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FJORDRANCHING WITH CONDITIONED COD

by

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ABSTRACT

In June 1986, 1600 pond-reared one-year old cod were released into a fjord after being conditioned with a pulsed 160 Hz sound signal to search for food at a feeding location. Echosounders, UW-video and ultrasonic transmitter tags were used to monitor the fish behaviour. The fish were fed four times a day (0900, 1200, 1500 and 1900) in the current lobe from a propeller.

A majority of the trained fish returned to the stimulus location, and also some "wild" cod and other species adapted the same behaviour. The ultrasonic tagged fish were distributed within 400 m from the stimulus location between the feeding periods. The experiment was terminated after three months. In this period the mean daily length increment was 0.6 mm/day.

INTRODUCTION

Luring of fishes by light or sound has long traditions in the fisheries of the world, ranging from the primitive method used by the Indians of the Amazon, imitating the sound of falling fruit (Goulding 1980, cited in Caufield 1983), to the sophisticated methods used by Japanese fishermen to attract fish and squid (Maniwa 1975). Classical conditioning techniques have been used since the days of Pavlov and have led to experiments for possible applications to fish farming. Fujiya (1980) and Olsen (1974) have conducted experiments for this purpose with red sea bream (Pagrus major) and saithe (Pollachius virens), respectively. Recent progress in the control of fish behaviour is reviewed by Balchen (1984).

Since 1983 large-scale production of juvenile cod has been possible (Øiestad et al. 1985), and today several commercial sites are producing juvenile cod for sale. The application of juveniles can roughly be grouped into intensive farming by traditional methods (Kvenseth et al. 1985), enhancement of local cod populations (Svåsand and Kristiansen 1985), and finally ranching with conditioned cod. All cod were tagged with Floy Anchor Tags (Svåsand 1985).

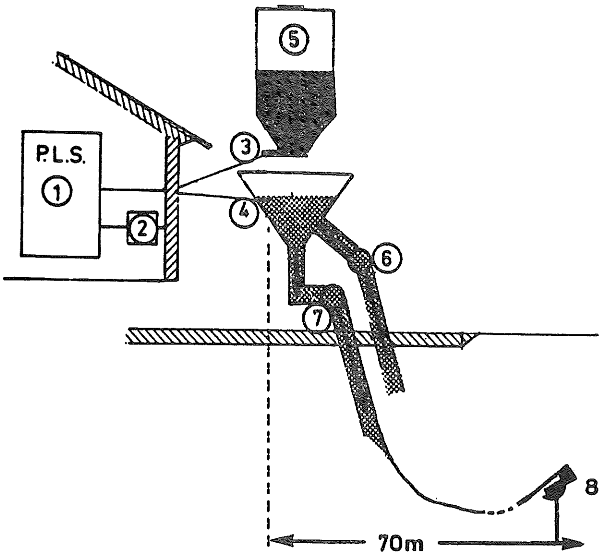
MATERIALS AND METHODS

The experiment was conducted in Osen, an inlet in Austevoll (60^0 5'N, 05^0 10'E), south of Bergen. The cod used in the experiment were reared in a pond in 1985, where they were conditioned with sound (as described below) to come to a feeding location (Folkvord et al. 1985). During the winter the cod were kept in net pens at Austevoll Aquaculture Station and in April 1986 they were transported by boat to Osen.

In the primary retraining period, which started on April 14, the fish were kept in an 80 m^3 net pen connected to a 16 m long raft. After 35 days, they were released into a 25,000 m^3 bay enclosed by a 110 m small meshed net. Here the training continued for another 35 days before the boundary net was removed. The experiment lasted for a further 5 weeks.

Food and feeding methods

The cod were fed with 5-7 mm commercially produced pellets, with a low-fat content (7%). During the primary training period the fish were fed by hand. After the fish were released from the net pen, feeding was conducted by a programmable logic system (Fig.1). The pellets were apportioned from a container, mixed with water and pumped through a pipe to the stimulus location, where they were spred by the current from a propeller mounted on the seabed (Fig. 1). Throughout the experiment the fish were fed four times a day (0900, 1200, 1500 and 1900), each feeding period lasting 10 min.



1. Automatic programmable logic system.
2. Signal generator and amplifier for the U.W.-loudspeaker.
3. Food quantity regulation.
4. Water level alarm.
5. Pellets container.
6. Water inlet.
7. Pellets and water to propeller.
8. Propeller.

Figure 1. The automatic feeding system used after the fish were released from the net pen.

Sound and conditioning

The cod shows greatest sensitivity to sound in the range 60 to 310 Hz (Chapman and Hawkins 1973). A pulsed 160 Hz sound signal, emitted by an underwater loudspeaker (University Sound, UW-30 Diatran), was therefore used to establish conditioned reflexes. The sound pulses lasted 160 ms, interrupted by pauses of 120 ms. The source level was 155 dB/μPa ref. 1 m. The signal preceeded the food presentation by one minute and continued throughout the feeding period. To secure high motivation the fish were fed to less than satiation. When feeding by hand, we stayed quietly 20 min at the raft before feeding to ensure that the fish were selectivly conditioned to the sound signal and not to i.e. the presence of the caretaker. In addition we performed irregular visits on the raft without feeding. Other sound sources, e.g. the propeller, were kept constant throughout the period.

Observation methods

To quantify the response to the signal, two 11^0 full beam width transducers were placed on each end of the raft, one meter below the surface. The signals from one of the transducers were transmitted and received by a 70kHz echo sounder. The fish echoes were integrated in seven preselected depth layers, five pelagic and two bottom-locked. The accoustic instruments were calibrated by using a standard target according to Foote et al. (1987). In addition, a Furuno 200 kHz echo sounder was used for mapping the fish distribution during feeding. Visual observations of fish behaviour were done from taped recordings taken by an underwater low-light video-camera (Fig. 2) placed below the observation raft.

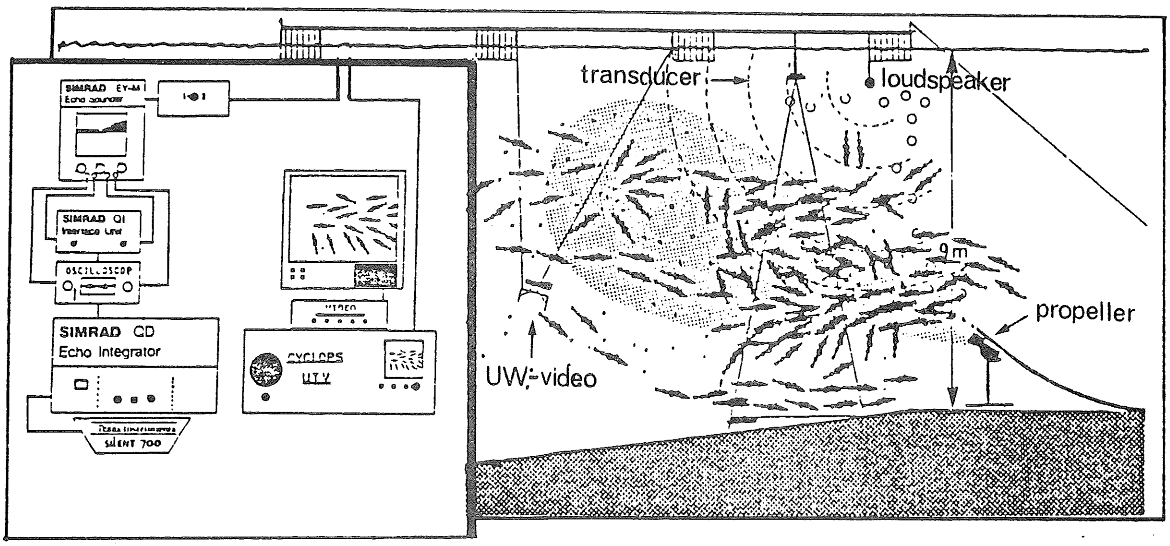


Figure 2. Observation equipment and rigging at the feeding location.

Telemetry

Three conditioned cod were captured in the second training period, anaesthetized with benzocain and tagged with ultrasonic transmitters (Mohus and Holan 1983) which were glued on carlin tags (Carlin 1955). Before release the fish were left undisturbed in a tank with good water exhange for two hours to recover.

Sampling

The echosounder was started 3 min before the feeding signal whereas the U.W. camera was started 1 min before and both remained on until 5 min after the feeding period. During feeding, the mean volume backscattering strength for each of the seven layers was printed with 36 sec intervals. During 24 hour observations, 15 min intervals were used. To control escapement during the second training period, trammel nets were set just outside the boundary net. Additional fish samples were also taken by hook and line from the observation raft and by trammel nets in the nearby area. Recaptures of the conditioned cod by local fishermen were registred through a release program with artificially reared cod, going on in the Austevoll region since 1982 (Svåsand 1985). Only the behaviour and a small part of the accoustic data and growth data are considered in this report.

RESULTS

Conditioning

During training in the net pen, the cod normally were distributed from midwater to the bottom during the day. They moved very slowly and showed no signs of schooling behaviour. Escape reactions, due to sudden changes in environment, e.g. passing boats, were diving and aggregation at the bottom of the net pen. When exposed to the conditioning signal for the first time, the cod showed similar escape reactions. These reactions ceased over the next four repetitions, and instead they formed a rapid swimming school near the surface. Tail beat frequency changed from 0.2 to 3-5 beat/sec. The schooling behaviour dissolved when feeding started. Once established, the conditioned reflex changed little during the training period. A starvation period of 30 h in the middle of this period reinforced the reaction - in fact, five of them jumped like salmon.

After being released into the enclosed bay, the cod spent 46 h adapting to the new environment and feeding method. During the first six days 29 conditioned cod were captured in trammel nets outside the boundary net. After ten days, the number of fish returning to the stimulus location seemed to stabilize. Small groups of 5-20 cod kept their pelagic behaviour from the net pen, while others became more demersal.

Feeding behaviour

When the sound signal started, the cod near the bottom ascended from the seabed and joined the others in a rapidly growing school. The school, consisting only of cod, circled around the feeding location up to 1 min. During the next minute the tightly aggregated school appeared slowly below the current lobe from the propeller (Fig. 3).

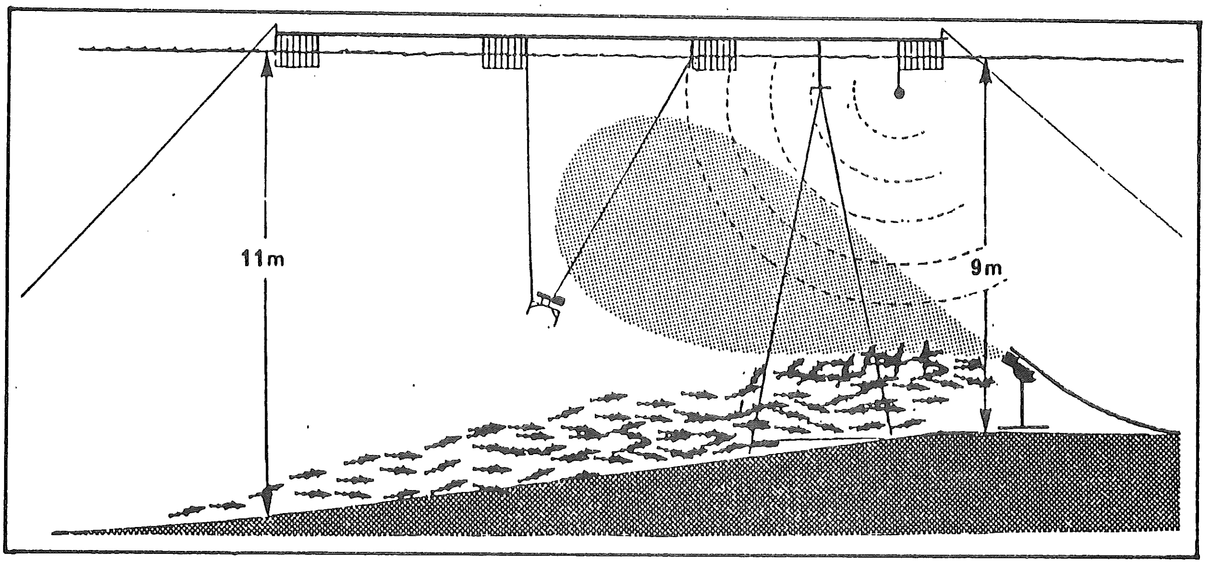


Figure 3. Soon after the soundsignal starts, the fish aggregate under the current lobe, waiting for the food.

When the pellets entered the current, the individuals near the pipe opening started feeding. They were now transported by the current together with the pellets 8-10 m backwards, immediately succeeded by others. When they reached the end of the current lobe, they dived, swam towards the propeller and repeated their feeding behaviour. This cyclic behaviour continued 2-3 min (Fig. 4). Later the pellets not eaten immediately, distributed over a larger volume and hence disorganized the initial cyclic behaviour. An echogram of the distribution of cod below the observation raft during feeding is shown in Fig. 5. When the feeding ended, most of the cod left the feeding location. However, some remained eating pellets off the bottom.

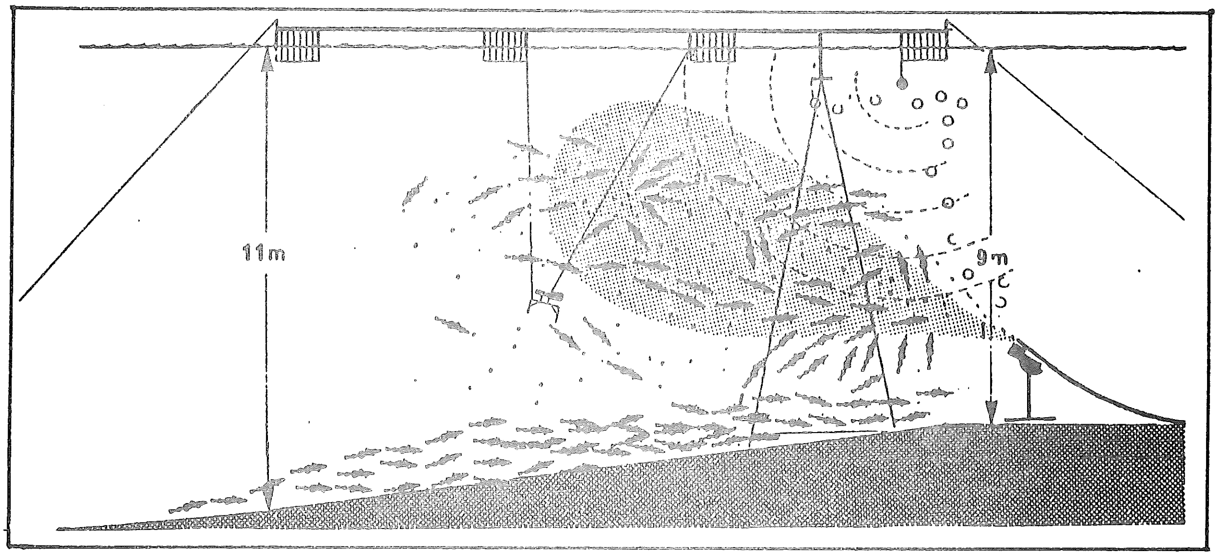


Figure 4. Immediately after the food arrives, the fish swim into the current lobe and start feeding.

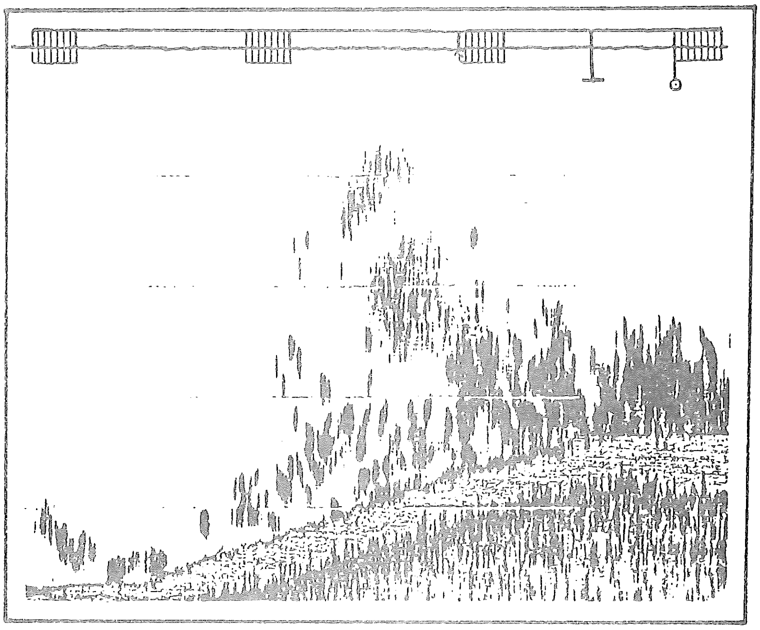


Figure 5. Echogram from a survey along the center of the observation raft. It was taken in the middle of one feeding period. The survey speed was 5 m per min, and the echoes describe the approximate distribution of the school.

The increase in fish abundance below the observation raft during feeding was also clearly reflected by the echo integrator output. Fig. 6 describes the changes in echo intensity during one feeding period, two weeks after the last boundary had been removed. The change after the sound signal has started reflects the conditioned behaviour. Typically, the highest value was reached shortly after the food had entered the current lobe.

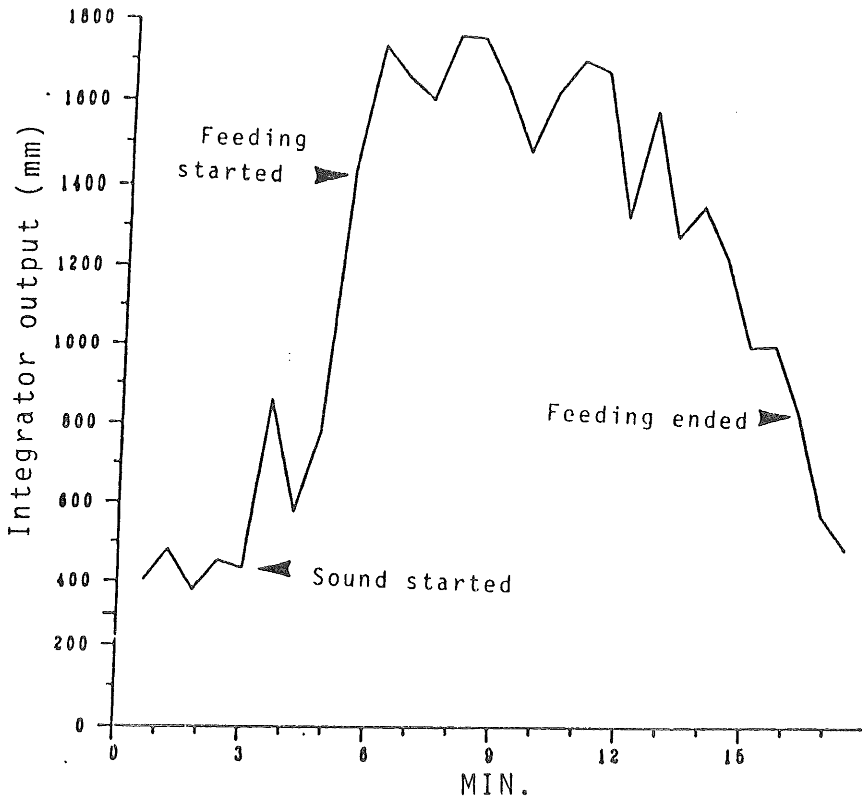


Figure 6. Variation in echo intensity in front of the feeding pipe during one feeding period.

Telemetry

The three fish tagged with ultrasonic transmitters were released into the enclosed bay, 5 min before feeding. The tagging did not seem to affect their response to the conditining signal. Two days after tagging the last boundary was removed. At least once a day, hydrophones were used to track the tagged fishes. During daytime they spent most of their time near the stimulus location (< 100 m), but were occasionally found upto 400 m away. During the night their activity was much lower, and in two successive nights the tagged cod remained at the same spot 15 m from each other from 11 p.m. to 4 a.m. This rhythm was also typical for the 24 h accoustic observations taken during the experiment (Fig 8).

To see if these results were representative, seven trammel nets were set close to the edges of the distribution area of the tracked fish, but none of the other conditioned cod were caught.

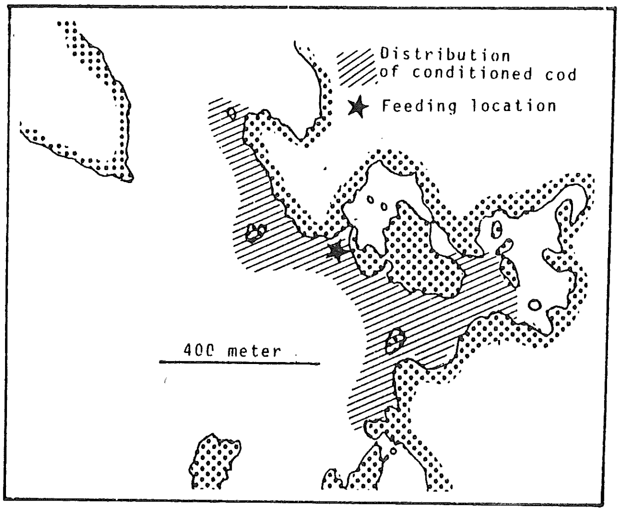


Figure 7. Distribution area of three cod tracked by telemetry during three 24 h periods.

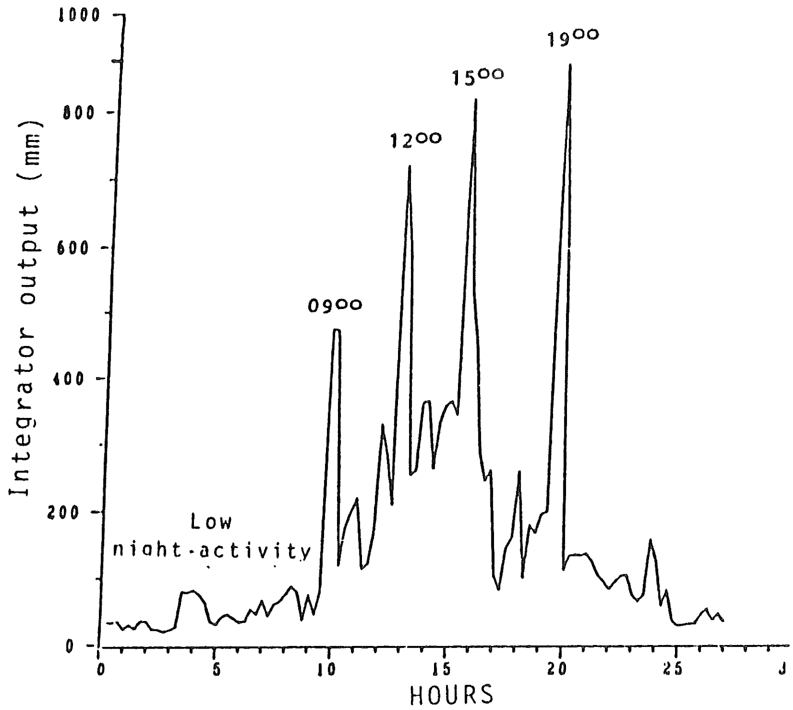


Figure 8. Mean echo intensity in each 15 min period in front of the feeding pipe during 24 hours.

Growth

All cod were measured and weighed March 10 , before transfer to the net pen at the experiment location. Mean length and weight were 23.0 cm (s=3.1) and 137 g (s=66). A sample of 20 cod taken by small meshed trammel nets at the end of the experiment (August 01) had a mean length of 30.8 cm (s=2.6) and a mean weight of 395 g (s=73). The corresponding daily lenght increment (DLI) and mean specific growth rate were 0.55 mm/day and 0.7% /day. DLI of 33 conditioned cod caught by local fishermen during the last part of the experimental period was 0.63 mm/day.

DISCUSSION

The results from this experiment show that cod can easily be trained to associate a feeding location with underwater sound pulses, and that it is possible to aggregate free-ranging cod by use of simple conditioning techniques, at least within a distance of 400 m from the stimulus location. Similar experiments earlier done with saithe (Olsen 1974) and red sea bream (Fujiya et al. 1980), indicate that these techniques also can be applied on other species. In Oita Prefecture, Japan, free-ranging red sea bream is ranched in a commercial scale by use of conditioning (T. Obayashi, Oita Prefectural Office, pers. com.).

The major problem of applying this technique to fish farming is to prevent escaping or loss of fish from the feeding area. In this experiment the change of environment was a critical period. After being released from the net pen to the enclosed bay the cod did not react to the feeding signal during the first 46 hours. Trammel net catches outside the boundary net proved that fish had escaped from the bay. During the experimental period 16 of the conditioned cod were caught by local fishermen between 0.5 and 5 km from the feeding location. They had evidently escaped from the experiment. The video observations showed that several hundred cod returned to the feeding location after the boundary was removed, but it was impossible to give an accurate estimate of the number.

Samples taken in the feeding area after the last boundary was removed, revealed a secondary conditioning of parts of the local wild fish populations. About 25% of the cod returning for feeding were "wild", and also other species such as saithe and pollack adapted the conditioned behaviour. The wild cod may compensate for the escaped cod, but high concentrations of other less valuable species may be a problem by taking a large part of the given food. The portion of natural diet in addition to the dry pellets is also of importance to the economics in a system like this.

We think the results are very encouraging, but the procedures tested here can obviously be improved. We hope to develop the methods of conditioning and releasing over the next years.