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Homing behaviour of pikeperch (*Sander lucioperca*) following experimental transplantation

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Homing behaviour of pikeperch *Sander lucioperca* was studied using ultrasonic telemetry. Twelve pikeperch were tagged with ultrasonic transmitters having a battery life of 14 months and released to Jyväsjärvi. Six of the pikeperch were originally captured from Jyväsjärvi and six were captured from Päijänne and transplanted seven km to Jyväsjärvi. Five of the transplanted pikeperch were observed near the original capture site less than two weeks after release. None of these fish later returned to Jyväsjärvi. Pikeperch originally from Jyväsjärvi stayed mainly in that lake for the duration of tracking. The data indicate that pikeperch exhibit site fidelity and are able to home after transplantation. The results also indicate that the two studied lakes may have semi discrete pikeperch stocks.

Introduction

Homing behaviour is defined as returning to a previously occupied place or area. This behaviour requires some site fidelity and orientation ability. Reproductive homing behaviour is a common and well-documented phenomenon for fish, especially salmonids. In their review, Lucas and Baras (2001) found published information on homing behaviour of 11 non-salmonid freshwater species. In their orientation fish can use different cues, including landmarks, sun, currents and olfaction (Lucas and Baras 2001). Odling-Smee and Braithwate (2003) reported in their review that fish can use memory to orientate in their natural environment. For example, smallmouth bass (*Micropterus dolomieu*) (Ridgway and Shuter 1996), largemouth bass (*M. salmoides*) (Hodgson *et al*. 1998, Richardson-Heft *et al*. 2000) and yellow perch (*Perca flavescens*) (Hodgson *et al*. 1998) have been reported showing homing behaviour after experimental transplantation. Homing behaviour after transplantation is also well documented in salmonids (e.g. Armstrong and Herbert 1997, Huntingford *et al*. 1998). Transplantation studies give information about learning and the ability of fish to navigate and possible behavioural distinctions between semi discrete populations.

In Europe pikeperch (*Sander lucioperca*) inhabit mainly eutrophic freshwaters and coastal areas of the Baltic Sea (Lind 1977, Lehto-

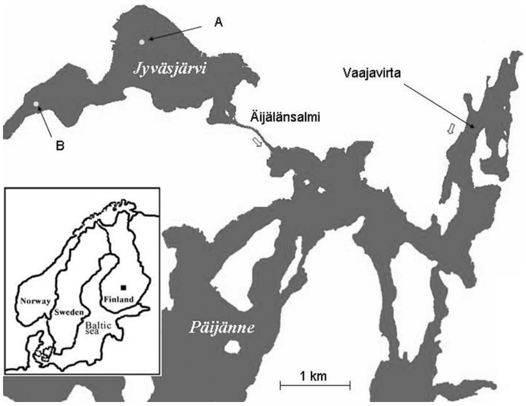

Fig. 1. Study area. A and B = locations where pikeperch were released. Arrows show direction of the current.

nen *et al.* 1984, van Densen 1994). In coastal areas, pikeperch populations migrate frequently between feeding, spawning and overwintering areas according to mark-recapture studies (Lehtonen and Toivonen 1988). In lakes, separate overwintering and spawning areas have also been observed (Nyberg *et al.* 1996, Jepsen *et al.* 1999). In Lake IJssel, marked pikeperch showed homing behaviour after transplantation (Willemsen 1977). Koed *et al.* (2002) reported homing behaviour of pikeperch in a lowland river after they had been transported over a hydropower dam.

The aim of this study was to determine whether adult pikeperch exhibit fidelity to certain locations in a lake system and if they can return to them after transplantation. Thus, the homing behaviour of pikeperch was studied by moving fish to a new location and monitoring their movements by ultrasonic telemetry.

Table 1. Limnological characteristics of Jyväsjärvi and Päijänne.

	Jyväsjärvi	Päijänne (northern part)
Area (km^2)	3.37	54
Maximum depth (m)	26	48
Total phosphorus (μg l^{-1})	35–40	15
Total nitrogen (μg l^{-1})	850	650
Colour (Pt mg l^{-1})	80–100	30–50
pH	6.9	6.9

Material and methods

Jyväsjärvi (62°14´N, 25°46´E) is connected to Päijänne via the Äijälänsalmi channel (length 700 m and maximum depth 4 m) (Fig. 1). Jyväsjärvi is eutrophic and Päijänne mesoeutrophic (Table 1). Water flow in the Äijälänsalmi channel is usually from Jyväsjärvi to Päijänne, but its direction changes occasionally. Cyprinids and percids have been observed to perform spawning migrations from Päijänne to Jyväsjärvi (Lilja *et al.* 2003). Vaajavirta is the main inflow of water to northern Päijänne and its mean flow in 2001 was 159 m^3 s^{-1}. The maximum depth in Vaajavirta is 25 m and the water is not stratified. The distance between Vaajavirta and Jyväsjärvi is about seven km via the watercourse.

In total 12 pikeperch were caught from two different locations, Jyväsjärvi and Vaajavirta (Päijänne), and transplanted to two new locations in Jyväsjärvi (Fig. 1). Six of the pikeperch were caught from Vaajavirta in July 2001 by angling. They were translocated to Jyväsjärvi in an aerated tank by boat. The mean total length of fish from Vaajavirta was 474 mm (range 395–535 mm). Fish from Jyväsjärvi were caught by trawl (n = 2) and gill nets (n = 4) in July–November 2001. The mean total length of fish from Jyväsjärvi was 594 mm (range 385–855 mm) (Table 2). The sex of the fish was not recorded.

Before tagging, pikeperch were kept in a cage in Jyväsjärvi for 0–3 days to observe possible mortality caused by catching and transportation. The fish were anaesthetized with MS 222 (concentration 0.2 g l^{-1}) until their opercular rate became slow and irregular. A transmitter was inserted into the body cavity through a midventral incision, which was closed with 3–6 silk sutures. The operation took from five to 15 min and recovery time was from five to 20 min.

The transmitters used were Sonotronics CT-82-2 and CTT-83 which operated at frequencies from 70 to 75 kHz. The duration of the transmitter battery was 14 months. The length of transmitters was 64 mm, diameter 16 mm and weight in water was 8 g. The tag/fish weight ratio in water was 0.1%–1.7% and 0.3%–4.4% in air. The often recommended tag to fish mass ratio in telemetry studies is smaller than 2% (in water) (Winter 1983). Tagging did not affect the critical swimming speed of pikeperch (Koed and Thorstad 2001) or rainbow trout (*Oncorhynchus mykiss*) (Brown *et al.* 1999) when tag/fish weight ratio was 0.2%–0.5% (in water) and 6%–12% (in air), respectively. In our study this ratio (in water) was at the maximum 1.7%, and 1.0% was exceeded in only two fishes, one in both groups. All tagged pikeperch started moving actively a few days after tagging and the incisions were observed to be well healed in recaptured fish ($n = 8$).

Marked fish were released in two locations (Table 2 and Fig. 1) in Jyväsjärvi at least one day after tagging. Fish were tracked from a boat with a Sonotronics DH 4-hydrophone and a USR 90W-receiver and positioned by triangulation. Tracking was done in both lakes at least three times a week during July and August and in September at least once a week. From October to December tracking was done every week in Jyväsjärvi but only twice in Päijänne.

The effect of original capturing place on staying in Jyväsjärvi was tested with Fisher's exact test. A fish was considered migrating off from Jyväsjärvi if it was observed at least once in Päijänne.

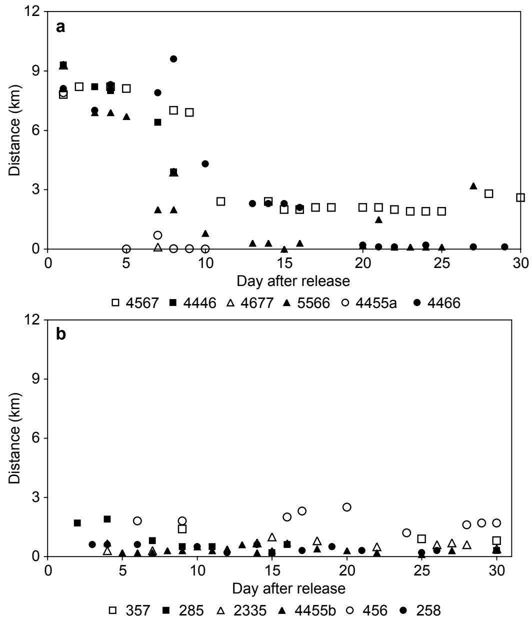

Fig. 2. Distance of fish (km) from the capture site (**a**) Vaajavirta and (**b**) Jyväsjärvi during 30 days after the release to Jyväsjärvi. Six pikeperch were captured from Jyväsjärvi and 6 fish from Vaajavirta. Numbers refer to individual codes of transmitters (Table 2).

Results

All pikeperch originally caught from Vaajavirta moved back to Päijänne within less than two weeks of their release to Jyväsjärvi. The distance of these fish from Vaajavirta decreased during the first 20 days after release (Fig. 2a). Five of the six pikeperch from Vaajavirta were observed near (< 2 km) the original capture site during the first

Table 2. Pikeperch captured in Jyväsjärvi and Vaajavirta (Päijänne) in 2001 and released in two different locations in Jyväsjärvi (A, B; *see* Fig. 1). Total length and transmitter codes are also given.

Capturing site	Total length (mm)	Date of release	Code	Release site	More information
Vaajavirta	480	9 Jul	4567	A	left Jyväsjärvi
Vaajavirta	470	10 Jul	4466	A	left Jyväsjärvi
Vaajavirta	395	10 Jul	5566	A	left Jyväsjärvi
Vaajavirta	535	10 Jul	4455a	A	left Jyväsjärvi
Vaajavirta	460	10 Jul	4446	B	left Jyväsjärvi
Vaajavirta	505	10 Jul	4677	B	left Jyväsjärvi
Jyväsjärvi	630	20 Jul	4455b	A	overwintered in Päijänne
Jyväsjärvi	780	17 Aug	2335	B	disappeared after 4 months caught later in Jyväsjärvi
Jyväsjärvi	385	14 Aug	456	B	disappeared after 1 month caught later in Jyväsjärvi
Jyväsjärvi	855	18 Oct	258	B	disappeared after 7 months
Jyväsjärvi	449	29 Oct	285	B	caught in Jyväsjärvi after 3 months tracking
Jyväsjärvi	462	6 Nov	357	B	disappeared after 2 months caught later in Jyväsjärvi

month after release, four of which were located within less than 0.2 km of the original capture site. One fish (4455a) was caught by an angler from the same place where it was originally captured. None of these fish were observed to return to Jyväsjärvi. One fish (4446) disappeared soon after leaving Jyväsjärvi, but was detected in Vaajavirta almost a year later in June 2002.

Pikeperch originally captured from Jyväsjärvi stayed in the lake. The distance from the original capture site remained almost constant during the first 30 days after release (Fig. 2b). One fish (4455b) moved to Päijänne six weeks after release and over a month later was about 20 km south in Päijänne. In spring 2002, it returned back to Jyväsjärvi. Two fish (456 and 2335) of this group disappeared after one and four months tracking, respectively. The reason was probably failure of the transmitters as both fish were later caught by gill net from Jyväsjärvi. Hence, these fish were assumed to have stayed in Jyväsjärvi.

The difference in behaviour of fish from Vaajavirta and Jyväsjärvi was statistically significant (Fisher's exact test: $p = 0.0087$) in respect to staying in Jyväsjärvi after tagging and release. In the test 5 pikeperch originally from Jyväsjärvi were considered as staying in the lake.

The release site in Jyväsjärvi did not affect the homing behaviour of pikeperch from Vaajavirta, because every fish of this group left the lake. The only pikeperch (4455b) from Jyväsjärvi, which was released at site A migrated later to Päijänne, but returned next year. However, the rest of this group occupied mainly the eastern part of the lake near site A after release. There seems to be a tendency to move back to original capture site also in Jyväsjärvi, which is shown as decrease in distance in the few first days just after release (Fig. 2b).

Discussion

The results of this study show clearly that pikeperch exhibit site fidelity to a certain location and when transplanted to different locations they return to the original location. This finding is in accordance with Willemsen (1977) who reported that 69% of marked pikeperch transplanted from the northern part to the southern part of Lake IJssel returned to the northern part. In homing studies rarely are all transplanted fish observed to migrate back (e.g. Ridgway and Shuter 1996, Richardson-Heft *et al*. 2000, Belanger and Rodriguez 2001). The reason may be failure in orientation, predation or the occupation of the home site by another individual. In our study, all tagged pikeperch were observed near the original capture site.

In a lowland river system Koed *et al*. (2002) observed homing behaviour in pikeperch that were moved over a hydropower dam. Five of 10 tagged pikeperch migrated upstream. Koed *et al*. (2002) suggested that these fish were returning to their original hatching place to spawn or less likely were exhibiting positive rheotaxis. According to our results, positive rheotaxis is not the main reason for homing behaviour, because the current in Äijälänsalmi channel is weak and usually towards Päijänne. Vehanen and Lahti (2003) did not observe upstream migration when transplanting pikeperch to a hydropeaking reservoir. Migrations between feeding and spawning habitats have been reported in coastal waters and in a lowland river (Lehtonen and Toivonen 1988, Koed *et al*. 2000). Fish in our study were captured after the spawning season, so the observed movements were not related to their migration back to spawning areas, but were probably related to feeding in those specific areas. In Vaajavirta, the habitat used by pikeperch had a distinct current whereas in Jyväsjärvi there is no such continuous current. Jyväsjärvi is a suitable habitat for pikeperch because fish originally captured there stayed in the lake. Hence, the reason for movements was not avoiding unsuitable conditions either.

The pikeperch from Vaajavirta were released in July and fish from Jyväsjärvi in July–November. This may have affected the results, because pikeperch are usually more active during summer and use different areas in different seasons. Jepsen *et al*. (1999) observed tagged pikeperch in October and December using deeper areas than in the summertime. Also Nyberg *et al*. (1996) found distinct overwintering areas in a large lake in their mark-recapture studies. However, three fish caught from Jyväsjärvi were released in summer and they stayed in the lake although one of them (4455b) overwintered in Päijänne.

It is unlikely, although possible, that the Päijänne pikeperch were familiar with the route from Jyväsjärvi back to Vaajavirta. None of these fish was later observed in Jyväsjärvi, which suggests that they do not naturally migrate between these two habitats. However, the fish did not try to migrate upstream from Jyväsjärvi but returned back to Päijänne which suggests that the latter is the preferred habitat for the fish which lived there before. The orientation from Jyväsjärvi to Vaajavirta was likely facilitated by olfactory cues because water flow from Jyväsjärvi to Päijänne occasionally changes and brings water from Päijänne to Jyväsjärvi. In the final stage of returning the pikeperch could have used landmarks for orientate (Lucas and Baras 2001).

Pikeperch seem to have certain site fidelity and to be a local fish in lakes at least within a certain season. Horrall (1981) discussed the possibility that homing of the related walleye (*Stizostedion vitreum*) to the spawning place is learned behaviour. However, Jennings *et al*. (1996) showed that spawning habitat selection in walleye has a heritable component. Imprinting of pikeperch to feeding areas has not been studied. Pikeperch has been stocked into both lakes of the present study but there is no information whether the tagged fish were stocked. If the stocked pikeperch fingerlings imprint to the release site, this should be taken into consideration in fisheries management. However, the current results indicate that Jyväsjärvi and Päijänne appear to have semidiscrete pikeperch stocks. Homing behaviour may be a very important factor ensuring the separation between these populations. More information about genetic structure of pikeperch populations in relation to feeding areas and annual movements of pikeperch is needed to study the likely local adaptations of fish stocks and their implications for fisheries management.

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