchment areas for which stocking schemes have been elaborated according to biologically sound principles are shown in Table 1 and Fig. 1 also indicates schemes which have been revised at least once. In 1982, 1983 and 1984 a further six river systems and one delimited area with several independent small streams will be included in these activities.

Where the establishment of a fish farm results in a drop in the potential trout production in any stream, the fish farm is legally obliged to carry out compensatory stocking. The total number of trout stocked under (i) the stocking schemes now in force, and (ii) the compensatory stockings by fish farms (shown in Table 2).

The recommended numbers of trout stocked according to the schemes may be reduced because of a lack of economic capacity on the part of the interested group of people (usually an angling club or a union of clubs). Furthermore, a number of two-year old fish are liberated directly into coastal waters and in river mouths. Thus, actual numbers fall short of those recommended and on an average the annual trout liberations in 1982 are as shown in Table 3.

Stocking in river systems for which no schemes have been worked out must also be included in the costing. It is, therefore, considered that trout at a value of about 2 000 000 D.Kr. were liberated into Danish streams and coastal areas in 1981/82.

2. ADMINISTRATION OF STOCKING SCHEMES

There is no public authority responsible for trout stocking in Denmark. All stocking and the associate management is performed by individual angling clubs or unions of clubs which cover the river systems in question.

The field investigations and the development of the stocking schemes are funded by public money, whereas the clubs themselves buy and liberate the fish at their own expense. By far the greater part of the trout liberated are bought as cultured fish from private, commercial trout farms. However, within the last couple of years a few clubs have started experiments in catching spawners, stripping them, hatching the eggs and rearing the different size categories of the fish themselves. Normally the rearing of pre-fed fry involves no problems but except for one case no clubs have had the possibility of producing older year-classes yet.

Several clubs have permission to catch wild spawners every autumn, strip them and place the eggs with commercial trout farms where they are reared to the appropriate stocking sizes. Rearing fry from wild spawners up to say two-year old fish in this way involves a certain selection, because in trout farms fish are selected for other criteria than in natural stocks (fish develop lack of shyness, they willingly take pelleted food and mortality is reduced because of faster growth). There is, however, no doubt that this practice preserves a certain genetic variety and fitness of the trout populations in the river systems in question. Fig. 2 shows those river systems where this kind of fishery management has been performed over a varying number of years.

There are still some unions or smaller clubs which undertake stocking in ignorance of existing schemes for parts of a river system, or they stock fish into systems where no biological investigations have been undertaken. They use fish casually bought from trout farms not knowing their origin, which often implies that the fish stocked are the cheapest, and often discarded fish, poorly adapted to natural waters. Typically this practice applies to two-year old fish for put-and-take fisheries.

3. FUTURE STOCKING ACTIVITIES

The above explanation of the present stocking activities indicates the need for better coordination of biological knowledge of natural trout strains, the definition and description of “optimal” fish for stocking and the selective breeding associated with the development of such strains.

The stockings which have been undertaken over the past years with varying intensity raise the important question of the possible effect or influence of such stockings on the original trout populations. To what extent does stocking affect biological parameters such as brown trout/sea trout relationship, age and size at smoltification, sex distribution of smolts and of sea trout, age and size at sexual maturity at first spawning, etc.? At present we do not know with certainty whether Denmark possesses pronounced brown and sea trout strains which are reproductively isolated.

The occurrence of early and late sea trout strains in larger river systems has been claimed, and such strains have been regarded as reproductively (i.e., genetically) separated. The early strain appeared in river mouths in March/April and could be fished in the main streams as early as May. Contrary to this the late strain was composed of small fish not present on the spawning grounds until just before and during spawning. It is not, however, clear whether these fish which have differing migration patterns were also reproductively separated. If so, why does the early strain occur so rarely in today's catches. Because reliable statistics for sea trout, distributed on size classes, sex and areas do not exist, we have only limited possibilities to resolve such questions.

In salmon (Salmo salar L.), late spawners (grilse) are dominated by males with a short sea life (i.e., 1.5 years), whereas early spawners (salmon) are composed of the rest of the males and by far the greater part of the females which have not yet spawned and have a sea life of at least 2.5 years before maturity. It is therefore tempting to claim that even if sea trout normally spawn several times in consecutive years, later and early strains in sea trout arise from differences in age and sex composition. In this way, young mature males and females would arrive late in the streams and -because they are small -spawn in the smaller tributaries, whereas the older mature fish (mainly females), together with a few large specimens which spawned previously, will stay a much longer time in the stream. In these the spawning grounds will be concentrated in the main stream. In this way, a certain genetic mixing might result (i.e., from large, but early spawners). Whether or not there is a genetic difference between the two strains is critical to the evaluation of the trout stocks. Among other factors the age and size at smoltification (the fastest growing young fish are first to become smolts, and the slowest growers smoltify later), however the average size of a smolt increases with its age of smoltification. Thus large smolt will become mature at an earlier age, which means that in any smolt year-class one would expect to find an increasing proportion of early smoltifying fish as the year-class progresses. This implies that young fish in small streams that grow relatively slowly would become smolts at two-three years of age but as relatively large smolts which might mature relatively early. Contrary to this, fast-growing young fish in the main stream may already become smolts at an age of one-two years, but their relatively smaller size requires that they return to the spawning grounds as large but late (i.e., by age) mature fish ("the early strain").

Under this hypothesis, factors which might have been responsible for the change in the trout population could have been the removal of spawning grounds in the main streams for navigation and draining and an intensified coastal and stream fishery for big sea trout. This may have lead to a reduction or removal of the possible genetically determined "large and early" sea trout strain, and a reduction of the natural sea trout population to a relatively later smoltifying and early maturing, slow-growing population with a small maximum size.

At the same time, these natural populations are exposed to great pressure from stocked farm-reared trout which are selected for fast growth and which are therefore relatively large at smoltification, mature early, have decreased growth and attain a small maximum size. It is not known to what extent these genetic mixtures counteract (the growth of young fish) or enhance (early maturity followed by slow growth) each other.

The achievement of the original objectives requires a better understanding of the biological characteristics of the natural sea trout strains in the river systems, particularly of the spawners to be stripped so that selection can be made of specimens especially fit for breeding. It also requires the recording of changes in numbers, period of immigration, size and age at smoltification besides possible changes in age-composition at maturity as a result of breeding and stocking over the next 20 years. Tagging of two-year old smolts and the wild trout from the stream under study and from other river systems as well as electro-fishing following stocking - will also be necessary to monitor the progress of such populations. Better knowledge of the time and size of stocking of all size groups is also needed. For example, it is normally recommended that fry should be pre-fed for three weeks before stocking. In the case of pond-reared fry this means that stocking normally takes place in March/April, whereas naturally hatched fry have not been detected in the streams until a month later.

It is, however, doubtful whether there are any great differences between strains of trout in the various river systems within a geographical region as limited as Denmark. There might originally have been great genetic differences in such parameters as size and age at smoltification and also the size of immigrants in brooks and small streams with direct outflow in the sea, which cannot be entered until October/November when precipitation is highest compared to the larger streams and rivers (i.e., Gudenå, Skjern å, Skive å), into which immigration is practicable at all times of the year. Possibly, the focus should be on developing a strain of trout which is adapted to all larger river systems and disregard the idea of individual strains for individual streams. This would essentially facilitate the production process in fish culture stations where the usual procedure of frequent screenings of equal size groups could be maintained. In this way, costs would also be reduced.

4. EXAMPLE OF A STOCKING SCHEME

The River Ribe å has a catchment area of about 680 km^2. The main stream rises in eastern Jutland about 41 m above sea level in the region close to the main stationary line of the last glaciation, and proceeds from there along a more or less straight line westward. After a course of about 71 km it discharges into the Wadden Sea 10 km west of the city of Ribe. Besides numerous smaller tributaries, the main stream receives two major tributaries, from the right the River Tved å and from the left the River Gels å, both themselves with larger and small tributaries.

A few of the tributaries are more or less polluted from farms and small villages, but the most important deterioration of the river as regards trout fisheries arises from early re-alignments and channelizations and, more recently, with a heavy-handed river management policy and weed cutting.

Besides trout the following fish occur in the river: rainbow trout (Salmo gairdneri Rich.), pike (Esox lucius L.), roach (Rutilus rutilus (L.)), dace (Leuciscus leuciscus (L.)), minnow (Phoxinus phoxinus (L.)), tench (Tinca tinca (L.)), gudgeon (Gobio gobio (L.)), eel (Anguilla anguilla (L.)), burbot (Lota lota (L.)), perch (Perca fluviatilis (L.)), ruffe (Gymnocephalus cernua (L.)), stickleback (Gasterosteus aculeatus (L.)), ten-spined stickleback (Pungitius pungitius (L.)) and also lampreys (Cyclostomata). It is known that salmon previously occurred in the river. Bream (Abramis brama (L.)) and pikeperch (Stizostedion lucioperca (L.)) also occur in adjacent lakes.

An old stocking scheme for trout fry dates back to 1951 which was more or less adhered to. In 1972 systematic electro-fishings and biotope evaluations were undertaken and from the spring of 1974 regular trout stockings were started according to a biologically sound stocking scheme.

Altogether 176 sites were inspected. Out of these 65 were estimated to be unsuitable for trout. Of the remaining 111 sites suitable for trout 33 were not electro-fished either because of difficult access or because the river was too large. The remaining 78 suitable trout sites were electro-fished, 32 of which were devoid of trout. On the remaining 46 sites trout densities between 0.3 and 245 per 100 m^2 were found. The total need for restocking was calculated at 89 000 fry distributed at 52 sites, 31 000 half-yearlings at 25 sites, 8 700 yearlings at 4 sites, and 16 600 two-year olds at 7 sites, besides an unspecified number mainly depending on economic capacity, though not exceeding 14 500 specimens.

This scheme was revised in 1981. This time 194 sites were inspected (Fig. 3). A few new sites were included but generally the sites were similar to those sampled in 1972. Out of the 194 sites 62 were estimated to be unsuitable for trout, of the remaining 132 trout sites electro-fishing was not performed at 27 either because of difficult access or because of the width of the river. Of 105 suitable trout sites where electrofishing was performed, only 15 were found to be devoid of trout. There was, therefore, a distinct improvement as compared to the previous investigation. At the remaining 90 sites suitable for trout densities of between 0.8 and 207 specimens per 100 m^2 were found.

The total stocking need today (Fig. 4) is calculated to comprise 47 300 fry at 36 localities, 20 900 half-yearlings at 16 localities, 13 300 yearlings at 14 localities and 16 400 2-year olds at 9 localities. Besides this an unspecified number (not exceeding 14 500) of two-year olds distributed in the main river at five localities. In conclusion, it can be stated that an immediate semi-quantitative estimation of the results of the electro-fishings shows an allover improvement of the trout population on the localities examined for the whole river system.

For a more reliable interpretation, localities examined in 1972 and 1981 were grouped in comparable and incomparable localities.

In 1972 a total of 82 localities of a total area of 9 946 m^2 were electro-fished, corresponding to 4 096 m of stream. In 1981 a total of 113 localities of a total area of 11 263 m^2 were electro-fished, corresponding to 5 140 m of stream.

Sixty-three localities are immediately comparable. At these localities electro-fishing was performed in over 3 088 m of stream, corresponding to an area of 6 372 m^2, whereas in 1981 at the same localities electro-fishing took place in over 2 890 m of stream corresponding to an area of 6 613 m^2. Even if both surveys were undertaken during autumn, there was great difference in individual run-offs. The summer of 1981 was very rainy, stream widths and depths were greater than in 1972. Thus the broad, shallow sea trout river Gels å was 18 percent wider on average and the other localities 14 percent wider in 1981 than in 1972. This meant increased difficulties when fishing in the River Gels å (average width in 1981 - 5.21 m) and at the same time it was possible for the fry to spread over a relatively larger area. Another significant factor is the year-class strength. During the investigation supplementary scale sampling was undertaken, and this showed that in the localities examined in the Gels å the 1980 year-class had been exceptionally small, whereas the 1981 year-class was of the same strength as the 1972 year-class. This situation was not detected in other parts of the Ribe å system.

Because of this discrepancy comparisons between the two years were made including and excluding the Gels å.

The results of the comparison are shown in Table 1. As the material is based on a reasonably large number of sites it is clearly demonstrated that stocking has had an exceedingly good effect on the total trout population in the whole Ribe å system.

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Table 1 Stream areas subject to trout stocking schemes in Denmark (up to 1981)

	Area (km^2)	% with stocking scheme
Jutland (1984)	29 643	59
Funen	2 984	85
Zealand (w.islands)	9 310	26
Bornholm	588	100
Total area	42 555	

Table 2 Recommended numbers of trout stocked into Danish waters (1981)

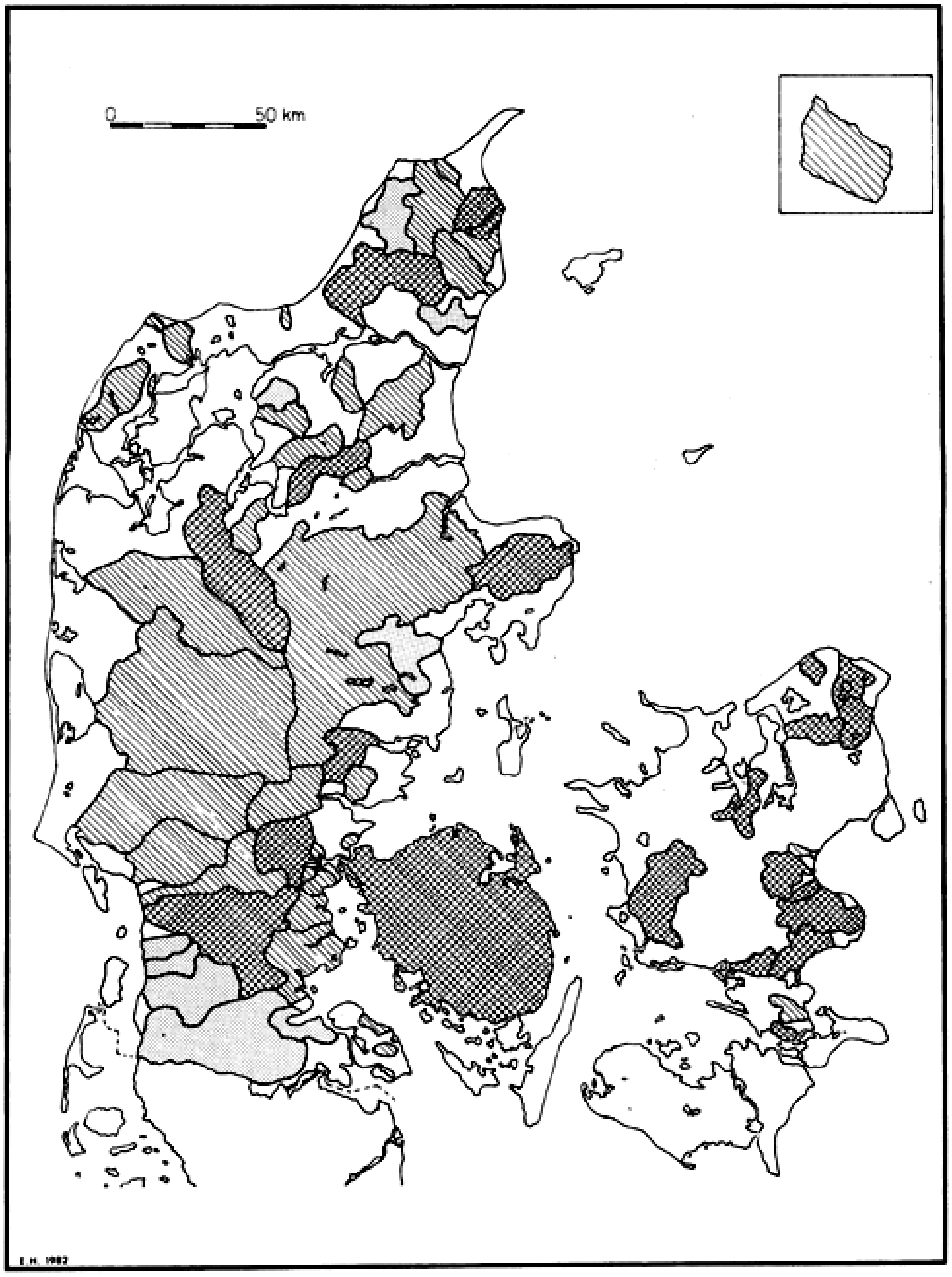
	Stocking schemes	Compensatory stocking
Fry	1 600 000	27 000
Half-yearlings	437 000	83 000
Yearlings	356 000	99 000
Two-year olds	273 000	15 500

Table 3 Actual numbers of trout stocked into Danish waters (1982)

	Number	Value (D.kr.)
Freshwater:		
Fry	1 600 000	152 000
Half-yearlings	350 000	273 000
Yearlings	200 000	240 000
Two-year olds	130 000	533 000
River mouths/coastal waters	75 000	308 000
Compensatory stocking from fish culture, all categories		250 000
Total	1 756 000	

Table 4 River Ribe å - comparable localities in 1972 and 1981

	1972	1981	Difference %
No. of sites: 63 (10 of these in Gels å)			
Metres electrofished - total	3 086.0	2 890.0	
Metres electrofished - Gels å	550.0	440.0	
No. of trout caught - total	2 012.0	2 273.0	
No. of trout caught - Gels å	1 139.0	831.0	
No. of trout/100 running m - total	65.2	78.7	21.5
No. of trout/100 running m - Gels å	207.1	188.9	-8.8
No. of trout/100 running m - outside Gels å	34.4	58.9	71.2
No. of trout fry caught - total	1 236.0	1 312.0	
No. of trout fry caught - Gels å	782.0	721.0	
No. of trout/100 running m - total	40.1	45.4	13.2
No. of trout fry/100 running m - Gels å	142.2	163.9	15.3
No. of trout fry/100 running m - outside Gels å	17.9	24.1	34.6
No. of older trout/100 running m - total	25.1	33.3	32.7
No. of older trout/100 running m - Gels å	64.9	25.0	-61.5
No. of older trout/100 running m - outside Gels å	16.5	34.7	110.2

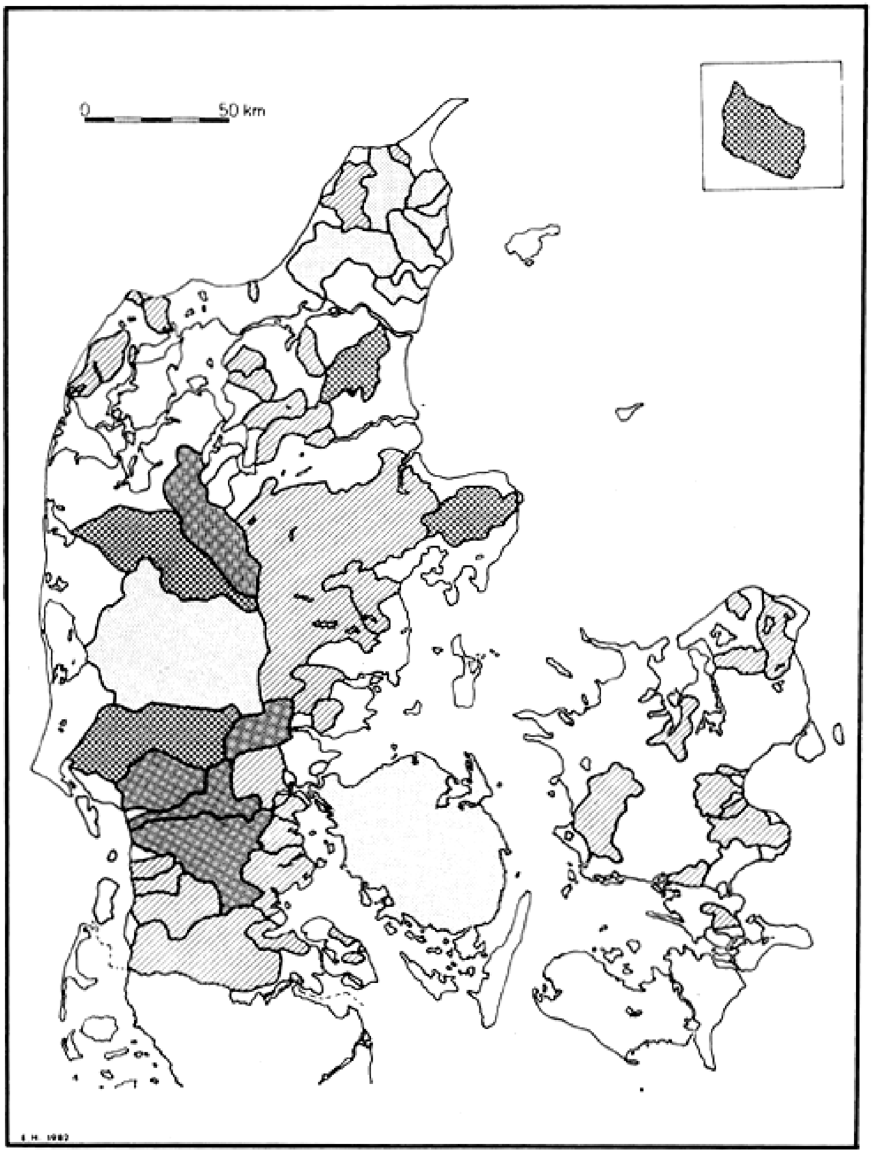


Schemes based upon only one field survey and not revised since.

Schemes revised at least once.

Schemes planned for autumn 1982–1984.

Fig. 1 Geographical distribution of stocking schemes based on catchment areas



Pond reared fish of more or less known origin.

Schemes previously fulfilled with fish from the systems' own strains, but now being fulfilled with pond reared fish of more or less known origin.

Schemes throughout the years fulfilled with fish from own strains

Schemes previously fulfilled with fish bought at random, but where now a production of trout of own strains has started.
The Funen - scheme includes a total of 60 streams systems, fulfilled with fish from the river Odense å.

Fig. 2 The origin of stocking material

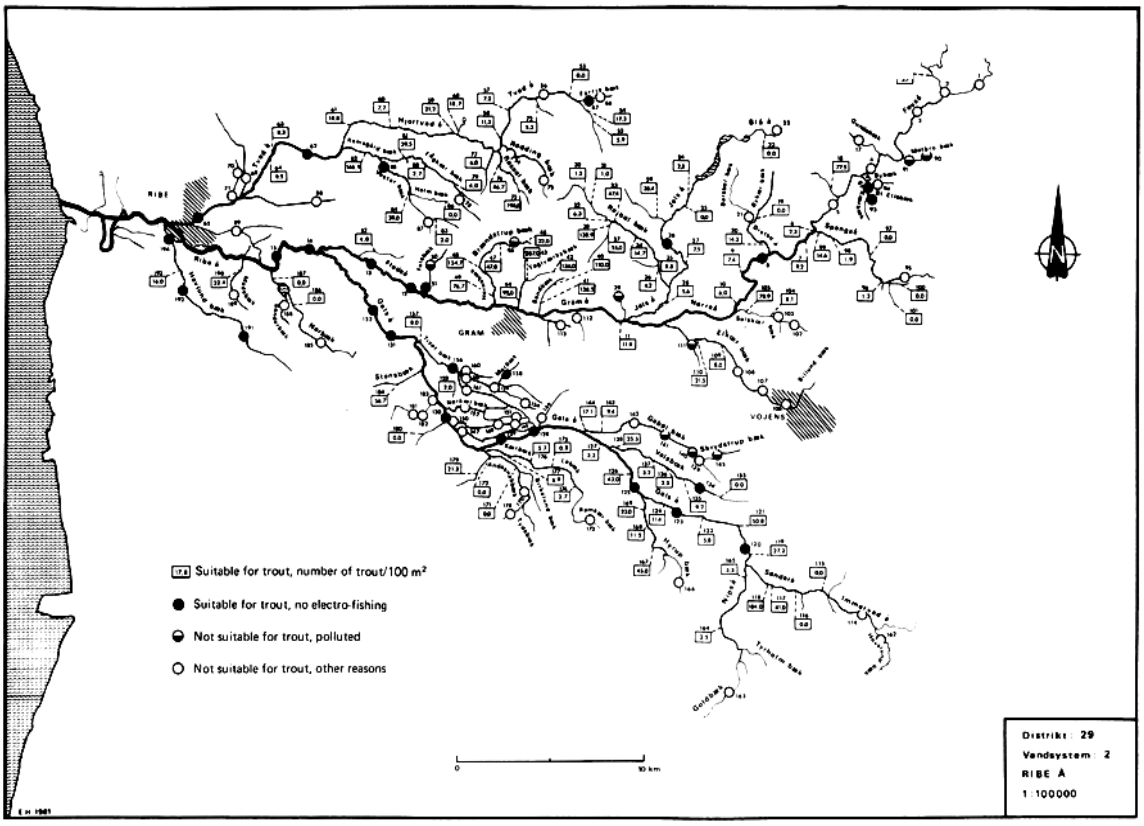


Fig. 3 Test fishing map of the Ribe River system

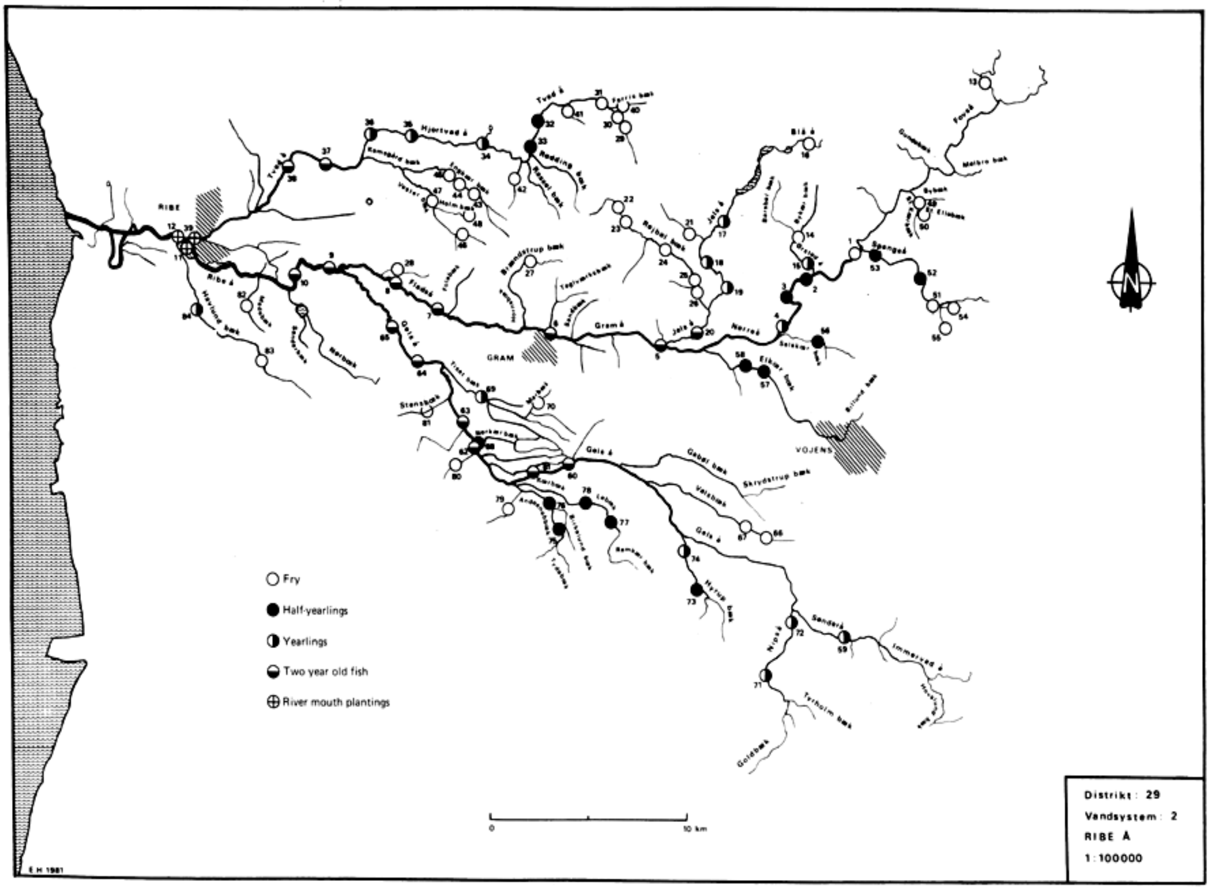


Fig.4 Liberation map of the Ribe River system

THE IMPORTANCE OF GENOTYPE, SIZE ON STOCKING AND STOCKING DATE TO THE SURVIVAL OF BROWN TROUT (Salmo trutta L.) RELEASED IN IRISH LAKES

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CONTENTS

ABSTRACT

The relative success of a series of brown trout (<u>Salmo trutta</u> L.) stocking experiments in a range of Irish lakes are outlined. Data indicate that in the case of yearling plantings, the direct offspring of wild trout survived in greater numbers than an inbred strain of trout. Size on stocking can be more important than genotype in relation to plantings of two-year old fish. The larger individuals tend to survive in greater numbers and contribute more to angling catches. Repeated stockings of trout in spring and autumn indicate that the former are more successful both in terms of survival and subsequent angling catches.

RESUME

En Irlande, on a procédé, avec des résultats variables, à toute une série d'expériences de repeuplement des lacs en truites (<u>Salmo trutta</u> L.). On a constaté, en cas de repeuplement avec des sujets d'un an, que les descendants directs de truites sauvages avaient un taux de survie supérieure à celui d'une race consanguine de truites. Si l'on utilise des poissons de deux ans, leur taille au moment du repeuplement peut jouer un rôle plus important que le génotype. Les truites les plus grosses ont tendance à avoir un taux de survie supérieur et représentant une part plus importante des captures. On obtient de meilleurs résultats (taux de survie, captures) en repeuplant les eaux au printemps plutôt qu'en automne et donne des exemples de leurs effets sur les stocks de truites. Il passe en revue les problèmes qui subsistent et indique brièvement le travail qui reste à accomplir.

1. INTRODUCTION

The Central Fisheries Board (formerly the Inland Fisheries Trust) was founded in 1951 to develop and promote brown trout (Salmo trutta L.) and coarse fish (principally pike (Esox lucius L.), bream (Abramis brama L.), rudd (Scardinius erythrophthalmus L.) and tench (Tinca tinca L.)) sports fishing in the Republic of Ireland.

There are many lake brown trout fisheries in Ireland. The Central Fisheries Board developed these lakes by improving the trout spawning and nursery areas in inflowing streams and by controlling the trout's predators (pike) and competitors (perch, Perca fluviatilis (L.)) in the lakes.

In the late sixties a combination of arterial drainage schemes and increased instances of organic pollution in streams resulted in serious reductions in wild trout recruitment rates to lake fisheries. A mjaor stocking programme was undertaken at that time in many lakes to maintain optimum trout stocks. In 1975 a long-term research programme commenced to evaluate the overall development programme on trout lakes (O'Grady, 1981). The current manuscript outlines some of the results of this study - the relative importance of genotype, size on stocking and the actual stocking date to the survival of planted brown trout in a range of Irish lakes.

2. MATERIALS AND METHODS

2.1 The study areas

Experimental stockings were carried out in nine lakes. They ranged in size from 1 to 1 883 ha. Details of the size, depths, water chemistry, geology and resident fish stocks in these waters are presented (Table 1).

2.2 Trout genotypes

Five discrete brown trout strains were used in these experiments. The Central Fisheries Board have developed a fast-growing variety (Roscrea trout) over the past 25 years. A brood pool of 1 000 breeding pairs of Roscrea trout are retained annually. Seven different strains of wild trout have been crossbred with the brood pool at intervals to prevent excessive inbreeding. Details of the evolution of this stock are presented in O'Grady (1981). The four additional strains of trout used in these experiments were F' wild trout - the direct offspring of wild Irish lake trout which were reared in fish-farm conditions from the egg stage.

2.3 The collection of quantitative data on trout stocks

In four of the lakes, trout population estimates were carried out at intervals to assess the survival of fish stocked experimentally. A Petersen tag recapture type exercise was used. Tagged trout were stocked and the water was subsequently gillnetted for a three to five day period to obtain a sample of both the introduced tagged fish and the resident stock for estimate purposes. Data indicate that the standing crop estimates obtained in this way were accurate (O'Grady, 1981a, in press).

In the remaining waters, samples of trout from experimental stockings were recaptured in gillnet gangs which were capable of catching a random cross section of the population present (O'Grady, 1981a).

2.4 Recognition of specific trout stocks

All of the trout stocked during the course of these experiments were either fin-clipped or tagged for subsequent identification purposes. The tags utilized were

Dennison floy anchor tags. Fin-clipped and tagged trout were never used in the same experiment in order to avoid the problem of possible differential mortalities from each marking technique. In experiments where fin clips were used for identification purposes and two genotypes were stocked, the same fin type was clipped in each group (i.e., a left and right pelvic or pectoral fin). Data indicate no differential mortality (P>0.05) in trout of identical genotype which has one or other pectoral or pelvic fin clipped (O'Grady, 1981).

3. RESULTS

3.1 <u>The influence of genotype</u>

In 1977 and 1978, seven relatively small lakes (0.4–130 ha) were stocked with autumn fingerlings or spring yearling trout. Each water was planted with fish of two strains, Roscrea trout and one F' wild group. Each group were marked by clipping a single fin. In October 1979, these waters were test-netted to establish the relative survival of the experimental stockings. Reasonable numbers of these fish were captured in four of the seven lakes. In all four waters there was a significantly higher (P < 0.05 or P < 0.001) survival of the F' wild strain (Table 2). In the remaining three lakes poor survival of both strains was probably caused by a combination of factors - predation by the resident pike stocks and both inter-and intra-species competition with resident trout and perch populations.

The Roscrea and F' wild trout used in these experiments were not homogeneous in terms of mean length values on stocking. The former group were larger in each case and maintained this differential (P<0.001) over the experimental period in at least three of the experiments (Table 3).

When the samples of fish recaptured in each lake were being removed from the gillnets, it was noted that some of the immature fish were soft-fleshed. Subsequently, when individual fish were being weighed and measured, the flesh texture of each immature trout was recorded. A distinct pattern emerged. All of the immature Roscrea trout were soft-fleshed. Their F' wild counterparts had much firmer musculature. Trout which would have matured later in the year were not utilized in this comparative test because maturing females tend to become soft-fleshed and ripening males usually develop a toughened skin.

3.2 <u>The importance of size on stocking</u>

The relevance of size on stocking to the subsequent survival of planted trout was illustrated in a number of experimental programmes. In each case, the larger group of fish survived and/or were cropped by anglers in greater numbers. In each experiment, the larger group of fish were significantly (P<0.001) bigger than their counterparts.

A. Roscrea two-year old and yearling trout

Both Roscrea two-year old and yearling fish were planted in Lough O'Flyn in April 1976. A large percentage (56.4 percent) of the former group were cropped by anglers in 1976 (April to September) and a significant number of these fish (33.1 percent) were still present in the fishery in October 1976. An additional 12 and 6 percent of this two-year old group were caught by anglers during the 1977 and 1978 angling seasons respectively. In contrast, none of the yearling Roscrea fish were recorded in angling catches in 1977 or in subsequent years. Five trout population estimates carried out in Lough O'Flyn at intervals from October 1976 to October 1979 indicate that few of these fish has survived (<3.0 percent) 17 months after planting.

A similar stocking programme in Lough Inchiquin yielded identical results with a greater number of the two-year old Roscrea fish surviving for a longer period (Tables 4 and 5).

B. Roscrea and F'Owel two-year old trout

Roscrea and F'Owel two-year old trout were stocked concurrently on three occasions. In one instance (O'Flyn, 1977) F'Owel trout were larger than their Roscrea counterparts. In the other two experiments (O'Flyn, 1976 and Inchiquin, 1976) the Roscrea trout were the larger fish. In each of the three experiments the larger batch of trout, irrespective of genotype, survived and/or were caught in greater numbers by anglers (Tables 4 and 5).

3.3 The influence of stocking date

Repeated planting of autumn yearling (19 months old) and two-year old (22–24 months old) Roscrea trout in Loughs O'Flyn and Sheelin illustrate the importance of the stocking date to the subsequent survival of planted trout. In each case, the two-year old fish survived in greater numbers for a longer period and thus more of these fish were cropped by anglers (Tables 6 and 7).

The numbers of autumn yearling trout which survived this first overwintering period, post-stocking, were checked in relation to four specific plantings (Sheelin, October, 1977 and 1978; O'Flyn, October 1976 and 1977). In both the Lough Sheelin stockings and in the O'Flyn October 1976 planting, only a small (8.9–25.6 percent) proportion of each stocked group survived overwinter - a 5–6 month period.

The 95 percent confidence limits obtained for the estimated number of autumn yearlings (October 1977) still present in Lough O'Flyn in February 1978 were too broad to indicate the precise overwintering mortality for this group. However, very few of these trout were caught by anglers in 1978 and 1979 (9.9 and 10.3 percent) and none of these fish were captured two years after planting during a population estimate (Tables 6 and 7). These data indicate a poor survival rate for this stocking.

4. DISCUSSION

The results of these experiments indicate that genotype can influence the survival of stocked trout. Significantly greater numbers of F' yearling trout survived than their Roscrea counterparts in four small lakes. A similar pattern was noted for domesticated and F' wild rainbow trout (Borgeson, 1966; Webster and Flick, 1974 and Reisenbichler and McIntyre, 1977) and brook trout (Flick and Webster, 1962 and Mason et al., 1967). The same trend has also been observed between different domesticated trout strains. (Cordone and Nicola, 1970: Brown, 1970; Rawstron, 1973 and Ayles, 1974) and also between transplanted wild and domesticated brown trout (Miller, 1953 and Strange and Kennedy, 1979).

The higher survival of F' genotypes in this study might be related to the fact that they were introduced into waters, similar ecologically to those occupied by their parental stocks. Ayles (1974) and Webster and Flick (1974) have stressed the importance of matching planted strains to specific habitats. The F' genotypes may also have higher stamina than their Roscrea counterparts. Green (1964) noted that F' brook trout have higher stamina than domesticated varieties. Fishfarm experiments indicated that Roscrea fish were tamer than the F' strains (O'Grady, 1981), a factor which might render the former group more prone to predation. Greene (1951), Vincent (1960) and Butler (1974) quoting McClaren also record that domesticated trout display a lack of wariness even after release from fish farms. Fishfarm experiments also indicated that F' genotypes will adopt a territorial stance given the opportunity (O'Grady, 1981).

Roscrea fish have difficulty in recognizing invertebrate food items for at least ten days after release and do not feed at the same rate as resident fish during this period (O'Grady, 1981). F' wild trout may not experience this difficulty. A combination, of some, or all, of these factors probably resulted in the higher survival of the F' genotypes. The unusually soft musculature of the Roscrea fish which did survive may also reflect the social stress which these fish were subjected to in an alien and competitive environment.

Size on stocking is of critical importance to survival and also influences the number of fish caught by anglers. The importance of this factor in relation to yearling and 2+ fish has been recognized previously for both brown trout (Brown, 1970; Cooper, 1974 and Fleming-Jones, 1978) and rainbow trout (Borgeson, 1966; Brown, 1970; Cooper, 1974 and Fleming-Jones, 1978). In Loughs O'Flyn and Inchiquin size on release was more important than genotype in determining subsequent angling returns. The cropping of larger trout in two-year old plantings has been noted previously (Shetter, 1944; Needham, 1947; Larson and Ward, 1955; Mullan, 1956; Hallock et al., 1961; Wagner and Wallace, 1963; Hansen and Stauffer, 1971; Templeton, 1971 and Cooper, 1974). The higher returns to anglers of larger trout might be related to an increased ability of these individuals to survive in competitive situations.

The date of planting can, of itself, seriously influence survival. Repeated autumn yearling plantings in Loughs O'Flyn and Sheelin failed to overwinter successfully. Comparable two-year old spring stockings survived in much greater numbers. Many authors report a similar differential survival pattern for autumn and spring stockings of non-migratory salmonids (Shetter and Hazzard, 1940; Needham and Slater, 1944; Shetter, 1944; Reimers, 1957; Buettner, 1961; Anderson, 1962; Brown, 1970; Templeton, 1971 and Cooper, 1974). A paucity of food in the autumn has been suggested as the reason for the poor survival (Brown, 1970). This does not hold in Irish lakes because autumnal standing crops for many invertebrate species are relatively high (Whelan and O'Connor, pers.comm.). Data indicate that, initially in Irish waters stocked fish tend to be surface feeders, ignoring the benthic invertebrates (O'Grady, 1981). Thus, an absence of surface food items in the autumn may result in the poor survival of fish stocked at this time of year.

The results of these experiments illustrate that several factors, genotype, size on planting and the stocking date, can seriously influence survival and therefore affect angling catches. These data will allow a rationalization of stocking procedure in Irish lake brown trout fisheries and contribute to a more efficient fisheries management programme. There are many small (1–30 ha) productive lakes in Ireland which are not fished intensively. Annual spring plantings of yearling F' genotype fish in these waters will ensure the maintenance of high stocks in circumstances where natural production is limited or absent. In larger waters, annual spring plantings of large two-year old trout will successfully supplement natural stocks. A 50 percent reduction of stock densities in Central Fisheries Board fish farms since 1978 has resulted in an increased growth rate of stocks (O'Grady, 1981). Two-year old Roscrea trout now (1981) average 30 cm in length. The Roscrea strain fish are the most useful for stocking purposes where two-year old trout are required because they grow more quickly in fishfarm conditions than F' strain fish (O'Grady, 1981). The reduction in fishfarm production because of the decrease in pond stock densities has been offset by the adoption of a cage-culture system in lakes.

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Table 1 Details of the study areas

Lake	Area (ha)	Max.depth (m)	Mean depth (m)	Alkalinity	Conductivity	Solid geology	Fish species
Sheelin	1 883	14	5	2.70	287	Carboniferous limestone	Bt, Pe, Pi, Ro, Ru, Br, T, St(3),St(9)
Mount Dalton	8	4	3	5.00	544	Carboniferous limestone	Bt
Doolin Pond	2.2	2.7	1.3	-	-	Carboniferous limestone	Bt, St(3), C
O'Flyn	130	19	4.5	2.80	282	Carboniferous limestone	Bt, Pe, Pi, Ru, Br, St(3), St(9)
Inchiquin	113	27	6	3.70	400	Carboniferous limestone sandstone, millstone grit, flagstone, shales	Bt, Pe, Pi, Ru, T, St(3), St(9)
Muckanagh	300	20	3	4.00	405	Carboniferous limestone	Bt, Pe, Pi, Ru, Br
Kilkee Reservoir	2.4	3.6	1.8	0.85	300	Millstone grit, flagstone	Bt
Gortglass	31	15	3	0.,50	104	Millstone grit, flagstone	Bt. Ch
Gloster Pond	1	-	-	-	-	Carboniferous limestone	Bt, Pe, Pi, Ru

Bt = brown trout; Pe = perch; Pi = pike; Ru = rudd; Ro = roach; Br = bream; T = tench; St(3) = three-spined stickleback; St(9) = nine-spined stickleback; C = carp; Ch = char

Eels present in all lakes

Alkalinity as milli equivalents per litre

Conductivity as reciprocal megohms

Table 2 The comparative survival of Roscrea and F' wild trout strains, stocked in a number of small lakes, as indicated by x^2 tests

Lake	Strain	Number stocked (1977/78)	Number recaptured (1979)	X^2	Significance
Gortglass	Roscrea	829	4		
	Mask F'	829	39	27.8	P<0.001***Mask F'>Roscrea
Mount Dalton	Roscrea	1 000	23		
	Mask F'	1 000	38	3.6	P<0.05* Mask F'>Roscrea
Doolin Pond	Roscrea	600	14		
	Sheelin F'	600	104	62.8	P<0.001*** Sheelin F'>Roscrea
Kilkee Reservoir	Roscrea	500	23		
	Sheelin F'	500	38	3.5	P<0.05 * Sheelin F'>Roscrea
O'Flyn	Roscrea	4 008	3		
	O'Flyn F'	4 008	5	-	Insufficient data
Muckanagh	Roscrea	3 175	0		
	Inchiquin F'	3 175	0	-	-
Gloster Pond	Roscrea	500	0		
	Sheelin F'	500	0	-	-

* = significant difference; *** = very highly significant difference

Table 3 A statistical comparison of the mean (x) length values of Roscrea and F' wild trout on stocking and subsequently on recapture in the Mount Dalton Lake, Kilkee Reservoir and Doolin Pond experiments

		On stocking (November 1977)					On recapture (October 1979)				
Lake	Trout strain	Mean(x) length cm)	SE	t value	Sig.	Sample	Mean(x) length (cm)	SE	t value	Sig.	Sample
Mount	Roscrea	13.9	0.31	6.74		50 fish	36.1	0.41	6.20		23 fish
Dalton	Mask F'	11.5	0.29		P<0.001 ***	50 fish	33.5	0.37		P<0.001 ***	38 fish
Kilkee	Roscrea	13.6	0.28	6.10		50 fish	41.5	0.40	4.26		23 fish
Reservoir	Sheelin F'	11.2	0.24		P<0.001 ***	50 fish	38.9	0.38		P<0.001 ***	38 fish
Doolin	Roscrea	12.5	0.27	3.20		50 fish	30.1	0.36	4.03		14 fish
Pond	Sheelin F'	11.6	0.30		P<0.001 ***	50 fish	28.4	0.31		P<0.001 ***	50 fish

*** = Very highly significant difference
SE = Standard error of the mean

Table 4 Data illustrating the importance of size to the survival of stocked trout

Lake	Strain	Age (months)	X Length (S.E.)	No. Fish Stocked	Date	Standing Crop Estimates ($\hat{N}$)				
						Oct '76	Feb '77	Oct '77	Feb '78	Oct '79
O'Flyn	Roscrea	24	28.3(0.13)	3,323	April'76	(1,262-694) 1,100	(1,395-586) 960	(209-10) 201	(332-20) 211	0
	Roscrea	13	14.7(0.13)	8,735	May '76	(280-47) 235	(265-1) 221	(254-1) 206	(247-1) 204	0
						Aug. '76	Aug '77	Sept '78		
Inchiquin	Roscrea	24	19.8(0.27)	2,806	April'76	(1,000-233) 617	0	0		
	Roscrea	12	14.5(0.21)	6,313	April'76	0	0	0		
						Oct '76	Feb '77	Oct '77	Feb '78	Oct '79
O'Flyn	Roscrea	22	21.4(0.13)	850	Feb '77	-	-	(354-32) 196	(396-87) 203	0
	F'Owel	22	23.4(0.16)	1,175	Feb '77	-	-	(566-116) 364	(883-141) 568	0
O'Flyn	Roscrea	22	28.2(0.13)	3,323	April'76	(1,262-694) 1,100	(1,395-586) 960	(209-1) 201	(332-20) 211	0
	F'Owel	22	19.8(0.13)	4,612	April'76	(892-580) 784	(1,247-612) 1,199	(640-280) 530	(690-261) 533	(70-1) 50
						Aug. '76	Aug. '77	Sept '78		
Inchiquin	Roscrea	24	19.8(0.27)	2,806	April'76	(1,000-233) 617	0	0		
	F'Owel	24	17.3(0.32)	3,300	April'76	(666-93) 380	(386-1) 197	0		

(S.E.) - Standard error of the mean length on stocking; (-) - 95% Confidence limits.

Table 4 Data illustrating the importance of size to the survival of stocked trout

Table 5 Data illustrating the importance of size in relation to angling catches of stocked trout

Lake	Strain	Age (months)	X Length	(S.E.)	No. Fish Stocked	Date	Angling Catch Estimates ($\hat{N}$)				
							1976	1977	1978	1979	1980
O'Flyn	Roscrea	24	28.3	(0.13)	3,323	April '76	(2,137-1,740)	(419-379)	(209-87)		
							1,876	399	199	0	0
	Roscrea	13	14.7	(0.13)	8,735	May '76	0	0	0	0	0
Inchiquin	Roscrea	24	19.8	(0.27)	2,806	April '76	(1,629-1,132)	(322-1) 159			
							1,352		0	0	0
	Roscrea	12	14.5	(0.21)	6,313	April '76	0	0	0	0	0
O'Flyn	Roscrea	22	21.4	(0.13)	850	Feb '77		(86-3)			
							-	480	0	0	0
	F'Owel	22	23.4	(0.16)	1,175	Feb '77		(437-128)	(440-101)		
							-	294	320	0	0
O'Flyn	Roscrea	22	28.2	(0.13)	3,323	April '76	(2,137-1,740)	(419-379)	(209-87)		
							1,876	399	199	0	0
	F'Owel	22	19.8	(0.13)	4,612	April '76	(1,422-1,325)	(401-278)	(331-74)		
							1,384	387	270	0	0
Inchiquin	Roscrea	24	19.8	(0.27)	2,806	April '76	(1,629-1,132)	(322-1)			
							1,352	159	0	0	0
	F'Owel	24	17.3	(0.32)	3,300	April '76	(617-273)	(321-0)			
							462	155	0	0	0

(S.E.) - Standard error of the mean length on stocking; (-) - 95% confidence limits.

Table 6 Data illustrating the importance of the stocking date to the survival of planted brown trout

Lake	Strain	Age (months)	X Length	(S.E.)	No.Fish Stocked	Date	Standing Crop Estimates ($\hat{N}$)				
							March'78	March'79			
Sheelin	Roscrea	23	22.4	(0.22)	33,296	March'77	(21,723-10,699)	(13,937-6,163)			
	Roscrea	19	21.3	(0.26)	20,827	Oct '77	16,211 (4,897-1,471)	10,281 (5,956-3,971)			
Sheelin	Roscrea	23	26.3	(0.18)	34,133	March'78	3,184 -	4,972 (8,180-5,454)			
	Roscrea	19	25.7	(0.2)	15,200	Oct '78	-	6,820 (4,685-3,123) 3,900			
							Oct'76	Feb '77	Oct '77	Feb '78	Oct '79
O'Flyn	Roscrea	19	24.3	(0.14)	3,338	Oct '75	(331-21) 163	(460-130) 280	(290-1)	(285-1)	
	Roscrea	24	28.2	(0.14)	3,323	April '76	(1,262-694)	(1,395-586)	131 (209-1)	127 (332-20)	0
O'Flyn	Roscrea	19	21.5	(0.15)	3,978	Oct '76	1,100 -	960 (490-260) 354	201 (560-73) 303	211 (530-71) 301	0 (47-1) 20
	Roscrea	22	21.4	(0.13)	850	Feb '77	-	-	(354-32) 196	(396-87) 203	0
O'Flyn	Roscrea	19	21.5	(0.15)	1,265	Oct '77	-	-	-	(1,202-291) 759	0
	Roscrea	22	22.3	(0.17)	1,081	Feb '78	-	-	-	-	(510-112) 216

(S.E.)- Standard error of the mean length on stocking; (-) - 95% confidence limits.

Table 7 Data illustrating the importance of the stocking date in relation to angling catches of stocked trout

Lake	Strain	Age (months)	X Length	(S.E.)	No. Fish Stocked	Date	Angling Catch Estimate ($\hat{N}$)				
							1977	1978	1979		
Sheelin	Roscrea	23	22.4	(0.22)	33,296	March '77	(*)	(1,841-1,287) 1,584	(1,423-364) 814		
	Roscrea	19	21.3	(0.26)	20,827	Oct'77	(*)	(*)	(190-0) 28		
Sheelin	Roscrea	23	26.3	(0.18)	34,133	March '78	-	(*)	(1,315-211) 701		
	Roscrea	19	25.7	(0.2)	15,200	Oct '78	-	-	0		
							1976	1977	1978	1979	1980
O'Flyn	Roscrea	19	24.3	(0.14)	3,338	Oct'75	(390-110) 294	(108-30) 68	0	0	0
	Roscrea	24	28.2	(0.14)	3,323	April'76	(2,137-1,740) 1,876	(419-379) 399	(209-87) 199	0	0
O'Flyn	Roscrea	19	21.5	(0.15)	3,978	Oct'76	-	(251-90) 163	(230-43) 141	(135-22) 93	0
	Roscrea	22	21.4	(0.13)	850	Feb'77	-	(86-3) 48	0	0	0
O'Flyn	Roscrea	19	21.5	(0.15)	1,265	Oct'77	-	-	(241-21) 125	(165-95) 130	0
	Roscrea	22	22.3	(0.17)	1,081	Feb'78	-	-	(490-141) 224	(460-100) 227	(170-30) 113

(*) - Trout which were below the angling size limit and not cropped; (S.E.) - Standard error of the mean length on stocking; (-) - 95% confidence limits.

REPEUPLEMENTS DE Salmo fario DANS LES MILIEUX AQUATIQUES DU SUD OUEST DE LA FRANCE; APPROCHE ECOLOGIQUE

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CONTENTS

RESUME

Pour les besoins de la pêche sportive, des déversements de truites communes sont effectués au moins une fois par an dans les cours d'eau à Salmonidés dominants (première catégorie dans la législation française) plus spécialement dans des secteurs de rivières dits “parcours de pêche”. D'autres secteurs sont aménagés en “réserve” de pêche où toute pêche est prohibée et où les jeunes truites sont maintenues jusqu'à la taille de 18 cm, taille légale de capture à laquelle elles sont déversées dans les parcours de pêche. Ces deux types de pratiques sont aussi en vigueur dans les lacs d'altitude également pêchés par les touristes.

La présente note tente une synthèse des connaissances actuelles sur l'adaptation des truites ainsi déversées et leur influence possible sur leur habitata.

ABSTRACT

For sportfishing salmonid rivers and streams (first class in French legislation) stocking with S. fario occurs at least once a year, especially in those areas designated “fishing areas” or “parcours de pêche”. Other parts of the rivers are managed as reserves where fishing is strictly forbidden and, every year, trout of legal size (more than 18 cm total length) are taken to the “fishing areas”. These two management strategies are also used for mountain lakes of the Pyrenees.

This paper is a synthesis of information on the behaviour of common trout on stocking and on the possible effects of this stocking on the environment. The main information is:

Trout coming from intensive fish culture are less wild than those coming from nursery streams (ruisseaux pépinières) or natural rivers. Mortalities of hatchery-reared fish are higher and so are their downstream migrations; territoriality takes longer to appear.

In lakes, the food consumption of hatchery-reared fish is greater than that of the wild fish and growth is, therefore, faster where size at stocking is more than 10 cm total length. In rivers condition decreases for a few weeks before the beginning of a new growth period. Catchability and hence fishing mortality are greater in hatchery-reared trout than in native ones.

The main influence of stocking on the environment concerns the invertebrate fauna and the benthos, both of which appear to become poor under heavy stocking of common trout, particularly in “stocking areas”.

1. INTRODUCTION

Les milieux salmonicoles de la région Midi-Pyrénées (France) comportent les lacs de la chaîne des Pyrénées elle-même et les cours d'eau à Salmonidés dominants dit de première catégorie dans la législation française.

Il s'agit de collections d'eau très fréquentées par les pêcheurs sportifs dont beaucoup sont des vacanciers recherchant les zones en question, pendant les congés d'été, en raison de leur attrait touristique.

La gestion de ces collections d'eau est sous la responsabilité d'Associations de Pêcheurs regroupées en Fédérations Départementales de Pêche qui exécuteront elles-mêmes les opérations jugées nécessaires au bon maintien du potentiel piscicole des eaux à Salmonidés. En effet, le recrutement issu des populations de S. fario autochtone ne suffit pas, dans l'immense majorité des cas, pour compenser le prélèvement effectué par les pêcheurs.

Le but de la présente note est d'exposer ces opérations qui sont en fait des empoissonnements, d'examiner leur influence sur la production exploitée des milieux en question et de comparer certains éléments de biologie des sujets ainsi introduits avec ce que l'on sait de sujets ayant passé toute leur vie dans le milieu. On tentera également une approche, en fait difficile. Compte tenu des connaissances actuelles, de l'influence possible de ces déversements de poissons sur le milieu considéré dans son ensemble.

2. LES REPEUPLEMENTS

Pour décider d'un mode de repeuplement et de son opportunité plusieurs facteurs doivent être considérés (Cuinat, 1971; Vibert, 1975; Arrignon, 1976): importance de l'effort de pêche, richesse du milieu en frayères naturelles et en zone d'abris pour les jeunes alevins, nombre de géniteurs et potentiel reproducteur, caractéristiques géographiques de la collection d'eau, conditions générales amenant une probabilité maximale de capture et obtention d'un prix de revient minimum, des sujets déversés réellement repêchés à la taille légale (Ricard et Roqueplo, 1976).

2.1 Les différents types de repeuplement pratiqués

2.1.1 Le repeuplement par oeufs ou alevins vésiculés

Ce mode de repeuplement sera efficace en cas d'insuffisance de géniteurs ou du manque ou de la médiocrité des frayères. Il se caractérise par le coût peu élevé de production des sujets déversés et par leur nécessaire rusticité.

Le modalités d'immersion utilisant toujours les boîtes Vibert varient avec les caractéristiques des lieux lesquels doivent satisfaire aux conditions générales suivantes: existence d'un courant d'eau de qualité à l'emplacement même de la boîte Vibert, boîte à l'obscurité totale, non-ensablement, non-envasement, rivières, sources et ruisseaux à eau limpide et à courant assez vif mais pas trop rapide.

En revanche les rivières à eau limpide et à faible courant peuvent donner de bons résultats si l'on surélève la boîte par rapport au fond (Vibert, 1975).

Le nombre d'oeufs à immerger sera fonction de la capacité biogénique du milieu et de la surface concernée; Cuinat (1971) a proposé un maximum de 10 m^2 en ruisseau ou 5 m^2 en rivière moyenne.

2.1.2 Le repeuplement par alevins ou truitelles de moins d'un an

Ce mode de repeuplement est destiné à éviter une trop forte prédation sur des alevins très jeunes. On pense que ces alevins nourris en pisciculture et déversés à une certain taille (5 à 10 cm) seront plus capables de résister aux conditions défavorables du milieu, prédation comprise. Les alevins sont déversés à l'issue de leur première période de croissance (octobre); on parle d'"alevins d'un été". Quelquefois ils sont aussi introduits en fin d'hiver (février) avant l'ouverture de la pêche. Les quantités déversées sont variables faute de données de bases sûres; ce sont des poissons produits soit en pisciculture (cf. ci-dessous) soit en ruisseau pépinière (cf. ci-après).

2.1.3 Repeuplement en sujets de plus d'un an, parfois de tailles légales

Les sujets ainsi déversés proviennent de piscicultures dites de repeuplement gérées par les Fédérations départementales de Pêche (Arrignon, 1976). Ils peuvent venir aussi de réserves de pêche (cf. plus loin) fonctionnant comme des viviers. Les repeuplements peuvent être annuels lorsqu'ils ne sont destinés qu'à compenser un effort de pêche léger. Ils sont parfois hebdomadaires pour permettre des captures en grand nombre pendant le week-end. Dans ce cas extrême, l'eau ne constitue plus que le simple support d'une population piscicole sans cesse renouvelée artificiellement dans des zones très ou trop fréquentes par les pêcheurs.

2.2 <u>Les milieux empoissonnés</u>

2.2.1 Les ruisseaux pépinières

Les ruisseaux pépinières sont des milieux naturels choisis et aménagés pour permettre dans de bonnes conditions l'éclosion des oeufs embryonnés et la croissance des alevins qui en sont issus pendant une période au plus égale à un an. Les sujets y sont élevés sans distribution de nourriture dans un milieu le plus "sauvage" possible, à l'abri de prédateurs et disposant de nombreuses caches. Lorsque le peuplement est très dense, il est nécessaire de faire des ponctions par pêche électrique et de transférer une partie des individus en aval, généralement sous-peuplé afin que les truites aient une croissance individuelle acceptable. Ainsi, les jeunes truites recueillies à la fin de l'élevage mesurent entre 6 et 12 cm à l'âge de 9 à 11 mois.

2.2.2 Les réserves de pêche

Certains secteurs sont classés en "Réserve de Pêche", soit par convenance (propriétés privées) soit par obligation (abord d'ouvrage) ou par opportunité biologique; (productivité piscicole élevée) (Arrignon, 1976). Dans ces milieux la pêche est normalement interdite pendant cinq ans; selon les besoins, une fois tous les ans ou tous les deux ans, la vidange se fait par pêche électrique, soit pour obtenir les géniteurs pour la production d'oeufs en pisciculture, soit pour repeupler en sujets de taille légale, en début ou en fin de période de pêche, les zones surexploitées par le pêcheur sportif.

Les réserves de pêches sont normalement mises en charge avec des oeufs embryonnés ou des alevins vésiculés et parfois avec des sujets venant de ruisseaux pépinières où ils ont donc passé quelques mois.

2.2.3 Les parcours de pêche

Ce sont les portions de rivières où la pêche est autorisée pendant la saison normale (en montagne, en général, mars à septembre). Ils sont dotés de commodités d'accès et autres aménagements qui en rendent la fréquentation agréable. Ils sont mis en charge, en cas de nécessité avec des sujets de taille légale issus des réserves de pêche. Dans des cas de surexploitation extrême, les déversements sont hebdomadaires comme dit plus haut, les poissons venant, éventuellement, directement de piscicultures de repeuplements.

2.3 Rendement de ces repeuplements, influence sur la production exploitée (Tableau 1)

On appelera rendement ou taux de reprise de repeuplement le rapport entre le nombre d'individus capturés à la taille légale ou à une taille plus élevée et le nombre de poissons déversés dont ils proviennent.

2.3.1 Cas des oeufs ou d'alevins vésiculés

Le taux de reprise est de 0,3 à 3 pour cent (très faible) l'implantation (definie par Cuinat, 1971, comme le taux de survie après atteinte de la taille légale), se traduisant par un étalement des captures sur plusieurs mois et éventuellement une reproduction dans le cours d'eau, et généralement bonne: analogue à celle des sujets sauvages.

2.3.2 Avec des poissons de moins d'un an

Les observations sont difficiles car les alevins de moins de 6 à 7 cm ne peuvent être marqués sans danger (seule est possible l'ablation de la nageoire ce qui limite les possibilités d'investigation). Cependant les rendements de déversement de truitelles de 6 à 12 mois ont pû être évalués en diverses occasions:

Dans la Nivelle (Pyrénées-Atlantiques), 11 pour cent des truitelles de 13 cm en moyenne (10 à 16 cm), déversées en février à partir de piscicultures, ont été reprises par les pêcheurs en avril et mai, à une taille moyenne de 15,5 cm (presque toutes au-dessous de la taille légale). Aucune capture ni survie ultérieure n'ont été observées (Cuinat, 1971).

Vibert (1975) signale que le taux de survie est de 5 à 20 pour cent entre le déversement et l'arrivée à la taille légale, la faible efficacité de ce type de repeuplement conduit donc à donner la préférence aux truitelles produites en ruisseaux pépinières.

En effet, après libération d'environ 1 000 truitelles de ruisseau pépinière dans la Nivelle, on a constaté une amélioration de la croissance (8 cm dans l'année suivant le transfer, au lieu de 3 à 4 cm dans le ruisseau d'origine); de plus, la capturabilité est inférieure à celle des truitelles de pisciculture intensive, ce qui, même dans des parcours très pêchés, explique que les reprises soient beaucoup plus étalées dans le temps.

Le taux de survie est très supérieur à celui de truitelles produites selon les techniques habituelles de pisciculture intensive: environ 30 pour cent par an soit approximativement le même taux que les truites autochtones; les reprises sont peu importantes mais réparties tout au long de la saison de pêche, pendant deux saisons consécutives; deux ans après le transfert, un nombre appréciable de ces truites étaient encore présentes dans le parcours et susceptibles de se reproduire; certains d'entre elles ont été encore capturées à une forte taille, dans ce même parcours dans la troisième saison après le transfert (Cuinat, 1971; Vibert, 1975).

D'une façon générale les repeuplements à partir d'alevins ou truitelles d'une taille entre 5 à 14 cm, déversés en fin d'été ou en hiver et provenant d'élevages extensifs (rigoles d'alevinage ou ruisseaux pépinières) permettent des taux de reprise faibles (0,5 à 20 pour cent) avec une implantation importante (Cuinat, 1971).

2.3.3 Avec des poissons d'un an et plus

Les mises en charge de poissons de grande taille s'accompagnaient toujours d'une très forte perte en raison de diverses difficultés d'adaptation. L'implantation, telle que la définit Cuinat (1971) est donc faible; en lac (Fabre et Senocq, 1981) 30 pour cent des sujets déversés subsistent au bout d'une année comportant six mois de saison de pêche. En rivière, Gayou et Simonet (1978) font état de faibles captures de poissons récemment introduits dans les secteurs étudiés. La dévalaison (cf. plus loin) semble la première cause de ces disparitions, surtout lorsque les empoissonnements ont lieu en fin d'hiver avant les crues printanières de fonte des neiges.

En rivière également, Abad (1982) a marqué des poissons de taille légale (18 cm) à l'automne; en six mois ces poissons avaient pratiquement tous disparu du secteur de rivière étudié en l'absence de toute pêche. Certains ont été ensuite retrouvés plusieurs kilomètres en aval.

En revanche, les individus de grande taille récemment déversés seront plus vulnérables à la pêche que les sujets sauvages de même taille. Les pêcheurs l'ont maintes fois constaté, reconnaissant les deux types de poissons à la couleur de la robe, plus claire chez les poissons récemment introduits, et au nombre et à la forme des tâches.

3. MAINTIEN DANS LE MILIEU: SEDENTARITE ET DEVALAISON

3.1 La territorialité

La hiérarchisation et l'acquisition d'un territoire par les jeunes alevins déversés dans un milieu ont été particulièrement étudiées dans la région Midi-Pyrénées notamment par Heland (1977, 1980) dont les observations sont résumés ci-après:

Dans un petit ruisseau affluent de la Nivelle, des alevins ont été déversés à résorbtion de la vésicule à raison de 5/m^2. Au début des observations quelques alevins se tiennent immobiles sur le fond dans les intersectices entre les galets. A partir du cinquième jour environ après la résorption, quelques uns présentent des mouvements de nage statique face au courant, très près du fond; en quelques jours les 2/3 des alevins adoptent cette nage stationnaire; dans le même temps les alevins capturent des proies qui sont entraînées par les courant; les proies sont capturées directement sur le substrat.

Les premiers comportements agressifs apparaissent très précocément; dès que les alevins sont capables de nager en eau libre ils ont des comportements de morsure et de chasse, cette agressivité devient plus fréquente au fur et à mesure que les alevins adoptent la nage statique; la fréquence des rencontres agressives semble liée à la densité des alevins en présence, cette agressivité conduit à la séparation de deux groupes:

- les plus agressifs et (ou) plus vigoureux chassent les autres et se partagent la zone favorable;
- les autres dominés dans les combats sont contraints de se cacher sous les blocs ou sous les berges et deviennent marginaux.

Un certain nombre d'alevins, parmi les plus gros, occupe de plus en plus fréquemment des postes de chasse situés dans les zones d'eau courante assez profondes.

Lors des déversements, les alevins vésiculés ou de très petite taille semble se disperser, à partir de la zone empoissonnée où ils ont été rassemblés, pour se fixer sur des postes de chasse qui ont une position particulière par rapport au courant et à la dérive d'invertébrés dont ils s'alimentent; l'apparition des comportements agressifs pour défendre ces postes provoque une structure territoriale, en forme de mosaïque qui perdra en partie sa rigidité chez les poissons plus âgés.

Cette territorialité explique la sédentarité des truitelles juvéniles au moins jusqu'à la fin du premier été. Plus tard, au cours de l'automne ou du premier hiver, des déplacements peuvent intervenir, en général sous forme de dévalaison.

Le comportement alimentaire joue un rôle déterminant dans l'acquisition du territoire. En effet, cette dernière apparaît comme une stratégie utilisée par les salmonidés d'eau courante pour exploiter la nourriture accessible dans le milieu sous forme d'un “flux d'invertébrés”. apporté par le courant d'eau (Heland, 1977). L'apparition du comportement agressif influe aussi sur le comportement alimentaire. En effet, une évolution parallèle se produit entre le développement du comportement agressif et l'attachement au poste de chasse, à partir duquel l'animal prélève la nourriture.

3.2 La hiérarchisation

Chez l'alevin de truite, l'apparitiion des comportements agressifs about it à l'établissement d'une hiérarchie. En effet, après une phase initiale d'indifférence, succède une phase de perception visuelle des congénères qui se traduit par le respect de distances interindividuelles entre alevins; ensuite, des rapports d'agréssivité s'instaurent dans la population et les alevins entrent en compétition pour les meilleurs postes de chasse et pour l'obtention du rang dans la hiérarchie sociale; la stabilisation territoriale conduit, par la suite, à une restriction des possibilités de rencontre entre alevins occupant des territoires limitrophes (Heland, 1977).

En définitive, les truitelles commencent par respecter entre elles des distances interindividuelles. Au sein de la population, des relations de dominant à dominé s'organisent, conduisant à l'établissement progressif d'une hiérarchie. Les truites dominantes vont progressivement se fixer géographiquement dans une zone, favourable, ce qui produit la stabilité momentanée des répartitions et fait aussi qu'un poste déterminé puisse convenir à plusieurs animaux successivement; il semble que la rigidité de la hiérarchie exprimée par les divers comportements agressifs, obligerait chaque poisson à se maintenir à sa place; puis, maintenu sur le même emplacement pendant un certain temps, l'animal s'y attache.

Heland a observé que certaines truitelles dominées manifestent une tendance marquée à s'enfoncer sous les pierres et à rester immobiles, là elles se nourrissent très peu et succombent d'anorexie au bout de quelques semaines; des qu'elles sortent vers l'eau libre, en général pour attraper une proie, elles sont attaquées par les dominantes et s'enfouissent à nouveau aussitôt ou s'enfuient vers l'aval, à courte distance, vers l'abri le plus proche. D'autres poissons ont carrément un comportement de dévalaison de plus grande amplitude surtout lorsqu'ils sont plus âgés.

3.3 La dévalaison

Heland (1977, 1980) souligne qu'il y ait trois sortes de dévalaison chez les très jeunes alevins et qu'elles se superposent légèrement dans le temps; la première coïncide avec l'émergence: au moment de la sortie des graviers les alevins apprennent la nage contre le courant et cela entraîne un glissement de certaines d'entre eux vers l'aval. Heland (1971) a constaté des déplacements vers l'amont mais ils étaient toujours beaucoup moins fréquents que les déplacements vers l'aval. La deuxième catégorie d'alevins dévalants (apparemment la plus nombreuse) se recrute parmi les alevins qui dévalent après l'émergence, mais avant les premières manifestations de la territorialité; cette période coïncide avec l'établissement de la nage statique. Chez ces derniers alevins, le mouvement de dévalaison est ample, durable et traduit en fait un manque d'aptitude à la nage face au courant. Le dernier type de dévalaison apparaît au moment de la mise en place de la hiérarchie par le jeu des comportements agressifs et se poursuit jusqu'après la stabilisation territoriale. Il concerne non seulement les alevins qui émergent tardivement et trouvent l'espace occupé, mais aussi des alevins dominés qui ne réussissent pas à établir de territoire au moment de la stabilisation lorsqu'il y a surpopulation.

Ces alevins dominés dévalants sont nettement distincts de dominés “sédentaires” évoqués plus haut.

Ils s'avèrent capables d'établir plus tard un territoire, dés que l'environnement le permet.

Les dévalaisons ont lieu essentiellement la nuit. Le jour les dévalants adoptent un comportement de nage statique et cherchent donc à s'organiser en territoire. Les alevins dévalants sont plus petits que les sédentaires et présentent très vite un retard de croissance que l'on retrouvera chez les adultes.

Les alevins nomades conservent pendant une dizaine de jours une forte tendance à la dévalaison qui diminue ensuite. Il est possible que dans des ruisseaux où les conditions de reproduction sont bonnes et les densités d'alevins élevées, une notable partie des dévalaisons aboutisse à une régulation de la population de juvéniles.

L'influence des facteurs du milieu sur la dévalaison a été étudiée par Cuinat et Heland (1979). Dans le Lissuraga les facteurs abiotiques en particulier le débit, ne semblent avoir aucune influence sur la dévalaison des alevins; plus tard, chez les truitelles, la dévalaison serait liée aux précipitations et aux crues; la température influencerait nettement le comportement de dévalaison de jeunes salmonidés. Tous ces facteurs abiotiques n'auraient cependant qu'un rôle déclencheur ou inhibiteur.

L'importance des dévalaisons d'alevins dans le Lissuraga ne semble pas liée à la densité d'alevins présents dans le ruisseau. D'ailleurs, si la dévalaison était liée à un phénomène de compétition territoriale, donc à la densité des alevins en présence, elle ne pourrait s'exercer qu'à partir de l'établissement de la hiérarchie sociale dans la population et non avant.

Les dévalaisons, bien étudiées chez le jeune comme on vient de le voir, sont aussi le fait des individus plus âgés. Les sujets de grande taille (plus de 10 cm de longueur totale) issus de piscicultures y sont particulièrement sensibles. Leur dévalaison, repérée par marquage, peut s'étendre sur plusieurs kilomètres (Abad, 1982).

4. COMPETITION SPATIALE AVEC LES INDIVIDUS SAUVAGES

L'aptitude des sujets déversés à prendre place dans un milieu parmi des sujets sauvages, dépendra de leur rusticité. Celle-ci est liée à des facteurs génétiques et aux conditions d'élevage et doit pouvoir se mesurer.

4.1 Les facteurs génétiques

Dans les lacs et les cours d'eau, la sélection naturelle amène l'élimination des sujets les moins résistants avant leur puberté. Des poissons introduits résisteront donc plus ou moins bien selon le potentiel légué par leurs ascendants (Cuinat, 1971). C'est pourquoi les meilleurs poissons de repeuplement sont en fait ceux issus de souches sauvages. Ces dernières sont d'ailleurs utilisées de plus en plus comme géniteurs dans les piscicultures de repeuplements (Cuinat, 1971).

4.2 Conditions d'élevage

L'incubation et les phases larvaires doivent se dérouler dans des conditions rappelant au maximum le milieu naturel (gravier, courant d'eau). La façon dont est distribué l'alimentation peut aussi favoriser la rusticité. On visera en effet à préparer le jeune poisson à la recherche de la nourriture et même à la chasse de proies mobiles analogues à celles dont il se nourrit après son déversement en eaux libres (Cuinat, 1971). C'est la raison pour laquelle on généralise l'emploi des ruisseaux pépinières (cf. plus haut).

4.3 Mesures de la rusticité

Gayou et Simonet (1978) ont mis au point des critères possibles d'appréciation de la rusticité destinés à comparer de ce point de vue des individus sauvages et d'autres élevés en pisciculture intensive.

Les critères les plus faciles à employer sont le temps de nage forcée obtenu dans un courant de vitesse contrôlée artificiellement et la lactacidémie du sang dosée pendant l'effort de nage prolongée et la phase de récupération.

4.3.1 Les critères de fatigabilité

Le temps maximum de nage effective, dans un courant d'eau artificiel de vitesse imposée et connue donne une bonne indication des capacités à lutter contre la fatigue.

Il en est de même de la lactacidémie. En effet, chez les poissons, la corrélation entre la fatigue et l'accumulation de l'acide lactique a été démontrée pour la première fois par Van Buddenbrock (in Gayou et Simonet, 1978).

Les lactates (sels de l'acide lactique) proviennent de l'activité musculaire et résultent de la métabolisation du glycogène contu dans le muscle. Les lactates rencontrés dans le sang pendant et après l'effort dérivent de ceux produits dans le muscle.

Si la métabolisation du clycogène musculaire incorporé dans le cycle de Krebs s'accomplit avec une réduction du taux d'oxygène, les lactates s'accumulent dans le muscle et passent dans le sang par simple diffusion.

Ainsi, lorsqu'un poisson est soumis à un effort intense, l'apport d'oxygène devient insuffisant malgré l'augmentation des mouvements respiratoires et l'acide lactique s'accumule.

A l'inverse, pendant la phase de récupération, la teneur du sang en oxygène redevient normale et les lactates en excès sont éliminés. Par conséquent, pendant la phase d'activité, le taux des lactates sanguins augmente rapidement, mais continue encore à s'élever pendant un certain temps après l'effort.

Le taux des lactates sanguins décroit lentement, pour atteindre la valeur initiale au bout de 24 heures de récupération (Soncondat, in Gayou et Simonet, 1978).

4.3.2 Résultats (Gayou et Simonet, 1978)

Parmi les individus venant de pisciculture, 50 pour cent des individus ne peuvent fournir un effort de plus de 30 mn dans les conditions expérimentales. Seuls 42 pour cent des individus nagent pendant une heure. En revanche, les individus issus du milieu naturel accomplissent des performances bien supérieures puisque 98 pour cent des truites testées accompliseent un effort complet de 60 mn (Fig. 1).

Ils apparaissent donc incontestablement plus résistants à l'effort que les individus élevés en pisciculture intensive, au comportement très hétérogène.

Après un effort de 60 mn, la lactacidémie observée chez les truites d'élevage atteint cinq fois la valeur de repos, alors que chez les truites sauvages, la valeur initiale n'est multipliée que par 4.5 (Fig. 2).

La différence devient très grande pendant la phase de repos puisque, au bout de deux heures de récupération, la lactacidémie est deux fois plus importante chez les truites d'élevage que chez les truites sauvages.

Enfin, la récupération des individus sauvages est beaucoup plus rapide, puisque, après quatre heures de repos, leur lactacidémie atteint seulement 1,5 fois la valeur initiale, alors que celle des truites d'élevage est près de cinq fois plus importante.

Ces observations montrent que, à effort de durée égale, les individus d'élevage sont beaucoup plus fatiguables que ceux issus du milieu naturel et qu'en particulier, leur résistance vis-à-vis du courant est amoindrie.

La chute de la lactacidémie, observée immédiatement à la fin de l'effort chez les sujets sauvages prouverait que cet effort n'a pas été assez prolongé pour les fatiguer; mais cette contrainte a été suffisante pour épuiser les sujets d'élevage et l'évolution de leur lactacidémie la met en évidence; en particulier, on constate l'apparition d'un taux élevé de lactates pendant la phase de récupération.

En conclusion, la moindre rusticité observée chez les truites d'élevage intensif se situe à deux niveaux:

- des temps de nage relativement limités, dans un courant d'eau à vitesse constante par rapport à ceux obtenus avec des truites sauvages;
- à effort égal, une fatigue physiologique plus intense, se traduisant par une accumulation importante de l'acide lactique et une élimination beaucoup plus longue que chez les truites sauvages.

4.3.3 Rôle possible de la sélection naturelle

La quasi totalité des truites sauvages a accompli d'excellentes performances de nage. En revanche, si certaines truites d'élevage intensif sont de bonnes nageuses, d'autres ne peuvent fournir que des efforts moyens et parfois très modestes.

La population de truites sauvages étudiée forme donc un ensemble homogène, alors que la population de truites d'élevage intensif montre une grande hétérogénéite. Ceci met en évidence un facteur de sélection qui opère dans le milieu naturel, mais qui est inexistant en pisciculture. En effet, en milieu naturel, les individus les moins résistants sont éliminés et il ne subsiste qu'un ensemble d'individus de bonne rusticité qu'il convient de faire acquérire aux poissons de repeuplement.

5. BIOLOGIE DES TRUITES COMMUNES INTRODUITES - COMPARAISONS AVEC LES TRUITES SAUVAGES

5.1 Reproduction

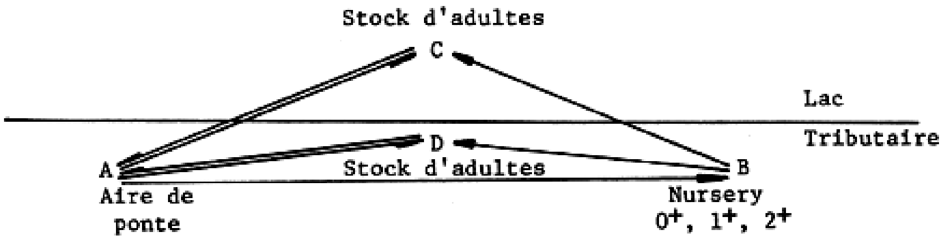
La reproduction de S. fario s'accompagne toujours d'une migration vers des frayères en amont, notamment étudiée en milieu lacustre (Fabre et Senocq, 1981). Mais cette migration survient également en rivière même lorsque les truites passent l'année sur des zones très riches en frayères (Abad, 1982). Les observations les plus précises sur a reproduction de S. fario pour la région Midi-Pyrénées sont celles de Fabre et Senocq dans un petit lac comportant un tributaire avec d'abondantes frayères.

La maturité sexuelle est acquise aux âges ci-dessous. Les mâles étant toujours plus jeunes que les femelles et les poissons sédentaires dans la tributaire étant mûrs plus tôt que ceux vivant dans le lac. Ceci est en relation avec la longévité des poissons.

L'âge de première maturité des S. fario du tributaire est conforme aux résultats de Gayou et Simonet (1978) sur la Neste d'Aure et à ceux de Vibert et Cuinat (1963) dans les Pyrénées-Orientales.

A la suite de leurs observations, Fabre et Senocq émettent l'hypothèse de l'existence de deux sous-populations et géniteurs, l'une vivant dans le lac, l'autre surtout dans le tributaire comme montré sur le schéma ci-dessous:

(Schéma)



Au niveau des frayères, il y aurait en effet deux montaisons sucessives de géniteurs.

Dès le mois de décembre, les S. fario pubères du tributaire sont déjà sur la frayère; à la même période, les géniteurs du lac ont pénétré dans la partie aval du ruisseau. Dans les deux cas, les mâles sont les premiers à effectuer la migration. Une partie des géniteurs lacustres parvient jusqu'aux frayères amont, soit après la reproduction des S. fario du tributaire, soit pendant cette reproduction, ce qui laisserait supposer un brassage des géniteurs. La frayère est donc fonctionnelle pour deux populations différentes. Les premières pontes ont lieu en décembre et les dernières dans le courant du mois de janvier.

La montée des adultes s'accompagne d'une descente de poissons d'un été ou plus âgés car l'apport entre octobre et fin décembre de jeunes sujets de taille jamais observée auparavant s'effectue en parallèle avec la baisse des effectifs de géniteurs S. fario du lac. On peut suggérer que la dévalaison s'opère en sens inverse du déplacement des adultes dans le ruisseau en période d'étiage. La brusque augmentation de la population dans le ruisseau favoriserait la descente de jeunes sujets issus des reproductions antérieures.

Le pourcentage observé des poissons migrants à cette période en fonction de l'âge est résumé ci-dessous:

Age	1+	2+	3+	4+	5+
%	2,4	24,3	40,0	25,8	6,3

En effet, la dévalaison concernerait plusieurs classes d'âge des truites du ruisseau.

Ces hypothèses rejoignent les résultats de Thorpe (1972) sur le Loch Level, d'après lesquels les truites fario migrent à des tailles variant entre 5 et 20 cm, selon qu'elles ont séjourné un ou deux ans dans le ruisseau qui fait fonction de nursery. Il serait souhaitable d'effectuer des analyses électrophorétiques afin de déterminer s'il existe des différences génétiques entre la population du tributaire et celle du lac. C'est en effet par cette méthode qu'Allendorf et al. (1976) démontrent la présence de deux populations de S. fario séparées génétiquement dans le lac Bunners Joarna.

Ces observations concernent les sujets sauvages ou introduits très jeunes (alevins vésiculés). Des poissons provenant de pisciculture et déversés à plus grande taille, éventuellement la taille légale de capture, amènent à maturité les produits génitaux mais ne semblent pas susceptibles d'activité sexuelle complète. En effet, leur présence sur les frayères est exceptionnelle et leur agressivité est inférieure à celle des sujets sauvages.

En rivière, Abad (1982) met en évidence, par des marquages systématiques de tous les poissons présents, dans un bief riche en frayères avant le début de la reproduction, la disparition de certains d'entre eux par migration de reproduction. Ces poissons absents en saison de reproduction sont retrouvés plus tard. Ceci comme 26 pour cent du cheptel marqué au début de l'étude.

Les poissons introduits dans le milieu à 1 ou 2 ans (âge légal de capture), parviennent à la puberté mais ne semblent pas se reproduire pour les mêmes raisons qu'au lac de Suyen.

5.2 Alimentation

5.2.1 Caractères généraux

La composition de la nourriture est variable suivant l'époque de l'année et la taille des truites, qu'elles soient autochtones ou introduites.

La diversité de régimes alimentaires décrits dans la plupart des travaux tend à prouver que la truite est opportuniste et que son régime est lié à la faune en place et c'est la comparaison entre le pourcentage des différents groupes d'invertébrés dans les contenus stomacaux et dans la dérive, préférentiellement recherchée, qui permet de connaître les preferences alimentaires des truites.

Ainsi dans le ruisseau de la Mousquère (Angeller, 1975) les larves de Diptères et d'Ephémères ne paraissent pas recherchées car leur proportion dans les contenus stomacaux est plus faible que dans la dérive; les Plécoptères sont en proportion équivalente, les Trichoptères font l'objet d'un choix car ils sont de trois à six fois plus importants dans les contenus stomacaux que dans la dérive.

Très souvent, deux classes d'âge adjacentes capturent le même organisme, mais à des stades différents; cette spécialisation saisonnière permet une diversification des possibilités alimentaires, une meilleure exploitation du milieu et une diminution des risques de compétition. La distance trophique entre deux classes d'âge consécutives augmente d'ailleurs avec la diversité des proies (Neveu et Thibault, 1977).

La fréquence des repas est en liaison avec la température; Elliot (1973) sur l'Estibère, note chez S. fario, un seul repas par jour pour des températures de 3,5 et 7.3°C, et deux repas à une température de 10,8°C; Neveu (1978) trouve également un repas à 4°C et trois à 18°C dans le Lissuraga. Enfin, la truite capture plus facilement la faune aérienne le jour que la nuit; les mollusques ne dérivant pas, leur capture nocturne est donc en rapport avec une activité plus intense de la truite (Neveu et Thibault, 1977).

5.2.2 Variation de l'alimentation avec l'âge

La consommation de faune aérienne augmente progressivement avec l'âge et la truite a tendance à diversifier sa nourriture au fur et à mesure de sa croissance.

Dans les ruisseaux pyrénéens (Neveu et Thibault, 1977) les truitelles consomment beaucoup d'Ephéméroptères et, en lac de montagne (Fabre et Senocq, 1981) elles se nourrissent à partir de Diptères et de crustacés (76,67 pour cent du nombre de proies ingérées), les S. fario de plus de 10 cm ont une alimentation à base de Dipères et de Ephéméroptères (75 pour cent des proies). A plus de 20 cm elles consomment 90,37 pour cent de Trichoptères, Diptères et Ephéméroptères. Plusieurs auteurs ont également signalé l'ingestion de mollusques à l'âge de 1 à 2 ans (Tableau 4 et Fig. 3).

Le nombre et la taille des proies est en grande partie fonction de la taille du prédateur et ceci est vrai à l'intérieur de chaque groupe de proie (Fig. 4) (Neveu et Thibault, 1977).

5.2.3 Influence de saison

L'influence de saison se traduit principalement par des variations de l'importance de certains groupes dans les captures.

Dans le Lissuraga (Neveu et Thibault, 1977) le bol alimentaire est constitué en majorité de:

- Plécoptères et Trichoptères en hiver
- Ephéméroptères au printemps
- Diptères en été
- Mollusques en automne (Fig. 5).

Selon Fabre et Senocq (1981) en lac de montagne, l'importance relative des différents groupes d'invertébrés varie de la façon suivante:

- les Diptères dominent de mars à juillet
- les Ephéméroptères sont les plus abondants en juin
- les Plécoptères sont présents en proportion constante
- la diversité de la nourriture est faible en mars; la quasi totalité des proies sont des Diptères (Fig. 4).

La croissance, le développement des gonades et l'embonpoint présentent des variations saisonnières liées directement à la quantité de nourriture ingérée. Ainsi, en lac de montagne (Fabre et Senocq, 1981), l'embonpoint de la truite s'améliore de janvier à octobre en rapport avec l'augmentation de la consommation.

Par leur abondance et leur qualité, les ressources alimentaires du milieu conditionnent étroitement la vitesse de croissance. La variation de ces ressources, au cours de l'année, entraîne donc des fluctuations dans la croissance. C'est ainsi que Fabre et Senocq ont observé un ralentissement de la croissance en hiver et au printemps alors que la faune invertébrée se trouve dans le milieu en quantité minimale et une accélération en fin d'été et en automne quand les apports, surtout exogènes, de nourriture sont plus importants. Ceux-ci représentent en effet jusqu'à 96 pour cent du poids de nourriture ingérée par les truites fario du lac étudié pendant le mois de septembre.

5.3 La croissance

5.3.1 Difficultés d'études (Fig. 6)

Les études de croissance dans les milieux concernés ici présentent deux types de difficultés:

Les annuli inscrits sur les écailles et qui traduisent normalement des arrêts de croissance annuels des poissons sont souvent difficiles à identifier (Gayou et Simonet, 1978; Fabre et Senocq, 1981). Il faut employer l'otolithométrie ou les méthodes de détermination statistiques de l'âge ou les marquages.

Les déversements, à plusieurs époques de l'année, de poissons de pisciculture introduisent des sujets n'ayant pas grossi dans le milieu et ne présentant pas de marque de croissance due aux changements saisonniers, mais plutôt à des stress liés aux manipulations en pisciculture. Ces poissons, en nombre et en taille souvent inconnus au moment de leur déversement ne se distinguent pas toujours morphologiquement au cours des diagnoses de terrain. Le relatif espacement des circuli et l'absence d'annulus central sur les écailles permettent seulement alors une certaine présomption.

5.3.2 Comparaison de sujets introduits et sauvages

La croissance ne peut donc être étudiée que lorsque les sujets sauvages et introduits peuvent être distingués sans erreur au besoin par des marquages.

Ainsi ont fait, Fabre et Senocq (1981) au lac de Suyen où une population sauvage a été comparée à un lot de truites fario introduites à 10 cm de longueur totale qui, dans l'intervalle d'âge et de taille étudié a grossi beaucoup plus vite que les individus “sauvages” (Fig. 7).

En effet, l'augmentation annuelle de la taille est de l'ordre de 6 à 8 cm au lieu de 3 à 4 cm chez les truites autochtones. Cette différence dans la vitesse de croissance est due principalement à ce que les sujets venant de pisciculture y ont pris l'habitude de manger tout ce qui leur était présenté à n'importe quel moment de la journée. Les truites autochtones seraient beaucoup plus sélectives dans le choix de leur nourriture, ne se nourrissant qu'à des périodes bien déterminées de la journée, ce qui entraînerait une alimentation moins abondante que celle des sujets introduits. De plus, contrairement aux poissons introduits, les truites autochtones se reproduisaient. Ceci soustrayait une partie de l'énergie normalement consacrée à sa croissance. A cela s'ajoutait le jeûne synchronique qui précède la reproduction et qui prive les poissons d'aports énergétiques pendant une période de l'annéee (Fabre et Senocq, 1981).

En d'autres circonstances, Abad (1982) a étudié la croissance de <u>Salmo fario</u> dans des zones où le recrutement naturel, très abondant, rendait superflu tous déversements. L'étude portait également sur des milieux où une population sauvage cohabitait avec une population venant de déversements réguliers d'alevins d'un été. Ces derniers sujets étaient reconnaissables à leur robe et certains d'entre eux avaient été marqués très jeunes par ablation de la nageoire anale. Leur croissance était sensiblement plus rapide que celle des poissons sauvages (Fig. 8). Ils n'ont pu être influencé par leur vie en pisciculture dans leur comportement alimentaire. En revanche, la sélection de géniteurs à croissance rapide sur les piscicultures fédérales peut-être permis, à terme, l'obtention de descendants auxquels cette qualité a été, en partie, transmise. Aucune recherche n'a été faite à ce sujet mais elle mériterait d'être effectuée.

Enfin, il faut noter que dans tous les cas étudiés, les sujets venant de pisciculture et introduits à plus d'un an ont subi un amaigrissement durant plusieurs semaines avant la reprise de la croissance pondérale quelle que soit l'époque de déversement, même en conditions favorables comme au lac de Suyen.

La perte de poids peut atteindre 20 à 30 pour cent (Fabre et Senocq, 1981), c'est pourquoi la croissance pondérale annuelle de la première année de séjour dans le milieu apparaît plus faible que celle de la deuxième année. Cet amaigrissement temporaire ne concerne pas les truitelles de moins d'un été.

5.3.3 Croissance des poissons sauvages dans différents milieux

Les croissances de S. fario acclimaté dans différents milieux (les populations sauvages ou poissons introduits au stade oeufs vésiculés ou d'alevins d'un été élevés en ruisseaux pépinières) sont extrêmement variables. Dans les réserves de pêche où l'on peut considérer, faute d'informations plus précises, que la densité de population est maximale par rapport aux capacités d'accueil, il semblerait que la croissance linéaire soit en partie fonction de l'altitude, comme en témoigne le tableau cidessous et la Fig. 9.

Réserve	Altitude	Age auquel Lt = 18 cm (1)	Auteur
Belestat	450 m	2,5 ans	Reyes, M. (n.p.)
Viane	550 m	3,0 ans	Abad (1982)
Alas	550 m	3,5 ans	Reyes, M. (n.p.)
Aulus	750 m	4,5 ans	Reyes, M. (n.p.)
Siguers	900 m	5,0 ans	Reyes, M. (n.p.)
Courtignou	1 100 m	5,5 ans	Reyes, M. (n.p.)

(1) Longueur totale minimale de capture

De plus, la croissance est plus rapide à altitude égale en lac qu'en rivière comme le montre le tableau ci-dessous:

Réserve	Altitude	Age auquel Lt = 18 cm (1)	Auteur
Bethmale	1 050 m	2,5 ans	Fabre et Senocq (n.p.)
Suyen	1 535 m	4,5 ans	Fabre et Senocq (1981)
Gloriettes	1 670 m	3,5 ans	Fabre et Senocq (n.p.)

Les relations possibles entre la croissance et d'autres facteurs du milieu aisés à mesurer, sont un des thèmes de recherche du Laboratoire.

5.4 Les mortalités

Les méthodes habituelles d'évaluation de la mortalité sont presque toujours en défaut dans les études de démographie des salmonidés de la région en raison de l'extrême variabilité du recrutement d'origine naturelle d'une année à l'autre et de la méconnaissance totale que l'on en a. De plus, les déversements de poissons de différents âges à plusieurs époques de l'année, sur les parcours de pêche, en nombre souvent inconnu par la Fédération de pêche elle-même, modifient les structures de tailles dans des proportions impossibles à préciser. La mortalité ne peut donc être étudiée que sur des secteurs non empoissonnés parce que peu pêchés ou dans des conditions expérimentales où les entrées de poissons sont strictement contrôlées.

En fait deux méthodes peuvent être envisagées: le marquage et l'étude de la longévité, c'est-àdire de l'âge maximum observé.

Les mortalités toujours abondantes observées chez le poisson en milieu sauvage sévissent jusqu'à l'âge d'un an. La prédation par les individus plus âgés est très importante surtout sur les frayères, pendant la fraie elle-même (Fabre et Senocq, 1981). L'âge d'un an peut être considéré comme celui de recrutement dans la mesure où les truitelles ont, au-delà de cet âge, le comportement des adultes et échappent aux fortes mortalités par prédation.

Au-delà de cet âge d'un an, l'espérance de vie et la longévité sont très variables d'un milieu à l'autre indépendamment de la pêche. En lac de montagne ou en rivière de faible altitude, la longévité peut atteindre huit ans; dans les eaux courantes d'altitude, elle ne dépassera pas cinq ans. Si l'on suit les suggestions de Lévèque, Durand et Ecoutin (1977) Z est alors de 0,75 dans le premier cas, et s'élève à 1,35 dans le second.

En fait, la mortalité est très variable avec l'âge et elle augmente en raison de la pêche au-delà de l'âge de première capture. Le fait le plus important est le suivant: Les poissons non sédentaires sont les plus vulnérables à la pêche (Abad, 1982) parce que sans doute plus attirés par les leurres. Les poissons élevés en pisciculture sont également capturés plus vite après leur déversement comme dit plus haut. D'après Abad (1982), la mortalité évaluée par marquage est deux fois moins importante pendant la saison de pêche pour les sujets sédentaires que pour les autres. Les pêcheurs sportifs l'ont souvent constaté; ils capturent plus facilement les individus de grande taille récemment déversés et par conséquent non sédentaires, que les sujets sauvages de même longueur qui cohabitent avec eux.

6. INFLUENCE DES REPEUPLEMENTS SUR LE MILIEU

L'espèce S. fario est autochtone dans les Pyrénées. En 1935, on note sa présence dans une soixantaine de lacs (Chimits, 1970). Le repeuplement systématique a débuté vers 1936 avec la création de la pisciculture de Cauterets (Hautes-Pyrénées).

6.1 Influence sur les espèces de salmonidés déjà présentes

Plusieurs auteurs ont vérifié la situation d'infériorité de la truite arc-en-ciel face à la truite commune non seulement en France mais aussi dans son pays d'origine, les Etats-Unis. Cette hiérarchie entre les deux espèces n'est pas due à une antériorité dans le milieu. Elle est explicable notamment par un comportement plus agressif de la truite commune particulièrement sur les frayères.

En plus, les truites fario ont un grossissement supérieur à celui des autres salmonidés qui cohabitent avec elles (Fabre et Senocq, 1981) avec une consommation égale de nourriture de même type. C'est donc l'espèce qui paraît la mieux adaptée lorsque le milieu présente un faible niveau trophique comme c'est le cas dans les eaux pyrénéennes.

Ces éléments expliquent en partie que S. gairdnerii, comme d'autres salmonidés, sont dominées dans la région en présence de S. fario.

6.2 Influence sur le millieu

Les observations peu nombreuses à ce sujet font état d'appauvrissement de la faune d'invertébrés (dérive et benthos) en cas d'introduction ou de repeuplements périodiques en truite fario. Cela a été constaté notamment en Afrique du Sud (FAO, 1970). Dans les eaux courantes d'altitude pyrénéenne il semble que la mise en réserve de secteurs de rivières où la densité de S. fario augmente alors considérablement amène aussi une diminution des invertébrés par rapport aux parcours de pêche en amont sur les mêmes cours d'eau. Ceci serait plus net en été qu'en hiver, période où les truites se nourrissent peu. Des recherches systématiques sont en cours au Laboratoire à ce sujet.

7. CONCLUSION

Les repeuplements périodiques en S. fario tels qu'ils sont pratiqués dans les milieux exploités par les pêcheurs sportifs satisfont à leurs exigences immédiates mais il n'est pas certain qu'ils soient la meilleur façon de tirer le parti optimum des milieux aquatiques concernés. Les effets récents de certaines fédérations départementales de pêche pour généraliser les déversements de sujets de moins d'un été et les résultats encourageants qu'elles obtiennent montrent l'intérêt d'augmenter la rusticité des poissons déversés. C'est ainsi que l'on augmentera la sédentarité de ces poissons, que l'on diminuera les difficultés alimentaires liées à leur transfert dans un nouveau milleu et que l'on pourra espérer de leur part une activité sexuelle complète.

Si ces différents points ont pu être relativement bien étudiés chacun dans des conditions écologiques ou expérimentales particulières, l'acquisition de la rusticité offre un très large champ d'investigations pour des recherches approfondies de génétique des populations de salmonidés.

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Tableau 1 Taux de reprise et implantation selon le mode de repeuplement et l'origine des sujets utilisés

MODE DE REPEUPLEMENT			ORIGINE DES SUJETS MODE D'ELEVAGE	RESULTATS	
Type	Taille ou Stade	Epoque		Taux de reprise	Implantation (1)
surdensitaire	légale	pendant saison de pêche	salmoniculture intensive	élevé: 60 à 90 %	très faible à nulle
Intermédiaire	légale	1 à 6 mois avant saison de pêche	salmoniculture intensive	assez élevé: 40 à 60 %	faible à nulle
Intermédiaire	sub-légale : 14 à 18 cm	généralement automne ou hiver	salmoniculture intensive	faible à moyen : 5 à 40%	généralement faible
d'entretien	alevins ou truitelles : 5 à 14 cm	généralement été à hiver	salmoniculture intensive	très faible à faible : 0,5 à 20 % (2)	généralement faible (2)
d'entretien	alevins ou truitelles : 5 à 14 cm	généralement été à hiver	élevages extensifs (rigoles d'alevinage ou ruisseaux pépinières)	très faible à faible : 0.5 à 20 % (2)	généralement appréciable (2)
d'entretien	œufs ou alevins vésiculés	hiver ou début printemps	sujets non nourris	très faible : 0.3 à 3 % (2)	généralement analogue à celle des sujets indigènes (2)

(1) « Implantation » = survie après atteinte de la taille légale, se traduisant par un étalement des reprises sur plusieurs mois,et éventuellement une reproduction dans le cours d'eau.
(2) Survie et implantation conditionnées dans une large mesure par le milieu récepteur : adaptation de la densité de déversementà la capacité biotique, action des prédateurs.

d'aprés CUINAT (1971)

Tableau 2 Taille et âge de S. fario mâtures dans le tributaire et dans le lac

Géniteurs du tributaire		Géniteurs du lac	
Taille et âge a la première maturité			
11,6 cm	3 ans	19,5 cm	4 ans
20,9 cm	4 ans	23,0 cm	5 ans
Taille et âge des plus grands géniteurs pêchés			
24,6 cm	6 ans	30,9 cm	7 ans
24,0 cm	6 ans	29,7 cm	7 ans

Tableau 3 Proportions des différents groupes d'invertébrés dans la dérive et dans les contenus stomacaux de S. fario. Cas du ruisseau de la Mousquère (Angelier, 1976)

	1973			1974	
	% dans les contenus stomacaux	% dans la dérive	% dans le benthos	% dans les contenus stomacaux	% dans la dérive
Ephémères	22	47,8	39,2	18,0	45,0
Plécoptères	3	3,0	20,0	10,5	10,0
Trichoptères	7	2,0	6,0	25,0	4,1
Diptères	8	32,0	15,0	25,0	27,7

Tableau 4 Etude des régimes alimentaires des S. fario en fonction de la taille (juillèt à septembre) (d'après Fabre et Senocq (1981)

	F 10		10 F 20		F 20	
	% N	% P	% N	% P	% N	% P
Trichoptères	0,80	4,28	10,26	27,44	17,91	26,88
Diptères	46,06	18,51	35,34	22,06	40,19	13,34
Plécoptères	4,74	6,87	13,86	16,42	2,17	1,77
Ephéméroptères	14,02	58,60	35,20	28,54	35,27	40,33
Coléoptères			2,35	4,51	2,49	11,46
Annélides					0,03	2,70
Mollusques			2,87	0,98		
Crustacés	29,61					
Insectes terrestres	4,70	11,67			1,07	2,85

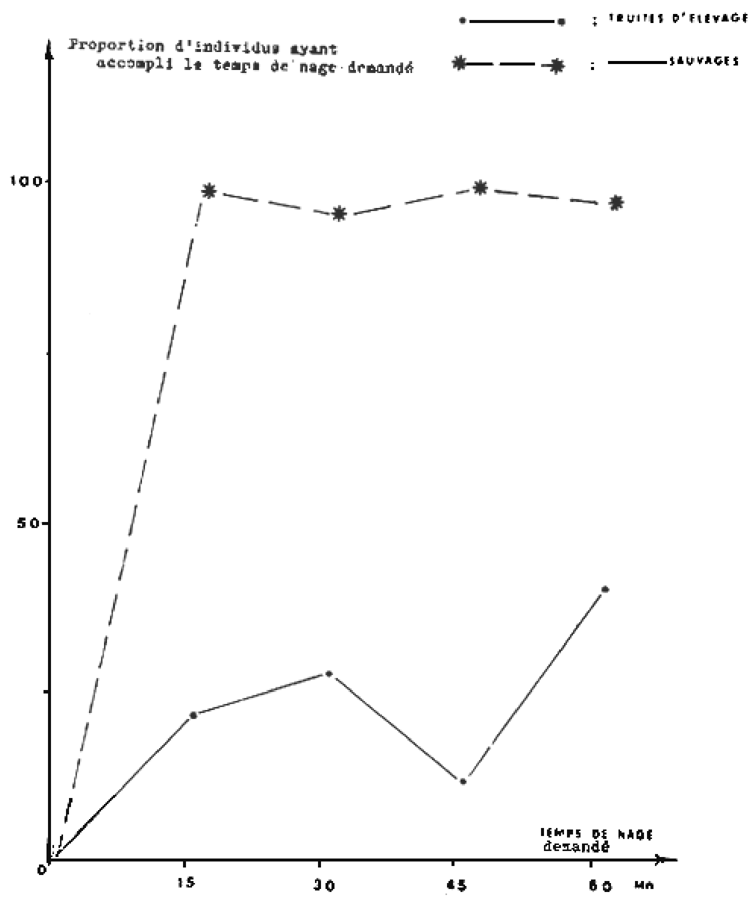


Fig. 1 Performances de nage des truites fario d'élevages intensif et "sauvage" (Gayou et Simonet, 1978)

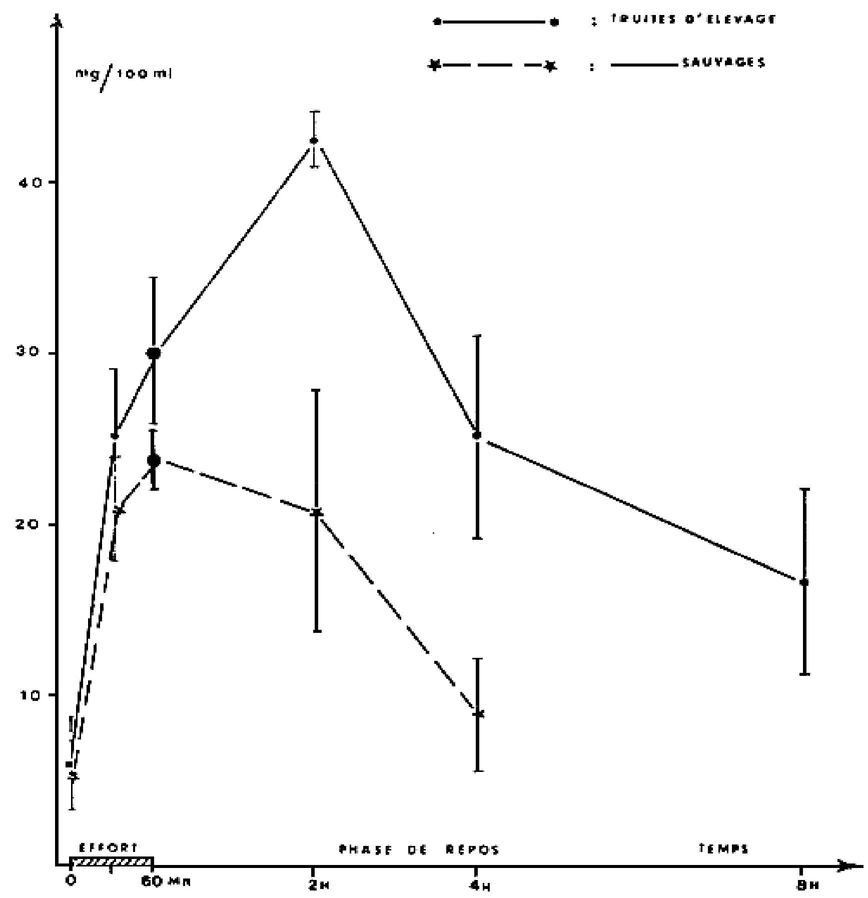
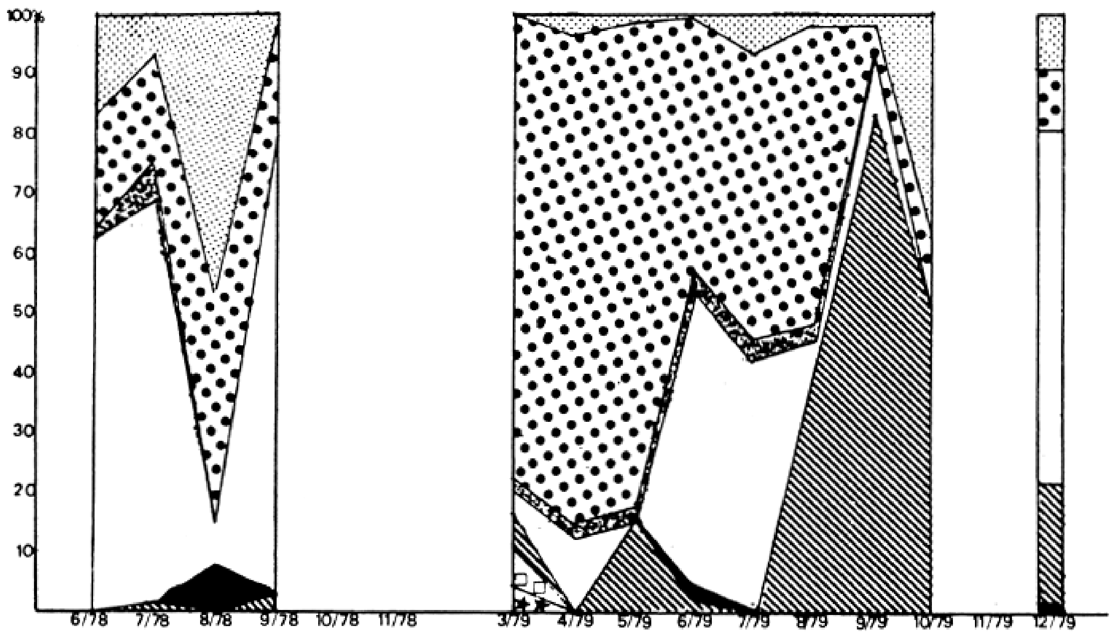
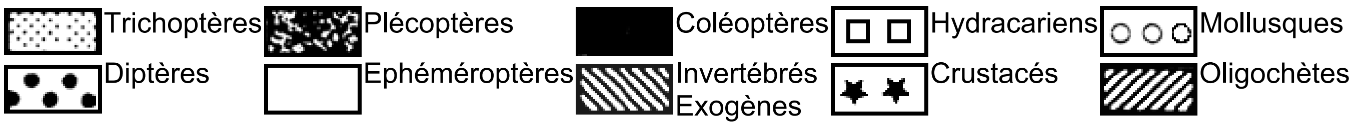


Fig. 2 Evolution de la lactacidémie des deux lots de truites pendant l'effort et au cours de la phase de repos après un effort de une heure (Simonet et Gayou, 1978)

S. fario > 20 cm



Abondance relative mensuelle des invertébrés ingérés.



10 < *S. fario* < 20 cm

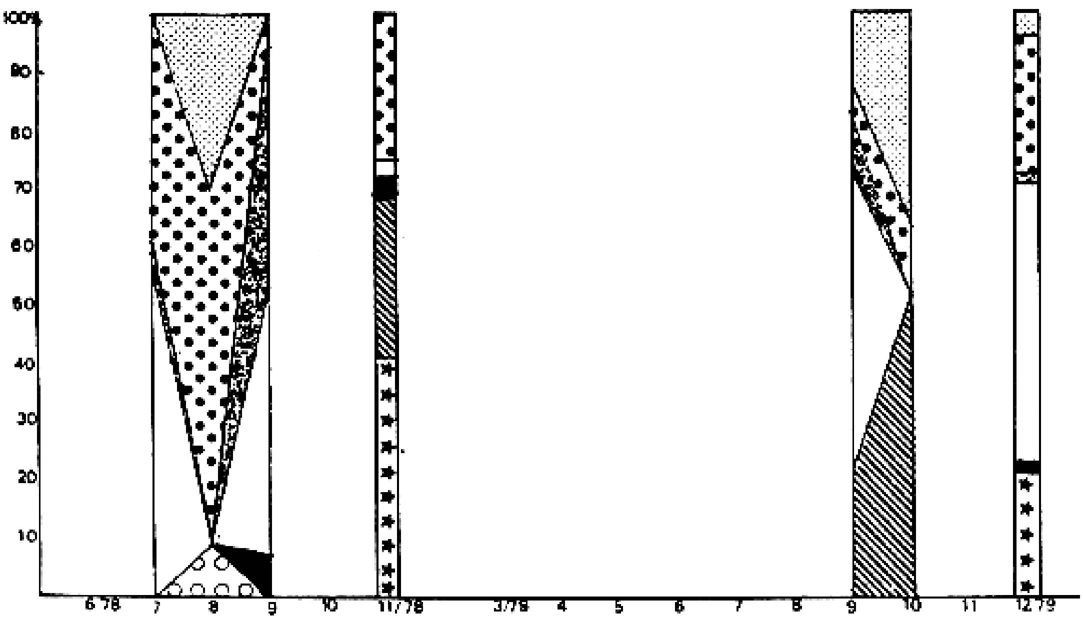


Fig. 3 Variations saisonnières de l'alimentation chez S. fario au lac de Suyen (Fabre et Senocq, 1981)

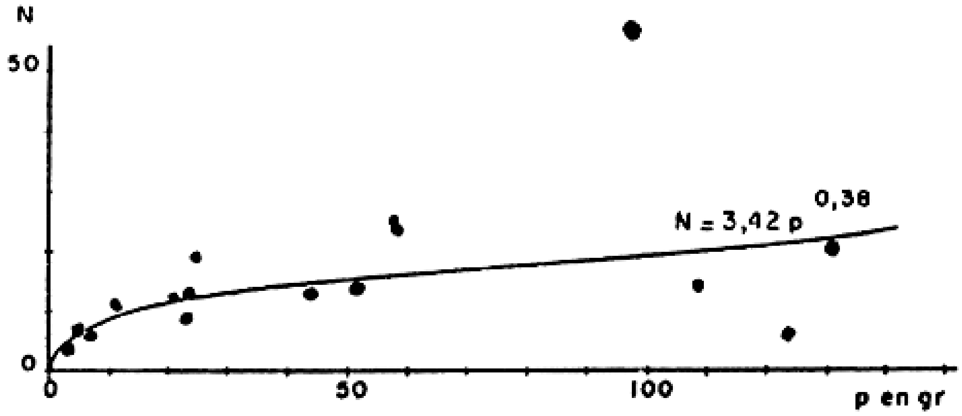


Fig. 4 Relation entre le nombre moyen de proies et le poids individuel moyen du poisson (p); in Neveu et Thibault (1977)

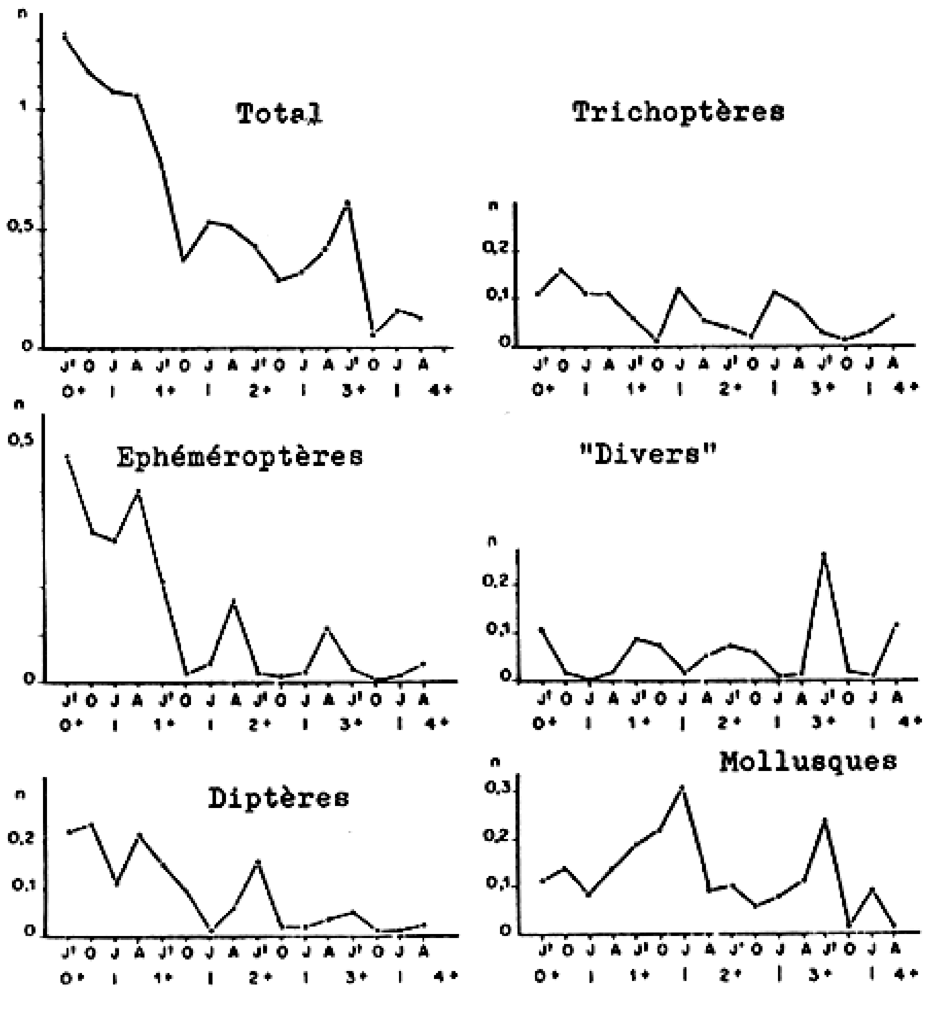


Fig. 5 Variations saisonnières du taux de consommation sur les principaux groupes d'invertébrés (n = nombre de proies par gramme de truite) in Neveu et Thibault (1977)

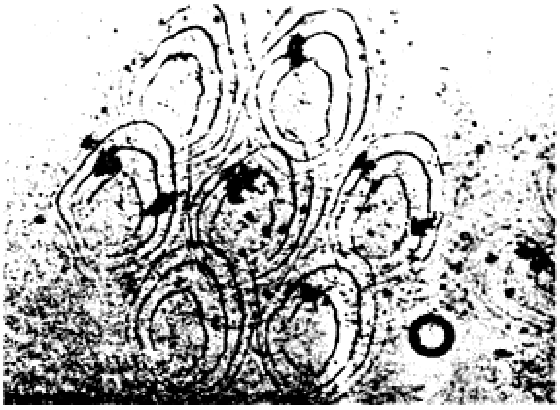


Photo a - Ecailles de O⁺

Photo b - Otolithe de O⁺

Photo c - Ecaille de 3⁺

Photo d - Otolithe de 3⁺

Photo e - Ecaille inutilisable pour la détermination de l'âge

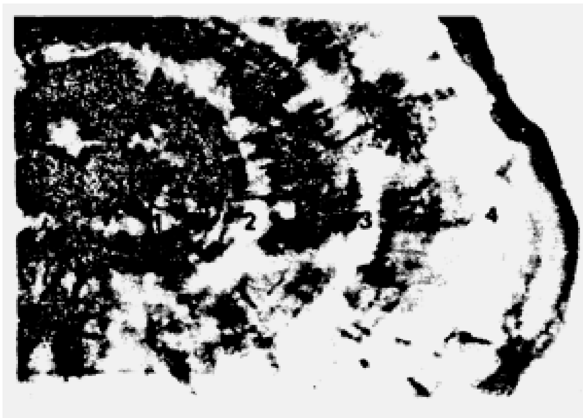


Photo f - Otolithe de 4⁺

Fig. 6 Difficultés liées aux choix du critère d'âge chez S. fario du lac de Suyen (Fabre et Senocq, 1981)

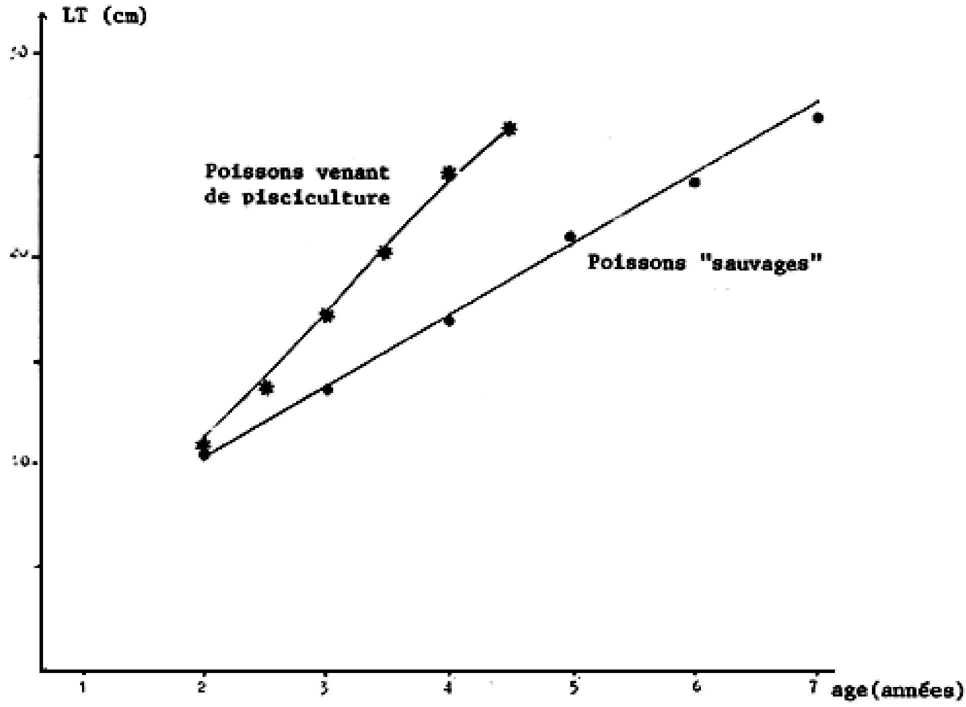


Fig. 7   Croissance comparée des S. fario sauvages et introduites de pisciculture au lac de Suyen (Pyrénées) d'après Fabre et Senocq, 1981

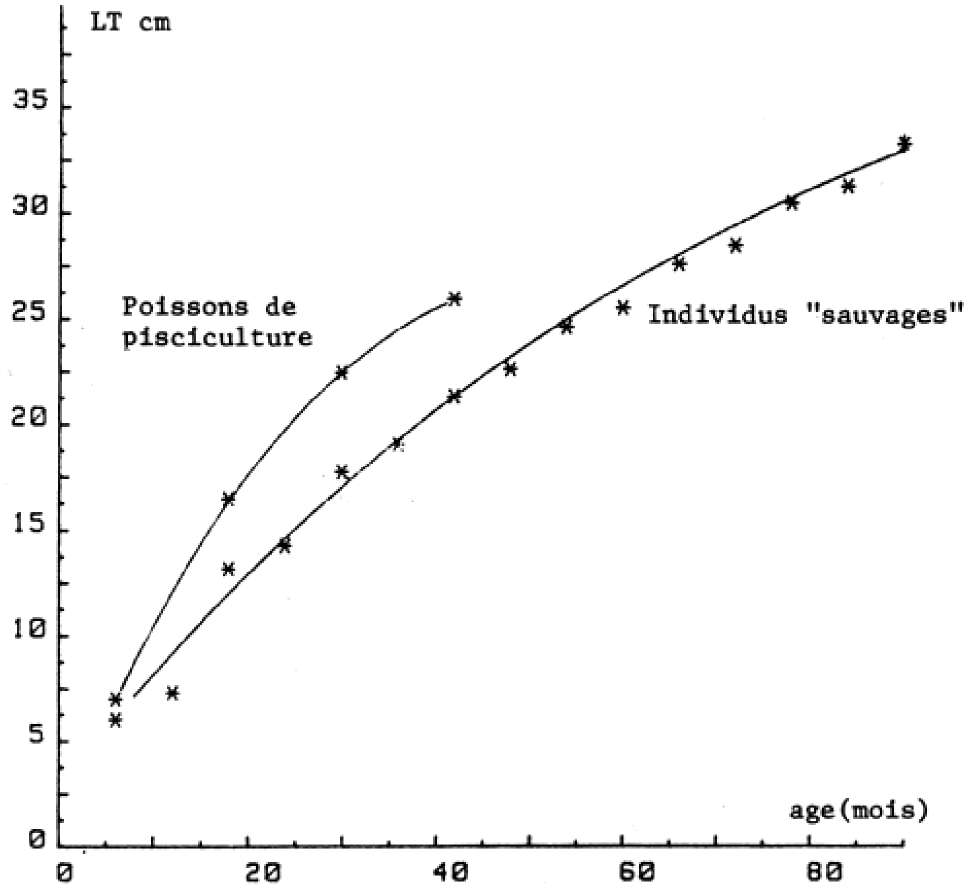


Fig. 8 Croissance linéaire comparée de S. fario de deux provenances dans la rivière Vebre (Abad, 1982)

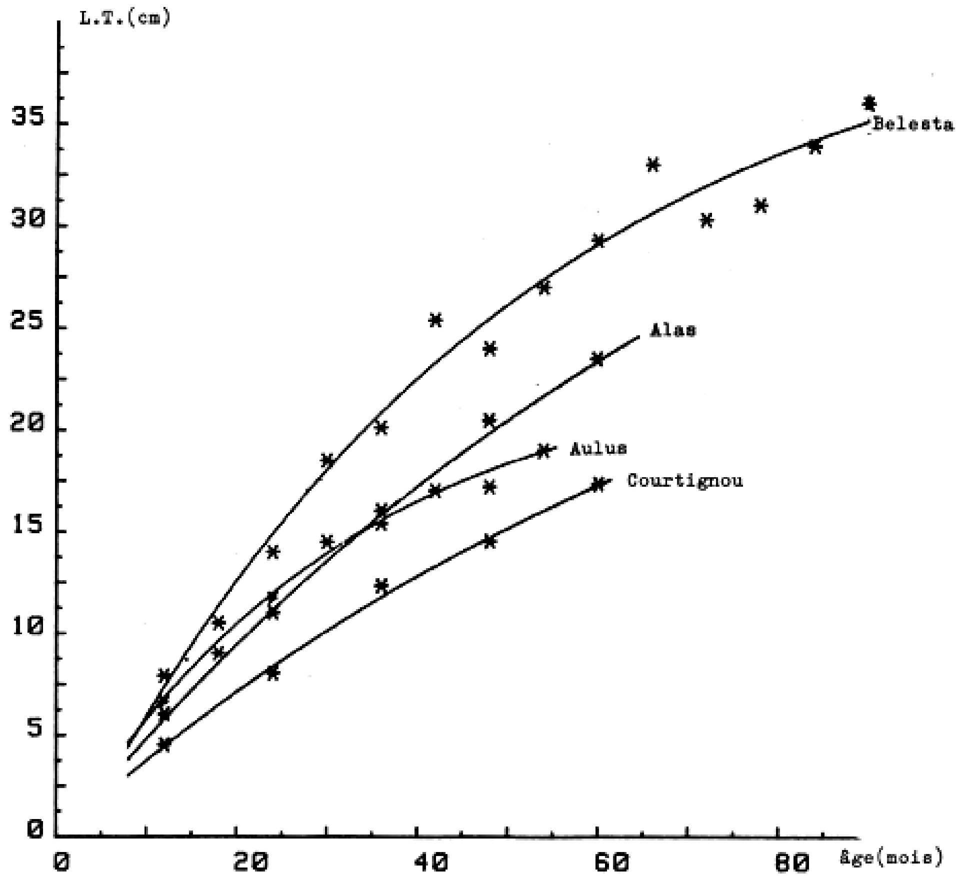


Fig. 9 Croissance linéaire comparée de S. fario dans des réserves de pêche installées à différentes altitudes (Reyes Marchant, n.p.)

PHYSIOLOGICAL EFFECTS OF STOCKING STRESS ON SALMON

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CONTENTS

ABSTRACT

The physiological effects of smolt transport were studied in connexion with comparative stockings of two-year-old Baltic salmon. Samples were taken just before transport from four hatcheries and after a five-day recovery at the stocking site. Physiological parameters describing the blood oxygen carrying capacity, energy reserves, and osmotic and ionic balance were determined.

Fish were transported from the fish farms under identical circumstances in regard to transport tanks, fish densities, and transport time. Continuous oxygenation was supplied in the transport tanks, and salt added to the transport water to give a salinity of circa 4 ‰. The experimental fish were allowed to recover for one week in small net pens in fresh water at the stocking site.

In all of the transport groups, the blood haematocrit value and haemoglobin concentration were lower following transport. The mean cellular haemoglobin content increased, however, with very high variation between individual fishes. The plasma glucose concentration, liver glycogen content, and muscle lipid content were reduced. The magnitude of this decrease differed considerably between the groups. The muscle water content decreased, but this decrease was statistically significant only in one of the groups. Plasma osmolality was not altered. However, a significant drop in plasma chloride and magnesium concentration was seen in one of the groups. The plasma protein concentration increased significantly in two of the groups.

The significance of these physiological changes is discussed, with special attention to the relation between smoltification and transport effects.

RESUME

Cette étude porte sur les effets physiologiques du transport sur des saumons de la Baltique de deux ans. Des échantillons ont été prélevés dans quatre établissements piscicoles juste avant le transport et après cinq jours de récupération sur le site de repeuplement. On a déterminé les paramètres physiologiques relatifs à la capacité de transport de l'oxygène par le sand, aux réserves énergétiques et à l'équilibre osmotique et ionique.

Les conditions de transport sont restées identiques en ce qui concerne les bacs utilisés, la densité des tacons et la durée de l'opération. L'eau du bacs était oxygénée en permanence et avait une salinité de l'ordre de 5/1 000. Sur le site de repeuplement, on a laissé les poissons récupérer pendant une semaine dans de petits enclos en eau douce.

On a constaté, dans tous les groupes, une diminution de la valeur de l'hématocrite et de la concentration d'hémoglobine dans le sang. Toutefois, la teneur globulaire moyenne en hémoglobine avait augmenté, avec de très fortes variations d'un individu à l'autre. La concentration de glucose dans le plasma la teneur du foie en glycogène et la teneur des muscles en lipides avaient diminué. L'importance de cette diminution variait dans de très fortes proportions d'un groupe à l'autre. La teneur des muscles en eau avait elle aussi baissé mais cette baisse n'avait de valeur statistique que dans un seul groupe. L'osmolarité du plasma est restée inchangée. On a constaté une nette diminution de la teneur du plasma en chlorure et en magnésium dans l'un des groupes. La teneur du plasma en protéines s'était nettement accrue dans deux groupes.

Les auteurs examinent ces variations physiologiques et leurs effets sur le repeuplement.

1. INTRODUCTION

In Finland the fish farms producing salmon smolts are mainly situated far away from the stocking sites on the coastline. During loading and transport (up to 500 km or 12 h) from the inland farms the fish are exposed to severe stress, the effects of which are not very thoroughly known.

The smolts seem to be very sensitive to handling. A medication treatment induces osmoregulatory imbalance (Bouck and Johnson, 1979) and even a slight descaling reduces the survival of coho salmon smolts in seawater (Bouck and Smith, 1979). During a routine transport the plasma cortisol, glucose and lactate concentrations increase and the liver glycogen content decreases (Wedemeyer, 1972; Specker and Schreck, 1980; Nikinmaa et al., 1981; ma) indicating a severe stress These disturbances are, at least in freshwater transport, associated with a lowered ionic concentration in plasma of coho salmon, rainbow trout and brown trout smolts (Aldrin, Mesager and Mevel, 1979; Soivio and Nikinmaa, 1981; Nikinmaa et al., 1982).

The physiology of juvenile salmon is greatly altered during parr-smolt transformation. Due to the differences between the physiological condition and stage of smoltification the stress responses and ability to recover from transport stress may greatly vary between separate fish groups during a short time interval.

Because the physiological status of the fish at the moment of stocking evidently affects the survival of the released smolts a project was started to clarify the optimal moment of parr-smolt transformation for transporting the smolts. In this study the physiological responses of fish with varying physiological background, owing to the evident differences in the smoltification stage, were investigated.

The oxygen carrying capacity of the blood was evaluated from the haemoglobin concentration (Hb) and haematocrit value (Hct) of the blood. Plasma glucose and lactate concentration were analysed to detect the general stress responses and smoltification stage of the fish. To judge the energy storages the tissue samples were analysed for glycogen (liver) and total lipid (muscle) concentration. The diagnosis of the osmoregulatory status of the fish was based on the water content of the muscle, the ionic and protein concentrations and the osmolality of the plasma.

2. MATERIAL AND METHODS

2.1 Experimental fish

Two-year old Baltic salmon (Salmo salar) from the stock of River Neva were used in the experiments. They were hatched from the eggs of a damfish population reared at Laukaa Fish Culture Research Station (LFCRS). The eggs were transferred to three private fish farms (Hanka Taimen Ltd., Nilakkalohi Ltd. and Saimaan Lohi Ltd.) at the eye spot stage. For the second year the fish were reared in outdoor earth-bottom ponds in all fish farms except LFCRS, where they were kept in 7×7 m^2 concrete basins. They were reared in fresh water at natural temperatures fluctuating seasonally between near 0 and 20°C. All the groups were fed with pelletted dry salmon food with seasonally varying rations (Westman et al., 1982).

2.2 Transportation

The fish were transported for stocking on 21 May, within the normal releasing time in southern Finland. Fish were starved for two days before transport. With a hand net 140 kg of fish were loaded into each transport tank (Ewos) with a volume of 2 400 1 (60 g fish/1 water). Salt (NaCl) was added to transport water in a concentration of 4 ppt

(65–70 mmol/l NaCl). Continuous oxygenation was supplied to the tanks. The transport time was adjusted to 8 h for each group irrespectively of the transportation distance. Water temperature at the start of transport was 4.2–6.0°C and at unloading 12.0°C.

On the stocking site, in the estuary of the River Kymi (fresh water) 150 fish from each transport group were transferred in a 70-1 basin from the tank into a 1 m^3 net cage, situated 20 m from the shore in 15 minutes. The fish were allowed to recover for five days in the net cages. During this time the fish were fed with pelletted salmon food twice a day. Because of the heavy spring flood the water salinity was 0 ‰.

2.3 Sampling and analyses

Blood and tissue samples were taken from each stocking group before the transport (pre-transport samples) and after the five-day recovery period on the stocking site (post-transport samples). Water temperatures at samplings are shown in Table 1. A day before sampling, the fish were placed in individual restrainers made of black plastic tubing (cf. Soivio and Virtanen, 1980). For sampling, the fish were immobilized with a sharp blow on the head. Blood was drawn from the caudal vessels in heparinized tuberculine syringes and analysed immediately for haemoglobin concentration (Hb) and haematoctic value (Hct) with cyanmethaemoglobin method. The rest of the blood was centrifuged within 3 minutes and the separated plasma was analysed for glucose concentration with Boehringer test kit No. 124 842, plasma chloride (Cl) concentration with Radiometer CMT 10 chloride titrator, plasma magnesium (Mg^{2+}) concentration with Wako test kit No. 273–32809, plasma total protein concentration with Biuret reaction and plasma osmolality with Wescor vapour osmometer.

For tissue determination small pieces of liver and white muscle were taken, white muscle always from the same place beneath the back fin. The glycogen content of liver was determined according to Harris et al. (1974). The total lipid of the muscle was determined with Boehringer test kit No. 124 303 from a 50-mg piece of muscle. To determine the water content a 100-mg piece of white muscle was dried to constant weight at 105°C.

The mean corpuscular haemoglobin concentration (MCHC) was calculated by dividing the Hb concentration with the Hct value. The condition factor (CF) was calculated from the formula

$$CF = \frac{W(g)}{1^3(cm)} \times 100.$$

Body silvering was determined visually on a scale 0–4 (4 = completely silvered, 0 = typical parr colouring).

The hypo-osmoregulatory capacity of the fish was determined prior to transport by exposing ten specimens from each group to artificial sea water (salinity 28‰). The exposures were made in static conditions with continuous aeration in 200 1 water volume. After 48 h exposure, blood and tissue samples were collected for ion and water balance determinations (Table 2). Restrainers were not used in these experiments.

3. RESULTS AND DISCUSSION

The physiological values determined from the pre-transport samples and the effects of seawater exposure are shown in Table 2. The values in Table 3 are for post-transport fish and differences from the pre-transport values are also given

3.1 The physiological condition and smoltification of the salmons in fish farms

The stage of smoltification in juvenile salmon can be determined from several physiological indices, e.g., the body silvering, hypo-osmotic regulatory capacity, ion and water balance in fresh water, and altered energy metabolism (Wedemeyer et al., 1980, Virtanen et al., 1981). In the stocking groups investigated, there were significant differences in these properties, indicating that the groups were at different stages of smoltification.

In the group from Hanka-Taimen fish farm, a well developed body silvering, high oxygen carrying capacity, good capacity to regulate body water and ions in sea water and reduced glycogen and lipid storages indicate a good migratory readiness. On the other hand, the group from Saimaan Lohi fish farm was characterized by more distinctive parr marks, weaker hypo-osmoregulatory capacity and higher glycogen and lipid reserves. This, together with the decreased concentration of plasma protein and chloride, indicate that this group was at early stages in smoltification. The two other groups (LFCRS, Nilakkalohi) were, according to most of the parameters measured, intermediary in relation to the groups from Hanaka-Taimen and Saimaan Lohi.

It is important to notice that a high migratory readiness as expressed with well developed body silvering and hypo-osmoregulatory capacity is associated with reduced glycogen and lipid stores (cf. Farmer, Ritter and Ashfield, 1978; Woo, Bern and Nishioka, 1978). On the other hand, sufficient energy reserves are necessary for fish to sustain the stresses connected with transport and stocking. Farmer, Ritter and Ashfield (1978) pointed out that it is recommendable to release smolts at the beginning of their migratory period to ensure higher energy reserves at that time.

3.2 Changes during the transport and subsequent recovery at the stocking site

3.2.1 Blood oxygen carrying capacity

When comparing the pre- and post-transport situation, the most pronounced changes were a decrease (15–23 percent) in blood Hct. Due to a smaller reduction in blood haemoglobin (Hb) concentration the MCHC was increased which indicates changes in red cell volume (RCV). During stress and hypoxia the erythrocytes swell, which increases their oxygen affinity (Soivio and Nikinmaa, 1981a). On the other hand, we have evidence that changes in plasma osmolality of Baltic salmon cause changes in RCV. However, no significant changes in plasma osmolality were seen in this study. Nikinmaa et al. (1982) have shown a similar decrease in blood Hb concentration and MCHC in brown trout at the end of the week's recovery from a 14 h transport in salt water (6 ‰). The reason for this shrinking of erythrocytes remains an open question.

Nikinmaa, Soivio and Railo (1981) observed temperature dependence of Hb concentration in rainbow trout. So, part of the decrease seen in Hb concentration may be due to the temperature increase (9.5–8.3°C) during the transport and the recovery period.

In all the high variation in MCHC values indicates that no balance in RCV regulation had been achieved.

3.2.2 Energy metabolism

The great differences in plasma glucose levels between the groups prior to the transport had almost disappeared at the stocking site. In the group with the most pronounced hyperglycemia (Saimann Lohi) the plasma glucose concentration had reduced to 25 percent of its original level, and in two other groups the reduction was over 50 percent. However, in the group with originally lowest glucose level (Hanka-Taiman), there was no significant decrease and the post-transport values of this group were the highest.

The liver glycogen content decreased by 25–59 percent. The decrease was greatest in the group with originally highest glycogen reserves (Saimaan Lohi) so that the post-transport values did not significantly differ between the groups.

Plasma lactate concentrations were still clearly elevated in spite of the five days' recovery period in three of the groups but not in the group from Saimaan Lohi fish farm. The muscle lipid content on the other hand, was significantly affected (a decrease of 29 percent) only in the group from Saimaan Lohi, which had the highest lipid and glycogen reserves prior to transport.

The condition factor was not significantly changed during transport.

Reduction of energy reserves is a typical phenomenon in continuous stress, and it also takes place in transport (Hyvärinen et al., 1977; Nikinmaa, et al., 1982). Too low energy reserves may be a reason for post-transport mortality (Hyvärinen et al., 1977). In this study, the post-transport levels of blood glucose and liver glycogen were still on a lowered level in spite of five days' recovery with feeding. However, the energy balance of the transported fish cannot be considered to be extremely critical, because the glycogen reserves were not empty, and muscle lipid was only slightly reduced. The relatively moderate effect of transport on the energy reserves is possibly due to the following factors:

1. The fish were transported in salt water which decreases the energy costs of osmoregulation and stress symptoms associated with transport Wedemeyer, 1972; Long, McComas and Monk, 1977, Nikinmaa et al., 1982).
2. The fish were fed during recovery, and thus allowed to somewhat restore their energy reserves.

The changes in glucose, glycogen and lipid levels were clearly associated with the start situation. In the group from Saimaan Lohi, the most pronounced decrease in these values can be accounted partly for metabolic changes connected with delayed smoltification. Although the fish in this group lost their energy reserves more than those in the other groups, their plasma lactate concentration was not elevated. This indicates that fish transported at early stages of smoltification recover better from transport stress. However lactate was the only indication to support this hypothesis.

3.2.3 Ionic and osmotic balance

The changes in osmotic and ionic balance were insignificant or quite small in all of the groups. No indices of impaired osmotic balance, often connected with transport in fresh water (Wedemeyer, 1972; Nikinmaa et al., 1982), were seen in the physiological state of transported fish. This again can partly be accounted for by saltwater transport, which decreases osmotic stress, and partly by feeding during the recovery period, which increases the energy available for osmotic work. It is evident that the changes in the concentrations of plasma protein and ions are due to the proceeding of smoltification, rather than the effects of transport. Virtanen (unpubl.) has found a temporary decrease in plasma concentrations of protein and certain ions during smoltification.

4. CONCLUSIONS

The results indicate that the physiological status of smolts is still somewhat unbalanced five days after transport. This may be a significant reason for high post-release mortality of the reared smolts compared with the natural ones (Toivonen, 1977). In order to reduce delayed mortality, attention should be paid to the following factors:

1. Fish to be released must have an optimal physiological condition and stage of smoltification.
2. Transport stress must be minimized, e.g., by decreasing the handling of fish, using sufficiently low fish densities and adding salt to transport water.
3. Fish must be allowed to recover from transport at the stocking site. A recovery time of more than a week is recommendable, and fish must be fed during this time.

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Table 1 Sampling dates and water temperatures at sampling

	Pre-transport samples		Post-transport samples	
	Sampling date	Temperature °C	Sampling date	Temperature°C
LFCRS	21/5/81	4.5	-	-
Hanka-Taimen	20/5/81	5.0	-	-
Nilakkalohi	20/5/81	5.7	-	-
Saimaan Lohi	19/5/81	5.1	-	-
Stocking site	-	-	26/5/81	14.0

Table 2 Physiological parameters for the stocking groups prior to transport in fresh water and the change caused by 48 hours' seawater exposure at a salinity of 28%. Means ± SKM's and n are given

Parameter:	Fish farm: LFCRS	n	Hanka-Taimen	n	Nilakkalohi	n	Saimaan Lohi	n
FRESHWATER VALUES:								
Fish								
length (cm)	15.2±0.2	(18)	21.5±1.0	(20)	20.4±0.3	(19)	17.1±0.4	(20)
weight (g)	29.1±1.2	(18)	98.6±15.4	(20)	68.0±3.2	(19)	43.6±3.7	(20)
condition factor	0.828±0.016	(18)	0.853±0.018	(20)	0.788±0.011	(19)	0.841±0.014	(20)
body silvering index (0–4)	2.7±0.10	(18)	2.9±0.23	(20)	2.4±0.14	(20)	2.2±0.16	(20)
silvered (%)	44		60		35		20	
Blood								
haematocrit	0.322±0.007	(19)	0.352±0.009	(18)	0.345±0.008	(20)	0.389±0.010	(15)
haemoglobin (g/l)	81.0±1.5	(19)	94.4±2.4	(20)	89.7±2.0	(20)	94.0±2.7	(19)
MCHC (g/l)	252.0±5.4	(19)	268.3±3.0	(18)	260.2±2.5	(20)	240.9±6.2	(15)
Plasma								
glucose (g/l)	1.92±0.14	(18)	1.29±0.08	(20)	2.06±0.17	(19)	3.80±0.22	(19)
lactate (mg/l)	56±3	(17)	44±7	(19)	52±3	(18)	103±8	(19)
chloride (meg/l)	129.4±1.2	(18)	134.6±1.1	(18)	128.8±1.4	(19)	119.1±2.0	(18)
magnesium (meg/l)	1.62±0.06	(15)	2.10±0.10	(19)	1.52±0.08	(19)	1.58±0.06	(17)
total protein (g/l)	33.6±0.9	(13)	29.9±1.4	(18)	22.7±2.6	(17)	20.1±2.9	(12)
osmolality (mOsm/kg)	300.3±1.9	(17)	310±2.9	(17)	307.1±3.2	(17)	297.4±2.7	(17)
Muscle								
total lipids (%)	0.69±0.06	(18)	0.55±0.05	(20)	0.58±0.04	(20)	0.75±0.05	(20)
water (%)	77.95±0.19	(17)	76.26±0.37	(20)	76.98±0.11	(19)	77.90±0.22	(19)
Liver								
glycogen (%)	1.60±0.21	(17)	1.64±0.23	(17)	2.22±0.21	(19)	2.73±0.31	(19)
CHANGE CAUSED BY SEAWATER EXPOSURE IN:								
Blood MCHC (g/l) Plasma	35.9±6.3	(9)	19.3±9.7	(10)	1.7±2.1	(9)	12.2±6.6	(5)
Plasma								
chloride (meg/l)	17.3±2.5	(9)	18.7±4.1	(10)	23.9±4.6	(10)	40.8±6.2	(7)
magnesium (meg/l)	0.80±0.11	(8)	0.53±0.17	(10)	1.37±0.44	(9)	2.43±0.68	(7)
osmolality (mOsm/kg)	43.4±4.8	(9)	34.9±6.6	(10)	36.2±7.9	(10)	66.2±6.8	(7)
Muscle water (%)	-1.48±0.19	(8)	-1.20±0.22	(10)	-1.60±0.37	(10)	-3.38±0.32	(8)
Mortality (%)	31		0		0		30	

Table 3 Physiological parameters for the stocking groups after transport and subsequent recovery in fresh water. Means ± SEM's and n are given on the upper line, below the absolute and relative changes from pre-transport values (Table 2). The statistical significance of the change is given with the following symbols:
NS = not significant; ○ = P<0.1; *= P<0.05; ** = P<0.01; *** = P<0.001

Parameter:	The stocking group originating from: LFCRS		Hanka-Taimen		Nilakkalohi		Saimaan Lohi	
Blood								
haematocrit	0.247±0.17	(7)	0.299±0.010	(10)	0.273±0.011	(10)	0.302±0.20	(10)
	-0.075***	(23 %)	-0.053***	(15 %)	-0.072***	(21 %)	-0.087***	(22 %)
haemoglobin (g/l)	71.4±2.7	(9)	92.2±8.7	(10)	74.7±1.9	(10)	88.1±3.5	(10)
	-9.6**	(12 %)	-2.2^{NS}	(2.3 %)	-15.0***	(17 %)	-5.9^{NS}	(6.3 %)
MCHC (g/l)	335.8±45.5	(7)	312.4±33.4	(10)	275.8±8.0	(10)	301.4±20.0	(10)
	+83.8°	(33 %)	$+44.1^{NS}$	(16 %)	+15.6°	(6 %)	+60.5**	(25 %)
Plasma								
glucose (g/l)	0.88±0.04	(8)	1.22±0.09	(10)	0.89±0.04	(10)	0.94±0.07	(6)
	-1.05***	(54 %)	-0.08^{NS}	(6 %)	-1.17**	(57 %)	-2.86***	(75 %)
lactate (mg/l)	166±14	(8)	160±24	(10)	254±46	(10)	96±11	(6)
	+110***	(196 %)	+116***	(264 %)	+202***	(388 %)	-7^{NS}	(7 %)
Condition factor	0.828±0.32	(9)	0.819±0.015		0.795±0.010	(9)	0.819±0.016	(10)
	0^{NS}	(0 %)	-0.034^{NS}	(4.0 %)	$+0.007^{NS}$	(0.9 %)	-0.022^{NS}	(2.6 %)
Liver								
glycogen (%)	1.20±0.09	(9)	1.17±0.29	(10)	1.10±0.17	(10)	1.13±0.20	(10)
	-0.40°	(25 %)	-0.47^{NS}	(29 %)	-1.12***	(50 %)	-1.60***	(59 %)
Muscle								
total lipids (%)	0.65±0.08	(8)	0.54±0.05	(10)	0.49±0.05	(9)	0.54±0.01	(10)
	-0.04^{NS}	(6 %)	-0.01^{NS}	(1.8 %)	-0.09^{NS}	(16 %)	-0.22***	(29 %)
water (%)	77.16±0.24	(9)	75.77±0.05	(10)	76.47±0.29	(10)	77.71±0.56	(10)
	-0.79*	(1.0 %)	-0.49^{NS}	(0.6 %)	-0.51^{NS}	(0.7 %)	-0.19^{NS}	(0.2 %)
Plasma								
chloride (meg/l)	126.3±1.9	(9)	128±2.3	(9)	130±2.8	(10)	126.0±3.3	(7)
	-3.1^{NS}	(2.4 %)	-6.0*	(4.5 %)	$+1.2^{NS}$	(0.9 %)	+6.9°	(5.8 %)
magnesium (meg/l)	1.45±0.14	(7)	1.55±0.07	(9)	1.44±0.05	(9)	1.66±0.08	(8)
	-0.17^{NS}	(10 %)	-0.55***	(26 %)	-0.08^{NS}	(5 %)	$+0.08^{NS}$	(5 %)
total protein (g/l)	30.5±2.5	(5)	35.3±1.6	(10)	28.2±1.5	(8)	31.9±3.8	(3)
	-3.1^{NS}	(9 %)	+5.4*	(18 %)	+5.6°	(25 %)	+11.9*	(59 %)
osmolality (mOsm/kg)	307.2±3.8	(9)	305.6±6.0	(8)	307.9±5.8	(10)	298.3±3.8	(6)
	$+6.9^{NS}$	(2.3 %)	-4.5^{NS}	(1.5 %)	$+0.8^{NS}$	(0.3 %)	$+0.9^{NS}$	(0.3 %)

FACTORS AFFECTING THE SURVIVAL AND DISTRIBUTION OF SALMON (*Salmo salar* L.) STOCKED IN UPLAND TROUT (*Salmo trutta* L.) STREAMS IN NORTHERN IRELAND

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CONTENTS

ABSTRACT

Atlantic salmon were stocked at the same density in successive years in upland brown trout streams as eyed ova, green eggs and swim-up fry. Their survival was evaluated by electric fishing during the late summer, and the results were compared with the survival rates in the naturally spawning trout population. Eyed ova showed the best survival rate and swim-up fry were marginally less successful, although the latter was in a year when competition was more intense due to higher trout fry densities. Green eggs gave the lowest survival rate, and this was attributed to the scouring effect of floods. Similarly, the effect of scouring was related to the lower survival of eyed ova in a high gradient stream compared to one of low gradient.

The presence of trout and older age classes of salmon was also found to affect the survival and distribution of planted salmon. When a stream contained trout and salmon parr the survival of salmon stocked as eyed ova was less than half that found when other fish were absent. A reduction in the survival of stocked salmon due to the competitive influence of trout fry was also noted below a stream barrier where much trout spawning had taken place. The survival of stocked salmon was also reduced considerably by the presence of yearling salmon parr in the stream. Changes in the trout population were similarly recorded following salmon stocking, and these suggested that while salmon fry do not affect trout fry survival, the presence of salmon parr does cause a reduction in trout fry stocks.

These competitive effects were related to the habitat preferences of salmon and trout. When the two species were living sympatrically about 70 percent of the fry of both were captured in sites of less than 20 cm mean depth, whereas only about 30 percent of the salmon fry population were found in this depth range when no trout or older salmon were present. Yearling fish were found in all the depth ranges sampled, but trout were limited in their distribution to areas of lower flow while salmon were not. Older trout were found mainly in the deeper areas.

Finally, an electrofishing survey of a range of depth related habitat types below a stocked area indicated that dispersal of stocked salmon fry was very limited. This result and the other findings are discussed in relation to their implications for salmon stocking exercises in trout streams.

RESUME

On a repeuplé des torrents à truites avec des saumons atlantiques en utilisant plusieurs années de suite la même densité d'oeufs embryonnés, d'oeufs verts et de fretin non nourri. Les taux de survie ont été évalués par pêche électrique en fin d'été; on les a comparés aux taux de survie des populations de truites frayant naturellement. C'est avec les oeufs embryonnés que l'on a obtenu le taux de survie le plus élevé. Les alevins mis à l'eau non nourris venaient juste après (et encore s'agissait-il d'une année où le frai de truite était très dense, d'où une concurrence particulièrement forte). En revanche, les résultats obtenus avec les oeufs verts étaient nettement moins bons, ce qui serait dû à l'effet d'appouillement des crues. C'est ce même phénomène qui expliquerait que le taux de survie des oeufs embryonnés soit plus faible dans les cours d'eau à forte dénivellation.

On a également constaté que la présence de truites et de saumons plus âgés avait un effet sur la survie et la répartition du matériel de repeuplement. Ainsi, le taux de survie des oeufs embryonnés diminuait de plus de moitié en présence de truites et de saumoneaux. On a également noté une réduction du taux de survie là où le frai de

truites était très dense, notamment en aval d'un obstacle où beaucoup de truites avait frayé. La réduction était très nette en présence de saumons d'un an. On a observé des modifications des populations de truites à la suite de ces opérations de repeuplement. A ce qu'il semble, le frai de saumon n'a pas d'influence sur la survie du frai de truite dont les stocks en revanche, diminuent en présence de saumoneaux d'un an.

Ces effets de concurrence étaient liés aux préférences du saumon et de la truite en matière d'habitat. Lorsque les deux espèces étaient sympatriques, on capturait environ 70 pour cent de leur frai dans des eaux de moins de 20 cm de profondeur en moyenne alors que l'on n'y capturait que 30 pour cent environ du frai de saumon lorsqu'il n'y avait pas de truites ou de saumons plus âgés. On a trouvé des juvéniles d'un an à toutes les profondeurs où l'on a prélevé des échantillons mais, à la différence des saumons, la répartition des truites se limitait aux zones à faible débit. Les truites âgées hautaient surtout les profondeurs.

Une étude par pêche électrique de différents types d'habitat, plus ou moins profonds, dans une zone repeuplée a montré que la dispersion du frai de saumon était très limitée. L'auteur tire de tous ces résultats un certain nombre de conclusions concernant le repeuplement en saumons du torrents à truites.

1. INTRODUCTION

Harris (1978) defined the basic constraint on any fishery management programme for increasing the numerical abundance of salmon (Salmo salar L.) in a river as the productivity of the water and its ability to produce and sustain fish stocks. If a fishery manager feels that the full potential of a river for the production of salmon smolts is not being realized due to inadequate recruitment, inaccessibility or pollution kills, artificial stocking is frequently carried out using a variety of techniques. These efforts have met with varying degrees of success in different rivers (Harris, 1978; Symons, 1979) but an evaluation of the physical and competitive factors regulating the survival of stocked salmon, and the impact on resident fish populations have not yet been fully quantified.

The work presently being undertaken in Northern Ireland covers various aspects affecting the survival of stocked salmon including comparative stockings of eyed ova, green eggs and swim-up fry in the same stream environment, comparative stockings of eyed ova in different streams, and the influence of resident brown trout (Salmo trutta L.) and older age classes of salmon on the survival and distribution of stocked salmon. The reciprocal effect of the impact of stocked salmon on the growth and survival of the resident trout population has also been monitored.

2. SITE

The study areas are the two feeder streams to Altnahinch Reservoir in the upper catchment of the River Bush (Fig. 1). The dam at the reservoir acts as a barrier to upstream migration from the River Bush, and brown trout were found to be the only resident fish species in the streams prior to the experiments.

The streams rise at an altitude of about 360 m on heather moorland which is subject to reafforestation. The larger of the two streams (stream 1) has impossible falls approximately 2.4 km upstream from the reservoir, and this investigation was limited to the area below this natural barrier. The overall gradient on stream 1 is about 1:35, and the mean width 3.7 m. The corresponding values for stream 2 are 1:22 and 1.8 m. The total catchment for both streams is about 12 km^2. The pH is about 7.2 in low flow conditions, but this can drop to pH 6.3 during floods due to run off from the peaty moorland. The bed of both streams consists mainly of coarse gravel and moss covered stones, although bedrock and peaty silt were found in some of the pools.

Fish barriers were erected on both streams during 1977 to prevent the immigration of trout to the areas above (see Fig. 1). On stream 1 this barrier was situated about 800 m upstream from the reservoir, providing a downstream control area which was accessible to trout and an upstream experimental area which was inaccessible. On stream 2 the barrier was situated at the bottom of the stream, thus isolating the whole area from trout immigration.

3. METHODS AND MATERIALS

All the salmon stocked in the experimental streams were obtained from River Bush adults taken in traps on the lower reaches of the river. All eggs and fry for stocking were retained in a hatchery situated beside the trapping installations prior to the experiments. All ova were placed in artificial redds using the pipe method described by Sedgwick (1960). The redds were separated by distances of less than 150 m. Salmon fry at the “swim-up” stage, i.e., with some yolk sac left, were stocked out evenly over all the available habitat using buckets. Green eggs were stocked out during December, eyed ova during March and swim-up fry during May. In all the experiments salmon were stocked out at an overall stream density of $6.2/m^2$.

Population estimates were carried out during March and late August to early September by electrofishing using a two anode technique to obtain high efficiencies (Kennedy and Strange, 1981). The sites sampled during March were chosen so that each covered a range of habitat types, and varied in area from 170 m^2 to 297 m^2. The summer sites varied in area from 11.3 m^2 to 182 m^2, and stop nets were sited to enclose, as far as possible, one depth related habitat type at a time, i.e., deep pool, shallow pool, riffle, etc. Water depths were measured on a grid system, and gradients using a manometer method.

The fork length of all fish was measured to the millimetre below, and weighings were carried out both on anaesthetized fish in the field and on electrofishing casualties. In this work, 1 April was taken as the start of the salmonid year.

4. RESULTS AND DISCUSSION

4.1 Comparative survival from salmon stocking with eyed ova, green eggs and swim-up fry

The mean summer densities and percentage survival of salmon fry which had been stocked in stream 1 by the three methods described are given in Table 1 for the years 1977–81. Eyed ova consistently produced the best survival rates with no significant difference between the three years when this stocking method was employed, the summer densities falling within the range 108.3 to 120.2 per 100 m^2. The survival rate from swim-up fry was marginally significantly lower than the best from eyed ova ($p < 0.1$), with a summer density of 103.3 per 100 m^2. However, this was in a year when trout fry densities were very high due to intense trout spawning in this area, and the resultant increased competition apparently influenced salmon fry survival (see section 4.3). Green eggs gave a highly significantly lower survival rate than eyed ova or fry stocking ($p < .001$), with a mean summer fry density of only 25 per 100 m^2. Kennedy and Strange (1981a) confirmed this result by further sampling during March 1978 and March 1979, when annual survival rates from eyed ova and green eggs were found to be 10.3 percent and 1.4 percent, respectively. They attributed the lower survival rate from green eggs to the scouring effect of winter floods which destroyed several redds completely. It seems probable that man is not so efficient at building redds as adult salmon, although Harris (1978) recorded that up to 30 percent of natural redds can also be washed away before the eggs hatch out.

4.2 Comparative survival from salmon stocking with eyed ova in two streams of differing gradient

Plantings of eyed ova are not so subject to losses due to scouring since the redds constructed for them only have to last a relatively short period of time and do not have to face the brunt of winter floods. However, even with these the effect of scouring was noted at Altnahinch.

Eyed salmon ova were stocked at the same densities in the experimental areas above the barriers in streams 1 and 2 during March 1981. No other age classes of salmon and trout were present in these areas at this time. The artificial redds were similarly constructed in each stream. During the week following planting severe flooding occurred in the area. Observation subsequently indicated that some of the redds in the high gradient stream 2 had been scoured out and others damaged, whereas redds appeared to be intact in stream 1 which has an overall lower gradient. Although the gradient of stream 1 could not be considered low at 1:35, long stretches are much less steep than this, whereas stream 2 is more uniformly steep.

Electrofishing in the summer confirmed that there was very poor survival of the salmon stocked in stream 2 compared to the experimental area of stream 1 (Table 2). The mean density of salmon fry in the experimental area of stream I was over five times greater than that in stream 2, where the distribution of fry was patchy, i.e., some redds had survived and some had not. Thus although eyed ova stocking has consistently produced good survival rates in an area of lower gradient, this method of stocking may not be so effective in torrential high gradient areas if flooding occurs before the alevins leave the redds.

4.3 Influence of resident fish on the survival of stocked salmon

Stocking of a 490 m stretch of the control area below the barrier on stream I was carried out using swim-up salmon fry during May 1980. Care was taken to distribute the fry evenly over the whole area. However, when sites were electro-fished over the length of the stocked area during August and September 1980, it was found that there was a highly significant ($p < .001$) downstream trend for increasing abundance of salmon fry relative to trout fry abundance (Fig. 2). This trend was non-linear, and a quadratic regression gave a significantly better fit to the data ($p < .01$). Neither the trout fry themselves, nor any of the older fish present showed any significant trends over the length of the stocked area. However, as pointed out by Kennedy (1980), many adult trout spawned in the upstream end of the stocked area after their spawning migration was blocked by the impassable barrier. Many more trout fry would, therefore, have hatched out directly downstream from the barrier than could possibly acquire territories and survive. Kalleberg (1958) has pointed out that in interspecies territorial disputes trout tended to be more successful than salmon. It is likely, therefore, that during the first few critical weeks of establishing territories the salmon in the upstream end of the stocked area were under much greater pressure from the large numbers of emerging trout fry in that area than were the salmon stocked further downstream. Downstream dispersal in this environment was found to be very limited (see section 4.7) and competition for space from large numbers of trout fry directly below the barrier has, therefore, had a very localized influence on the survival of stocked salmon fry.

In earlier work described by Kennedy and Strange (1980) the survival of stocked salmon was also found to be influenced by the presence of older age-classes of salmon parr in the stream. The summer densities of salmon fry derived from ova stocking when streams contained trout and salmon parr was only about half that recorded when trout alone made up the resident stock (Fig. 3). Similarly, after removal of all the fish from the experimental area in stream 1 the summer salmon fry density from eyed ova stocked in 1981 was more than twice that found in the downstream control area which contained trout and salmon parr (Table 2). The salmon fry were also larger in the experimental area with a mean size of about 6.2 cm compared to only 5.2 cm in the control area. Although the work has not yet resolved the relative importance of inter and intra species competition, the biomass calculations of Kennedy and Strange (1980) suggest that there is also a certain amount of niche segregation between the two species. Both the streams at Altnahinch were found to be carrying only about two thirds of their standing crop capacity prior to the introduction of salmon (Fig. 4).

4.4 Influence of stocked salmon on resident trout

Egglishaw and Shackley (1973) suggested that the introduction of eyed salmon ova from a lowland hatchery gives the salmon an artificial advantage over the naturally spawned trout due to earlier hatching of the salmon eggs - advanced because of higher hatchery temperatures. Kennedy and Strange (1980) did not find any unequivocal influence of introduced salmon fry on trout fry survival at Altnahinch, although some increased competition may have been evident in a significant reduction in the growth rate of trout fry in stream 1 following salmon stocking. However, substantial declines in the densities of trout fry were recorded in both streams following the second introduction of salmon (Fig. 3). The inference is that although salmon fry do not affect trout survival, as also recorded by Le Cren (1965), the presence of salmon parr does cause a reduction in trout fry stocks. This is contrary to the results of Egglishaw and Shackley (1980), who found no evidence that salmon stocking had a detrimental effect on any age class of trout in a stream. Certainly the work at Altnahinch did not demonstrate any consistent change in yearling trout densities or growth rates which could be attributed to the introduced salmon.

4.5 The distribution of trout and stocked salmon in relation to depth and gradient

Various authors have suggested that variation in fry survival may be related to the amount of predation by older age classes of both salmon and trout (McCrimmon, 1954; Mills, 1964). However, Kennedy and Strange (1980) noted only occasional predation by trout on fry, and no predation at all by salmon parr on fry. This led them to suggest that competition for space is a more important regulating influence on fry survival. Other work being carried out in the Altnahinch streams is designed to determine the extent of this competition for space by quantifying the distribution of each age-class of each species in relation to water depth and flow (Kennedy and Strange, 1982).

The results indicated consistent significant correlations of density with water depth over three years of sampling. The findings for one year (1977) are summarized in Fig. 5 as the density of each age class in each depth range expressed as a percentage of the overall abundance of that age class. Fry were highly significantly more abundant in shallow water sites than deeper sites ($p < .001$). During the three years 71.8 percent of the salmon fry and 64.5 percent of the trout fry were captured in sites of mean depth less than 20 cm. The older trout were highly significantly more abundant in deeper water ($p < .001$), with only 6.3 percent of these being captured in sites shallower than 20 cm mean depth. The yearling fish showed an intermediate relationship, being found in all the depth ranges sampled, but with a tendency for higher numbers in mid-range depths, significant in the case of trout ($p < .05$). There were similar correlations in the abundance of each age class with the actual areas of shallow, mid-range and deep water habitat available within sites, whatever their mean depth.

The distribution of salmonids in relation to water flow was assessed from site gradients (Table 3). Salmon fry were significantly more abundant in high gradient riffle areas in all years, but trout fry only showed this trend significantly in 1978. The older trout were significantly less abundant in areas of high gradient confirming that they are found in the slow-moving pools. Yearling trout were also highly significantly negatively correlated to stream gradient, but the yearling salmon did not show any significant correlation to this parameter in any year, i.e., yearling salmon are apparently able to exploit a whole range of flow regimes while trout are limited to slower flowing areas. Jones (1975) has previously pointed out that salmon are better adapted than trout for living in fast flowing water due to their having larger pectoral fins, which can be used for holding the fish to the bottom by deflection of the current. This ability of salmon to occupy areas to which trout are not so well adapted concurs with the results described in section 4.3, where trout on their own apparently did not occupy all the available habitat

(Kennedy and Strange, 1980). These results also confirm that yearling salmon can occupy the same habitat as, and by inference compete with, fry of both species.

4.6 Influence of resident fish on the distribution of stocked salmon

A change in the habitat occupied by a species resulting from the addition or removal of a closely related species is regarded as the strongest and most direct evidence of interspecific competition for a resource (Diamond, 1978). This criterion was used as a test of the interspecific influence of trout on salmon by carrying out the 1981 stocking of the experimental section of stream 1 after removal of all the resident fish. The distribution of salmon fry in this area and in the control area which contained all age classes of salmon and trout was investigated in relation to habitat type as before.

The results show that the distribution of salmon fry changes considerably in the near absence of competition from other fish (Fig. 6). In the control area the distribution of salmon fry is significantly correlated to that found in previous years (p .01) with 84.7 percent of them being captured in sites with mean depths less than 20 cm. However, in the experimental area there is no significant correlation of the salmon fry distribution with either those in the control area or in previous years. Only 30.4 percent of the salmon fry were captured in sites of less than 20 cm mean depth, and high densities of fry were found in all the depth ranges sampled. In fact, in the absence of other fish it appears that the shallowest areas are least preferred by salmon fry with the mode of abundance occurring at mean depths of 15 to 25 cm. This is a similar distribution to that previously recorded for 1+ salmon and may be related to the more rapid growth of fry in the absence of competition from other fish. A study of the distribution of fry in the presence of salmon parr but in the absence of trout has yet to be completed.

4.7 Dispersal of stocked salmon fry

An assessment of the extent of downstream dispersal of salmon planted as swim-up fry was made at Altnahinch in 1980. The fry were planted out in May over a 490 m stretch below the barrier in stream 1. In addition to the electrofishing carried out to assess survival within the planted area (see section 4.3) a number of sites were sampled during late August for a distance of 330 m below the most downstream stocking point (Fig. 7). Salmon fry were almost totally absent from the deepwater sites in this unstocked area, and in the five sites which were less than 25 cm deep, the mean density of salmon fry was only 23.7 per 100 m^2 (the mean density of these at comparable sites in the stocked area was 119.7 per 100 m^2). Over 70 percent of the salmon fry captured below the stocked area were taken within 100 m of the lowest stocking point, and 200 m below the stocked area the density had fallen to 8.9 per 100 m^2.

These findings are comparable to those of Egglishaw and Shackley (1973) in the Fender Burn, where the downstream density of salmon fry below a site planted with eyed ova tailed off following an exponential decay pattern until no fry were captured at sites further than 400 m below the stocking point. These authors also noted that very few fry moved upstream, and the density 120 m above a stocked site was only 10 percent of that recorded at the stocking site.

Both these studies, therefore, confirm limited dispersal of stocked salmon and are contrary to the earlier work of Elson (1962) on the Pollett River, where he reported that planting of salmon fry at sites 1.5 miles apart resulted in "… relatively uniform dispersal and good utilization of the stream throughout the entire experimental area". However, Elson's plantings were carried out at the end of August, and fry planted at this stage must show a great tendency for dispersal than fry newly emerged from redds. In fact, the Altnahinch findings suggest that salmon stocked out as swim-up fry do not even disperse as far as fry emerging from a redd. This may be due to the limited yolk sac available to the fish at this stage, when they must quickly acquire a territory or die. Certainly these results emphasize the need for an even distribution of fry during planting out operations.

5. CONCLUSIONS

Percentage survival rates are frequently quoted as a measure of the success of stocking exercises, but as pointed out by Mills (1964) and Egglishaw and Shackley (1980) these are related to initial stocking densities, with mortality rates increasing as densities increase. A more definitive measure is the holding capacity of a stream for fry. Le Cren (1965) assessed this at about 7 to 10 fish per m^2 during September for trout fry in small streams in the north of England in the absence of other fish. The present studies indicate tht the overall summer holding capacity of Altnahinch stream 1 for salmon fry in the presence of salmon parr and trout is in the range of 103.3 to 120.2 per 100 m^2. This was increased to 229.8 salmon fry per 100 m^2 in the absence of other fish. These figures were all derived from initial stocking densities of about 620 salmon per 100 m^2. However, the minimum initial stocking density required to achieve these summer densities has not yet been investigated. As reviewed by Symons (1979), this type of assessment is vital if unnecessary mortality of stocked fry is to be avoided.

Elson (1975) considered that an egg deposition of 168 per 100 m^2 (140 per 100 yards^2) was the optimum required for the Miramichi River in Canada. However, the assessment of juvenile survival from which this was derived (Paloheimo and Elson, 1974) indicated that underyearling densities in this river system are much lower than those in the Altnahinch streams i.e., the holding capacity of the Miramichi for juvenile salmon appears to be much lower than at Altnahinch. It is not clear if this is due to less extreme climatic conditions in Northern Ireland, a greater degree of enrichment producing a more abundant food fauna in Northern Ireland streams, differences in the densities of other competing fish species, or is simply due to the fact that the assessment in the Altnahinch streams was carried out in a more suitable nursery habitat for juvenile salmon than the depth and flow regimes encountered in the Miramichi. A combination of these factors is the most likely, but the implications are clear - it is most unwise to extrapolate optimum stocking densities from one river system to another.

At Altnahinch it was found that the effect of scouring by floods can influence the survival of planted ova considerably. Mills (1973) suggested that under natural conditions gradient is one of the main factors limiting salmon spawning in certain streams, with gradients of greater than about 3 percent causing inaccessibility to adult salmon. However, the results described by Kennedy and Strange (1980) indicated that if scouring of planted eggs does not occur, the high overall gradient of stream 2 at Altnahinch did not in itself produce lower holding capacities in terms of fry densities. It was also confirmed that in the presence of salmon parr and trout, salmon fry can inhabit areas of localized high gradient (Kennedy and Strange, 1982). However, the results also indicated that the overwinter mortality or emigration of salmon fry from the higher gradient stream 2 was greater than in stream 1, and the standing crop in terms of biomass was consistently lower. The implication is that calculations of optimum stocking density should also be based on the holding capacity of a stream for salmon parr as well as salmon fry, otherwise the unnecessary mortality effect on stocked fish may simply be delayed from the first year of life to the second. Certainly, the stocking of high gradient streams with ova at any stage can be a hit and miss affair depending on the post stocking weather conditions. Fry stocking in such areas would probably give more consistent success, although this has not so far been tested. What has been confirmed is that optimum utilization of the available habitat in any stream will only occur if care is taken to distribute ova or fry evenly over the river. Stocking only adjacent to convenient bridges or access points will give unsatisfactory results.

While it appears that overall stream gradient can regulate salmon parr survival, the results at Altnahinch also indicated that these will exploit all habitat types in a lower gradient stream. For this reason, Kennedy and Strange (1982) consider that intraspecific competition for space between salmon parr and fry is a critical regulating factor affecting fry survival. Certainly Kennedy and Strange (1980) recorded only half the survival rate of salmon fry stocked in the presence of salmon parr compared to when salmon parr were absent. Stocking operations should, therefore, also be regulated by the density of salmon parr already present in a stream. There may even be a case for alternating years of heavy and light stocking in streams, but the efficacy of this has not yet been assessed.

Similarly, the evaluation of the effect of resident trout on the survival of planted salmon has not yet been completed. Initial results at Altnahinch have confirmed the influence of trout fry on salmon fry. Also, much higher summer densities, improved growth rates and a full utilization of all the available habitat by salmon fry have been recorded in the absence of salmon parr and trout. Only after observations on the survival and distribution of salmon fry in the presence of salmon parr without trout can the relative effects of inter- and intra-specific competition be properly assessed. This work is scheduled for the Altnahinch streams in 1982.

The results of the studies at Altnahinch have certainly confirmed that the survival of stocked salmon is dependent on a number of inter-related factors, and indicate the potential for production of in Northern Ireland rivers. However, optimum utilization of a salmon resource available for stocking requires a careful assessment of local conditions and resident fish populations. The holding capacity and recommended stocking densities for one area cannot be considered as definitive and extrapolated ubiquitously throughout the range for the species.

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Table 1 Details of the population densities of trout fry and stocked salmon in stream 1 at Altnahinch as assessed by electrofishing during late August and early September in the years 1977–81. The percentage survival of salmon stocked each year at a standard density of 6.2/m^2 as eyed ova, green eggs or swim-up fry is also included

Year	Salmon stocking method	Mean summer fry density (N 100/m^2) Trout (from natural spawning)	Salmon (from artificial stocking)	Percentage survival of stocked salmon
1977	Eyed ova	36.6	120.2	19.4
1978	Green eggs	34.9	25.0	4.0
1979	Eyed ova	24.9	118.8	19.2
1980	Swim-up fry	91.3	103.3	16.7
1981	Eyed ova	31.4	108.3	17.5

Table 2 Mean summer densities and percentage survival of salmon stocked as eyed ova at a standard density of 6.2/m^2 in two streams of differing gradient at Altnahinch in 1981. All fish had been removed from the experimental areas prior to salmon stocking, whereas the control area contained salmon parr and all age classes of trout

Stream	Overall stream gradient	Area sampled	Details of stocked salmon survivors Mean Density (N 100/m^2)	Percentage survival
1	1 : 35	Control area	108.3	17.5
		Experimental area	229.8	37.1
2	1 : 22	Experimental area	41.9	6.8

Table 3 Correlation coefficients of the summer densities of each age class and salmon and trout in relation to the gradient at each site during 1977, 1978 and 1979 in the Altnahinch streams

Species	Age class	Year 1977	1978	1979
Trout	0+	0.1147	0.3540*	0.3702 MS
	1+	-0.6636***	-0.5265***	0.6818***
	2++	-0.5588**	-0.6518***	-0.5442**
Salmon	0+	0.4610**	0.3877*	0.7585***
	1++	-0.1844	-0.2166	-0.0472

*	$p < 0.05$
**	$p < 0.01$
***	$p < 0.001$
MS	$p < 0.1$ marginally significant

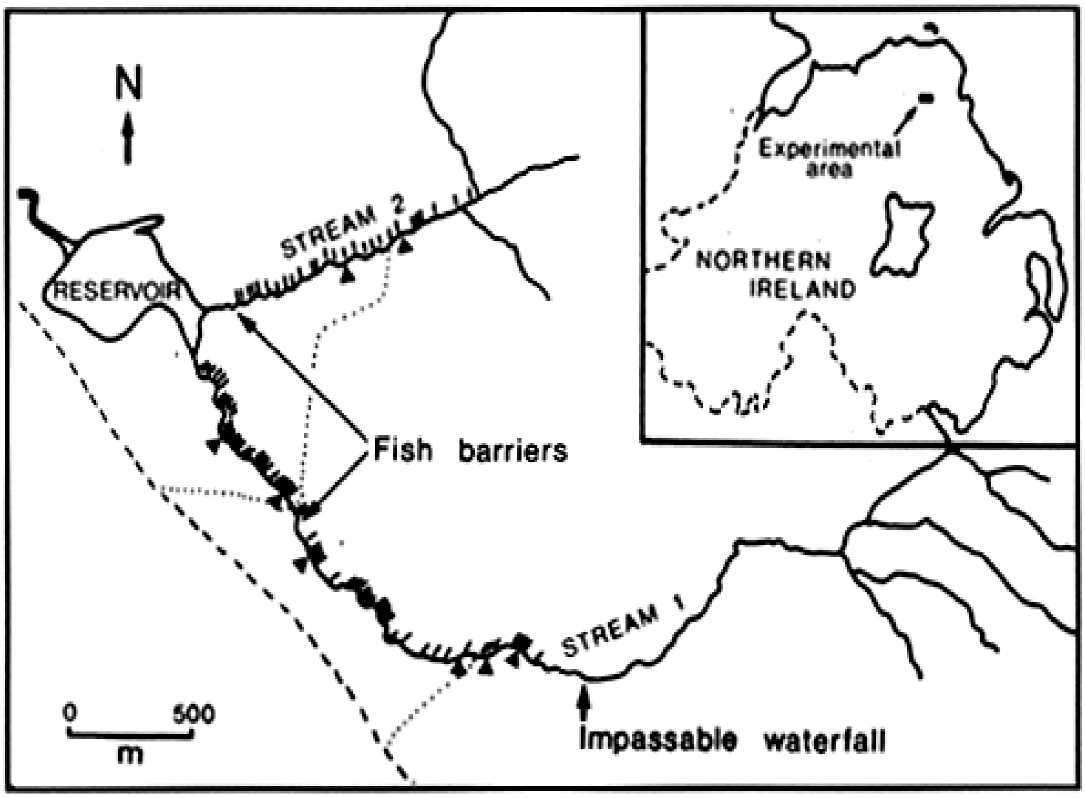

Fig. 1 Map of the experimental Altnahinch streams in Northern Ireland showing the position of fish barriers and the electrofishing sites samples during August/September (\) and March (▼)

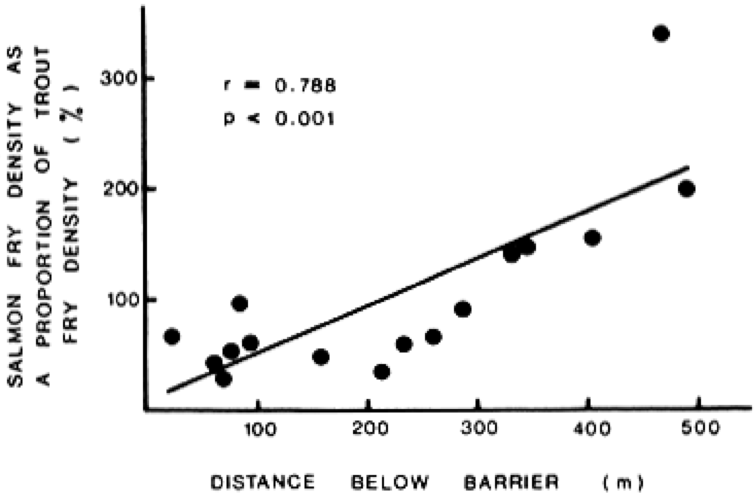

Fig. 2 Densities of stocked salmon fry expressed as percentages of trout fry densities at sites in a 490 m stretch below an impassable stream barrier during August and September 1980

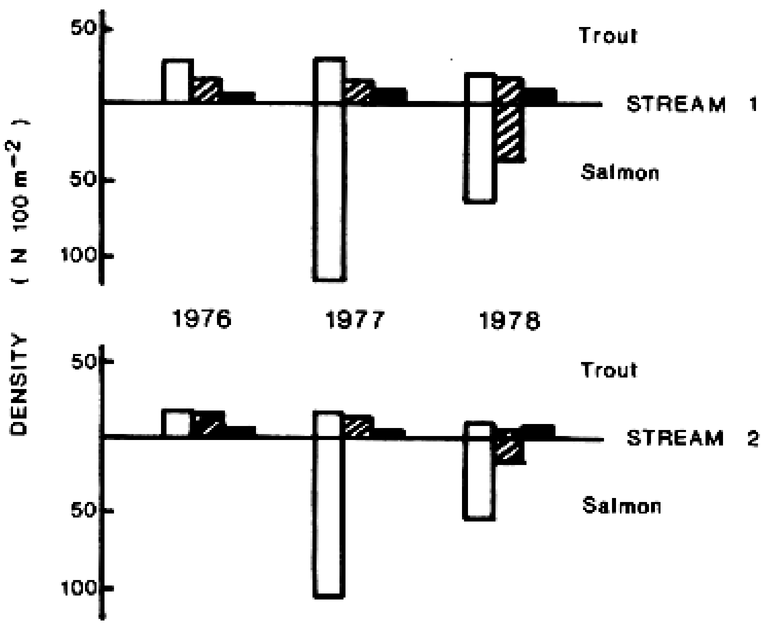

Fig. 3 Mean population densities of trout and stocked salmon (numbers 100 m^{-2}) in the two Altnahinch streams during March 1976, 1977 and 1978 (0+ ☐, 1+ ▨ ; 2+ and older ■)

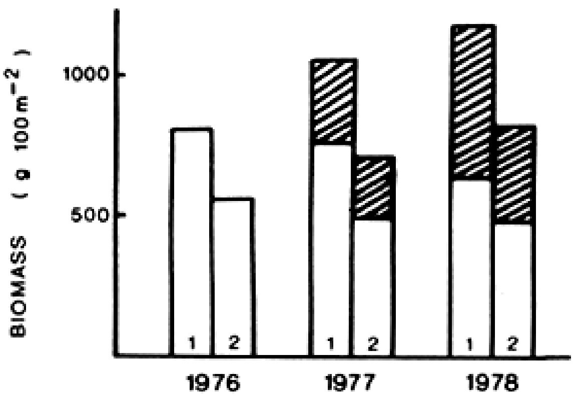

Fig. 4 Mean biomass of trout and stocked salmon (100 g m^{-2}) in the two Altnahinch streams during March 1976, 1977 and 1978 (trout□; salmon ▨)

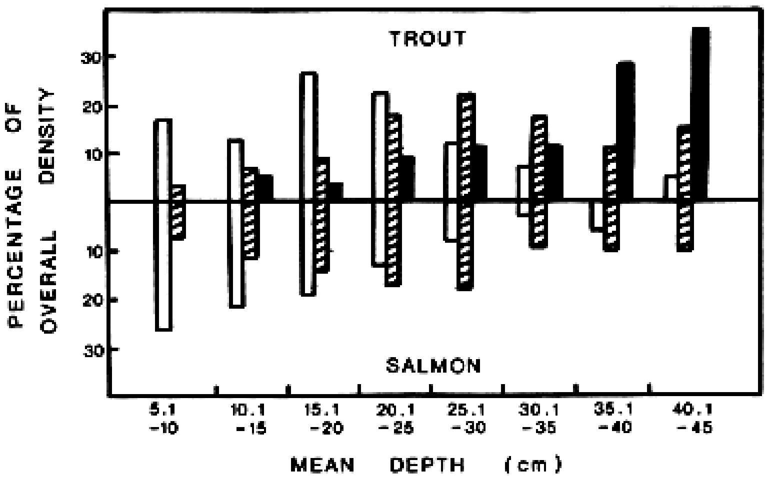

Fig. 5 Population densities of each age-class of salmon and trout captured in various depth ranges, expressed as a percentage of their overall abundance, in the two Altnahinch streams during August and September 1977 (0+ □; 1+ ■ ; 2+ and older ▨)

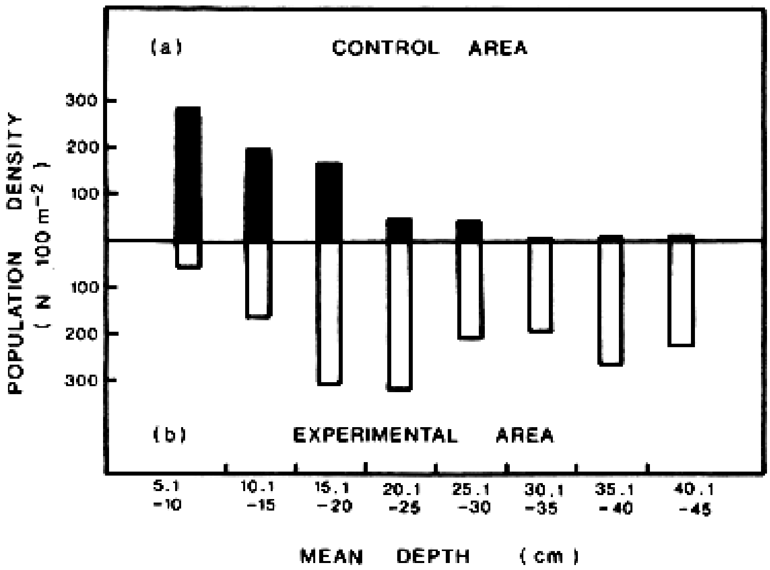

Fig. 6 Population densities of salmon fry (N 100 m^{-2}) captured in various depth ranges (a) in the presence of salmon parr and all age-classes of trout in the control area of stream 1 (■), and (b) in the absence of other fish in the experimental area of stream 1 (□) at Altnahinch during August and September 1981

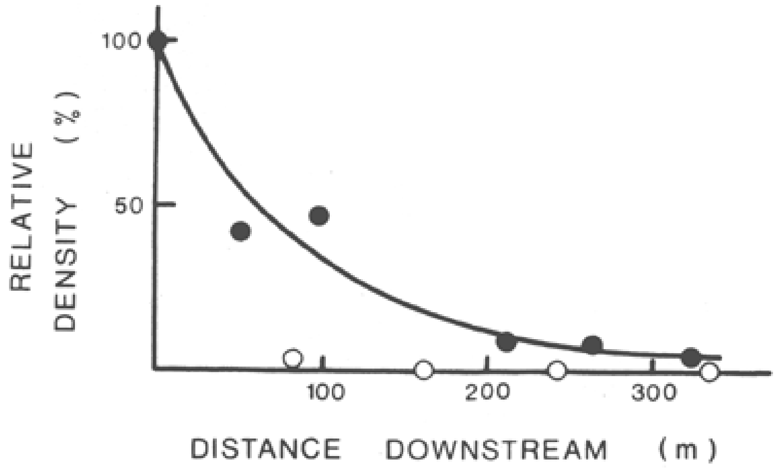

Fig. 7 Relative densities of salmon fry during August and September 1980 expressed as a percentage of the mean density in the stocked area (103.3 per 100 m^2) at varying distances downstream from the lowest stocked point in Altnahinch stream 1 (sites < 25 cm mean depth●; sites > 25 cm mean depth ○). The curve has been fitted by eye to the results from sites < 25 cm deep. Stocking of the upstream area had been carried out with swim-up fry at a density of 6.2 m^{-2}.

SALMON SMOLT STOCK ENHANCEMENT IN THE RIVER TUMMEL, SCOTLAND

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CONTENTS

ABSTRACT

The number of salmon Salmon salar L. spawning in the upper River Tummel has always been regarded as low and from 1953 to 1981 an average of only 153 adults have migrated into it each year. The river is 79 km long, including 48 km through lochs, and it is fed by numerous tributaries, which together drain an area of 820 km^2. There are major hydro-electric installations, with dams and diversions regulating the flow and affecting the successful migrations of smolts and adults. In 1979 a potential productivity of 165 000 smolts per year was determined. At present 10 000–15 000 smolts migrate each year, the majority being two or three years old and between 10 and 15 cm long. A programme of planting six streams with unfed fry commenced in April 1980, eggs being obtained from impounded adult fish.

Instantaneous mortality rates (M per day × 100) of the 0+ age class during the first growing season were low at 0.68–1.25 for plantings at 2.0–3.5/m^2, and were usually 1.2–1.4 at plantings of 5/m^2. Presence of 1+ salmon did not increase mortality of 0+ salmon. Mortality rates in the year following the first growing season were, at 0.14–0.39, low when compared with those of natural populations. The presence of large numbers of 1+ salmon in 1981 did not decrease numbers of trout. Mean daily growth rates of 0+ salmon were generally above 2 percent, with rates being lower in 1981 than in 1980. At the end of the growing season in 1981, 11 400 of an estimated 13 516 1+ salmon present in the streams were larger than 90 mm, and survivors from these will probably migrate as smolts in 1982.

RESUME

Le nombre de saumons, Salmo salar L., frayant dans le cours supérieur de la Tummel, l'un des principaux affluents du Tay, a toujours été considéré comme faible; entre 1953 et 1981, seuls 153 adults en moyenne y ont migré chaque année. La Tummel a 79 km de long, dont 48 km à travers des lacs, et elle est alimentée par de nombreux affluents qui baignent une superficie totale de 820 km^2. Il y a sur la Tummel plusieurs grands ouvrages hydro-électriques, avec des barrages et des dérivations qui règlent le débit des eaux et qui gênent la migration des tacons et des adultes.

En 1979, on a étudié l'écologie du saumon dans le réseau formé par le cours supérieur de la Tummel et par ses affluents. Compte tenu des résultats des recherches sur les populations naturelles de saumons et des expériences de repeuplement, on a évalué la productivité potentielle à 165 000 tacons par an. On estime à 10 000–15 000 le nombre des tacons descendant chaque année la rivière; la majorité d'entre eux ont deux ou trois ans et une longueur de 10 à 15 cm. En avril 1980, on a lancé un programme de repeuplement de certains cours d'eau du réseau avec du frai. Les oeufs utilisés sont prélevés sur des adultes pris au piège. L'auteur donne des détails sur les techniques utilisées, sur les taux de survie et de croissance du frais et sur l'efficacité du projet telle qu'on peut la juger à l'heure actuelle.

1. INTRODUCTION

The number of salmon Salmo salar L. spawning in the upper River Tummel, a major branch of the River Tay in Scotland, has always been regarded as low, and in recent time (1953–81) an average of only 153 adults have migrated through a fish counter into Loch Tummel each year (see Fig. 1). The river from its headwaters on the River Ba down to its junction with the River Garry is 79 km long, including 48 km through lochs, and it is fed by numerous tributaries, which together drain an area of 820 km^2. The low number of adults has been attributed at different times to various causes: to falls near the entrance to the river making access difficult, the several hydro-electric installations, predation of juveniles by pike Esox lucius L. and trout Salmo trutta L., loss of direction by smolts migrating through the large lochs, poor spawning areas and inadequate food resources for fry.

During 1979 a survey of the river and its main tributaries was carried out to assess the potentialities for increasing smolt production and subsequent adult runs through a programme of fry planting, designed on the basis of research carried out in previous years (Egglishaw and Shackley, 1973, 1977, 1980). The survey included an examination of physical, chemical and biological characteristics of the river and details are given in a report entitled “The stock of salmon in the upper River Tummel”. Fry planting commenced in the spring of 1980 and growth and survival of the fish was monitored.

This paper summarizes the observations made during 1979, including some earlier work, and describes the current state of the smolt enhancement programme.

2. THE UPPER RIVER TUMMEL

The arrangement of the lochs and streams in the drainage basin of the River Tummel is shown in Fig. 1. Streams to the west of Dunalastair flow over much harder and less soluble rocks (granodiorite, psammitic granulite) than those to the east of Dunalastair (black schist and limestone out-crops) and their alkalinity (ppm as $CaCO_3$) expresses this difference (range 4.4–18.4 in summer and 0.2–4.6 in high water during the winter for streams in the west, compared with 28.0–60.0 in the summer and 8.4–28.0 in winter for streams in the east). Most of the land in the valley is moorland, usually of heather, but with rough grassland and bog near streams and rivers. Large areas of the moorland have been planted with conifers, and semi-natural woodlands, both coniferous and deciduous, also occur. There is little arable farming. The total population of the valley is about 700. Tourists are attracted to the area by the scenery and for recreational activities.

Since 1927 there have been several dams, weirs, diversion tunnels and aquaducts constructed for hydro-electric generation. The developments resulted in the formation of new reservoirs and the extension of natural lochs flooded spawning areas, as well as created habitats suitable for pike and trout. Fish passes have been provided at five barriers (Fig. 1) and these offer possibilities for monitoring upstream movement of adult salmon.

The salmon smolt populations of the upper River Tummel have been the subject of a number of investigations since 1959. The principal migration of smolts through the fish ladder at the east end of Loch Tummel takes place from March to early June. The majority of smolts are two or three years old and between 10 and 15 cm long. During the period 1967–73, 16 424 were tagged and, of these, 353 were later recaptured as adults.

Most were caught off West Greenland (42 percent) and in the River Tay (53 percent). The fish caught in the River Tay had spent one to three winters at sea.

Trout were present in all 17 streams surveyed in 1979 and salmon were present in four. Since two of the latter (Kynachan, Kinardochy) are stocked by the Tay District Salmon Fisheries Board, a proportion of the fish found could have resulted from artificial planting. The salmon in the two other streams (Frenich, Inverhadden) must be of natural origin. No salmon were found in the streams running into Loch Rannoch or in tributary streams further west. The densities of 1+ age class salmon in the four streams in which they were present ranged from 18 to 35 per 100 m^2, which is similar to densities found in the highly productive Shelligan Burn at the same time of year in the period 1966 to 1979 (i.e., 11–41 per 100 m^2) (Egglishaw and Shackley, 1977). In sections of the River Tummel which have a low, stable flow, high densities of salmon were found (53 and 61 0+ fish per 100 m^2) but sections which fluctuate in flow depending on electricity generation requirements had lower densities (3 and 8 0+ fish per 100 m^2). Only low numbers of salmon were found in the River Gaur and none in the River Ba.

The survey indicated that the production of salmon smolts in the upper Tummel Valley system is much lower than its total production potential. In 1975–77 and 1980 and 1981 and estimated 10 000–15 000 migrating smolts reached Clunie Dam (Struthers, 1978, 1978a). The total production potential of the upper River Tummel was estimated to be 165 000 smolts per year (Egglishaw <u>et al.</u>, 1981).

3. MATERIALS AND METHODS

3.1 <u>Fry planting</u>

The brood stock used to supply the eggs was collected from the River Tummel. Fish were trapped and held until they were ready for stripping (Struthers, 1982). Eggs were counted and kept in a hatchery until required. The unfed fry, with remains of the yolk sac still visible, were planted out as described by Egglishaw <u>et al.</u> (1982). Details of the streams stocked, areas and planting densities, with dates in 1980 and 1981 are given in Table 1. In 1980, 67 136 of the fry were planted at a density of 2.0–2.1/m^2 evenly distributed in three of the more acid streams draining the granodiorite around Loch Eigheach. The remainder were planted at densities of 3.5–6.2/m^2 in the streams draining mainly from the slightly richer psammitic granulite into Loch Rannoch. In 1981 planting densities in all streams were 4.6–5.3/m^2.

3.2 <u>Fish population and growth estimates</u>

At the end of each growing season the numbers of salmon (and trout) present in sections of an area stocked and in sections downstream were estimated by isolating them with stopnets and catching the fish enclosed with electric stunning apparatus (Egglishaw, 1967, 1970). Each estimate (Leslie/DeLury method) was based on four fishings (units of effort) during which between 75 and 95 percent of the fish present were caught in the first two fishings. The lengths of all fish were measured to the nearest millimetre from the tip of the jaws to the fork of the tail. Weights of fish were read from curves relating known fresh weights and lengths. The numbers of survivors at the end of the growing season were estimated. For this purpose the number of salmon in a section not fished was determined from the product of the area of the section and the mean density of salmon in adjoining upstream and downstream sections (Egglishaw and Shackley, 1977). Survival rates to the time of fishing were determined. As the period between planting and electro-fishing at the end of the growing season varied, it is more appropriate to compare instantaneous mortality rates, M. These were calculated according to the formula:

$$M = (\log_e N_1 - \log_e N_2) / (t_2 - t_1)$$

where N_1 is the number of fry stocked at the beginning of the period at t_1 days and N_2 is the number of fish present at electrofishing at the end of the period at t_2 days.

4. RESULTS

4.1 Survival of the salmon

The percentages of fish surviving from the plantings to the time of electrofishing at the end of the growing seasons are given in Table 2. Values of the instantaneous mortality rates, M per day × 100 are also shown. The instantaneous mortality rate of 0+ salmon in the Shelligan Burn remained constant until November (Egglishaw and Shackley, 1977). The values of 0.68 and 0.98 for the populations in Duibhe and in Camghouran, respectively, in 1980 are very low mortality rates for salmon in their first year, and probably can be attributed to the low stocking densities (2.0 and $3.5/m^2$) and the low trout population (2.44 and 1.01 g/m^2 trout of all age-classes, repsectively). Values of M per day × 100 obtained during planting experiments on the Fender Burn (a highly productive tributary of the River Tilt flowing through areas of limestone and black schist) ranged from 0.81 to 1.24 (Egglishaw and Shackley, 1980) and were related to the stocking densities (3 to $30/m^2$) of the fry. Values of M × 100 for the natural population of salmon in the Shelligan Burn (River Almond) ranged between 0.84 and 1.81 for six years (1966 to 1971). In this stream, too, these rates of loss of salmon in their first growing season were related to their population densities (range 2 to 12 on 1 July) (Egglishaw and Shackley, 1977).

The mortality rates of the 0+ salmon in the different streams in the upper River Tummel in 1981 were remarkably similar, M per day × 100 for five of the seven values ranged between 1.28 and 1.41. The stocking density for all streams was about $5/m^2$. The presence of 1+ salmon in five of the stocked areas did not seem to increasse mortality, when compared with areas without 1+ salmon (Camghouran upper, Craiganour).

Of 121 128 fry planted in five streams in 1980, 13 516 (11.2 percent) were surviving in the streams as large parr at the end of their second growing season in September 1981. As they were dispersed right down to the mouth of three streams (Camghouran, Aulich, Dall) it is possible that others had entered Loch Rannoch and the estimates given in Table 2 could be minimum rates of survival. Mortality rates (M per day × 100) between the mid dates of electrofishing in 1980 and 1981 (346 to 388 days for different streams) ranged from 0.14 in Dall Burn to 0.39 in Camghouran lower. These are low mortality rates for salmon in their second year and are comparable to rates of usually 0.28 to 0.40 between successive autumn fishings for salmon in the experimental plantings in the Fender Burn. After the first growing season, mortality rates of the natural population of salmon in the Shelligan Burn were, during 1 December to 31 March, 0.51 ± 0.24 (mean and standard error of six years), during 1 April to 31 May, 1.09 ± 0.54 and during 1 June to 31 October 0.50 ± 0.19 (Egglishaw and Shackley, 1977).

The presence of large numbers of 1+ age class salmon in the streams in 1981 did not appear to have affected the numbers and biomass of trout.

4.2 Growth of the 0+ age class

The mean weights of the 0+ salmon at the end of the growing seasons in 1980 and 1981 are given in Table 3. This table also includes the daily growth rates (G) calculated according to the formula:

$$G = (\log_e W_2 - \log_e W_1)/t_2 - t_1$$

where W_1 is the mean weight of fry at planting, time t_1 days, and W_2 is the mean weight at the end of the season, time t_2 days.

The highest mean rate, of 2.60 percent per day, occurred in the Duibhe Bheag and generally the rates were above 2 percent per day, with rates being lower in 1981 than 1980. The low mean rate of 1.37 percent per day for fish in Camghouran upper was presumably owing to that site being at a much higher altitude (Table 1) and therefore colder, than the others. Temperature was found to be the most important factor determining growth of salmon in the Shelligan Burn (Egglishaw and Shackley, 1977). In all streams of 1981 trout of 0+ age-class grew slower, and attained smaller mean sizes by the end of the growing season, than they did in 1980.

Samples of 0+ salmon were caught in all streams during the spawning season to determine monthly growth rates in weight. Rates declined from very high levels during May (G per month 90– 210 percent in 1980; 84 to 111 percent in 1981 with Camghouran upper 58 percent) to lower ones during August (22–47 percent) and, throughout the growing season, were generally higher in 1980 than in 1981.

4.3 Growth of the 1+ age class

The salmon planted in 1980 attained mean weights of between 9.45 g and 10.59 g in the five streams stocked. Approximately 11 400 of the 13 516 1+ age class salmon estimated to be present in the streams at the end of the growing season were larger than 90 mm. A high proportion of the survivors from these are likely to migrate downstream as smolts during the spring of 1982. About 7 800 will move out of Loch Eigheach catchment (Table 1) and will have to travel 28 km to reach Dunalastair smolt trap. The remainder, from Loch Rannoch catchment, will move between 8 and 17 km to Dunalastair. A total 484 1+ age class salmon longer than 85 mm were tattooed with a fluorescent mark to indicate the stream of origin.

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Table 1 The numbers of unfed salmon fry planted in tributary streams of the upper River Tummel in 1980 and 1981

	1980						1981				
	Extent		Altitude	Date	No. of fry	Density	Extent	Date	No. of fry	Density	
	Length (m)	Area (m²)	(m)			No./m²	Length (m)	Area (m²)			No./m²
Loch Eigheach											
Eigheach	350	3 092	265–280	25/4	6 575	2.1	0	0	-	-	-
Duibhe	1 100	15 143	270–280	19/5	30 777	2.0	1 000	13 883	1 – 8/5	72 448	5.2
Duibhe Bheag	1 400	14 750	300–315	15/5	29 784	2.0	1 300	12 452	28/4–6/5	65 542	5.3
Loch Rannoch											
Camghouran upper		0	375–415	-	-	-	1 400	9 503	24/4–4/5	49 049	5.2
Camghouran lower	600	5 723	206–230	1/5	20 027	3.5	500	4 958	23/4–4/5	22 862	4.6
Dall	400	2 846	218–229	8/5	21 630	6.2	400	2 846	1–4/5	15 079	5.3
Aulich	750	4 875	215–235	12/5	22 910	4.7	700	4 173	29/4–5/5	20 888	5.0
Craiganour		0	245–285	-	-	-	800	3 899	23/4–5/5	20 170	5.2

Table 2 The numbers of 0+ and 1+ age class salmon surviving on the dates shown from the 1980 and 1981 plantings of the tributary streams of the upper River Tummel. The instantaneous mortality rates are given as M per day × 100. Eigheach was not sampled in 1981. Data on numbers and total biomass of trout are included.

		Salmon						Trout			
Stream	Date	No. of 0+	% surviving	M×100	No. of 1+	% surviving	M×100	No./100 m² 0+	1+	2+	g/m²
1980											
Eigheach	29–30/9	1 248	19.0	1.06	0			8	6	1	1.30
Duibhe	25–27/8	15 716	51.1	0.68	0			4	4	2	2.44
Duibhe Bheag	13–17/10	4 463	15.0	1.25	0			9	3	3	2.35
Camghouran lower	18–24/9	4 917	24.6	0.98	0			15	2	0	1.01
Dall	28–29/8	3 770	21.4	1.38	0			20	10	8	4.50
Aulich	10–15/9	2 828	12.3	1.70	0			26	9	2	2.21
1981											
Duibhe	21/8–7/9	13 806	19.1	1.35	7 127	45.3	0.21	4	3	4	2.10
Duibhe Bheag	8/9–14/10	7 000	10.7	1.41	1 790	40.0	0.25	3	2	3	1.00
Camghouran lower	12–15/10	2 285	10.0	1.37	1 099	22.4	0.39	7	3	1	0.97
Camghouran upper	20–23/10	8 679	17.7	0.99	0			3	3	1	1.08
Dall	18–20/8	3 719	24.7	1.28	2 313	61.4	0.14	32	14	6	4.64
Aulich	21–26/8	5 654	27.1	1.16	1 187	42.0	0.25	63	16	4	4.30
Craiganour	10–16/9	3 066	15.2	1.38	0			14	35	6	6.85

Table 3 Growth rate in weight (mean G per day) of 0+ salmon between planting and the end of the growing season. Weight at planting was 0.13 g and fish are assumed not to grow in weight after 15 September

	1980			1981		
Stream	Weight at end of season	Time	G×100	Weight at end of season	Time	G×100
	(g)	(days)		(g)	(days)	
Eigheach	2.27	143	2.00			
Duibhe	2.72	119	2.56	1.98	134	2.03
Duibhe Bheag	3.11	122	2.60	2.03	136	2.02
Camghouran upper				0.87	139	1.37
Camghouran lower	2.27	137	2.09	1.43	139	1.73
Dall	2.40	130	2.24	2.00	135	2.02
Aulich	1.74	126	2.06	1.82	135	1.96
Craiganour				1.43	139	1.73

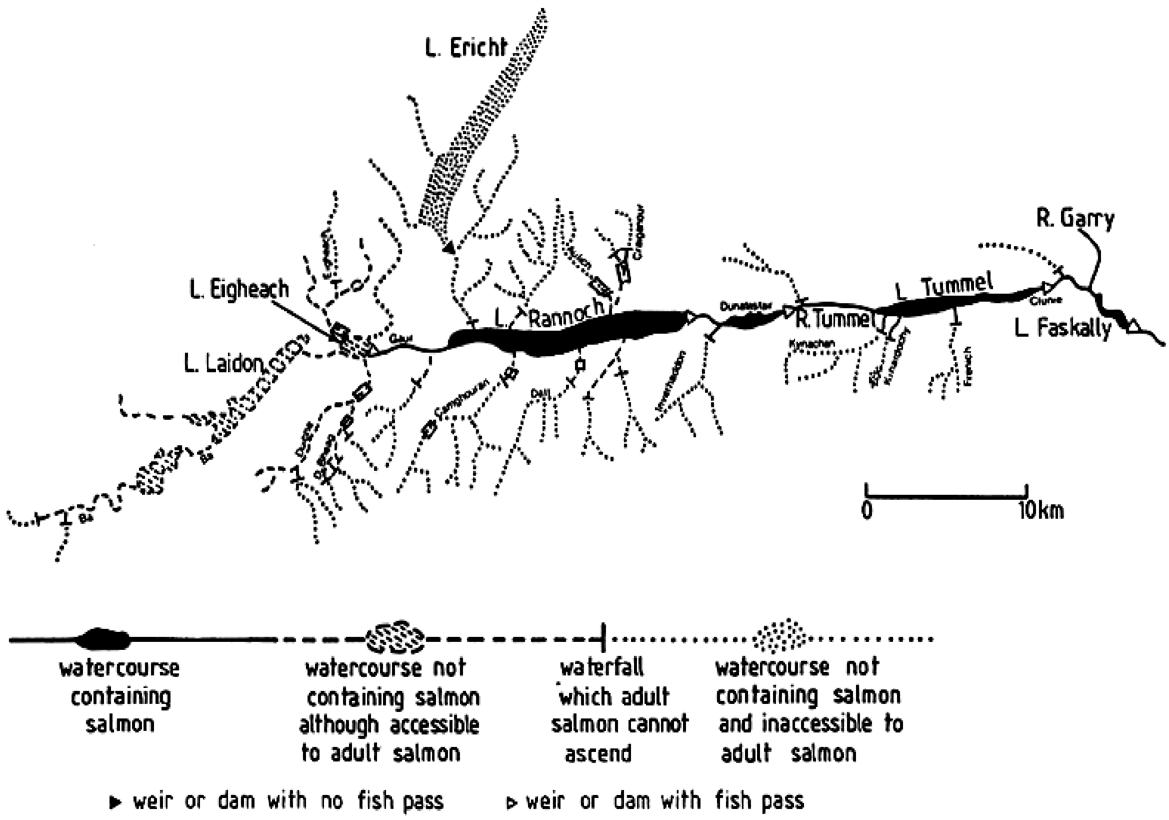

Fig. 1 The distribution of juvenile salmon in the upper River Tummel and its tributaries in 1979. About 71 ha of stream bed is accessible to the average of 153 adult salmon which enter the upper River Tummel each year. Juvenile salmon were found in only 25 ha. Areas which have been planted with fry are boxed.

A REVIEW OF FISH STOCKING IN FINLAND

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CONTENTS

ABSTRACT

The objectives of fish stocking in Finland have been to compensate for the damage done by hydro-construction, water level regulation and water pollution, particularly noticeable in the case of river-spawning fish species; to maintain, strengthen and improve the quality of fish populations; and to create entirely new fishing opportunities.

Fish stockings have increased considerably since the fifties. In 1980, stockings of 21 fish species (15 native and 6 introduced) and one crayfish species were carried out. In that year, 196.3 million newly-hatched fish were stocked, of which about 88 percent were whitefish (Coregonus sp.) and 9 percent were pike (Esox lucius). The number of cultivated, one-summer old or older stocked juveniles was 34.4 million individuals. The vast majority of these (83 percent) were also whitefish. The next most frequently stocked were brown trout and sea trout (Salmo trutta m. lacustris and S. trutta m. trutta), pike, Atlantic and landlocked salmon (S. salar and S. salar m. sebago) and grayling (Thymallus thymallus). In the near future in Finland, the obligation to stock salmon, sea trout and brown trout and whitefish in particular, will increase considerably because of the necessity to compensate for the damage caused by construction in the water systems.

Stocking of newly-hatched fish have been most successful primarily in waters in which the natural reproduction of a species has been disturbed, as well as in some cases in the introduction of certain species to new locations. However, such stockings have evidently not significantly improved the catch in waters where the species is already reproducing in sufficient quantities. A well planned and executed stocking with sufficiently large juveniles has usually had good results in water suitable for the species. It has proved to be difficult to increase the profitability of fisheries, by stocking into waters whose quality has deteriorated as a result of hydro-construction, lake water level regulation or pollution. This paper deals species by species with the fish and crayfish stockings carried out in Finland, and evaluates their results.

RESUME

En Finlande, les objectifs du repeuplement sont les suivants: compenser les dommages occasionnés par la construction d'ouvrages hydro-électriques, par la régulation du niveau des eaux et par la pollution aquatique, dommages particulièrement graves dans le cas des espèces frayant dans les cours d'eau; renforcer les populations de poissons et en améliorer la qualité; créer des possibilités de pêche entièrement nouvelles.

La pratique du repeuplement s'est considérablement développée depuis les années cinquante. En 1980, les eaux ont été repeuplées avec 21 espèces de poisson (15 indigènes et 6 exotiques) et une espèce d'écrevisse; on a utilisé 196,3 millions de poissons nouvellement éclos, dont environ 88 pour cent de poissons blancs (Coregonus sp) et 9 pour cent de brochets (Esox lucius). Le nombre de juvéniles d'élevage, d'un été ou plus, utilisés pour le repeuplement atteignait 34,4 millions d'unités. Ici aussi, il s'agissait dans la grande majorité des cas (83 pour cent) de poissons blancs. Parmi les espèces les plus utilisées ensuite, on citera la truite (Salmo trutta m. lacustris et S. trutta m. trutta), le brochet, le saumon atlantique et le saumon des eaux intérieures (S. salar et S. salar m. sebago) ainsi que l'ombre commun (Thymallus thymallus). Dans un proche avenir, il faudra faire un effort de repeuplement encore plus important, notamment en ce qui concerne le saumon, la truite et le poisson blanc, pour compenser les dommages occasionnés par les ouvrages construits sur les cours d'eau.

Le repeuplement avec des poissons nouvellement éclos a été particulièrement efficace dans les eaux où la reproduction naturelle d'une espèce avait été perturbée ainsi que dans certains cas d'introduction. Evidemment, ces opérations n'ont pas entraîné de forte augmentation des captures dans les eaux où la reproduction était déjà satisfaisante. Les opérations bien planifiées et bien menées de repeuplement avec des juvéniles suffisamment développés ont en général donné de bons résultats dan les eaux qui convenaient aux espèces utilisées. On a observé qu'il était difficile d'accroître grâce au repeuplement la rentabilité des pêches dans les eaux dont la qualité s'était dégradée par suite de la construction d'ouvrages hydro-électriques, de la régulation du niveau des lacs ou de la pollution. Les auteurs examinent espèce par espèce les opérations de repeuplement effectuées en Finlande avec des poissons et des écrevisses et en évaluent les résultats.

1. INTRODUCTION

1.1 Inland waters and their state

The inland waters of Finland cover 31 613 km^2, which is about 9.4 percent of the total area of the country. There are over 60 000 lakes, 17 of which have a surface area of more than 200 km^2. Typically, the lakes are joined through sounds and short streams forming long water courses. The total length of the rivers exceeds 20 000 km.

The lakes are shallow, the average depth being 7 m. Most of the lakes (86 percent) are oligotrophic and the eutrophic lakes (14 percent) are generally located in the south and southwest, in clay-soil areas.

Technological and economic development have brought with them marked changes in the condition of the Finnish lakes and rivers. The damming of rivers, clearing of obstructions, dredging, flood control measures, regulation of water levels and stream flows, water pollution, timber floating and forest ditching have all had a deleterious effect. Some 20 percent of the total surface area of Finnish lakes is significantly affected by waste water, and the water level in most large lakes is being regulated for purposes of hydro-electric power generation. About 1 400 km^2 of the coastal waters have also been changed from their natural state. The major portion of the largest rivers, about 9 000 km combined length, is at best only in satisfactory condition from the point of view of fisheries.

The stocks of many valuable river-spawning migratory fish species have been seriously damaged by the river damming and construction operations. Concerning the Finnish rivers flowing into the Baltic, salmon (Salmo salar) are still found only in three rivers. The natural salmon smolt production from Finnish territory to the Baltic nowadays amounts to less than 350 000 individuals instead of the 2.5 million that existed when the waters were in their natural state. The number of spawning rivers for the landlocked salmon, sea trout (S. trutta m. trutta), brown trout (S. trutta m. lacustris), migratory whitefish (Coregonus lavaretus and C. muksun) and lamprey (Petromyzon fluviatilis) have also declined dramatically.

The construction of hydro-electric power plants, regulation of water levels and other such activities, have decreased in Finland in recent years, and the water quality has been improving through more effective waste-water treatment.

1.2 Management of fish stocks

Under the Fisheries Act the owners of fishing waters are responsible for the conservation and management of fish stocks. Waters within village limits are generally jointly owned by local landowners, those outside the villages by the State. Currently about 85 percent of all inland fishing waters are privately owned. Fishing rights are generally held by the owners, each landowner's share and fishing rights in a jointly-owned water area depending on the size of his estate (Munne, 1980; Sjöblom et al., 1980).

Under the Fisheries Act (coming into force on 1/1/83) the water owners from a village will be obliged to form a fishing commune to define the extent of fishing rights for each shareholder. These obligations can, however, be transferred to a larger administrative body, the so-called "Fisheries Area".

Government responsibility for both inland and marine fisheries and their management in Finland is vested in the Ministry of Agriculture and Forestry. Most State-owned waters are administered by the National Board of Forestry. There are three government-sponsored organizations for fisheries and their management: the Federation of Finnish Fisheries Associations, the Federation of Finnish Recreational Fishermen's Associations and the Finnish Fish and Game Association.

In the management of fish populations in Finland, fish stocking plays a central role. Through stocking, fish populations already present are preserved and strengthened, and exhausted stocks are replaced with new ones. In acclimatization stocking a new fish species is introduced to a watercourse; in supplementary stocking a species already living in the watercourse but diminished in numbers is stocked; in transfer stocking mature fish are transplanted from one body of water to another; in repetitive stocking species not reproducing in natural conditions are stocked. Obligatory stockings, which are made pursuant to decisions in Water Courts, are aimed at the repair of damage caused to fish stocks by hydro-construction or other changes in water courses (Sjöblom et al., 1980).

Fish stockings in Finland are primarily financed by fishing communes in privately owned waters, the State and others, e.g., hydro-electric power companies, cities, industry, etc., who make mostly obligatory stockings (see Salojärvi, 1982).

Government fish culture is organized by the Finnish Game and Fisheries Research Institute and its ten aquaculture stations. The latter do not generally sell juvenile fish but use them for stocking in places where wild stocks have become depleted and are in danger of extinction, for ensuring fish farms of a steady supply of wild fish eggs, or for research and trial purposes. In addition, fish are released in the sea and the larger inland water bodies for general management purposes.

2. FISH STOCKING IN FINLAND

2.1 General

Fish stocking has increased considerably since the fifties. Since 1978 the Finnish Game and Fisheries Research Institute has prepared annual statistics which have included details concerning the number of juveniles released, the number of established fish hatcheries and their capacities. These statistics are obtained through a questionnaire sent out to all fish farms (Sumari and Eskelinen, 1980). Data abstracted from the fish-culture statistical report and relating to the stocking of juveniles over the period 1978–80 are presented in Tables 1 and 2.

The stocking of all significant species over the period has increased. In 1980, stocking of 21 fish species (15 native and 6 introduced) and one crayfish species was carried out. In that year, 196.3 million newly-hatched fish were stocked, of which about 88 percent were whitefish (Coregonus sp.) and 9 percent were pike (Esox lucius). Newly-hatched whitefish and pike are released mainly because eggs of these fish are easily come by and techniques for their incubation are known. The number of newly-hatched juveniles released depends to a large extent on random factors, and varies considerably.

In 1980, the number of cultivated, one-summer or older stocked juveniles was 34.4 million individuals. The vast majority of these (83 percent) were also whitefish. One-summer whitefish, of length approximately 10 cm and introduced into inland waters, amount to six fish per hectare of Finnish lake. The next most frequently stocked were brown and sea trout (Salmo trutta m. lacustris and S. trutta m. trutta), pike, Atlantic and landlocked salmon (S. salar and S. salar m. sebago) and grayling (Thymallus thymallus).

The value of juveniles produced for release by fish hatcheries and natural food ponds was approximately 25 million FIM (U.S.$ 6.3 million) in 1980. The cost of stocking per water hectare of inland waters and of the coastal fishing zone was approximately 2.5 FIM.

2.2 Stocking of cultivated juveniles

2.2.1 The whitefish (Coregonids)

The total number of one-summer whitefish are as follows for the four most important species:

Coregonus lavaretus (L.) s. str.	30–55 percent	(8 876 000 ind. in 1980)
C. muksun (Pallas)	20–30 percent	(7 986 000 ind. in 1980)
C. peled (Gmelin) s. Berg	10–20 percent	(5 164 000 ind. in 1980)
C. pidschian (Gmelin)	5–10 percent	(3 109 000 ind. in 1980)

Small numbers of C. oxyrhynchus L. have also been stocked.

C. lavaretus is raised most commonly in northern Finland, from the largest rivers of which cultivated strains have also originated (Salojärvi, 1982a, 1982b).

Most of the stockings with C. pidschian have been carried out in regulated Lake Inari area. Only the Lake Inarijärvi strain has been used in fish farming. C. muksun is raised and employed for stocking purposes throughout the country. Natural stocks of the species are meagre, and lack of eggs has limited cultivation. The raising of brood fish in fish farms has increased the availability of eggs and the species has been stocked more frequently. C. peled was introduced to Finland in 1965 and it has increased rapidly in the management of lakes in south and central Finland where whitefish have not previously existed and also in eutrophicated lakes (see Westman and Tuunainen, 1983).

In addition to the species mentioned above, hybrid whitefish forms are cultivated. Annually, large numbers of juveniles are transferred from north Finland to the southern parts of the country, where the demand exceeds the supply.

The hatching of vendace (C. albula) eggs is spasmodic and only newly-hatched juveniles are stocked.

2.2.2 Atlantic salmon, sea trout and brown trout

The objective of the stocking of Atlantic salmon smolts is to compensate for the damage caused by hydro-construction. The stocked numbers of smolts have greatly increased over the last few years and will increase even in the near future with the implementation of certain large-scale stocking schemes based on decisions in Water Courts. Stocking of Bothnian Bay is carried out using the three indigenous salmon strains from rivers draining into the area still left. The original salmon strains from the rivers of the Bothnian Sea and the Gulf of Finland have disappeared and strain from the River Neva (U.S.S.R.) is being used for stockings in these.

Sea trout and brown trout are cultivated in all parts of the country and are employed in the management of both the inland waters and the coastal districts. The number of migratory juveniles produced for stocking purposes is larger than the reduction in numbers of wild juveniles. A large proportion of trout releases are made in connexion with voluntary management of fish stocks. Several different strains of sea trout and brown trout are used in production and hence the species compete for the same space at fish farms.

2.2.3 Other salmonids and grayling

In addition to Atlantic salmon and sea trout and brown trout, salmonid fishes used for stocking are landlocked salmon, char (Salvelinus alpinus), lake trout (S. namaycush), brook trout (S. fontinalis), grayling (Thymallus thymallus) and rainbow trout (Salmo gairdneri). Some 50–150 thousand landlocked salmon smolts are produced annually. The cultivated strain is a relict form from the Vuoksi watercourse (Seppovaara, 1962; Westman, 1970). Juveniles are released in the Vuoksi watercourse and in the northernmost Finnish lakes. Char and lake trout are mainly cultivated and stocked in north Finland. Juveniles from the native char strains are released annually to the extent of 50 000 individuals.

A more important species for the management of fishing waters is the North American lake trout, which has become acclimatized to Finnish conditions (Mutenia, Simola and Tuuniainen, 1983). The numbers of this species stocked are 50 000–300 000 specimens annually. The production numbers for the brook trout and splake, both originating from North America (Westman and Tuunnainen, 1983), are far smaller than the former species.

Cultivation of grayling, as with char and lake trout, is concentrated in the northern part of the country. Annual production of one-summer juveniles for stocking purposes has been on average 500 000 individuals.

The stocking of natural waters with rainbow trout is not carried out very much, and is primarily for “put and take” fishing. The rainbow trout is the only species of significance in food fish production (Westman and Tuunainen, 1983).

2.2.4 Pike, perciforms and cyprinids

Pike (Esox lucius), perciforms and cyprinids are cultivated in Finland far less commonly than salmonids. Cultivation is concentrated in south Finland. Newly-hatched pike fry are stocked annually to the extent of around 20 million individuals. Eggs are obtained from brood fish caught on the spawning grounds in the wild. A large proportion of pike eggs are incubated in temporary field hatcheries.

Pike-perch (Stizostedion lucioperca) is the only perciform cultivated, the annual production (below 100 000 individuals) of one-summer old fingerlings satisfying only a small part of the demand. An obstacle to greater production is the lack of eggs.

There is little cultivation of cyprinids. A few score thousand juveniles of bream (Abramis brama), carp (Cyprinus carpio) and tench (Tinca tinca spp.) are stocked annually (Ahlfors, Kummu and Westman, 1983; Westmand and Tuunainen, 1983).

3. CULTIVATION OF JUVENILES FOR STOCKING

3.1 Production methods

The main production methods for juveniles of the more important cultivated species are presented in Table 3. In whitefish stocking, one-summer fingerlings are used and these are produced almost entirely in large natural food ponds up to 200 ha in size. The eggs required for raising whitefish migrating into the sea are obtained for the most part from brood fish caught in the wild. In fresh water, brood fish, river-spawning forms, have had to be reared artificially. Brood fish have been raised extensively on natural food in small lakes but recently an increasingly large number have been raised by intensive cultivation methods at fish farms.

Eggs which are incubated in jars hatch in May–June and fry are released in the ponds as soon as they hatch. Production per hectare is an average 50–60 kg during the summer. Variations in production capacity owing to pond type and local climatic differences are great. Increasing production capacity by fertilization and additional feeding has been attempted. Over 90 percent of the total surface area (4 700 ha) of natural food ponds throughout the whole country is used for whitefish cultivation.

The transference of whitefish juveniles from natural food ponds to stocking waters is in many cases arranged so that the fingerlings are carried by the water to the site when emptying the pond. For transfer stockings, fish are either collected in a catching box sited in the drainage ditch or are caught in the pond in small mesh trap nets.

Cultivation methods for grayling and pike-perch differ very little from the above. Eggs of both species required for raising purposes are mainly collected from the wild. Pike-perch are stocked in natural food ponds either as eggs, as newly-hatched fry or as feeding juveniles.

Smolts and juveniles of salmon, trout and other predatory salmonids are produced principally by the conventional intensive cultivation method at fish farms. As a result of the drastic weakening of wild salmon stocks, the acquisition of eggs from wild spawning is unreliable as well as insufficient to meet needs. Hence, the amount of eggs required for stocking purposes has been ensured by establishing brook fish stocks at fish farms. In order to prevent genetic weakening of stocks and domestication in farm conditions, brood fish shoals are as far as possible raised from wild-collected eggs.

Incubation trays are generally employed for incubating the eggs of salmonid fishes. For the first year of rearing the fish are generally raised in rearing halls in small plastic tanks. The most common site for the second year of rearing are largish earthen ponds with continuously changing water. Swedish-style concrete circular tanks are also utilized to a certain extent. The most common age for stocking is two years, but in northern Finland three-year old smolts are also released. For feeding purposes factory-produced dry feed is employed almost exclusively.

Trials have been initiated in raising juveniles in the warm-water effluent of power stations (Tuunainen et al., 1981). New techniques, including water recirculation, heat exchange using exchangers and pumps, and the pre-treatment and post-treatment of water, have recently been adopted particularly at the incubation and fry stage.

3.2 Fish farms

The number of fish farms in Finland increased during the seventies. Developments during the period 1978–80 regarding the number of fish farms and various production centres are presented in Table 4.

Fish farms are owned by the State, fishery associations, private persons and fish enterprises, or by wood processing, power and similar companies. The State fish cultivation stations produce eggs and juveniles for further rearing at other farms, and the State also raise fish for their own stocking programmes, which are carried out for research purposes, for safe-guarding the supply of eggs, or for supplementing fish stocks in State-owned water bodies. The fish farms owned by the fisheries associations and companies produce juveniles for their obligatory stockings or for voluntary fish stock management purposes. The production of fish for stocking by private commercial fish enterprises is marketed for voluntary management of fishing waters. An appreciable proportion of juveniles needed for obligatory stocking purposes are produced under contract at private commercial fish farms.

In terms of specializations, the fish farms vary considerably. Farms involved solely with hatching are located near the places from which eggs can be collected from wild brood fish. Private natural food pond enterprises are not generally involved in hatching operations. The largest commercial enterprises are specialized in the production of one stage or another. The state's central fish cultivation stations are involved in the most comprehensive activities of all covering brood fish raising, egg hatching and juvenile raising, of many species and strains using intensive cultivation and natural food pond methods.

3.3 Cultivation facilities

A large proportion of fish-farm rearing space is given over to the raising of rainbow trout for food. Net cages and net enclosures are utilized almost entirely for this purpose. The production of rainbow trout in Finland in 1980 was almost 5 000 t. Rainbow trout is marketed after the third rearing period, when it weighs 0.5–1.5 kg.

Hatching jar or cylinder capacity has not increased significantly over recent years, in spite of the fact that the amount of stocking has increased. Owing to the wide variation in the quantities of eggs obtained from the wild, there is an excess of incubation space when compared to average years. It has thus been possible to incubate more eggs by raising the degree of utilization. The increase in hatching trough space for salmon, trout, rainbow trout and char is keeping pace with the growth in the number of eggs requiring incubation.

The rearing space at fish farms has kept pace with the increase in production. The increasing intensification usage at fish farms is leading to wider use of circular tanks. Water conservation aspects also affect the type of ponds and basins utilized. Waste arising through fish cultivation operations must be collected in a more controlled manner as well as more quickly than previously. This has resulted in attempts at making ponds self-cleaning. The monitoring guide issued by the water protection authorities recommends that net-cage establishments be prohibited in inland water districts.

Natural food pond cultivation increased rapidly throughout the seventies. The size of the ponds, their location and number of ponds per station depend on the nature of places suitable for use as ponds. The average size of ponds is greatest in northern Finland.

3.4 Distribution of juvenile production

The distribution of salmonid and coregonid juvenile production in 1978 is illustrated in Fig. 1. The principal area for production is northern Finland, where the adverse effects of constructions in inland waters on the natural production of these fish are at their strongest. The concentration of production in northern Finland is greatest with those species the juveniles of which are raised in natural food ponds. This results from the abundance of sites suitable for use as fish ponds and also from the fact that the State grants more money from its employment fund for pond construction in northern Finland than for the same purpose in the southern part of the country. Several non-salmonid species utilized in stocking schemes live at the extreme northern limits of their range in Finland and these are raised and employed for stocking in southern Finland.

4. RESULTS OF STOCKING

In order to investigate the results of fish stocking, large numbers of fish are tagged in Finland annually. The usual form of tagging is by means of the Carlin tag. Table 5 presents the number of fish tagged with Carlin tags in Finland during the period 1978–80. During the last couple of years one-summer whitefish in particular have been marked by nose-tagging.

4.1 Coregonids

The coregonid species used for stockings in Finland in the last few years are Coregonus pidschian (Gmelin), C. lavaretus (L.), C. oxyrhynchus (L.), C. muksun (Pallas), G. peled (Gmelin) and C. albula (L.). C. pidschian, a benthos feeder in the lakes of Finnish Lapland, has been released into the lakes of northernmost Finland. For example, in order to compensate for damages which have been caused to the fishery on Lake Inari by water level regulation, one million autumn fingerlings per year will be stocked. A monitoring programme for the evaluation of the results of the stocking scheme is currently underway. The results are unknown at present since full-scale stocking has been carried out only over the last few years. The mean recruiting age (t) for C. pidschian in Lake Inari is 4–5 years (see Toivonen et al., 1981).

C. lavaretus, the migratory whitefish, is the species which has been stocked in highest numbers in Finland. Most of the newly-hatched larvae have been stocked into the sea but also into the lakes in smaller numbers. In inland waters mainly one-summer old fingerlings have been used. In his report for this symposium, Salojärvi (1982) deals with the results of stockings with this species. The results from stocking with fry in inland waters have usually been quite poor (average catch 2–4 kg/1 000 stocked in eight lakes) but with autumn fingerlings quite satisfactory (average catch 120–150 kg/1 000 stocked in eight lakes). Catches based on stocks maintained by stocking with about 1–3 kg fingerlings/ha/year have been reported from nothern Finland.

C. oxyrhynchus, a whitefish species typical to the lake district of Finland, has been recently used for stocking only in small quantities and the results of stocking with autumn fingerlings are unknown. There is at least one remarkably successful stocking with this species. Lake Pyhäjärvi (154.5 km^2), in southwest Finland, was stocked with fry of C. oxyrhynchus in 1921–23 after a previous attempt with C. lavaretus fry in 1910–13 failed. C. oxyrhynchus established a permanent stock in the lake and the annual catches have been over 100 t.

C. muksun, a plankton feeder from eastern Finland, is one of those whitefish species which will become more and more common in fisheries management in Finland. Numerous practical experiences with this species are very promising. However, only a few studies have been made on it. In small forest lakes in southern Finland it did very well (see Hakkari et al., 1983; Pruuki, Pursiainen and Westman, 1983) feeding on zooplankton and giving an annual net production of 2 kg/ha in one experimental lake and 23 kg/ha in another.

C. peled, a Siberian plankton feeder, has been introduced in a number of Finnish lakes after its importation in 1965. There is at least one very successful introduction with newly-hatched larvae of C. peled. This is the Lokka reservoir (maximum area 417 km^2) in Finnish Lapland, where the catch was 15 kg/1 000 introduced fry (see Salojärvi, 1982). Also stocking attempts with fingerlings have given fairly good results. In the Lokka reservoir, the catch has even been 12 percent (10 t) of the total catch (see Westman and Tuunainen, 1982). In small forest lakes in southern Finland it has given good results too, the annual net production being 4 kg/ha in one experimental lake and 31 kg/ha in another (see Hakkari et al., 1982; Pruuki, Pursiainen and Westman, 1983).

C. albula, the vendace or cisco, is a plankton feeder. Numerous new stocks have been established by transplantation of adult fish or fry of vendace mainly at the end of the 19th and the beginning of the 20th century. Stocking of lakes with newly-hatched larvae has been very common up to the seventies because the eggs have been readily available and their incubation is easy. On the basis of practical experiences, it is commonly believed nowadays that stocking of large lakes with vendace fry is unprofitable.

4.2 Stocking results of salmon, sea trout and brown trout in the seventies in Finland on the basis of taggings

Reared salmon smolts have been released into the Baltic Sea in Finland since 1959, sea trout smolts since 1962 and brown trout in inland waters since the fifties. The results of stockings have been followed by means of tagging experiments. The tag most commonly used was the Carlin tag. The mean number of tagged salmon in each experimental group during the seventies was in the main about 1 000. In experimental groups of sea trout and brown trout there have generally been about 500. Salmon stocking has been done mainly in spring when the water temperature in the river approaches 10°C. Salmon smolts have been two-three years old. Sea trout and brown trout stockings have also mainly been in the spring though quite a large proportion have also been released during the autumn, when the age of the fish has been two summers.

Salmon smolts have been released into the estuary or its surroundings. However, some experiments have been carried out with stocking salmon quite far from the coast and from the estuary. For instance, in the Archipelago Sea salmon have been released into the coast of the Aland Isles in brackish water. Freshwater resources in the area are severely limited.

Sea trout stockings have been carried out mainly in the coastal area. Some of the smolts have been transported further from the coast by boat and a smaller part have been released into the rivers or river mouth surroundings.

Brown trout smolts released into inland waters have been mainly dispersed to the shores of lakes. However, some brown trout stocking has been done in the rivers flowing into lakes and a small proportion in rivers flowing into the Baltic Sea.

Sea trout and brown trout stocking has been made over almost the same period.

The mean length of wild salmon smolts in the River Simojoki has been 15.5 cm. The mean length of salmon smolts employed for stocking has been about 14 cm. Sea trout and brown trout stockings have mainly been done using smolts of 18–20 cm (mean). However, in the regulated lakes bigger smolts (about 25 cm) have been used.

The migration pattern of salmon of the northern strains differs from that of the southern ones. Salmon strains of the rivers flowing to the Bothnian Bay area are wide-migrating. Most of these fish migrate to the southern Baltic proper. Southern stocks, for instance River Neva stock released from the estuary of the River Kymijoki which flows into the Gulf of Finland, do not migrate so far. On the basis of tagging results, only 14 percent of all recoveries have been made outside the Gulf of Finland. In comparison with River Oulujoki stock in the Bothnian Bay area, the majority of recoveries have been made in the Baltic proper. In the Bothnian Sea area tagged salmon of River Neva stock and River Iijoki stock (Bothnian Bay) were released in the estuary of the River

Kokemäenjoki. Recoveries of River Neva stock were mainly made in the Bothnian Sea area. Outside this area only 12 percent of all recoveries were caught. River Iijoki stock migrated mainly into the Baltic proper and less than 50 percent were caught in the Bothnian Sea area.

Sea trout do not migrate to the same extent as Atlantic salmon. The majority of recoveries of sea trout taggings have been made within 100 km from the release point (Toivonen and Tuhkunen, 1975). It has also been observed that sea trout migrate with the current in the Gulf of Bothnia. The current flows along the Finnish coast in a northerly direction and along the Swedish coast in a southerly direction. Sea trout taggings in the northern part of the Bothnian Bay area have revealed that more than 10 percent of all recoveries have been made from the Swedish coast to the Bothnian Bay, where fish have migrated with the current by following the coastline.

The migration area of brown trout is also not so extensive as that of landlocked salmon. In the watercourses brown trout mainly stay in or near lakes where they have been released in contrast to landlocked salmon which migrate several hundred kilometres along the watercourse.

A diminishing trend in yields per 1 000 released salmon smolts since 1972 has been very obvious. The 1972 summer was exceptionally warm and this might explain the good results of stockings. Later years have, however, given progressively worse results. The reason might be less favourable weather conditions. However, the total catch of salmon in the Baltic Sea has not decreased in a similar way as tagging results show. It is obvious that stocking has given poor results only through tagged fish. Untagged fish must have given much better results than the tagging results suggest. The reason seems to be dependent on taggings and one important fact is the increase in numbers of unreported tags. During the last three-four years limitations on salmon fishing have been demanded because the wild stock is in danger of being destroyed due to the lack of spawners. These plans to limit salmon fishery might have resulted in the fisherman being any more eager to recover tags because they are afraid of catch limitations. However, a similar trend is also observable from sea trout tagging results, but no plans have been made to limit sea trout fishing.

Salmon stocking has mainly been carried out in the Bothnian Bay area in the sixties and seventies. That is the reason the best tagging series are available from this area. The results of tagging show that the mean yield per 1 000 released smolts was about 330 kg in 1970. The lowest stocking result has been obtained from the smolt year-class 1972 when the result was about 830 kg. After this year the results have diminished rapidly. In 1975 the result was a little less than 400 kg and in 1978 a trifle over 150 kg.

The results of stocking of sea trout in the Bothnian Bay area also follow this descending trend. However, there is one exception. The best year was not 1972, when the result was about 150 kg, but 1973 when the result was 230 kg. Since then the results have fallen even as far as 60 kg in 1977. Sea trout tagging on the other parts of the Finnish coast do not form a continuous series for comparison purposes. However, it can be observed that the mean yield per 1 000 released sea trout was about 300 kg in 1972 in the Gulf of Finland but in 1976 yield had fallen to a level of 190 kg. A similar trend can also be found in sea trout tagging in the region of the Archipelago Sea and the Bothnian Sea.

Stockings with brown trout produced slightly better results in the sixties than in the seventies. For instance, in the Vuoksi watercourse, the mean yield per 1 000 stocked brown trout was 205 kg in the sixties. However, in the seventies it was only 80 kg. In brown trout stockings it is also possible to discover similar evidence of better results in 1972 and 1973 just as in the salmon and sea trout taggings (Toivonen et al., 1983).

The results of tagging salmon, sea trout and brown trout have shown that smolt releases during the spring give better results than those made in the autumn. In the Simojoki River in the Bothnian Bay area it has been observed that smolt migration of salmon stocks when the temperature in the river rises to 10°C. The river water temperature has been used as a guide for timing the salmon stocked.

4.3 Other salmonids

Introduction of lake trout in natural waters in northern Finland have given positive results, and in Lake Inari the lake trout catch is already about 10 percent of the total catch (Mutenia, Simola and Tuunainen, 1983).

Stocking of brook trout and splake has met with little success, and current interest in the farming of these species is very little (see Westman and Tuunainen, 1983).

4.4 Pike, perciform and cyprinids

There are no known investigations on the stocking of newly-hatched pike, but their significance in increasing pike catches on the basis of the observed practical results, has been very little. In stocking activities, there is an increasing tendency to release 3–5 cm long juveniles cultured in natural food ponds. At present, no definite details relating to the results of stocking are available.

Regarding the transfer stocking of mature fish, it has proven possible to acclimatize pike-perch in numerous waters. According to reports (Toivonen et al., 1981) pike-perch exists in 476 Finnish lakes. It was regarded as occurring naturally in 129 of these, and solely as a result of stocking in 94 places. Stocks which had been reinforced by stocking, or whose origins were unknown, occurred in 79 lakes. Pike-perch had been released without effect in 174 lakes. The cultivation and stocking of one-summer pike-perch juveniles is on the increase in Finland. In practice, stocking has often been shown to have produced good results.

The best results with carp have been obtained with two or three-year old juveniles at least 20 cm in length and weighing circa 150 g or more. In inland waters, the rate of return of carp tags has varied between 0–32 percent, which in terms of a catch means 0–336 kg/1 000 stocked individuals. However, no economically profitable results have so far been obtained from stocking (Ahlfors, Kummu and Westman, 1983).

4.5 Summary of the results obtained with stocking

Stocking of newly hatched fish has been most successful primarily in waters in which the natural reproduction of a species has been disturbed, as well as in some cases where certain species have been introduced to new locations. However, such stocking has evidently not significantly improved the catch in waters where the species is already reproducing in sufficient quantities.

A well planned and executed stocking with sufficiently large juveniles has usually had good results in water suitable for the species. It has proved to be difficult to increase, by stocking, fishery profitability in waters whose quality has deteriorated as a result of hydro-construction, lake water-level regulation, or pollution.

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Table 1 Fish stockings in Finland over the years 1978–80 (for further information see Table 3)

Species	Stockings (1 000 individuals)								
	Newly hatched and feeding juveniles			Juveniles of one growth period in age			Juveniles of at least two growth periods in age		
	1978	1979	1980	1978	1979	1980	1978	1979	1980
Coregonids									
Whitefish, vendace	114 233	111 407	174 096	20 557	26 074	27 389	1 153	8	1 033
Atlantic salmon	560	632	130	25	72	165	313	278	507
Trout									
Sea trout, brown trout	2 354	3 095	2 230	180	317	398	1 437	1 738	2 108
Other salmonids									
Landlocked salmon, rainbow trout, char, brook trout, lake trout, grayling	4 604	4 196	1 523	560	623	753	247	142	288
Other fish									
Pike, pike-perch, bream, carp, tench	16 778	24 992	18 304	931	2 326	1 836	10	10	6

Table 2 Production to stockings in 1980 (1 000 individuals)

	Newly hatched[4]	1 summer old[5]	1 year old	2 summers old	2 years old	3 summers old	3 years old	older	Total (excluding newly hatched)
Whitefish									
Coregonus pidschian	5 970	3 109	-	-	-	-	-	-	3 109
C. lavaretus	155 470	8 876	-	1 022	-	-	-	-	9 898
C. muksun	5 211	7 986	3	6	-	-	-	-	7 995
C. peled	675	5 164	936	-	5	-	-	-	6 105
Coregonus sp.	5 550	1 315	-	-	-	-	-	-	1 315
Vendace									
C. albula	1 220	-	-	-	-	-	-	-	-
Atlantic salmon									
Salmo salar	130	-	165	24	390	-	92	1	672
Landlocked salmon									
S. salar m. sebago	180	4	-	36	95	6	1	-	142
Sea trout									
S. trutta (m. trutta)	509	71	113	153	529	65	11	0	942
Brown trout									
S. trutta m. lacustris	1 069	169	42	121	903	164	71	1	1 471
S. trutta m. fario	652	0	3	-	-	-	-	0	3
Rainbow trout									
S. gairdneri	-	53	2	23	27	15	-	-	120
Char									
Salvelinus alpinus	693	25	5	-	-	0	25	-	56
Brook trout									
S. fontinalis	-	-	3	-	7	-	-	-	10
Lake trout									
S. namaycush	-	-	-	-	44	4	5	0	53
Grayling									
Thymallus thymallus	650	661	-	-	-	-	-	-	661
Pike									

Esox lucius	17 894	1 722	-	-	-	-	-	-	1 722
Bream									
Abramis brama	150	30	-	-	-	-	-	-	30
Carp									
Cyprinus carpio	-	3	4	3	2	-	-	-	12
Tench									
Tinca tinca	-	-	-	1	-	-	-	-	1
Pike-perch									
Stizostedion lucioperca	260	76	-	-	-	-	-	-	76
Crayfish									
Astacus astacus	-	1	-	-	-	-	-	-	1

[4] Salmonids free-swimming fry

[5] Pike fingerlings a few weeks old

Table 3 Details of the principal production methods for fish species raised in Finland

Species	Egg acquisition: Natural spawning	Egg acquisition: brood fish cultivation on farm	Egg acquisition: brood fish cult./natural waters	Principal culture method: natural food ponds	Principal culture method: intensive cultivation	General stocking age and size		Rearing spaces and methods during the first (I) and second (II) periods of growth: Pond and basin type I	Pond and basin type II	Pond size I	Pond size II	Initial density (ind./m²) I	Initial density (ind./m²) II	Food	Stocking size Production (ind./m²)
Whitefish	+++	+++	+	x		1s	8–12 cm	nfp		100 m²–200 ha		1–3		natural	0.5–2
Salmon	(+)	+++			x	2 y	15–20 cm	ab	ep	1–7 m²	50–500	1500–3000	50–300	dry	50–200
Trout	+	+++			x	2 y	18–23 cm	"	"	"	"	"	"	"	"
Grayling	+++			x		1 s	8–10 cm	nfp		5–50 ha		1–3		natural	0.3–1
Pike	+++			x		<1 s	5–8 cm	nfp		100 m²–10 ha		5–10		natural	1–4
Pike-perch	+++	(+)		x		1 s	6–10 cm	nfp		100 m²–15 ha		0.5–3		natural	0.2–1

s summer
y year
nfp natural food pond
ab artificial basin
ep earthen pond

Table 4 Growth of cultivation capacity of Finnish fish farms over the years 1978–80

Capacity		1978	N	1979	N	1980	N
Incubation capacity in egg-litres							
Hatching jars		10 980	(42)	10 910	(52)	10 920	(52)
Incubator trays		8 150	(46)	10 270	(47)	10 430	(52)
Type of pond							
Artificial basins	ind.	1 743	(49)	2 213	(73)	2 021	(62)
	1 000 m^2	14		15		21	
Earthen ponds	ind.	1 424	(118)	1 459	(128)	1 684	(169)
	1 000 m^2	650		686		806	
Net cages and enclosures	ind.	295	(44)	300	(40)	562	(91)
	1 000 m^2	256		211		255	
Natural food ponds	ind.	496	(154)	538	(169)	603	(180)
	ha	3 816		4 636		5 093	
Fish farms, total	ind.	324		362		422	

N = Number of fish farms involved

Table 5 Fish markings with Carlin tag 1978–81

Species	1978	1979	1980	1981
Lamprey				444
Baltic herring	9 119	13 533	2 436	7 323
Pike	772	322	829	831
Vendace				999
Whitefish	6 269	3 718	6 405	469
Rainbow trout			100	
Atlantic salmon	14 128	18 640	22 448	26 703
Landlocked salmon	1 507	2 496	2 989	2 483
Sea trout	5 433	21 835	13 220	5 900
Brown trout, non-migr.			100	
Brown trout	7 498	13 826	11 901	13 984
Char	1 096		995	
Lake trout	1 500	4 981	2 493	1 495
Grayling	1	162	29	29
Smelt		999	1 126	
Bream	1 384	131	115	613
Crucian carp				1
Carp		623	1 996	1 096
Ide		110		
Roach	2 096			2
Rudd				5
Cod	2 218			
Burbot	1 505	443	1 083	904
Perch	3 390	400		1 131
Pike-perch	498		37	
TOTAL	58 414	82 219	68 302	64 412

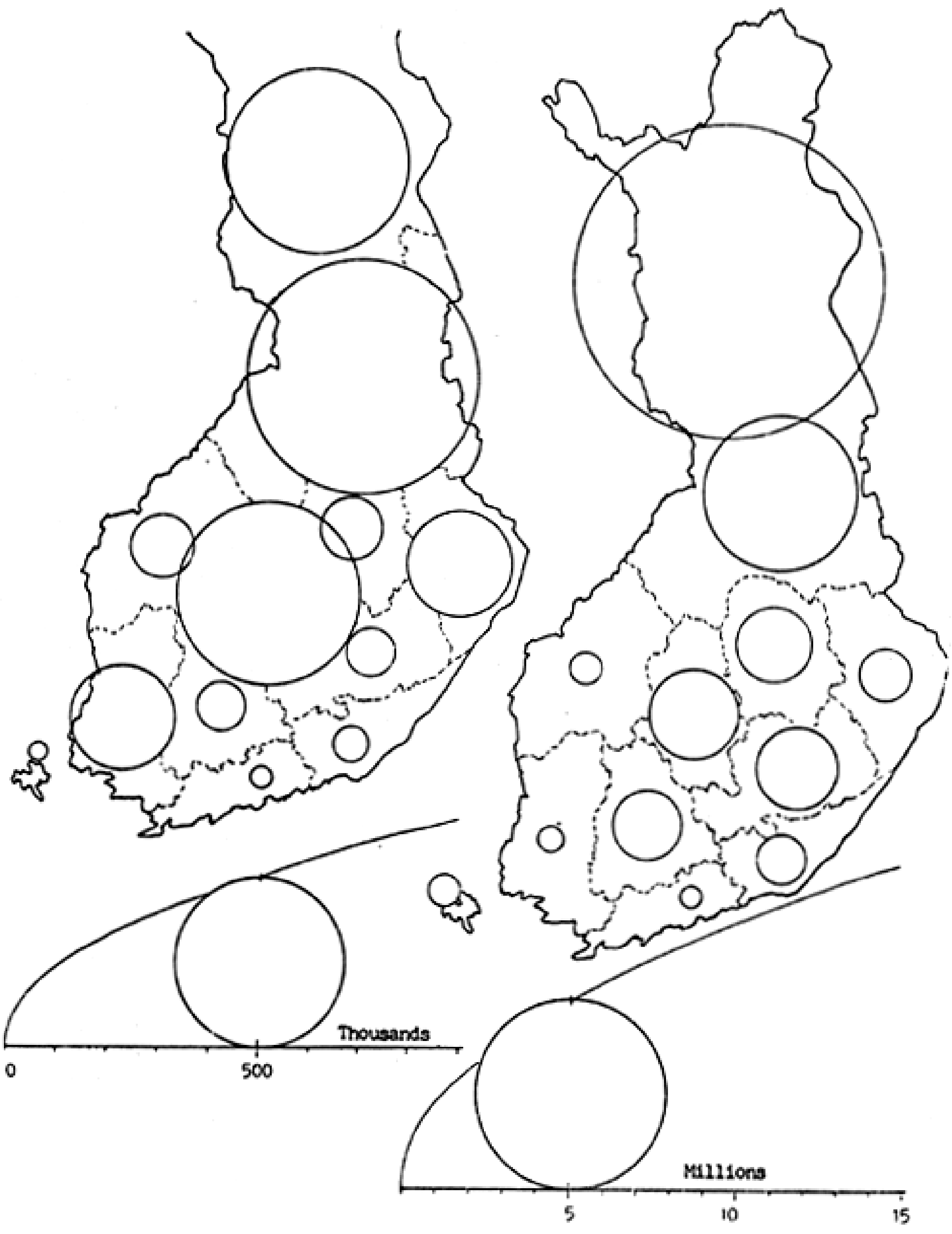

Fig. 1 The distribution of salmonid fish juvenile production in Finland in 1978. On the left salmonids, on the right coregonids. Production of newly-hatched fish not included.

STOCKING OF FISH IN SWEDEN FROM THE PERSPECTIVE OF TAGGING

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CONTENTS

ABSTRACT

Large-scale tagging of fish in Sweden has a history of more than 30 years. There have been great changes in technique and purpose and also in the fish species under study and the number of fish tagged. This paper reviews the history behind these changes and also attempts to evaluate and discuss some of the now obvious mistakes as well as the evident successes. This review will only cover fresh waters as sea-going salmon and trout are dealt with by the Swedish Salmon Research Institute.

RESUME

Le marquage des poissons se pratique sur une grande échelle en Suède depuis plus de 30 ans. Il va sans dire que les techniques ont beaucoup évolué, que les fine poursuivies et les espèces étudiées ont elles aussi changé et - ce qui n'est pas le moins important - que le nombre des poissons marqués est ajourd'hui beaucoup plus élevé. L'auteur examine ces changements, certaines des erreurs qui ont été indubitablement commises et certaines réussites incontestables. Cet examan ne porte que sur les poissons d'eau douce anadromes et catadromes autres que le saumon, espèce dont s'occupe un institut suédois spécialisé.

1. INTRODUCTION

The ides of tagging fish came to Sweden from England and was tried here for the first time by Trybom in 1903, who tagged eel and brood fish of salmon and trout with very poor results (Trybom, 1903, 1910 and 1911). During the period 1903–48 a couple of other fisheries biologists also tried to tag fish with more or less the same poor results. It was not until Börje Carlin (1948) began to rationalize the technique for smolt rearing that things improved. Carlin needed good tags and tagging techniques for production control. During the period 1948–55 he developed the method of tagging fish in the back under the dorsal fin. The real breakthrough came when he inserted a link between the wire attached to the fish and the tag (Fig. 1).

Carlin's major interest (as Director of the Swedish Salmon Research Institute until 1971) was the release of salmon in the Baltic. His ideas were soon successfully tried on other fish species but, as Carlin was not very interested in these, the responsibilities for tagging of species other than salmon and some sea-migrating trout fell upon the Institute of Freshwater Research.

At this institute a small administrative department was started, dealing mainly with service to external taggers, such as correspondence and payment of rewards. Except for a few yearly tagging experiments all the tagging of freshwater fishes was carried out by local fisheries administrations who also made their own evaluation of the material. Unfortunately, this has led to an incomplete evaluation of the material as local administrations usually had narrow alms and an unclear conception of the overall picture. The situation is not cased by the fact that to-date all date is recorded manually. This is in strong contrast to the Swedish Salmon Research Institute where Carlin early saw the advantage of computers. However, changes are now on the way even at the Institute of Freshwater Research.

2. CHANGES OVER THE PAST THIRTY YEARS

2.1 Numbers tagged

The most obvious change is the steady increase in numbers of fish tagged (Fig. 2) - from almost none in 1945 to nearly 65 000 in 1978.

The need for continued tagging is increasingly questioned on the basis of the supposedly limited advantages to acquiring further information. However, at present the main factor limiting the extent of tagging is money, the shortage of which may limit further increases in numbers tagged.

Initially, the numbers tagged in each experiment varied between 1 and 1 500 fish. That this variation has now been reduced can be seen from the standard error values in Table 1. Even the mean numbers of fish tagged in each experiment has reached a certain level of stability at least for the most important species. For example, initially the mean number of trout tagged fluctuated around 100 and had a wide range of variability but in the last few years the mean has increased to about 300 and is less variable.

Salmon have undergone a similar trend with a present mean of about 500 tagged fish which corresponds well with the lower return rates compared to trout (Fig. 3).

Lake trout, a species in which recovery rates are very high, have changed conversely, from a high mean number of tagged fish at the start of the experiments to a low number today. Other species such as rainbow trout, grayling, pike and char have still not stabilized.

2.2 Species tagged

Over the years 20 freshwater species have been tagged (Table 2).

Interest in the different species has changed over the years (Fig. 2). Most remarkable perhaps is the increase in trout tagging especially during the seventies. In the sixties the rainbow trout was under intense study but the fish did not come up to expectations as a species suitable to compensate for damage to the ecosystem due to hydro-power and interest in tagging the species has now died, although the species rainbow trout is still widely used in "put and take" sports fisheries and in fishfarming.

The lake trout, which Svärdson brought to Sweden as roe in 1958, have been tagged since 1962 and have proved to be of great value in some lakes; experiments with this species are still going on. (Results are presented elsewhere at this symposium by Gönczi and Nilsson.)

In the effort to improve fishing, a number of hybrids have been tested (Table 2). More than 20 000 of these hybrids were tagged from 1962 to 1976 but the results are rather poor and no fish of this category have been tagged since 1976.

2.3 Methods

A number of tagging methods including streamer tags, floy tags, nose tags, colour injections, freeze and heat branding as well as modifications of the Carlin tags have been tried, but so far nothing has proved superior to the Carlin tag. Even the method of attaching tags described by Ottosson (1981) has remained unchanged since the fifties. Only the anaesthetic has been changed from the carcinogenic urethane to MS 222 (ethyl m-aminobenzoate methanesulphonate).

2.4 Purpose

The main objective of tagging programmes was originally to investigate questions of fish especially in connexion with evaluation of how installations for generating hydro-power would influence the fish populations. Later when it became obvious that hydro-power plants and dams had an adverse effect on the fish stock, experiments were aimed at finding fish stocks suitable for the modified environment.

A number of species introductions were attempted to mitigate these adverse effects but of species such as lake trout, rainbow trout, brook trout and hybrids, only lake trout proved successful.

When it became clear that exotic species were not completely successful the search transferred to the different strains of trout. This is one of the main reasons for the tremendous increase in trout tagging together with trout production control. Great numbers of trout are reared and released every year to compensate for spawning damage due to hydro-power installations.

2.5 Results

No real review of all information on freshwater tagging has ever been made in Sweden. The results given here are a preliminary attempt at such an anlaysis.

2.6 Recoveries

For each species all the recovered fish from 1963 and 1965–74 have been pooled on a yearly basis and the cumulative recoveries in percent plotted. The result can be seen in Figs. 3 and 4. There is, of course, a great deal of variation from experiment to experiment but this will be dealt with in later papers.

2.7 <u>Survival rate estimates</u>

The same material as for the recoveries has been used. The estimates are calculated according to Ricker (1975) and are shown in Table 3.

3. DISCUSSION

In the past the designers of tagging experiments have been overambitious. In an urge to solve too many problems the tagged material was so diffused that there were often too few recoveries to furnish definite answers. This has improved today but hopefully ambitions will be further limited and the number of tagged fish in each experiment will be increased. Knowing the numbers of recovered fishes needed for proper statistical analysis and somewhat more of what to expect from these recoveries should make it easier for today's fishery workers to design adequate experiments.

There have already been changes in the species selected for tagging which reflect changing preferences in species suitable for stocking. These trends will doubtless continue in the future. It is, however, unlikely that rainbow trout, hybrid salmonids, whitefish, perch, roach and pike will be very much in demand for tagging in the near future; rainbow trout and hybrids, because their survival rate is so low that stocking with them does not last in any lasting improvement in the fishery (Table 3). They continue to be suitable for “put-and-take” fisheries, where recoveries are good (Fig. 3). Recovery rates for roach and perch are so low (Fig. 4) that they would have to be tagged in great numbers to obtain any results. Whitefish and pike have good recovery and survival rates and are, therefore, suitable for tagging but these species may be considered to be of low priority for economical reasons.

Both survival rate and recovery rate are rather low for trout but the variation in the material is high and the means given do not reveal the entire truth. The main cause of variation in recovery rate is the range of sizes of trout used for stocking. The recovery rate increases tremendously with increasing size. This will, however, be discussed in detail by other authors.

Trout tagging will continue partly for production control and partly for evaluation of different strains in the search for selected strains suitable for various purposes. It would be desirable to be able to give performance characteristics for each strain. One fisheries biologist told me that he was looking for a “square trout” suitable for hydro-power reservoirs. It is probably going to take some time before he finds one.

Salmon have a high survival rate but low recovery rate. The growth is, however, so good in great lakes that it is in great demand for stocking. Salmon will continue to be tagged in the future but mostly for production control.

Another fish in great demand, in this case from the sport fisheries, is grayling. Although it has been tagged for many years very few results are available. My opinion is that far too few fishes have been tagged in each experiment (Table 1) in relation to the low recovery rate (Fig. 3). Another design with greater numbers tagged but fewer experiments would be preferable.

Zander is a species stocked in many south-Swedish lakes. The interest is easily explained by the recovery curve (Fig. 4). Unfortunately, the curve is very primitive and some improvement is desirable.

The results from tagging lake trout are most spectacular. Both recovery and survival rates are very high, which means that natural mortality must be very low. One of the administrators has observed that “lake trout never die”, in the sense that an experiment on most other species is usually followed for seven years and then filed, because there are hardly any recoveries after that, whereas lake trout continue to be caught and the files are therefore difficult to close.

One problem with Carlin tags is that many newly released young fish are caught in nets used to capture larger fish, because the metal wires tangle in the meshes. This problem is especially pronounced in fresh water where the number of nets are very high in relation to the water volume and can perhaps be overcome by modified Carlin tags with polythene monofilament attachment. Experiments are underway and if successful tagging methods will be modified.

Objectives of tagging programmes other than production control and evaluation of different species and strains are stock assessment and evaluation of stocking methods. The use of tagging as a tool for stock assessment is almost entirely neglected in Swedish fresh waters and must be improved to increase the output from the numerous tagging experiments carried out.

Techniques for rearing and transportation of fish are well developed but the last step releasing the fish from the transporter - is in great need of improvement. Having been fed and cared for with great tenderness over a number of years the fish are then suddenly handed over to a hurried lorry driver who wants nothing more than to get rid of them. More money and care must be spent on this final step to lower the variations in recoveries between experiments which cannot be explained in any other way than by differences in stocking success. It is not to fatten the seagulls that rivers and lakes are stocked with high quality fish.

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Table 1 Mean size (X) of the experiment in numbers of tagged fish as well as the standard-error (SE) on a yearly basis

	Char		Lake trout		Trout		Salmon		Rainbow trout		Grayling		Pike	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1950	446	413	-	-	103	60	35	8	-	-	-	-	-	-
1951	391	324	-	-	77	37	1	-	-	-	-	-	34	27
1952	170	67	-	-	156	91	38	22	-	-	-	-	28	17
1953	153	89	-	-	244	65	20	-	-	-	-	-	38	10
1954	165	80	-	-	158	58	104	50	15	-	134	125	23	7
1955	93	37	-	-	133	45	206	188	-	-	91	-	93	17
1956	115	38	-	-	60	15	146	135	-	-	37	15	233	79
1957	144	42	-	-	321	67	386	243	-	-	70	28	132	61
1958	90	41	-	-	108	29	402	249	-	-	43	18	81	39
1959	245	161	-	-	141	36	555	286	-	-	26	11	199	-
1960	416	157	-	-	118	43	740	111	175	-	127	87	73	26
1961	1 139	299	-	-	197	48	513	96	190	27	114	99	106	36
1962	444	353	91	-	327	68	295	147	456	77	147	116	53	12
1963	274	110	1 000	-	158	45	699	82	305	46	171	152	20	16
1964	498	-	562	100	152	23	177	84	175	36	51	38	50	-
1965	35	6	-	-	106	17	223	56	330	42	58	-	82	48
1966	73	22	950	-	88	13	268	83	141	43	53	21	25	4
1967	138	25	401	65	156	32	199	86	206	24	133	39	66	19
1968	102	26	452	24	142	17	207	70	133	24	71	47	18	5
1969	163	51	528	66	138	16	190	90	164	30	78	-	72	23
1970	258	67	550	50	290	25	302	235	211	99	53	21	35	5
1971	84	41	625	52	266	21	302	95	219	74	44	9	44	3
1972	258	61	575	101	243	17	462	109	97	-	62	-	46	13
1973	302	70	213	101	273	19	470	73	374	-	102	-	249	-
1974	418	58	327	42	291	18	625	65	386	-	55	20	122	-
1975	223	69	250	88	268	14	392	70	333	-	45	-	65	32
1976	325	66	284	36	273	14	521	59	-	-	78	-	-	-
1977	450	50	436	78	259	16	500	0	-	-	56	16	-	-
1978	1 500	-	278	43	290	14	455	28	600	-	-	-	40	-
1979	-	-	213	20	265	13	458	29	27	-	31	-	-	-
1980	42	-	154	21	249	14	536	41	-	-	67	53	-	-
1981	-	-	248	56	302	23	506	77	-	-	-	-	-	-

Table 2 Freshwater species tagged during the period 1950 to 1981

Char	Salvelinus spp. (alpinus complex)
Lake trout	S. namaycush (Walbaum)
Brook trout	S. fontinalis (Mitchill)
Trout	Salmo trutta (L.)
Salmon	S. salar (L.)
Rainbow trout	S. gairdneri (Richardson)
Grayling	Thymallus thymallus (L.)
Whitefish	Coregonus spp.
Cisco	C. albula (L.)
Perch	Perca fluviatilis (L.)
Sander	Lucioperca lucioperca (L.)
Pike	Esox lucius (L.)
Roach	Rutilus rutilus (L.)
Bream	Abramis brama (L.)
Burbot	Lota lota (L.)
Silver eel	Anguilla anguilla (L.)
	Lake trout × char
	Brook trout × char
Hybrids	Lake trout × brook trout
	Salmon × trout

Table 3 Survival rate estimate. Material from 1963 and 1965–74

Species	Total numbers released	Total numbers recovered	Instantaneous rate of mortality (Z)	Coefficient of determination (R^z)	Survival rate/in %
Lake trout	56 955	16 677	0.73	0.84	48.1
Char	32 587	6 341	0.78	0.95	45.8
Salmon	52 548	4 339	0.87	0.79	42.1
Pike	5 071	696	0.89	0.92	41.2
Grayling	9 432	917	0.90	0.98	40.5
Perch	2 220	92	0.99	0.98	37.3
Whitefish	4 187	761	0.99	0.95	37.3
Trout	201 913	28 212	1.16	0.84	31.3
Rainbow trout	38 507	8 896	1.29	0.90	27.5
Hybrids	16 285	3 116	1.30	0.96	27.3

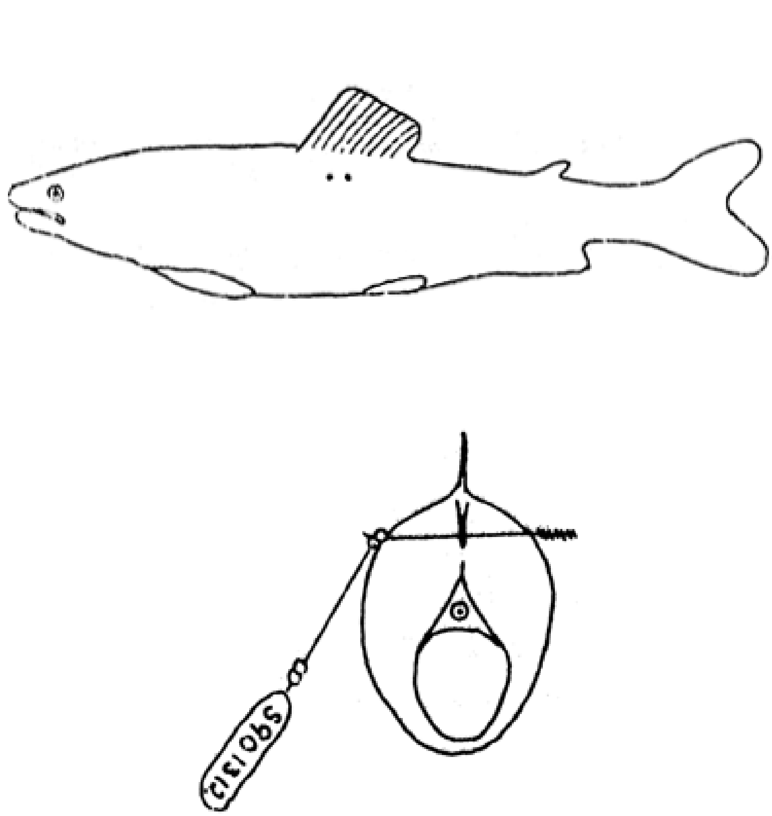

Fig. 1 Method of attaching a standard Carlin tag to a fish (Ottosson, 1981)

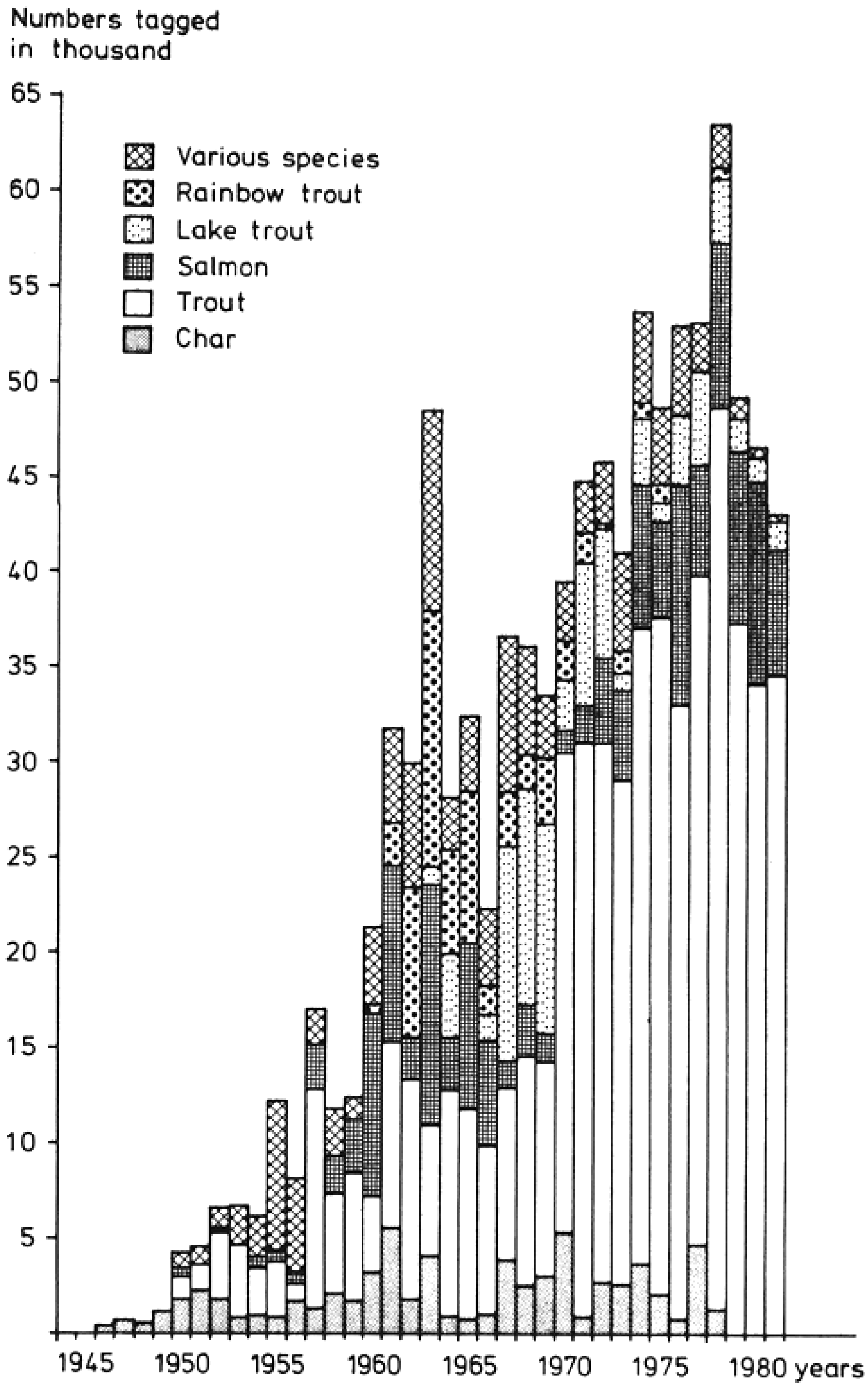

Fig. 2 The total numbers of tagged fish handled by the Institute of Freshwater Research from 1946 to 1981

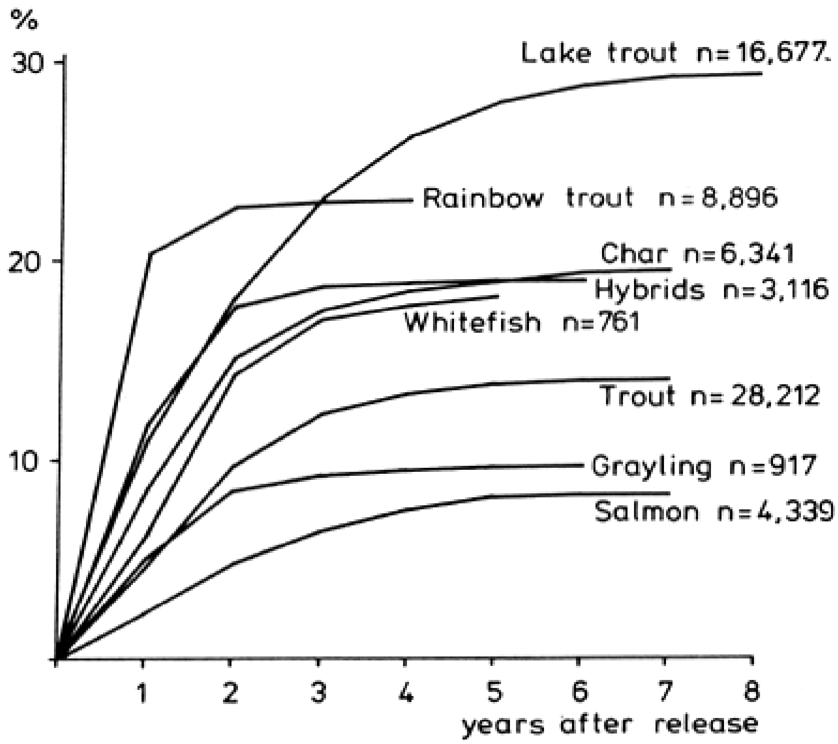

Fig. 3 The cumulative recoveries of tagged salmonid fishes in percentage. Material from 1963 and 1965–74. The number n is the total number recovered for each species

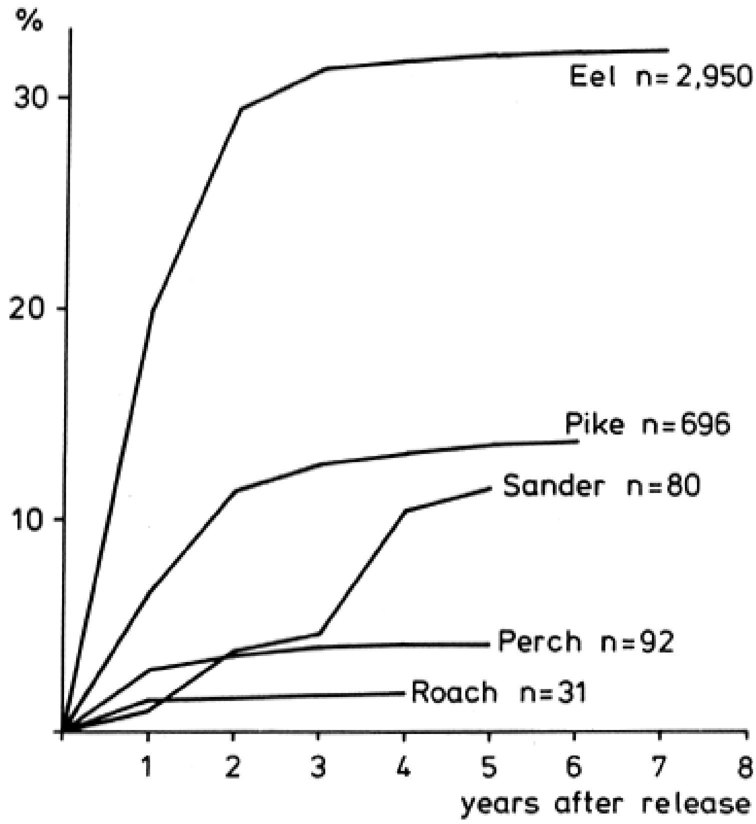

Fig. 4 The cumulative recoveries of tagged fish others than salmonids in percentage. Material from 1963 and 1965–74. The number n is the total number recovered for each species

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