Ann. Zool. Fennici 33: 569–575
Helsinki 28 November 1996
ISSN 0003-455X

Survival after catch in trap-nets, movements and growth of the pikeperch (*Stizostedion lucioperca*) in Lake Hjälmaren, Central Sweden

Per Nyberg, Erik Degerman & Berit Sers

Nyberg, P., Degerman, E. & Sers, B., Institute of Freshwater Research, National Board of Fisheries, Pappersbruksallén 22, S-702 15, Örebro, Sweden

Received 21 August 1995, accepted 4 April 1996

Lake Hjälmaren is a shallow eutrophic lake with an intense commercial fishery. The pikeperch is the most important species from an economical point of view. A total of 2 299 individuals with a total length of 22–39.5 cm were marked with Dart tags during late June–early August 1990. The fish were caught in commercial trap-nets, measured, marked and released immediately at the place of capture. In total 1 900 recaptures were recorded and the number of recaptured individuals were 887 (38.6%). Six individuals were recaptured 20 times and one fish 39 times in trap-nets, before it was caught and killed in a gill-net. These figures show that the fishing is intense. 48% of the fish that were recaptured once and released were recaptured also a second time. They also show that the young pikeperch tolerate capture in trap-nets and also survive post-capture handling before the release quite well. The pikeperch showed a very stationary behaviour during the growth season and many individuals were captured repeatedly in the same trap-net, both during the season of tagging and following seasons. On average pikeperch smaller than 30 cm were caught less than 2 km from the point of release, whereas fish 35–39 cm on average were caught 4–5 km away during summer. In the autumn the pikeperch moved from shallower areas to the deeper central part of the lake and were caught in gill-nets in the winter-fishery. The average rate of growth of pikeperch in the size 25–30 cm at the time of marking was 51 mm/365 days until they reached 40 cm (legal size limit). After that, the size selective gill-net fishery significantly affected the average growth rate, by catching and removing the most fast growing individuals.

1. Introduction

Lake Hjälmaren (59°20′N, 15°85′E) is the fourth largest lake in Sweden. The lake was extensively used by different categories of fishermen until 1994. Sportfishing for pike (*Esox lucius* L.) and perch (*Perca fluviatilis* L.) is very popular both during winter and summer and what may be called a subsistence fishery with gill-nets was of importance until 1994. Then, a new Fishing Act and Fishing Ordi-

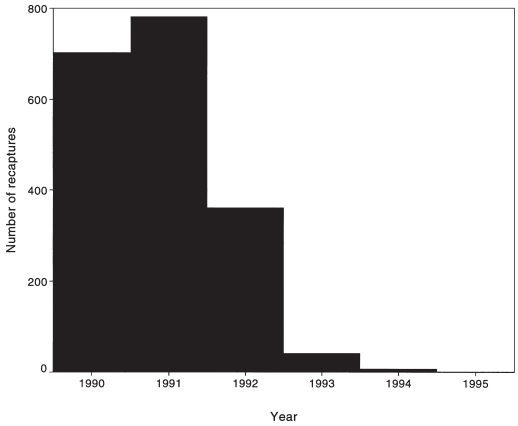

Fig. 1. Yearly numbers of recaptures of tagged pikeperch in 1990–95.

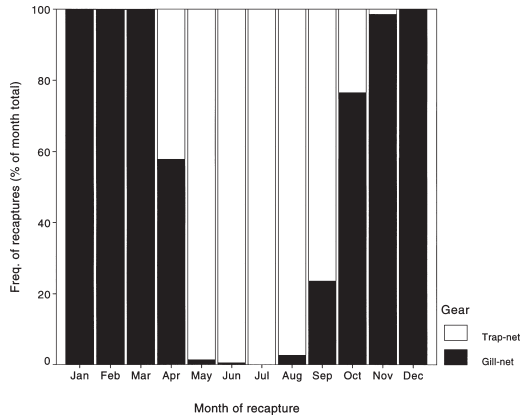

Fig. 2. The relative monthly distribution of recaptures of pikeperch made in trap-nets and gill-nets, respectively.

nance favoured the commercial fishery, by reducing the kind and amount of fishing gear allowed to be used by non-commercial fishermen. Pikeperch has been and is still the most important species in the commercial fishery, both in weight and from an economical point of view. The importance of eel (*Anguilla anguilla* L.) has been increased by yearly stockings. Other important species are pike, perch and the introduced American crayfish (*Pacifastacus leniusculus*).

Fifty-three commercial fishermen are occupied in the lake and have permission to use a fixed maximum number of fishing-gear. There are no closed seasons in the fishery and the only restrictions are minimum legal sizes for pikeperch (40 cm) and eel (55 cm). The gill-nets used in the pikeperch-fishery must have a mesh-size of above 50 mm (knot to knot). Trap-nets of different mesh-size are used during the summer.

Due to the eel stockings, fine mesh-size trap-nets have increased in importance. About 80% of the total yearly catch of pikeperch is, however, caught in gill-nets during September–April. Catches are primarily made of a single year class and variations in year class strength have led to yearly catches being in the range 53 to 246 tonnes during 1969–94. The catches were generally highest in the beginning of the period, when the lake was even more eutrophicated than today (Svärdson & Molin 1981). In 1993 and 1994 the yield of pikeperch was 68 and 79 tonnes, respectively. The increased eel-fishery and the use of fine-mesh trap-nets were claimed to catch and kill large amounts of pikeperch of less than 40 cm.

The primary aim of this tagging experiment was therefore to investigate the degree to which young pikeperch survived both capture in trap-nets and the handling before release. Secondary aims were to study movements during different seasons and growth rates of the young pikeperch.

2. Lake Hjälmaren

Lake Hjälmaren is a shallow and eutrophic lake which consists of four relatively isolated basins from the west to the east: Hemfjärden, Mellanfjärden, Storhjälmaren and Östra (Eastern) Hjälmaren. Even the southern part is partly isolated from the main basin, Storhjälmaren. Average depth and water quality differs a lot between these basins. Hemfjärden is very shallow (average depth: 1.0 m), eutrophicated and of little importance for the pikeperch. Storhjälmaren, has a maximum depth of 18 m and an average depth of 6.9 m. The corresponding depths in the eastern part are 20 m and 4.9 m and in Mellanfjärden 3 m and 1.8 m, respectively. Due to the shallowness, the water column only occasionally stratifies thermally for short periods during the summer. The total area of the lake is 450 km^2, (excluding the western basin 25 km^2). The average concentration of total phosphorous in May–October, 1981–93 was 48 µg/l in the main basin, the corresponding concentration of total nitrogen 0.72 mg/l and the average secchi-disc depth was 2.5 m. The total volume of phytoplankton varies during the season and the average volume during May–October,

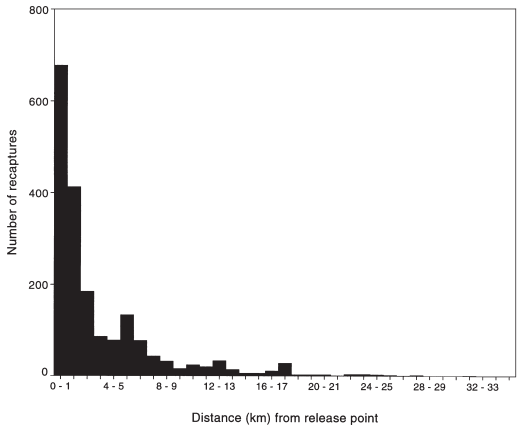

Fig. 3. Distances (km) from release point for recaptures during summer (May–October)

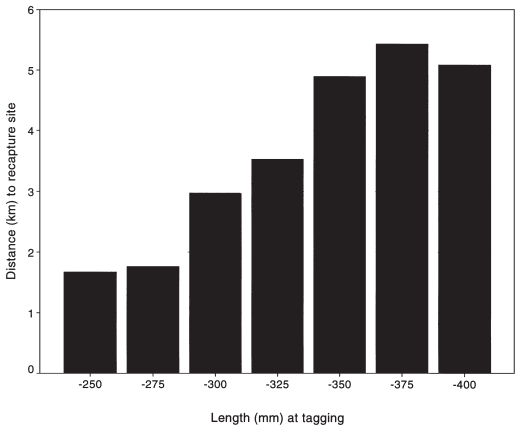

Fig. 4. Average distance (km) of recapture from release point for pikeperch of different size at tagging.

1991–94 was 0.81 $mm^3 l^{-1}$. The maximum concentrations of chlorophyll a in spring reaches 20–40 ug/l in the main basin. The yearly average water temperature (1.5 m depth) was 8–10°C during the study, with summer maxima of 20–24°C.

3. Methods

The pikeperch were caught in trap-nets during commercial fishing. The fishermen put all the pikeperch smaller than the legal size in a 100-l barrel. The fish was immediately picked up from the barrel, measured (total length), marked with nylon Dart tags (Yamashita & Waldron 1958, Hallprint Ltd., Australia) un-anaesthetized and released at the place of capture. The tagging places were distributed all over the lake where a trap-net fishery existed and the geographical position of each trap-net was identified. When calculating the position of the average release point in each area, the number of fish marked in each trap-net was taken into consideration.

Tags from recaptured dead or killed fish were sent to the Institute of Freshwater Research together with information about time and place of recapture and total length of the fish. Under-sized live fish were length-measured, the number of the tag read, the place of recapture noted and the fish released. The kind of fishing-gear used was also noted in both cases. Recapture positions were identified geographically to the nearest km. The recaptures were divided into two periods: April–October and November–March. The first period corresponds to the trap-net season, and the second to the gillnet season. A certain overlap in the use of fishing gear existed in April–May and September–October. Very few gill-nets were, however, in use during June–August.

When calculating the rate of growth, only fish with a total length of 25–30 cm at the time of marking and recaptured in trap-nets were used. This was because larger fish were caught and killed in gill-nets too soon after marking to make meaningful growth calculations. The growth rate was also calculated for a sample (n = 30) of fish that were recaptured in gill-nets during winter or trap-nets in spring-early summer before the start of the growth season. 17 of these fish were also recaptured in the second growth season after marking. As the markings were performed during about 1.5 months, growth rate has been expressed per 365 days, irrespective of when the fish was marked. Information about weekly water temperatures was collected from the water plant in the city of Arboga, which has the water inlet at a depth of 1.5 m.

4. Results

4.1. Markings and recaptures

In total, 2 299 pikeperch with a total length of 203–399 mm were marked during late June–middle of August 1990. The average length was 297.5 mm. 887 individuals (38.6%) of the marked fish were recaptured once or more. 68 individuals were recovered 5 times, 28 individuals 10 times, 6 individuals 20 times, 2 individuals 32 times and 1 individual 40 times. As several individuals were recovered more than once, the total number of recaptures was 1 900. The initial mortality due to the handling and marking of the fish was evidently high, as the proportion of the fish that was recovered increased with the number of times of recapture: 887 (38.6%) of the marked individuals were recaptured once or more, 646 of these were released and 312 (48.3%) were recaptured a second time, 245 of these were released and 161 (65.7%) individuals recovered a third time, 137 of these were released and 102 (74.4%) individuals were recaptured a fourth time.

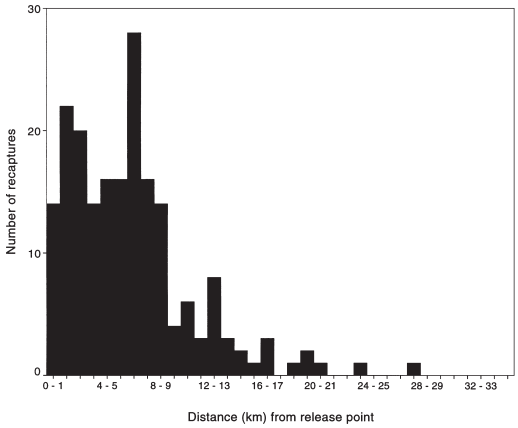

Fig. 5. Distances (km) from release point for recaptures during winter (November–April).

Most recoveries were made in 1990 and 1991 after which the number of recoveries decreased drastically and very few were recovered after 1992 (Fig. 1). The recaptures were made in trap-nets during the summer and in gill-nets in late autumn and winter (Fig. 2). During 1990–92, over 75% of the recaptures were made in trap-nets, but the proportion recovered in gill-nets increased over time as the pikeperch grew larger. In 1993–1995, 42–59% of the pikeperch were caught in gill-nets.

4.2. Movements

Most recaptures were made very close to the place of marking during the summer period (April–October) (Fig. 3). 1 731 recoveries, where exact location of recapture place was known, were made at an average distance of 2.9 km from the release point. 50% of the recaptures were made within 1 km from the marking place. There was a statistically significant difference (ANOVA, $p < 0.001$) in the average distance of recapture from the release point between small and larger pikeperch. Fish smaller than 30 cm had on average moved less than 2 km from the point of release, whereas fish 35–39 cm had moved 4–5 km on average during the summer (Fig. 4). During the winter period (November–March) the pikeperch were recaptured at a longer distance from the release point (Fig. 5) and the average distance from the place of tagging for 155 recoveries was 6.3 km. 50% of the recaptures, however, occurred within 6 km of the marking place. During the summer the pikeperch were generally recaptured in the area where they had been marked. This was valid not only for the year of marking, but also for all recaptures, i.e. also the following years (Fig. 6). The only exception was in area 5, from which the only recapture (1 fish) was made in area 4. During the winter-fishery with gill-nets the recaptures of fish marked in areas 1, 2 and 4 aggregated in area 4 and recaptures of fish marked in area 6 were made in area 5. The fish marked in area 3 were, however, recovered in the same area (Fig. 7).

The pikeperch marked in areas 1, (5) and 6 were on average recaptured slightly more than 5 km from the release point during the summers, while fish tagged in area 7 moved very little and were on average recovered 1.6 km from the marking place. The pikeperch marked in area 7 also moved very little between summer and winter and were on average recovered 3.6 km from the release point during winter. Fish tagged in areas 1 and 2 moved the largest distances between summer and winter and were on average recaptured 8.2 and 8.8 km from the release point during the winters (Table 1).

One individual pikeperch that was marked in the western part (area 2) was recaptured 16 times between August 1990–May 1993, before it was reported as dead. One fish tagged in the central area was recaptured within an area of 4 km^2 36 times during September 1990–July 1993 and then moved in a westerly direction and was recaptured another 4 times in August–November 1993. Another fish marked in the more or less isolated eastern basin was recaptured 6 times in the central part of the basin during July–August 1990 and 15 times in the western part of the basin during May 1991–July 1992 (Fig. 8).

Table 1. Average distance (km) from release point for recapture of pikeperch marked in different areas (n = number of recaptures) and maximum depth in the areas.

Area number	Average distance from release point (km)		Max. depth (m)
	Summer	Winter	
1	5.0 (n = 17)	8.3 (n = 6)	3
2	2.9 (n = 393)	8.8 (n = 49)	10
3	3.1 (n = 199)	5.4 (n = 10)	14
4	2.8 (n = 665)	5.0 (n = 62)	18
5	5.4 (n = 1)	–	18
6	5.2 (n = 155)	6.0 (n = 15)	10
7	1.6 (n = 301)	3.6 (n = 13)	20

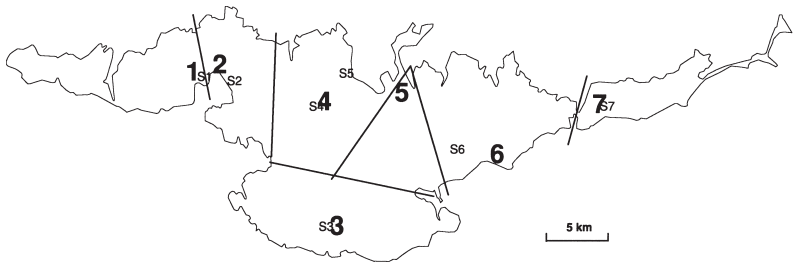

Fig. 6. Location of average release points and average points of recapture during summer. (1, 2 etc. = average point of release in each area. S1, S2 etc. = average point of recapture of pikeperch tagged in different areas).

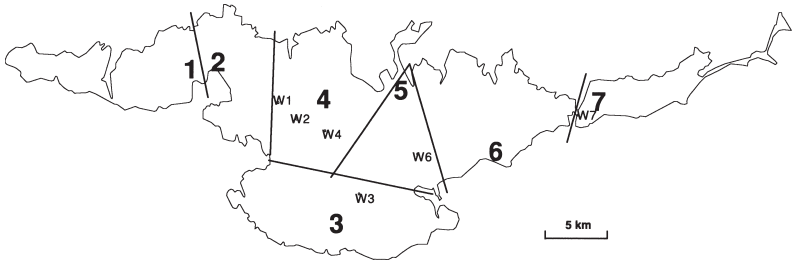

Fig. 7. Location of average release points and average points of recapture during winter. (1, 2 etc. = average point of release in each area. W1, W2 etc. = average point of recapture of pikeperch tagged in different areas).

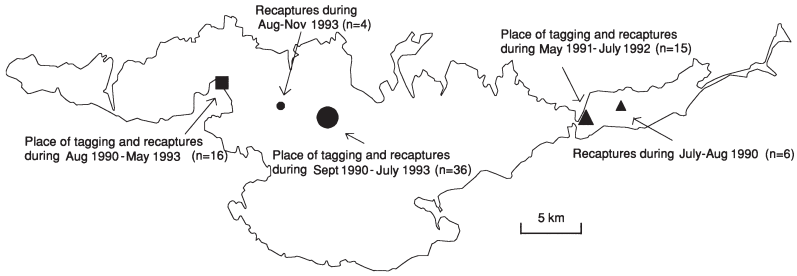

Fig. 8. Sites and number of recaptures of three individual pikeperch tagged in different areas.

4.3. Growth rate

There were great differences in growth rate between individual pikeperch. The difference decreased somewhat with increasing size and when the fish got close to the legal size limit (40 cm) (Fig. 9). The average growth in length of fish 25–30 cm at the time of marking was 51 mm/365 days until they reached 40 cm. The increment in length was significantly ($p < 0.001, r^2 = 0.71$) correlated to the number of days after marking, according to the equation: length increment = 0.14 × days after marking + 10.2. The growth rate of 30 pikeperch in the same size class (25–30 cm) that were caught in gill-nets during winter or in trap-nets in spring–early summer was 55 mm the first year and 52 mm the second year after tagging. The calculations were restricted to pikeperch < 40 cm at recapture, because pikeperch recovered in gill-nets were significantly longer than those recaptured in trap-nets (ANOVA, $p < 0.001$, with three covariates: length at marking, number of days between marking and recovery and number of times of recapture). This multiple regression also showed that the length increment was also dependent on how many times the pikeperch had been recaptured. The yearly length increment of a pikeperch that had been recaptured 10 times was on average 12.6 mm less than of a fish that had been recovered only once.

5. Discussion

The total rate of recapture (38.6%) was relatively high, despite an evidently high initial mortality due to the marking. Of the pikeperch recovered

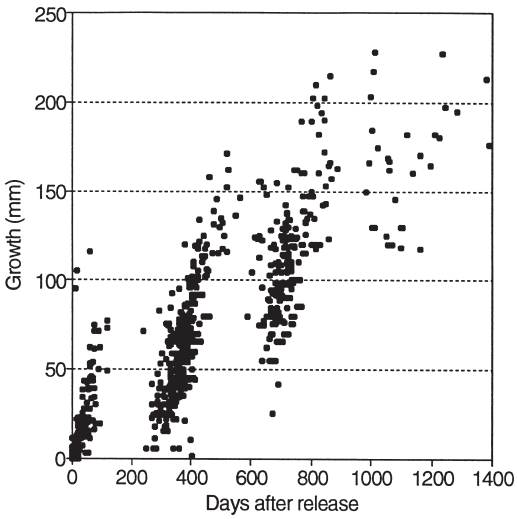

Fig. 9. Growth rate (length increment in mm) of pikeperch 25–30 cm at the time of tagging and recaptured in trap-nets before a total length of 40 cm.

three times, as many as 74.4% were captured also a fourth time. In coastal waters on the Finnish side of the Baltic Sea the average recapture rate was 20.9% (Lehtonen & Toivonen 1988), and Puke (1952) gives recapture rates of 18.6 and 23.2% of the pikeperch marked in Lake Vänern in 1947 and 1948, respectively. Our results clearly show that the fishing intensity in Lake Hjälmaren is high and also that the survival rate of the young pikeperch caught in trap-nets is high, if handled in a proper way by the fishermen. This is illustrated by the fact that almost 50% of the fish that were recaptured once and released also were recaptured a second time. The very high recapture rate also show that the mortality, due to the tag, must be very low after the initial increase in mortality due to the marking.

Due to that there was an unknown degree of mortality caused by the recapture in trap-nets and the handling before release, our data does not permit any calculation of the rate of exploitation or fishing mortality.

The term movement implies a lower degree of displacement than migration (Fickling & Lee 1985). Migration was defined by Nikolski (1963) as "a mass movement from one habitat to another". As the "displacements" in Lake Hjälmaren evidently are small, we use the word movement. The pikeperch were very stationary during the growth seasons in most basins (Table 1). They moved the longest distances (5–5.4 km on average) in basins 1, 5 and 6. Area 1 is very shallow and an important feeding area during the summer. In the northern part of Europe the pikeperch is known to move to deeper waters in autumn (Puke 1952, Deelder & Willemsen 1964, Lehtonen 1979, 1983, Lehtonen & Toivonen 1988). In lake Hjälmaren local fishermen know that pikeperch leave the shallow area 1 for the deeper waters of the main basin after a few nights of frost and this may occur before the end of what we define as the summer period (May–November). From the markings performed in area 5, only 1 individual was recaptured. (This was probably due to a very high post-marking mortality caused by the high prevalence of *Saprolegnia* sp on almost all caught fish.) The relatively long distance moved during summer in area 6 is hard to explain, but the coast is very open and exposed. In the other areas the movements during the summer were small (1.6–3.1 km). Larger pikeperch had on average a wider home range than smaller ones (Fig. 4). The pikeperch were recovered longer distances from the release point during the winters. It is well known that the pikeperch moves/migrates and spends the winter in deeper areas (Puke 1952, Lehtonen 1979, 1983, Colby & Lehtonen 1994). The distances from the release point of the recoveries were longest in areas 1 and 2, which are the most shallow areas and the pikeperch have to move to the deeper areas in the central part of the lake. In contrast, the fish marked in area 4 only had to move a short distance to reach deeper waters (Fig. 6). Pikeperch marked in area 6 moved in the opposite direction, compared to the fish tagged in area 1 and 2, to reach to winter places in deeper waters. Only very few individuals marked in area 7 left the area at all. This is explained by the fact that in this area, both shallow areas, preferred by the pikeperch during the growth season, and deep parts for the winter period are found (Table 1). It is previously known that pikeperch normally do not move very long distances during a specific season. Of the pikeperch that were tagged and released in Dettern, a small basin of Lake Vänern, 80% were recovered in Dettern (Puke 1952) and on the Finnish side of the Baltic Sea, 75% of the recaptures were usually made within 10 km from the tagging place (Lehtonen & Toivonen 1988).

The climate and water temperature are well known to affect the growth rate of the pikeperch (Svärdson & Molin 1973, Colby & Lehtonen 1994).

The maximum summer temperature (20–24°C) and the average temperature during June–September, which includes the major part of the growth season, did not differ very much between the years 1990–93. The growth rate (5.1 cm/365 days) for pikeperch in the length group 25–30 cm at the time of tagging, is similar to what

Svärdson and Molin (1966) found (for fish 30–36 cm) from scales in the same lake, but lesser than in the Helsinki sea area (ca 6.3 cm/year in the same size) (Lehtonen 1979). The calculated growth rates from tagged fish are probably minimum values, since it is probable that tagged fish will grow slower than un-tagged individuals. The growth rate was found to differ between individuals that had been recaptured repeatedly and those that were recovered only once. The reason for this is probably that the ones recaptured many times had spent a longer part of the growth season in captivity in the trap-nets, where they do not feed. An individual recaptured 10 times would approximately have spent 20 days in captivity, which would correspond to a 'loss of length increment' of approximately 10 mm.

Growth rate, calculated from the length at recapture in trap-nets, was found to decrease at total lengths above 40 cm. This is the legal size limit and the gill-nets mostly used are of a suitable mesh size (50 mm) to catch 40 cm pikeperch. The very intense gill-net fishery will catch the most fast growing individuals of each cohort and thus decrease the apparent average growth rate of the fish caught in trap-nets.

6. The significance of the results for the management of the pikeperch population in Lake Hjälmaren

The commercial fishermen have been closely involved in this experiment. They now know that even if many young pikeperch are caught during certain periods, this is due to multiple captures and not to a high abundance *per se*. This fact has taught the fishermen that they must handle the trap-nets and the pikeperch very carefully, if the young pikeperch is to survive and be caught later at a legal size. Due to the stationary behaviour during the growth season, the fishermen have also realised if a pikeperch is caught and released at the beginning of the season, there is a good chance that it will be caught at a larger size in the same trap-net at the end of the growth season. Even if not shown here, some defined areas in the lake are pronounced nursery areas for young pikeperch during the summer and it might be beneficial to restrict the fishing intensity in these areas.

References

Colby, P. J & Lehtonen, H. 1994: Suggested causes for the collapse of pikeperch, Stizostedion lucioperca (L.), populations in Northern and Central Finland through comparisons with North American walley, Stizostedion vitreum (Mitchill). — Aqua Fennica 24: 9–19.

Deelder, C. L. & Willemsen, J. 1964: Synopsis of biological data on the pike-perch Lucioperca lucioperca (Linnaeus) 1758. — FAO Fisheries Synopsis 28: 1–58.

Fickling, N. J. & Lee, R. L. G. 1985: A study of the movements of the pikeperch, Lucioperca lucioperca L., population of two lowland fisheries. — Aquaculture and Fisheries Management 16: 377–393.

Lehtonen, H. 1979: Stock asessment of pikeperch (Stizostedion lucioperca L.) in the Helsinki sea area. — Finnish Fish. Res. 3: 1–12.

— 1983: Stocks of pikeperch (Stizostedion lucioperca L.) and their management in the Archipelago Sea and the Gulf of Finland. — Finnish Fish. Res. 5: 3–16.

Lehtonen, H. & Toivonen, J. 1988: Migration of pikeperch, Stizostedion lucioperca (L.), in different coastal waters in the Baltic Sea. — Finnish Fish. Res. 7: 24–30.

Nikolski, G. V. 1963: The Ecology of Fishes. — Academic Press, London.

Puke, C. 1952: Pikeperch studies in Lake Vänern. — Rep. Inst. Freshw. Res. Drottningholm 33: 113–139.

Svärdson, G. & Molin, G. 1966: Gösen i Hjälmaren och Mälaren. Information from the Inst. Freshwater Research 1. 25 pp.

— 1973: The Impact of Climate on Scandinavian Populations of the Sander, Stizostedion lucioperca (L.). — Rep. Inst. Freshw. Res. Drottningholm 53: 112–139.

— 1981: The Impact of Eutrophication and Climate on a Warmwater Fish Community. — Rep. Inst. Freshw. Res. Drottningholm 59: 142–151.

Yamashita, D. & Waldron, K. 1958: An all-plastic dart-type fish tag. — California Fish and Game 44: 311–317.