Atlantic halibut - *Hippoglossus hippoglossus*

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Biology, ecology and genetics

Distribution

The Atlantic halibut is distributed throughout the northern part of the Atlantic Ocean and in parts of the Arctic Ocean (Fig.1) (1). The species is particularly abundant along the Norwegian coast, the Faroe Islands, Iceland, and southern Greenland. It may also be encountered in the North Sea and the western part of the Baltic Sea. Along the east coast of North America, the halibut is distributed from Hudson Strait southward to the southern Grand Bank and St. Pierre Bank.

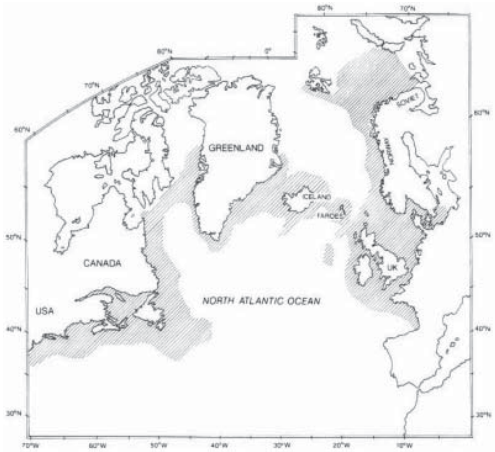


Fig. 1. *Distribution of Atlantic halibut (hatched areas) in the North Atlantic (1)*

Capture

The Atlantic halibut has been an attractive species for European fishermen, and high fishing intensity has resulted in depletion of stocks in several areas (2). The capture of Atlantic halibut in Europe has declined from an all time high of 10 000-15 000 tonnes in the period 1950 to 1965, to less than 2 000 tonnes in 2004 (3). In 2004, the main countries fishing for Atlantic halibut were Norway (1,034 tonnes), Iceland (574 tonnes), Faeroe Islands (497 tonnes), and United Kingdom (251 tonnes).

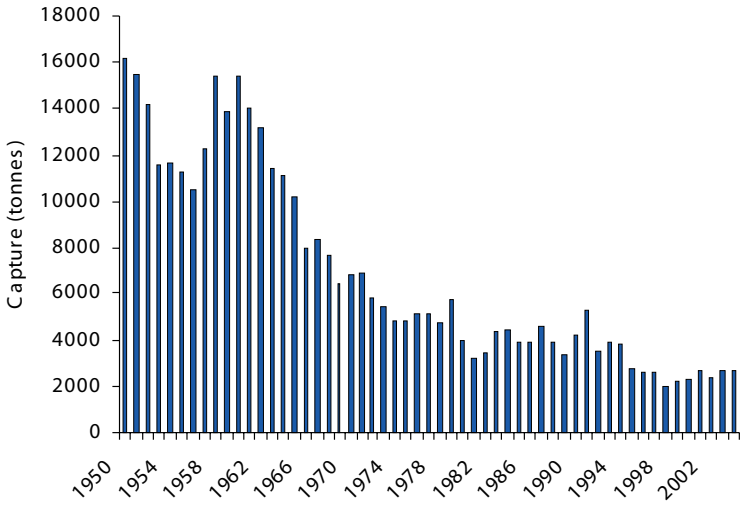


Fig. 2. *Capture of Atlantic halibut in Europe (3)*

Biology

The Atlantic halibut is a long-living flat fish that may exceed weights in excess of 250kg. Spawning occurs in deep water (300-700m) in the period December to March, although peak activity is generally observed in January and February. The early life-history stages of the Atlantic halibut in the wild are poorly understood, however, it is known that both the planktonic eggs and larvae may drift significant distances with ocean currents. After metamorphosis juvenile halibut adopt a benthic life-style. Coastal areas with depths of 20-60m often serve as nursery areas before the halibut undertake migrations to distant areas, both shallow and deep waters. The species displays sex-dependant growth rates where males attain sexual maturity at a younger age and smaller size than females. In a study of maturation age in the Faroe Islands in the 1980s, the average age of sexual maturation in males was estimated at 4.5 years, 55cm and 1.7kg, whilst in females it was 7 years, 110-115cm and 18kg (2). However, age at first maturity displays individual, temporal and spatial variation. After spawning halibut leave the spawning grounds and may be found in deep and shallow waters, both inshore and offshore. The Atlantic halibut is a batch spawner and may release eggs every 3rd day for up to 15 batches in any given spawning season.

Population genetics

Early tagging experiments demonstrated that mature Atlantic halibut return to the same spawning site over repeated spawning seasons (2). Such observations lead to the suggestion that the species may display population genetic structuring (4). Evidence from biochemical genetic studies has revealed either a lack of or only weak evidence of population genetic differentiation between geographically distinct samples (5, 6, 7, 8). A more recent study utilising highly polymorphic microsatellite DNA markers revealed a lack of population genetic structuring (9). However, this study utilised small sample sizes and considered only a limited geographic area. It is possible that as is the situation for other marine species, a greater number of polymorphic markers and more intense sampling may illustrate population genetic structuring in this species. Until such a large-scale study has been conducted, it is not possible to draw any conclusions regarding the population genetic structure of this species.

Certain traits that may be under quantitative genetic control (e.g., growth, timing of spawning) show phenotypic variation among halibut collected from geographically distinct locations. For example, earlier spawning is generally recorded in Atlantic halibut in northern Norway compared to southern Norway. However, the biological significance of such variation, and the relative importance of genetics and environment on these differences are not known. Consequently, it is at present unclear as to whether or not the Atlantic halibut displays local adaptation or not.

Breeding and culture practices

Production

Experimental aquaculture of Atlantic halibut was initiated in Norway and Iceland in the mid 1980s, however, it was not before the late 1990s that significant commercial production was realised.

	1998	1999	2000	2001	2002	2003	2004	2005 (provisional)
Norway			100	100	100	500	500	500
Iceland		453	5	189	250	250	250	300
UK	20	50	30	100		95	105	105
Total	*20*	*503*	*135*	*389*	*350*	*845*	*855*	*905*

Tab. 1. *Halibut aquaculture production (in tonnes) (10)*

Whilst yearly production fluctuated in the period 1998-2005, there has been a general increase, and at present approximately 1 000 tonnes is produced by aquaculture on a yearly basis within Europe. Norway is the primary producer of Atlantic halibut followed by UK and Iceland. It is likely that within the next decade, aquaculture production of Atlantic halibut will overtake wild capture.

Due to its good taste and limited availability, Atlantic halibut is often regarded as an exclusive product with prices that reflect this. Whole fish can reach market prices of 10-15 €, making it an economically attractive species for further aquaculture development.

Hatchery practices

Broodfish used for gamete collection are most often wild caught individuals that are kept in captivity. Whilst some high performing F1 individuals are also used for gamete collection, a practise that varies greatly from farm to farm, and country to country, the majority of juvenile production still arises from wild broodfish.

Ripe females kept in large shallow tanks are coaxed onto stripping boards that are often neoprene covered to protect the slime layer. Eggs are stripped into jars and fertilised externally with sperm from 1-3 stripped males. The process from incubation to weaning is best carried out at approx. 6ºC although temperatures between 3-8°C are tolerated for this phase. Eggs are incubated in the dark in cylinders where they are suspended in the column through continuous flow of cooled and preferably often sterile salt water. After approximately 2 weeks (82 degree-days), eggs hatch and the resultant yolk-sac larvae are transferred to larger incubation silos which may vary between 1 and 15 cubic meters. Start-feeding has historically been the major bottleneck in halibut juvenile production where in excess of 75% mortality at this stage was common in early attempts. Both semi-intensive and intensive feeding methods have been utilised although intensive methods are almost exclusively used at present. Light quality and strength was demonstrated to be of significance in addition to quality of Artemia to feed upon. Addition of algae and zooplankton to the tanks has also increased survival during this critical phase. After metamorphosis where the larvae become fry and the left eye migrates to the right eye, the halibut will often seek the bottom of the tank. At this stage they can be reared in very

shallow flat-bottomed tanks that are either round or long with water inlet at the top end. They are gradually weaned onto commercial feeds and reared in this manner until approximately 5g.

Grow-out

From 5g to approximately 30-50g the halibut continue to be reared in shallow land-based through-flow tanks fed with commercial diet. At this stage halibut can be transferred to adapted marine cages which have flat bottoms with tight mesh so that they can rest on them. Some cover may be required for these relatively shallow cages in order to avoid fish from becoming sun burnt. Size at slaughter is preferably over 5kg although 3-5kg fish are also marketable. Grow-out usually takes 2-4 years of cage rearing.

Selective breeding

The life-cycle for Atlantic halibut was first closed in culture in Norway in 1992/93 when offspring from the 1985 year class were first used for breeding at the Institute of Marine Research Austevoll research station outside Bergen. However, despite the life-cycle having been closed since the early 1990´s, at present the majority of halibut production is still based upon wild captured individuals being used as broodstock. No systematic selective breeding programme for Atlantic halibut is in operation in any country in Europe, although this topic has been addressed on several occasions, most recently in a Norwegian meeting run by the Norwegian Flatfish Forum (March 2006).

In a recent experimental breeding project funded by the Norwegian Research Council, 22 family groups were produced in 1997-1998 (11). In this study, family survival rate varied from 50 to 84,6% and between 30 and 78,8% for the 1997 and 1998 year classes respectively. Mean weight varied from 1.0 to 1,6 kg at ca 3½ years for the 1997 year class and from 0.4 to 1.1 at 2½ years age for the 1998 year class. The significant differences in both growth and survival suggest additive genetic variation for these traits. This has the potential for exploitation in a future commercial breeding programme. Although a breeding plan has been designed for Atlantic halibut in Norway (12), there is first a need for more knowledge about the spawning process of halibut in order to obtain a more stable egg quality and control maternal effects.

A small and initial breeding programme has been conducted on the West Atlantic (Canada). An attempt to establish a low cost breeding programme for halibut in Scotland without rearing families separately until tagging failed due to too big variation in survival of different family groups, with a consequently low effective population size and increased inbreeding rate (13).

Concentration of research on other production-limiting factors such as weaning, diet and pigmentation problems have received a greater focus than establishment of halibut breeding. However, it is likely that a selective breeding programme will be initiated in the near future.

Interaction studies

At present, there are no available data on the number of farmed escaped halibut in the wild. However, due to the fact that many halibut are reared in land-based facilities where escapement to the wild is either difficult or impossible, and the level of production is still low, it is likely that there are few farmed escapees. No scientific

studies investigating the numbers of escapees, and genetic or ecological interactions of potential escapees in native stocks have been conducted. Furthermore, no studies have been carried out looking into the potential genetic or ecological differences between cultured and wild Atlantic halibut.

Due to the fact that aquaculture production of this species is currently based upon collecting gametes from wild captured adults that are not the product of a selective breeding programme, it is likely that the genetic differences between the F1 farm progeny and wild individuals is limited. However, it is predicted that the genetic difference between wild and cultured Atlantic halibut will increase if a selective breeding programme for this species is successfully implemented.

Conclusions/Implications

Throughout most of its range, the Atlantic halibut has already been heavily exploited through over-fishing, and it is likely that this leaves the species in a vulnerable state with respect to potential impacts from escapees from halibut culture or further exploitation. At the present level of aquaculture production however, and with the use of wild caught broodstock for gamete collection, it is likely that genetic impacts of escapees on wild populations are minimal. However, this topic has not been studied, and this situation may quickly change if a selective breeding programme for this species is initiated and the level of production increases.

Clearly, in order to be able to predict or understand the potential genetic interactions between farmed and wild Atlantic halibut, a significantly better understanding of its population genetic structure and potential fitness-related genetic differences this may give rise to, is required. Furthermore, a better understanding of the biology and ecology of the halibut in the wild, especially with respect to the early life-history stages, is required.

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