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Movements of female lumpsucker *Cyclopterus lumpus* in a Norwegian fjord during the spawning period

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Norwegian Institute for Nature Research

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Female lumpsucker. Photo: Finn Økland.

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Abstract

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Lumpsucker are distributed throughout the North Atlantic Ocean, and migrate considerable distances between offshore feeding areas and shallow inshore spawning areas. In July 2006, a study on the movements of female lumpsucker during the spawning period was carried out in Øksfjord, Northern Norway. Twenty fish (mean body mass 3.2 kg, range 1.5-4.8 kg) were tagged with acoustic transmitters and released in the inner part of the fjord. Their distribution was subsequently recorded by 22 automatic acoustic receivers distributed throughout the study area. All the fish migrated rapidly out of the fjord. The average time of leaving the fjord (17 km from the release site) was three days, and within one week after release all the fish had left the fjord. The fish did not return to Øksfjord within the nearly three-month study period. These results indicate that female lumpsucker stay in the fjord only for a short time during the spawning season, and that they depart the spawning ground immediately or a few days after spawning. The tagged females were likely in the beginning of the spawning period when they were tagged, based on 1) the mass/length relationship of the tagged females, 2) the fact that eggs could be seen when implanting the transmitters, and 3) because 18 out of 19 females (95%) caught at the same time and sites as the tagged fish had large egg masses. We suggest that the tagged females, when they left the study area in Øksfjord, either left inshore areas migrating back to the ocean because they had finished spawning, or that they continued the spawning, but moved to new fjord systems in search for new males. Whether individual females visit several fjords during the spawning period and search for males over a relatively large area should be addressed in future studies of this species.

The female lumpsucker in this study were actively swimming, and often did so against the tidal current. There were no indications that female lumpsucker were passively drifting with the currents, or that they used the tidal current actively to move out of the fjord. The fish were, on average, moving a minimum of 0.72 km per hour relative to the ground during the study. Such extensive movements might make these females highly vulnerable to exploitation by passive gears used in the commercial fishery.

During the outward migration, 75 % of the fish were recorded close to salmon farms. However, the tagged fish left the fjord without staying for extended periods around the fish farms (the longest stay being 5.8 hours), and therefore did not seem to be specifically attracted by the fish farms. Based on these results, female lumpsucker seemed to have limited potential to act as vectors for transmission of parasites and diseases between aquaculture farms and wild fish. Previous studies have shown that lumpsucker is among one of the most preferred hosts of the sea louse *Caligus elongatus*.

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Contents

Preface

This study was performed as a collaboration between scientists from Kyoto University, Norwegian Institute for Nature Research (NINA), Norwegian Institute of Fisheries and Aquaculture Research and SINTEF Fisheries and Aquaculture during Dr Hiromichi Mitamura's post doctoral visit at NINA in the period 2006-2008. The study benefited from using the infrastructure, including automatic listening stations, of a concurrent study of Atlantic cod in Øksfjord, Finnmark, funded by The Norwegian Seafood Federation Research Foundation. Hiromichi Mitamura received funding from the Japanese Society for the Promotion of Science and the Norwegian Research Council. The lumpsucker study was funded by NINA. We would like to thank Rune Nilsen, Tom Andreassen, Pablo Sanchez-Jerez, Anders Økland, Arvid Fredriksen and Trygve Solvar Johansen for assistance during the field work.

Trondheim, November, 2007

Eva B. Thorstad

Ventral sucker of a female lumpsucker, which can be used for attachment to, for instance, stones. Photo: Hiromichi Mitamura.

Roe from one individual female. Photo: Hiromichi Mitamura.

1 Introduction

Lumpsucker (*Cyclopterus lumpus*, also known as lumpfish, family Cyclopteridae) are distributed throughout the North Atlantic Ocean, on both sides of the North Atlantic, and migrate considerable distances between offshore feeding areas and shallow inshore spawning areas (Davenport 1985). It is not known whether the species is divided in several distinct populations. However, there are indications that lumpsucker home to the same spawning locality every year (Schopka 1974, Thorsteinsson 1981). Such homing behaviour suggests that separate spawning stocks could be maintained, even if they mix on the oceanic feeding grounds, provided that adults return to the shore that they left as juveniles (Davenport & Thorsteinsson 1989).

Female lumpsucker are fished commercially for their roe, which is used for caviar production. Commercial fishing occurs in inshore regions on both sides of the North Atlantic, during the spawning migration (Goulet et al. 1986, Sunnanå 2007). According to Norwegian landings, the lumpsucker stocks have declined from the mid-80s, probably as a result of over-exploitation (Sunnanå 2007). The spawning stock is assumed to have a rather weak recruitment at present, but no immediate threat to the stock is seen. However, the stock is rather low, compared to historic levels, and care should be taken in managing the stock and exploitation level (Sunnanå 2007). There is also concern about declining lumpsucker stocks in Canada (Hoenig & Hewitt 2005).

Despite the economic importance of this species, parts of their life cycle are not well known, and little is known about their spawning migration. Adult lumpsucker are believed to feed semi-pelagically offshore during most of the year, migrating inshore in late winter and spring to reproduce (Bagge 1964, Blacker 1983, Davenport 1985, Holst 1993). They are generally believed not to feed during the spawning migration in inshore areas (Collins 1976, Davenport 1985, Davenport & Thorsteinsson 1989), although feeding has been recorded during the spawning migration in the near shore areas of the Barents Sea and during spawning in the Varanger Fjord (Kudryavtseva & Karamushko 2002). Spawning occurs in spring or early summer (Davenport 1985). Males arrive inshore before females and establish nest sites in shallow water. Nest site characteristics are variable, the minimum being a crevice or depression in the substrate (Goulet et al. 1986). Females migrate inshore asynchronously, making it possible for males to court and spawn with several females during the spawning period. The eggs in a male's nest can be the result of single or multiple female spawnings. Additional eggs acquired from multiple spawnings are deposited adjacent to previously spawned eggs, and the total number of eggs in a male's nest vary from 10 000 to more than 200 000 eggs (Goulet et al. 1986). Females leave the nest site immediately after spawning, while males remain with the eggs and provide parental care until the eggs hatch. Males aerate the eggs and defend the nest against predators (Mochek 1973, Goulet et al. 1986, Goulet & Green 1988). The incubation period is influenced by ambient water temperature, and may last for 1-2 months (Mochek 1973, Collins 1976, 1978, 1979, Goulet et al. 1986). In their first year, juveniles stay in coastal waters in tidepools or in pelagic waters, often attached to floating seaweeds (Daborn & Gregory 1983, Moring 1989, Moring & Moring 1991, Moring 2001, Ingólfsson & Kristjánsson 2002). In their second year, young lumpsucker take up a pelagic mode of life and are no longer associated with seaweed (Ingólfsson & Kristjánsson 2002). After two to four years feeding in the ocean, adult lumpsucker return to inshore areas to spawn (Collins 1979, Sunnanå 2007).

Aquaculture is one of the most important human impact factors in Norwegian marine ecosystems. In 2004, there were 1155 active farm concessions in Norway (Fisheries Directorate 2004), and it is likely that the aquaculture industry will increase considerably in the future, both as salmon farming expands and as farming of new species (e.g. Atlantic cod *Gadus morhua* and halibut *Hippoglossus hippoglossus*) become viable industries. Community compositions of wild fish at coastal fish farms have been described on occasion (Dempster et al. 2002), and large-scale attraction to farms demonstrated (Bjordal & Skar 1992, Dempster et al. 2004). It is, therefore, possible that marine aquaculture imposes negative effects on the organisms living around the farms, for example by modification of migration routes, or by increasing the risk of parasite and disease transfer between cultured organisms and wild fauna. The sea louse *Caligus elongatus* is an ectoparasitic copepod found on more than 80 different fish species (Kabata 1979). Lumpsucker and Atlantic cod are among the most preferred hosts of *C. elongatus*, and it is speculated that *C. elongatus* may become a serious pest of farmed cod (Øines et al. 2006, Øines & Heuch 2007). *C. elongatus* is already known as a problem for the Altantic salmon *Salmo salar* farming industry (Pike & Wadsworth 1999, McKenzie et al. 2004), and large numbers of adult *C. elongatus* are frequently found on farmed salmon in autumn, particularly in the central and northern parts of Norway (Øines et al. 2006). *C. elongatus* may transfer between different host species (Øines et al. 2006). Hence, information on the movements of lumpsucker in relation to fish farms is important in assessing their potential for transferring *C. elongatus* between fish farms and between wild fish and farmed fish.

A study on the movements of female lumpsucker during the spawning period was carried out in Øksfjord, northern Norway, in July 2006. Twenty females were tagged with acoustic transmitters and released in the inner part of the fjord. Their distribution and movements were recorded by automatic acoustic receivers deployed throughout the fjord system. The aims of the study were to 1) examine the movement patterns of female lumpsucker during the spawning period, and 2) assess the potential for lumpsucker to act as a vector for transmission of parasites and diseases between aquaculture farms and wild fish.

Atlantic salmon farm in Øksfjord. Photo: Hiromichi Mitamura.

2 Study area

The study was carried out in Øksfjord in Finnmark County, northern Norway (70° 08' 40 N, 22° 17' 40 E, **figure 1**). The maximum difference between low and high tide in the fjord is approximately 1.6 m, while the maximum depth is approximately 300 m, at the mouth of the fjord. The commercial fishery of lumpsucker is highly seasonal in this area. Mature lumpsucker are caught in the period April to mid-June using gillnets fished from small vessels. There are four salmon farm sites in the fjord, but only three of these were in use during the study (**figure 1**). In addition, the fjord houses an Atlantic cod farm (**figure 1**). These farms attract a range of wild fish species, including Atlantic cod and saithe *Pollachius virens*, which feed on uneaten food from the farms (Dempster & Uglem, unpublished results).

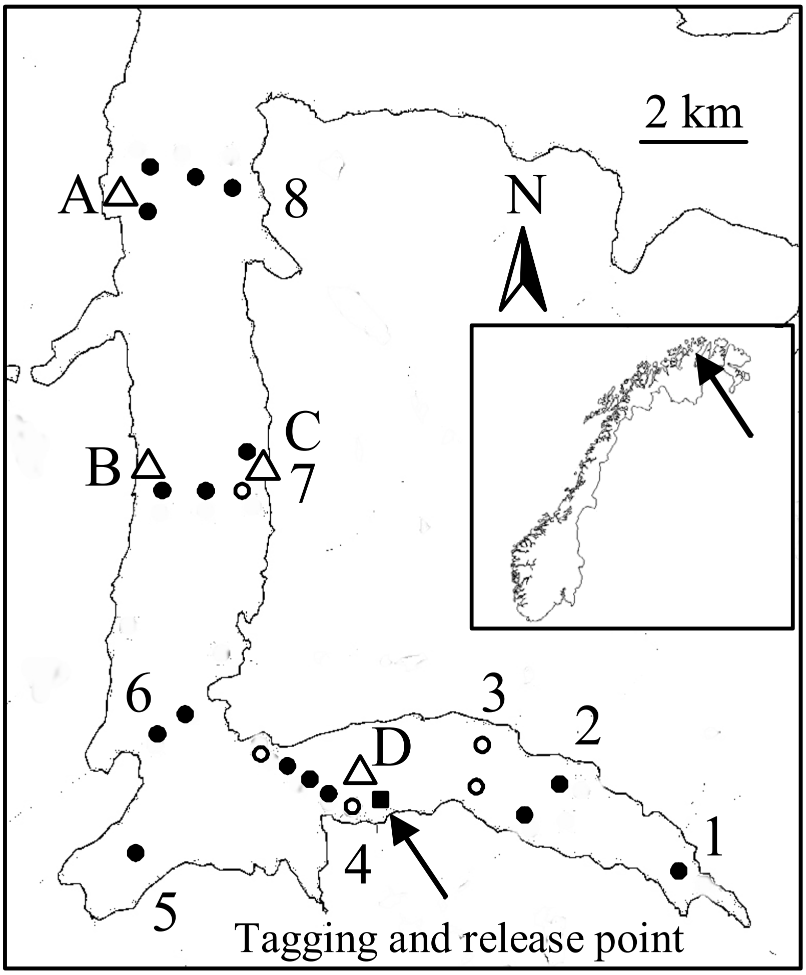

Figure 1. *Øksfjord in Finnmark County, northern Norway, showing four locations where lumpsucker were captured (**Δ** A, B, C and D), and the release site of all tagged fish (■). Automatic receivers were arranged in arrays across the fjord, which are labelled 1 to 8 (● indicate receivers with a normal range, whereas **o** indicate receivers with reduced range deployed at fish farms and at the release point). There was one Atlantic cod farm in the fjord, close to capture site C, and four Atlantic salmon farm sites, but only three of these were in use during the study as the farm close to the release point was not in use.*

Study area in Øksfjord. Photo: Hiromichi Mitamura.

Holding net pen where the fish were kept between catch and tagging. Photo: Hiromichi Mitamura.

3 Materials and methods

Lumpsucker (n = 41; 2 males and 39 females) were captured with gillnets at four different sites in Øksfjord during 7-10 July 2006 (**figure 1**). The fish were kept in a holding tank, with constant water flow, on board the fishing boat after capture. All fish were transported to the tagging location in the inner part of the fjord within 5 hours of capture, where they were tagged with individually numbered anchor T-tags and stored in a small holding net pen (diameter of 5 m and depth of 4 m) until acoustic tagging. There was no mortality during transport or during holding in the net pen. The two males were among the smallest fish captured (**figure 2**); spawning female lumpsucker are typically larger than the males (Goulet et al. 1986). Nineteen female fish were killed for analyses of reproductive status (**figure 2**). Only one of these had no eggs, while the remaining 18 (95 %) had a large mass of ripe eggs (mean egg mass 0.91 ± 0.41 kg (S.D.), range 0.43-1.68, **figure 3**). The mass/length relationship of the female without eggs was clearly lower than for the females with ripe eggs (**figure 2**).

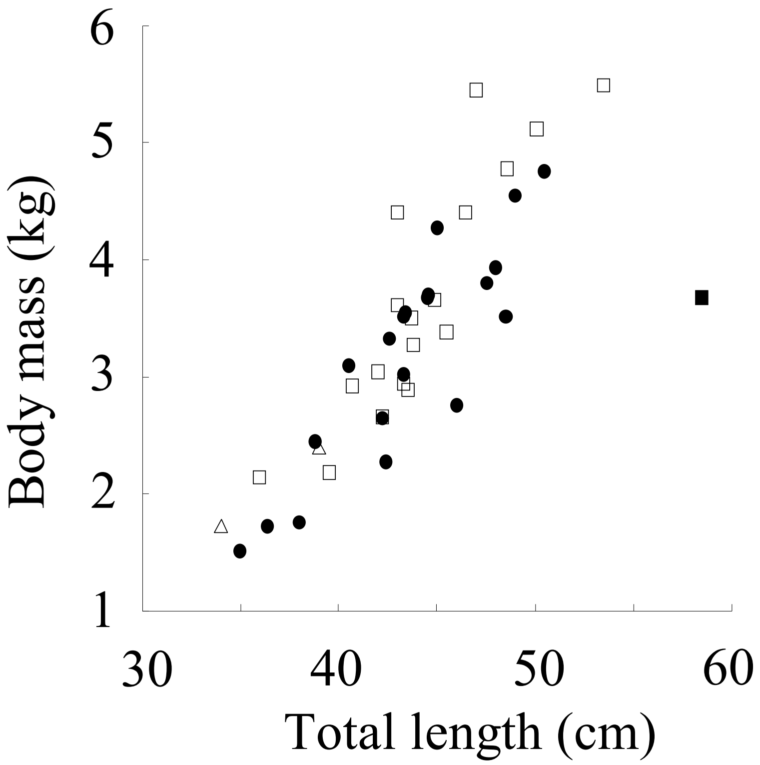

Figure 2. *The relationship between total length and body mass of 2 male (Δ) and 39 female lumpsucker captured in Øksfjord in 2006. Twenty females (●) were tagged with acoustic transmitters. The remaining 19 females were killed and analysed for reproductive status (□ represent females with ripe eggs and ■ a female with no eggs).*

The remaining 20 females (**table 1**) were tagged with coded acoustic transmitters (VEMCO Ltd., Canada, model V13, diameter of 13 mm, length of 36 mm, mass in water of 6 g) on 10 July 2006. Body mass of the tagged fish ranged from 1.5 to 4.8 kg (mean 3.2 kg ± 0.9), and total body length ranged from 35 to 51 cm (mean 43 cm ± 4.2) (**table 1**). The transmitter mass in water ranged between 0.1 and 0.4% of the fish body mass. The mass/length relationship (**figure 2**) indicated that all the tagged females could be considered to have ripe eggs. Ripe eggs were also observed during the surgical procedure for most of the females, although eggs can be difficult to see through the small incision when implanting transmitters. Surgery was carried out under anaesthesia induced with 2-phenoxy-ethanol (Sigma Chemical Co., St Louis, MO, U.S.A., 1 ml per 1 l seawater, immersion period 1 min 39 s ± 14 s). An incision (~ 1.5 cm) was made on the ventral surface posterior to the pelvic girdle of the fish, and the transmitter was inserted into the peritoneal cavity. The incision was closed using two or three independent silk sutures (1/0 Ethicon). The implantation procedure lasted approximately two minutes. The fish were held in the storage pen at the tagging location for three days before they were transported by boat to the release location in a holding tank (400 l) with constantly flowing water. No adverse effects of surgery on the behaviour of the fish were observed in the net pen. All fish were released in the inner part of the fjord on 13 July 2006 (**figure 1**).

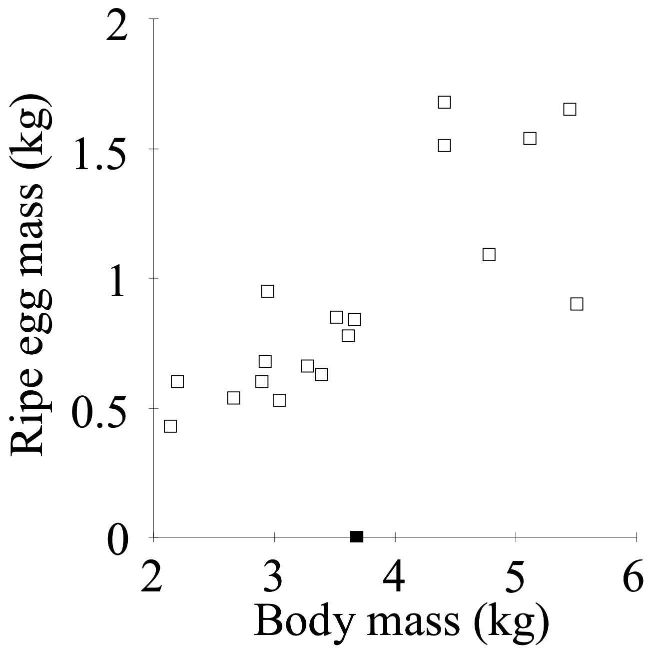

Figure 3. *The relationship between eggs mass and body mass of 19 female lumpsucker captured in Øksfjord in 2006, of which 18 females had ripe eggs (□) and 1 female no eggs (■).*

Table 1. *Total body length, body mass and capture location of 20 female lumpsucker tagged with acoustic transmitters in Øksfjord in 2006. Tidal phase when the fish passed receiver arrays 7 and 8 is also given (flood is the 4-h period during incoming tide, ebb is the 4-hour period during outgoing tide and slack is the 4-hour period during high or low tide). Capture locations and receiver arrays are shown in* ***figure 1****.*

Tag ID	Body length (cm)	Body mass (kg)	Capture location	Tidal phase when fish was passing array 7	Tidal phase when fish was passing array 8
1	49.0	4.55	D	flood	ebb
2	48.0	3.93	D	slack	flood
3	38.0	1.76	D	flood	ebb
4	44.5	3.68	A	ebb	slack
5	46.0	2.76	C	slack	slack
6	47.5	3.80	A	flood	ebb
7	42.6	3.33	C	flood	ebb
8	50.5	4.76	A	flood	slack
9	36.4	1.72	C	ebb	flood
10	42.4	2.28	A	ebb	flood
11	48.5	3.52	A	ebb	slack
12	43.4	3.55	B	slack	flood
13	40.5	3.10	B	ebb	flood
14	43.3	3.02	A	flood	ebb
15	43.3	3.52	A	flood	ebb
16	38.8	2.45	B	slack	flood
17	42.2	2.65	B	slack	slack
18	44.6	3.70	C	ebb	slack
19	35.0	1.52	C	slack	ebb
20	45.0	4.28	A	ebb	flood

The movements and distribution of the tagged fish were recorded by 22 automatic receivers (receiver model VR2) deployed on anchored ropes at different sites throughout the fjord system (**figure 1**). Distance (measured mid-fjord) from the release site to the outermost receiver array was 17 km. The receivers recorded the identification code and date and time of detection from the individual transmitters when a tagged fish was present in the receiver range. The depth at the sites where the receivers were deployed varied between 23 and 300 m. Typically the receivers were attached to the ropes at approximately half the distance to the bottom, apart from the receivers deployed at the fish farms (**figure 1**), which were suspended 20 m below the water surface. The average distance between the receivers positioned in arrays/curtains across the fjord was 500 m. Range tests showed that the minimum detection range varied between a radius of 600 - 700 m. A shorter range was needed to record possible attraction of the tagged fish to the fish farms. The detection range of the receivers at the fish farms were, therefore, range restricted by attaching a waterproof conical plastic cap filled with air over the hydrophone, reducing the range to a 150-200 m radius. The data were downloaded from the listening stations on 3 and 4 October 2006.

The direction, speed, and timing of movements of individuals were reconstructed from the downloaded data. Distances between receiver arrays were measured along a mid-fjord transect. Results of distances moved must be regarded as minimum distances, because fish are unlikely to have taken the shortest route between the receiver arrays. To test for a relationship between fish movements and fish farms, the data recorded at the fish farm closest to the release site were excluded as this was not in use. Tidal data from the Norwegian Hydrographic Service (www.vannstand.statkart.no/main.php) were used to analyze the relationship between fish movements and tide. All values are given as mean ± standard deviation.

Lumpsucker that were killed and analysed for reproductive status. Spaghettitags were used to separate individuals. Photo: Hiromichi Mitamura.

4 Results

All tagged lumpsucker departed from the study area within seven days after release (mean 3 days, range 1-7 days, **figure 4**). They did not return to Øksfjord within the nearly three-month study period. Hence, none of the fish showed homing to their capture sites. Of the 20 tagged fish, 17 (85%) left the fjord within four days after release, whereas the three remaining fish (15%) left seven days after release (**figure 4**). After release, five of the fish (25%) moved directly from the release site to the outermost part of the fjord (mean time from release to first recording at array 8 was 19 h ± 6 h). The remaining 15 fish (75%) moved back and forth around the release site, especially between array 2 and array 4 (**figure 5**), before departing from the study area. Minimum distance covered by fish during the study (based on cumulative distance moved between receiver arrays after release until departure from the fjord), was on average 22.9 ± 6.8 km (range 17-39). This corresponds to a mean movement speed of 0.72 ± 0.42 km $hour^{-1}$ (range 0.15-1.7 km $hour^{-1}$). There was no significant correlation between the movement speed and total length of the fish (Spearman rank correlation coefficient test, r_s = 0.091, n = 20, P = 0.69).

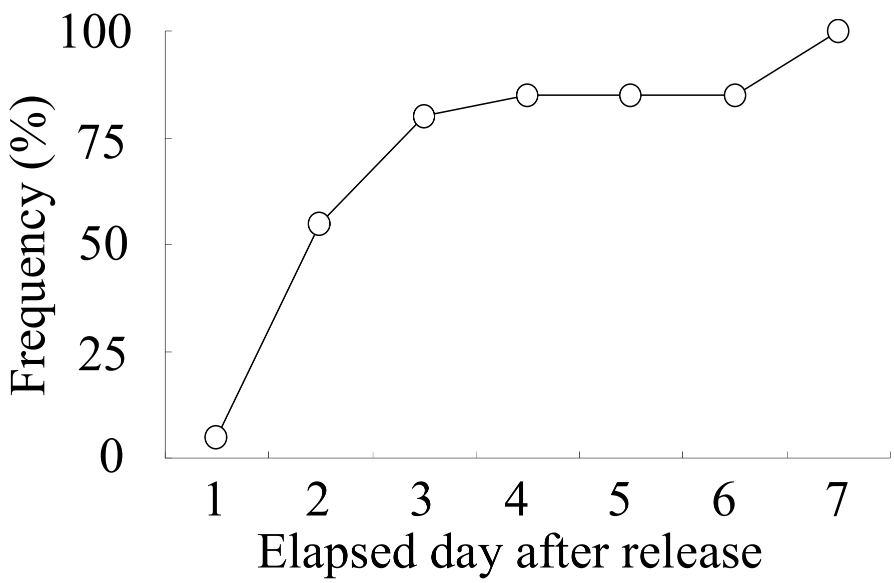

Figure 4. *Elapsed days after release in relation to the cumulative frequency of tagged lumpsucker (n = 20) that departed from the study area in Øksfjord in 2006.*

All 20 fish showed directional and rapid movement to the outermost fjord array, once they had left array 6. The fish frequently swam towards the outer fjord against the incoming tide, and there were no indications that the fish were drifting passively out of the fjord with the tidal current, or that they were using the tidal current actively to move out of the fjord. The proportion of fish departing array 6 did not differ between the period of outgoing (8 fish, 40%) and incoming tide (12 fish, 60%) (Goodness of fit test, χ^2 = 0.8, P = 0.37), or between day and night (day: 06:00-18:00, n = 9, night: 18:00-06:00, n = 11, Goodness of fit test, χ^2 = 0.2, P = 0.65). Further, there were no significant differences in movement speed between the periods of incoming tide (IT) and the outgoing tide (OT) from array 6 to array 7, and from array 7 to array 8 (Mann-Whitney U test, array 6 to 7: N_{IT} = 10, N_{OT} = 10, U = 48, P = 0.88, Array 7 to 8: N_{IT} = 14, N_{OT} = 6, U = 19.5, P = 0.25). Similarly, there were no significant differences in movement speed between the day and night (Mann-Whitney U test, array 6 to 7: N_{day} = 9, N_{night} = 11, U = 39, P =

0.42, array 7 to 8: N_{day} = 9, N_{night} = 11, U = 29.5, P = 0.13). Fourteen (70%) fish passed through array 7 or 8 during the incoming tide, and no individual passed through both array 7 and 8 during the outgoing tide (**table 1**).

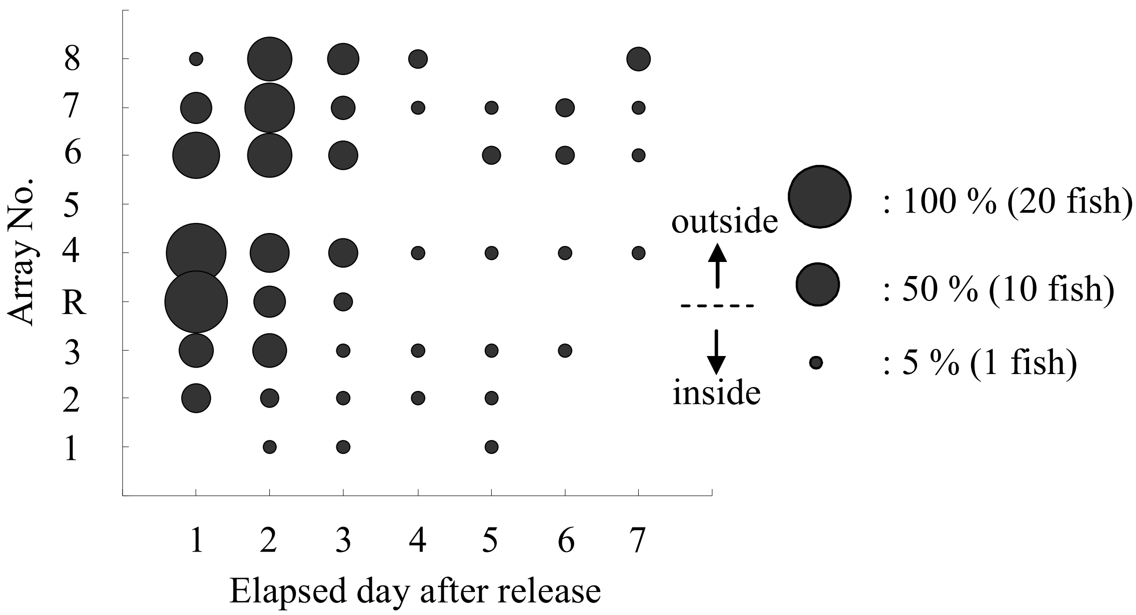

Figure 5. *Horizontal distribution of tagged lumpsucker after release in Øksfjord in 2006, based on recordings at the different receiver arrays. "R" represents the release location, with receiver arrays 1-3 located further in the fjord than the release site and receiver arrays no. 4-8 located outside (see **figure 1**).*

Lumpsucker were recorded in the close vicinity of the fish farms, but they left the fjord without staying for extended periods around the fish farms. During the outward migration, 15 fish (75%) were detected by the four range restricted listening stations at the fish farms (the farm close to the release site excluded). Fourteen fish were detected by the listening station at the Atlantic salmon farm, and 3 fish were detected at the cod farm. Each fish was, on average, recorded at a fish farm 2.3 times, giving a total of 35 recordings at fish farms. Nine fish visited more than one of the fish farms. The stay in the vicinity of fish farms was on average 64 ± 51 minutes (based on individual averages, which varied from 11-182). The shortest stay at a fish farm was 5 minutes and the longest stay 346 minutes (61 ± 51 minutes, range: 5-346, at the Atlantic salmon farm, 56 ± 54 minutes, range: 23-118, at the cod farm).

5 Discussion

Detailed information on female lumpsucker behaviour during the spawning migration is generally lacking. Females visiting nests depart immediately after spawning, without participating in rearing the eggs (Goulet et al. 1986). It has been suggested that egg laying occurs in two or three batches at intervals of 8-14 days (references in Davenport 1985). However, whether females lay several batches of eggs in one male's nest, or whether they spawn together with several males is unknown.

Acoustic tagging and tracking of lumpsucker within Øksfjord revealed that fish departed the fjord rapidly, indicating that mature females stay in the fjord only for a short period during the spawning season. The tagged females were likely in the beginning of the spawning period when they were tagged, based on 1) the mass/length relationship of the females, 2) the fact that eggs could be seen when implanting the transmitters, and 3) because 95% of the analysed females caught at the same time and sites as the tagged fish had large egg masses. Observations of spent females disappearing from the catches in the Gulf of White Sea in Russia (Mochek 1973) are consistent with our conclusion that females departed from the fjord immediately, or a few days, after spawning. Mochek (1973) noted that spent females disappeared from the catches after 2-3 days. After a few days with capture of only males, spawned females once again began to be caught, and this pattern of periodic appearance of spawned females in the catches continued throughout the summer. An Icelandic tagging programme (including mainly females, with < 5% of the tagged fish being males), provided similar results (Schopka 1974). Fish tagged in a spawning area and subsequently recaptured in the same locality were either recaptured within the first three weeks after tagging (of which most fish were recaptured within the first week), or one year later during the next spawning season (Schopka 1974). Hence, also these results indicated that the spawning of individual females in the study area was accomplished in one to three weeks, after which they left the spawning ground.

We suggest that the tagged females either spawned in Øksfjord (extensive movements between arrays 2 and 4 in the inner part of the fjord may have been searching for males and subsequent spawning) and then migrated back to the ocean, or that they moved to new fjord systems in search of new males with nests. There are several neighbouring fjords to the study area, where we had no listening stations, which the lumpsucker females may have visited. Lumpsucker are highly migratory, moving between the ocean feeding grounds and inshore spawning areas, and females may easily move between neighbouring fjord systems in search of males. Whether individual females visit several fjords during the spawning period and search for males over a relatively large area should be addressed in future studies. We hypothesise that the distance covered by females in search of males may be dependent on male densities.

The female lumpsucker in this study swam actively, and often did so against the tidal current. For many species, such as plaice *Pleuronectes platessa*, sole *Solea solea* and Atlantic cod, selective tidal stream transport is used as a migratory mechanism (summarized by McCleave & Arnold 1999, Forward & Tankersley 2001). In selective tidal stream transport, a fish ascends into the water column to drift or swim with the transporting tide and descends to the bottom to hold position on the opposing tide, which can lead to considerable reduction in the energy necessary for horizontal movement. However, there were no indications that female lumpsucker were passively drifting with the currents, or that they used the tidal current actively to move out of the fjord. The fish were, on average, moving a minimum of 0.72 km per hour relative to the ground during the study. Such extensive movements suggests female lumpsucker are vulnerable to capture by the passive gears used in the commercial fishery during the reproductive season.

This is the first time, to our knowledge, that lumpsucker are tagged with telemetry transmitters, and no studies of tagging effects in this species are available. However, the transmitters were small compared to the size of the fish (Jepsen et al. 2005), there was no mortality during the three days of holding in a net pen after tagging, the incisions healed in the same manner as in other species tagged with internal transmitters and the fish appeared in good condition at release. Based on the movement activity and swimming speeds recorded immediately after release, tagging did not seem to have any major limiting effect on the swimming activity. Whether the tagging affected spawning activity is not known. However, for several other species, tagging with similar methods has successfully been performed prior to spawning without influencing spawning activity (reviewed by Jepsen et al. 2002). Baras (1995) reported the successful tagging of a female barbel less than 48 h before spawning, where the fish made its final upstream run and spawned at the same time as untagged fish. For a few individuals, transmitter implantation may have inhibited spawning (Jepsen et al. 2002).

A basic assumption, both for intra- and interspecific horizontal transfer of pathogens in fish, is that they interact. While a high proportion of the lumpsucker females were observed in the close vicinity of fish farms, they were present for only short periods (hours), which suggests they were likely not major vectors of pathogens between aquaculture farms and wild fish. We hypothesize that the periods the lumpsucker females were observed close to fish farms does not represent a specific attraction to farms, as it would be reasonable to expect longer and repeated visits if this was the case. Other fish species that are attracted to fish farms, such as Atlantic cod and saithe, may be resident for many months, and feed on waste fish food (Dempster & Uglem unpublished results). Since lumpsucker in most cases are reported not to feed during the spawning migration (see introduction), it is unlikely that they are attracted by the uneaten food and concentration of other prey items around the farms.

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