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The presence of experienced cod (*Gadus morhua*) facilitates the acoustic training of naïve conspecifics

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Cod were trained to associate a 250 Hz sound with food by classical conditioning in the presence or absence of experienced fish. Adult cod adapted to sea cages were placed in an experimental cage located 80 m from shore. There were two feeding platforms, placed on opposite sides of the cage, each equipped with a transducer, videocamera and a feeding pipe used to deliver the feed from shore. There were 6 training sessions per day. In the first experiment 20 naïve fish were trained on their own. On the third day the fish started to eat the feed and learned to search for feed on the feeding platforms. On the 6th day there was the first response to the acoustic signal and on the 8th day the fish reacted consistently to the signal. In the second experiment, 10 naïve cod (students) immediately started to follow a group of 9 trained cod (teachers) to the feeding platforms. In the third experiment, 19 students and 1 teacher were released into the cage. In the first session the teacher swam directly to the correct platform and then began to cruise between platforms. The first student followed the teacher to a platform 8 minutes later and a group of students 2 minutes later. After two days of training the teacher was removed to see if the students had aquired the acoustic training. Already in the first acoustic session on their own the students reacted correctly to the sound signal.

Keywords: acoustic training; cod; fish behaviour; *Gadus morhua*; schooling behaviour; sound signal

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Introduction

In the traditional fisheries there are two major problems. One is the great energy consumption required to catch fish, especially by trawls that have to be dragged through the water. The second is the bycatch of undersized fish and unwanted species, sometimes endangered species, which have low chance of survival once they enter the fishing gear. The question arises whether it might be feasible to use knowlegde about fish behaviour, social learning, classical conditioning and acoustic training to aggregate fish and entrap with minimal energy requirement and with the possibility of sorting out and releasing all unwanted bycatch without mortalities.

Birds and mammals use social learning to assist in finding food, e.g. it is clear that when a few seagulls start to feed on fish offal from a boat that quickly large numbers of birds approach. From a distance of several km using visual and possibly acoustic stimuli the birds are able to conclude from the behaviour of other seagulls that they have found feed. In the sea visual stimuli can only be used for a distance of a few meters up to some tens of meters, depending on clarity of the water. Chemical stimuli may have a longer range, e.g. Atlantic cod (*Gadus morhua*) has been found to react to a line with baited hooks up to seven hundred meters away (Løkkeborg 1998). Acoustic stimuli, especially low frequency sound signals, can travel longer distances in water than in air (Hawkins 1993). Fish are most sensitive to low frequency sounds 100-300 Hz (Popper and Carlson 1998) and some of them could detect loud sounds coming from a distance of at least several km (Hawkins 1993).

Many species of fish have been trained to associate a sound signal with fear (Hawkins and Sand 1977) or food (Abbott, 1972; Midling et al. 1987; Levin and Levin, 1994). The utility of acoustic training was demonstrated for the first time for fish, when conditioned juvenile red sea bream, *Pagurus major* (Temminck and Schlegel) were conditioned to associate sound signals with food before they were released into a small bay in Japan. Three months later a large fraction of the conditioned fish responded to the sound signal and some wild red sea bream were attracted as well (Fujiya et al. 1980). These fish fed mainly on wild prey but sound was used to gather the fish prior to harvesting. Acoustic training was also successfully applied to cod (*Gadus morhua*) ranching in Norwegian and Icelandic fjords (Midling et al. 1987; Björnsson 1999, 2002).

Social learning of fish is important in foraging and avoiding predators (Brown and Laland 2006). It has been demonstrated that the presence of trained common carp (*Cyprinus carpio*) facilitates the acoustic training of naïve fish (Zion et al. 2007). In two ranching studies a significant part of the fish attracted to the feeding site were of wild origin, 16% of the red sea bream (Fujiya et al. 1980) and 25% of the cod (Midling et al.1987). This indicates that releasing acoustically trained fish could potentially be a way to aggregate wild fish to facilitate fishing and/or farming free-ranging fish without sea cages.

The main aim of the study was to provide information that might be helpful in developing a new fishing and farming method based on using acoustically conditioned cod. More specifically the aims were to find out how long time it would take to train cod to come to a specific feeding location as a response to a sound signal. Furthermore to find out how much this training time could be reduced in the presence of 'teachers' and how many 'students' one teacher could handle.

Methods

The experiments were carried out in a sea cage located at the innerside of Langeyri, a gravel spit in Álftafjördur in Northwest Iceland (Figs. 1-2). Álftafjördur is an 11 km long, 2-3 km wide and 30-40 m deep fjord. The fetch from the inner end of the fjord to the spit is 7.5 km. The cage was moored in the shelter of the gravel spit about 80 m from shore at a depth of 20 m. The circular cage was made of 40 m long double collar polyethylene plastic pipes (225 mm diameter) and black, knotless nylon netting (210/96 51 mm mesh size). The cage had a 1 m high railing with jumpnet sowed to the net bag which was 11 m in diameter and 9 m deep in the center (Fig. 3).

On each side of the cage, parallel to the shore 0.6 m wide and 2.4 m long wooden platforms extending 2.0 m into the cage were securely strapped on the top of the two plastic pipes. Horizontally, at a depth of 3.55 m a feeding platform 2.0x1.5 m made of stainless steel frame and galvanized mouse netting were hung with four bridle ropes from each of the wooden platforms with the long end of the feeding platform almost touching the inner side of the net bag (Fig. 3). A system was constructed to deliver the feed from shore to each feeding platform. Adult herring (*Clupea harengus*) was cut into small pieces of average weight 8 g, excluding head, tail and innards. For the whole herring the protein content was 17.5% and fat content 18.0%. A well pump (max 25 l/min) placed in the sea near shore was used to pump seawater continuously to two 32 mm polyethylen pipes running from a wooden structure at the top of a 20'container used as a control room on shore to the feeding platforms (Fig. 4A). The several meters difference in height between the two ends of the pipe was required to flush the feed to the feeding platforms. The water was pumped continuously (10 l/ min in each pipe) to make sure that the fish could not use a change in water volume as a feeding cue. The 25 mm polyethylen pipe coming from the pump was split in two 25 mm pipes stuck into the wider feeding pipes (Fig. 4A). The flow to each pipe was adjusted with valves. At the other end of the feeding pipes flexible rubber tubings were attached and adjusted to divert the feed onto the feeding platforms. At the time of feeding, the half frozen pieces of herring were weighed and counted and a ladder climbed to the top of the container to deliver the feed. To prevent clogging in the feed pipe one piece was put in the pipe every 20 s. The pipe with running water was briefly pulled out of the feeding pipe while inserting each piece of feed. It took in most cases 8-12 minutes for each food piece to travel to the feeding platform. In most days there were carried out 6 feeding sessions, usually alternating between the two feeding platforms but for some periods of time they were selected randomly.

As a sound source a special buoy was developed by Star-Oddi Ltd. It was made of a watertight cylinder made of PE1000 containing, 250 Hz transducer, two 12v batteries and electronics required to start and program the sound signals. In this study the buoy was kept in the control room where it was operated without disturbing the fish. The buoy was connected with two 250Hz transducers (sx53, Sensor Technology Ltd., Canada) attached to a piece of wood above the feeding platforms at a depth of 2.4 m (Fig. 3). The fronts of the transducers were directed into the center of the cage. There was a switch in the control room to select between the two transducers before the bouy was activated or stopped with a special plug. In most feeding sessions the sound signal started 1-5 minutes prior to the entrance of the first piece of feed. The source level of these transduces were about 120 dB re 1µPa at 1 m, considered enough to be detected by cod anywhere in the sea cage unless when there was much background noise (wind, waves, heavy rain). In each feeding session the buoy was programmed to send out sound signals for 6 minutes. The signals consisted of twelve 20 s bouts with 10 s of silence inbetween (=360 s). Each bout consisted of 20 sound signals, each lasting for 0.2 s with 0.8 s silence between. This was to imitate calls made by birds and mammals which commonly consist of series of repeated calls interrupted with silence.

A hydrophone (Type 8106 with a preamplifier, Bruel and Kjær, Denmark) was attached to a sonar (Tritech Super SeaKing Sonar, 375/624 KHz, United Kingdom) located near the center of the cage about 2 m below the surface to be able to hear the sound signals inside the control room while observing the fish on the videoscreens. The sonar was adjusted to sweep across the cage through both feeding platforms. The floating collar, the feeding platforms and the shape of the net bag could be easily seen at any time and the experimental fish when they entered into the 20° sonar beam. The sonar was also equipped with a videocamera (oe15-100c/101c Kongsberg, Norway) (Fig. 4B).

Two underwater videocameras (Obit 3000, Aquacam AS, Steinsvik, Norway) were attached directly above the feeding platforms at a depth of 1.85 m (the distance from the camera to the feeding platform was 1.7 m, adjusted so that the feeding platform filled the screen). The cameras could be rotated in any direction with joysticks in the control room. To limit visits to the sea cage during conditioning of the fish each camera was equipped with 4"paintbrush to clean the lenses of airbubbles and dirt. By turning the camera the lense could be wiped with the brush. The signal was sent from the cage to a receiver positioned on top of the container. In the control room there were two screens to monitor the feeding platforms (Fig. 4B). The behaviour of the fish was recorded (Sony DVCAM S25) onto tapes (Sony PDV-184 N) for a few minutes just after the sound signal was emitted. For most feeding sessions the behaviour was recorded for about 10 minutes on both tapes, starting 1 minute before the sound signal. A detailed description of the behaviour of the fish and the environmental conditions was also written down in a logbook.

The 50-60 experimental cod weighing 1-5 kg had been on-grown in sea cages and fed on frozen herring for about six months prior to the experiments. Two circular cages, about 2 m in diameter and 2 m deep were used to store fish in the study, well outside the hearing range of the sound signals. The fish in both cages were fed to saturation once a week on large pieces of herring.

Before each experiment the required number of fish were weighed and their length measured. To get an accurate weight measurement and reduce physical stress during handling the fish were not fed for about a week prior to weighing. Each fish was tagged with a special tag developed for the study. It was to be identifiable by the video cameras located above the feeding platforms. The tags were made of a 4 cm wide black canvas tape used for repairing books and folded together to form a square. The identification number was written with a white paint marker 2 mm wide (Artline 400 XF), one capital letter and one digit number. The tags were located dorsally between the head and the first dorsal fin (Fig. 5), sutured to the skin with one stitch in each corner. During operation the fish were wrapped in moist cloth with a hose of running seawater in the mouth to provide enough oxygen. Initial trials showed that white tags with black letters were unreadable on the videos due to overexposure.

Three experiments were carried out. The first one with 20 naïve fish conditioned from 10 June to 19 June. The experimental fish were not fed and left unattended in the cage for a period of eight days to clear their digestive system before the weighing on 27 June. In the second experiment, lasting from 28 June to 3 July, 10 experienced fish, socalled 'teachers' were mixed with 10 naïve fish, socalled 'students'. The 10 cod from Experiment 1 showing the fastest growth rate (G) were selected as teachers, where $G = 100*(\ln W_2-\ln W_1)/d$, W_1 and W_2 the initial and final weights (g) and d days between weighings. Condition factor (K) at the start of an experiment was used as a measure of the nutritional state of the fish, where $K = 100^* W_1/L_1$^3 and L_1 was the initial length (cm) of the fish.

During the starvation period the fish had attempted to remove the tags and some tags looked worn and were repaired and loose tags were firmly attached. One of the teachers (A1) died right after the release to the cage and thus there were actually 9 teachers and 10 students in the second experiment. In the third experiment, lasting from 10 July to 16 July, there were 19 students and one teacher (C5), selected as the fastest growing fish (after 6 days of starvation).

From the videocameras located above the feeding platforms it was possible to record the time of entrance for each fish, see the direction and speed and how the fish moved together in a group with one leading fish in front of the group. However, it was not possible with these methods to get an overview of the swimming pattern within the cage and thus under ideal conditions, minimal wind and clear seawater, the swimming pattern was observed from above the cage. This was done at the 4^{th} and 6^{th} day during Experiment 1 when the fish were commonly cruising between the feeding platforms (13 June 19:45-20:00 and 15 June 13:30-14:00 and 16:10-16:20). The sea cage was usually visited using a small inflatable rowboat mainly to adjust the orientation of the equipment. An attempt was made to limit these visits to a bare minimum and never before, during or right after a feeding session.

Seawater temperature was obtained with a continuous temperature recorder (Starmon mini, Star-Oddi Ltd., Iceland) located about 100 m south of the experimental cage at a depth of 5 m. Windspeed and direction was estimated by the first author at the location of the study, initially in the morning and later at every training session (Appendix 1). The maximum windspeed per day and wind direction at maximum windspeed was obtained from an official weather station located at Bolungarvík, 18 km northwest of the experimental cage (Table 1), based on 10 minutes average windspeed and wind direction recorded every 3 hours.

Results

Acoustic training

It took 6-7 days to acoustically train 20 naïve cod (Experiment 1), but less than a day to train 10 naïve cod accompanied with 9 trained cod (Experiment 2) and less than a day to train 19 naïve cod accompanied with one trained cod (Experiment 3, Table 1, Appendix 1). Usually there were 6 training sessions per day and in most cases 40-80 pieces of feed weighing a few hundred grams given per day (Table 2). For the first six days the total food intake was highest in Experiment 2 and lowest in Experiment 3, 5.8% and 3.3% per initial fish biomass, respectively (Table 2).

The learning process was stepwise for the 20 naïve cod learning by themselves (Experiment 1). During the first day the fish remained deep in the cage and avoided the feeding platforms. During the second day they approached the feeding platforms causiously without touching the feed. During the third day they initially took the feed reluctantly and with apprehension and later with increased eagerness. They quickly learned to associate the feed with the platforms (location) and started to cruise between the platform in search for food. By the end of the sixth day there was the first indication that the fish responded to the sound signal (time) and from the 8^{th} day they consistently responded to sound (in >50% of the sessions) (Appendix 1, Table 1). During this 10 day experiment there was no evidence suggesting that the fish had learned to use direction of sound to find the correct platform. Excluding the first four days it usually took 4-6 minutes for the fish to find food after the sound signal (Table 1).

The acoustic training of 10 naïve fish was facilitated by the presence of 9 trained fish (Experiment 2). The trained fish (teachers), were selected from the first experiment according to growth performance (Table 3). In this experiment there was no apprehensive period as in the first experiment. The teachers used their previous training to find the feeding locations and to respond to the feeding signals. Apparently, their unapprehensive behaviour made the naïve fish (students), unafraid of the new environment and they immediately started to follow their teachers to the feeding platforms at the sound of the signal. During the first day there was no evidence indicating that the fish used direction of the sound to locate the feed. However, during days 2-6 it was clear that the fish were also using direction of the sound to locate the feed and it normally took them about 1 minute from the start of the sound signal to enter the correct feeding platform (Table 1). On several occations the response to the sound signal could be observed with any of the three a video cameras. The reaction was immediate to the first tone and the fish swam with high speed to the correct feeding platform.

In one day when the fish did not respond immediately to the sound the wind and wave action may have masked the sound signal. In feeding sessions 75-77 the wind was blowing 15 m/s from NE causing considerable wave action at the tip of the spit. The fish showed no reaction to the sound signal in sessions 75 and 77 when sound signal came from feeding platform 2 located upwind but reacted to the sound signal in session 76 when the sound signal came from feeding platform 1 located downwind (Appendix 1). During the latter half of the final day in Experiment 2 the fish appeared to ignore the sound signal and took the feed reluctantly probably because they had become satiated with the energy rich diet (Appendix 1).

The acoustic training of 19 naïve fish was facilitated by the presense of 1 trained fish (Experiment 3). During the first feeding session the only teacher (C5) swam directly to the correct feeding platform, took the feed and spitted it out. Two minutes later it swallowed two pieces of feed and started to cruise between platforms. Eight minutes after C5 found the feed the first student followed him to platform 1 and two minutes later a group of students to platform 2. During the rest of the first day the teacher always reacted immediately to the sound signal and went to the correct platform, usually with some students following. In the two final feeding sessions of the first day one student (K5) beat the teacher for the correct platform. During the second day the teacher and K5 competed for first arrival at the correct feeding platform in response to the sound signal. After the teacher had been removed from the sea cage at the beginning of the third day, the students left on their own reacted immediately to the sound signals and usually came directly to the correct feeding platform. It usually took them only 1 minute to find the feed (Table 1). During days 4-7 the students always reacted to the sound signal and usually swam directly to the correct feeding platform. K5 made a mistake and went to the wrong platform in three feeding sessions in a row (sessions 111-113) and in one additional case (session 125) (Appendix 1), whereas in all four cases the main school of fish went to the correct feeding platform. At this time the weather was calm and thus the ambient noise must have been minimal.

Schooling behaviour

In most cases the fish swam together as a group with one leader in front of the group. The group leader received most of the feed. The leadership was most evident in Experiments 1 and 3. In Experiment 1, C5 was a leader for two days, E1 for one day and A4 for the four final days (Table 1). In Experiment 3, C5 the only teacher in the group was the leader during the first two days until it was removed from the sea cage. K5 then became the leader for the next four days but N2 took over for the final day (Table 1). During the long leadership in Experiment 1, A4 clearly ate most of the food and grew fastest, twice as fast as the second best fish, E1, which was a leader for only one day (Table 4). The growth performance was better for E1 than C5 which was a leader for two days.

Only 15% of the fish in Experiment 1 were gaining weight compared to 94% in Experiment 2. Interestingly, it was only A4, the former 4-day leader in Experiment 1, who lost weight in Experiment 2 (Table 4). There was not a significant difference in growth rate between the teachers and students in Experiment 2 (Single factor ANOVA, P=0.75). In general the group leaders were small to average but in all cases they were among the 5 slimmest fish in the group (Table 5).

The fish were never seen cruising straight between the feeding platforms but seemed to move along curved paths above the feeding platforms along the net wall. The observations indicated four types of swimming pattern: (1) An ellipse tilting down from a feeding platform to the deepest part of the cage. The fish would usually lazily circle around one feeding platform for some time before turning to the other platform (Fig. 6A). (2) An 8-shaped curve tilting down from a feeding platform to the deepest part of the cage and then up again to the other side of the cage with a bit more intensity of search (Fig. 6B). (3) An ellipse at a constant depth slightly above both feeding platforms. Commonly the minimum diameter of the ellipse was less than half the diameter of the cage (Fig. 6C). This was the most intensive search pattern seen shortly after feeding and when the fish were swimming with greatest speed. Sometimes the group leader was seen taking a U-turn to reenter the feeding platform before going to the other side of the cage (Fig. 6C). (4) An 8-shaped pattern in which the group was seen taking a U-turn after passing a feeding platform to recheck the platform from the side. If smell or pieces of feed were noticed it turned around to reenter the platform. If no evidence of feed the fish moved to the other side of the cage in a circular pattern above the other feeding platform (Fig. 6D).

Discussion

Acoustic training

It took 6-7 days to acoustically train 20 naïve cod, but less than two days to train 19 naïve cod accompanied with one trained cod. This demonstrates the ability of social learning of cod as has been found before for common carp (*Cyprinus carpio*) receiving acoustic training with or without teachers (Zion et al. 2007).

As soon as the 20 naïve cod were put in the experimental cage they formed a group, usually with one fish leading the group for some time. The group of naïve cod was apprehensive in the new environment and touched the feed with great care at first. In dangerous environment, e.g. where predators may be present, it may be advantageous to refrain from feeding (Milinski 1993) as fish with a large meal in the stomach are less likely to escape an attack from a predator. Some of the experimental fish may have experienced the danger of taking bait from a long-line. This apprehensiveness of the naïve fish was immediately lost in Experiments 2-3 in the presense of trained fish that showed no fear in the new environment.

The stepwise learning of the naïve fish was evident. During the apprehensive period it was not possible to train the fish as they did not come to the feeding platforms at the time of the sound signal. After the fish had overcome the fear of the new environment they quickly learned the best feeding locations in the sea cage and soon started to cruise between the two feeding platforms in search for food (Step 1). Then it took additionally a few more days to associate sound with the time of feeding (Step 2). Finally, it took several more days to associate direction of the sound with location and time of feeding (Step 3). To train fish to associate sound and feed it is necessary that the fish come to a feeding platform containing feed during emission of sound. This was only possible after the fish had reached the first step. Due to variation in delivery of the feed by the feeding system it happened occasionally that the feed or smell from the feed pipe entered before or after the sound emission (Appendix 1) and this may have slowed down the acoustic training.

In the presense of one or more teachers the naïve fish showed no timidness and quickly came to Step 1 in their learning process and thus were ready for acoustic training. The schooling behaviour of the naïve fish with the teacher(s) kept them in a visual contact and thus they were able to notice an immediate reaction of the teacher to the sound signal, e.g. by an increase in swimming speed or a change in direction. This clearly facilitated the acoustic training of the naïve fish. The final step was the most difficult achievement and sometimes a well trained fish made a mistake and went to the wrong feeding platform.

Noise from wind and wave action could prevent the hearing of cod. On a windy day sound signals coming from the direction of the noise source (upwind) were detected less than sound signals coming from the direction opposite to the noise source (downwind). This confirms an earlier study which showed that the hearing ability of cod was reduced when the angle between noise and sound projector was 45° or greater (Chapman and Johnstone 1974).

On several occasions the reaction of the fish to the sound signal could be observed with any of the three cameras. In all cases the reaction was immediate to the first tone and in most cases the fish went straight to the correct feeding platform. Sometimes the fish made mistakes and searched frantically the closest platform before going to the correct one or went towards the correct platform but then turning around to recheck the wrong platform. The group leader (K5) was seen going to the wrong platform three feeding sessions in a row, while the main group went to the correct platform. However, these were exceptions to the rule and in majority af cases the fish went directly to the correct platform. These results confirm earlier findings of the ability of cod to detect direction of sound both in the horizontal and vertical plane (Chapman and Hawkins 1973; Schuijf and Buwalda 1975; Hawkins and Sand 1977). In the study by Zion et al. (2007), the common carp were not able to select the correct feeding platform in the experimental tank, most likely because of the echoes of the 400-Hz sound signals from the walls. The present study shows that a sea cage with net walls is more suitable than a tank for training fish to respond to sound direction.

Schooling behaviour

The study shows that cod have a tendency to form schools, defined as synchronized and polarized swimming groups (Pitcher and Parrish 1993). As soon as the 20 naïve cod were released into the experimental cage they formed a school which moved around in the cage. Initially, they were not hunting for food and their schooling behaviour may rather have been a response to the new and potentially hazardous environment perhaps to reduce their perceived predatory risk (Pitcher and Parrish 1993) although these cod are of the sizes that can be hunted by relatively few predators. In nature, the clumped distribution of cod is well known by fishermen and has been documented in fish surveys (Pennington 1996). Using acoustic methods it has been found that cod generally live in groups, small and large (Rose 1993; DeBlois and Rose 1995). Some workers have suggested that schooling may benefit fish in finding feed (Pitcher and Parrish 1993; Rose 1993) whereas Eggers (1976) has pointed out that the prey consumption per individual fish may decrease with schooling.

After the group of naïve fish had overcome the fear of the new environment and assured that the feed was safe and desirable they generally searched for food in a group with one fish as the leader. The leadership lasted for a variable length of time, from less than a day to four days. The change of a leadership happened peacefully and without any noticeable aggression or fighting. Because the feed was presented at two locations the group generally cruised constantly between them. At first this cruising was relentless although most intensive following a meal. Generally, the feeding platform which gave the last meal was searched more carefully, a response developed for the commonly clumped distribution of prey (Pennington 1996). The searching effort and swimming speed was clearly reduced towards the second experiment when many of the fish had been satiated in line with the findings by Björnsson (1993). Towards the end of the third experiment when the fish had been trained to use direction of sound their swimming speed appeared to be reduced and the search less intensive. Thus, they were able to save energy with this knowledge.

The group leader had to swim faster than the rest of the group. If the lead was not enough when approaching the feeding platform he would sprint to the platform and if it contained pieces of feed he quickly consumed most of it before the group caught up with him. Many times the leader was seen taking a U-turn to reenter the feeding platform and then if no feed was seen he would sprint to catch and outswim the group which swam with a more uniform speed. Based on these observations, the leader was using much more energy than the average fish but he was also consuming more food than the rest. This can be best seen in the first experiment where the 4-day leader A4 grew twice as fast as the second fastest grower. Fish E1 which was a leader for only one day outperformed C5 which was a leader for two days, perhaps due to his smaller size and thus lower metabolism relative to his food intake. More food consumption by the group leaders is in agreement with the findings by DeBlois and Rose (1996).

Contrary to the findings by Rose (1993) and DeBlois and Rose (1996) the group leaders were not larger than the average fish. Instead, they were close to average or below average in size and even the smallest fish in the group (E4) and the second smallest (N2) fish of 19 were group leaders for a day (Table 5). This is also different from the findings by Reebs (2001) that shoals of naïve golden shiners, *Notemigonus crysoleucas*, were more likely to follow large than small conspecifics with experience. However, the group leaders were always among the slimmest fish in the groups (Table 5) confirming the findings by Krause et al. (1992) and Krause (1993) that position preference was determined by nutritional state, with hungrier fish located in front positions. The chances of the group leaders of obtaining feed are greater but their risks of predation are also greater (Krause 1993; Bumann et al. 1997).

It may take some time for a leader to gain enough confidence by the group to follow him. An example is the beginning of Experiment 3 when the teacher would go straight to the correct platform at the sound of a signal and then start to cruise between the platforms. For about 10 minutes the 19 naïve fish would stay as a group outside the cruising path of the teacher but then judging from his behaviour they considered it safe and desirable to start following him to the feeding platforms. On a few other occasions a new leader was not followed by the group until he gained confidence by the group members, probably by demonstrating the ability to find food. The present results indicate that the maximum number of fish that a single trained cod can guide is more than 19, considerably higher than the 6-10 suggested for common carp (Kohler 1976). In the present study the best teacher was selected based on growth performance and most likely the results would have been different if the teacher had been randomly selected. Most likely the level of training and the selfconfidence of the teacher will to a large extent determine the number of fish that he will be able to train. A few well trained and confident teachers released into a cage full of students is likely to initially train a few and then with growing numbers of teachers most of the fish in a cage will be trained.

The observed swimming pattern of the school is probably to a large extent influenced by the containment in the sea cage and may have limited relevance to the swimming pattern of fish in the wild. However, for further behavioural studies of fish in sea cages it may be of some value to know the basic swimming pattern of caged cod and how it is affected by food availability and may perhaps shed some light on the processes involved in changing a direction in a group of fish (Bumann and Krause 1993).

Potential application of the results

Based on the present results, it is hypothesized that acoustically trained fish can be used to attract wild conspecifics to a trap. It is likely that fish that have been acoustically trained inside a cage could be made to swim between two feeding stations in the sea with the help of the conditioning signal. If the two feeding stations are located in an area where wild fish of the same species are plentiful it is likely that some of them will join the trained fish on their way to a feed bag (see Björnsson in press) deployed during the acoustic emission (Fig. 7). It would not be enough to use just one feeding station since the conditioned fish would tend to linger around it and thus only affect wild fish in the nearest neighbourhood of the feeding station. If instead two or more feeding stations were operated alternatively the conditioned fish could be made to swim between them in a response to an acoustic signal and thus would be more likely to encounter wild fish which might join them on their route towards the sound source. By repeating the acoustic training several times it is likely that more and more wild fish would join in and be trained to become teachers. Thus gradually the school of teachers would grow bigger and their influence on the wild fish become bigger. At the same time more and more feed would be required as a reward for proper behaviour. This training period could be either relatively short (several days) with the purpose to trap the wild fish without too much feed cost or relatively long (several months) with the purpose of on-growing wild fish without the cost of sea cages before trapping the fish at the time of harvest (Björnsson in press). Clearly, this hypothesis of using trained fish to facilitate capture or ranching of wild fish must be tested thoroughly before it can be implemented commercially.

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Table 1. The daily summary of the acoustic training of cod at Langeyri northwest Iceland in three experiments with two digestion periods in between. Day number in each experiment (Day), mean daily sea temperatures (°C) at 5 m depth (Temp.), maximum wind speed at a weather station in Bolungarvík 18 km NW of Langeyri, calculated as 10 minute average every 3 hours (Wind sp.), wind direction at maximum windspeed (Wind dir.), median time to find feed in minutes from start of sound signal (TFF), response to sound signal (RS), directionally correct response to sound signal (DRS), cruising between platforms (CBP) and identification number of the group leader (Leader). For RS, DRS and CBP the score is 1 if >50% of the feeding sessions are positive.

Date	Exp.	Day	Temp.	Wind sp.	Wind dir.	TFF	RS	DRS	CBP	Leader	Comment
10.06	1	1	7.4	5	NE		0	0	0		Fish remain at bottom
11.06	1	2	7.7	3	W		0	0	0		Approach platforms
12.06	1	3	8.5	5	W	30.0	0	0	1		Start to eat and cruise
13.06	1	4	8.9	3	W	28.0	0	0	1	C5	A leader is formed
14.06	1	5	8.8	3	E	6.0	0	0	1	C5	Cruising betw. platforms
15.06	1	6	8.5	10	N	5.0	0	0	1	E1	A new leader takes over
16.06	1	7	8.9	12	NE	4.0	0	0	1	A4	A new leader takes over
17.06	1	8	8.5	7	NE	5.5	1	0	1	A4	A cons. reaction to sound
18.06	1	9	8.8	4	NE	5.0	1	0	1	A4	Group splits betw. platf.
19.06	1	10	7.4	5	E	2.5	1	0	1	A4	A4 eats most of food
20.06			6.6	5	N						8 d. digestion per. starts
21.06			6.8	4	E						
22.06			7.2	4	N						
23.06			8.3	3	NE						
24.06			9.2	4	N						
25.06			9.1	4	NE						
26.06			8.9	5	NE						
27.06			9.4	8	N						
28.06	2	1	9.4	8	NE	1.5	1	0	1		Students follow teachers
29.06	2	2	9.2	6	NE	2.0	1	1	1	E4	React to direct. of sound
30.06	2	3	9.6	10	NE	1.5	1	1	0		Fish linger under platf.
1.07	2	4	9.5	**16**	**NE**	1.0	1	1	0		Noise affect. sound sign.
2.07	2	5	9.3	14	N	1.0	1	1	0		Reaction to first tone
3.07	2	6	9.3	5	N	2.0	1	1	0		Take feed reluctantly
4.07			9.6	4	N						6 d. digestion per. starts
5.07			8.7	4	N						
6.07			9.4	2	NE						
7.07			9.8	4	N						
8.07			9.5	4	N						
9.07			9.7	3	N						
10.07	3	1	10.2	6	W	0.5	1	1	1	C5	Students follow teacher
11.07	3	2	10.3	2	N	1.0	1	1	1	C5	Reaction to first tone
12.07	3	3	8.8	5	E	1.0	1	0	1	K5	C5 removed, new leader
13.07	3	4	8.4	4	E	1.0	1	1	1	K5	React to direct. of sound
14.07	3	5	9.5	4	N	0.5	1	1	1	K5	Group to correct platf.
15.07	3	6	9.9	3	W	1.0	1	1	1	K5	Reaction to first tone
16.07	3	7	9.7	3	N	1.0	1	1	1	N2	Reaction to first tone

Table 2. Daily food intake in the three experiments at Langeyri, northwest Iceland. Experiment number (Exp.), day number in each experiment (Day), feeding/training sessions per day (Sessions), pieces of feed given per day (Feed n), amount of feed given per day (Feed g), cumulative feed in experiment (Cum. feed g) and cumulative feed in experiment as % of initial weight of fish (Cum. feed % per i.wt.).

Date	Exp.	Day	Sessions	Feed n	Feed g	Cum. feed g	Cum. feed % per i.wt.
10.06	1	1	4	14	260	260	0.40
11.06	1	2	3	9	231	491	0.75
12.06	1	3	5	48	791	1282	1.96
13.06	1	4	5	61	778	2060	3.15
14.06	1	5	6	58	606	2666	4.08
15.06	1	6	6	51	492	3158	4.84
16.06	1	7	6	75	571	3729	5.71
17.06	1	8	6	60	460	4189	6.41
18.06	1	9	6	86	455	4644	7.11
19.06	1	10	6	196	1211	5855	8.96
28.06	2	1	6	161	1107	107	1.96
29.06	2	2	6	95	722	1829	3.23
30.06	2	3	6	54	352	2181	3.85
1.07	2	4	6	57	352	2533	4.48
2.07	2	5	6	64	390	2923	5.16
3.07	2	6	5	58	362	3285	5.80
10.07	3	1	6	35	170	170	0.26
11.07	3	2	6	66	362	532	0.82
12.07	3	3	5	63	330	862	1.34
13.07	3	4	6	73	393	1255	1.94
14.07	3	5	6	74	432	1687	2.61
15.07	3	6	6	75	426	2113	3.27
16.07	3	7	6	69	446	2559	3.96

Table 3. Length (cm) and weight (g) of cod at the beginning (L_1, W_1) and end (L_2, W_2) of experiments (after a digestion period). Fish in Exp.1 were weighed on 9 and 27 June, in Exp. 2 on 27 June and 9 July, in Exp. 3 on 9 July. Condition factor (Cond. f.) at the start of each experiment was used to estimate the nutritional condition of the fish. Growth rates (G) in Exp.1 were used to select 10 teachers for Experiment 2 and growth rates in Exp. 2 to select one teacher for Exp. 3 (Qualifiers). The teachers are indicated in bold and group leaders are underlined.

Exp.	Fish nr.	L_1	L_2	W_1	W_2	Cond. f.	G (%/day)	Qualifiers
1	A1	68	69	3290	3232	1.046	-0.09	6
1	A2	62	63	2492	2541	1.046	0.10	3
1	A3	66	67	3269	2838	1.137	-0.74	
1	A4	67	68	2782	3146	0.925	0.65	1
1	A5	71	71	4624	4188	1.292	-0.52	
1	B1	70	71	2820	2801	0.822	-0.04	4
1	B2	63	64	3280	3125	1.312	-0.25	
1	B3	65	67	3394	3370	1.236	-0.04	5
1	B4	67	67	3478	3122	1.156	-0.57	
1	B5	75	76	4902	4360	1.162	-0.62	
1	C1	64	65	3532	3372	1.347	-0.24	10
1	C2	62	63	2702	2427	1.134	-0.56	
1	C3	72	73	5030	4316	1.348	-0.81	
1	C4	63	63	2574	2353	1.029	-0.47	
1	C5	68	70	3092	3036	0.983	-0.10	7
1	E1	58	59	1905	2024	0.976	0.32	2
1	E2	67	69	3660	3496	1.217	-0.24	9
1	E3	72	73	3718	3388	0.996	-0.49	
1	E4	53	54	1313	1265	0.882	-0.20	8
1	E5	68	69	3448	3188	1.097	-0.41	
2	**A1**	69		3232				
2	**A2**	63	63	2541	2675	1.016	0.27	
2	**A4**	68	68	3146	2939	1.001	-0.36	
2	**B1**	71	71	2801	2811	0.783	0.02	
2	**B3**	67		3370		1.120		
2	**C1**	65	64	3372	3532	1.228	0.24	
2	**C5**	70	70	3036	3396	0.885	0.59	1
2	**E1**	59	58	2024	2254	0.985	0.57	
2	**E2**	69	69	3496	3602	1.064	0.16	
2	**E4**	54	55	1265	1352	0.803	0.35	
2	F1	72	71	3806	3928	1.020	0.17	
2	F2	66	66	2630	2732	0.915	0.20	
2	F3	61	60	2253	2395	0.993	0.32	
2	F4	69	69	3928	3992	1.196	0.09	
2	F5	66	66	2833	3092	0.985	0.46	
2	H1	77	78	4692	4902	1.028	0.23	
2	H2	77	78	4364	4379	0.956	0.37	

2	H3	58	57	1689	1765	0.866	0.23
2	H4	69	69	3524	3638	1.073	0.17
2	H5	59	58	1833	1981	0.892	0.41
3	**C5**	70		3396		0.990	
3	I1	71		4112		1.149	
3	I2	67		3368		1.120	
3	I3	65		3096		1.127	
3	I4	73		4432		1.139	
3	I5	73		4452		1.144	
3	K1	75		4538		1.076	
3	K2	75		5016		1.189	
3	K3	73		4072		1.047	
3	K4	72		4552		1.220	
3	K5	68		2754		0.876	
3	L1	65		2867		1.044	
3	L2	60		2142		0.992	
3	L3	66		2595		0.903	
3	L4	65		2657		0.968	
3	L5	65		2680		0.976	
3	N1	64		2535		0.967	
3	N2	55		1605		0.965	
3	N3	58		2240		1.148	
3	N4	52		1445		1.028	

Means in exp.:	L_1	L_2	W_1	W_2	Cond.f.	G
Exp.1	66.0	67.0	3265	3079	1.107	-0.266
Exp.2*	66.1	66.1	2979	3092	0.990	0.249
Exp.3**	66.4		3219		1.057	

*A1 excluded, **C5 excluded

Table 4. Fish in Experiment 1 and 2 sorted by growth rate. The teachers in experiment 2 shown in bold.

Experiment 1: Fish number	G (% per day)	Experiment 2: Fish number	G (% per day)
A4	0.647	**C5**	0.590
E1	0.319	**E1**	0.566
A2	0.102	F5	0.460
B1	-0.036	H5	0.409
B3	-0.037	H2	0.367
A1	-0.094	**E4**	0.350
C5	-0.096	F3	0.322
E4	-0.196	**A2**	0.270
E2	-0.241	**C1**	0.244
C1	-0.244	H3	0.232
B2	-0.255	H1	0.230
E5	-0.413	F2	0.200
C4	-0.472	H4	0.168
E3	-0.489	F1	0.166
A5	-0.521	**E2**	0.157
C2	-0.565	F4	0.085
B4	-0.568	**B1**	0.019
B5	-0.617	**A4**	-0.358
A3	-0.744	**A1***	
C3	-0.806	**B3****	

* Died on the weighing day (27 June); ** Died near the end of Experiment 2

Table 5. The position of a group leader within the group with respect to ascending order of length, weight and condition factor at the start of an experiment (20 fish in Exp. 1 and 19 fish in Exp. 2 and 3).

Exp.	Leader	Days	Shortest (cm)	Lightest (g)	Slimmest (cond. factor)
1	A4	4	10-12	6	3
1	C5	2	13-15	8	5
1	E1	1	1	1	4
2	E4	1	1	1	2
3	K5	4	12	9	1
3	N2	1	2	2	3

Appendix 1. Acoustic training of cod at Langeyri, northwest Iceland 2008. Experiment number (Exp.), feeding session nr. (Feed.), feeding platform nr. (Platf.), platform selected randomly (Rand.), date and time at beginning of sound signal, windspeed (m/s) and direction estimated on location, response to sound signal (RS), directionally correct response to sound signal (DRS), cruising between platforms (CBP), find food during sound signal (FFS), platform 1 (P1), platform 2 (P2). For Rand., RS, DRS, CBP and FFS a score of 1 means yes.

Exp.	Feed.	Platf.	Rand.	Date	Time	Windsp.	RS	DRS	CBP	Leader	FFS	Comment
1	1	1		10.06	10:40	N7						Fish remain at bottom of cage
1	2	2		10.06	12:42							Fish remain at bottom of cage
1	3	1		10.06	14:42							Fish remain at bottom of cage
1	4	2		10.06	21:27							Approach platforms from below
1	5	1		11.06	16:36	0						Approach platforms from below
1	6	2		11.06	20:00							Enter platforms after s. signal, do not eat
1	7	2		11.06	20:28							Enter platforms after s. signal, do not eat
1	8	1		12.06	7:52	SW5						Fish find food after s. signal, spit out feed
1	9	2		12.06	10:01							Fish find food after sound signal
1	10	1		12.06	14:49							Find food after s. signal, search platform
1	11	2		12.06	17:10	SW5						Find food after s. signal, search platform
1	12	1		12.06	18:52				1			
1	13	2		13.06	8:47	0			1			Fish find food after sound signal
1	14	1		13.06	15:26				1			Fish find food after sound signal
1	15	2		13.06	16:31				1	C5		Fish find food after sound signal
1	16	1		13.06	18:14				1	C5		Fish find food after sound signal
1	17	2		13.06	20:27				1	C5		Fish find food after sound signal
1	18	1		14.06	8:52	0			1	C5		Fish find food after sound signal
1	19	2		14.06	10:39				1	C5	1	Used smell from hose to anticipate feed
1	20	1		14.06	11:20				1	C5	1	
1	21	2		14.06	14:12				1	C5	1	
1	22	1		14.06	15:41	NE10			1	C5		Fish find food after sound signal
1	23	2		14.06	17:44				1	C5		Fish find food after sound signal
1	24	1		15.06	8:05	NE5			1	C5	1	
1	25	2		15.06	9:16				1	E1	1	
1	26	1		15.06	10:57				1	E1		Fish find food after sound signal
1	27	2		15.06	12:23				1	E1		Fish find food after sound signal
1	28	1		15.06	15:25				1	E1	1	
1	29	2		15.06	16:56		1	1	1	E1	1	
1	30	1		16.06	8:51	NE10			1	A4	1	
1	31	2		16.06	10:21				1	A4	1	
1	32	1		16.06	12:21		1		1	A4	1	
1	33	2		16.06	18:44		1		1	A4	1	
1	34	1		16.06	20:20				1	A4		Fish find food before sound signal
1	35	2		16.06	21:41				1	A4		Noise from wind?
1	36	1		17.06	10:01	NE5			1	A4	1	
1	37	2		17.06	10:52		1	1	1	A4	1	
1	38	1		17.06	13:39				1	A4		Fish find food after sound signal
1	39	2		17.06	15:11		1	1	1	A4	1	
1	40	1		17.06	16:44		1	1	1	A4		Find food after sound signal, feed. system
1	41	2		17.06	18:59		1		1	A4	1	
1	42	1		18.06	8:49	NE5	1	1	1	A4	1	
1	43	2		18.06	10:29		1		1	A4	1	
1	44	1		18.06	12:21		1		1	A4	1	Group splits between platforms, smell
1	45	2		18.06	14:21		1		1	A4	1	Group splits between platforms, smell

1	46	1		18.06	17:40		1		1	A4	1	Group splits between platforms, smell
1	47	2		18.06	23:28							Electrical problems, no video
1	48	1		19.06	11:28	NE5	1		1	A4	1	Use smell
1	49	2		19.06	13:30		1		1	A4	1	
1	50	1		19.06	15:23		1	1	1	A4	1	
1	51	2		19.06	18:12		1	1	1	A4	1	
1	52	1		19.06	19:52		1		1	A4	1	
1	53	2		19.06	21:24		1		1	A4	1	
2	54	1		28.06	9:16	N10	1	1	1	E1	1	Teachers and students swim in one group
2	55	2		28.06	10:32				1	C5		
2	56	1		28.06	11:55		1	1	1	C5	1	
2	57	2		28.06	15:55		1		1	E1	1	
2	58	1		28.06	18:05		1		1	E4	1	
2	59	2		28.06	20:32		1	1	1	E4	1	A student (F2) eats the first piece of feed
2	60	1		29.06	9:50	N10	1	1	1	E4	1	
2	61	2		29.06	11:04		1		1	E4	1	
2	62	1		29.06	12:35		1	1	1	C5	1	
2	63	2		29.06	13:45				1	E4		Fish show less interest
2	64	1		29.06	17:55		1	1	1	E4	1	
2	65	2		29.06	20:26		1	1	1		1	
2	66	1		30.06	9:28	NE5	1	1	1		1	
2	67	2		30.06	11:04		1	1			1	Fish linger under platform
2	68	1		30.06	12:28		1	1			1	Fish linger under platform, satiated?
2	69	2		30.06	16:30		1	1			1	Fish linger under platform, satiated?
2	70	1		30.06	20:24		1	1			1	Fish linger under platform, satiated?
2	71	2		30.06	21:22		1	1			1	Fish linger under platform, satiated?
2	72	1		1.07	9:32	NE10	1	1	1	C5	1	
2	73	2		1.07	10:29		1	1	1		1	
2	74	1		1.07	15:01		1	1	1		1	
2	75	2		1.07	15:42	NE15						Stay deep, do not repond to sound, noise?
2	76	1		1.07	17:23	NE15	1	1			1	
2	77	2		1.07	18:10	NE15	1				1	Stay deep, do not detect direction, noise?
2	78	2	1	2.07	9:42	N5	1	1			1	Random selection of platform starts
2	79	2	1	2.07	10:20	N5	1	1		E1	1	
2	80	1	1	2.07	13:23	NE10	1	1			1	
2	81	2	1	2.07	15:36	NE10	1	1	1	E1	1	
2	82	2	1	2.07	19:52	N5	1	1	1	F3	1	Immediate reaction to first tone
2	83	1	1	2.07	21:16	N5			1	F3		Fish find food before sound signal
2	84	2	1	3.07	8:48	0	1	1	1	F3	1	
2	85	2	1	3.07	10:04	0	1	1	1	C5	1	
2	86	1	1	3.07	12:48	N5						Ignore sound signal, satiated?
2	87	1	1	3.07	15:41	N5						Ignore sound signal, spit out feed
2	88	1	1	3.07	21:27	0	1	1			1	Take feed reluctantly
3	89	1		10.07	9:31	NE5	1	1	1	C5	1	The teacher (C5) spits out feed
3	90	2		10.07	10:28	0	1	1	1	C5	1	Students follow teacher to the platform
3	91	1		10.07	13:01	NE5	1	1	1	C5	1	
3	92	2		10.07	15:12	NE5	1	1	1	C5	1	
3	93	1		10.07	18:18	SW10	1	1	1	K5	1	A student (K5) becomes a leader
3	94	1		10.07	18:18	SW5			1	K5		Fish find food before sound signal
3	95	2		11.07	9:39	0	1	1	1	C5	1	Immediate reaction (C5) to first tone
3	96	1		11.07	10:43	NE5	1	1	1	C5	1	Immediate reaction (K5) to first tone
3	97	2		11.07	13:28	NE5			1	C5		Fish find food before sound signal
3	98	1		11.07	16:26	0	1	1	1	C5	1	C5 waits in front of feeding hose
3	99	2		11.07	19:59	0	1	1	1	C5	1	Immediate reaction (K5) to first tone
3	100	1		11.07	23:17	0	1	1	1	C5	1	C5 and K5 sprint for the platform
3	101	2		12.07	13:58	0	1	1	1	K5	1	C5 removed, students respond correctly
3	102	1		12.07	14:53	0	1	1	1	K5	1	Immediate reaction to first tone
3	103	2		12.07	15:46	N5			1	K5		K5 finds food before sound signal
3	104	1		12.07	18:21	N5			1	K5		N5 finds smell before sound signal
3	105	2		12.07	20:59	N5	1		1	K5	1	K5 goes to wrong platform

3	106	1		13.07	10:01	0			1	K5		Fish find smell before sound signal
3	107	2		13.07	11:57	SW5	1	1	1	K5	1	
3	108	1		13.07	13:38	SW5	1	1	1	K5	1	K5 shows aggression
3	109	2		13.07	16:59	N5	1	1	1	K5	1	
3	110	1		13.07	18:23	NE5			1	K5		K5 finds smell before sound signal
3	111	1		13.07	21:37	0	1	1	1	K5	1	Group to correct platform, K5 not
3	112	2		14.07	11:15	0	1	1	1	K5	1	Group to correct platform, K5 not
3	113	1		14.07	13:28	0	1	1	1	K5	1	Group to correct platform, K5 not
3	114	2		14.07	14:52	0	1	1	1	K5	1	
3	115	1		14.07	16:33	N5			1	K5		K5 finds smell before sound signal
3	116	2		14.07	20:00	SW5			1	K5		K5 finds smell before sound signal
3	117	1		14.07	22:57	NE5	1	1	1	K5	1	K5 reacts correctly to the first tone
3	118	1	1	15.07	10:13	NE10			1	K5		Find feed just before first tone
3	119	2	1	15.07	11:19	NW10	1	1	1	K5	1	Some fish at P1, searched it in panic
3	120	1	1	15.07	13:38	NW10	1		1	K5	1	K5 at P2, started towards P1 then P2
3	121	2	1	15.07	15:13	NW5	1	1	1	K5	1	
3	122	1	1	15.07	17:01	NW5	1	1	1	K5	1	
3	123	2	1	15.07	22:17	NE5	1	1	1	K5	1	Immediate reaction to first tone
3	124	2	1	16.07	9:02	0	1	1	1	K5	1	Immediate reaction to first tone (K5)
3	125	2	1	16.07	12:08	0	1	1	1	K5	1	Group to correct platform, K5 not
3	126	2	1	16.07	15:38	NE5	1	1	1	N2	1	Group to correct platform
3	127	1	1	16.07	16:27	NE5			1	N2		Find feed just before first tone
3	128	2	1	16.07	19:45	NE5	1	1	1	N2		Immediate reaction to first tone
3	129	2	1	16.07	22:57	NE5	1	1	1	N2		Immediate reaction to first tone

Figure 1. A photograph of Álftafjördur and Langeyri, the gravel spit where the experimental sea cage was located at the far side of the spit.

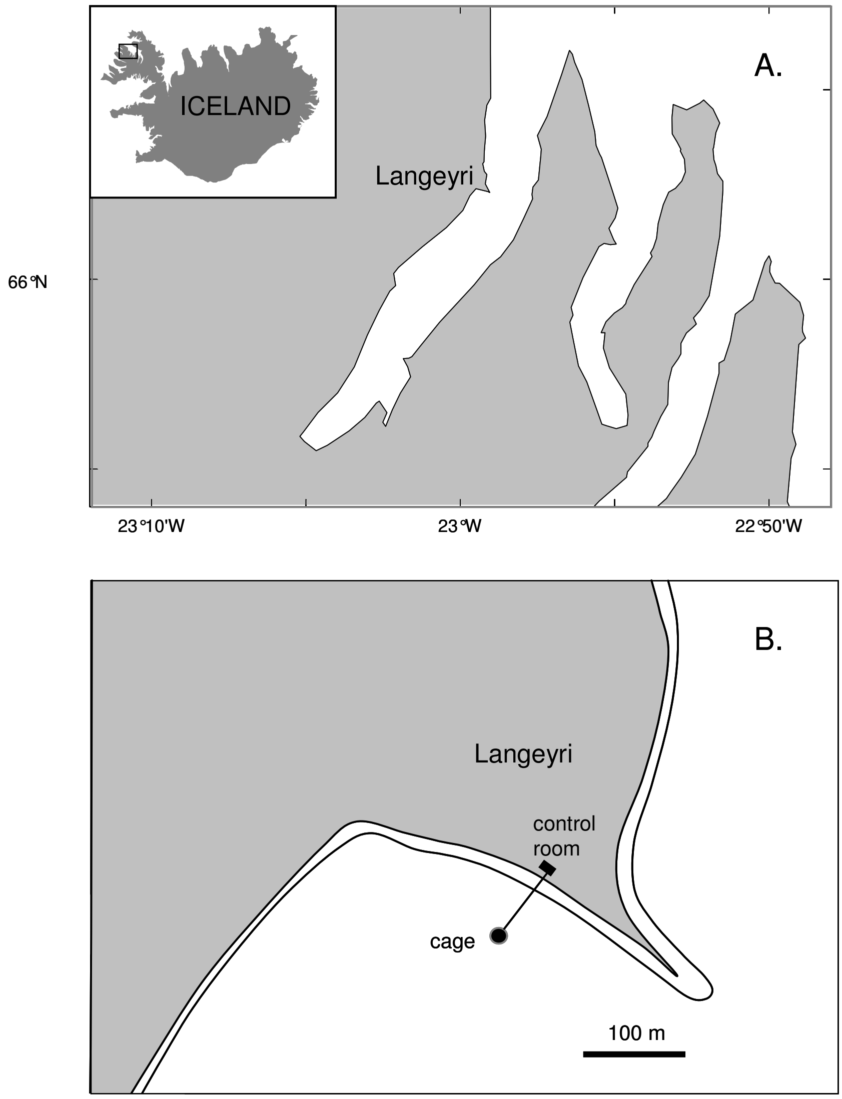

Figure 2. A map of the fjord area in northwest Iceland where the experimental cage was located. A. An overview of Álftafjördur and the gravel spit (Langeyri), B. A closer look at Langeyri showing the experimental sea cage and control room onshore.

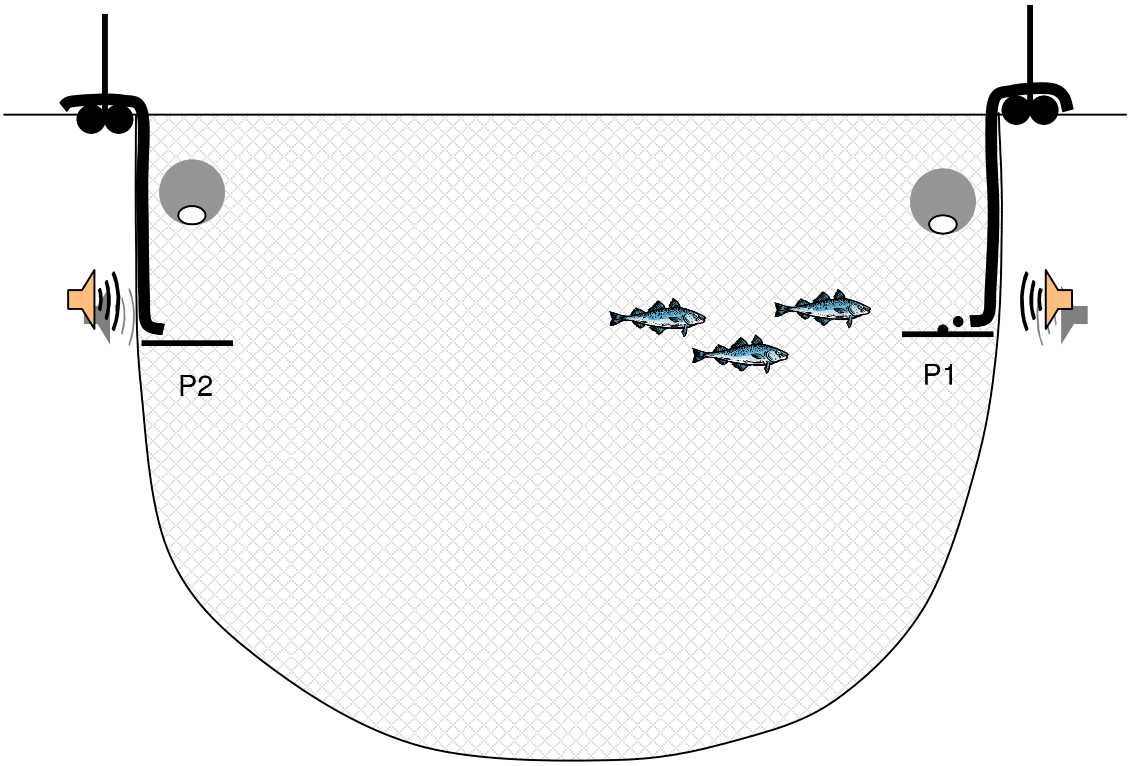

Figure 3. A side view of the experimental cage from the perspective of the control room. P1 and P2 are the feeding platforms with feeding hoses, transducers and video cameras.

Figure 4. The control room. A. from outside showing the feeding system where seawater was pumped to two feeding pipes running from the roof of the container to the two feeding platforms (P1 and P2). The receivers for the video cameras can also be seen. B. from inside showing the screens of the video cameras monitoring the two feeding platforms (left), the sonar (above) and the videocamera attached to the sonar (right). A cod and a jellyfish can be seen on P1 and the feeding platforms and the netbag on the sonar. The equipment on the right was used to record the videos.

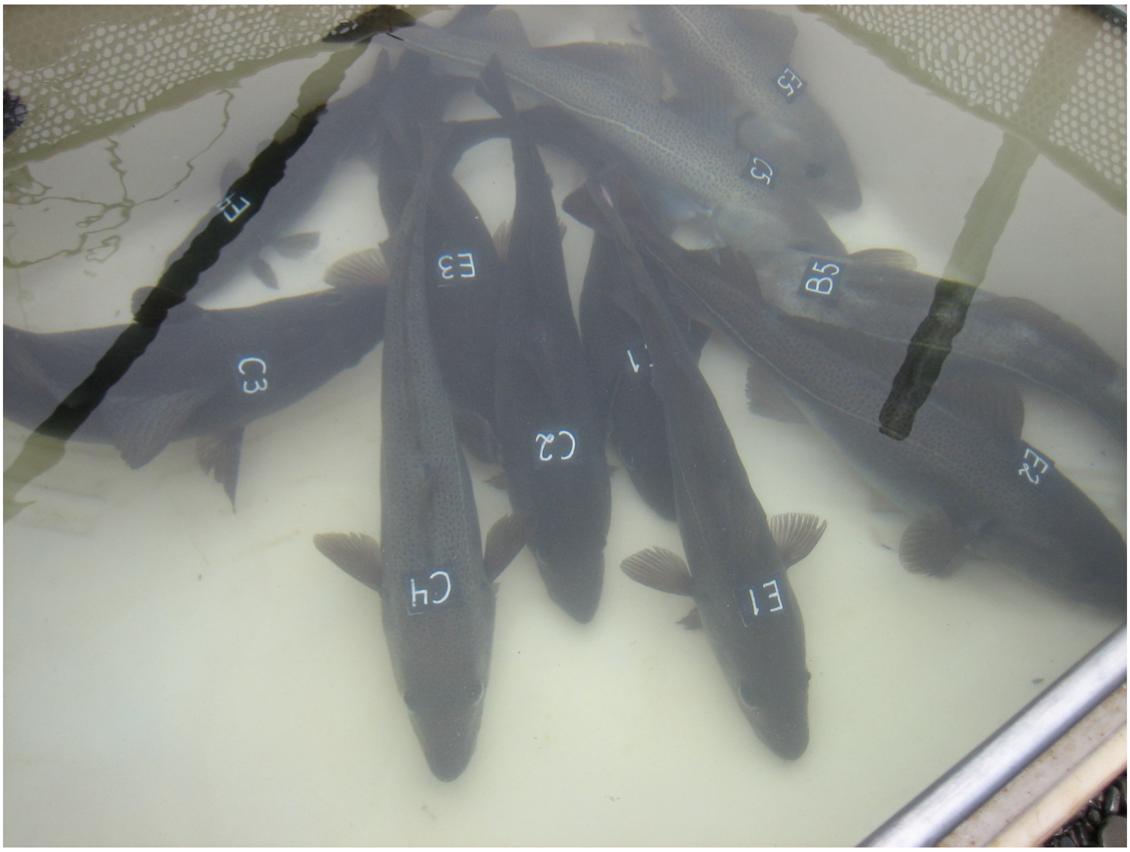

Figure 5. The fish were tagged dorsally to be able to identify them individually on the videos.

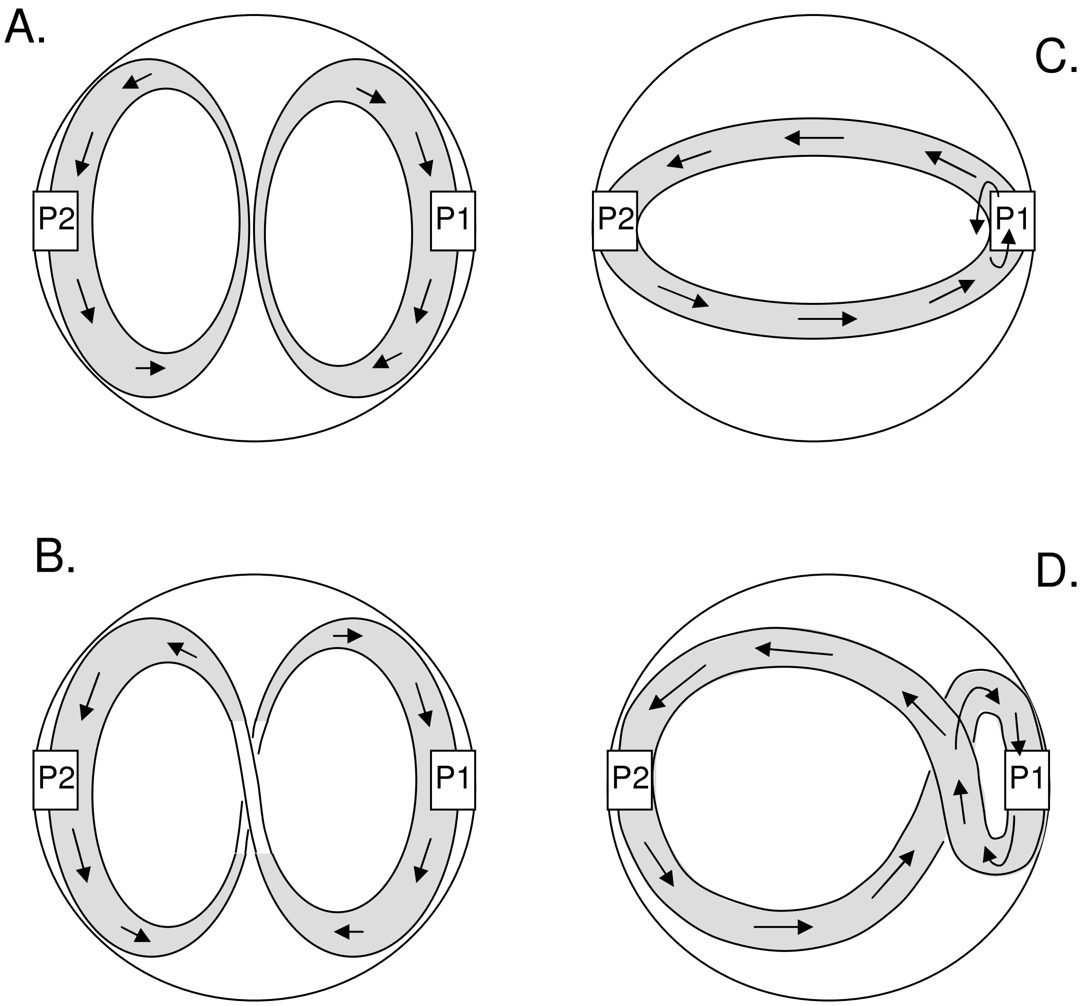

Figure 6. The types of swimming pattern of the cod school according to observations from above the cage. The width of the swimming area (grey) is used to indicate three-dimensional aspect of the pattern and P1 and P2 the feeding platforms. A. Circles from the bottom of cage to the feeding platform. The group of fish may for some time only visit P1 and for some time only P2. B. An 8-shaped pattern from P1 down to the bottom of the cage and up again to P2. C. An ellipse touching both feeding platforms when fish are cruising intensively between platforms at the same depth. D. An 8-shaped pattern with a U-turn near one of the feeding platforms.

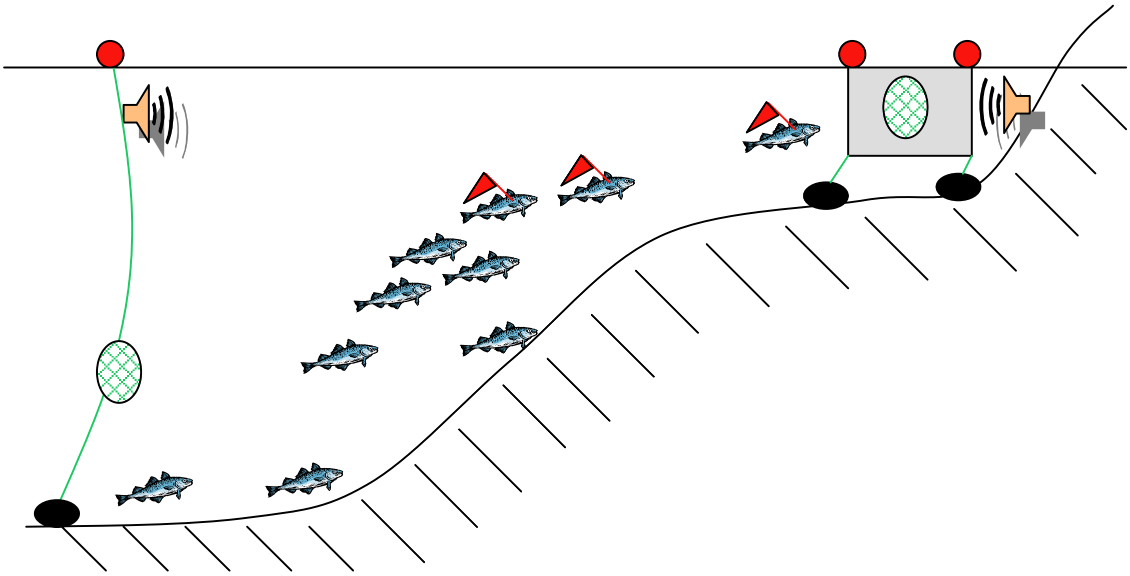

Figure 7. An illustration of an hypothesis how acoustically trained fish (the ones with the flag) can be used to lure naïve fish to a trap. A sound signal is given at the time of deployment of a feed bag and the trained fish will approach with some naïve fish following.