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Fishing mortality on silver eels, *Anguilla anguilla* (L.), in Denmark

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Abstract
A total of 2198 silver eels were Carlin-tagged and released at two sheltered and one exposed site in the western Baltic Sea. A total of 547 tagged silver eels were recaptured, corresponding to recovery rates from 19 to 38% at the different sites. The majority of the recaptured silver eels was reported from within a radius of 20 km and within a period of less than 16 days after release. There was no clear correlation between recovery rate and number of pound nets or pound net density. The locations of recoveries from Øresund suggest that significantly more silver eels migrated northward. In Roskilde Fjord a similar investigation carried out in the late 1960s suggested that fishing mortality had fallen about 50% over this period. In Roskilde Fjord, the estimated spawner escapement has dropped from 14.6 to 7.1 tonnes since the 1960s.

Keywords: *Anguilla*, silver eels, tag recovery, mortality, fishing effort.

Introduction
The European eel population is claimed to be outside safe biological limits and the current fishery to be unsustainable (ICES 1998). There has been a simultaneous decrease in recruitment and catches throughout Europe; the causes remain unknown. In Denmark, as in most of northern Europe, the silver eel fishery is economically far more important than the fisheries for yellow eel and glass eel. The total Danish catch of silver eel has decreased from a level of 1886 tonnes in the 1960s to 528 tonnes during the 1990s (Ministry of Food, Agriculture and Fishery: Official Danish fishery catch statistics for 1999, unpubl.). The catch per unit effort (CPUE) started to decline in the south-eastern part of Denmark during the early 1960s (Hoffmann *et al.* 1979). The declining eel stock has been a factor in reducing the number of pound nets in use (Danmarks Fiskeriforening 1998). The purpose of the present paper was to analyse the emigration pattern and recovery of tagged silver eels from coastal areas with varying fishing intensities.

Method
Study area
All along the coasts of the Baltic Sea, pound nets (von Brandt 1984) are used to catch silver eels migrating toward the Atlantic Ocean. The size and sex composition of silver eels captured in the more sheltered estuaries differ markedly from that of those caught in more exposed, marine areas (Tesch 1977). Øresund is one of the straits linking the Baltic and the North Sea, and here the fishing for silver eels peaks during October. In Øresund (Figure 1), the migrating silver eels are almost entirely large females (Svärdson

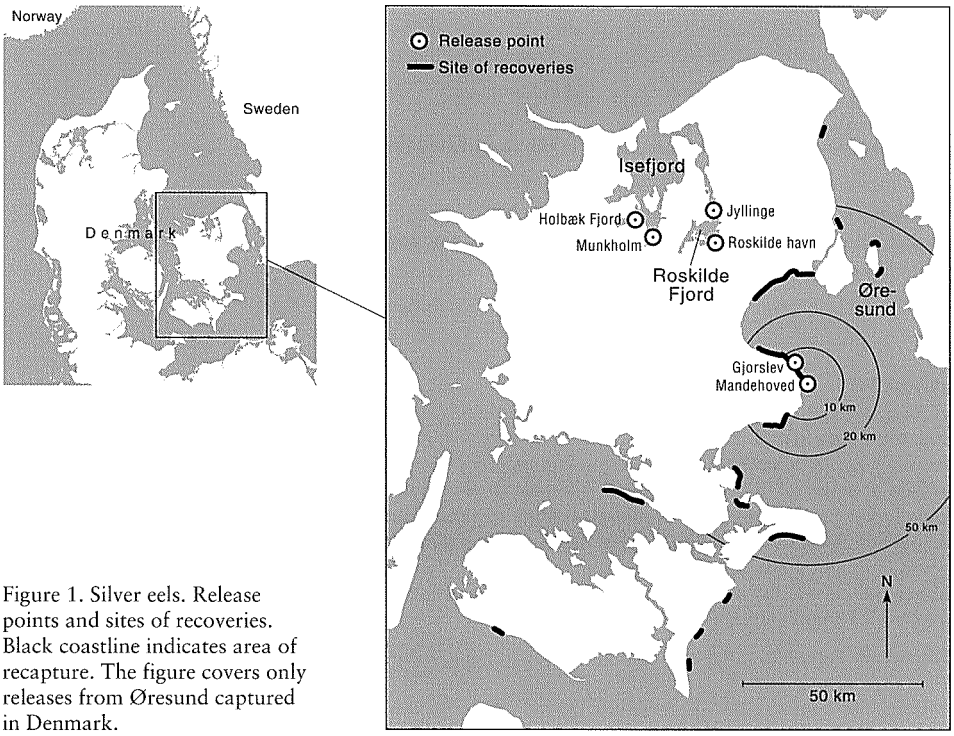

Figure 1. Silver eels. Release points and sites of recoveries. Black coastline indicates area of recapture. The figure covers only releases from Øresund captured in Denmark.

1976, Hoffmann *et al.* 1977). In the sheltered Isefjord and Roskilde Fjord (Figure 1) small male eels dominate the silver eel catches and peak catches of silver eels are usually made in September.

Capture and tagging

All silver eels used for tagging were caught in the same areas as they were released. In Øresund, the eels tagged were much larger than in both Roskilde Fjord and in Isefjord (Table 1). The eels were retained up to one week before tagging. Prior to tagging, the silver eels were anaesthetised with chlorobutanol. A Carlin tag (Carlin 1955) was

Table 1. Release locations, number released, size and total recovery of tagged silver eels from the western Baltic Sea.

Release locality	Release site	Release, n	Length, cm ± SD	Weight, g ± SD	Recoveries, n (%)
Øresund	Gjorslev	599	71.9 ± 9.3	829.0 ± 285.0	94 (16)
	Mandehoved	599			133 (22)
Roskilde Fjord	Jyllinge	250	38.0 ± 2.4	98.0 ± 17.7	80 (32)
	Roskilde havn	250			109 (44)
Isefjord	Holbæk Fjord	250	37.8 ± 2.1	86.0 ± 17.5	68 (27)
	Munkholm	250			64 (26)

attached by a U-shaped polyethylene thread passed through the dorsal musculature, 3-5 cm anterior to the dorsal fin. The tagged eels were kept in aerated fresh water until released at sunset the same day. The eels were released in batches of 200-250 individuals on nights during 8-10 October 1996 in Øresund and 28-30 September 1998 in the fjords.

Fishing effort

The fishing effort was recalculated from a survey of the Danish pound net fishery in 1994 (Koed & Pedersen 1996). This survey mapped the positions of all pound net licences granted by the fishery authorities (Koed & Pedersen 1996). The maps were used to sum the number of pound nets within various distances (radius of 10, 20, and 50 km) from the release positions. The total area of the sea surface was calculated to give an estimate of the pound net density within varying distances from the release locations.

The fishermen were informed about the experiment through direct contact, through their union, and by advertisements and articles in local newspapers. A reward of the equivalent of 7 US$ was offered for each returned tag together with information on where and when the fish was caught.

Results

In total, tags from 547 silver eels were recovered. In Øresund 19% of the eels were recaptured, compared to 26% in Isefjord and 38% in Roskilde Fjord (Table 1).

At all sites, the majority of the recaptures was made within less than 16 days, and in Øresund one third of all recaptures was made within the first two days (Table 2). In 1998 the last eel was captured after 66 days; three additional eels were captured in the spring of 1999.

Table 2. Timing of recapture of 430 tagged silver eels, stocked at exposed (Øresund) and sheltered (Roskilde Fjord and Isefjord) coastal locations in the western Baltic Sea.

	Number (%) of eels recaptured			
Release locality	Day 0-2	Day 3-8	Day 9-16	>Day 16
Øresund	75 (36)	104 (50)	13 (6)	15 (7)
Roskilde Fjord	11 (9)	34 (27)	33 (26)	50 (39)
Isefjord	6 (6)	38 (40)	37 (39)	14 (15)

Eels released in the sheltered fjords were all recaptured within the same fjords at distances of less than 50 km from the point of release. Of the batches released at the more exposed sites in Øresund, 27 (12%) eels had migrated more than 50 km before being recaptured. Recoveries were mostly reported from the Danish pound net fisheries. Thirteen eels crossed Øresund and were captured on the Swedish coast in Kattegat. One eel was captured in Oslo Fjord in Norway.

In Øresund a total of 172 (76%) eels were recaptured north of the site of release compared to 55 eels (24%) captured to the south. Of the 55 eels, 28 recaptures were reported from one particular pound net positioned one kilometre south of the release location. These results suggest that a significant proportion of the eels (binomial test, $p \ll 0.05$) migrated northward.

Table 3. Recovery of 502 tagged silver eels from the western Baltic Sea. The number and percentage of recovered tags are compared to the fishing intensity at different distances from the release localities.

	Recovery		Fishing effort	
Release site	Distance, km	Tags recovered, number (%)	Number of pound nets, n_p	Density of pound nets, $n_p \cdot km^{-2}$
Gjorslev	1-10	40 (43)	17	0.1
	11-20	7 (7)	53	0.1
	21-50	47 (50)	770	0.2
Mandehoved	1-10	39 (37)	31	0.2
	11-20	26 (25)	57	0.1
	21-50	40 (38)	773	0.2
Jyllinge	1-10	38 (53)	301	5.1
	11-20	5 (7)	153	3.6
	21-50	29 (40)	69	0.1
Roskilde havn	1-10	61 (60)	335	6.1
	11-20	14 (14)	67	3.6
	21-50	26 (26)	118	0.2
Holbæk Fjord	1-10	44 (67)	207	3.5
	11-20	9 (14)	69	0.4
	21-50	13 (20)	83	0.0
Munkholm	1-10	35 (55)	275	4.5
	11-20	27 (42)	128	1.3
	21-50	2 (3)	62	0.1

There was no clear correlation between recovery rate and number of pound nets or pound net density (Table 3). In the fjords, the pound net density may reach more than six pound nets per square kilometre (Table 3). The majority of recoveries was reported from a radius of less than 10 km from the point of release (Table 3). At all but one site more recoveries were reported from remote pound nets (more than 20 km from the release site) than from pound nets at intermediate distances (between 11 and 20 km from the release point) (Table 3).

Discussion

The present tagging experiments were carried out in different years and with different stocks of eels, which were dissimilar with regard to size. This obviously puts limitations on comparing the results from stock releases that differ significantly from each other. However, the four tagging experiments in the sheltered fjords can be compared to each other, and the two tagging experiments in Øresund are comparable to earlier tagging experiments in the Baltic Sea (Ask & Erichsen 1976, Sers *et al.* 1993, Westin 1998).

The present high recovery rate of 19-38% is about the same level as reported by Ask & Erichsen (1976), Sers *et al.* (1993) and Westin (1998) who reported between 16

and 49% recaptures from releases in the Baltic Sea. These results indicate a high level of fishing mortality on silver eels in the Baltic Sea.

A high fishing mortality on emigrating eels is also suggested by the short interval between release and recapture. In the present experiment, most eels were recaptured within 16 days, and in Øresund all recaptures were made within the year of release. This is in contrast to the findings of Westin (1998), who reported 45% recaptures during the month following release, 34% were recaptured later in the same year, and 21% were recaptured in the following year. The reason for this is that eels released in the central Baltic Sea are exposed to fisheries over a longer migrational distance than eels released in Øresund.

As a passive fishing gear, the fishing efficiency of pound nets depends on the activity of the fish, and more actively migrating silver eels will be more vulnerable than less active individuals. This may explain some of the differences between the timing of recaptures in the sheltered fjords and the more exposed coastal area. Most eels were recovered in the fjords where the densities of pound nets are high compared to the open coast in Øresund (Table 3). Other factors than the number of pound nets and pound net density are of importance to the rate of recovery. The position of a pound net may be equally important for the catch efficiency on migrating eels. At remote distances (20-50 km) high numbers were recovered despite a low density of pound nets (Table 3).

The locations of recoveries from Øresund suggest that most silver eels migrated in a northward direction, which is the natural direction of migrating silver eel at these sites. However, southward currents at the time of release possibly influenced the positioning of the recoveries. Only 8% (17 fish) were reported from areas more than 15 km south to the point of release. Likewise, Westin (1998) reported 6% of recaptured silver eels in a direction opposite to the natural migration route.

The number of pound nets reported by Koed & Pedersen (1996) may not reflect the true fishing effort (Table 3). A fisherman is not required to have his pound net positions registered, but registration ensures the rights of a fisherman to use particular positions. However, the pound net positions may not all be in use throughout the year.

The decrease in stock size and catches during the last 30-40 years in Danish waters has affected the number of pound nets along the coast (Danmarks Fiskeriforening 1998). Surveys of the number of pound nets for the entire Danish fishery in 1978 (Østrin 1979), and again in 1997 (Danmarks Fiskeriforening 1998) suggest a decrease in the fishing effort from 4144 active pound nets in 1978 to 947 pound nets in 1998.

A reduced fishing effort is also indicated by tag-recapture experiments on silver eels undertaken in Roskilde Fjord in the late 1960s. These experiments were similar to the present study with respect to sizes and sites of release but dates of release may have been earlier in the migratory season (K. Popp-Madsen, pers. comm.). In the 1960s, the resulting tag recovery was 80% (DFU 1970), while in the present study, total recoveries had dropped to 38% (Table 1). This suggests that during the last 30 years, fishing effort in Roskilde Fjord may have decreased around 50%.

The effect of reduced fishing mortality on the biomass of silver eels that survives to migrate from Roskilde Fjord may be estimated from catch data. The total annual mean catch (yellow and silver) in Roskilde Fjord in the years 1968-1970 was 235 tonnes, of which 25% were silver eels (Vinner 1985). In 1998 the total catch was 17.2 tonnes (E. Christensen, pers. comm.). Assuming the same percentage of silver eels in the total catch (25%), these data suggest that while in the late 1960s 14.6 tonnes of silver eels

escaped the fishery in Roskilde Fjord, in 1998 only 7.1 tonnes escaped the fishery. This is equivalent to a reduction of around 50% in silver eels leaving Roskilde Fjord since the 1960s.

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