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Halibut behaviour as a means of assessing suitability of ongrowth systems

Jens Chr. Holm, Stig A. Tuene and Jan Erik Fosseidengen

Institute of Marine Research, Austevoll Aquaculture Research Station, N-5392 Storebø Norway

Halibut behaviour in net pens has been studied using direct observation, underwater video and/or hydroacoustic equipment. Rearing experience includes a wide range of fish weights (50-10.000 g) and fish densities (4-150 kg/m^2).

Individual halibut is able to change their coloration on the ocular side from their white-spotted benthic camouflage to the uniformly brown-grey pelagic camouflage within a minute and vice-a-versa. The proportion of fish with pelagic camouflage on/near the bottom was high in the net pens with high densities, and such groups also showed suboptimal growth. The results also indicated an increase in pelagic swimming activity in the net pens with the highest densities. High light levels and low temperatures decreased the pelagic swimming activity of the fish. Halibut in net pens reared at low densities did not spread evenly on the bottom, but were usually found in clumps.

Introduction

In the last 20 years, aquaculture research in Norway has included Atlantic halibut. Contrary to Atlantic cod, which also has been an object of aquaculture investigation in the same decades, basic biological knowledge was almost absent when the halibut research was initiated. In the early 1970s, the first attempts to rear Atlantic halibut were conducted by the Institute of Marine Research (Solemdal et al. 1974). The first comprehensive review of Atlantic halibut ecology was published as late as 1990 (Haug 1990).

Most ongrowth operations of Atlantic halibut is expected to start with fish of at least 100 g size. Atlantic halibut weighing more than 20 kg may double their weight within a four- or five-month period, providing a 0.5% daily weight increase (Haug et al. 1989). If future market demands for halibut will be less than 10 kg, the fish's natural growth potential will not be fully exploited. With improved rearing procedures in the future, expected growth rates for fish between 100 g and 5 kg should be at least 0.5% per day in a 26 month production period (Holm et al 1995).

Several methods for ongrowth technology have been - and are currently - tested. On shore, both traditional tanks and modular systems have been used. So far, most of the offshore systems have been modified Atlantic salmon net pens. However, growth rate in large groups of net pen raised halibut has not fulfilled the 0.5 % daily weight increase expectation. This paper try to describe some of the problems connected to cage rearing of halibut, and to suggest how some of these can be solved.

Material and methods

This paper is based on observations from different tank and cage experiments with juvenile and adult Atlantic halibut carried out the last 8 years. Standard halibut cages, i.e. standard salmon net cages with a stable bottom panel attached underneath, were used.

The main experiment was carried out in four cages of 12 x 12 x 5m. The experimental period lasted 132 days and started 13 September 1996. Sea temperature at 5m depth varied from 14.5 C (September) to 5.8 C (January).

The experimental fish (1994 yearclass) origined from wild caught brood fish, and was stocked according to Table 1. The fish was tended and fed in surplus by a commercial fish farmer.

Table 1: Experimental set-up in main experiment lasting 132 days from 13 September 1996. Densities are calculated according to a realistic cage bottom area of 120 m^2. Bottom coverage are calculated from formula in Björnsson (1994).

Group no	No of fish	Mean weight (g)		SGR (%/d)	Density (kg/m^2)		Bottom coverage (%)	
		start	termination		start	termination	start	termination
1	6000	1000	1248	0.17	50	62.4	263	301
2	4000	1000	1346	0.23	33	44.9	175	210
3	4000	1200	1547	0.19	40	51.6	196	227
4	6000	1200	1394	0.11	60	69.7	293	321

Acoustic backscattering within the halibut cages was observed with a hydroacoustic system, «Merdøye» [Cage-eye], operating at 50KHz (Lindem Data Acquisition, Oslo, Norway). An acoustic transducer with a 42° beam width was positioned under the centre of the cage bottom, transmitting towards surface. Echo energy at 0.5 m depth intervals was integrated and average values (n=48 pings) were stored every minute throughout the day in a PC.

Video observations were obtained in selected periods, while visual observations were obtained daily. Physical conditions (water temperature, wind, light, weather), swimming activity and appetite was monitored twice a day in all cages.

Results

Atlantic halibut can use a large repertoire of skin coloration on it's ocular (right) side. When oxygen saturation is low, or water content of nitrogen or carbon dioxide are too high, the coloration of head and anterior parts become significant darker. If this stressor are maintaining or increasing it's impact, a majority of the ocular surface can become dark.

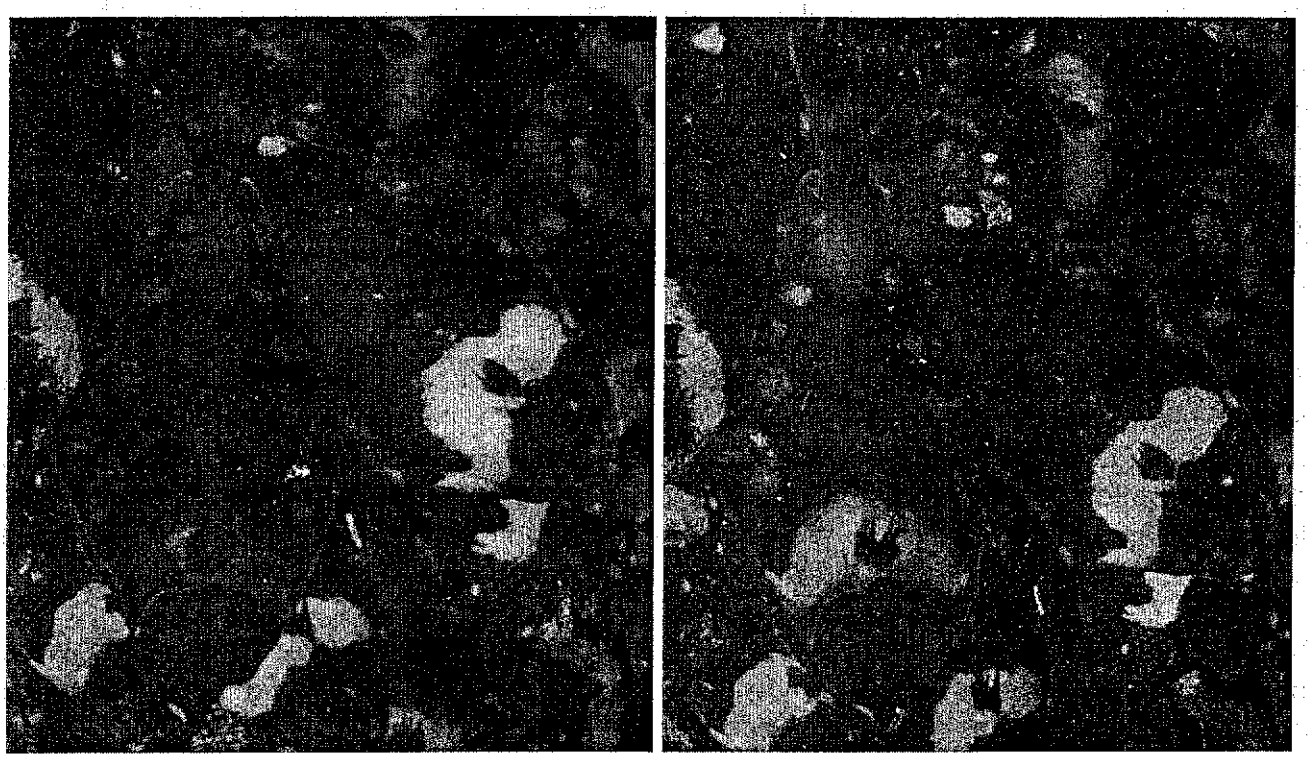

Fig.1: Benthic and pelagic camouflage in juvenile Atlantic halibut. The pictures show the same two fishes. The right picture is taken 60 seconds after the left one. In the left picture, please note the greyish fish without distinct white spots with head downwards covering most of the left half of the picture. This individual was swimming some seconds ago, and has just established contact with bottom. Still the swimming colouration is displayed. The other individual at the right side (body axis oriented 4 o'clock) on the left picture displays a distinct bottom camouflage. This benthic coloration is characterised by a distinct arc-shaped white band posterior to operculum, including the area of pectoral fin base. The camouflage includes 5-6 white spots at dorsal and anal fin base. The pelagic camouflage is brown-grey. At the right picture, bottom camouflage is developing in the left fish, but is still less pronounced compared to the other fish with longer benthic contact.

When fish is swimming, a brown-grey pelagic camouflage (Fig 1) will appear within a minute. This coloration is lighter than in a severe stressed or blinded fish. The benthic camouflage is characterised by a distinct arc-shaped white band posterior to operculum, including the area of the pectoral fin base (Fig 1). The camouflage includes 5-6 white spots at dorsal and anal fin base.

Halibut in cages prefer to rest at bottom when satiated or undisturbed (Fig 2 left). In small densities, fish tend to clump under each other. Even under high densities, fish will not tend to distribute evenly over the whole bottom area. Aggregating individuals on bottom show almost always a distinct bottom camouflage and no stress signs. If density is increased, an increasing number of individuals will start to swim.

The density-dependent activity was demonstrated in a 5 x 5 x 5 m gages stocked with 550 ind of 1kg November 1997. The fish started to increase it's activity June 1998. From mid-July about 150-200 fishes were constantly swimming (including «whooping, Fig 3). The fish was transferred to a 12 x 12 x 5m cage 29 July. The fish changed it's behavour momentarily , and have until 14 August (today) shown a behaviour like those in Fig 2.

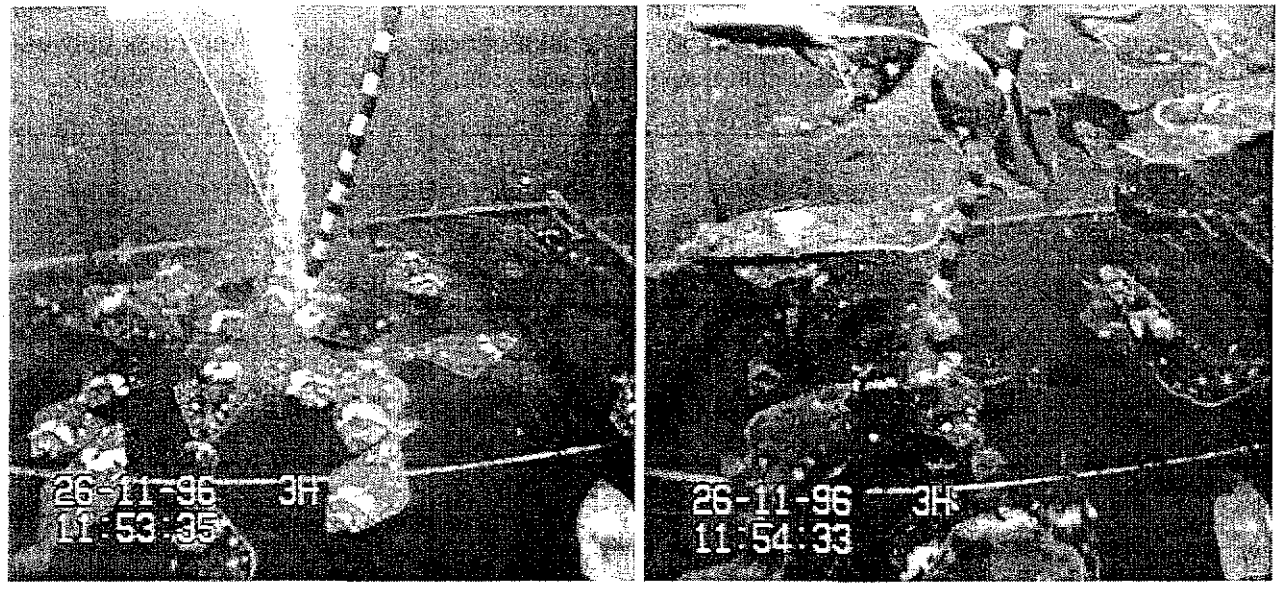

Fig 2: A small group of juvenile halibut resting on the bottom panel in a 5 x 5 x 5m cage (left). Most of the individuals show distinct bottom camouflage. The white rope in the lower part of the video image indicates how much the bottom panel is stretched. A feeding tube (marked with white and black bands) introduces air bubbles and water near bottom in the centre of the cage. Some saithe can be seen as black shadows underneath the cage corner. Date and time code in left bottom corner of the image. Feeding in the same group of halibut shown is shown in the right picture. Feeding started 50 seconds before the right picture. Camera position was identical. The feed pellets are positively buoyant, and some particles are seen as white spots to the left and over the mouth of the feeding tube. Most of the fish show partly faded bottom camouflage.

Vertically, fish distributed in the available water column in the main experiment, normally with a denser shoal 1.5 - 2.0 m thick near the bottom. Horizontally, fish will normally swim both clockwise and counter-clockwise. Fish tend to aggregate not more than 1.5 m away from the vertical panels. The mean numbers of fish swimming in the 60-70 m^2 area near the side panels were always higher than the numbers swimming in the 80 m^2 centre feed dispersal area (Table 2). The fishes near the vertical panels were swimming both prior and after feeding periods, while those swimming in the middle, were almost absent both before and after he feeding sessions.

Table 2: Behavioural scores (for halibuts swimming at 0-2.5m water depth not more than 1.5 m away from side panels, denoted «side» and for fishes in same vertical position in the rest of the cage, denoted «centre») from the main experiment. Behavioural scores ranged from 0 to 4: score 1= less than 0.2% of stock swimming, score 2: 0.2-2%, score 3: 2-10% and score 4: more than 10%. Centre swimming are the fish' appetite response since all the registrations were carried out during first automate feeding period (08:00 -10:00, feed dispersal area in the middle of the cage). Asterisks denote significant differences between the two temperature intervals within a specific cage group (Student's t-test, $p<0.05$).

Temperature interval (C)	Side swimming in group no 1	2	3	4	Centre swimming in group no 1	2	3	4
6.0 - 7.9	2.8	2.6	3.0	3.5	1.8	1.6	1.5	1.7
13.0 - 14.9	3.1	2.8	3.4 *	3.7	1.9	2.7 *	2.8 *	3.2 *

Except for group 1, a relative higher activity in the area near the side panels was observed when low was compared with high temperature (Table 2).

In cages with densities higher than groups 1 to 4 (e.g. 100 kg/m^2), an increased number of fishes breaking the surface («whooping») has been observed (Fig.3). The same behaviour was observed in groups 1-4 later in the autumn. Contrary to the standard horizontal swimming described above, surface-breaking fish are clearly tilted upwards, most of the mouth opening in the air. The fish tend to spit water due to the combination of opercular movements and collapse of the membrane in the mouth cavity normally preventing water from emerging through the mouth.

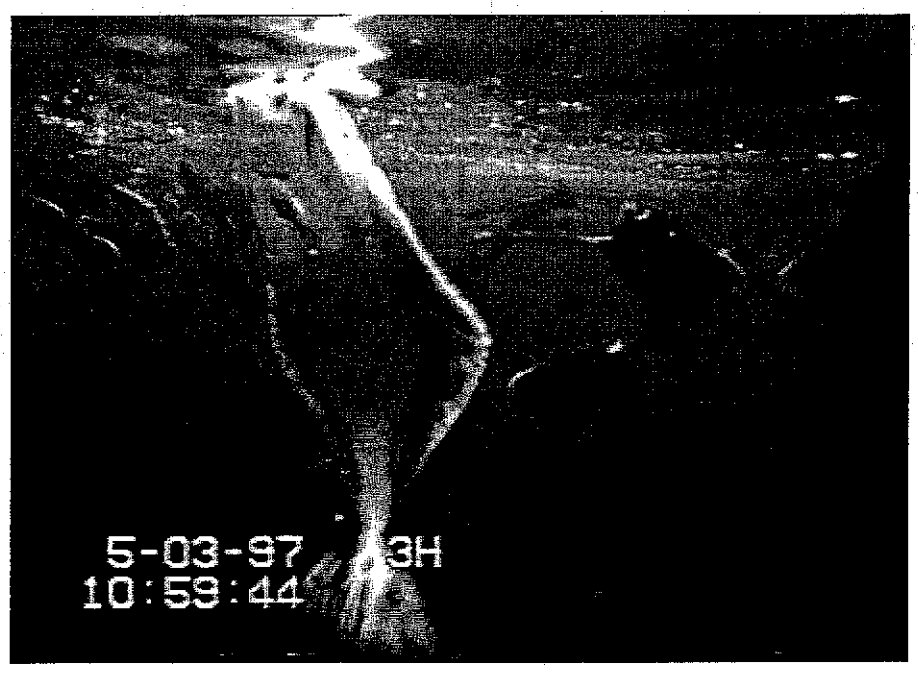

Fig 3: Slow swimming Atlantic halibut (size 3-5 kg) in a 12 x 12 m net cage of 6 m depth. Camera at 1 m depth with a slightly positive angle. Nearest individual seen from the blind (left) side. Parts of the mouth opening is above surface. Water temperature at 1m depth was 5.9 C.

The numbers of «whoopers» in the main experiment was near to 0 until 25 November (Day 0 to 74), in the same period when water temperature at 5m depth exceeded 8.0 C). The number of surface-breaking individuals varied normally between 1 and 5 % of cage population during the rest of the period (Fig. 4).

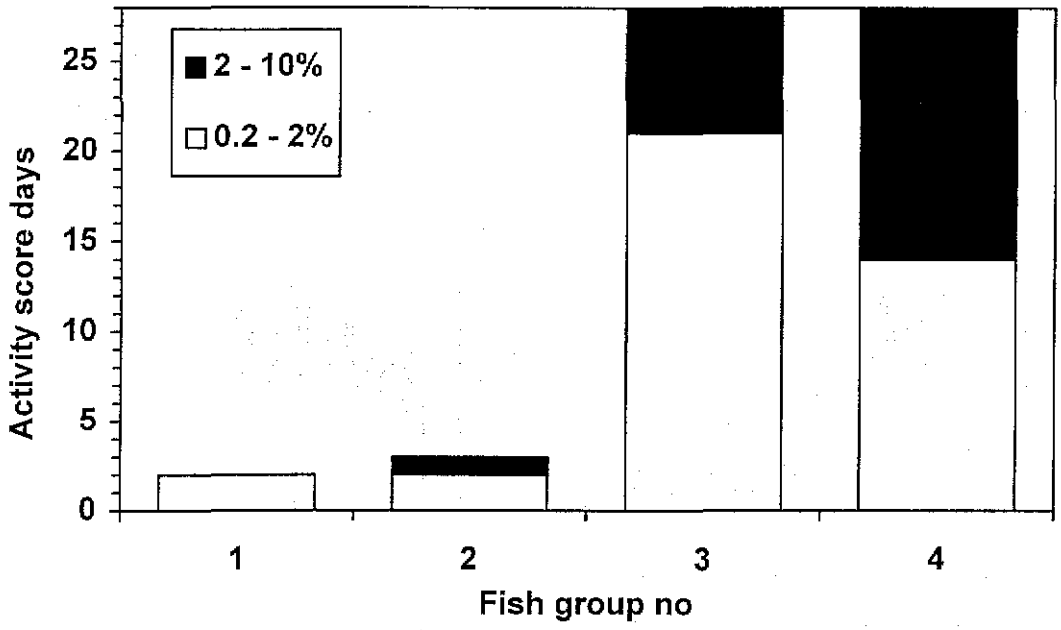

Fig 4: The fraction of the halibut populations breaking surface («whooping») last 58 days in the main experiment. A total number of 28 observation days are included in the figure.

The total swimming activity at 0 - 2.5 m depth was higher on cloudy than on sunny days (Fig 5).

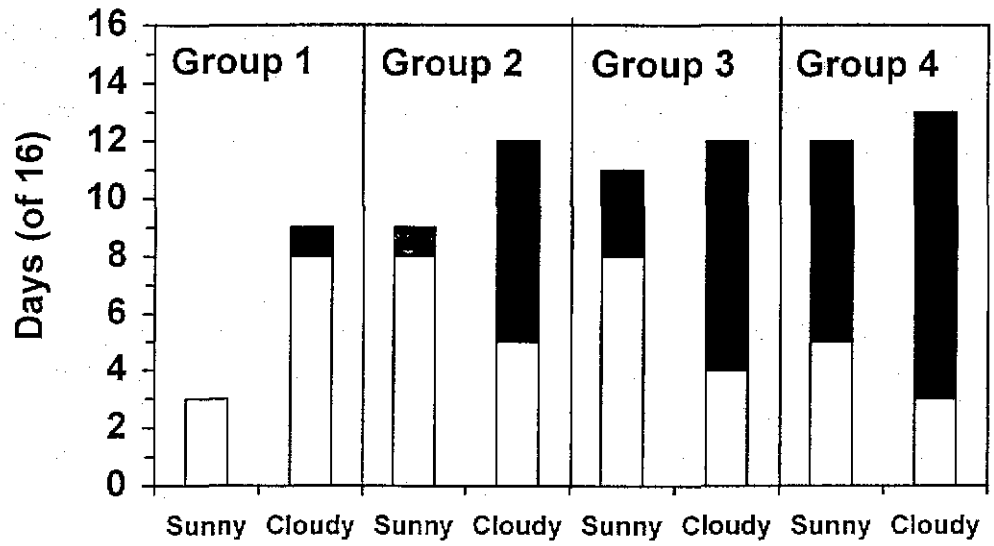

Fig 5: Horizontal swimming activity at 0 - 2.5 m water depth in Atlantic halibut. Data were obtained from visual observations at 16 distinct cloudy and 16 sunny days at the end of the experiment. Bars indicate number of days were more than 2 % (more than 80 - 120 ind.) of the cage population were swimming at water depths less than 2.5 m. Solid part of the bar indicate days were more than 10% of the population (more than 400 - 600 fish) were positioning themselves in the same volume.

Atlantic halibut tend to show a nocturnal swimming activity (Fig. 6). Low light levels seem to induce higher swimming activity, both in the upper water column (Fig 5), both also swimming in general (Fig 6). Addition of artificial light seems to suppress this increased swimming activity (Fig 6). The addition of extra light during daytime have no significant effects on swimming activity.

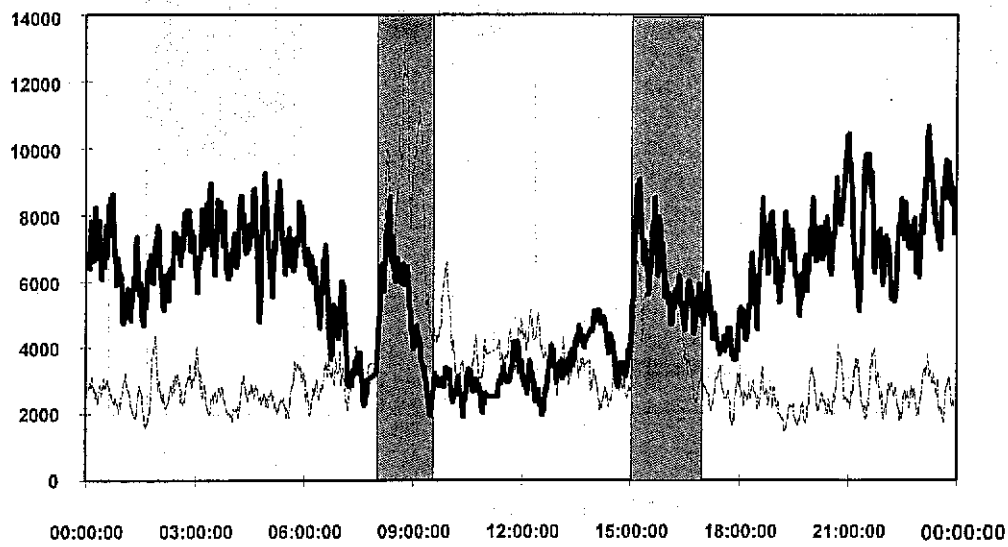

Fig 6: Acoustic reflection (ordinate) in two 12 x 12 x 5m net cages containing 2+ Atlantic halibut during 08 November 1996. One group received additional light from surface (thin dotted line), other was subject to ambient light conditions (thick solid line). Shaded areas are feeding periods (Sunrise 09:23, sunset 17:21).

Response to feed in Atlantic halibut vary. The clear response seen from pictures in Fig 2 as well as in Fig 6 is not observed frequently. The behaviour described by Fig 2 is related to superior growth rates. Often fish tend to show weak or absent responses to feed, especially when feed pellets sink rapidly to bottom without no further movements.

Discussion

The two types of camouflage observed can both be a defence against predators, but will also help the halibut as a predator itself. The benthic camouflage will be favourable for capturing small prey by visual fixation (e.g. Olla et al. 1972) as well as more ambush hunting in general. Both the dark opercular as well as the light blind side in the pelagic camouflage will increase the probability that the halibut detects prey first.

The clumping at bottom is observed in several flatfishes held in captivity. It is proposed that this is a surrogate for the behaviour for burying itself in sand (Honda 1988). Different kinds of bottom substratum might alter the tendency of unevenly distribution.

Increased swimming activity seems to relatedto both fish size and bottom coverage. Differences observed, both in main experiment as well as between fish in main experiment and larger fish under comparable conditions, might also be related to an expected shift in

search behaviour. Small individuals (less than ca 300g) feed mainly on benthic crustaceans, while larger halibut tend to be more and more piscivorous (Haug 1990).

Metabolic demands increase with body size (Brett and Groves 1979), as well as an increased foraging capacity is expected due to increases in perceptive, digestive, locomotor and capture capacities (Persson and Diehl 1990). Swimming speed is shown to be related to hunger level in Atlantic salmon (Juell 1993), and similar is expected in Atlantic halibut. Decreased risk of predators related to size might also influence upon swimming activity.

The decreased swimming activity related to low temperatures is probably a result of decreased metabolic demands. The decreased feeding activity support this, as well the observed seasonal changes in feeding intensity (McIntyre 1953).

The part of swimming activity resulting in contact with surface («whooping») is related both to temperature and size. Large fish at low temperature tend to have the highest incidence of «whoopers». The behaviour might be a modification of horizontal swimming. Since temperature decrease the swimming activity, it might also decrease the swimming speed, either directly or via altered metabolic demands. The halibut has no swim bladder, and is dependent on a hydrodynamic lift in order to maintain a vertical position. If swimming speeds decrease, the fish has to tilt it's body in order to maintain direction of the vector. At low densities, fish remain at bottom under low temperatures, but in the main experiment bottom coverage was over optimum (Björnsson 1994), and a large fraction was forced to swim. With an extreme body tilt angle, halibut loose their visual orientation and are aggregating in the corners and along side panels as observed.

High swimming activity in non-feeding periods is a practical indicator on too high rearing densities.

The lack of feeding response is sometimes characterised as an anorectic condition. If temperature is under 6C, feeding activity are almost absent in halibut. However, in higher temperatures, halibut is still hard to feed efficiently. In a group of halibut with a mean size of 422g held in tanks at 8-10C, Tuene and Nortvedt (1995) observed that no individual fed all 18 days feed were offered. The mode number of consumption was 12 days, while 12% of the individuals fed on fewer than 7 days, and they generally had low feed intake.

If the halibut is more dependent on prey motion in order to release feeding behaviour than earlier expected, this might explain some of the difficulties. If a natural size-dependent shift in feeding behaviour occurs, individuals in a group of halibut might have differences in which stimuli that release feeding behaviour. Feeding technology may also be modified if a shift occurs. The visual impression of the feed particle may be too different to natural food items, so that feed pellet coloration, buoyancy, shape etc. must be modified. In dense farming populations, modification should aim to improve the chasing behaviour of pelagic halibut.

The presence of light with intensities above a certain threshold and low bottom coverage seem to keep the fish at bottom, and ensure strong feeding response slightly over the bottom. Too high densities and/or to high swimming activity seems to reduce the feeding efficiency and/or feed retention.

Implications for ongrowth systems

If possible, the bottom area available to each individual must be kept at levels probably as those recommended by Björnsson (1994). Densities could be kept low (100-200% bottom coverage) or extra horizontal panels can be added in the net pens. Efficient feeding as well as removing dead or diseased halibuts are problematic in cages with extra horizontal panels. Changing nets due to fouling should be taken into consideration when designing halibut cages.

Possibilities of suppressing energy-demanding swimming during non-feeding periods should be investigated.

If distinct corners are avoided in the net pen design by the use of octagonal or round surface area the probability of aggregation of surface-swimming halibuts will be lowered. This is especially important for large fish and low temperatures.

Feed and feeding systems that allow shifts in feeding behaviour should be investigated. Feeding halibut up to ca 300g in tanks with a sinking pellets are slightly favourable compared to floating pellets, and the smallest fish have the largest advantage of a sinking pellet (Nortvedt and Tuene 1995). Larger fish can probably be given a positive or neutrally buoyant pellet of relatively large size, more similar to natural prey. A floating pellet must be offered near the bottom of the net pen.

The possibilities of feeding the halibut efficiently at low light levels should be further investigated.

Acknowledgement

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