Stocking practices of anadromous whitefish, Coregonus lavaretus lavaretus, in Bothnian Bay, Finland; evidence from gillraker numbers

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Stocking practices of anadromous whitefish, *Coregonus lavaretus lavaretus,* in Bothnian Bay, Finland; evidence from gillraker numbers

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with 7 figures

Abstract: Anadromous whitefish *(Coregonus lavaretus lavaretus)* are economically one of the most important fish species in the Baltic Sea in Finland. Most of the biggest rivers in the Finnish Bothnian Bay have been blocked by hydropower plants, and natural reproduction of anadromous whitefish can only occur in small areas. Therefore, millions of fry and one-summer-old whitefish are stocked in the coastal area of the Finnish Bothnian Bay. The eggs are generally stripped from fish ascending the river at spawning time in October. As a lot of whitefish have been stocked in inland waters, a part of them have descended to the sea and river mouths. These fish are densely-rakered forms, which can be distinguished from sparsely-rakered anadromous whitefish. The proportion of these densely-rakered whitefish was 12,3 % in the River Kemijoki and 17,0 % in the River Simojoki in samples caught in summer. Likewise in samples caught from the sea, especially in the northern Bothnian h 1: Bay, there were densely-rakered whitefish. Due to these different whitefish forms, a cross-breeding is possible when anadromous whitefish are stripped. Annual examination of gillraker distributions in different rivers showed that artificial breeding has not threatened the stock purity of anadromous whitefish because the number of other whitefish forms caught during spawning time has been only 0,07 % The mean number of gillrakers varied from year to year in the rivers studied but no clear trend could be seen.

Introduction

According to the most recent catch data of the Finnish Game and Fisheries Research Institute, whitefish *(Coregonus lavaretus)* is the third most important fish in the Baltic Sea after the Baltic herring and salmon. In 1994, professional fishermen caught 1104 tonnes of whitefish from the Finnish sea area, valued at 16.6 million FIM (about 3.7 million USD). Additionally, recreational fisheries catch was about the same amount of whitefish from the sea. So, the total catch was about 2 000 tonnes. There are two sympatric whitefish forms in the Baltic Sea, the sea-spawning whitefish *Coregonus lavaretus widegreni* the river-spawning anadromous whitefish *Coregonus lavaretus lavaretus* (HIMBERG & LEHTONEN 1995*).* The distribution of gillraker number in sea-spawning and anadromous whitefish are very similar. The mean number of gillrakers of sea-spawning whitefish is 25–26 (from about 20 to 30) and of anadromous whitefish about 29 (from about 23 to 35). As they overlap, it is difficult to separate these whitefish forms from each other by using only gillraker numbers (HIMBERG 1970, LEHTONEN 1981). In the Bothnian Bay, the sea-spawning whitefish is, however, considerably smaller than the anadromous whitefish. The former will not grow bigger than about 30 cm in the northern part of the Bothnian Bay whereas the latter can be twice as long and the mean length of adult ones is about 45 cm.

Three main rivers in the northern part of the Finnish Bothnian Bay, the Rivers Oulujoki, Iijoki, and Kemijoki, have been dammed for electric power production. To compensate for losses to natural reproduction, the power companies are obliged to stock large numbers of whitefish on the sea coast and in the rivers above the lowest dam. The yearly compensation in the northern Bothnian Bay is over four millions one-summer-old anadromous whitefish and in

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the rivers about three millions one-summer-old densely-rakered whitefish, *Coregonus lavaretus pallasi* (45–60 gillrakers) (ZITTING-HUTTULA et al. 1995, 1996). In several other rivers the whitefish stocks are supported by stocking, although whitefish can ascend and spawn in those rivers without any hindrance. Altogether, many millions of one-summer-old fry are released yearly (Fig. 1). Populations of sea-spawning whitefish are completely sustained by natural reproduction, and no stockings are made.

The eggs of anadromous whitefish are generally stripped from fish ascending the river at spawning time in October. Since it is theoretically possible that the sea-spawning whitefish may occur in the river mouth simultaneously with the larger, anadromous form, the smallest fish (< 35 cm) are not stripped in order to avoid the cross-breeding of these sympatric stocks. In the sea, there are, however, also two other whitefish forms, which have been stocked in inland waters, and a part of them descend to the sea. In coastal waters, there occur *Coregonus peled* (GMELIN) with about 50–60 gillrakers. These fish are heavily stocked in the reservoirs in the upper part of the River Kemijoki, where they also reproduce naturally (SALONEN & MUTENIA 1992). Additionally, another densely-rakered whitefish *(Coregonus lavaretus pallasi)* is caught.

In nature, behavioural differences may prevent cross-breeding, although hybridization has been noted (SVÄRDSON 1979). Artificial hybridization is possible when brood fish arc caught and stripped, because different forms of the same length can be mixed with each other. Without gillraker counts, it is difficult to distinguish other whitefish forms from the anadromous whitefish, because their appearance and size are so similar. As the number of gillrakers is one of the most stable and reliable morphological characters (HIMBERG 1970, LINDSEY 1988), gillraker samples are taken from each river at spawning time to get information about the number of different whitefish forms in the spawning populations of anadromous whitefish. If cross-breeding occurred between whitefishes, it would be quite easy to detect it within the first generation because of the high mean number of gillrakers in stocked densely-rakered forms (45–60 according to SVÄRDSON 1979). Intermediate gillraker numbers are typical for F1-hybrids (SVÄRDSON 1952, MAMCARZ 1992).

In this study, we have examined the gillraker numbers of whitefish stocks in river mouths in spawning time and compared them with whitefish caught from river mouths and coast area in summer. The main reason is to study, does the artificial breeding threaten the stock purity of the anadromous whitefish by mixing different whitefish forms with each other.

Study area, material and methods

Samples of fish for gillraker counts were collected annually in autumn during spawning time in 1981–1995 from the main rivers of the Bothnian Bay. These are the Rivers Kalajoki, Oulujoki, Kiiminkijoki, Iijoki, Simojoki, Kemijoki, and Tornionjoki (Fig. 2). From 100 to 200 fish from each river were studied in every year. The whitefish samples were taken from local fishermen. Usually, gill nets or dip nets were used as a fishing method. The samples were taken over the whole spawning time to obtain a representative sample of the whole spawning population. A part of studied whitefish were used for breeding, but not all of them, because the spawning season is simultaneous in most rivers. In practice, it would not have been possible to arrange the sampling so that only stripped fish were taken for the study.

In the 1980s, samples were also taken in summer with gill nets from the mouth of the R. Kemijoki. The gillraker numbers of these whitefish reflect the stock composition found in the river mouth outside the spawning period. Also whitefish caught in early summer in the 1980s and 1990s from the R. Simojoki with a trap net used for descending salmon smolt were sampled

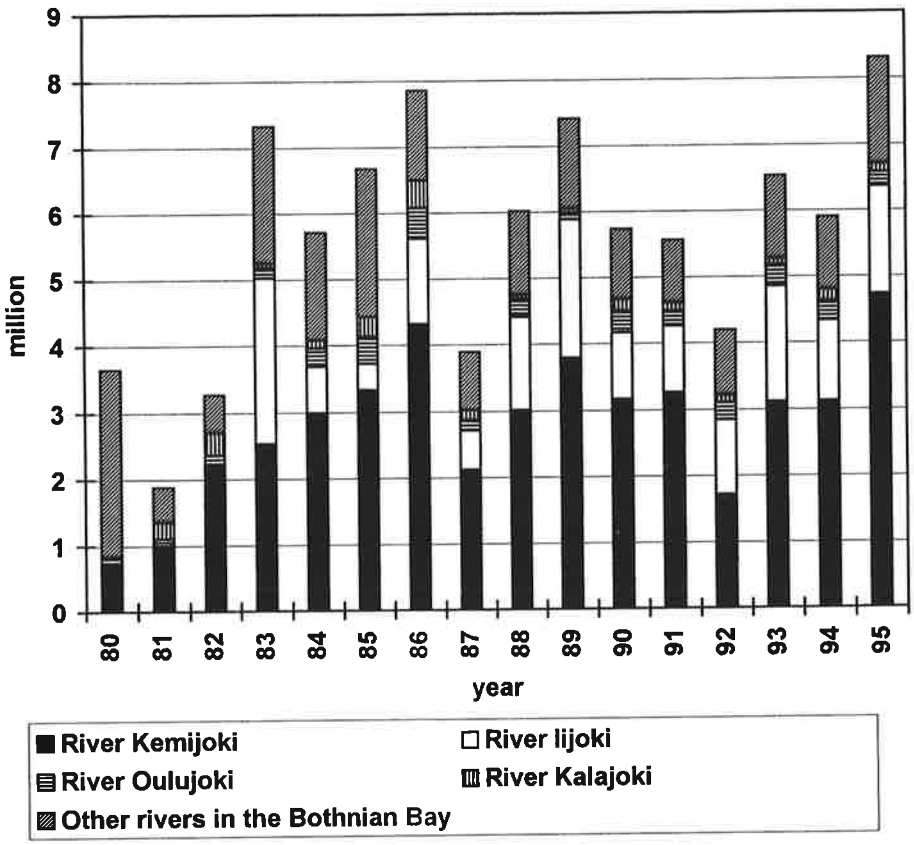


Fig. 1. The number of stocked one-summer-old anadromous whitefish in the Bothnian Bay in 1980–1995.

for gillrakers. These summer samples from both rivers were compared with the spawning populations.

Samples of fish for gillraker counts were also collected from Bothnian Bay to determine whether there were differences between whitefish of different size groups. In the southern and northern part of the Bothnian Bay, the gillraker distributions of whitefish from trap nets for salmon as well as for vendace and herring were studied. In this study, the border between the northern and southern part of the Bothnian Bay is about between the R. Oulujoki and Kalajoki (Fig. 2). Whitefish caught from the vendace traps should represent the whole whitefish population living in that sea area because all size groups were included. The whitefish caught with salmon traps were mostly adult anadromous whitefish, thus representing the spawning population.

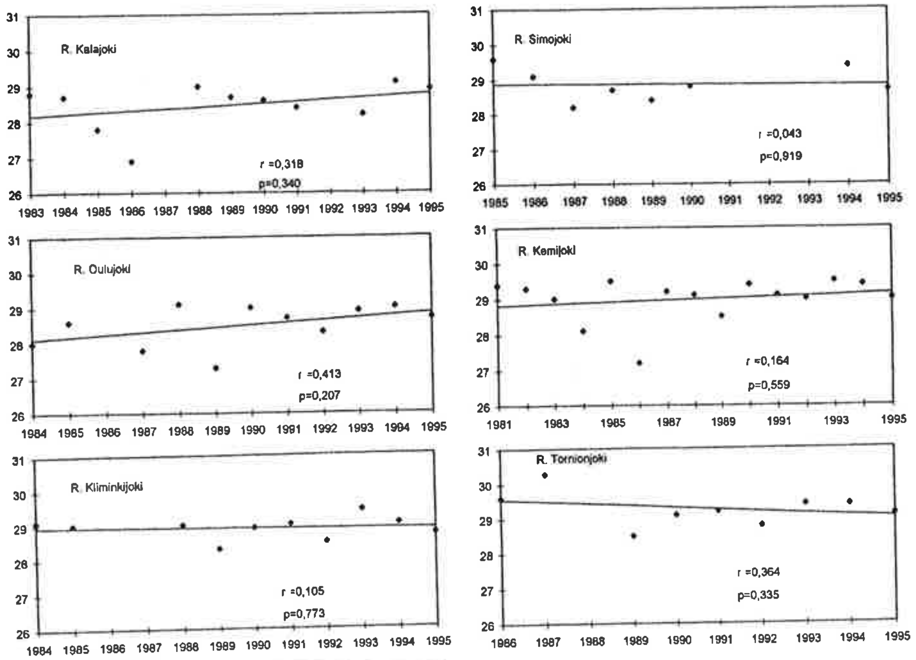
The gills from all whitefish were removed with scissors either in the field or the laboratory and were frozen for later study. The number of gillrakers in the first are were counted under a binocular microscope. The change of the mean number of the gillrakers of the spawning anadromous whitefish during the study period in each river was studied with a correlation analyses. The gillraker distributions in summer and autumn samples in the R. Kemijoki and Simojoki were compared with a Mann-Whitney U-test.

Fig. 2. The study area.

Results

When anadromous whitefish are fished with gill nets at spawning time in the rivers, bar length 50–60 mm is most often used compared to gill nets with the bar length 25–30 mm that is used for sea-spawning whitefish in the Bothnian Bay.) Due to the size difference, sea-spawning whitefish are not caught with the methods used (LEHTONEN 1981). Accidental hybridization may be more probable if specimens with high gillraker numbers occur among spawning whitefish, because they would be in the same size class. However, the total number of anadromous whitefish studied in October in years 1988–1995 was 10 680, and only seven specimens with over 40 gillrakers (these were 41, 43, 44, 54, 57, 58, and 60) were found (0,07 %). The mean number of gillrakers varies quite randomly from year to year (Fig. 3), and no trends can be seen in the rivers studied except the R. Iijoki, where the mean numbers have slightly risen (r=0,679; p=0,015). Whitefish caught from each river in spawning time had a modal gillraker count of 27–31 without any clear differences between the years.

The gillraker distributions of whitefish caught in summer and in spawning time were different in the mouth of the R. Kemijoki. In summer, the mean number of gillrakers was 32,6 (S.D.=8,23) compared to 29,0 (S.D.=2,37) in autumn. Also in the R. Simojoki, the mean number of gillrakers was higher in summer samples (29,7; S.D.=9,86) than in autumn samples (28,9; S.D.=2,27). The higher standard deviation in summer shows that the stock composition of whitefish was more heterogeneous in summer than in autumn. In both rivers, there was a statistically significant difference between the summer and autumn samples. In R. Kemijoki, the Mann-Whitney U-test value was 130,088 and p<0,001 and in the R. Simojoki U=69,658 and p<0,001. In both rivers, the



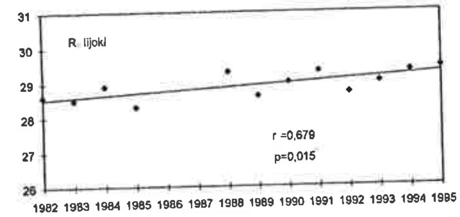


Fig. 3. The plot of mean gillraker counts of spawning populations of anadromous whitefish in different rivers in the Bothnian Bay in the 1980s and 1990s with a trend line. A correlation coefficient and p-value is given. A part of the data is from JOKIKOKKO (1986).

summer samples included many densely-rakered whitefish, which form another peak in the range of 45–55 gillrakers (Fig. 4 and 5). In the R. Kemijoki, 2,3 % of the studied whitefish had more than 40 gillrakers and in the R Simojoki the proportion was 17,0 %. This suggests that the whitefish populations are mixed in the rivers and on the coast, but in autumn only the anadromous whitefish was caught. Summer samples include mostly young and small whitefish which probably descended from inland waters.

Whitefish caught in salmon trap nets in the northern part of the Bothnian Bay had a modal gillraker count of 31 as compared to a modal count of 26 for whitefish caught in vendace and herring trap nets (Fig. 6). The mesh size of the bag in salmon trap was 40–50 mm (bar length), so the caught fish were mostly adult specimens and ready to spawn in autumn. According to the size and gillraker distribution, it was clear that the catch consisted primarily of anadromous whitefish. Their mean size did not differ much from the size of autumn spawners. The mean number of gillrakers was quite high, 30,1 (S.D.=2,77), but only two densely-rakered specimens (both had 53 gillrakers) were among the catch. The whitefish catch in the vendace and herring trap was more complex. That can be seen from the high S.D. (7,38). Owing to the high proportion of sea-spawning whitefish, the mean gillraker number was lower (28,0) than in salmon trap catches. The number of whitefish with 40–60 gillrakers, although higher than in salmon trap, did not raise the mean number very much.

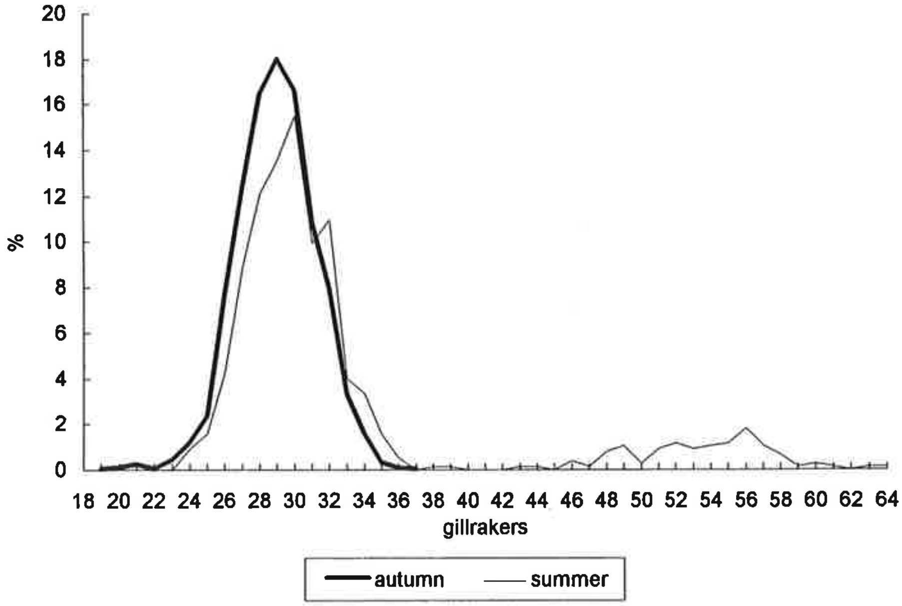


Fig. 4. The gillraker distributions of whitefish caught with gill nets in summer (n = 774) ad autumn (n = 2526) in the mouth of the River Kemijoki in the 1980s and 1990s.

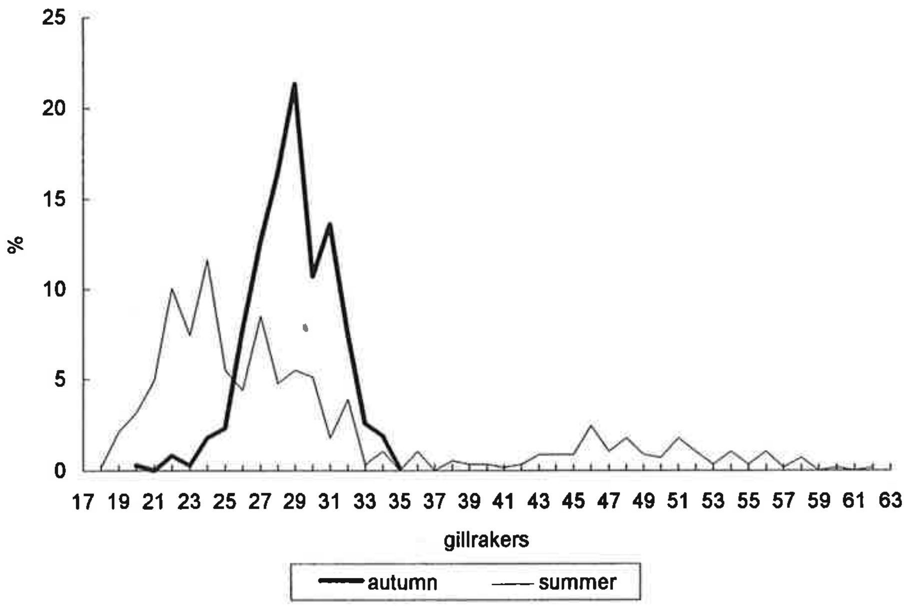


Fig. 5. The gillraker distributions of whitefish caught with a trap net in summer (n = 566) and with gill nets in autumn (n = 736) in the River Simojoki in the 1980s and 1990s.

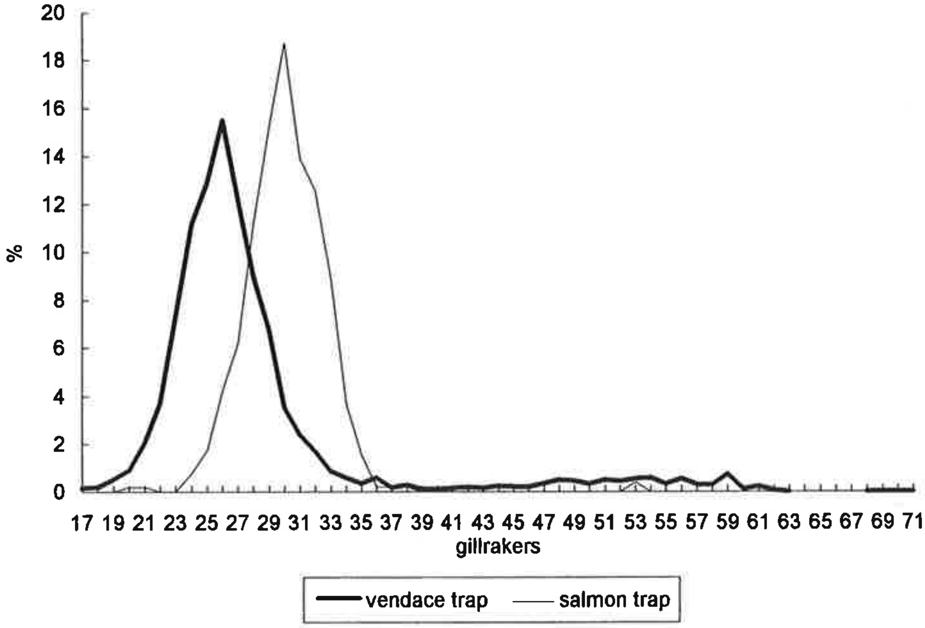


Fig. 6. The gillraker distribution on whitefish caught with trap nets for vendace and herring (n = 7939) as well as with trap nets for salmon (n = 518) in the northern Bothnian Bay in the 1980 and 1990s.

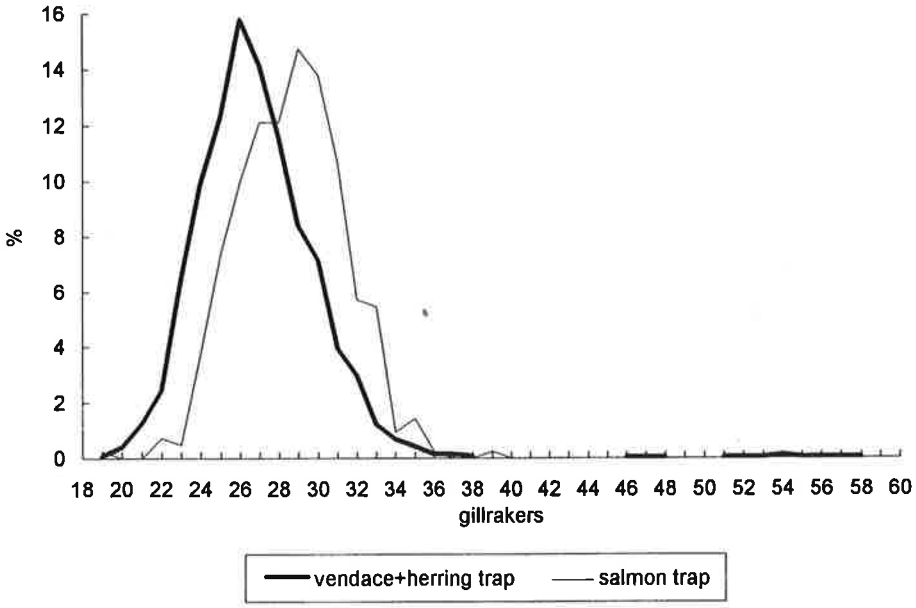


Fig. 7. The gillraker distributions on whitefish caught with trap nets for vendace and herring (n = 2783) as well as with trap nets of salmon (n = 421) in the southern Bothnian Bay in the 1980s and 1990s.

In the southern part of the Bothnian Bay, the mean number of gillrakers in whitefish caught with a vendace trap was even lower (26,9; S.D.=3,31) than in north. The reason for lower gillraker number was that most of the fish were sea-spawning whitefish and there were no densely-rakered whitefish in the catch (Fig. 7). In the southern area, the mean number of gillrakers of whitefish caught with salmon trap (29,4; S.D.=2,45) was near the number found in northern part of the Bothnian Bay.

Discussion

In Finland, there have been no earlier studies available to show how artificial breeding has affected the stock composition. There has been no special need to examine the artificial breeding from this point of view until the compensatory stockings started in 1983, when ascending whitefish were started to take for brood fish in river mouths in large scale. These stockings increased the number of released fish to levels where inadvertent hybridization between different whitefish forms became more likely than before. In 1976–1980, no densely-rakered whitefish were found from the samples taken in different months and with different fishing gear in northern Bothnian Bay (LEHTONEN 1981), so most of the densely-rakered forms found in this study do originate from the compensatory stocking made in inland waters since 1983.

The results showed that in the R. Iijoki there is a slight upward trend in mean gillraker numbers, but the reason for that is uncertain. If the reason was hybridization, it ought to be seen also in the R. Kemijoki, where quite many densely-rakered whitefish have been caught in summers. Secondly, only three whitefish with gillraker numbers between the anadromous whitefish *Coregonus lavaretus lavaretus* and the densely-rakered *C. l. pallasi,* were found during the last ten years. These fish may be F1-hybrids because of their intermediate gillraker number (SVÄRDSON 1952, MAMCARZ 1992), but it is obvious that hybrids have not raised the mean number of gillrakers in the rivers studied.

In many places, it has been noticed that the range of the gillraker counts has increased considerably either because of artificial breeding (MAMCARZ 1992, SZCZERBOWSKI 1992) or hybridization in nature (SVÄRDSON 1979). Our results suggest that, despite the fact that there were some densely-rakered whitefish in the samples studied, they did not affect the stock composition to a noticeable extent. Perhaps genetic and biochemical studies would reveal some change in the stock structure, but the counting of gillraker numbers is a useful way to check the spawning stocks and their variation (MAMCARZ 1992, SZCZERBOWSKI 1992). Theoretically, our assessments do not prevent hybridization of different whitefish forms, but they do provide the possibility to evaluate afterwards their effect. If only gillrakers of fish chosen for breeding could be count, it would be a more direct way of testing for hybridisation. However, this is not possible because too many brood fish are stripped to study them all.

The artificial propagation of anadromous whitefish can be continued with the current methods without too much fear of mixing the different whitefish forms, although care must be taken to preserve original stock integrity and diversity. Differences in reproductive behaviour should keep the whitefish forms separate although they are sympatric in the sea or river. Generally, the fishing methods in the rivers, the gill nets and dip nets, will be suitable for the anadromous whitefish. More studies are needed concerning the fate of the numerous descending young whitefish in those rivers where compensatory stocking are made. It is probable that they are not viable in the sea, because their proportion as adult fish is very small. However, there are not much data available concerning the gillraker counts of one-summer-old whitefish that originated from the eggs stripped in the river mouth. This would readily reveal the hybrids among the offspring. It would be very important to know this because of lower growth rate of hybrids and higher mortality rate of their offspring (MAMCARZ 1992).

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