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Dispersal of tagged juvenile turbot *Scophthalmus maximus* on the Norwegian Skagerrak coast

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Abstract

In the autumn of 1992 and spring 1993, 1076 artificially hatched and reared turbot *Scophthalmus maximus* of total length 15–25 cm were tagged and liberated at four locations on the Norwegian Skagerrak coast. In the 3 years after the release, 2% of the turbot were reported recaptured, mostly from the summer recreational gill-net fisheries. Recaptures were made at coastal sites within a range of about 50 km from the release locations. No reports came from the open Skagerrak or the North Sea. The recapture rate appeared to be positively correlated with size at release, but the individual growth in length was low compared with growth rates reported from other areas. © 1997 Elsevier Science B.V.

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1. Introduction

Along the Norwegian coast the turbot *Scophthalmus maximus* occurs from the Skagerrak to western Finnmark but the species is most common along the south and southwest coasts (Wollebæk, 1924; Nielsen, 1986). It is a highly valued fish on the market but the abundance is considered too low to support a target fishery. The recorded landings are mostly by-catches in gill-net fisheries for other species. Along the Norwegian Skagerrak coast recent commercial landings were 5–10 t year^{-1}.

Very little research has focused on the biology and distribution of the naturally occurring turbot in Norwegian waters. The basis for assessing the potential for increased exploitation is therefore weak. In Denmark, stocking experiments have been carried out (e.g. Nicolajsen, 1993), and questions were also raised in Norway about the potential for enhancing the natural population by releasing cultured juveniles in coastal waters. Both the fishery and enhancement interests require more documented information on the biology and ecology of wild as well as released turbot.

The turbot inhabits the sandy and rocky bottom from the sublittoral down to at least 70–80 m (Nielsen, 1986). The juveniles are found in shallow water (Rae and Devlin, 1972; Jones, 1974) and there is a movement towards deeper waters with size and age. The adults return to shallow areas during the spawning season which generally occurs in the period April–August (Nielsen, 1986) but probably with a peak in May–July in the North Sea (Rae and Devlin,

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1972; Jones, 1974; Knijn et al., 1993). In the western North Sea, females attain sexual maturity at an age of 4–5 years and a mean length of 46 cm (Jones, 1974). There is a pronounced sexual dimorphism in growth and for North Sea turbot, L_∞ values of the von Bertalanffy growth equation of females and males were estimated to be 64–65 cm and 49–56 cm, respectively (Mengi, 1963; Jones, 1974).

This paper focuses on the dispersal of juveniles from the shallow nursery areas and is based on a series of tagging experiments conducted in 1992–1993. Similar studies were reported from the Galician coast in northern Spain (Iglesias and Rodríguez-Ojea, 1994) and extensive liberation experiments were also made in Denmark (Nicolajsen, 1993). The aim of this study was to gain information on likely dispersal ranges of juveniles released at relatively shallow coastal sites. The tagged turbot had been hatched and reared in the laboratory and were liberated at an age of 14–24 months and size range 15–25 cm. Analyses of recapture data from the first 3 years following the releases are presented.

2. Material and methods

2.1. The fish

The turbot used in this study had been used in experimental growth studies before being transferred to Flødevigen to be tagged and released in nearby coastal waters. For the first 11 months, the fish were reared on artificial feeds in tanks at the Bergen High Technology Centre (Imsland et al., 1995). From the start of the experiment the juveniles were split into four groups which were raised at constant temperatures of 10, 13, 16 and 19°C. The hatching date was 7 July 1991 and the broodstock was wild-caught turbot from western Norway.

There was negligible mortality during the transportation from Bergen to Flødevigen in June 1992. In Flødevigen the four groups were kept separately in water pumped from 19 m depth. The temperature was measured daily, and in 1992 the minimum and maximum temperatures recorded were 3.6 and 17.2°C, respectively (mean 9.6°C). The turbot were fed artificial feeds as in Bergen.

2.2. Tagging and release

The fish originally kept at 13, 16 and 19°C were released on 28 August 1992. By then, the 10°C group fish were considered too small to be tagged. These were kept over the winter and released on 10 May 1993.

Yellow Floy tags (FD-68 B Anchor Tag) were anchored at the base of the dorsal fin on the eye side, at a position approximately one-third of the length of the dorsal fin posterior to the first ray. Individual weight and length were recorded. Numbers, mean total length, mean weight and age of the released fish are given in Table 1. After tagging, the fish were kept in tanks for 1–4 days prior to the release. No mortality occurred in this period.

Four release sites were selected which were assumed to offer suitable habitats for juvenile turbot (5–15 m depth, sandy substrate) (Fig. 1). The fish

Table 1
The four groups of juvenile turbot, *Scophthalmus maximus*, released on the Norwegian Skagerrak coast in 1992 and 1993. Numbers in parentheses are standard deviations

	Group 1	Group 2	Group 3	Group 4
Incubation temp. (°C)	10	13	16	19
No. liberated	206	285	256	329
Date liberated	10/5/93	28/8/92	28/8/92	28/8/92
Age at liberation (months)	22	13	13	13
Mean length at lib. (cm)	17.1 (2.1)	16.4 (1.9)	20.4 (2.1)	22.1 (3.1)
Mean weight at lib. (g)	119.6 (51.1)	88.1 (38.4)	184.0 (65.3)	230.3 (87.1)
No. recaptured	3	2	4	12

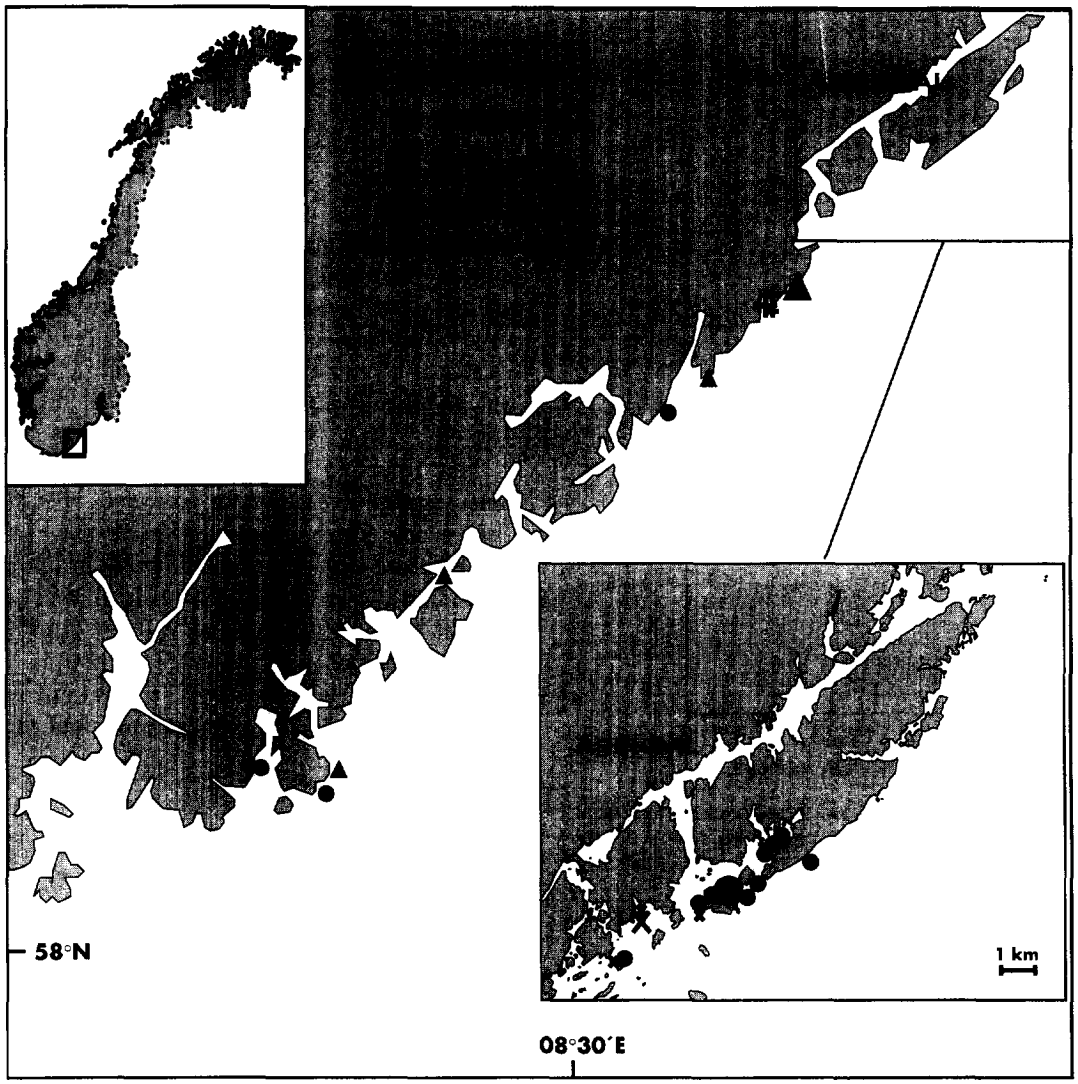

Fig. 1. Locations on the Norwegian Skagerrak coast where juvenile turbot were released (large symbols) and recaptured (small symbols). See Table 1 for data on each group of juveniles released.

were released at the surface, and to ensure some local dispersal the boat was steaming slowly forwards. The fish seemed to descend immediately.

The experiment was advertised by posters at fish markets and fishing tackle shops in nearby towns, as well as by press releases which led to interviews in local newspapers and the regional radio. The public was asked to record date, location and depth of capture, gear type, length and weight of the fish, and if possible, to keep the fish frozen. A reward of NOK 25 per tag was promised.

3. Results

3.1. Distribution of recaptures

Recaptures were reported from coastal locations within a range of 50 km from the release sites (Fig.

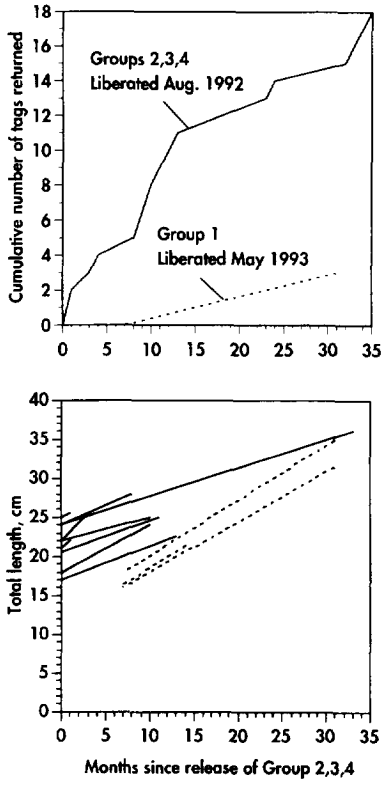

Fig. 2. Cumulative number of tagged turbot juveniles recaptured (upper), and individual growth in length during time at liberty (lower): solid line, fish from Groups 2, 3 and 4; dashed line, fish from Group 1.

1), and as of September 1995, 21 tag returns were recorded. Many local recaptures were made, and the few more distant reports came from locations to the southeast of the release areas. All catches were made in relatively shallow waters (i.e. less than 30 m depth), and with very few exceptions by gill-nets. Most reports came from the recreational fishery and from the period April–September (18 tags). For the turbot released in August 1992 the recapture rate appeared highest during the first summer after the release (Fig. 2), but the cumulative curve was almost linear overall, and tags were still being returned throughout the third year. The distance between release and recapture site did not increase with time at liberty, i.e. equal proportions of local and distant recaptures were made throughout the period of recovery.

3.2. Proportions recaptured

Of the total number of turbot released on 28 August 1992, 18 or 2.1% were reported recaptured after 3 years. The recapture rates were 0.7%, 1.6% and 3.6% for the groups raised at 13, 16 and 19°C respectively. There was an apparent increase in the proportion recaptured with temperature during the culture phase and, thus, size at liberation (Table 1). Of the 10°C group liberated in May 1993, three (1.5%) had been reported recaptured after 32 months.

3.3. Individual growth

Few recapture reports included precise and reliable records of fish length or weight. For the few fish which were measured, the length increment since release was very variable between 0.3 and 1.2 cm $month^{-1}$ (fig 2). The three fish at liberty for two growth seasons, which were in their third year of life, had reached a length of 31.5–36.0 cm. Seven specimens had been weighed, and during the 1–2 years at liberty they grew at a mean rate of 0.21% day^{-1} (SD = 0.07).

4. Discussion

This study should be regarded as a pilot study of dispersal, survival and growth of cultured juvenile turbot released in Norwegian coastal waters. The sources of error of tagging studies of this kind have been discussed extensively by others, e.g. tagging mortality, tag loss, non-reporting, and spatial and temporal variation in the fishing intensity (Ricker, 1975) and poor performance of the laboratory-reared fish in the wild (e.g. Blaxter, 1975; Howell, 1994). Iglesias and Rodríguez-Ojea (1994) found that all the turbot tagged with T-tags near the caudal peduncle kept in captivity for 1 month survived, but after 1 year 8% of the fish had lost the tag. Non-reporting is probably a lesser problem in this case because each fish caught is handled manually. The fact that few fish are recaptured, as the turbot is mainly obtained as a by-catch, may be a greater problem.

The results indicate, however, that juvenile turbot of size 15–25 cm must be expected to disperse within a range of at least 50 km from the release site.

In the present study, all the distant recaptures were made to the southeast of the release sites. This suggests that the turbot had a tendency to move with, rather than against, the prevailing coastal current. Turbot of comparable size liberated in shallow water (less than 25 m depth) in Spain showed only limited dispersal within about 5 nautical miles from the release sites (Iglesias and Rodríguez-Ojea, 1994). Those released in deeper waters on the continental shelf, however, showed much greater movement.

The proportion recaptured obtained in this study seemed low compared with the 9.5% after 1 year reported from Spain (Iglesias and Rodríguez-Ojea, 1994), but was of the same magnitude as the Danish results (Nicolajsen, 1993). When comparing the different groups of fish liberated, there was a positive relation between the mean size at release and the proportion recaptured, but this result is uncertain when considering the rather low number of individuals in each group. There may have also been qualitative differences between the release locations, causing variable mortality.

The limited data on growth since liberation can be compared with published population growth curves from the North Sea. Mengi (1963) found that the mean length of male and female group 1 turbot was 19.5 and 20.2 cm in September. The size of the 13, 16, and 19°C groups at liberation (Table 1) was thus similar to the wild fish of the same age. After 10 and 13 months at liberty, i.e. group 2, the length of the fish recaptured was 22.5–25.0 cm. This is in the lower part of the length range of the same age-group in the North Sea which ranges from 23 to 33 cm in September (Mengi, 1963). Only three fish recaptured as 3-group were measured, and their length range was 31.5–36.0 cm which is also low compared with the mean lengths of wild group 3 in the North Sea (Mengi, 1963; Jones, 1974). These comparisons suggest that the growth of juvenile turbot in the Skagerrak is slow compared with turbot in the North Sea. Unfortunately, there are no local growth data available for comparison.

The released turbot also grew notably slower than the remaining fish kept in the laboratory at constant temperatures. The average daily weight growth rate of the released fish averaged 0.2% (range 0.1–0.3) day^{-1}, whereas the average daily growth rate averaged 0.5% day^{-1} among turbot in the same size range reared at 10 and 16°C over a 12 month period (Imsland et al., 1996). This suggests that the relatively low growth rates of the released fish could be due to food limitation.

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