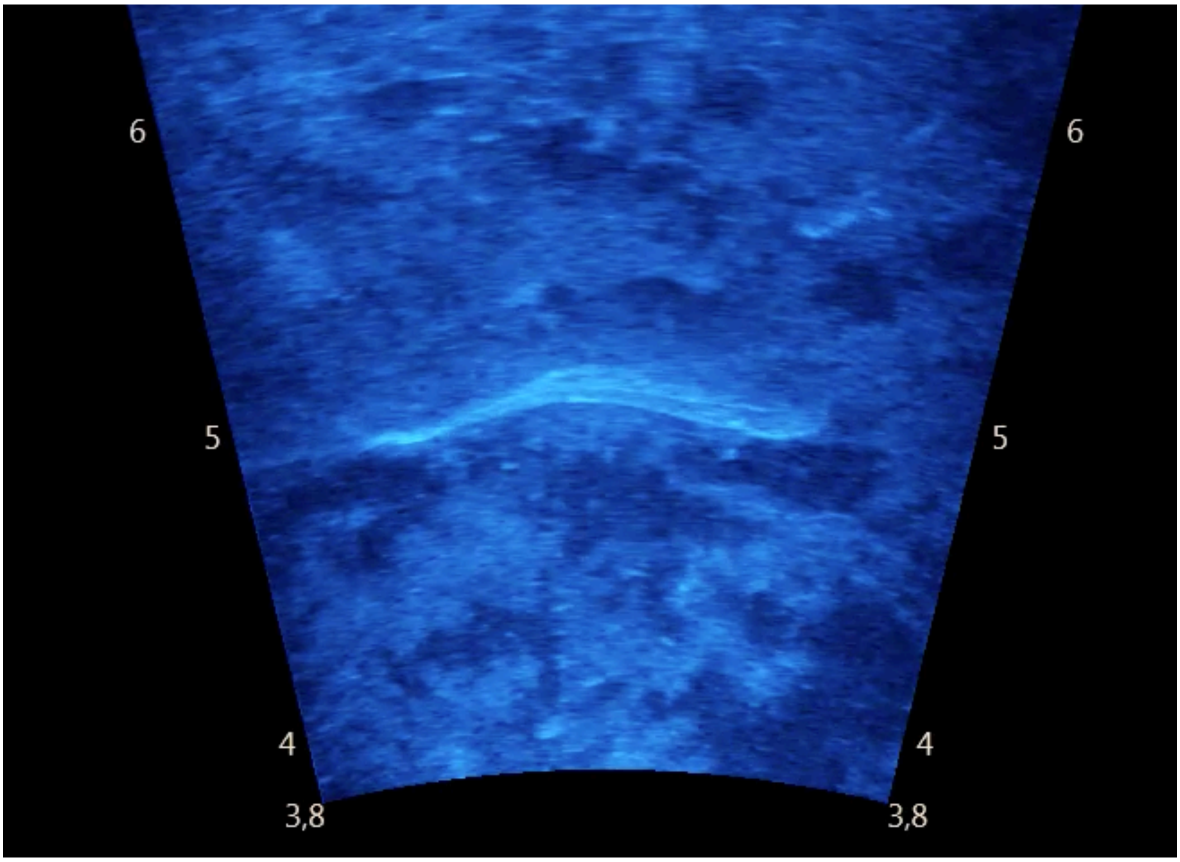
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and
Agricultural Sciences

Defining habitat demands of Wels catfish (*Silurus glanis*) in a Swedish lake

- A look into muddy waters

David Spange



Department of Aquatic Resources

Institute of Freshwater Research

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Defining habitat demands of Wels catfish (*Silurus glanis*) in a Swedish lake

- A look into muddy waters

Definiering av den europeiska malens (*Silurus glanis)* habitatkrav i en svensk sjö.

David Spange

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Abstract

The wels catfish (*Silurus glanis*) is a rare species in Swedish waters, it demands higher water temperatures than most lakes and rivers can offer. One of the few locations with naturally occurring wels catfish in Sweden is Lake Båven, situated about an hour and a half south of Stockholm, in the county of Södermanland. Due to declines of the Swedish catfish populations, which are mostly a result of human impacts such as the destruction of spawning habitats, conservational actions are now needed in purpose to secure the future of the species in Sweden.

The aim of the present study was to gain more knowledge of the poorly understood spawning behaviours, the habitat preferences and the movement patterns of wels catfish in Lake Båven. During field studies in the summer of 2017, answers to these questions were searched for by the use of radio-telemetry and an advanced imaging sonar. While the telemetry could provide a larger picture of the movements of specific individuals, the imaging sonar could give a more detailed view of, for instance, behaviours, sizes and number of individuals. The observations made can hopefully provide useful knowledge in the strive towards preservation of this threatened freshwater giant.

Our findings imply a far more social behaviour within the species than we expected. Recordings from several locations show dozens of mature individuals close together, however, no observations of fry or juveniles could be confirmed. A strong preference was found for habitats containing dense surface-covering vegetation. The telemetry studies showed a great individual variation in movement between the tagged fishes during the studies, including a high grade of overlap between the different home ranges, implying that the wels might be less territorial than we expected.

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1. Introduction

Detrimental effects such as pollution, habitat loss and overexploitation are threatening many fish species, both in marine and limnic ecosystems (McGuire 1997, Kime 1995, Aarts *et al*. 2004). One example of such a species is the European- or wels catfish (*Silurus glanis*), which globally is not threatened, but in Sweden is considered classified as vulnerable (VU) (Artdatabanken, 2006). By gaining more knowledge about the wels' ecology, we will have a better chance of obtaining a successful, evidence based management of the species in Sweden. Wels catfish is filling an ecologically important niche as a top predator. Apex predators are in many cases considered important for overall ecosystem function by exerting a top down control to the system (Hessen & Kaartvedt, 2014).

Viable populations of wels catfish in Sweden can also be interesting from other perspectives. For instance, the presence of such an imposing species could lead to an increase in ecotourism. In Sweden, all fishing aimed at the wels catfish is banned because of its status as vulnerable. In other European countries like Spain and Italy, however, the wels catfish is considered a highly appreciated game fish, attracting well-paying sports fishermen due to its massive size and strength. With larger populations and a solid management of the species, a limited, strict catch and release sport-fishing after the species could be possible in Sweden as well in the future.

1.1 The wels catfish

The wels catfish is a large freshwater fish in the catfish family (*Siluridae spp.*), and the largest fish obligate to freshwater in Europe (Bouletreau & Santoul 2016). Many records claim body lengths up to five metres, and weights of about 300 kilograms. However, the validity of these claims is doubtful. In an article from 2016, Bouletreau & Santoul discusses the uncertainty of some of the most well-known records of giant wels catfishes.

Even though tales about these mythically giant specimens are to be seen as stories with little evidence to support them, there is no doubt that the wels can grow to impressive sizes. Using sport fishing methods, specimens reaching up to just over 2.7 metres in length, and weighing more than 130 kilograms have evidently been caught (Bouletreau & Santoul 2016, International Game Fish Association 2015). The wels catfish is often described as strictly nocturnal, lying inactive under rocks or other sheltering objects in the water during the daytime (Danek *et al*. 2016). However, some of the literature suggests that this strictly nocturnal behaviour does not always occur, and instead show evidence for a less pronounced nocturnal behaviour (Slavik *et al.* 2007).

The male wels catfish matures sexually at an approximate body length (BL) of 80 cm, while females mature at about 90 cm BL. In the more southern parts of the species range, this corresponds to an age of about three years for males, and 4 years for females (Alp *et al*. 2004). However, due to the cold climate in Sweden, the catfish here mature at an older age; 6-8 years, but at the same BL (Ivösjöns fiskevårdsförening 2013).

The species requires water temperatures of 20-22°C in order to successfully reproduce (Copp *et al.* 2009), while the ideal temperature for maximum growth are as high as 25°C (Hilge. 1985).

According to the literature, the male follows the female, where after they entwine during the act of spawning. The female catfish then releases 25 000-33 000 eggs*kg^{-1} body weight, into a nest that the male has prepared. The nest is often an excavation made in the bottom substrate, and is located in shallow, warm waters with much vegetation. (Copp *et al.* 2009) The yellow eggs have a diameter of 3 mm and are attached to vegetation. They are guarded by the male until they hatch after approximately 3 days, depending on temperature. The 7 mm long larvae stay attached to vegetation during the first few days after hatching, until their yolk sacs are depleted (Muus. 1981). The larvae are sensitive to sunlight and therefore stay in the nest during the first days after depletion of the yolk sac (Copp *et al.* 2009). During this period, their diet consists of plankton, but since the growth rates are fast, the fry reaches a length of 3-4 cm in the first month. The diet early switches to macroinvertebrates, and later to include mainly small fish (Muus 1981). It is not clear if low degrees of spawning, or a high mortality in offspring is the strongest limiting factor in the reproduction. More knowledge about the reproduction itself, as well as about the early life stages in the wels catfish life history is needed.

When the water temperature drops to 7-12°C in the autumn, the wels cease to eat, and become inactive (Copp *et al.* 2009). The winters are spent in the deeper parts of the water, in an inactive state, but some activity can still be shown even during winter (Slavik *et al.* 2007).

Movements during winter have been explained as a response to low levels of oxygen (Danek *et al.* 2013). In spring when temperatures rise above 12°C, the metabolism starts to rise, and the wels catfish starts to forage. As in other fish, the metabolic rate is positively correlated with the surrounding temperature, and major parts of the yearly energy intake in wels catfish takes place during spring, prior to spawning (Copp *et al.* 2009). The differences in activity depending on season reflects in home range size. Slavik *et al.* 2007 found that the largest home range sizes were found among adult individuals during summer, with an average size of just above 15 700 m^2. Knowledge about home ranges can give various types of information, for instance can non-overlapping home ranges be a result of territoriality. An understanding of the fish movements and home range size during the spawning period might also give an insight in how far apart spawning sites need to be in order to avoid competition between territorial males. The home range concept has earlier been applied on fish in lotic systems (Crook 2004, Slavik *et al.* 2007), but can also be applicable in lentic systems. Home range size typically increases with increased size of the animal, and home range size is larger for fish in lakes than in rivers (Minns 1995). Factors such as variation in prey abundance might also alter home range size for piscivores (Fish & Savitz 1983).

Knowledge about the species ecology and reproduction is limited. Most of the published studies are based on observations made either in water systems where the species has been introduced, and subsequently become invasive (Benejam *et al.* 2007, Carol *et al.* 2009), or from aquaculture (Alp *et al*. 2004). Applying these types of findings onto the ecology of native populations can be deceptive**.** Examples of factors that could change between these different environments could for instance be access to food, water temperature and the stability of water temperature before, during and after spawning, density of sexually mature individuals, presence and configuration of spawning sites, and mortality amongst eggs, fry and juveniles.

1.2 The wels catfish in Sweden

The heat-thriving wels is a relict from the latest post glacial heat period. During this warmer era, the landmass was still depressed as a result of the load of the recent inland ice, leaving large areas sub-sea level, creating a massive freshwater lake called the Ancylus lake. As the load of the ice disappeared, the landmass started to rise. This diminished the large Ancylus lake to what has become the modern-day Baltic sea. The process left a large number of smaller lakes and rivers scattered over the rising landmass, resulting in fragmentation of fish stocks, creating new populations more or less isolated from each other.

Because of its requirements in terms of water temperature, the range of the wels in Sweden is limited to the southern parts of the country. Successful spawning is dependent on high summer temperatures and normally doesn't occur every year (Ulikowski 2004). This naturally sporadic reproduction has made the species perhaps even more susceptible to anthropogenic disturbances. The southern regions of the country that are warm enough to sustain populations of wels catfish, are also perhaps the ones most heavily affected by factors such as eutrophication and drainage, which both to a large extent are results of the intense agricultural activity in these areas (Naturskyddsföreningen, 2009). The drainage is mostly created by ditching, and also channelization of natural streams and rivers by straightening their path and reducing obstacles in the waterways, thus increasing the speed of the current. These actions have reduced, or completely annihilated many of the spawning grounds for the wels catfish. In Lake Båven, this have resulted in a depletion of areas suitable for spawning catfish, giving room for only a few individuals to spawn. This give raise to a low reproductive rate for the population, as well as it likely leads to a genetic bottleneck, lowering the overall fitness for the population (Hällholm, 2016).

In the autumn of 2017, a national action plan for wels catfish was launched. During the following years the goal is to keep the rejuvenation in stabile numbers, or ideally, increase it. Furthermore, the number of reproducing fish should be higher, thus contributing to a larger genetic diversity in the Swedish populations of Wels catfish (HaV, 2017).

1.3 Purpose

This report aims to answer some key questions regarding the wels catfish ecology, questions that need to be answered in order to obtain a successful management of the species in Sweden. The following questions were sought to be answered:

Can we confirm that spawning took place during 2017?

What does an ideal spawning habitat look like?

Do artificial spawning nests provide opportunities for more fish to spawn?

Can information about movements and home ranges give indications on how far apart spawning nests need to be located, in order to maximize their function?

By trying to answer the question of what the wels catfish need in its environment in order to thrive, we hope to learn where, and in what manner efforts should be made. If we succeed in filling some of the knowledge gaps about the wels catfish ecology, actions such as protecting key environments, and increasing the spawning areas can be made.

This report discusses one part of several parallel projects carried out by the Swedish University of Agricultural Sciences (SLU), Sportfiskarna, and the county administration board of Södermanland. The observations that are described in this text, were followed up during September 2017 with electrofishing from boat. One goal with this effort was to catch young of the year catfish, which would confirm that reproduction had taken place during the year. No catfishes were however caught during this monitoring fishing, therefore the success of the spawning this year cannot be verified.

2. Materials and methods

2.1 The study area

Lake Båven is a lowland lake (21,1 metres above sea level) in Södermanland county, Sweden. It has a surface area of 64,2 km^2, a mean depth of 9,4 metres, and a maximum depth of 48 metres (Länsstyrelsen 2008). The lake has an overall clear water, and an oligotrophic - mesotrophic character (Länsstyrelsen 2008). The lake however, has a strongly irregular shape (Fig. 1), with a high number of smaller bays and lakes connected to the larger water body through more or less narrow channels. In some of these smaller areas, the conditions differ greatly compared to those in the larger parts of Båven. The trophic status can be skewed more towards the eutrophic direction, and the Secchi depth is considerably lower in these parts. The temperature in these areas are often higher than in the rest of the lake, and the vegetation is dense, both in- and around the water. In some cases, the littoral vegetation has formed dense floating mats, completely covering the surface. These mats can in some cases reach out more than 10 metres from the shoreline.

The current study was carried out in mainly two of these smaller lakes connected to Lake Båven, Lake Lillsjön and Lake Hornsundssjön. These lakes are located in the north-western part of Båven (Fig. 1). They are nutrient rich, have an overall low Secchi depth, and a high level of vegetation. Mainly Lake Lillsjön, but also Hornsundssjön have a substantial number of floating mats in the littoral zones. Floating mats are aggregations of mostly terrestrial vegetation that forms a layer, comparable to a lid covering the surface area, providing shade and hiding places. These floating mats range from small patches of only a few square metres, to larger areas reaching up to several 100 m^2. A distinctive feature with these floating mats, that make them differ from quagmires and bogs, are that they have free water underneath them, where fish can move around. Beside these areas with floating mats, many other types of littoral zones are present in the studied areas. For instance, overhang of alder and willow are present in several spots. Submerged alder root systems are also present, but mostly limited to the channels between the lakes. In addition to the floating mats, there are several jetties in the lakes, that somewhat resemble the floating mats regarding the coverage of surface, providing shelter and shading.

The areas that were studied had a water depth of up to about 2 m, and with a soft bottom consisting of soft sediment. Between April and October, the surface level of Lake Båven normally drops about 0.5 metres, leading to the draining of shallow areas, possibly including important spawning grounds (Nyköpingsåarnas vattenvårdsförbund, 2017).

2.2 Artificial spawning nests

Five nests were constructed after a model previously used in *S. glanis* aquaculture (FAO 1984). Three smaller sprout trees (approx. 2 m. in length each) were bound together with their root-ends upwards, forming a tripod structure, inside which the catfish were supposed to spawn (Fig. 2). The nests were placed in the lake in May 2017, close to shore in water depths of about two metres (Fig. 3). Temperature loggers were placed in the vicinity of each nest. Building- and placing of the nests and temperature loggers were done by *Sportfiskarna.* The nests were studied for activity of wels catfish using ARIS. Each nest was observed for 20 minutes on three different days. When approaching a nest, the engine was turned off in order to minimize the risk of scaring fish

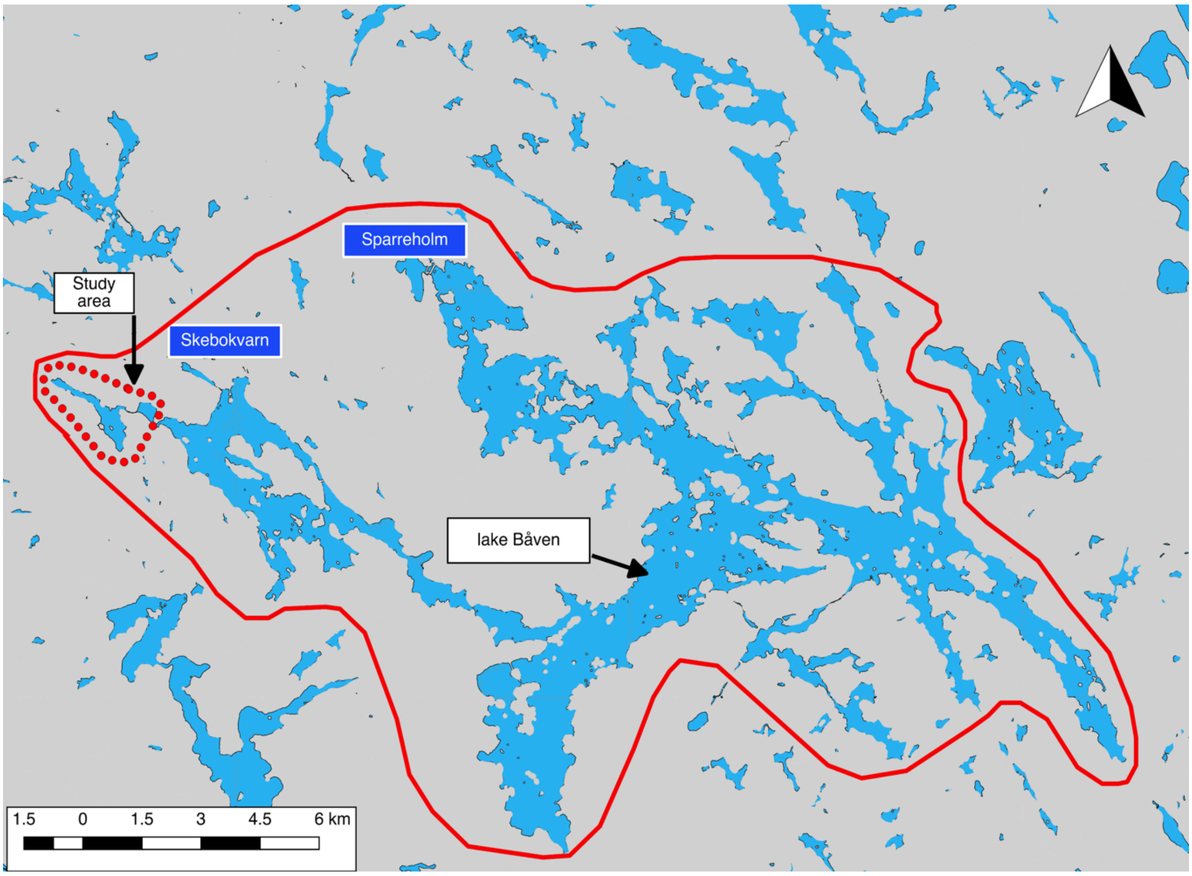

Figure 1. Overview of Lake Båven, within the red line, and the study area of Lake Lillsjön and Lake Hornsundssjön, within the dotted red line. Skebokvarn and Sparreholm are the two nearest villages to the study area.

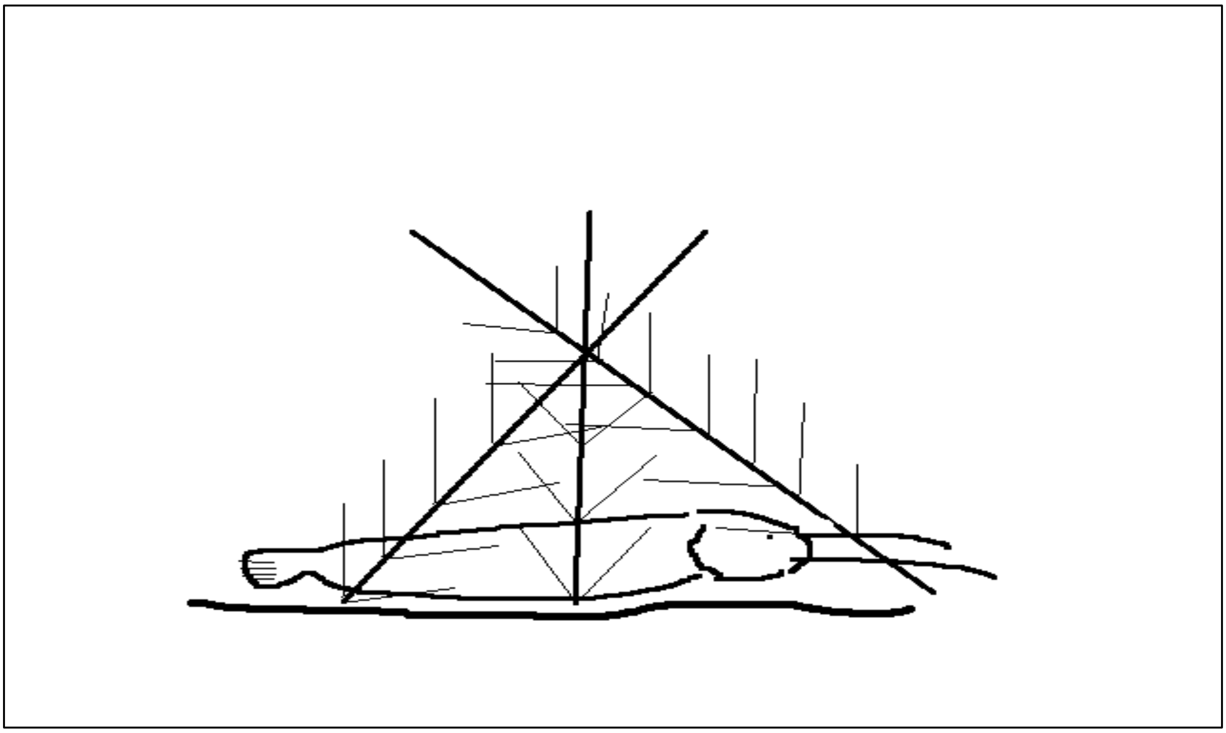

Figure 2. Male catfish guarding nest of the type that was placed in lakes Hornsundssjön and Lillsjön. The sprout trees used in the construction are bound together in the root-end, and placed upside down in the water.

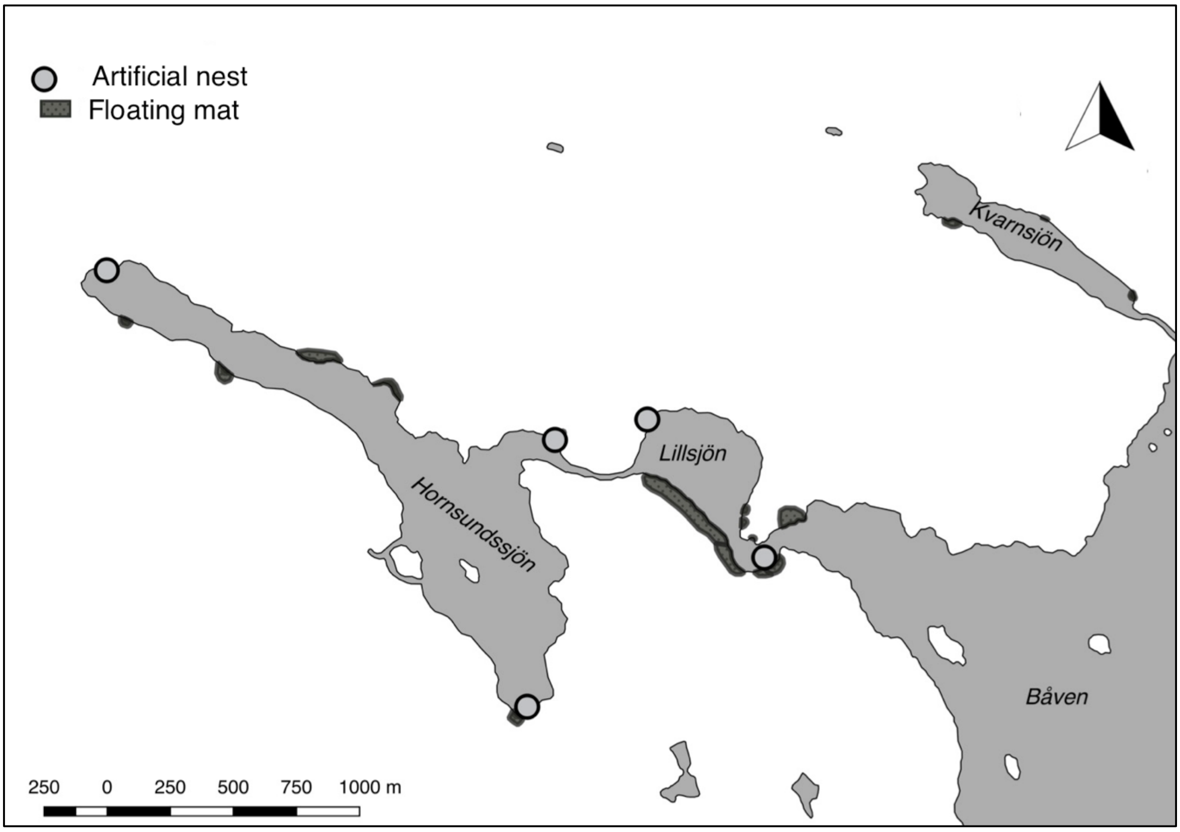

Figure 3. Map showing location of artificial spawning nests and areas with floating mats, in the three different study sites, Lakes Kvarnsjön, Lillsjön and Hornsundssjön. The larger water surface marked 'Båven' is in fact only *a small part of the main body of Lake Båven. Some of the floating mats on the map are slightly enlarged in order to become visible.*

2.3 Tracking and observing

2.3.1 | Radio-telemetry

Radio-telemetry studies of tagged fish sought to answer questions regarding the movements of the tagged fishes, and the size and locality of their home ranges. Equipment from manufacturer ATS (advanced telemetry systems) type R410 was used to localize seven wels catfish tagged with radio tags in 2014 by the county administration board of Södermanland. These seven fish were at the time ranging between 101 and 136 cm in length, and between 6.8 and 19.8 kg in weight (Tab. 1). Sex determination was only possible in one fish, this female was the largest of the tagged fish, with a length of 135 cm and a bodyweight of 19.8 kg.

Table 1. *Information of the wels catfishes tracked using radio-telemetry summer 2017. Data obtained during monitor fishing in 2014.*

Fish no.	Length, cm	Weight, kg	Gender	Location
0	127	13,4	-	Lillsjön
1	103	8,1	-	Hornsundssjön
2	119	9,9	-	Hornsundssjön
3	130	12,8	-	Lillsjön
4	136	16,5	-	Lillsjön
5	101	6,8	-	Lillsjön
6	135	19,8	female	Lillsjön

Telemetry readings were made at a total of 33 different days during the period of May-September, with focus on June-July. This resulted in a total of 157 registrations (Fig. 8.) mostly collected during daytime, but at some points also during night. Readings were made from an open boat equipped with an 18 hp outboard engine. The routine was similar for each of these 33 days, going close to shore, around lakes Lillsjön and Hornsundssjön, in that order, with some deviations, where the route differed slightly (Fig. 4). Some of the data points are also registered by *Sportfiskarna*, using the same equipment but not following the routine route. When scanning for fish, the receiver was set to shift automatically between signals with an interval of 5 seconds, thus searching for all tagged fish within a time period of 5x7 seconds. When doing this, a high RF gain (receive sensitivity) was used in order to maximize the spatial range. When a signal was found, the boat was slowed down and guided towards the increasing receiver signal until getting close enough to the fish to obtain a GPS coordinate. When closing up on the fish, the RF gain was gradually decreased in order to more accurately determine the precise location of the fish. Coordinate was taken in the coordinate system SWEREF 99.

The software used was the app “Svenska koordinater” from App store, installed on Apple IPhone 7, and Apple IPhone 6+. The accuracy of the GPS coordinates was mostly within the range of 4-6 metres, with a couple of outliers between 2-12 metres, the accuracy of the signal was shown on the screen in real time. The program was on a couple of occasions controlled against a handheld GPS unit. No difference in accuracy was noticed between the two devices. Results was analysed using the software *Quantum GIS.* By creating polygons between the outer data points for each individual, home ranges could be constructed in the program. In addition to this, activity of the tagged fish was tested against temperature data, in order to find out if a positive correlation between rising temperatures and activity could be found. Activity was defined as stationary (0) and active (1), where a fish found on open water were assumed to be active, while a fish found in the littoral were assumed to be stationary.

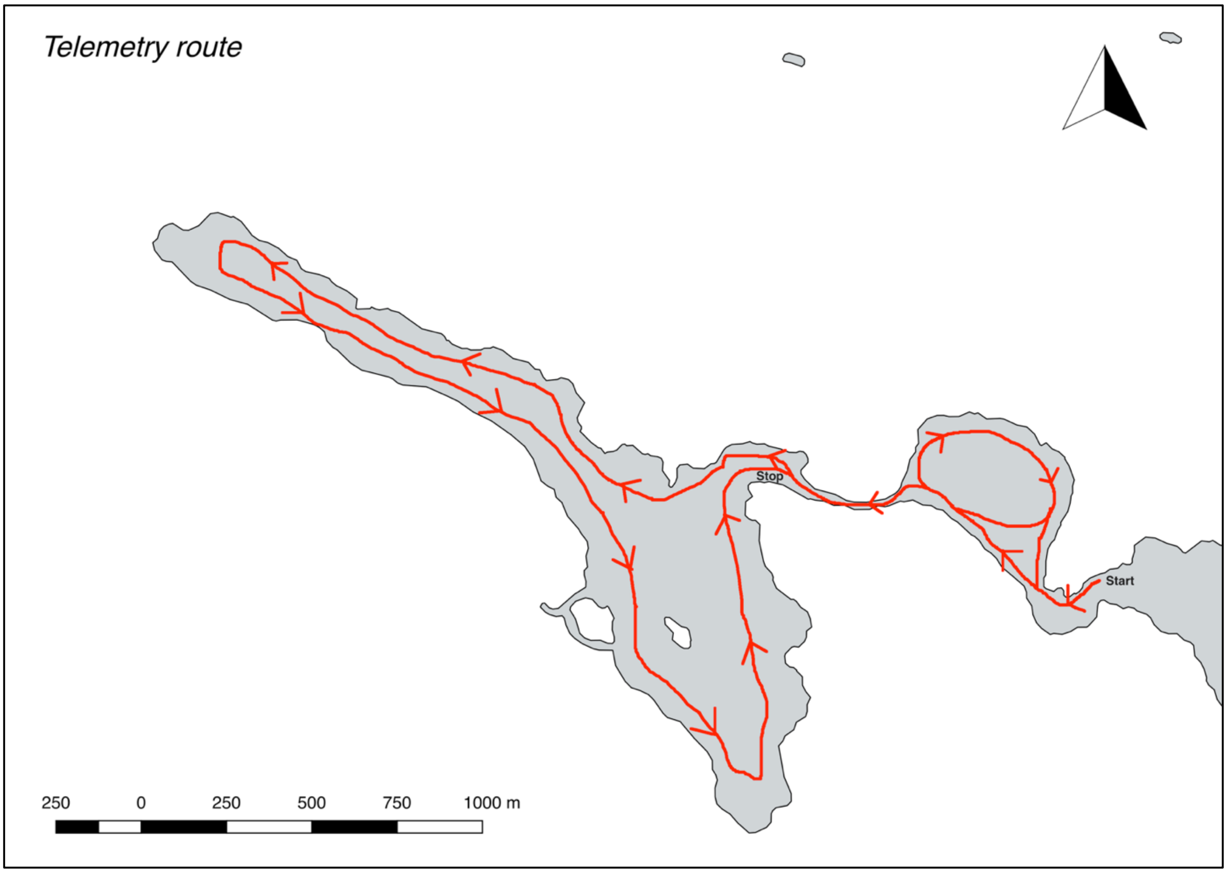

Figure 4. The standard route during the telemetry readings. The route took in general about two hours to drive, depending on how many of the tagged individuals we found.

2.3.2 | ARIS

In addition to the telemetry readings, an imaging sonar (Sound metrics® ARIS Explorer 1800) was used. Transmitting acoustic signals in 96 separate beams, it interprets the returning echoes from these transmissions into real time, video quality images, showing objects that are in front of the device. The ARIS device was mounted on a custom-made mount in the bow of the boat (Fig. 5), and was equipped with an ARIS rotator AR2, enabling radio controlled aiming of the device. The ARIS was connected to a laptop from which control of settings and live watching could be done directly from the boat. The system was powered by a 12V, 85 Ah gel battery. The advantages of using an imaging technique based on sound rather than light is obvious during the conditions of our study sites. Despite high turbidity and darkness, the imaging sonar made it possible to see into the water in a way a traditional camera does not allow.

The usage of ARIS was mainly aiming to answer questions regarding behaviours, habitat preference and function of artificial nests. When concluding which habitat types that were the most ideal for wels, the number of individuals that were seen served as a predictor for habitat quality, supposing that the areas with the highest number of wels were the most ideal. Beside quantification purpose, the ARIS was also used in order to search for behaviours that would indicate spawning, and to assess the function of the artificial spawning nests. Spawning should be easy to detect if filming with the ARIS at the right time, when the male fish pursuit and subsequently wraps around the female during the fertilization.

Data of water temperature was collected automatically by loggers during the season. The temperature data and the literature concerning spawning temperatures, was considered when analysing ARIS material for signs of spawning.

Figure 5. Photo showing the setup of the ARIS device in the front of the boat. When recording, the device was lowered into the water by turning the long metal arm into a vertical position. The ARIS could then be turned using the ARIS rotator AR2, seen on the picture as a shackle to which the metal arm is attached

2.3.3 | ARIS, experimental setup

Filming with ARIS was done during 12 different days. Most observations were made during daytime, but on some occasions the recordings were made during the dark hours, in order to find out if presence of catfish under the floating mats differed from daytime. Location in which to film were randomly selected within both areas with and without floating mats, giving rise to a total of 46 samples in Lakes Lillsjön, Hornsundssjön and Kvarnsjön (Tab. 2).

Filming took place during ca. 5-10 minutes on each sample site, depending on underwater visibility, e.g., sites with more vegetation took generally longer time to get a good view of, hence longer time would be spent on these sites. When the site was considered thoroughly covered, the next site was picked. Of these 46 sample sites, 18 were sorted under the category floating mats, and the 28 remaining sites fell into the four different categories: overhang, jetties, reed bays and shading/ hard bottom (Tab. 2). At every site, coordinates, pictures and additional notes were taken. The categories were defined after the field period, by using the documentation from the sites. When analysing the material, the main different information that was looked for were: number of catfish per site, and their behaviours (such as movement patterns and social behaviour). Further analysis was made of ARIS-material in order to assess if any differences could be found regarding habitat composition between the different floating mat samples, aiming to explain differences in catfish presence between these sites. Factors such as bottom structure and cardinal direction were considered. The differences in bottom structures within the floating mat group, gave raise to two subdivisions, one of them showing a more irregular bottom structure, while the other had a flatter structure. Beside these factors, the individual length of the fishes was also considered, since large fish might be more territorial and therefore solitary to a larger extent than smaller fish.

Table 2. *The different types of habitats that was covered in the ARIS observations.*

Habitat type	Description	Number of sites
Floating mat	A habitat type defined by the presence of floating mats. Soft bottoms, and typically not deeper than 2 metres.	18
Overhang	Branches of mainly alder trees, protruding over the water, close to the surface, often sharing many features with the floating mat habitats.	11
Jetty	With the same type of coverage of surface as the floating mat sites have, but less adjacent macrophytes, and are likely to have more disturbances connected to human activities than rest of the categories.	5
Reed bays	With moderate to high levels of vegetation, mainly common reed (*Phragmites australis)* but also water lilies.	6
Shading/ hard bottom	Littoral areas with shading from mainly oak- or coniferous trees. Branches further above surface than in 'overhang' category. Harder bottom compared to other categories, and often with larger rocks and logs.	6

Alongside the shorter, and more numerous samples described above, monitoring of a few larger fish were also done. These sessions were longer (approx. 1 h/sample) and made on a couple of locations where large individuals had been seen in previous observations (Fig. 12). The aim of these sessions was to give a more detailed picture of the catfish behaviour than the shorter samples which instead focused on gaining data from many locations. What we looked for in particular were behaviours that could be signs of spawning or nest guarding.

2.3.4 | Temperature measurements

When the artificial spawning nests were put into place by *Sportfiskarna* during spring, one temperature logger (Onset HOBO Pendant UA-001-64) was mounted on a pole, just beside each spawning nest. A total of 5 loggers on the same locations as the artificial spawning nests registered water temperature data every hour between May 12 and September 25 (Fig. 13, 14). These readings provide detailed information of water temperatures during summer, giving an opportunity to correlate our observations of the fishes with the corresponding water temperatures.

2.4 Statistical analysis

A significance level was set to 0,05 for hypothesis testing. All statistics was made using the software *R studios 1.1.419*

The type of bottom structure, cardinal direction and individual lengths of the fish was tested to see if they had an influence on the number of wels catfish at the floating mat sites. The hypotheses were that the irregular bottoms would have more catfish present than the flat ones, so would also habitats facing south rather than in other directions. Lastly, sites with larger fishes was expected to have a lower number of individuals. Testing this was done with a multiple linear regression analysis. This show if there is a linear connection between response- and explanatory variables.

In addition to the regression analysis, the influence of bottom structure on number of catfish was also examined using a Kruskal-Wallis test. This is illustrated in figure 10. The Kruskal-Wallis test is similar to a t-test, but non-parametric in contrast to the parametric multiple regression. This is suitable when testing a variable that is not continuous, like the ´number of individuals´ variable.

To test the hypothesis that rising water temperature, have a positive effect on activities, each registered telemetry coordinate was labelled as an ‘active’ or ‘inactive’ coordinate. This was determined using QGIS, by assuming that fishes found in the littoral zone was more likely to be inactive than the ones found on open water. To test if there was a shift towards more registrations of active fish or not, a generalized linear regression model was used, which is a model type frequently used when dealing with binary data. The data on activities was set as a binomial variable, since the possible outcome for each coordinate results either in 1) active or 2) inactive, and the values are independent of each other.

3. Results

3.1 Artificial spawning nests

When studying the artificial spawning nests with ARIS, no wels catfishes could be seen. Four out of five nests were surrounded with relatively dense vegetation of mostly water lilies. This rich vegetation lowered the visibility somewhat, however, large fishes like an adult catfish would likely have been visible despite this. Each nest was studied for 20 minutes on three different days. No wels catfishes was observed at the nests, on any occasion.

3.2 Defining habitat demands

No spawning could be confirmed when analysing the data. Our findings indicate a clear preference for areas containing floating mats (Fig. 11, Tab. 4). Of the 28 samples lacking this feature, only two catfish were observed (Tab. 7 appendix), whereas the other sites lacking floating mats had no catfish at all (Tab. 5,6,8 appendix). A majority of the samples (11 of 18) containing floating mats, contained catfish (Tab. 4). Several of the floating mat-samples did furthermore contain numerous individuals of body lengths indicating that they should be sexually mature (majority of fish ≥1 m). These groups of fishes could be relatively dense, with some individuals appearing very close to each other.

In order to assess if any habitat differences between different floating mat samples could explain the variations in catfish presence, further analysis of ARIS data was made. The focus was mainly on differences in bottom structure and cardinal direction. The body length of individual fishes was also assessed, since larger fish might be more territorial than smaller individuals

When assessing bottom structures from the ARIS material, and testing statistically with Kruskal-Wallis test in R, a significant pattern could be seen showing a higher catfish presence at the sites with an irregular bottom structure underneath the floating mats than in the ones with a flatter bottom (Fig. 10) (Kruskal-Wallis, chi-squared = 9.9426, df = 1, p = 0.001615), suggesting that this feature might serve as a predictor on whether a habitat is suitable for catfish spawning. The irregularities were often pit-like, and differed in size between approximately 1-2 meters across. No significance was found to support that either cardinal direction, or individual length of the individuals did have an effect on whether a site held catfish or not, or how many individuals there were.

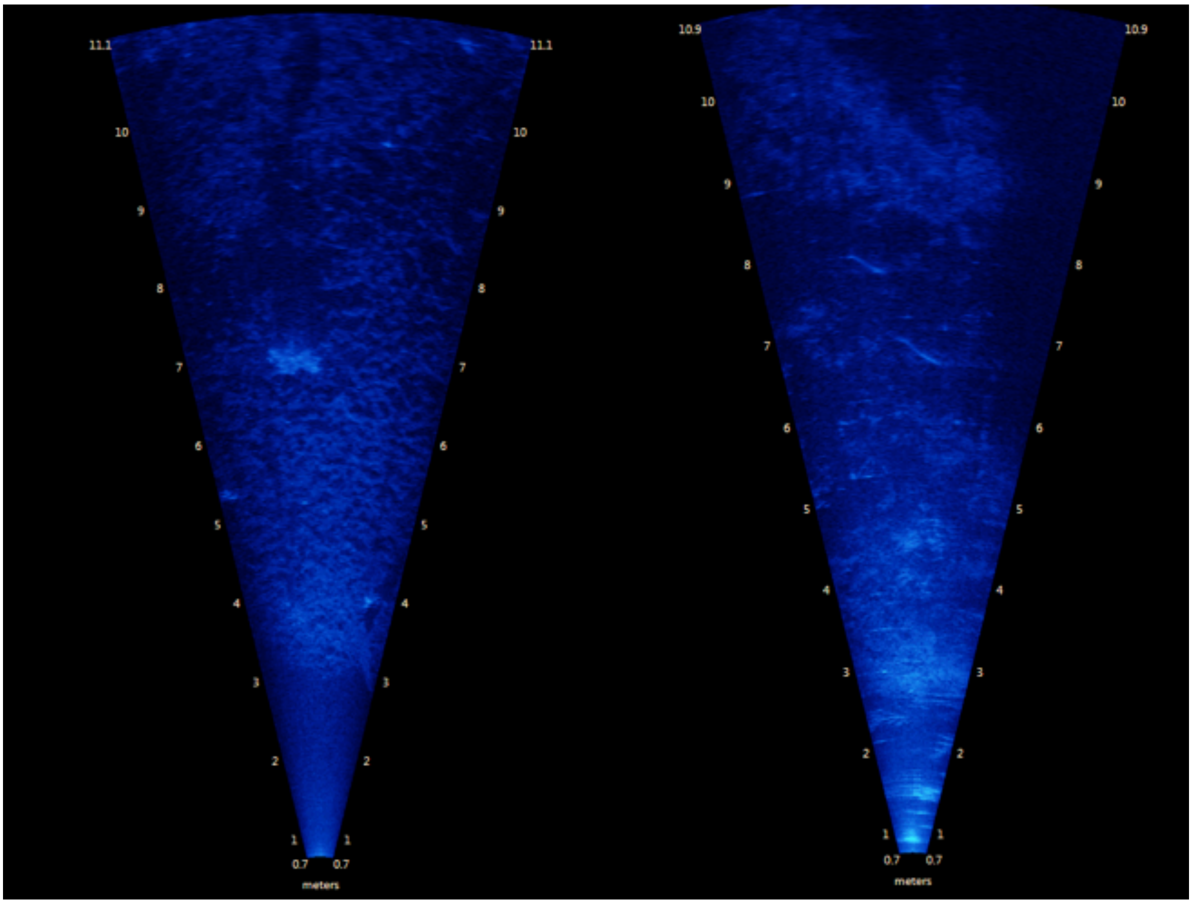

Figure 6. Example on two different bottom structures. Both pictures are taken from underneath floating mats, but the left picture have the flatter topography, while the right picture show a more irregular bottom shape, with larger dark spots that mark lower parts in the bottom. In the middle of the right picture, at 7-8 m distance, two wels catfishes can be seen as diagonal lines, lighter in colour than the background.

3.3 Behavioural studies

During the behavioural studies at the floating mats, no spawning behaviour or nest guarding could be concluded. It was however sometimes noticed that some of the individuals showed a behaviour where they made a rapid whipping movement with the tailfin, powerful enough to stir up the bottom sediment in a cloud visible on the ARIS recordings.

The fish, was in most cases seen in groups of varying sizes (Tab. 4). Within these groups, no aggressive or territorial behaviours was apparent, even if fish could be seen following each other at times. Many fishes moved around in a slow pace in circular movements, but did not seem to ever leave the coverage of the floating mats during our observations. Other individuals were laying still on the bottom, in a resting position.

Furthermore, some others could on several occasions be seen standing diagonally in the water column, with their head up towards the underside of the floating mats. During these observations, the fishes was often still, making the position resemble some kind of resting position.

Some of the sites that we did find to have large numbers of fish, and/or particularly large individuals (2 m) were visited on several occasions, in these cases only one occasion was counted as a sample. When revisiting these sites, it seemed that these floating mat areas held a fairly constant number of individuals at all observations, both during day- and night time. The body lengths could be approximated using a measuring function in the program ARIScope (Fig. 12). The majority of fish observed appeared to be in the length span of 100-120 cm (Fig. 7). However, some individuals with estimated body lengths (BL) around two metres, was observed, but also smaller individuals could be seen at some points.

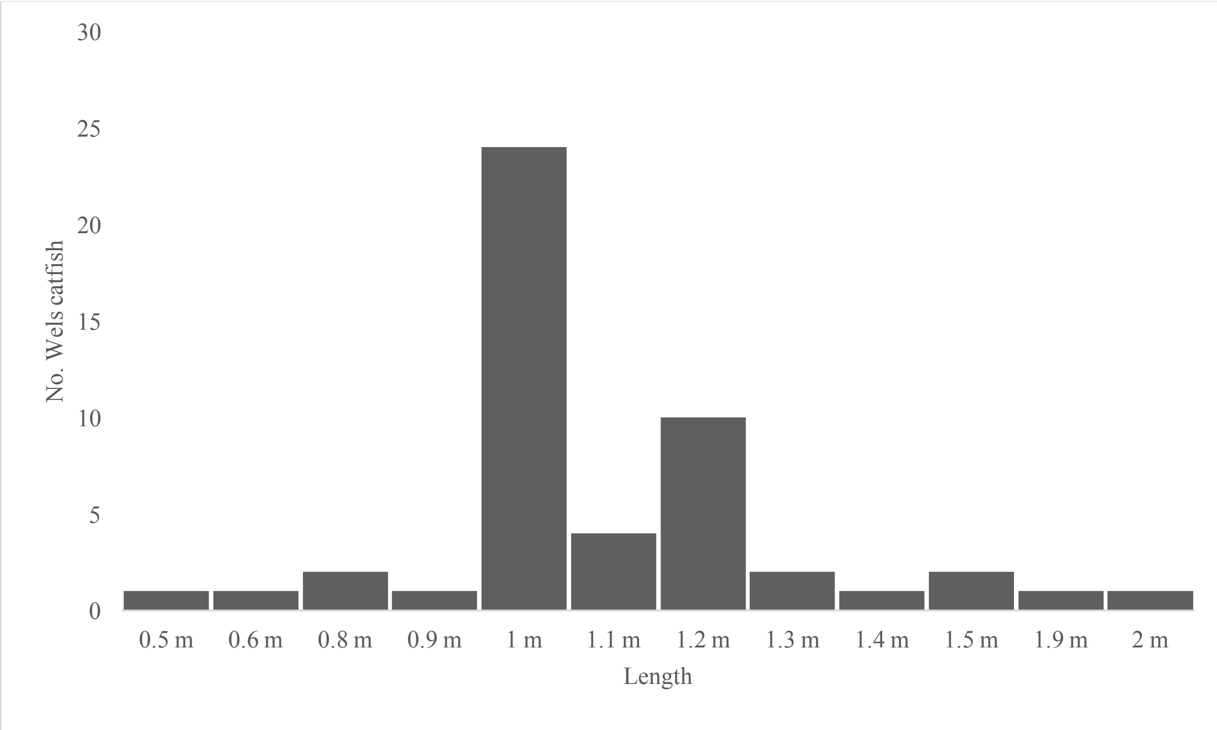

Figure 7. Size distribution of wels catfishes, a clear majority of the fishes were estimated to be 1.0-1,2 metres long.

3.4 Movements and home ranges

During telemetry studies, the tagged individuals were always found in Lakes Lillsjön or Hornsundssjön, or close to the inlet from the larger Lake Båven to Lillsjön (Fig. 8). However, on several occasions, one or more of the tagged fishes could not be found. The tagged individuals were found in different types of littoral habitats, but also occasionally in open water (Fig. 9). Fish number 1 and 5, were the only individuals that frequently were localized in open water, both in lake Hornsundssjön. However, in general, fish were most often found adjacent to-, or directly underneath floating mats (Fig. 9).

When constructing home ranges for the fishes using GIS software, a strong overlap can be seen for several of the tagged fishes. Movements between the lakes also occurred. Home range sizes differed to a high grade between the fishes, ranging between 365 and 79 024m^2 (Tab. 3, fig. 8).

Table 3. *Number of telemetry registrations, and home range sizes for each fish.*

Fish	registrations	Home range sizes (m^2)
0	10	365
1	27	79 024
2	15	14 639
3	7	10 029
4	29	23 107
5	30	72 133
6	39	18 817

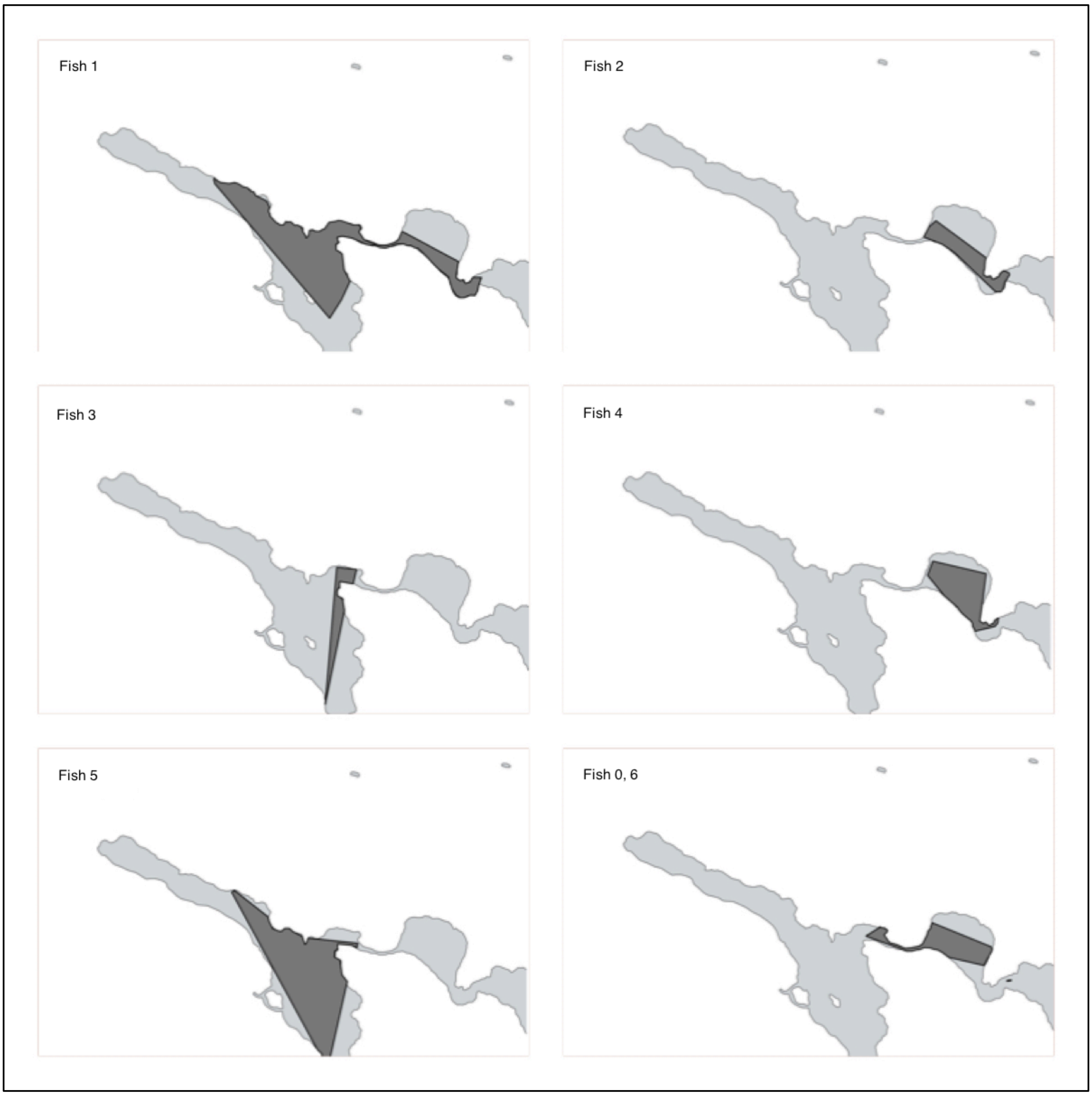

Figure 8. Estimated home ranges of individual fish. Note that fish no. 0 and 6 are presented in the same panel. Fish no. 0 have a very small estimated home range, represented as a small dot in the lower right corner of the last panel.

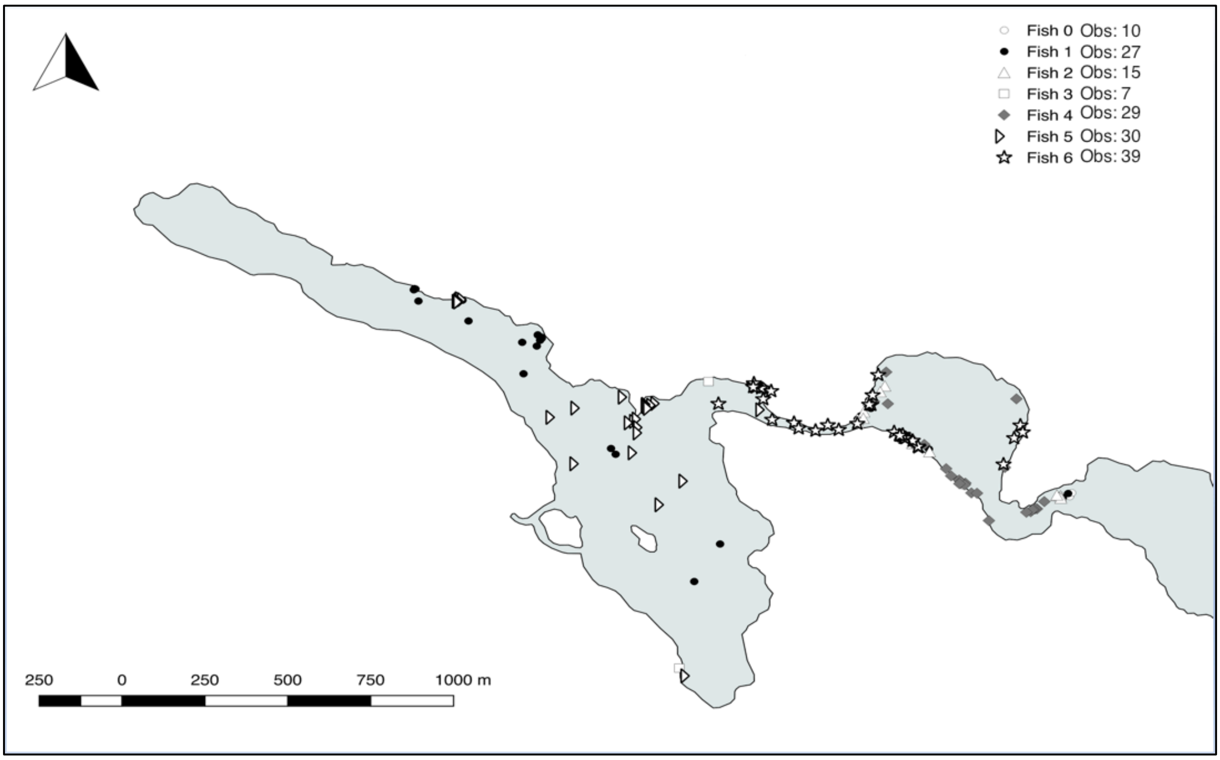

Figure 9. Overview of telemetry data obtained between May-September 2017. The highest concentrations of coordinates were found close to shore in lake Lillsjön, and in the channel connecting Lillsjön with lake Hornsundssjön. Fish number 1 and 5 was mostly found in lake Hornsundssjön and often in open water. Number of observations presented for each fish in legend.

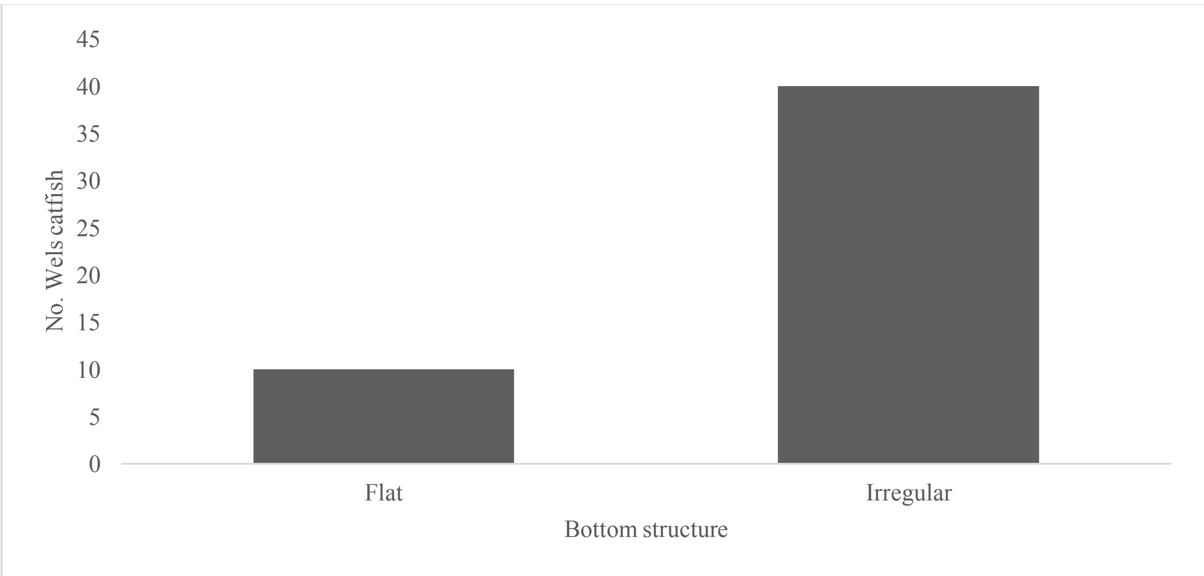

Figure 10. Differences in catfish presence between 1) flat bottoms and 2) bottoms with an irregular surface. The two subgroups show a large difference regarding presence of wels catfish. A total of only nine individuals were seen in the samples lacking irregularities in the bottom.

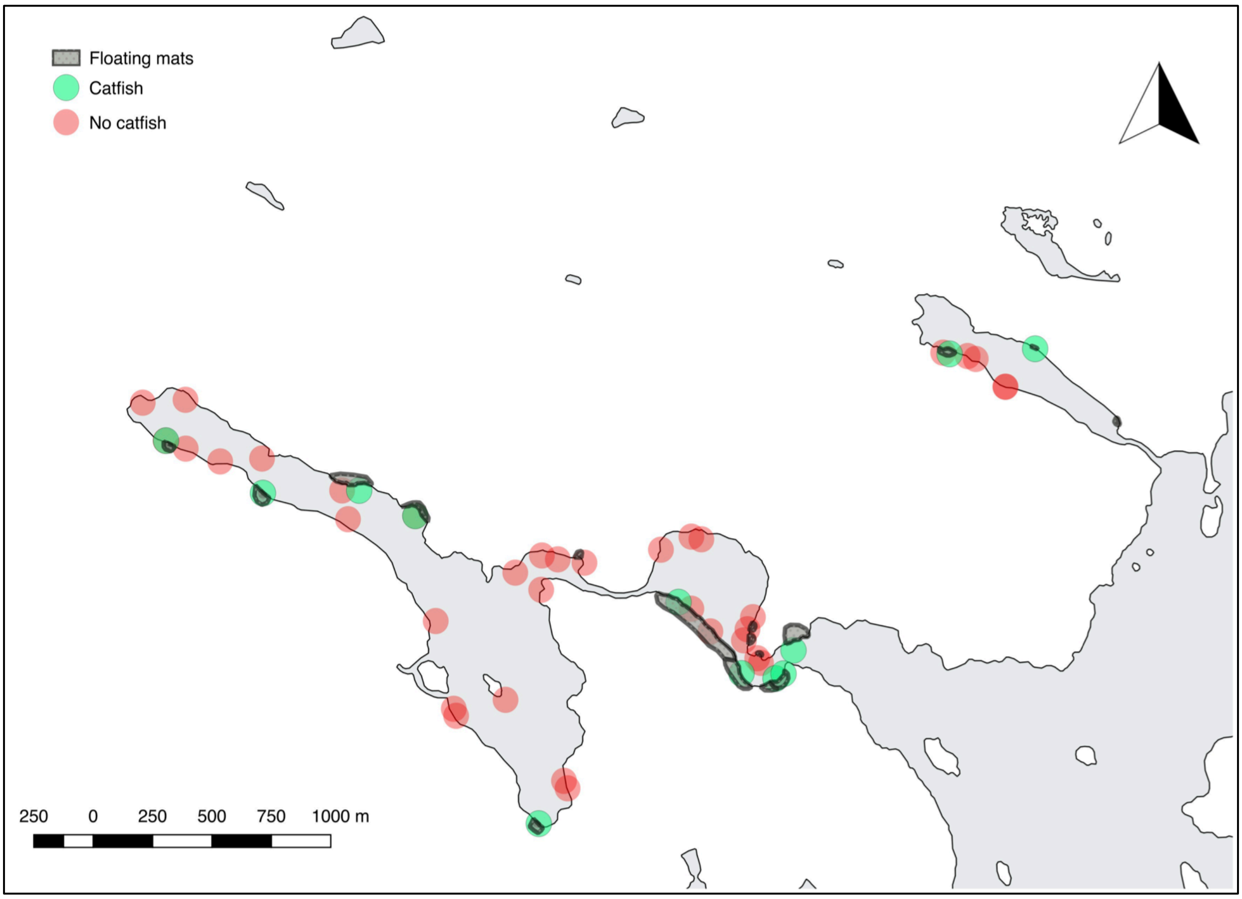

Figure 11. Green dots showing ARIS-sites with catfish, red dots represent sites without catfish. As seen, the green dots strongly correlate with areas containing floating mats.

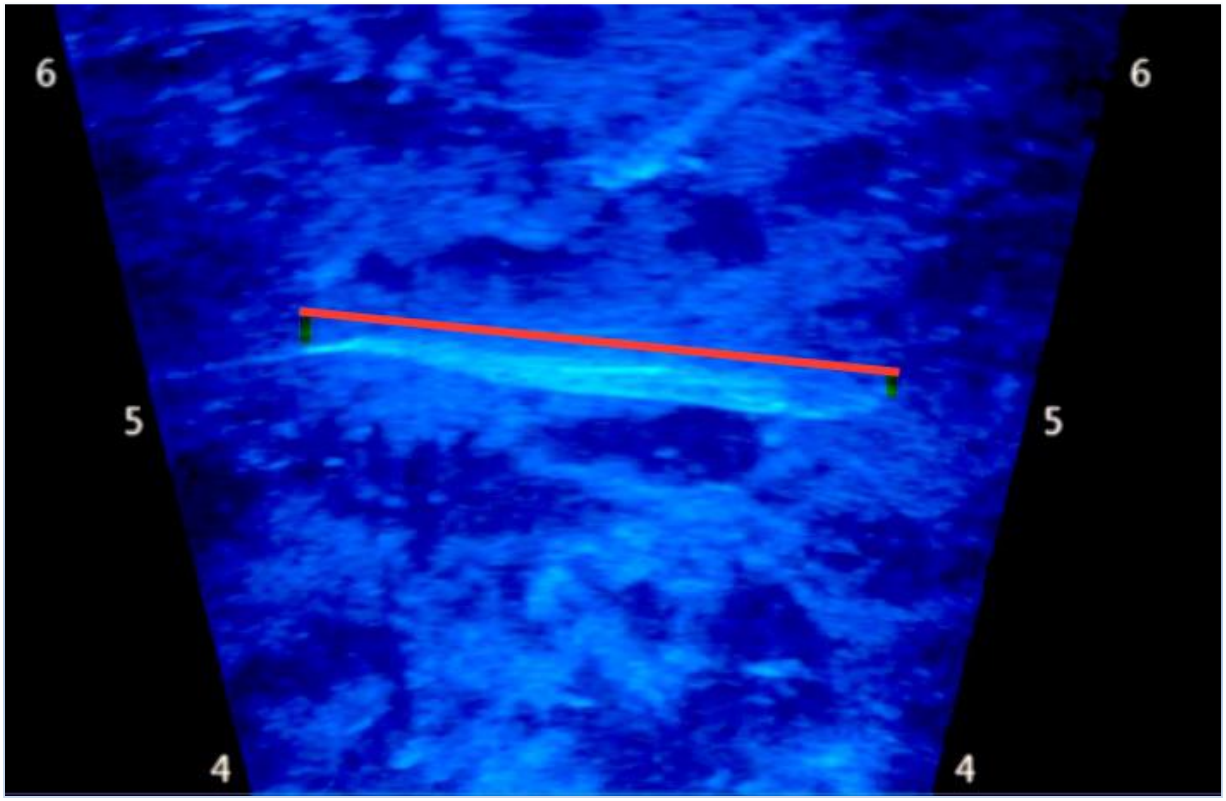

Figure 12. The red line represents approximately 1.8 metres, and reach from tail to nose on the fish. Since the fish is not totally straightened, the actual TL is probably slightly above 1.8 m. Red line is not made in ARIScope, but inserted afterwards.

3.5 Temperature

The data registered by the temperature loggers in Lakes Lillsjön and Hornsundssjön between May 12 and September 25 were compiled to show average daily water temperatures (Fig. 13, 14). Between May 12 and 31 the average temperature in Lake Hornsundssjön increased from 10.71°C to 18.99°C, and from 10.66°C to 16.77°C in Lake Lillsjön. In the first half of June the water temperatures decreased again. A more continuous period of temperatures of 20°C or more were not reached until late July. In Lake Lillsjön, temperatures reached above 20°C for 18 days in a row, starting on July 20. In Lake Hornsundssjön, 14 consecutive days with an average temperature of 20°C or more were noted, starting July 24. No relationship between the activities and the tagged individuals and water temperature was found.

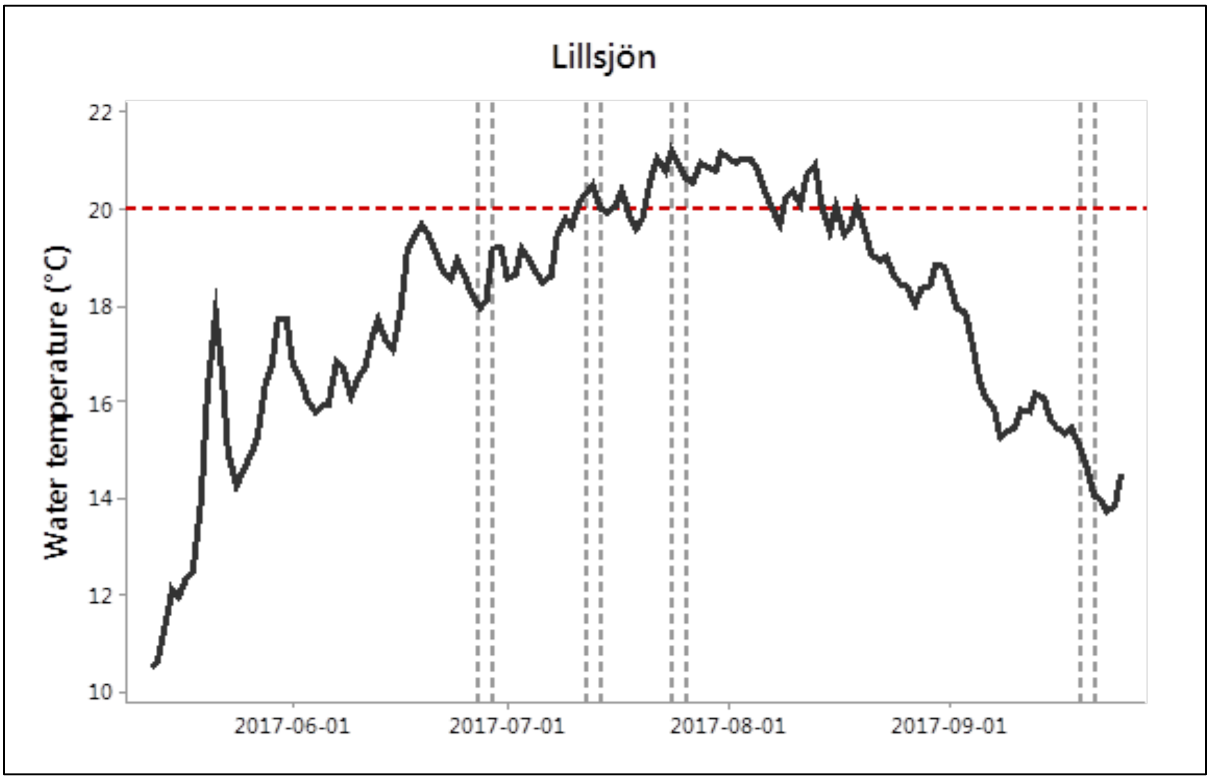

Figure 13. Daily average water temperatures in lake Lillsjön. 20°C line marked with red. The dotted, vertical lines show dates where ARIS observations have taken place. As seen, two out of four occasions coincided with daily avg. water temperatures >20° C in the lake,

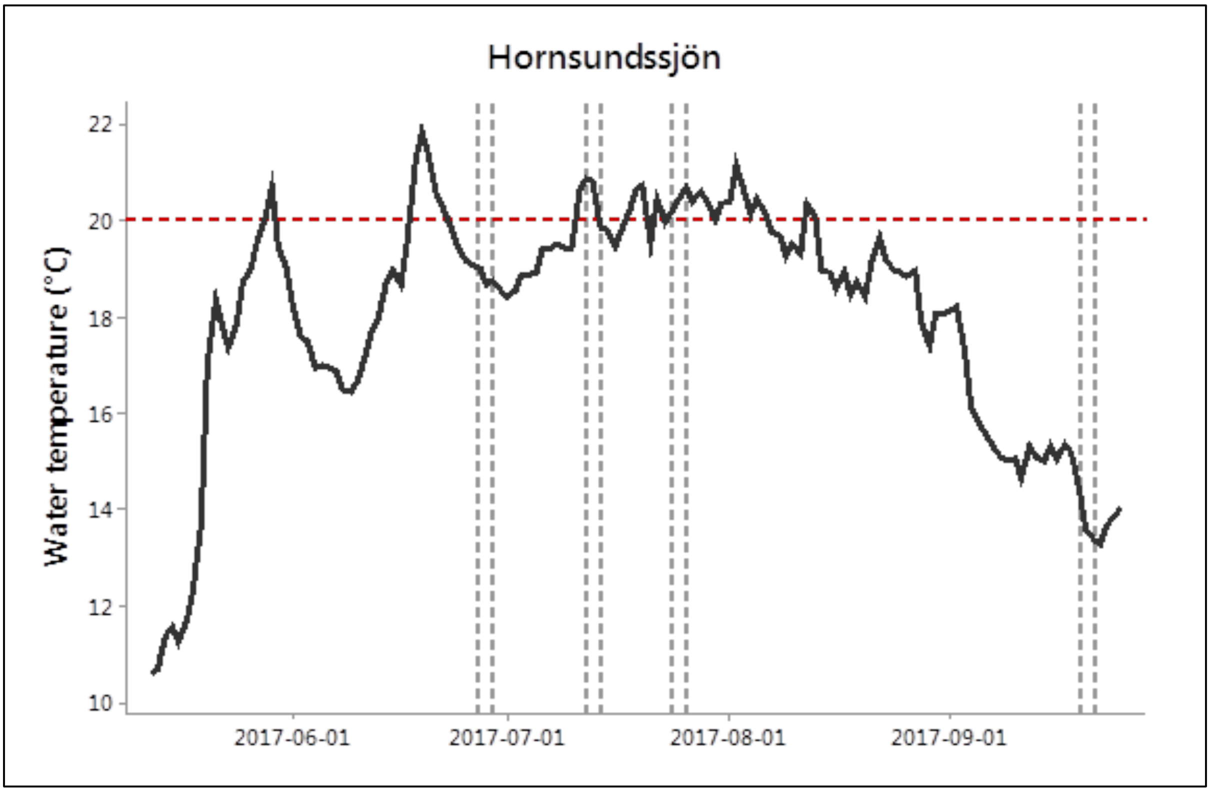

Figure 14. Daily avg. in lake Hornsundssjön. As seen, two out of four occasions coincided with daily avg. water temperatures >20° C

4. Discussion

4.1 Social behaviours

The perhaps most surprising result obtained from the observations done with ARIS, was the finding of groups of relatively large individuals (≥ 1 m BL) together in what we judge as habitats likely to serve as spawning areas.

This seemingly social nature of the wels catfish that we saw during ARIS observations stands in opposite to the view on the species as an aggressive and territorial fish (Copp *et al.* 2009). We instead found that the wels catfish seemed to gather in clusters of sometimes tenths of individuals under the floating mats, either lying passively, but most often slowly circulating within areas of a few square metres. On some occasions, some fishes were so close together that they more or less were on top of each other. Earlier studies from Lake Båven have stated, based on that no more than ca. 15 individuals should have room to spawn (Hällholm 2016) because a lack of suitable spawning locations. This is thought to be an effect of the species supposedly large territory sizes, and fierce territorial behaviour. Based on our results, it can be questioned if the information regarding this type of territorial behaviour is correct in all cases, or if more individuals than expected can coexist in small areas also during the spawning periods, and spawn more closely together than we thought. During our observations, we could not conclude that spawning took place, neither did we observe any offspring. We did however, on some occasions, observe behaviours that very well might have been connected to nest guarding, like whipping with the tailfin, a behaviour that possibly can be a way to keep eggs clean and oxygenated (Copp *et al. 2009)*.

One possible alternative is however that the fish we observed in larger groups were in fact fish that did not have the opportunity to spawn, but rather aggregated in some sort of 'bachelor/bachelorette' groups close to the spawning sites, while other more solitary individuals in the vicinity claimed the actual spawning sites. Earlier reports on the wels catfish in Lake Båven state that the number of spawning individuals are low, and that this is a result of a lack in spawning locations (Hällholm 2016, Enqvist 2015). If what we saw under the floating mats indeed were adult non-spawning individuals, this additionally supports the idea that the spawning locations are too few in relation to the population. Future observations of spawning would give confirmation of the importance of having this type of floating mats available for sustaining viable catfish populations in lake Båven. Not only would it give us information about the spawn itself, but also knowledge about where to find the fry and small catfishes, which are yet to be observed in their natural environment. Obtaining more knowledge about the early life stages in the wels catfish life history is crucial in the process of getting all the information needed to carry on an effective, evidence based management of the species in Swedish waters.

Our results clearly indicate an importance of floating mats as a dwelling place for wels catfish during spring and summer in the studied areas. In relation to other habitat features such as overhang, submerged roots and underwater vegetation, we found a positive correlation between the presence of floating mats, and presence of catfish. However, the presence and significance of for instance submerged root systems attached to the downside of the floating mats could not be assessed, making it impossible to out rule a larger importance of roots than indicated by the results obtained in this study. In some of the areas containing floating mats, there was also shrubs of *Salix* growing on top of the mats. These shrubs might very well have root systems that extend through the floating mats, and into the water.

The uneven number of ARIS samples for each habitat type, with an overrepresentation of floating mat sites, was mainly a result of the fact that classifications of the habitat types was made after the field period, by using documentation from each site. If similar habitat categories are being used in future studies, a more even distribution is to recommend.

4.2 Suitability as spawning place depending on bottom structure

Regarding the bottom structure, we found that the sites with floating mats, that also held catfish, often did seem to have a somewhat more irregular bottom topography than the ones lacking catfish. It was often hard to conclude the exact structures of the bottom through the ARIS material, but a trend that a flat structure, without these pit-like irregularities held less catfish could be seen. The cause of these structures cannot be concluded without further studies, but they could for instance be explained by that they are naturally occurring on these sites, or made by the fishes as either a result of some kind of nest-preparing behaviour, or simply as a mere effect of the large-bodied fishes moving around over the loose sediment bottom. If the latter explanation is correct, the irregularities would not serve as a good predictor on suitability as a habitat for wels catfish. However, it cannot be excluded that some of the structures that was assumed to be irregularities on the bottom, in fact may have been roots hanging from the downside of the floating mats, rather than objects on the bottom. This ambiguous interpretation was a result of that it, occasionally, was hard to conclude where in the water column objects were located. If a preference for these type of fine root systems could be concluded, a reasonable explanation for this could be that they are of importance during spawning. For instance, they might serve as a substrate on which eggs are attached (Muus 1981). This could perhaps be an explanation to the behaviour we observed several times, when fishes seemed to stand relatively still in the water, with the head up against the 'roof'. This might have been signs of nest guarding.

4.3 Movement patterns and home ranges

Home ranges differed greatly in size, and showed a significant overlap between the different individuals. The overlap might imply that the territoriality in these fishes are not that strong. Also, here there is an insecurity to the results that come from the fact that we don't know how much, and where, the fish moved between our data points. It is evident, however, that the home areas are significantly larger (mean= 31 159 m^2) than what's stated in the literature (mean=15 700 m^2) (Slavik *et al*. 2007). This is likely due to the fact that wels catfish mostly have been studied in rivers, where fish home ranges generally are smaller than in lakes (Minns 1995). Home range sizes differed largely between individuals. Fish 0 was practically stationary compared to all other fishes, moving only within 365m^2 during the whole research period. Since the location differed more than we could disregard as measurement error, the conclusion was that the fish was still alive and changed location slightly. One possible explanation for this has to do with this areas proximity to the open water of Lake Båven; when this fish did move, it might have moved into open water, where it was hard to find. This results in a possibly large margin of error in the home range estimation for fish no. 0.

As seen in the results, the water temperature exceeded 20°C in the study areas during longer periods in July and August. An initial idea was to investigate if swimming distances correlated either positively, or negatively with an increase in water temperature. An increase in swimming distances could be a result of a rising metabolism, driving the fishes to a more intense search for prey (Copp *et al.* 2009). On the other hand, the opposite could be expected at temperatures close to 20°C, when some of the fishes should claim a spawning site, therefore becoming less active (Copp *et al. 2009)*. However, it is not clear how much the individuals move between our telemetry samplings. Since we could not track the fish constantly, and because some of the tagged fishes disappeared during periods, we would build in a large insecurity in our results if basing a model upon this relatively low resolved data. Because of this, I chose not to estimate swimming distances, but instead try to grade the activity, depending on where we found the individuals during the telemetry studies. It was assumed that a fish found in open water most probably was moving, while fish found in the littoral assumed to be more inactive. This assumption was based upon the reasoning that open water provides few, or no hiding places, and mostly serve as hunting grounds. No correlation could be found for temperature and activity, something that might depend on the small sample size – only seven individuals.

It cannot be excluded that the procedure in which the fish was localized during the telemetry readings might affect the results of the readings, thus possibly affecting the distribution of observations in different habitats. Even if trying to approach the fish as careful as possible, it can be affected by the boat. One possible effect of this can be that the fish seeks refuge under the floating mats, thus skewing the results towards more observations in sites containing this feature, even if the fish in some cases might not have been under a floating mat when the signal first was picked up.

One additional factor that might have an impact on the level of activity and home range size, is the gender of the fish. At least during the period in- and around spawning, when the male is guarding the nest, a difference can be expected between the genders (Copp *et al 2009*). If future efforts in tagging and sexing more wels in Lake Båven are made, we might obtain a better understanding of their patterns of movement and activity grade over the season, depending on gender and size. This might contribute to a more effective management

4.4 Diel activity

During the telemetry readings at night, as well as the ARIS observations during night, there did not seem to be any obvious difference regarding fish behaviour or number of localized individuals compared to daytime observations. This might be a result of the high turbidity, levelling out the dial differences in light to some extent, giving more consistent conditions for hiding and foraging around the clock. However, research have shown no such effect from turbidity, at least on behaviour of smaller catfish (<1150 g) (Danek *et al.* 2016). One possible explanation to this apparent lack of diurnal behaviour could perhaps be that the study was performed in the period of June-July. Copp *et al.* 2009, states that the most intensive foraging period is in spring. Being so close to the spawning period, which normally occurs in July, it is possible that the foraging during this time was so intensified compared to the rest of the year that it was occurring more or less around the clock.

4.5 Artificial spawning nests

Artificial spawning nests for fish have been used successfully in conservational purposes in other benthic species, such as the endangered relict darter (*Etheostoma chienense*), a small perciform fish endemic to rivers in Kentucky (Piller & Burr 1999).

No wels catfish could be seen in, or close to the spawning nests during our field studies. This might be explained in several ways. The model, which normally is used in aquaculture, might not be optimal for catfish spawning in natural habitats, where the fish might have better natural sites. They might also be placed in areas that are not suitable for spawning. The observed presence of catfish in the floating mat-spots might give raise to new ideas concerning the design of artificial spawning nests. Instead of building tripod nests placed on the bottom, artificial floating mats could possibly be placed upon the surface. Alternatively, a web-like structure serving as a 'skeleton' for vegetation to easily overgrow, could be used, thus creating semi-natural floating mats. This can be compared to the placing of shipwrecks on the ocean floor for corals to colonize upon. The tripod-style nests have earlier been used in aquaculture, where it should be considered that they might work simply because there are no alternatives. Also, possible differences in farmed fish and wild fish behaviour due to factors such as abundance and degree of domestication (behavioural changes compared to wild fish) should be considered. Another factor that should not be overlooked, is the placement of the nests. The nest should be placed adjacent, but not too close to natural spawning places. The idea was to increase the number of spawning places in the lakes, without placing the nests too close to natural spawning places, thus risking intrusion in other male fish territory. This could, according to the theory that the male wels is aggressively defending its territory, make the constructed nest practically uninhabitable. Since the nests were placed in the lake early in the season, no macrophytes had yet emerged. Later in the season, dense populations of mainly water lilies occupied four out of five of the spawning nest-sites. It is fair to assume that dense populations of macrophytes might make it harder for a large fish to move, thus making them avoid such places.

4.6 ARIS as a tool for ecology studies on wels catfish

The ARIS device shows large potential as a tool for studies on behaviour as well as for assessing population size, spatial distribution of individuals, and for rough assessment of size on individuals. Species determination of individual smaller than 0,5 m (BL) was found to be hard, since it was difficult to assess the body shape and movement pattern in these smaller fish. In the larger fish, the slithering eel-like body movements of the catfish became more easily detected, and in combination with the sheer size of these fish, the risk of mistaking other species for catfish were considered negligible.

The validity of the method as a measuring tool for assessment of fish length cannot be determined without controlling the results against data from monitor fishing, or performing measuring in a controlled environment, where fish can be controlled measured. For determining size distribution patterns within our data, we found the ARIS to be a useful tool. When using the ARIS for behaviour studies in connection to spawning, a protocol should be developed in order to attain a method that disturb the fishes as little as possible.

The ARIS can be remotely controlled, which makes it possible to mount the device stationary and monitor a spot during a longer period of time, and also minimizing the possible disturbance from the boat.

5. Conclusions

The studies performed on wels catfish in Lake Båven during the summer of 2017, give an increased insight into key factors in wels catfish ecology. The results include information about demands on habitat for spawning, social behaviours and movements during the spawning period, factors that have been hard to study using only monitor fishing and telemetry. This hopefully can contribute to an effective usage of the resources and efforts that are put into the conservation of this species in Swedish waters. Still, more information is needed regarding spawning and early life stages, hopefully, this report can also be used as an underlay to form future observations of wels catfish upon.

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Populärvetenskaplig sammanfattning

- Den europeiska malen: en ökad insikt i beteenden och habitatkrav hos den hotade malen (Silurus glanis) i Sverige.

Den värmeälskande europeiska malen är en ovanlig och dåligt studerad art i den svenska faunan. Trots sin imponerande storlek och sin förkärlek för grunda vatten, så känner få människor till denna udda invånare av sydsvenska åar och sjöar. På grund av mänsklig påverkan på främst dess leklokaler har bestånden minskat, och arten är nu i behov av vår hjälp för att kunna uppnå stabila bestånd. För att öka kunskapen om denna arts beteenden i samband med lek, och identifiera vilka krav den ställer på sin levnadsmiljö under denna period, undersökte vi några områden i sjön Båven som är kända för att hysa mal. Undersökningarna gjordes med radiopejling samt en avancerad typ av ekolod som återger undervattensmiljöer och fiskar med en videolik upplösning (ARIS).

Malen är Europas största sötvattensfisk, och en av de största I världen. Den nordligaste förekomsten finns i Sveriges sydliga delar. Malen är i Sverige en postglacial relikt, en art som migrerat hit under den värmeperiod som uppstod strax efter den senaste istiden. Under arton- och nittonhundratalen har bestånden i Sverige minskat kraftigt på grund av bland annat föroreningar, dammbyggnationer samt sjösänkningar. Idag finns i Sverige naturligt förekommande malpopulationer endast i fyra vattensystem, ett av dessa är Båven. Båven är en stor, flikig sjö i Södermanland, ungefär 10 mil söder om Stockholm. Flertalet förgreningar och mindre sjöar hänger samman med Båven genom naturliga kanaler. Kanalerna och dessa mindre sjöar är rika på vegetation, och har om sommaren ett varmt och grumligt vatten, i motsats till de större delarna av Båven som istället har en mer näringsfattig karaktär med ett större siktdjup. På flertalet ställen i de grunda, varma områdena har vegetationen bildat stora gungflymattor, under vilka öppet vatten finns. I de varma och grumliga delarna trivs malen, och det är här leken sker om sommaren när temperaturen överstiger 20°C. Malen är, som nämndes ovan, en stor fisk. Sportfiskare runt om i Europa har bärgat exemplar som närmat sig tre meter i längd och vägt bortåt 140 kg. Den är en opportunistisk och nattaktiv rovfisk, som äter allt ifrån fisk och däggdjur till sjöfågel. Det föredragna bytet är dock fisk, och i Båven utgörs dieten troligen till största del av karpfiskar såsom mört och braxen.

Under våren 2017 påbörjades de första i en serie av projekt, som syftar till att öka kunskaperna om Båvens malar, och säkerställa att ett livskraftigt bestånd av arten ska finnas. Detta är ett samarbete mellan Sveriges lantbruksuniversitet (SLU), länsstyrelsen i Södermanland och organisationen Sportfiskarna.

Sommaren 2017 studerades malar i tre grunda, näringsrika sjöar som hänger samman med Båven: Lillsjön, Hornsundssjön och Kvarnsjön. Radiotelemetri (pejling), samt en akustisk kamera (ARIS) användes till detta. Fördelen med ARIS gentemot en traditionell kamera är att ARIS, som nyttjar ljud istället för ljus för att skapa en bild, fungerar trots grumliga vatten och brist på ljus. Information från telemetri och ARIS kompletterades med vattentemperaturmätningar. Genom att korrelera observationer med temperaturen som råder vid tillfället, kan viktiga indikationer fås på om observationen till exempel kan ha att göra med leken.

Information om Båvens malar har tidigare varit begränsad till provfiskedata och telemetristudier. Användandet av ARIS ger en helt ny insyn i malens liv, genom att erbjuda ett icke inkräktande sätt att studera såväl beteende som levnadsmiljön under ytan, och därtill även erbjuda möjligheter att uppskatta antal fiskar samt deras ungefärliga storlekar.

Under strandkanternas täta vegetation i de undersökta delarna av Båven fann vi relativt omgående ett större antal malar, ibland i grupper om ett tiotal eller fler. Under de tjocka gungflymattorna verkade fiskarna trivas bäst. Det var i denna typ av habitat den absoluta majoriteten av fiskarna verkade uppehålla sig. Många fiskar var runt metern långa, men även fiskar som var runt två meter långa observerades. Den stora förkärleken för just gungflyn som noterades under sommaren ses som en viktig indikation på att denna typ av skyddande habitat är viktigt för reproduktionen av mal.

Undersökningarna med ARIS gav bilden av en överraskande social fiskart, som delade levnadsutrymme med flera artfränder i täta grupper. Dessa observationer rimmar illa med uppfattningen att malen är aggressiv under tiden runt leken, då hannarna sägs försvara sitt revir mot inkräktare. Även om inga konkreta bevis för lek kunde konstateras, sågs vissa beteenden som skulle kunna relateras till vård av rom eller yngel. Till exempel noterades vid några tillfällen piskande rörelser med stjärtfenan, något som skulle kunna ha att göra med renhållning, eller syresättning av ägg. Vattentemperaturen i slutet av juli och början av augusti översteg de 20°C som i litteraturen brukar nämnas som en kritisk gräns för reproduktionen.

Vid telemetristudierna såg vi att några individer rörde sig över stora delar av sjöarna som studerades. I vissa fall rörde sig individer även mellan sjöar, och uppsökte flera olika gungflyområden. Andra individer föreföll röra sig mindre, och höll sig i regel till en begränsad strandsträcka. Malarna var aktiva dag som natt, och vid flera tillfällen fann vi fiskar simmandes på öppet vatten under dagtid. I likhet med ARIS-observationerna sågs även här att malen verkar föredra tät vegetation, och allra helst gungfly i den mån det förekommer. Vid flera tillfällen överlappade olika malars områden, något som tillsammans med ARIS-observationerna av malar i grupper bidrar till bilden av en fisk som inte är aggressivt revirhävdande.

Studierna av mal i Båven under sommaren 2017 bidrar till en ökad insikt i de habitatkrav som malen har, och kan bidra till att man på ett effektivt sätt kan hantera de problem som vi ställs inför, under strävan mot att förbättra malens situation i svenska vatten. De ger även en inblick i malens naturliga beteenden, något som tidigare varit svårstuderat. Genom denna ökade förståelse för malens ekologi, får vi en bättre chans att på ett effektivt sätt nyttja de resurser som står till hands för att uppnå ett friskt bestånd av mal.

Appendix

Table 4. *Individual data over floating mat samples. The coordinates in N, E columns are in SWEREF99*

Date, time	*N*	*E*	*No. fish*	*Body length, in metres*	*Habitat type*	*Cardinal direction, in degrees*	*Bottom structure, 0=flat 1=irregular*
2017-07-13 12:09	6546839	597752	0		floating mat	210	0
2017-07-13 12:24	6546933	597672	0		floating mat	210	0
2017-07-13 12:38	6546960	597618	5	0.8,0.9,1.0,1.1,1.0	floating mat	210	1
2017-07-13 14:32	6547317	596510	1	1.0	floating mat	67	0
2017-07-13 16:08	6547628	595461	1	0.5	floating mat	200	0
2017-07-13 16:47	6547411	595869	9	1.0,1.0,1.0,1.0,1.2,1.1,1.2,1.0,1.2	floating mat	250	1
2017-07-13 18:19	6546044	597030	10	1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.5	floating mat	200	1
2017-07-14 08:53	6547987	598759	8	1.3,1.2,1.2,1.1,1.0,1.0,1.0,1.1	floating mat	207	1
2017-07-14 09:03	6547992	598732	0		floating mat	197	0
2017-07-14 09:31	6547851	598994	0		floating mat	215	0
2017-07-14 09:51	6546761	598102	8	1.2,1.2,1.2,1.2,1.5,1.0,1.0,1.0	floating mat	196	1
2017-07-14 10:31	6546644	598026	1	2.0	floating mat	161	1
2017-07-14 11:01	6546665	597883	1	0.6	floating mat	255	0
2017-07-25 12:56	6548008	599119	2	0.8,1.0	floating mat	4	0
2017-07-25 13:48	6546664	598060	4	1.9,1.2,1.4,1.3	floating mat	80	0
2017-07-25 14:14	6546728	597949	0		floating mat	11	0
2017-07-25 14:27	6546848	597908	0		floating mat	130	0
2017-07-25 14:38	6546898	597931	0		floating mat	130	0

Table 5. *Individual data over shading/hard bottom samples. The coordinates in N, E columns are in SWEREF99.*

Date, time	*N*	*E*	*No. fish*	*Body length in metres*	*Habitat type*	*Cardinal direction*
2017-07-13 14:18	6547011	597040	0		Shading/ hard bottom	SE
2017-07-14 11:28	6546802	597893	0		Shading/ hard bottom	E
2017-07-14 13:55	6546190	597151	0		Shading/ hard bottom	E
2017-07-14 14:06	6546556	596890	0		Shading/ hard bottom	NW
2017-07-25 14:04	6546709	597965	0		Shading/ hard bottom	N
2017-07-25 19:31	6546221	597136	0		Shading/ hard bottom	E/NE

Table 6. *Individual data over the overhang samples. The coordinates in N, E columns are in SWEREF99.*

Date, time	*N*	*E*	*No. fish*	*Body length in metres*	*Habitat type*	*Cardinal direction*
2017-07-13 13:15	6547177	597544	0		overhang	W
2017-07-13 13:58	6547082	596931	0		overhang	NW
2017-07-13 16:22	6547595	595544	0		overhang	S
2017-07-13 17:36	6546519	596672	0		overhang	W/SW
2017-07-13 17:47	6546490	596682	0		overhang	W/SW
2017-07-14 09:15	6547851	598994	0		overhang	SW
2017-07-25 12:32	6547978	598835	0		overhang	S
2017-07-25 12:41	6547966	598869	0		overhang	SW
2017-07-25 16:29	6547123	597222	0		overhang	E
2017-07-25 16:45	6547137	597110	0		overhang	N
2017-07-25 17:54	6547628	595459	0		overhang	SW

Table 7. *Individual data for the reed bay samples. The coordinates in N, E columns are in SWEREF99. Note the two wels catfishes that was observed in the second last sample.*

Date, time	*N*	*E*	*No. fish*	*Body length in metres*	*Habitat type*	*Cardinal direction*
2017-07-13 14:54	6547317	596510	0		reed	NE
2017-07-13 16:34	6547542	595689	0		reed	S
2017-07-14 13:00	6547153	597043	0		reed	N
2017-07-14 14:15	6546882	596596	0		reed	W
2017-07-14 14:37	6547422	596274	2	0.7,0.8	reed	N/NE
2017-07-25 15:47	6547231	597672	0		reed	N

Table 8. *Individual data for samples with jetties. The coordinates in N, E columns are in SWEREF99.*

Date, time	*N*	*E*	*No. fish*	*Body length in metres*	*Habitat type*	*Cardinal direction*
2017-07-13 15:03	6547422	596202	0		jetty	N
2017-07-13 15:56	6547785	595363	0		jetty	W
2017-07-14 11:37	6547220	597714	0		jetty	N
2017-07-14 14:58	6547554	595865	0		jetty	NE
2017-07-25 17:45	6547797	595543	0		jetty	NE