Master thesis

Movements of pikeperch, bream and pike in Lake Ringsjön, Sweden

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Abstract

Movements occur among many different organisms and a suggested theory about the pattern of these movements is called the Ideal free distribution. It states that individuals in a complex area with different quality of the habitats will distribute themselves proportionally after resources in the different habitats, so that they can maximize their fitness. Lake Ringsjön is a complex lake, which consists of three different basins of different habitat and quality. In this study, we monitored the movements of three fish species, Pikeperch, Bream and Pike in lake Ringsjön. The aim was to investigate fish movements (occurrence and patterns) between the basins, from spring until winter. This study also compared the growth rate of resident individuals and individuals moving between basins. The result shows a difference between species in their movement pattern, with pikeperch moving from the shallow Western basin into the deeper Eastern basin during the monitored period. The pikeperch that changed basin were also found to have a higher growth rate compared to those which did not change basin. The pike showed no movements between the basins and the bream had a few individuals that changed basins.

Introduction

Movements occur among many different organisms and a suggested theory about the pattern of these movements is called the Ideal free distribution (IFD). The concept is applied to different organisms and it states that individuals in a complex area with different quality of the habitats will distribute themselves proportionally in relation to available resources, in the different habitats if there is a negligible cost of the fitness (Haugen T et al. 2006; Fretwell & Lucas. 1969). This will allow the individuals to maximize their fitness even in habitats with less quality since there is a benefit of choosing and spreading due to less competition; there will be more consumers in a higher quality patch and fewer consumers in a lower-quality patch when IFD is fulfilled (Williams et al. 2013). The main drives of animal movements are food competition, food resources and breeding, were the organisms strive to find an optimal habitat with better food availability and better spawning areas. Predation is also a driving force which pressures organisms to move to increase the survival rate. These are the main factors of a population's dynamics (Cressman R et al. 2004) and could trigger a movement in the area. Organisms also perform seasonal movements between different habitats for different reasons. For instance, an optimal spawning area could be overflowing by fish since there will be a large amount of individuals migrating to these habitats to spawn. Different species show different behaviors when migrating. Some species are known to move long distances such as pikeperch (*Sander lucioperca*) (Lappaleinen J et al. 2003) while others such as pike *(Esox Lucius)* are territorial species that do not move to the same extent (Skov C et al. 2008; Vehanen T et al. 2006).

Knowledge of fish movements in a lake can have several benefits. Fish often have high economic values that often results in a high fishing effort which could lead to overfishing. Therefore it is important to know the movements of the species to be able to protect the species and their spawning areas. Information about spawning areas and specific nursing areas for offspring provides management opportunities for critical habitats which are important to protect (Landsman et al. 2011). This knowledge could aid incentives to increase population of an overexploited species. Furthermore, when performing a biomanipulation there is often a substantial need of lowering the density of planktivorous fish to be able to increase zooplankton density and grazing rate on algae (Wysujack K & Mehner T. 2002; Lacerot et al. 2013). However according to the IDF, when performing a biomanipulation in one basin, new individuals could move into the biomanipulated basin due to less competition for resources and also reproduce, which minimizes the success of biomanipulation. It is therefore crucial to know the movements and migrations of the targeted fish to be able to harvest them efficiently, but also to avoid by-catches of valuable piscivorous fish.

Lake Ringsjön in the South of Sweden is a lake currently being subjected to biomanipulation, planktivorous and benthivorous fish such as bream (*Abramis brama*) and roach *(Rutilus rutilus)* have been removed since 2005. The lake also holds a thriving fishery mainly targeting piscivorous fish such as pikeperch. Hence, to be able to efficiently remove targeted species, while sparing economically valuable species, it is important to gain insight about the movement patterns of different species and how that shapes seasonal variations in distribution patterns and, as a consequence, opportunities for selective fishing. Pikeperch and bream have in other studies been known to migrate to spawn (Lappaleinen J et al. 2003; Gardner CJ. 2013) and it is important to pinpoint where these spawning areas are located. Ringsjön has a complex morphometry with three different basins where one basin is only connected by a narrow and shallow sound. Therefore, a tagging approach was applied to monitor the movements of fish between these basins (capture-recaptures).

The aim of this study was to investigate the movement patterns of pikeperch, bream and pike in lake Ringsjön. I focused on the movement patterns between three major basins with different morphology (one shallow and two deep), suggesting there are differences in their suitability as spawning and foraging habitats that may induce seasonal shifts in habitat use. There is a small and narrow sound between two of the basins that could be an obstacle for movements between basins. The hypothesis was that there will be less movement between the basins with the small sound and more movements between the other basins. It was also hypothesized that the different species will move differently, pikeperch and bream will probably move between basins and pike will not move these distances.
This study also investigated if the movements between the basins were species-specific movements and if there were any benefits of changing basin by looking at difference in growth rate between resident and moving individuals.

Material and methods

Site description

Lake Ringsjön is located in south of Sweden (55°529 N; 13°329 E). Lake Ringsjön is divided in two main basins; the Eastern and Western basin which are separated by a narrow and shallow sound that potentially could limit the exchange of individuals between the basins (fig 1). The Eastern basin in turn can be divided into two parts were one is called Eastern basin and the other Sätofta basin. The basins consist of different habitats were the Eastern basin and Sätofta have a deeper depth with a maximum depth of 16-17m while the more shallow Western basin have a maximum depth of 5m. The mean depth of the Eastern basin is 6.1 m while Sätofta and Western basin have a mean depth of 3 m. Eastern basin have a stony morphology while the Western and Sätofta have a sandy morphology (Strand J. 1999). These different habitats have an important role when considering fish distribution since species have different habitat preference. Lake Ringsjön became eutrophicated during the 1960s and 1970s and a nutrient reduction program was inserted. In the late 1980s biomainpulation was inserted which is still ongoing.

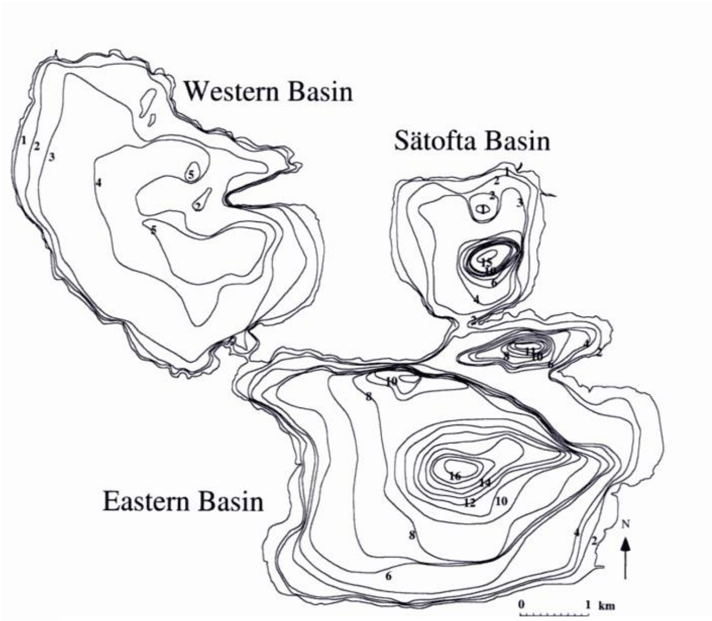

Figure 1 A map of lake Ringsjön with the different basins and depths.

Studied species

The fish targeted in this study were bream (*A. brama*), pikeperch (*S. lucioperca*) and pike (*E. Lucius).* The distribution of tagging between the species depended on the supply of fish in the catch. In this study, the total amount of individuals tagged was adapted to the time limit of the master thesis.

Tagging method

Standard T-bar anchor tags were used to tag the different species in this study. The targeted fish were tagged with a t-bar tag on the back of the fish located under the dorsal fin of the

fish, by using a tagging gun (Avery Dennison 08958 Tagfast III). Each individual was given a unique id-number, but different colors on the tags were also used for different basins to facilitate identification and prevent misreading. Over 2800 individuals were tagged, distributed between basins and species according to figure 1.
The T-tag method focuses on the releasing and recapturing of the fish. Movement is then assessed from the spatial location of release and recapturing. The major advantage is that it is often possible to tag a large number of individuals, but the drawback is the low precision in individual movement patterns.

Capture and recapture

The tagging of the fish in the different basins occurred in May and June in 2013, i.e. during the spawning season for pikeperch and bream and shortly after the spawning season of pike. During the summer the trawling boats were not active because high temperature increases the risk of injuring non-target fish. The fishing started again in October and continued until January 2014. A trawl towed between two boats was used for catching and recapturing the fish. Caught individuals were tagged and measured and released in the same basin as caught. Recaptured individuals were measured and released back in same basin as recaptured.
The probability of catching a fish that have shifted basin is dependent on both the fishing effort and the area of the different basins. The fishing effort during the capture and recapture can be seen in table 1.
Unfortunately, it was not possible for me to control the fishing effort in the different basins, so interpretations of movements need to consider how the distribution of fishing effort when recapturing fish may influence the probability of detecting any movements. At times with high water levels, the trawling boats cannot enter the Western basin because of a low bridge over the sound.

Table 1 The percentage of fishing effort in the different basins of lake Ringsjön.

Fishing effort in each basin			
	Western basin	Eastern basin	Sätofta
Time (min)	1350	6876	315
% of total fishing time	15,8	80,5	3,7

In addition, data of the recaptured fish were also provided by a commercial fisherman and from recreational fishing. These fishermen had placed nets in different parts of the whole lake. The nets were placed in the Eastern basin during the summer and colder seasons. In the Western basin, only a few nets were stationed and removed after the summer season.

Statistics

Spss was used for statistics. Anova and t-test were performed on the growth rate of pikeperch using days as a covariate. One-way Anova and t-test were also performed on the size intervals of the bream and pikeperch which migrates and non-migrates.

Results

The total number of individuals tagged was 2844. The distribution of the tagging was: 2047 bream, 635 pikeperch and 157 pike (figure 2). The distributions of the tagged bream were 50% was tagged in the Western basin, 40% in the Eastern and 10% in Sätofta. There were a similar distribution of tagged pikeperch were 45% in the Western basin, 48% in Eastern basin and 7 % in Sätofta. 75% of the Pike were tagged in the Western basin, 20% in Eastern basin and 5 % in Sätofta. The distributions were dependent on the fish catch and therefore are the distributions not equal between the basins.

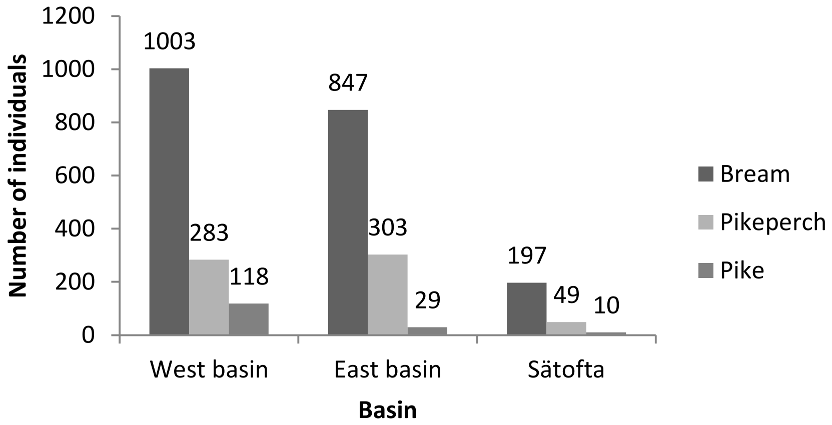

Figure 2 The distribution of the tagged fish in lake Ringsjön. A total of 1404 were tagged in the Western basin, 1179 in the Eastern basin and 256 in Sätofta.

In total, we recaptured 255 tagged individuals (~9% of total tagged). The spatial and species-specific distribution of the recaptured individuals can be seen in figure 3 were nearly 74% of the recaptures were pikeperch and most of them, 121 individuals were caught in the Eastern basin. 47 pikeperch were recaptured in the Western basin and 7 in Sätofta. Only a few pikes and breams were recaptured.

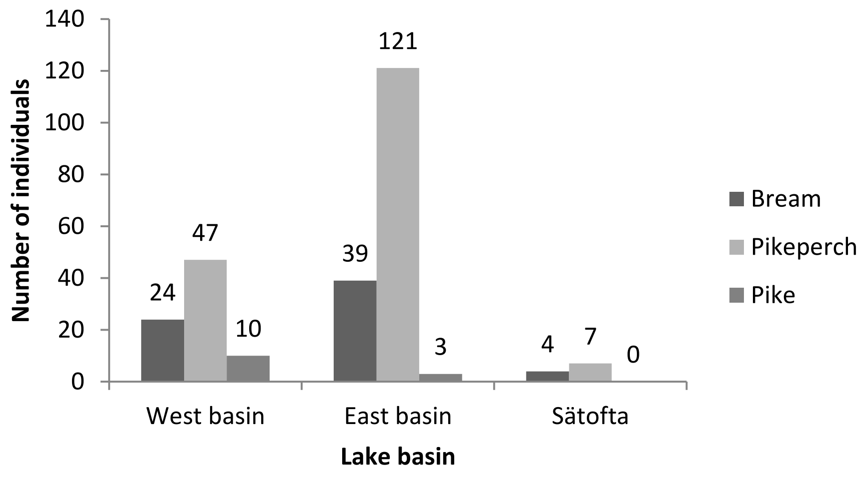

Figure 3 Recaptures of tagged fish species in the different basins of Lake Ringsjön.

We caught 71 individuals (28% of recaptured individuals) in a different basin from where they were originally tagged. Of these 71 individuals, most were caught in the Eastern basin and only a few had moved into the Sätofta basin (fig 4). Pikeperch was the species which changed basin the most frequently. There were only a few bream which changed basin and only one pike which moved to another basin but it was found dead, close to the sound in the Eastern basin.

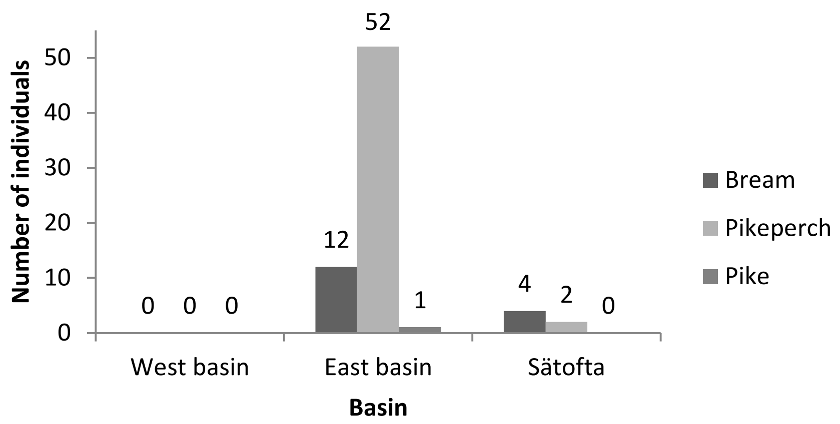

Figure 4 Recaptured individuals which were caught in different basins than they were originally tagged.

None of the pikeperch recaptured in the Western Basin, were originally tagged in another basin which suggests that there were no movement into the Western basin. This is in contrast to the patterns for the movements into the Eastern basin were almost 44% of the recaptured pikeperch had originally been tagged in another basin (fig 5). Into Sätofta there was a small movement of pikeperch from other basins. The Western basin was the only basin in which no immigration could be detected.

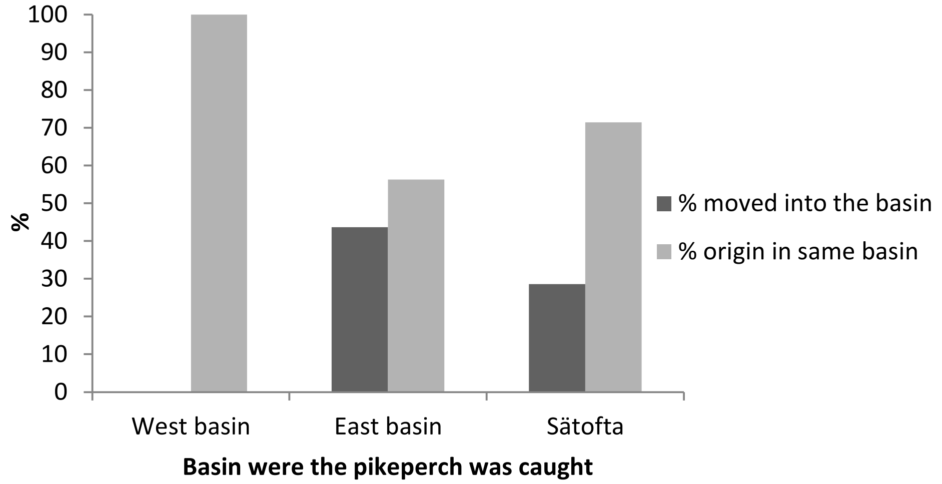

Figure 5 The percentage of the recaptured which moved into the basins and which had stayed in the same basin.

51% of the recaptured pikeperch that were originally tagged in the Western basin changed basin (fig 6). In the Eastern basin, only 3 % of the recaptured pikeperch changed basin whereas in Sätofta almost 38% of the recaptured fish moved into this basin from another basin.

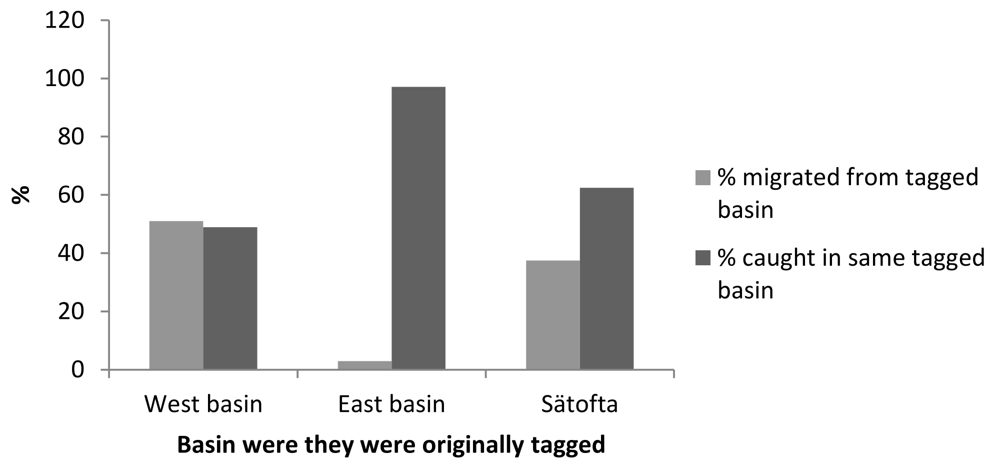

Figure 6 The proportion of the recaptured individuals which were tagged in the same basin and changed basin compared with those which stayed in the same basin.

No movement occurred into the Western basin instead there was a high movement from the Western basin into the Eastern basin. There was also a small exchange between the Eastern basin and Sätofta were a total of 4 individuals changed basin (fig 7). Most of the pikeperch in the Eastern basin remained resident.

The density of total tagged pikeperch was highest in Western basin with 19 pikeperch/km^2 whereas in the Eastern basin the density was 15 pikeperch/ km^2. Sätofta had a density of 12 pikeperch/ km^2. There was indeed a higher fishing-effort in the Eastern basin making the probability of detecting movement from the Western to the Eastern basin higher. To have the same probability of the recapturing pikeperch in all basins, the fishing effort of the total fishing time should be about 56% in the Eastern basin. In reality there was 81% of the fishing effort in the Eastern basin which makes it more difficult to find a tagged fish in the Western basin with the fishing time spend in the basin.

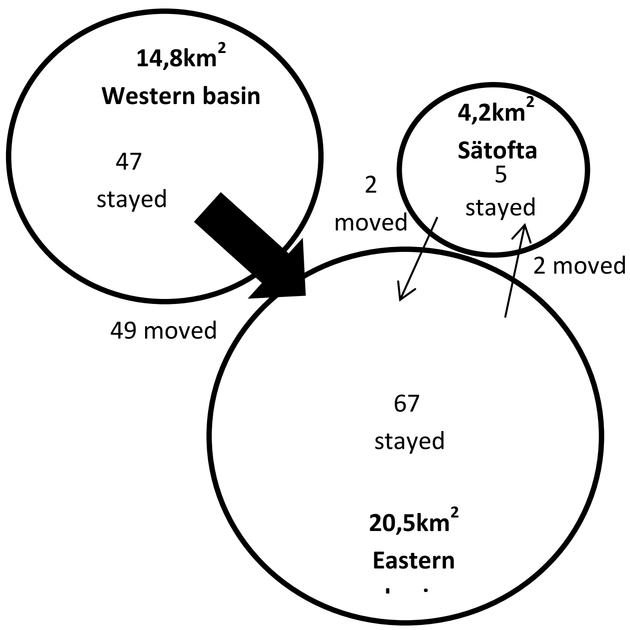

Figure 7 Summery of the pikeperch movements in lake Ringsjön.

Comparison of growth rates between moving and resident pikeperch showed a higher growth rate of pikeperch that moved compared to those which stayed (figure 8). An Ancova with days since tagging as a covariate was conducted to test for differences in the growth rate between resident and moving pikeperch. There was a significantly higher growth rate of moving pikeperch in comparison to resident fish (Ancova p=<0,001, F=15,83, df=1, fig 8).

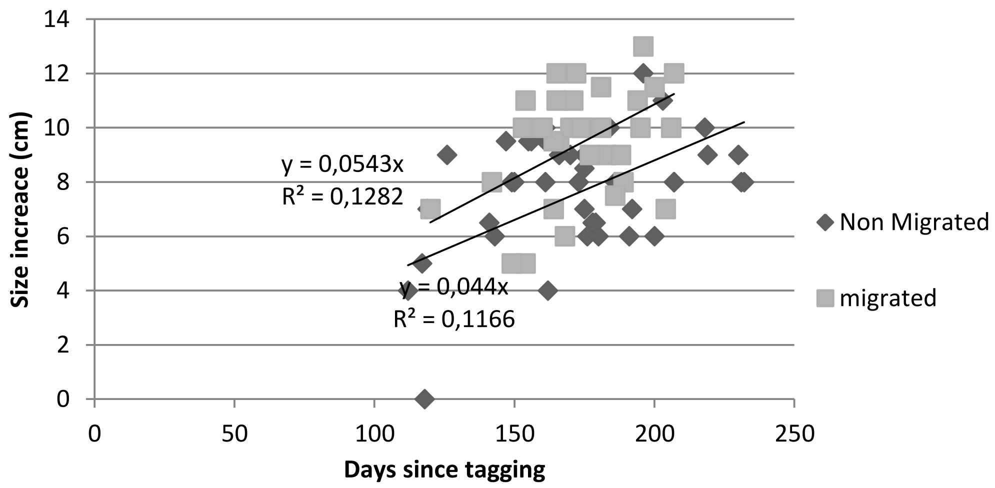

Figure 8 The different growth rate of pikeperch. The pikeperch that change basin have a higher growth rate compared to those which stay in the same basin.

When looking at the size of the fish which changed basin, the smallest pikeperch was 37 cm and the largest 73cm. A one-way Anova was conducted on the size difference between resident and pikeperch that changed basin. The size of the pikeperch that changed basin was significantly larger (p= <0,03, F= 4,807, df=1) with average length 54 cm total length compared to resident pikeperch with 51 cm (fig 9).

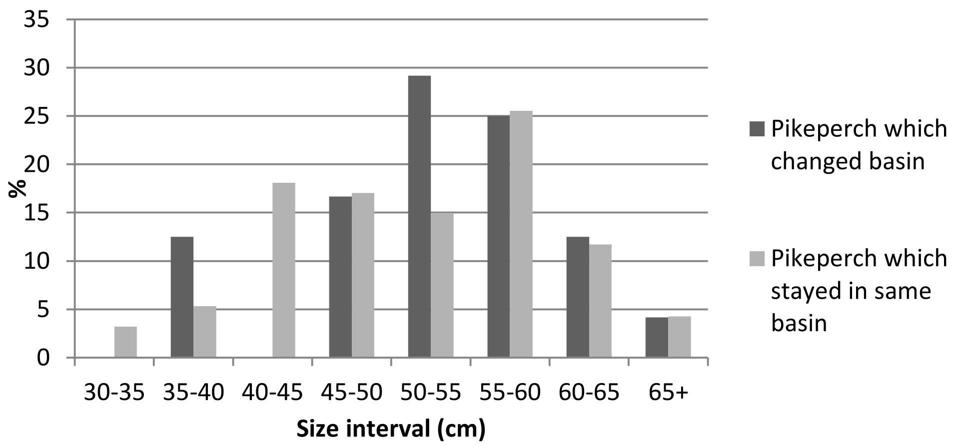

Figure 8 Comparison of size interval between pikeperch which changed basin and resident pikeperch.

The smallest size of bream which changed basin was 43cm and the largest was 56cm. 50% of the bream that changed basin was in the size interval of 50-55cm and 54% of those which stayed were in the same interval, hence the size distribution of resident and moving bream were similar. There are no large differences in the distributions of the size interval which can be seen in figure 10 and a univariate Anova showed no significant difference (p=0,113, F=2,584, df=1).

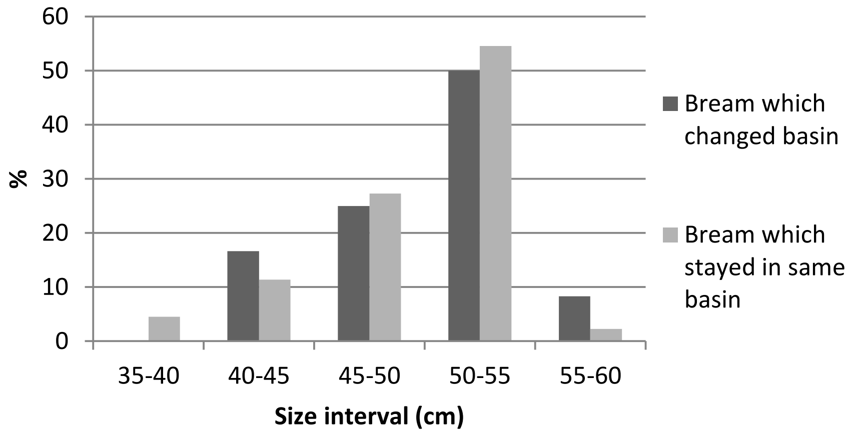

Figure 9 Comparison of size interval between bream which changed basin and resident bream.

Discussion

The results of this study show that movements of fish occur between the basins in lake Ringsjön. Secondly, we also found that movement patterns were highly species-specific. The pikeperch seemed to be the most active of the species studied and moved between all basins, expect into the Western basin. The Western basin had a high movement out of the basin but none into the basin. Bream were not recaptured in any larger amounts, which make it difficult to assess their movements. However there were some bream being caught in other basins which indicates that movement of bream can occur. Pike did not move at all between basins. There was only a small exchange of bream and pikeperch between Eastern basin and Sätofta. Other studies have showed that these two species migrate between different habitats and at different times of the year, such as movements between deeper depths and shallow areas, (Lappaleinen et al. 2003; Gardner C.J. 2013; Probst et al. 2009; Grift et al. 2001). Pikeperch have also been seen to move between rivers and lakes and from rivers to the Baltic sea just before spawning since there is a better habitat for the eggs in warmer and more oxygen rich waters (Lappaleinen et al. 2003). As applied to our study system, this could suggest that the pikeperch move into the shallow and warmer western basin to spawn and then move back to the deeper basin when it starts to be colder. However since only a few recaptures occurred in the summer, the exact time when the movements mostly occurred are hard to establish. When assessing the result of movements by pikeperch between the basins, the sizes of the basins and different fishing effort should be considered since it affects the results of the estimated flow. The Eastern basin is larger, were more fishing effort is needed to have the same probability of capturing a fish that changed basin, compared to the Western basin has a smaller area and higher probability of catching a pikeperch which have moved into the Western basin.

The theory of IFD which states that individuals in a complex area with different quality of the habitats will distribute themselves proportionally after the resources in the different habitats so there will be a there is a negligible cost of their fitness (Haugen T et al. 2006; Fretwell & Lucas. 1969). This could be applied to the results of fish movements in lake Ringsjön since the results show movements between basins with different habitat types. The Western basin is more shallow and not an optimal habitat for pikeperch foraging and yet there were high densities of pikeperch in the basin that seemed to move to the much deeper Eastern basin. The IFD could be used to analyze the drive to disperse themselves due to negligible cost of their fitness (Fretwell & Lucas. 1969). Since the Eastern basin is a more suitable habitat for the pikeperch, intra-individual competition for food in the basin must be high. Therefore could some individuals of pikeperch take the risk of staying in the less optimal habitat of the Western basin during the spring and summer to reduce the intra-competition. The decreased competition could increase the fitness of the individuals. This could be supported by looking at the result of the growth rate since the growth rate was higher for the pikeperch which moved into the Eastern basin. The advantage of being in the Western basin could be lowered after some times and this could explain why there is a high movement into the optimal habitat of Eastern basin, since the fitness could be negatively affected. However the increase in growth rate does not necessarily mean that there is an increase of fitness. Higher growth rate just states that there is energy put into growing larger and the reason is not known.

Other studies have tested the IFD and predicted a model which states that when temperature drops, the IFD is no longer applicable (Hughes & Grand. 2000). According to Kelsch 1996 fish will prioritize temperatures which optimize their swimming ability instead of growth rate. The metabolism will decrease when entering colder water and the fish do not need to feed as much (Elliott 1982). This could suggest that the pikeperch move into the Eastern basin from the Western basin during the colder season, since the food competition is no longer an issue due to the colder temperatures in the lake. However it is not certain that the food competition is highest in the Eastern basin.

This study also shows that different species act different when considering movements. The pike did not show any sign of changing basins in this study and the monitoring method was not precise enough to see the movements within a basin to be able to relate to the IFD theory. Other studies have seen that pike respond to high densities and are able to move for long distances when necessary (Grimm & Klinge 1996: Lucas MC, 1992). The study by Haugen et al. (2006), also showed that the pike dispersed themselves according to IFD by moving from areas with high densities to an area with lower density to reduce the risk of mortality.

The bream's movement patterns were not possible to assess since there were too few recaptures. The few recaptured fish had moved into the deeper Eastern basin, which suggests that bream behavior is more similar to pikeperch than to pike. This is supported by other studies were bream seem to perform spawning migrations in spring, but also migrations to deeper areas as water temperatures drops (Probst N-W et al. 2009; Gardner C.J. 2013). Unfortunately, only a few bream were recaptured, which makes it hard to assess the movements of bream in lake Ringsjön.

It is important to know the movements of different species in lake Ringsjön since it is undergoing biomanipulation. The aim is to favor the piscivors as pikeperch and pike and to lower the densities of benthivores such as bream (Persson A et al. 1999; Wysujak K & Mehner T. 2002). However following the IFD theory, the spatial specific fishing of some species could affect the movement and distribution of the remaining fish as they seek to reduce intra- and interspecific competition.

There is a need for further studies of the movements in Ringsjön to cover all seasons and to be able to separate between different driving forces, such as movements due to food searching, foraging and spawning migrations. It would also be preferred to better the design sampling efforts to obtain more comparable data. Also using radio-tagging would be preferred since you can get a higher spatial resolution on the monitoring and you are able to see the exact movements of the fish. However this method is very costly and has limited individuals which can be used (Pedersen B & Trevorrow MV. 1999).

In conclusion the IFD can be used to explain the movements of pikeperch between the different basins of lake Ringsjön, where there was a high movement from the shallow Western basin to the deeper Eastern basin. However, temperature could have an important role when considering the movements during the colder season of the year. The pikeperch which change basins have a higher growth rate compared to the resident pikeperch. Also, the hypothesis about the narrow sound, between the basins which was believed to be an obstacle for fish, can be dismissed since there are movements occurring trough the sound. This study also shows that there are different behaviors for the different species when considering movement. Unfortunately, too few breams were recaptured to assess their movements and the pike did not change basin.

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