The effect of stocking size on the first winter survival of whitefish, Coregonus lavaretus (L.), in the Gulf of Bothnia, Baltic Sea

Article *in* Fisheries Management and Ecology · April 2002

DOI: 10.1046/j.1365-2400.2002.00282.x

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Fisheries Management and Ecology, 2002, **9**, 79–85

The effect of stocking size on the first winter survival of whitefish, *Coregonus lavaretus* (L.), in the Gulf of Bothnia, Baltic Sea

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Abstract The anadromous whitefish, *Coregonus lavaretus* (L.), is the most numerous fish species stocked in the Gulf of Bothnia, Baltic Sea. One-summer-old-whitefish fingerlings are mostly 8–10 cm long when released annually in September–October, whereas the wild whitefish are 10–12 cm at that time. About 6 million, one-summer-old, spray-marked, whitefish were released in the northern and central parts of the Gulf in 1995–1998. To study the effect of the stocking length on the survival of the marked fish, the length of the recaptured whitefish as 1-year-olds was back-calculated. Altogether 1106 whitefish recaptured in the Gulf of Bothnia were analysed. The back-calculated length was slightly greater than the stocking length but not as large as the length of the wild fish. In the central part of the Gulf of Bothnia, where the mean stocking length was more than 10 cm, the back-calculated length was 10.5–11.1 cm. In the northern part of the Gulf the mean stocking length varied between 8.8 and 10.0 cm annually, and the corresponding back-calculated mean lengths were 9.3–9.7 cm. It also seemed that bigger fingerlings started their feeding migration earlier or they migrated faster than the smaller ones to the southern parts of the Gulf of Bothnia.

KEYWORDS: growth, length at 1-year-old, spray-marking, stocking, whitefish.

Introduction

In the Gulf of Bothnia, 5–10 million, one-summer-old, anadromous whitefish, *Coregonus lavaretus* (L.), are stocked annually. The fingerlings are released in late autumn. Most of the whitefish are stocked for compensatory purposes by hydropower companies. In the Finnish water courts of law decrees, only the number and age of stocked whitefish are prescribed. This has caused criticism among fishermen, because according to some observations naturally born one-summer-old whitefish are larger than the stocked individuals of the same age. It has been argued that because of their smaller size the stocked fish are not as viable as the wild ones. On several occasions the size of the fingerlings in autumn has been strongly correlated with the survival during the first winter (Shuter & Post 1990; Johnson & Evans 1991; Buijse & Houthuijzen 1992; Conover 1992). In northern areas, where the growing season is short and the winter long, the juveniles need to store much energy within a short time period to survive the first winter.

The energy reserves of the stocked fish are consumed by survival in first winter, and feeding migration, which may extend up to 500 km south from the stocking place (Leskelä, Jokikokko & Huhmarniemi

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2002). The migration towards south is to obtain better food resources (Lehtonen & Himberg 1992). For example, in the northern Gulf of Bothnia the biomass of macrozoobenthos is as low as 1 g m^{-2} (200–500 individuals m^{-2}) whereas in the southern Gulf of Bothnia the biomass is reported to be 10–60 g m^{-2} (3000–5000 individuals m^{-2}) (Andersin, Lassig & Sandler 1977). Additionally, the warmer temperature and longer growing season in the south also promotes better growth of young whitefish.

The objective of this study was to determine, if (a) length of the stocked, one-summer-old whitefish was related to their survival in the sea; and (b) if the back-calculated length of the marked whitefish, which were caught simultaneously at different places and compared with show if the size of the fish reflected the migration speed or time.

Materials and methods

The stocking results of whitefish in the Gulf of Bothnia can be evaluated only by marking experiments, because the anadromous whitefish reproduces naturally, and it is impossible to distinguish the stocked and wild fish from each other in the sea area. Another, naturally reproducing whitefish, the sea-spawning whitefish, *C. lavaretus widegreni* (Malmgren), also lives in the Gulf of Bothnia (Himberg & Lehtonen 1995). The two forms are difficult to separate, especially because the gillraker numbers overlap (Himberg 1970; Lehtonen 1981). Fluorescent pigment spray marking of large numbers of young fish has already been used with success in salmonid studies (Phinney, Miller & Dahlberg 1967; Phinney & Matthews 1969, 1973) and after modification it was found applicable for one-summer-old-coregonids (Friman & Leskelä 1998; Leskelä 1999).

Fish were marked either in the release site at the sea or in the ponds before transportation to the release site. A small number of marked fish and an unmarked control group of fish were kept in net cages to check mortality after marking. During marking the water temperature was less than 10 °C, which was in accordance with the recommendations of Friman & Leskelä (1998). The pigment was mixed with water (1:1) and sprayed with six bars pressure. One or two tones of marking equipment were available. The highest daily marking rate was about 100 000 fish per day, if two sets of equipment and a three man crew were used. The method and equipment used was described in detail by Friman & Leskelä (1998).

In the central part of the Gulf of Bothnia, 1.6 million one-summer-old-whitefish were spray-marked and released in the years 1995 and 1996. In the northern part of the Gulf of Bothnia a total of 3.9 million marked whitefish were released in 1996–1998. (Fig. 1, Table 1). Green, red and yellow pigments from the Fiesta Daylight Fluorescent Colours, LMP-series were used. Release took place in September–November. All stocked fish were raised in natural food ponds, into which they were released in spring as newly hatched fry without supplementary feeding.

Samples of fish were collected from professional fishermen along the coast of the Gulf of Bothnia between 1995 and 1999. As the marked whitefish had not yet recruited to the whitefish fishery, most of the samples were taken from the by-catch of mainly herring, *Clupea harengus* L., and whitefish, *C. lavaretus*, trapnets with a bag of 10–12 mm mesh-size (bar length). Some samples were obtained from trawls or winter seines. The spray mark was detected under an ultraviolet lamp. The length of all marked fish was measured and an impression of the scales was made on a piece of plastic. The scales were measured from the focus to the first annulus and to the

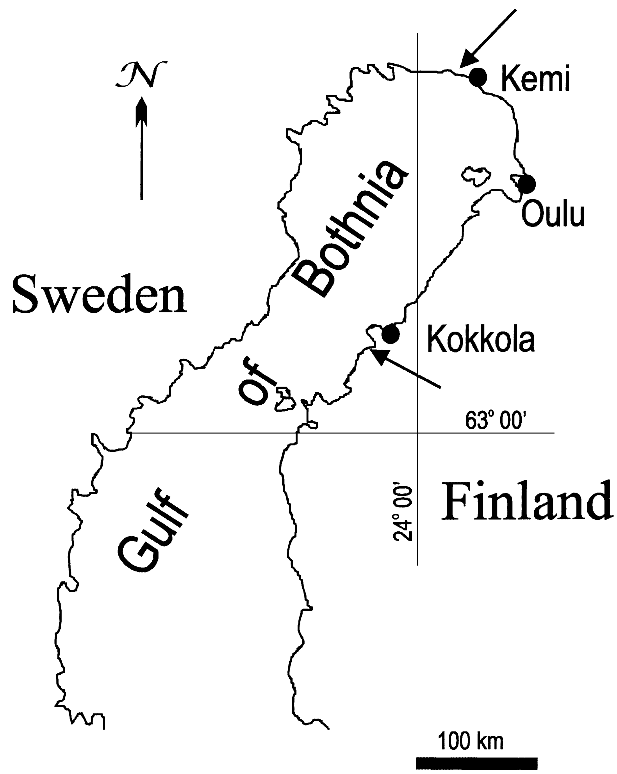

Figure 1. The stocking places of the spray-marked whitefish in central and northern Gulf of Bothnia.

Table 1. Numbers marked and the mean stocking lengths of spray-marked whitefish in different years and the back-calculated mean lengths at an age of 1 year of the recaptured fingerlings. The statistical significance of the difference between the stocking length and the back-calculated length is also given

Stocking place	Stocking year	Number of marked and released	Mean stocking length mm (n)	SD	Back-calculated length mm (n)	SD	Difference (P)
Central	1995	692 700	107 (572)	9.8	111 (136)	12.9	< 0.000
Central	1996	898 500	102 (932)	7.4	105 (72)	12.1	0.015
North	1996	1 320 000	100 (339)	3.6	97 (490)	7.6	< 0.000
North	1997	1 513 000	88 (619)	5.1	93 (304)	9.7	< 0.000
North	1998	1 081 000	90 (412)	4.2	94 (104)	12.8	0.009

edge. Back-calculation was based on the regression between scale radius and fish length developed for anadroumous whitefish caught in the northern Gulf of Bothnia (Raitaniemi 1998), i.e. fish length $= 12.362 \times (\textit{scale radius})^{0.6583}$, $r^2 = 0.988$.

The length at release and the back-calculated length of the recaptured fish at 1-year-old were compared using the non-parametric Kruskal–Wallis test. The H_0 was that the mean length of the stocking group and the back-calculated length of the recaptured fish originating from that group were the same and thus, the survival would not be affected by the stocking length. The back-calculated lengths of fish caught at the same time from different parts of the coast were also compared. The H_0 was that the back-calculated length at 1-year-old was the same in all areas. That assumption meant that the stocking length would not affect the migration speed or spatial distribution of the stocked whitefish. As the fish were stocked in the late autumn, it was assumed that the stocked fish would not grow in the sea after the release. Also the length of the control fish kept in the fish farm showed that there was no growth during the winter months.

In the northern Gulf of Bothnia the effect of the stocking length on the survival was studied by comparing the mean length of the spray-marked fish caught with a winter seine in March–April before the next growing season and the mean stocking length. The assumption was that if the size of the stocked fish had an effect on survival, the smallest fish would die during the first winter, and the mean length of the recaptured fish would be greater than that of stocked. Again it was assumed that the fish did not grow between release and recapture.

Results

The number of the recaptured whitefish was low when compared with the total number of marked fish. From fingerlings stocked in the central Gulf of Bothnia, length was back-calculated from 136 fish (0.02% of marked fish) of the 1995 year-class and 72 fish (0.01% of marked fish) belonging to 1996 year-class. In the northern Gulf of Bothnia back-calculated length was determined from 490 fish released in 1996 (0.04% of marked fish). The respective numbers for the release in 1997 and 1998 were 304 (0.02%) and 104 (0.01%). Most of the whitefish were recaptured in the year following release.

The mean length of marked groups varied little from year to year (Table 1). In 1995, the mean length of all stocked whitefish in Kokkola was 106 mm and the back-calculated length of the captured fish was higher (111 mm; $P < 0.001$). The size distribution was quite broad (Fig. 2a), and this was mainly because of three different stocking groups. The mean stocking length of two groups was 96 mm, which was significantly ($P < 0.001$) smaller than the back-calculated mean length of the recaptured fish. The stocking length of the third group was 115 mm, which was significantly ($P = 0.010$) larger than the back-calculated mean length. In 1996, the mean length of the stocked fingerlings was 102 mm, only slightly less than the back-calculated length of recaptured whitefish (104 mm; $P = 0.015$). Again, the distributions of both the stocking length and the back-calculated length were wide (Fig. 2b).

The whitefish stocked in the northern Gulf of Bothnia were somewhat smaller than their counterparts in the central Gulf of Bothnia (Table 1). In 1996, the mean stocking length was 100 mm, which was more than the back-calculated 97 mm of the recaptured fish ($P < 0.001$). In 1997, the stocking length was 88 mm, significantly less than the back-calculated 93 mm of recaptured fish ($P < 0.001$). The 1998 stocking length was 90 mm, again significantly less than the back-calculated length of 94 mm ($P = 0.009$). The stocking length of fingerlings varied much less in the northern Gulf of Bothnia than in the central Gulf of Bothnia (Fig. 3a–c). In

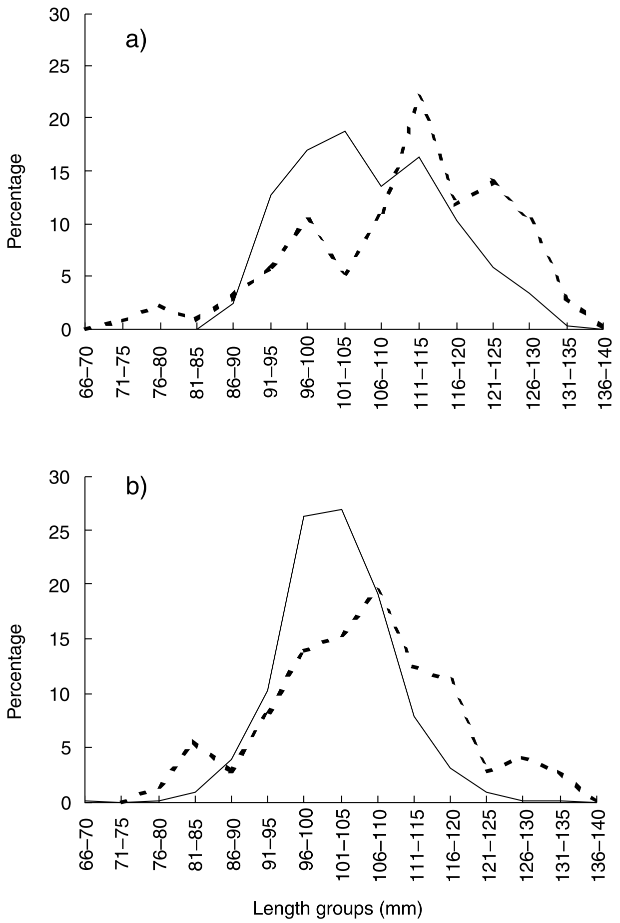

Figure 2. The length distribution of one-summer-old whitefish, when stocked (solid line) in central Gulf of Bothnia in years 1995 (a) and 1996 (b), and the corresponding back-calculated lengths (dashed line) as 1-year-old based in fish caught on later years.

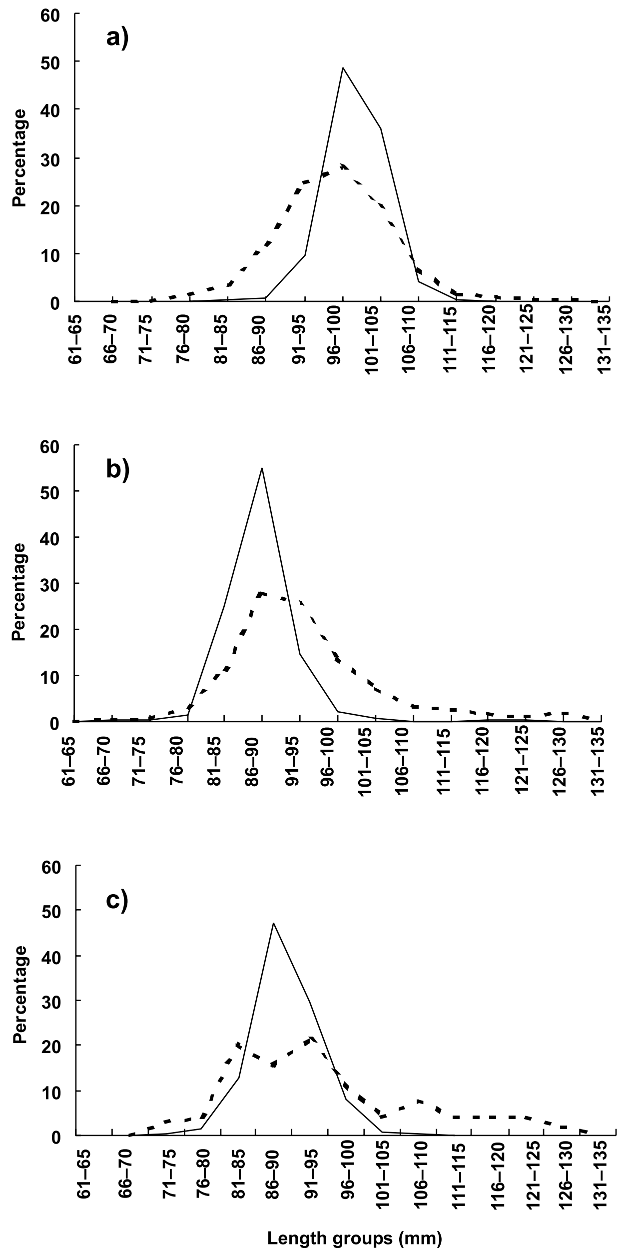

Figure 3. The length distribution of one-summer-old whitefish, when stocked (solid line) in northern Gulf of Bothnia in years 1996 (a) 1997 (b) and 1998 (c), and the corresponding back-calculated lengths (dashed line) as-1-year-old based on fish caught in later years.

March–May 1997, altogether 18 whitefish marked in the northern Gulf of Bothnia were caught with a winter seine in the northern Bothnian Bay. Their mean length was 101 mm, which was only slightly more ($P = 0.032$) than the mean length of the stocking group in 1996.

When the back-calculated lengths of the spray-marked fish caught from the sea area off Oulu in June and July in 1997 were compared, the fish caught in June were significantly longer than fish caught from the same area in July ($P < 0.001$) (Table 2). The back-calculated lengths of fish caught in July and August did not differ from each other ($P = 0.415$). Also in 1998 the fish caught in June were longer than fish caught in July, and the difference was just significant ($P = 0.05$). In Kemi no difference in length was found between the recapture months.

Discussion

The optimum size of the whitefish fingerlings used in compensatory stocking has been discussed in the Gulf of Bothnia ever since the large stocking programme began in the late 1970s. Especially in the northern Gulf of Bothnia, it has been argued that the stocked

Table 2. The back-calculated mean length (in mm) of the spray-marked whitefish released in the northern Gulf of Bothnia and recaptured from the sea area off Oulu and Kemi in next June and July

Caught in year	Sea area	Mean length in June (*n*)	Mean length in July (*n*)	Difference (*P*)
1997	Oulu	99 (45)	95 (140)	0.000
1997	Kemi	97 (129)	96 (140)	0.267
1998	Oulu	96 (29)	90 (58)	0.050
1998	Kemi	92 (118)	94 (20)	0.236

fingerlings are too small to survive through their first winter in the sea. The recaptures made in this study indicated that whitefish fingerlings stocked for compensatory purposes may survive over their first winter both in the northern and central Gulf of Bothnia. The mean size of the stocked whitefish groups varied from 88 to 106 mm. In subarctic and subalpine lakes in northern Finland the mean length of 1-year-old whitefish varied between 58 and 119 mm, but were mostly 80–100 mm (Lehtonen & Niemelä 1998). Also in Switzerland the mean length of 1-year-old whitefish were between 80 and 95 mm (Ruhlé & Gammeter 1998). Thus, the latitude and ambient linked temperature and the length of the growing season are not necessarily reflected in the whitefish size at the end of the first growing season.

The back-calculated mean length of stocked and recaptured fish at the end of the first growing season was slightly more than the mean stocking length in both study areas and in almost all study years. The only exception was the 1996 year-class in the northern Gulf of Bothnia, when the stocked whitefish were larger than in other study years in that area. The results suggested that within the size range studied here larger individuals survived better over their first winter. However, the difference in the mean length of the stocked fish and the back-calculated mean lengths of the recaptured fish were, in most cases, although statistically significant, very small. The reason for the higher mortality of the smaller fingerlings may be starvation during winter or predators or both. According to Lehtimäki (1984), the size of the stocked whitefish had a clear effect on stocking results when there were predators present. In a lake with predators, the size group 10.5 cm gave an 18 times higher recapture rate than the size group 7.2 cm, whereas in a lake with no predators the two size groups gave similar recapture rates (Lehtimäki 1984). When it comes to starving, fish length may not be as important a variable as fish condition or its fat content. However, as only fish length can be back-calculated, it was assumed that a large fish within a group should be in good condition.

The back-calculated mean length of the fish that had survived their first winter was less than the length of wild whitefish at the same age (Ikonen, Hietanen & Tuikkala 1985; Jokikokko 1985). The stocking length does not necessarily need to be as high as the length of the wild fingerlings, which means that the present production practice may continue and there is no need to drastically increase the length of stocked whitefish. However, the number of the recaptured young whitefish was low and the actual stocking success can be evaluated only after the whitefish catch produced by the stocked fingerlings can be estimated. The potential catch produced by the stocked fingerlings depends on survival and growth. Although related to survival, fish length at 1-year-old may not be related to the fish growth in future. In Lake Geneva, for example, the back-calculated mean length of stocked whitefish was smaller than that of wild specimens at age one, but differences in length by their third autumn were negligible (Champigneulle & Gerdeaux 1992). The stocking practice in Lake Geneva was different from that in the Gulf of Bothnia, in Lake Geneva stocking was with pre-fed fry in summer.

The length difference between June and July in the sea area off Oulu in 1997 and 1998 suggested that the bigger fish migrate earlier or faster southwards to their feeding grounds than smaller ones. However, it is difficult to be sure whether those fish caught in June were released earlier than the fish caught in July. Usually the natural food ponds are emptied just prior to freezing, and it may take more than a month to empty the ponds and transport all the fish into the sea. The fish released in the early part of the stocking season might have migrated farther than fish released several weeks later. It is also possible that the stocked fingerlings grew in the sea after stocking. Although the ponds are emptied in late autumn when the growing season is over, the sea water is normally a few degrees warmer than the pond water. This may cause biases when back-calculated length at an age of 1 year is compared with the stocking length.

According to Pierce, Rasmussen & Leggett (1996) the differences between back-calculated length and the true length were the greatest in 1-year-old fish. In nearly all cases, where the difference was evident, true lengths were greater than back-calculated length. If this was true in the current study, the real length of recaptured specimens would have been higher emphasizing the significance of the stocking length. However, Pierce *et al.* (1996) concluded that the back-calculation reasonably estimated the length at age, if correlation between length and scale radius is high as in the present study. Finally, this study has shown the efficiency of back calculation and spray marking methods to determine the survival of stocked fish over their first winter in the sea.

Acknowledgments

We thank the Voimalohi company and especially its research leader Mrs Tarja Zitting-Huttula for good co-operation during the planning of the study. We also thank the several companies responsible for whitefish stocking in southern Bothnian Bay who have co-operated with us during the study. We also thank the staff of the Voimalohi Oy and the field stations of the Finnish Game and Fisheries Research Institute for the arrangements and field work during the markings and collecting and handling the fish samples.

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