RECAPTURE RATE, GROWTH AND SEX OF STOCKED CULTURED EELS *ANGUILLA ANGUILLA* (L.).

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ABSTRACT

A total of 84,791 Alcian blue marked eels, size range 15 - 33 cm, were released in a lake, a fjord and an open coastal area. Recaptures were made by fishermen up to 4 years following release. Recaptures were most successful at the freshwater lake where 12.6 % were recaptured, 2.7 % in the fjord and 0.2 % at the open coast. Length increment was estimated to be between 2.5 and 6.5 cm annually. The sex ratio (female/male) of yellow eels increased in subsequent years of recaptures, possibly as a result of environmental sex determination following release. The use of Alcian blue for a long-term marking experiment, based on samplings by fishermen, are concluded to be questionable.

Key-words : *Anguilla*, stocking, recapture rate, growth, sex.

TAUX DE RECAPTURE, CROISSANCE ET SEXE D'ANGUILLES (*ANGUILLA ANGUILLA* L.) ALEVINÉES À PARTIR D'ÉLEVAGE.

RÉSUMÉ

Un total de 84 791 anguilles marquées au bleu alcian, de taille comprise entre 15 et 33 cm, ont été relâchées dans un lac, un fjord et une aire côtière ouverte. Des recaptures ont été faites par des pêcheurs jusqu'à 4 ans après le relâchage. Les recaptures ont été les plus réussies dans le lac d'eau douce où 12,6 % ont été recapturées, 2,7 % dans le fjord et 0,2 % dans la côte ouverte. L'accroissement de la taille a été évalué entre 2,5 et 6,5 cm par année. Le sex-ratio (femelle/mâle) des anguilles jaunes a augmenté avec les années successives de recapture, peut-être à la suite d'une détermination environnementale du sexe après le relâchage. Il est conclu que l'utilisation du bleu alcian pour une expérience de marquage à long terme, basée sur des échantillonnages effectués par des pêcheurs, reste discutable.

Mots-clés : *Anguilla*, alevinage, taux de recapture, croissance, sexe.

INTRODUCTION

A drastic decline in the Danish eel stocks during the past 30 years is evident from the official catches. In the 1960s the yearly catch fluctuated between 3,197 and 4,723 tonnes and in the 1990s it has dropped to 1,023 - 1,568 tonnes. The decline in eel stocks coincides with a notable decrease in recruitment to the Baltic beginning in the 1940s (HAGSTRÖM and WICKSTRÖM, 1990). Throughout Europe a general decline in recruitment has been recorded since the beginning of the 1980s (MORIARTY, 1990).

To enhance eel populations, and utilize the production capacity of inland waters deficient of eel, a national stocking programme was initiated in 1987 (RASMUSSEN and GEERTZ-HANSEN, 1998). The government and fish licence funded the programme and particular streams and rivers, with public access to the fishery, were stocked. In 1990 the stocking programme was expanded to coastal areas and during the 1990s between 2.5 and 8.5 million elvers have been released annually.

Results from stocking have been achieved in streams, with regard to the method of stocking (spot *versus* scatter), growth and mortality rates of stocked fry (BISGAARD and PEDERSEN, 1991 ; BERG and JØRGENSEN, 1994). The time schedule for the experiments has been short, 3 - 12 months, and no result of yield is available for streams. Long-term stocking in closed freshwater systems has been described with positive results of yield by TOLONEN and PURSIANEN (1992) and WICKSTRÖM *et al.* (1996). Results from stocking eels in open marine water systems are difficult to achieve, especially due to the lack of appropriate methods of marking or tagging eels. Apart from this study, the only other known study in open marine water systems has been undertaken by ANDERSSON *et al.* (1991), who marked elvers with radioactive europium at the coast of the Baltic proper.

In order to achieve some experience from stockings : a lake, a fjord and an open coast were stocked with Alcian blue marked eels in 1988. The aim was to obtain information on the value of cultured eels as stocking material (NIELSEN, 1989). Cultured eels are grown under high densities and the feed is artificial. In aquaculture a dominance of males is observed and growth of males stops at a length of about 40 cm (EGUSA, 1979). Status reports from returned eels in 1988 and 1989 have been reported by NIELSEN (1989) and NIELSEN (1990).

Study sites

Hjarbæk Fjord (Figure 1) is a shallow inlet of the Limfjord with a water surface of 25 km². The mean and maximum depth is 2 and 6.5 m. During 1966 - 1991 a sluice was operating, preventing saltwater to penetrate and turned Hjarbæk Fjord into a freshwater lake with affluent from 4 streams.

The Isefjord covers a water surface of 305 km². Freshwater affluent is primarily surface run off. The salinity is 18 ppt, mean and maximum depth is 5 and 17 m.

South Funen : this area is an open coast between the isles Tåsinge and Langeland and with a salinity of about 12 - 14 ppt. The area is flat with a gravel bottom patchy vegetation and depth is less than 4 m.

Figure 1
Map of Denmark with study sites.

Figure 1
Carte du Danemark avec les sites de l'étude.

MATERIAL AND METHODS

The eels used in the experiment were imported from France and England as glass eels and cultured until release. After about 6 - 12 months of feeding the eels were sorted according to length in 3 batches : 15 - 22, 23 - 26 and 27 - 33 cm. Each batch was given a different mark code by 1 - 3 Alcian blue spots, ventrally, by use of a jet inoculator (HART and PITCHER, 1969). A total of 84,791 eels were marked and released during June, August and October with an approximate density of 40 eels/ha at the study sites. Length, weight and sex were measured from subsamples. NIELSEN (1989) mentions that some minor growth might have occurred between marking and release because of time lag between marking and release. The sex was determined macroscopically (SINHA and JONES, 1966). All the examined eels were either male or undifferentiated (Table I).

The fishermen were requested to return marked eels no matter legal size, which is 38.0 cm at Hjarbæk Fjord and 35.5 cm at the other study sites. The standard mesh size in the cod end of fykes and pound nets is 11 mm (knot to knot) and eels of length less than approximately 35 cm are not fully retained in the fishing gear. Returned eels were examined with regard to batch, yellow/silver stage, sex, length (0.5 cm), and weight (1 g). The mean annual growth increment in Table I was calculated for each batch by using pooled length data. This was done by subtracting mean length at recapture (L_r) from mean length at time of release (L_o) according to $Gr = (L_c - L_o) / (Lt - L_o)$, where $(Lt - L_o)$ represents the time between release and recapture. When length data from 1989 were used, $(Lt - L_o) = 2$, assuming 2 growth seasons.

Table I

Total number of marked eels released in 1988. Length, weight and sex measured from subsamples (N = 100).

Tableau I

Nombre total des anguilles marquées relâchées en 1988. La longueur, le poids et le sexe sont mesurés à partir de sous-échantillons (N = 100).

		Month of release							
		June	August	October	Sex				
Study site	Batch	n	n	n	$\bar{L}$ cm	$\bar{W}$ g	Range cm	Male %	Undiff. %
Hjarbæk Fjord	S	5,341	0	0	20.8	11.2	15 - 22	0	100
	M	3,256	0	1,754	25.3	26.0	23 - 26	0	100
	L	1,238	0	1,856	30.0	52.0	27 - 33	100	0
Isefjord	S	11,129	0	7,734	21.0	11.1	15 - 22	0	100
	M	12,906	0	3,431	24.5	25.0	23 - 26	0	100
	L	8,371	0	1,838	31.0	58.4	27 - 33	100	0
South Fynen	S	0	14,539	0	21.5	11.5	15 - 22	0	100
	M	0	8,281	0	24.5	25.0	23 - 26	0	100
	L	0	3,117	0	32.5	65.0	27 - 33	100	0

Batch : S = Small ; M = Medium ; L = Large.

RESULTS

Recapture rate

During 1988 - 1992 recaptures totalled 2,985 marked eels. The return of marked eels was most successful at Hjarbæk Fjord ; at this site 12.6 % of the released eels were recaptured. At the Isefjord only 2.7 % were recaptured and of these 90 % were caught in the year of release. At the open coast at South Funen very few eels were recaptured, 0.2 %. At all study sites large eels were represented with the highest recapture rate (Table II).

Table II

Recaptures of batch marked eels released in 1988. Gr = estimated annual growth rate.

Tableau II

Recaptures des lots d'anguilles marquées relâchées en 1988. Gr = taux de croissance annuel estimé.

		Recaptures								
	Batch	Released n	1988 n	1989 n	1990 n	1991 n	1992 n	Total n	Total %	Gr cm
Hjarbæk	S	5,341	10	101	62	0	1	174	3.3	5.3
	M	5,010	243	508	82	0	13	846	16.9	3.4
	L	3,094	476	188	8	0	0	672	21.7	2.5
	Total	13,445						1,692	12.6	
Isefjord	S	18,863	27	0	0	0	0	27	0.2	2.4
	M	16,337	146	1	5	1	0	153	0.9	5.2
	L	10,209	963	86	3	2	0	1,054	10.3	4.5
	Total	45,409						1,234	2.7	
South Fynen	S	14,539	0	2	2	0	0	4	< 0.1	-
	M	8,281	0	4	16	0	0	20	0.2	6.5
	L	3,117	3	18	11	0	0	32	1.0	4.3
	Total	25,937						56	0.2	

Growth

A plot of length increment of recaptures against time, for the 3 different cohorts at Hjarbæk Fjord is presented in Figure 2a -b -c. The figures show that mean length at recapture varied little during the fishing season, May to October. From pooled length at catch data the mean growth increment was estimated to be between 2.5 and 6.5 cm annually (Table I). Differences in length between males and females were small but females were in some cases significantly larger (Table III).

Figure 2
Length increment (mm) between size at recapture and release at Hjarbæk Fjord. Month number 1 refers to July 1988. A) Small eels ; B) Medium eels ; C) Large eels. The number in each month is given on top.

Figure 2
Accroissement de la longueur (mm) entre la taille à la recapture et au relâchage dans le fjord Hjarbæk. Le mois numéro 1 se rapporte à juillet 1988. A) Petites anguilles ; B) Anguilles moyennes ; C) Grandes anguilles. Le nombre pour chaque mois est indiqué en haut.

Table III
Length and weight of yellow eels from Hjarbæk Fjord.

Tableau III
Longueur et poids des anguilles jaunes du fjord Hjarbæk.

Year	Batch	Female					Male				
		n	$\bar{L}$ cm	SD	$\bar{W}$ g	SD	n	$\bar{L}$ cm	SD	$\bar{W}$ g	SD
1988	S	0	-	-	-	-	7	27.9	(1.5)	34	(8)
1989	S	53	31.4	(3.3)	53	(20)	43	31.4	(3.7)	56	(18)
1990	S	53	34.6	(3.6)	71	(21)	6	32.7	(1.9)	60	(10)
1988	*M	14	30.0	(2.4)	45	(14)	193	28.4	(2.1)	39	(11)
1989	M	197	32.5	(2.3)	59	(17)	247	32.8	(2.5)	62	(16)
1990	M	55	33.3	(3.2)	62	(19)	8	32.3	(3.0)	64	(20)
1992	M	3	33.6	(2.3)	58	(21)	1	32.5	-	57	-
1988	*L	26	34.6	(2.7)	63	(15)	432	32.7	(2.4)	63	(15)
1989	*L	27	36.2	(2.0)	78	(15)	131	34.8	(1.9)	74	(14)
1990	L	5	39.7	(6.9)	121	(78)	3	35.5	(0.7)	72	(17)

* Denotes significant difference in length of male vs female (t-test ; $p < 0,05$).

Sex and silvering

At time of release, sex was unknown due to undifferentiated gonads in the smallest size groups (S+M). In the large size group (L) the percentage of males was recorded to be 100 % (Table I). The sex ratio of recaptured eels at Hjarbæk Fjord shows that the percentage of females increases in subsequent years of recapture (Figure 3). At the open coast at South Funen recaptures in 1990 were also in favour of females with 88 and 91 % of females in medium and large eels, respectively. At the Isefjord only 5 % of the 1989 recaptures were females.

Figure 3
Sex ratio of yellow eels recaptured at Hjarbæk Fjord. The number of examined eels is given on top of bars.

Figure 3
Sex-ratio des anguilles jaunes recapturées dans le fjord Hjarbæk. Le nombre des anguilles examinées est indiqué en haut des barres.

Male silver eels were present in recaptures in 1988 and 1989. A total of 125 male silver eels were recorded with a mean length of 35.2 cm (SD 1.9) in the size range 30.5 to 40.5 cm. In 1989 silver eels make up 30 % of the recaptures of large and 10 % of medium eels (Table IV).

Table IV

Silver eels in % of total recaptures from Hjarbæk Fjord.

Tableau IV

Anguilles argentées en % des recaptures totales dans le fjord Hjarbæk.

Year	Batch	n	%	$\bar{L}$ cm	min - max cm	$\bar{W}$ g	min - max g
1988	L	12	2.5	34.1	30.5 - 40.5	70	53 - 96
	M	0	-	-	-	-	-
	S	0	-	-	-	-	-
1989	L	57	30.3	36.0	31.0 - 38.0	82	50 - 115
	M	51	10.1	34.6	30.5 - 37.5	77	48 - 104
	S	5	5.0	34.0	34.0 - 40.0	80	64 - 107

DISCUSSION - CONCLUSION

Recapture rates are influenced by several factors : visibility of the mark, gear selectivity for size, fishermen's intention to examine their catches for eels with marks, migration out of study site, fishing effort and mortality factors. A very important factor is visibility of the mark. In NIELSEN's (1988) review on marking and tagging methods applied to the eel, Alcian blue is recommended as a promising and relevant marking method. DEKKER (1989) found that the visibility of the Alcian blue mark was too weak to rely on recaptures from commercial fishermen or anglers. This accords with observations from a small Danish lake stocked with Alcian blue marked eels. Results from this lake show that the mark is still clear, but not on the outside of the fish 7 years after release (unpublished data). To identify the Alcian blue mark the skin needs to be removed and often a cut deep in the flesh needs to be done. The impression is that visibility of the mark on the outside of the fish is inversely related to growth rate.

The reason for the high recapture rate at Hjarbæk Fjord compared to Isefjord and South Funen is unknown. In general marked eels were recaptured within the study sites, but eels were occasionally caught in freshwater tributaries of the Isefjord. At the open coast at South Funen NIELSEN (1989) suggests that strong currents in the area may spread the eels to areas where the fishermen were not informed of the marking experiment.

With a quite different marking method, radioactive europium, ANDERSSON *et al.* (1991) recaptured 1.3 % and 3.5 % of two stockings of elvers, during 5 years of sampling. Their sampling programme was limited and survival rate was thought to be much higher. From stockings in closed freshwater systems TULONEN and PURSIANEN (1992) report high recapture rates from 27.4 to 56.1 %. In a similar stocking experiment WICKSTRÖM *et al.* (1994) report recapture rate of 11.3 %.

NIELSEN (1989) noted a time lag between time at marking and release and some minor growth might have taken place before release. Size selectivity of the fishing gear at the study sites may also be of importance. However, mean annual increment between 2.5 and 6.5 cm is within the expected growth rate (WICKSTRÖM *et al.*, 1994 and ANDERSSON *et al.*, 1991). BISGAARD and PEDERSEN (1991) give absolute growth data from a Danish stream. They released individually tagged cultured eels with a mean length of 20.0 cm, corresponding to the size of small eels in this study. After one year an average length increment of 3.6 cm (range 0.3 - 6.6 cm) was recorded.

The increasing proportion of females observed during the study at Hjarbæk Fjord (Figure 3) may be a result of male silver eels emigrating from the marked cohort, leaving proportionally more females behind. On the other hand, the batch of large eels were all determined to be males at release. It is generally accepted that the sex of eels is not genetically determined, but sex differentiation of individuals is influenced by environmental factors (COLOMBO and ROSSI, 1978 ; COLOMBO and GRANDI, 1996). From histological studies of gonads, COLOMBO and GRANDI (1996) find that testis (syski organ) contain oocytes from which ovaries can be differentiated until a body length up to 34 cm, which makes the eel very sex labile. HOLMGREN and MOSEGAARD (1996) suggest that early growth status may influence the future sex of sexual undifferentiated eels. Their results indicate that fast growing individuals turn into males. This may contribute to the explanation that males were dominating in the first year and later turned out to be females in the following years.

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