EPSILON
AQUACULTURE LIMITED

The Halibut Hyperbook®

Just press "Esc" on your keyboard at any time if you want to leave this Hyperbook show

PRESS FOR NEXT PAGE

HOW TO USE THIS HYPERBOOK

Navigating around this Hyperbook is easy:

- **If you just want to proceed to the next page, simply "left click" on your mouse**
- **If you want to use a "hyperlink" to jump to another part of the book, position your cursor over the appropriate button or text (a pointing finger symbol will appear), and left click**

- **You can practice this here**

- **Try clicking on this button**

- **When you are ready, proceed to the Main Menu page (click on this button)**

You have completed your first “hyper-jump”

Click on this button to return

MAIN MENU

THE MAIN SECTIONS OF THE HYPERBOOK

(Press the appropriate action button)

- Introduction to halibut cultivation
- The markets
- The production process
- The technologies and equipment employed
- Site selection
- Legal and administrative issues
- Suppliers
- Business planning

Useful internet links

NOTE: This is the "Main" home page - you can return here from anywhere by pressing the blue house symbol

USEFUL INTERNET LINKS PAGE

This Hyperbook contains several “pages” which have links to useful or interesting web-sites. These are mainly located in the LEGISLATIVE and SUPPLIERS sections.

They are easily identified : ***(Example icon only – do not click on this***

You can access these links as appropriate while you are working with the Hyperbook, provided you are “on line” when you start the Hyperbook session

Back to Main Menu

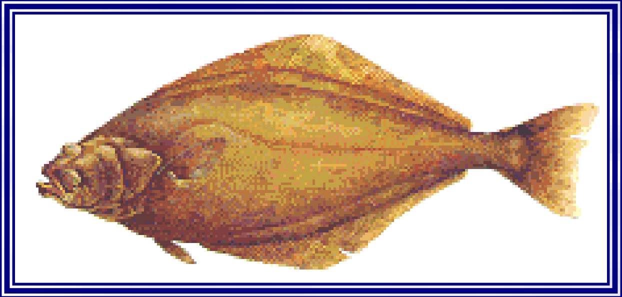
INTRODUCTION TO HALIBUT CULTIVATION

The Atlantic halibut (*Hippoglossus hippoglossus* L.) is the largest of the flatfish and one of the largest marine fish in the UK. It is classified as a demersal fish because it lives on or near the bottom.

Halibut are found on both sides of the North Atlantic, in cold boreal and subarctic waters with a temperature of around 5 to 8°C. In the Northwest Atlantic, halibut range from the coast of Virginia to the south to the central west coast of Greenland to the north (latitude 70ºN).

Atlantic halibut in the Gulf of St. Lawrence grow rapidly and steadily, by around 7.5 to 9.5 cm a year. Contrary to other flatfish, they continue to grow vigorously beyond the age of 10. A 20-year-old individual can easily measure 2 m (over 6 ft.) in length.

In general, female Atlantic halibut have a faster growth rate and a larger maximum size than males.



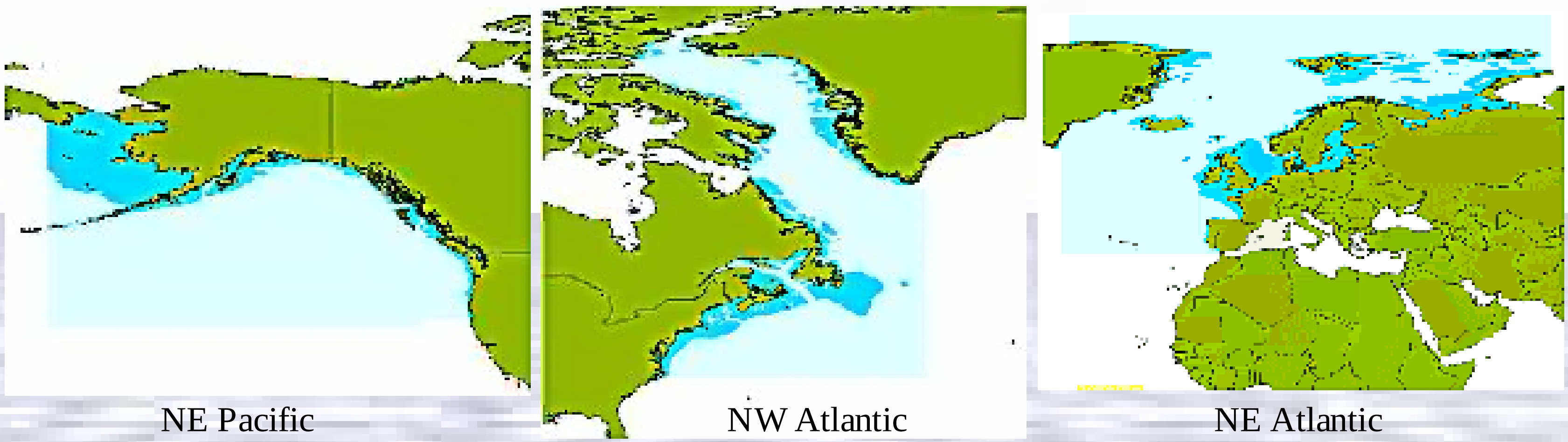
INTRODUCTION TO HALIBUT CULTIVATION - Continued

Despite the limited information available on the reproduction of Atlantic halibut in the wild, there are some indications that this species reaches sexual maturity at approximately 10 to 11 years of age, or at a length of 70 to 100 cm (25 to 40 in.). Based on observations from scientific winter and spring (January and May) trawl surveys in the Gulf of St Lawrence, halibut seem ready to spawn at this time of year. Although the spawning grounds of halibut have not been precisely identified in the Gulf, it is acknowledged in the literature that reproduction probably takes place at depths of over 180 m (100 fathoms). The estimated pelagic life of eggs and larvae is 6 to 7 months, a situation that promotes their dispersal by the current. Halibut metamorphose into flatfish at about 35 to 45 mm in length, when they adopt a demersal existence. Their diet differs according to their size. Based on an analysis of stomach contents, halibut under 30 cm long eat almost exclusively invertebrates, such as shrimp, small crab and krill. The diet of medium-sized halibut, from 30 to 70 cm in length, also includes small fish (sand lance, small Gadidae). Halibut 70 cm and over eat mainly fish (flounder, redfish, Gadidae). On account of their large size and active nature, adult Atlantic halibut do not seem to be preyed on by other marine species.

INTRODUCTION TO HALIBUT CULTIVATION - Continued

The greatest world-wide landings are of Pacific halibut (*Hippoglossus stenolepsis*) which stand currently at around seven times the tonnage for Atlantics. These two species are of similar high quality and are often interchangeable, particularly in markets for frozen produce. The third species which is sometimes included in records of landings and imports is the much inferior Greenland halibut (*Reinhardtius hippoglossoides*) which was the subject of the recent dispute between Canada and Spain. It is not generally regarded as a substitute for the other two high value species and so is only considered briefly in this Hyperbook. The biology of Pacific halibut is thought to be very similar to that of the Atlantic species, but the fishery situation is quite different. It is controlled by the International Pacific Halibut Commission which enforces a tightly regulated fishery within the conservation area off the coast of Alaska (e.g. 12 hour fishery openings are not unknown). Outside the conservation area the Japanese and the Russians fish alongside the Canadians and Americans. However the current management regime of the fishery ensures that the market is subject to feast and then famine as the grounds are opened and closed. The first opening is in May and the season normally lasts no later than September.

Click here to see a geographic illustration of principle fishing areas



Principle Fishing Areas for Pacific and Atlantic Halibut

INTRODUCTION TO HALIBUT CULTIVATION - Continued

The potential for farming of Atlantic halibut has been under investigation since the early 1980's, with researchers in Norway reporting on the first attempts to rear larval halibut in captivity. Significant research and development commenced in the UK in the late 1980's, and has been followed by work on halibut cultivation in Canada, Iceland and to a lesser extent Chile.

The development of the species has enjoyed a level of state funding in some of these countries which is almost unparalleled, and which reflects the way that the success of salmon farming has placed aquaculture into the strategic thinking of governments. With pressure on salmon prices and therefore threats to jobs and coastal economies, governments have shared with industry the drive to diversify into new species. Halibut has been the logical and indeed only choice for most of these cool-water regions. State support and R&D packages over the last 10-15 years have reputedly amounted to tens of millions of pounds in the case of Norway, and even several millions in the UK.

INTRODUCTION TO HALIBUT CULTIVATION - Continued

The hatcheries have been the bottleneck for the industry so far, and it is with some evidence of increasing success in the hatcheries that we can hope for signs of a true commercial industry emerging. The following data is very loosely based upon anecdotal information which is circulating amongst the halibut countries at the present time, and should not be construed as representing a 100% accurate picture of the industry: the hatcheries are all commercial companies which guard their secrets carefully, but which are also prone to sending out optimistic projections in order to maintain the momentum on the part of their parent companies or state organisations.

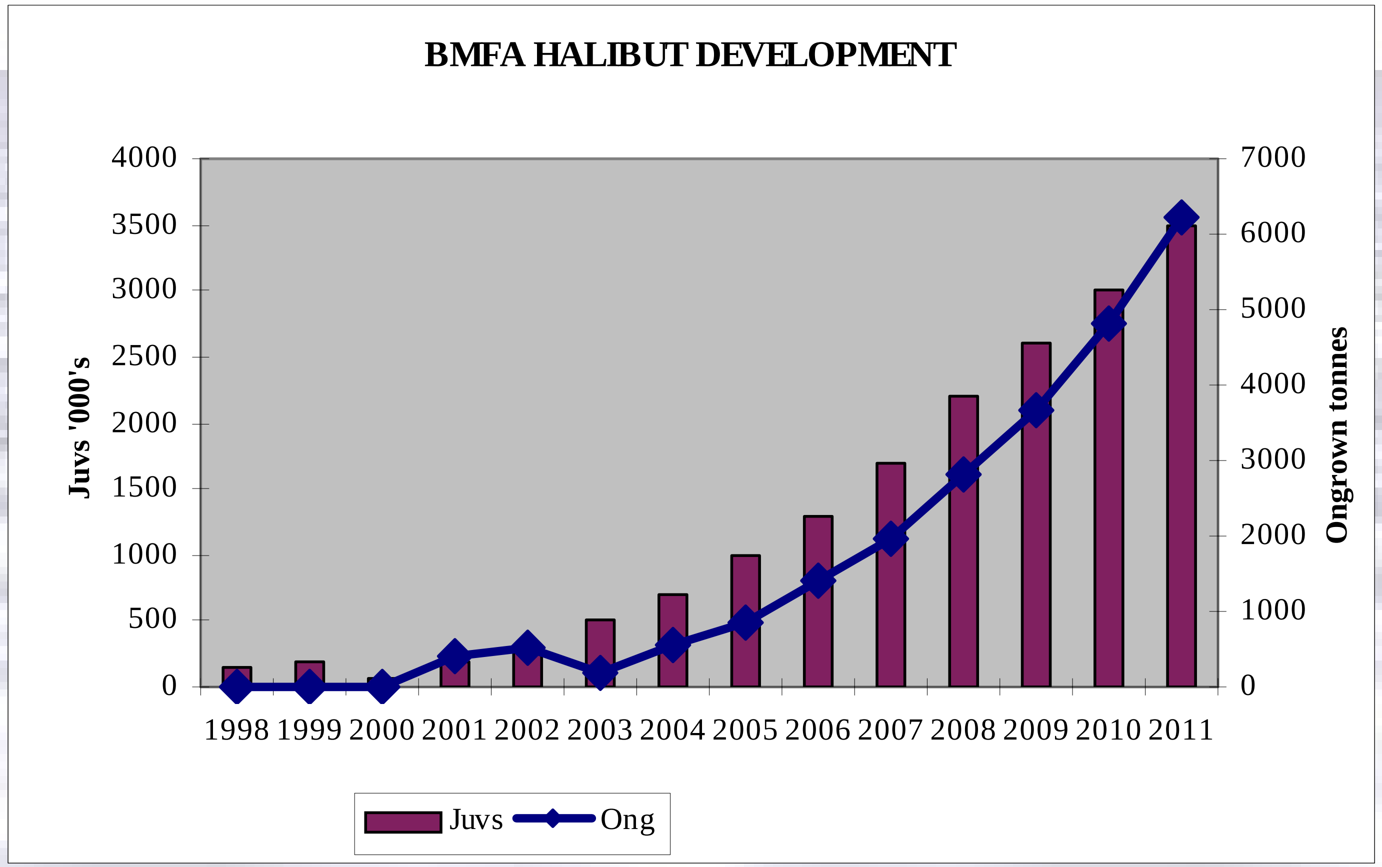
Year	Norway	Iceland	UK	Canada
1994	350			
1995	75			
1996	100	25	10	12
1997	260	60	30	5
1998	350	300	150	20
1999	400	400	200	50
Intensive Hatcheries	12	1	4	2

Juvenile Production in '000's

INTRODUCTION TO HALIBUT CULTIVATION - Continued

The British Marine Finfish Association's long term plan

- As hatcheries develop productive capacity, so the ongrowing production in later years should increase.
- *(Note: "Juvs" = Juveniles, "Ong" = Ongrown)*



INTRODUCTION TO HALIBUT CULTIVATION - Continued

Halibut ongrowing can be achieved in both land-based tanks (with or without recirculation) and in flat-bottomed floating sea cages. In the latter case, there is a requirement for a “nursery phase”, located on shore. This grows typical hatchery-produced juveniles of 5-10g into “cage-ready” juveniles of 100g or larger.

Halibut tend to feed and grow well at temperatures ranging from 8 to 15° C, and in areas where these temperatures are maintained for most of the year, halibut can reach a market size of 3-4 kg in 24-27 months at sea.

Female halibut grow faster than male halibut, and this causes some concerns for ongrowers. The production of all-female fish from hatcheries may be possible in the future, but in the meantime a production and harvesting strategy which accommodates this growth differential is required.

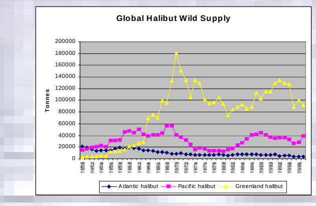
Traditionally appearing on the market as large wild fish of 10kg or more, there is a premium price for larger farmed halibut. Nevertheless, with a good fillet yield and portioning characteristics, there is also a clear market opportunity for smaller fish.

THE MARKETS FOR HALIBUT

The global and regional "market" for Atlantic halibut is presently defined by the availability of supply from the wild fishery. This situation will change as aquaculture comes on-line in the future.

Although this Hyperbook is concerned with the cultivation of Atlantic halibut, it would be unwise to ignore the other two species - Pacific and Greenland halibut.

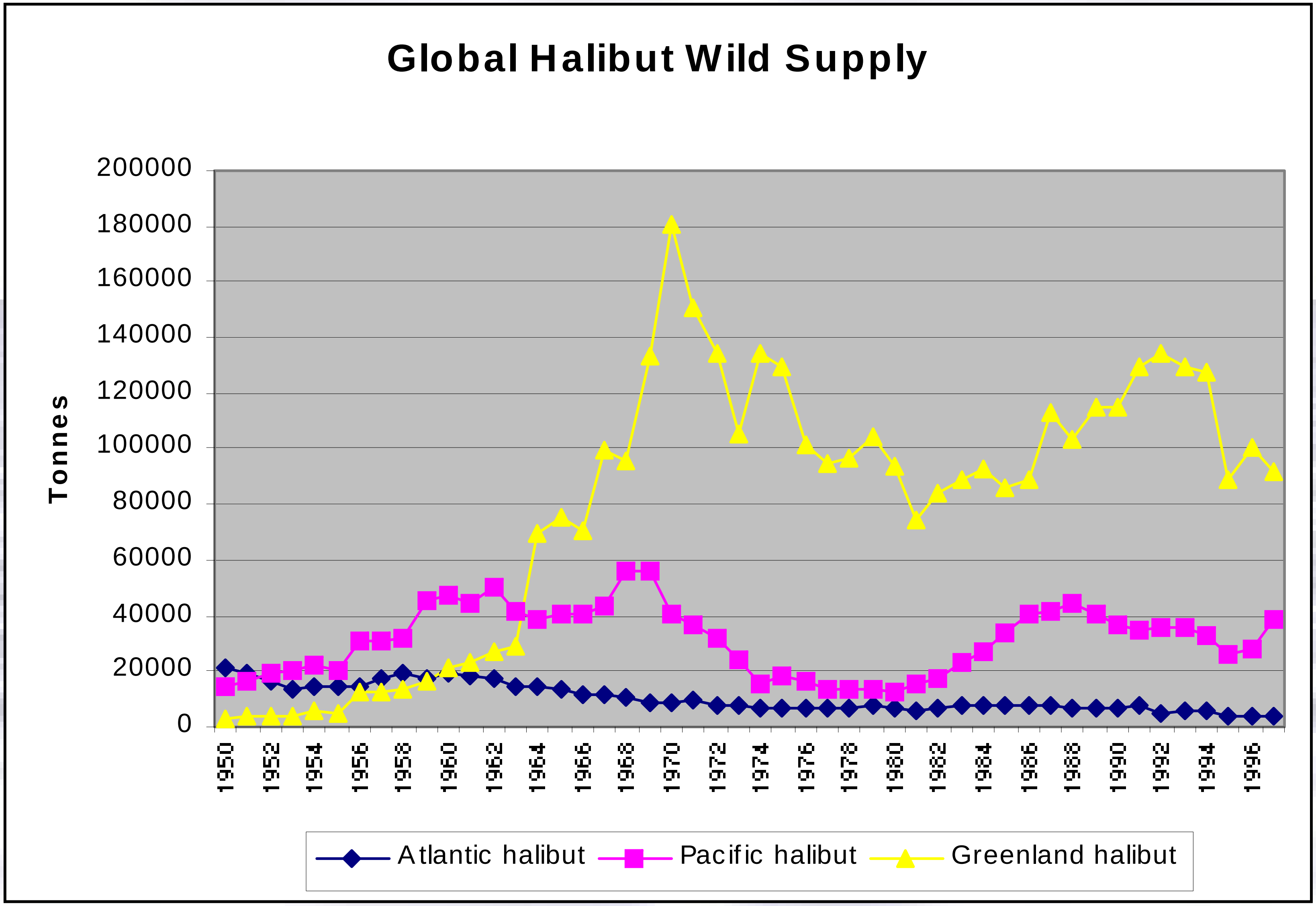
Click on the thumbnail to see the global wild supply data



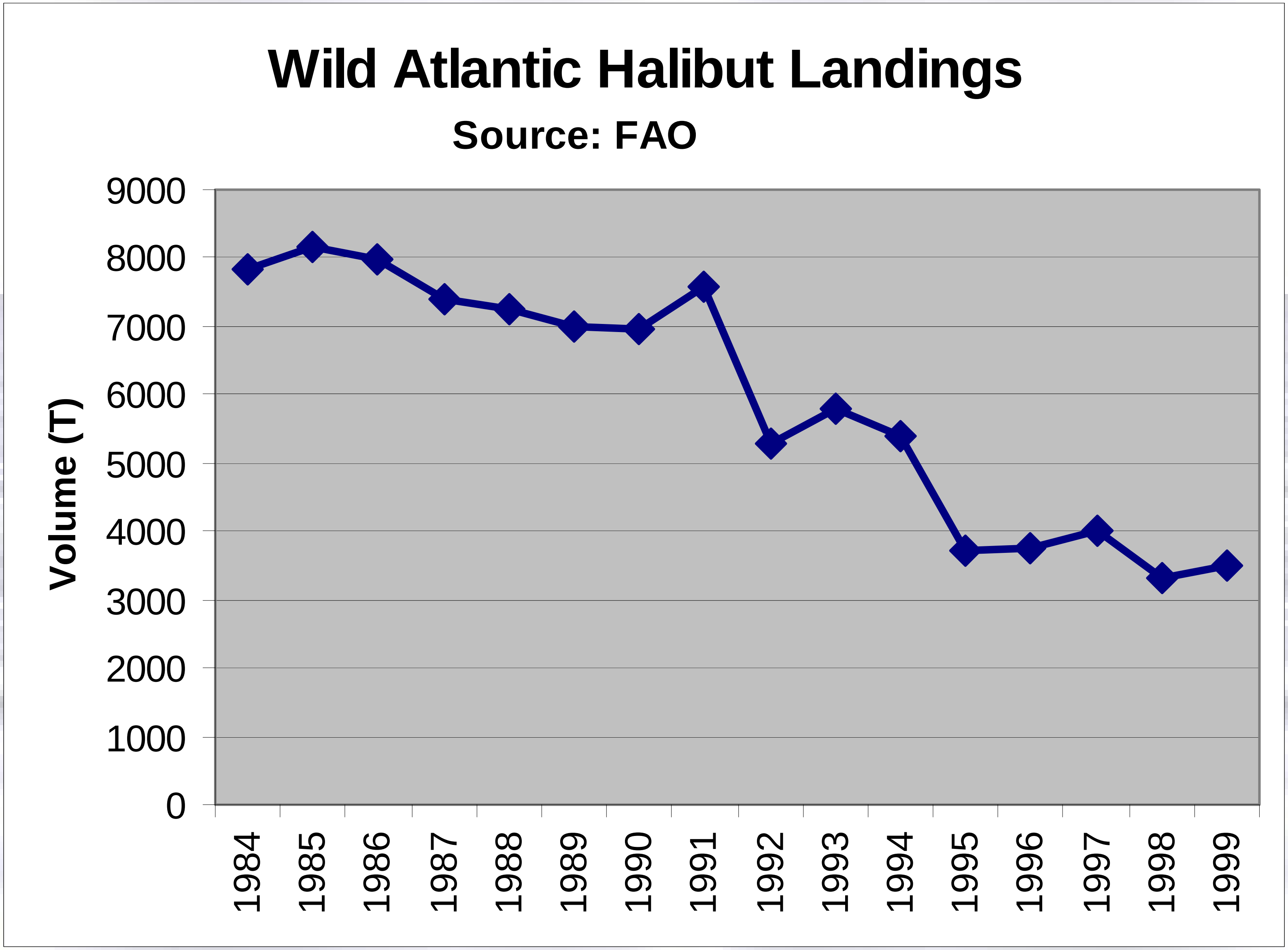
Atlantic halibut (the main farming target species) has been steadily declining in the wild since the 1950's – from some 20,000 tonnes per annum down to the current figure of less than 4000 tonnes per annum.

The similar-quality Pacific halibut has maintained a higher level of supply, albeit with some fluctuations over periods of several years. Controlled by the International Pacific Halibut Commission, current quotas for this species in 2000 amount to some 28,000 tonnes.

The much inferior Greenland (or "black" or "mock") halibut was not utilised until the early 1960's, but reached a production peak of almost 180,000 tonnes (in 1971), and is still available at a level of some 80,000 tonnes per annum.



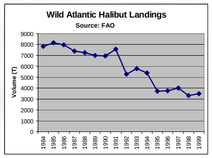
Global Halibut Wild Supply
Tonnes
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
Atlantic halibut
Pacific halibut
Greenland halibut



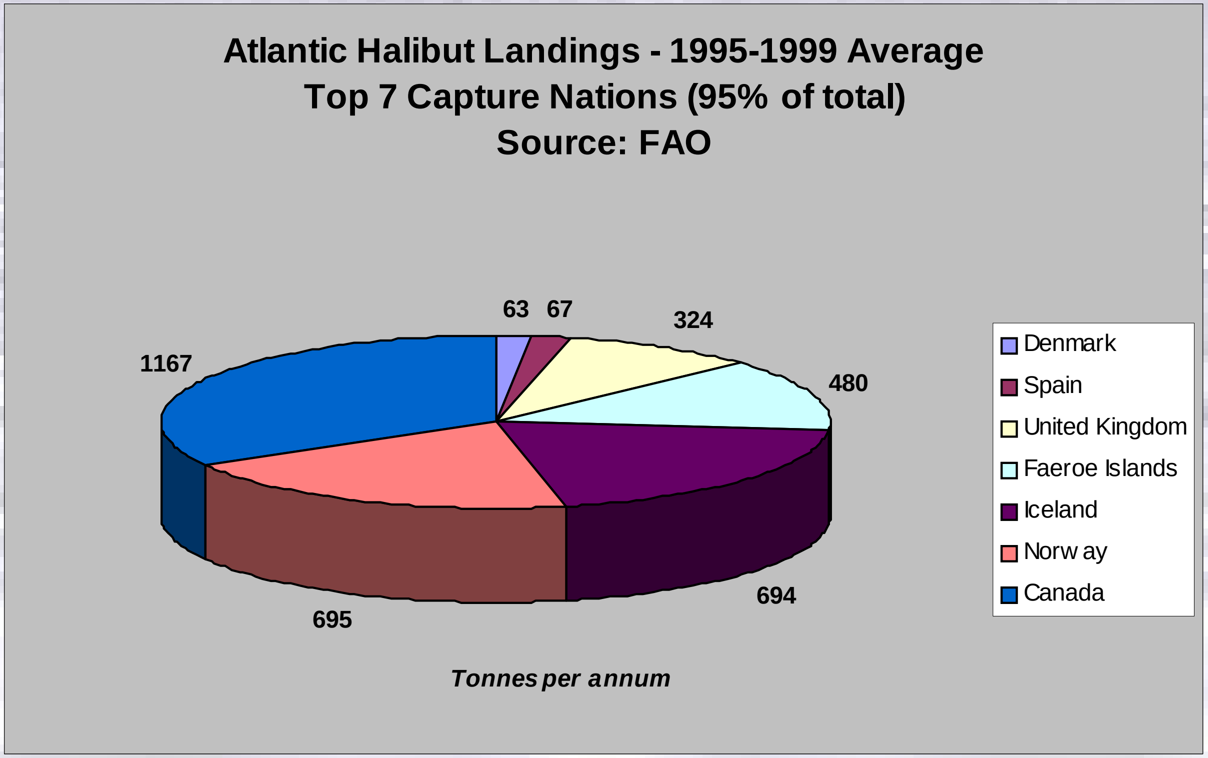
Wild Atlantic Halibut Landings
Source: FAO
Volume (T)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

THE MARKETS FOR HALIBUT - Continued

The wild supply situation for Atlantic halibut shows a dramatic decline - click on the thumbnail for more detail



The main capture nations are: Canada, Norway and Iceland

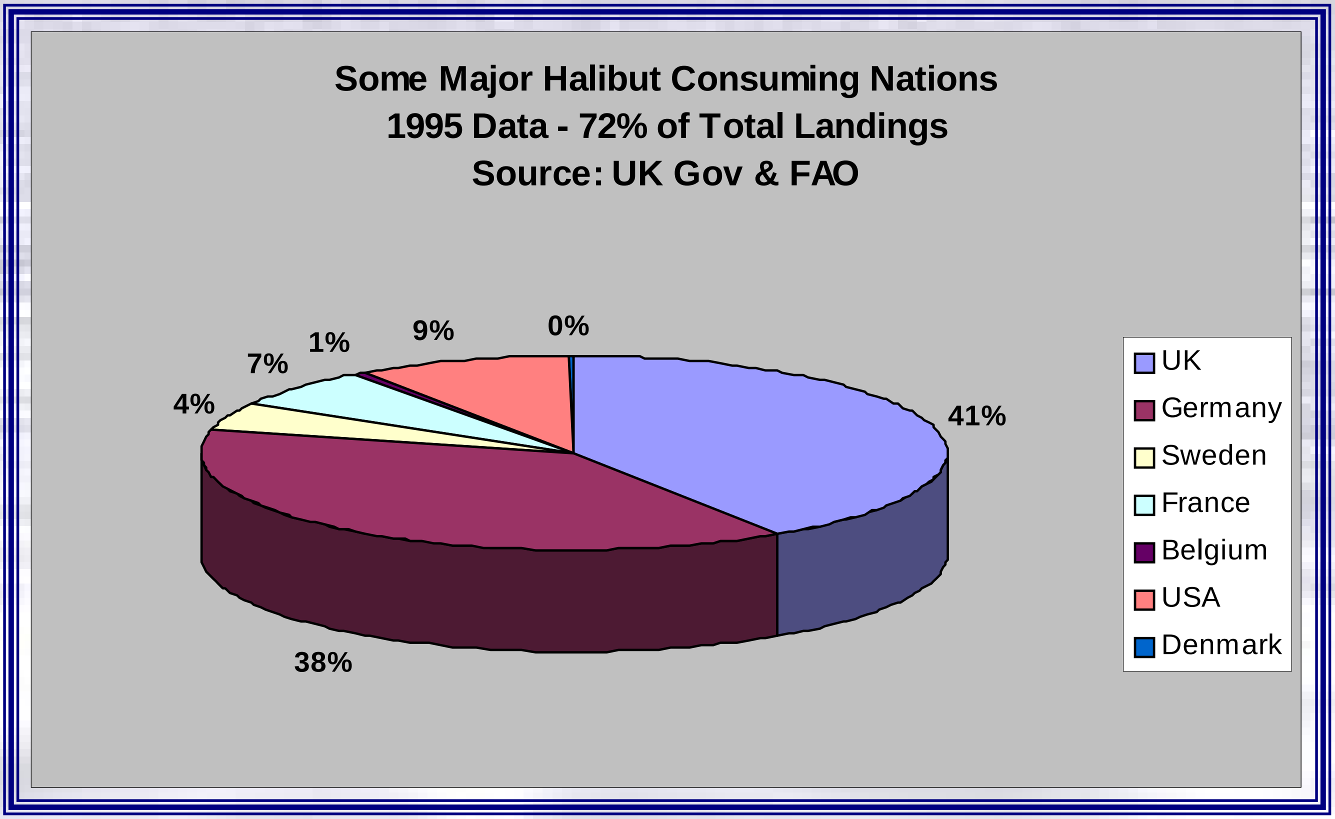


THE MARKETS FOR HALIBUT - Continued

Data for principle consuming nations for Atlantic halibut are less accessible than those for landings, but the figure below is indicative. Note that the data only covers about 70% of the landings in that year - but that domestic consumption by the main capture nations (Canada, Norway and Iceland) is not recorded. Japan is also a major consumer of Pacific halibut, and may import some Atlantic halibut as well.

The main messages from this type of analysis are:

- **The UK is a major consumer**
- **Germany is *apparently* a major consumer**



THE MARKETS FOR HALIBUT - Continued

The UK and general European market for halibut is discussed in a recent study.

You can find this report as a .pdf document “Market Survey Report” inside the main Hyperbook folder. Click “exit” to leave this show, if you want to see the report now

Atlantic halibut has a good market potential in the UK, but is not apparently well appreciated in the other European countries surveyed. The UK market is likely to be consuming around 900-1000 tonnes of Atlantic halibut per annum.

Several analysts in previous studies suggest a medium-term price for farmed halibut of some £5.50 per kg, at a production level of some thousands of tonnes per annum. Current wild prices (depending upon market segment) are in excess of this – for example £7.00 to 8.00 per kg, for fish of 1-5 and 15-30 kg mean weight. There is some difficulty in correlating the official UK government data on import or first-sale value of halibut with actual values quoted in the survey undertaken for this study. 100 tonnes per annum of Norwegian-produced halibut is being sold at delivered prices of around £5.50-£6.00 per kg

Restaurants and good-food pubs commonly use fresh Atlantic halibut, for which they are currently paying about £9.00 per kg eviscerated whole fish, or the equivalent of about £18 per kg for skinless boneless portions. By the time halibut reaches the consumer, the value of the flesh can be in the region of £60+ per kg in restaurants and anything from £10-20 per kg in retail outlets.

There appears to be broad support for increased farming of Atlantic halibut, mainly in the UK. The desired attributes of farmed halibut would include: good quality, lower price, consistent availability, good farming image, size and portion control, traceability.

THE MARKETS FOR HALIBUT - Continued

The aforementioned market survey, in addition to summarising the current situation and prospects for several aquaculture species, presented three particularly important concepts when considering species such as halibut:

1. The scale and value niches of the UK foodservice sector

2. A methodolgy for considering "farm to fork" value transfers

3. The importance of considering "fillet yield" from aquaculture species

Full details can be obtained from the report, but the following pages of the Hyperbook introduce the subjects.

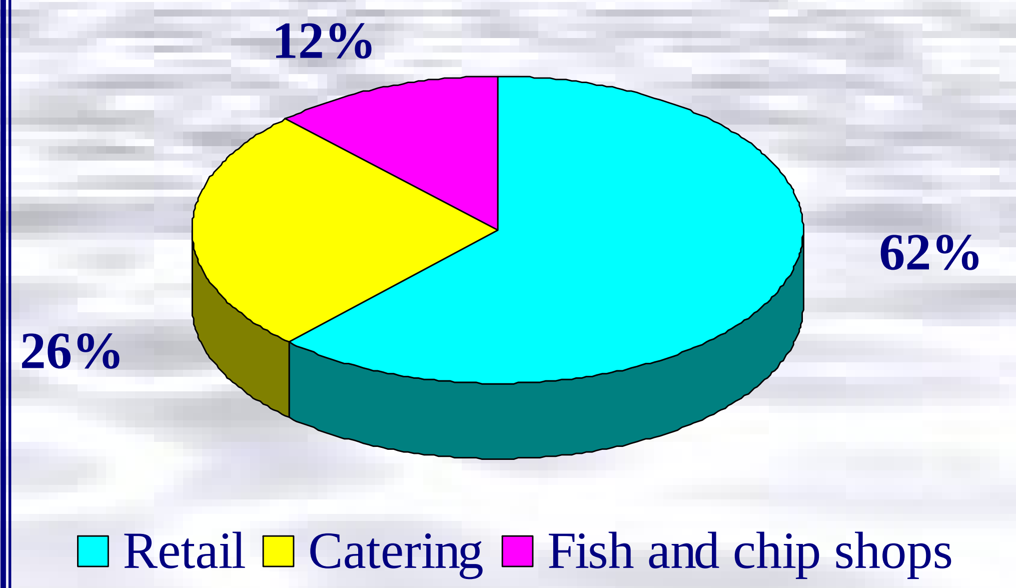
THE MARKETS FOR HALIBUT - Continued

Seafood is purchased in two broad categories by consumers:

- **Retail - where it has to be prepared for eating at home**
- **Foodservice - where it is purchased in a ready-to-eat form**

There are overlaps where shops and petrol stations sell ready-prepared meals, and sub-categories such as take-away foodservice. The main distinction between the two broad categories is that the consumer pays more per unit piece of protein in foodservice than he/she does in retail.

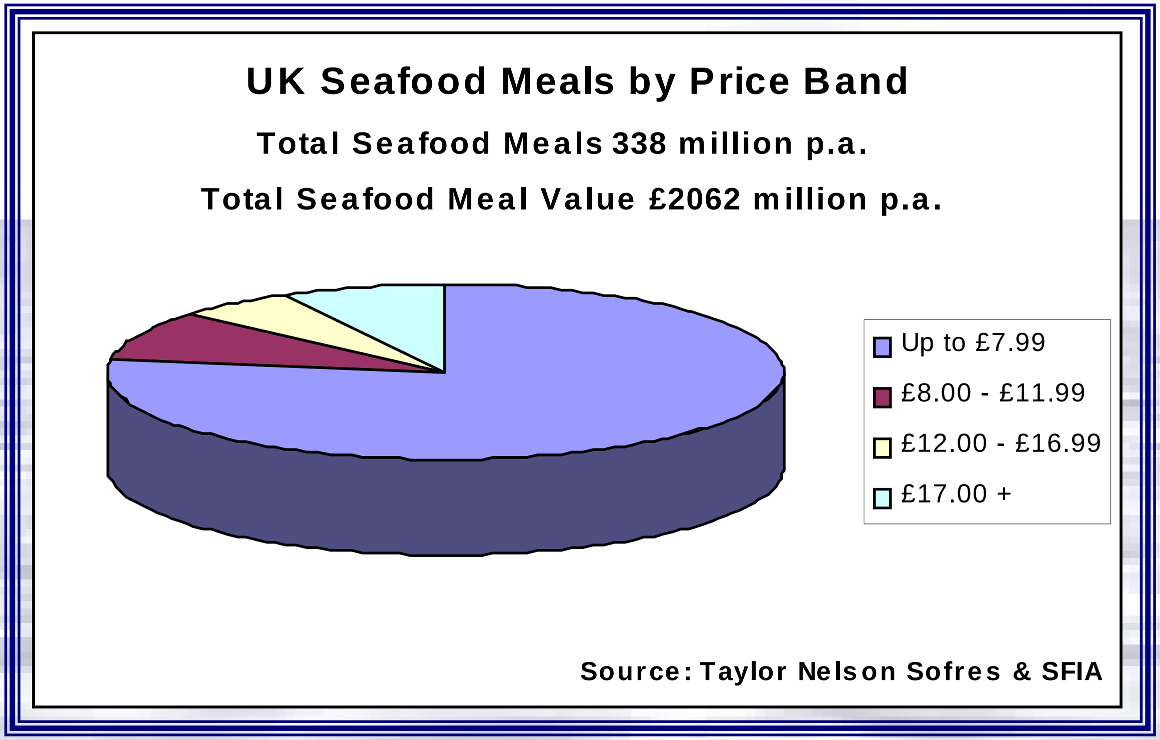
The balance between seafood retail and foodservice



Source: SFIA, Foodservice Intelligence & Superpanel

THE MARKETS FOR HALIBUT - Continued

UK seafood consumption in foodservice - in terms of number of meals and their values - is interesting:



- **338 Million seafood meals per annum**
- **25% of them costing more than £8 per meal**
- **Imported farmed seabass has become a "staple" of the UK restaurant trade - in the absence of any other high quality farmed product**

THE MARKETS FOR HALIBUT - Continued

The "Farm to Fork" concept is a way of understanding how aquaculture products are valued by consumers - and how the value of the product works backwards through the supply chain to the aquaculturist at the edge of his tank or cage.

EXAMPLE - Halibut in a restaurant or "good food" pub

• Cover price (200g flesh)	£14.00
– Less VAT	£11.92
– Less chef's 65% margin	£4.17
– Less veg, sauces etc.	£3.50
• So restaurant can buy fillets for	£17.50/kg
• Halibut fillet yield	50%
• So restaurant can buy whole fish for	£8.75/kg

- **Farmers have to think how to get their fish from "edge of cage/tank" to restaurant - perhaps being <u>in partnership</u> with the rest of the supply chain**
- ***(Note that the consumer is paying the equivalent of £35 per kg for whole halibut in this example!)***

THE MARKETS FOR HALIBUT - Continued

The other important factor in considering the "real" value of cultivated halibut relates to the current trends which are being exhibited by the consumer - and by the foodservice and retail sectors:

- **UK consumers are increasingly opting for fillet only (no bones, skin, eyeballs)**
- **This trend is probably happening across Europe - but more slowly**
- **It is reflected in the sale of "fillet recipes" in foodservice, and in pre-packed fillets in the retail chill cabinets**
- **Aquaculture has a certain cost of production for whole fish**
- **But the consumer is only really valuing the flesh component**
- **So any consideration of "inherent value" of the product has to take into account the yield of the fish in question**

- **Halibut, fortunately, has one of the best fillet yields of all the common edible marine fin fish species in the UK - estimated at some 50%of the eviscerated whole fish weight**

THE MARKETS FOR HALIBUT - Conclusion

The main halibut market messages from this section are:

- **Atlantic halibut is declining in terms of wild supply**
- **The UK is already a significant consumer of Atlantic halibut - perhaps some 33% of world supply**
- **Halibut is popular with UK chefs - and with restaurant consumers**
- **The fish provides a good fillet yield, and also provides thick fillets and portions**
- **There is a good niche for cultivated halibut in the foodservice sector - which has had to use imported farmed seabass so far (in the absence of any other reliable and desirable products)**
- **The “value transfer” calculations appear to support reasonable values for cultivators, at prices which the consumer can afford**

Some halibut recipes

THE PRODUCTION PROCESS

Introduction

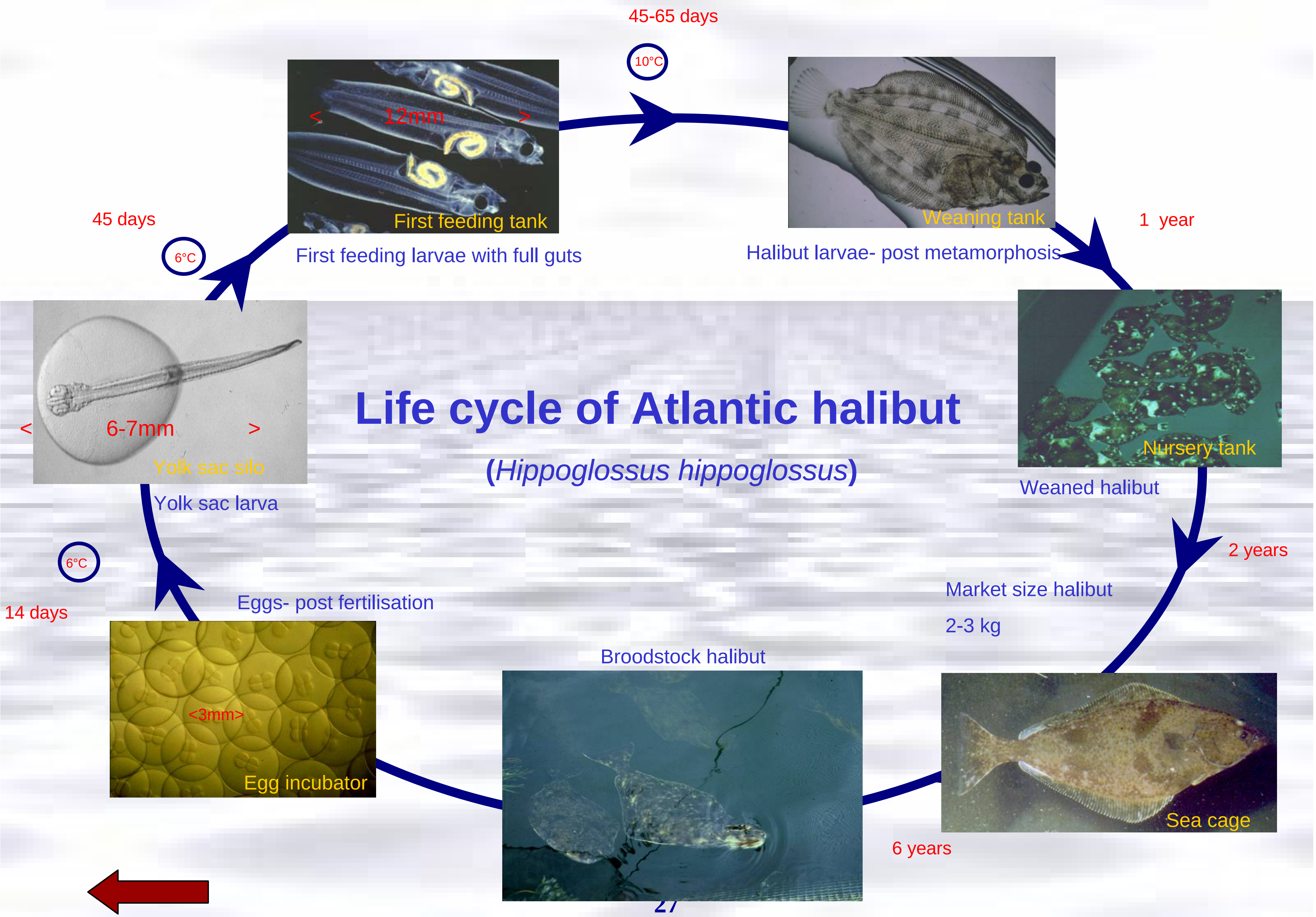
Click here to see a graphic representation of the life cycle

This Hyperbook will focus on the main life cycle stages of production of Atlantic halibut:

- **Hatchery**
- **Nursery**
- **Ongrowing**

The Hyperbook can not provide every detail, and it is

recommended you visit other resources to obtain more information.


Life cycle of Atlantic halibut
(Hippoglossus hippoglossus)
45-65 days
10°C
< 12mm >
First feeding tank
First feeding larvae with full guts
Weaning tank
Halibut larvae- post metamorphosis
1 year
Nursery tank
Weaned halibut
2 years
Market size halibut
2-3 kg
Sea cage
6 years
Broodstock halibut
Egg incubator
<3mm>
Eggs- post fertilisation
14 days
6°C
Yolk sac larva
Yolk sac silo
< 6-7mm >
45 days
6°C

Hatchery - Broodstock 1

The Encyclopaedia of Aquaculture tells us that ….

In the wild, mature halibut gather every year in winter in defined spawning grounds at depths of up to 700 m (2,300 ft). Halibut are batch spawners that produce up to 15 but more usually 5-10 batches of 100-200,000 eggs at 3- to 4-day intervals over a 1- to 2-month spawning period (2); different geographical stocks spawn at different times over the period February through May, usually at water temperatures of 5-7 Deg.C (41-45 Deg.F) or less.

Males reach maturity at a younger age or size than females; e.g. Faeroese males mature at 4-5 years of age; 55 cm (22 in.) in length and 1-3 kg (2.2-6.6 lb) in weight, whereas corresponding females mature at 7-9 years of age, 110+ cm (43 in.) in length and at weights of >15 kg (33 lb). Most large fish captured in the wild are females, with males rarely exceeding 50 kg (110 lb).

Hatchery - Broodstock 2

In captivity, broodstock tanks for halibut range from 4 to 10 m3 in volume, and are typically stocked with fish at densities of up to 10 kg/m2, with a male:female ratio of 1/2:1. Tanks are supplied with chilled water in order to maintain optimum conditions: typically no more than 13º C in the tank's "summer" period, and as close as possible to 6º C during the spawning period. Water exchanges are low due to the cost of chilling water which is to be used in a flow-through system, and recirculation is increasingly being investigated in order to improve this situation. Norwegian hatcheries, with access to deep and cold water in the fjords, are at a distinct advantage in terms of cost of temperature control. However, even in Norway and northern Iceland, water chilling is still required for some periods of the year.

Broodstock halibut can be subjected to photoperiod control of spawning in much the same way as for turbot, although the degree of fine control with halibut is not as reliable as for turbot. Spawning season in the wild stocks would be around February to April, and there is still a considerable emphasis on halibut hatchery activity during the winter months in European hatcheries, even with photoperiod control. This reflects the higher costs of water and air cooling in the summer, and is not otherwise a biological necessity.

Hatchery - Broodstock 3

Halibut broodstock nutrition was originally based on mixed frozen industrial fish, but this approach has now been completely abandoned due to the risks of disease introduction. The replacement has been a semi-moist pellet extruded in a sausage skin, available as a dry mix for re-hydration.

Some doubt arose during 2000 about the “sausage mix” in terms of egg yields and quality, and there were further refinements of the diet. Some hatcheries are still concerned about broodstock nutrition, and supplementation with frozen natural feeds is probably still practised within the industry – although sterilisation of the feed is essential in order to maintain biosecurity.

The other development which would be welcomed by industry is an appropriately-sized high quality dry pellet broodstock diet. Broodstock halibut are large fish, and are perceived to require dry pellets which are larger than the capacity for most feed mills in the extrusion process (typically 18mm).

Hatchery - Broodstock 4

Halibut are manually stripped during the spawning season, with females ovulating several times during the season, on a cycle which varies between individuals but which is commonly 70-90 hours. Broodstock individual weights vary considerably, and males are usually smaller than females. Typical egg yields from female fish can be 6-8 l by volume during each spawning season, or around 300,000 eggs. Stripping is usually undertaken within the broodstock tank due to the difficulty of handling such large fish. Fertilisation takes place immediately after egg collection, and both wet and dry techniques can be used.

For details of stripping & fertilisation techniques, press here

Stripping & Fertilisation

Once ovulatory rhythms are established, each broodfish should be examined at the appropriate interval and an attempt made to strip eggs. Eggs have to be stripped from the female fish without coming into contact with seawater, i.e., the fish have to be removed from the water at least until the gonadal pore is visible and out of the water. However, the large size of the brood females and their shape preclude manual lifting and the following procedure, which requires a minimum of two persons, is commonly adopted. First the tank water level is lowered to approximately 45 cm (18in.). A table constructed from aluminium, plastic, or other suitable material, free from any sharp edges, is often used to position the broodfish for stripping. The table, which should be approximately 2 m long, has two fixed and two adjustable legs whose lengths are such that the fixed end of the table is above the water level in the tank while the other adjustable end is submerged. The selected broodfish is gently guided onto the inclined surface of the table, whereupon the submerged end is raised and the adjustable legs lengthened, lifting the fish clear of the water. This procedure is possible with smaller broodstock. With larger fish some farms use a pulley- or winch-operated system to raise the table. After carefully drying the area around the gonopore, eggs are stripped from the brood female into 2 to 3-L graduated jugs by gentle posterior-anterior hand pressure.

In some instances females fail to release eggs, which have been ovulated into the ovarian lumen, even when assisted by stripping. The retention of eggs can cause blockages when this material starts to degenerate inside the fish. Blocked females can be injected intramuscularly with antibiotics (amoxycillin or oxytetracycline), which generally induce the release of the egg debris within three days.

A similar procedure is used to strip male fish. Males generally continue to produce milt for the duration of the spawning seasons of the different females in the same tank. Again the fish must be carefully dried and the milt then stripped into 250 mL graduated containers. The gametes should then be transferred to the hatchery in a light-proof insulated box as temperatures must be maintained below 6 Deg.C and light affects osmolarity and, in turn, the buoyancy and handling of the eggs. Ideally the egg incubation facility should be a purpose-built room whose temperature is maintained at 6 Deg.C. Before the eggs are fertilised the milt should be checked for motility under a microscope (444X) after adding a few drops of seawater to a drop of milt. Although generally males continue to produce milt throughout the spawning period of the females, toward the end of the season some males may become spent or their milt becomes viscous and very difficult to handle. Providing the fish are not spent, high spermatocrits can be diluted and hence made more fluid by treating brood males with 25ug/kg of GnRHa. Milt can also be stored in a refrigerator for seven days or an adjustable freezer at -4 Deg.C for 29 days without any loss of viability. Once a ready supply of milt is assured, then one can proceed with fertilisation.

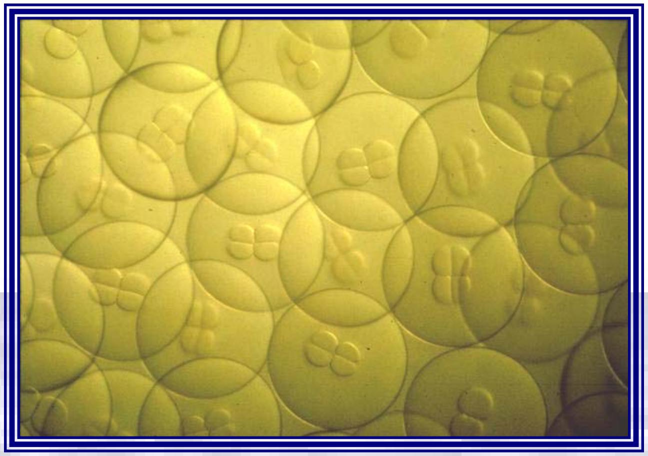
The eggs are "wet fertilised" in a ratio of 250:1:250 egg to milt to UV sterilised seawater by first diluting the milt with the sterilised seawater and then quickly adding the mixture to the eggs. The eggs and diluted milt should be gently stirred by hand and then left undisturbed for 20 minutes. Sperm motility ceases after 2-3 minutes although fertilisation is complete in less than a minute. After 20 minutes the eggs should have absorbed water and become fully water-hardened. They are then washed in two further changes of sterile seawater to remove excess milt and any egg debris or ovarian fluid. The fertilised eggs are then stocked in egg incubation systems in a dark room at 6 Deg.C. A small sample (about 100 eggs) of each egg batch is retained in full-strength seawater in a screw top jar for assessments of fertilisation rate or egg quality, as described in the following section.

Hatchery - Egg incubation

Approximately 80-90% of the eggs stripped from a good female fish will appear to be properly fertilised and capable of incubation, and this is undertaken in conical upwelling vessels ranging in volume from 70 to 500 l . Control of water temperature and cleanliness is vital during this stage - optimum temperature appear to be around 5-6º C, and the water is usually filtered and UV sterilised. There is a tendency for neutral or even negative buoyancy with halibut eggs, which can vary from batch to batch. Consequently stable and oceanic levels of salinity are to be preferred in halibut hatcheries.

Survival through the 14-17 days of the egg incubation phase is variable, but tends to average 50%. Dead eggs which drop to the bottom of the conical vessel during incubation must be removed regularly in order to maintain water quality. The incubation vessels are usually equipped with bottom-flushing mechanisms, but because of the negative buoyancy of even viable eggs, there is sometimes a requirement to apply a salt plug technique, to fully separate the dead material from the live eggs so that the dead material can be removed without wasting good eggs.

Near the end of the egg incubation, at around 75 day-degrees (DD), the eggs are gently netted out and surface sterilised with peroxyacetic acid or gluteraldehyde. They are then transferred to the Yolk Sac (YS) incubation vessel, and allowed to hatch.



Halibut eggs - 4 cell stage

Halibut yolk sac larvae

Hatchery - Yolk Sac incubation 1

This protracted phase is one of the most problematic for halibut hatcheries, and clearly distinguishes this marine species from others which are reared in captivity. The yolk sac phase lasts from hatching at c. 85 DD to the point of first feeding on live prey, usually at 250-300 DD. At a constant temperature of 6º C (the optimum level), the phase therefore lasts some 40-50 days. By contrast, newly hatched turbot larvae have absorbed their yolk sac and begun to feed within 3-4 days. During the entire 28 day period the larvae are slowly developing, but are vulnerable to environmental stress, water quality problems and microbial attack.

As in egg incubation there is a tendency towards negative buoyancy with halibut YS larvae, and indeed there is a change in the vertical orientation behaviour of the larvae during the YS period. Rearing vessels are therefore also conical in design, to facilitate a slow upwelling of clean water, and to permit single point extraction of dead material from the base of the conical. UK and Canadian hatcheries have tended to concentrate on small YS conicals, commonly 500 L but with some hatcheries using 900 L or even 1.8 m3 vessels. By contrast, Norwegian hatcheries have adopted the use of very deep "silos", with volumes of 10 or even 20 m3. There may be advantages to the Norwegian vessels, but in practice the difference has arisen because of the broodstock supply situation: Norwegian operators have, for many years, had an abundance of broodstock fish and consequently very large batches of eggs and larvae, permitting the use of big, deep silos. UK hatcheries, after 11-12 years of development, are only now beginning to amass good numbers of broodstock fish and thus big egg batches. Previously the batches were much smaller, and only the small 500 L YS vessels were appropriate.

Temperature control, absence of light, attention to water quality and hygiene are all important factors during the YS phase. Survivals in good batches can be 75%, but the accepted UK industry average is closer to 50%. Some Norwegian literature and anecdotes claim higher survivals in their larger YS silos (>90%), and there is some corroborating evidence that this can occur.

Hatchery - Yolk Sac Transfer to First Feeding

The movement of the larvae out of the YS conicals and into the first feeding (FF) or larval rearing tank is at different stages of development, depending upon individual hatchery preferences. Many UK hatcheries move larvae into the bigger, flat-bottomed larval rearing tanks at 150-180 DD. Some Norwegian hatcheries move out only at 270-290 DD. The Icelandic hatchery (Fiske) moves larvae out at 250 DD. In every case, first feeding is not likely to commence until at least 250 DD, and indeed the new Norwegian approach is to deliberately delay the presentation of live feed until 270-290 DD, claiming it leads to a better synchronicity and success rate in establishment on feed.

In the case of early movements, such as in the UK, this is caused by a degree of pragmatism: experience has shown that in the UK YS vessels there is a tendency for large mortalities to begin if the larvae are left in place longer than 150-180 DD. UK operators thus prefer to move the larvae into the clean FF tanks, and allow the larvae to continue the remainder of yolk sac absorption for a further 10-15 days, until Artemia can be offered.

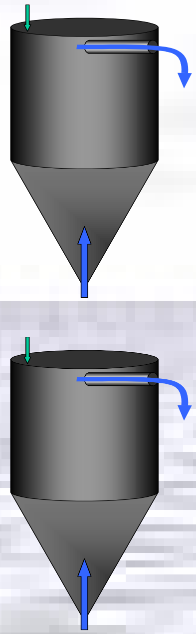
In practice this approach probably does give the optimum overall survivals for the UK hatcheries, but it is not necessarily a perfect system: actual establishment on first feed, assessed when the larvae are 300 DD+, is rarely more than 35% i.e. of the larvae moved out of YS systems at 150-180 DD, more than 60% commonly fail to ingest Artemia over the next 2-3 weeks, and slowly die. This Transition phase problem is a serious bottleneck for all halibut hatchery operators at the moment, and in conjunction with the rest of the YS phase, represents a serious constraint to the industry. From hatched larvae to actual first feeding, the average transfer success is in the region of 50% + 30% i.e. some 15%. This compares very unfavourably with most other marine species which are being reared in aquaculture: the percentage of hatched larvae which actually start to eat live feed is close to 100% for turbot, bass, bream, sole. There is clearly room for much improvement in this aspect of halibut rearing.

This whole subject area is being studied in a LINK Aquaculture project - press the button

Problems with the Hatchery Cycle - LINK FIN22

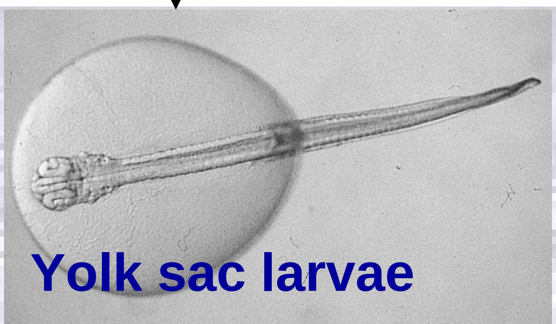
Broodstocks

Eggs in incubation



So what are the unique problems for halibut ?

- Long yolk sac phase
- Failure to feed on *Artemia*

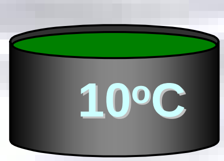


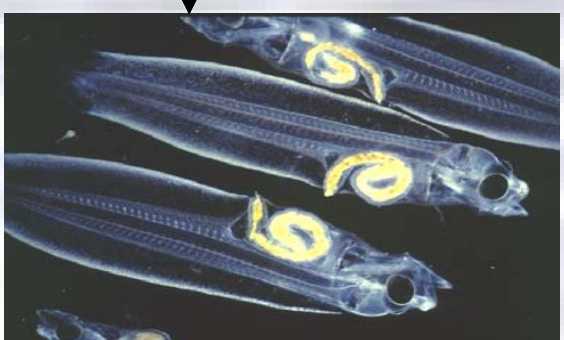
- Achieved good progress in other stages
- Cost UK industry £2.8 million in 99

Endogenous

Exogenous

Illuminated, Green





Larvae feeding on *Artemia*

Metamorphosed fish feeding on dry pellets

SEAFISH

Hatchery - Larval Rearing

Typical halibut larval rearing tanks vary between 2 and 10 m3, and are circular flat-bottomed tanks similar to those used in turbot rearing. Green water rearing appears to be essential for halibut, with *Nanochloropsis, Isochrysis* and *Nanochloris* being commonly used. Light levels are normally kept quite low (in the order of tens of lux at the water surface). There is usually a very low flow of clean water introduced to the tank from the early stages. Live feed in many hatcheries consists entirely of enriched Artemia, whilst most Norwegian hatcheries and one UK producer utilise additional copepod feeding for a part of the cycle.

Rearing temperatures rise from around 10º C at first feeding to no more than 12-13º C during the later stages. Weaning commences when a significant number of halibut larvae have adopted a demersal mode, i.e. settled on the tank bottom. This is around a mean weight of 150 mg, and weaning can usually commence some 45-55 days after first feeding was initiated. Tank hygiene throughout the extended larval rearing phase is probably important, although hatcheries vary in their approach to this aspect. Tank bottom siphoning on a regular basis is generally considered important, although this becomes increasingly problematic as larvae begin to settle on the bottom towards the end of this phase.

For more detailed information on this phase, press the button

Until 1997, the larval rearing phase was considered to be another serious constraint area for hatcheries using the Artemia feeding systems, but there has been considerable improvement since that time. A much better understanding of the importance of Artemia enrichment and overall feed levels has improved this phase significantly for these hatcheries, and a success through the larval feeding stage of > 40% is now apparently possible with many batches. Larvae reaching the end of this phase are now much stronger than previously, and transfer to weaning has become a relatively straightforward procedure.

For more detailed information on live food production, press the button

Larval Rearing

The tanks used for initial feeding with live feeds are usually circular, 1-5-6.0 m in diameter, 1-2 m deep, and flat bottomed with a tangential inflow and central gridded outflow drain. Unlike the earlier egg and yolk-sac stages, the first-feeding larvae require light for feeding (100 lux is commonly used but some hatcheries use brighter light). Tanks are often provided with a peripheral collar, which serves to shade the walls of the tanks from the above-tank lighting. The photoperiod is 24 hr continuous light (LL) and the water temperature ideally 6-8 Deg.C. Light intensity levels are gradually increased during the period of larval rearing up to 1000 lux by day seven post-first feeding. Temperature can also be gradually increased up to 12 Deg.C.

Before stocking with larvae, the tanks are “greened” with appropriate microalgae at concentrations of up to 10/7 algal cells/L; these concentrations are maintained by further daily additions of algae up to approximately 500 degree days posthatching. Larvae are stocked at 200 degree days posthatch by some hatcheries, although recently there has been a move to delay first-feeding as late as 270 degree days. Stocking densities range from 2 to 7 larvae/L. Water flow rates are increased from 1 to 5 L/min during first-feeding, although some hatcheries also use aeration to maintain an upwelling current and a good dispersal of larvae, live feed organisms, and microalgae within the tank.

By 220-270 degree days posthatch larvae are ready to take first feed. Different hatcheries use a range of different protocols principally because procedures are still being optimised. Generally, hatcheries that have access to supplies of copepods prefer to use them because it is widely recognised that they provide the ideal nutritional source for halibut. However, because of difficulties in culturing or obtaining supplies from the wild, copepods are invariably in short supply. Hence, their use has to be rationed. Most hatcheries start-feed with enriched *Artemia* as halibut larvae at 13-14 mm in length are already larger in size than most marine larvae at start-feeding. A few units initially use rotifers, although these are generally considered to be too small for halibut to prey upon.

Artemia can only be used successfully as a first-feed for halibut larvae if its nutritional composition is first supplemented with enrichment of additional nutrients, in particular, sources of essential polyunsaturated fatty acids and amino acids. Enrichment aims, in part, to simulate the nutrition provided by copepods or by the natural zooplankton diet of wild halibut. Enrichment procedures for *Artemia* show considerable variation among hatcheries because the detailed nutrient requirements of first-feeding halibut, and in turn the appropriate enrichment levels needed to meet those requirements, are not fully known. In a number of hatcheries the *Artemia* are enriched with mixtures of Super Selco (INVE Aquaculture, Belgium) and a marine heterotroph Algamac 2000 (Aquafauna Biomarine Inc., USA). These are then added to the tanks at the rate of 1,000 *Artemia* nauplii/L twice a day; this corresponds to a daily ingestion rate for each halibut larva of approximately 2000-3000 prey organisms/day. As the nutrient composition of the enriched *Artemia*, and in particular the polyunsaturated lipid levels deteriorate over time, it is essential that the fish eat all the added *Artemia* within a few hours. Accordingly, *Artemia* additions are matched closely to consumption levels. Where possible the *Artemia* are supplemented with 20% copepods. Using such proportions, hatcheries have achieved 30% survival through first-feeding and 90% fully pigmented fish. Most of the mortalities occur during the initial phases of first-feeding and after 350 degree days, losses are minimal. Tank hygiene can become a problem, so every day dead larvae and debris are removed by siphoning.

By 600-700 degree days, the fish are fully pigmented, metamorphoses and starting to settle on the bottom of the tanks. They are then ready for transfer to weaning systems. If the fish are in good condition and around 100-130 mg in size, the process of weaning can generally be accomplished in 2-3 weeks.

Algae Production

Algal Culture Methods

There are two basic methods for culturing algae. One is called a "Batch culture" the other is called a "Continuous culture".

Batch Culture

In this method algal cells are allowed to grow and reproduce in a closed container. They have a finite amount of nutrient, and when that is exhausted, their growth stops and eventually they die. These types of cultures typically last for about one week. After that, if you wish to continue the culture you must "sub-culture" by adding some cells from the old culture into a flask containing fresh growth medium. This type of culture is undertaken in 2.5 & 10L glass flasks – and in polythene bags ranging from 100 to 250 L

Continuous Culture

This method of culturing algae differs from the batch culture method in that fresh medium is added to the culture at a constant rate and old media (and some of the algae cells) is removed at the same rate. The culture therefore never runs out of nutrients. Hygiene and prevention of contamination is essential, and such systems rarely run indefinitely. On a small scale they can be run in 20L plastic carbouys – with a percentage harvest once per day (often about 20%). Larger commercial systems are now on sale.

Return to main section

Click for Rotifers

Rotifer Production

General

Rotifers (scientific name = *Brachionus*) are brackish water crustaceans commonly used as a starter feed for marine fish larvae. They are considered to have a higher nutritive value than *Artemia.* One of the most commonly used species is *Brachionus plicatilus* with a mean size of 250-260 µm. However, there are different strains of this species which differ in size (larger strains of 300-350 µm and smaller ones of 150-200 µm) and growth rate.
Rotifers can reproduce asexually in favourable conditions by laying one or two large eggs that hatch into females which in turn produces more females. This parthenogenetic reproduction is the basis of mass culture techniques.

Culture techniques

Rotifers are mostly produced in batch cultures and fed initially on marine microalgae such as *Chlorella* or *Nannochloropsis* and then supplemented and/or enriched with bakers yeast or special yeast-based preparations. In this way the composition of the rotifers can better meet the HUFA and vitamin C requirements of many marine fish species. Extra enrichment with emulsified or micro particulate products is also possible. In a standard batch culture systems using some of these specially developed products, rotifers can be produced at 3000-4000 per ml. Generally, this cannot be achieved with normal yeasts or algae. Unexplained collapses of batch cultures can occur. This is a major problem in commercial scale systems. New continuous culture techniques in recirculation systems offer a more consistent supply of high quality rotifers at densities ten times higher than in batch cultures. This is achieved by maintaining better water quality in the system with protein skimmers, ozone treatment and biological filtration. In experimental recirculation systems, densities of 3000 rotifers per ml were sustained. It was estimated that up to 2 billion rotifers can be produced per day at a cost of 54,000 Euros, compared to 94,400 Euros for producing the same number in a conventional batch system.
Disinfection of rotifers is still a bottleneck. However, bacteria levels in high density continuous cultures tend to be lower and more stable than in batch cultures. Another bonus is that rotifers produced in continuous cultures are larger than in batch systems.
Rotifers can be harvested with a 75 µm mesh net and rinsed thoroughly with fresh sea water before feeding to fish larvae.

Return to main section

Click for Artemia

Artemia Production - 1

General

Artemia salina, or brine shrimp, are the most widely used live prey in marine larviculture. The nauplii are hatched from dry cysts most of which are collected from the shores or harvested from the waters of salt lakes, or as a by-product of salt production. The market supply of *Artemia* has fluctuated a great deal in recent years. The Great Salt Lake in Utah, USA was the sole source of *Artemia* cysts for many years, supplying >90% of the world requirement. In 1997, the El Nino effect resulted in excessive rainfall and snow melt in the catchment area. This reduced the salinity of the lake, causing a disruption to cyst supply that led to a world shortage. Several new sources have had to be found, mainly in Russia and China.

Over the years the demand for *Artemia* cysts has increased with the development of fish cultivation. However, their availabilty from year to year has become less reliable and the quality of cysts, in terms of hatching success (>80%), individual dry weight and energy content, can vary with geographical source and between strains. Differences in culture methods, harvesting methods, handling and hatching success can all affect the nauplii, in terms of their size and weight (mg of hatched nauplii per gram of cysts) and their nutritional value and energy content. The maximum time that cysts can be stored before hatching success is compromised is no more than a year. Consequently, price has increased significantly, particularly for the best quality cysts.

Methodology

When selecting which strain of *Artemia* to use, the size of nauplii that the larvae can ingest is a very important factor to consider. Also, hatching efficiency (nauplii per gram of cysts), hatching percentage and time taken to hatch are other important characteristics.

Many types of containers are suitable for hatching *Artemia* cysts. These include conical-based cylinders with water circulation that keeps the cysts in suspension, funnel-shaped containers aerated from the base and plastic bags. Natural sea water, at 25-30 oC and pH 8-9, is used as the culture medium and a high dissolved oxygen level is required. Continuous illumination is recommended.

To increase the hatching rate, decapsulation (i.e. the removal of the outer hard shell = chorion) and disinfection of *Artemia* cysts to reduce the bacteria load are advisable before the cysts are introduced into the culture vessel. *Artemia* nauplii can be heavily contaminated with bacteria, mainly *Vibrio* spp, resulting in their transfer to larval rearing systems with the live feed.

Decapsulation is achieved by hydrating the cysts (in fresh or sea water <35 parts per thousand at 25 oC for 1-2 h) followed by short exposure to a hypochlorite solution. Then the cysts need to be washed and the chlorine residues removed. For hatching, a density of <10 gram of cysts per litre of water is recommended.

Within 24 h the nauplii will have hatched. Harvesting is done by siphoning through a 125 µm mesh. The harvested nauplii retained on the mesh should be washed thoroughly before feeding to the larvae. If necessary, they can be stored at 1 - 4 oC in aerated containers for up to 48 h with minimum enegy loss.

Return to main section

Click for Artemia 2

Artemia Production - 2

General Quality of nauplii

Newly-hatched nauplii, at the instar I stage have a high energy content are the most suitable for feeding to marine fish larvae. Within 24 h of hatching at 25 the nauplii go through a moult stage when the calorific value can decrease by 20%.
Bioencapsulation of *Artemia* (also known as enrichment or boosting with selected HUFAs and vitamins for 24 hours after hatching) has significantly improved the culture of marine fish larvae in terms of survival, growth, success at metamorphosis and overall larval quality (reduced malformations, improved pigmentation, increased resistance to stress and disease). Various enrichment emulsions are available, differing in their fatty acid composition. Traditional EPA-rich formulations have been replaced by those with high levels of DHA and arachadonic acid. Vitamin C has also been incorporated into boosters to increase levels of ascorbic acid. Techniques for cyst decapsulation, high-density nauplius hatching and enrichment, washing and harvesting on a large scale have been standardised and automated.

Nauplius to adult
***Artemia* can also be cultured from nauplii to the pre-adult stage in intensive or extensive systems.**
In intensive systems, hatched nauplii are introduced at a density of 10,000 per litre. It is a filter feeder, filtering continuously so feeds (e.g. algae, yeasts, microparticulate diets) must be dosed continuously or at pre-set times to maintain an optimum food concentration. Solid wastes must be removed from the rearing vessel. Water temperature, salinity, pH and dissolved oxygen levels are similar to those described for hatching cysts. After 2 weeks, the *Artemia* will have grown to 8mm, with a yield of 5 g (wet weight) per cubic metre of culture medium.
Higher yields have been produced in through-flow systems.

Return to main section

Click for Copepods

Copepods

General

One of the advantages of using copepods is their higher nutritional value compared to *Artemia* and rotifers. Also, they are usually smaller than the other live feeds making them more suitable for some marine fish larvae. Some copepod species have a nauplius stage that is 50-75 µm in length. Several copepod species are being tested for their nutritional value and ease of culture. They include harpacticoid copepods, e.g. *Tisbe,* and calanoids, e.g. *Calanus* and *Pseudocalanus*.

The different life stages of copepods can provide much improved nutrition of fish larvae, resulting in better survival, pigmentation and feeding morphology of the larvae. As yet, industry take-up of this nutritional advantage has been limited. Harvesting copepods from the sea is possible in some coastal regions but availability is seasonal and it carries the risk of disease transmission and parasite introduction. Culture methods include semi-extensive ponds and more intensive systems but as yet, commercial scale systems for the reliable and economic production of copepods, and in particular intensive culture systems, are not well established. Candidate species for commercial culture of marine fish larvae will need to have the following characteristics – small size, a short generation time, tolerance to high densities in culture, tolerance to changes in temperature and salinity.

Culture methods

Although calanoid copepod culture is feasible, the high volume systems for culture in captivity are perceived to be too expensive and unreliable for most intensive hatcheries in the UK. Through research into calanoid copepod culture in Australia, an automatically controlled 500-litre recirculation system was developed that produced 450,000 nauplii per day for over 400 days. It was predicted that in locations where flow-through systems could be used in preference to re-circulation systems then production could be increased.

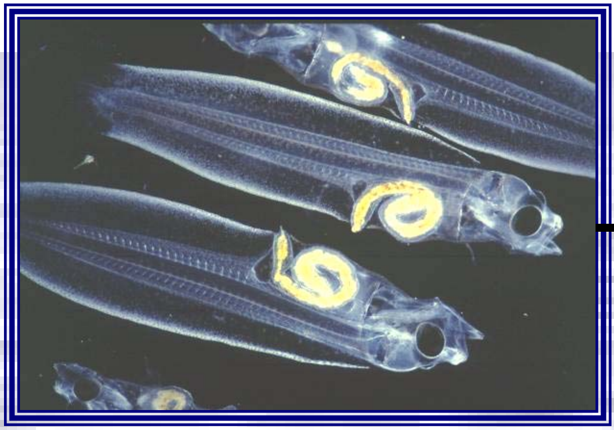
Intensive culture of harpacticoid copepods appears to offer good prospects in the UK for large-scale production. They can be held in captivity at high densities. There are a number of protocols for laboratory-scale production. Research being carried out at SFIA Ardtoe is addressing methods for the intensive cultivation of *Tisbe holothuriae.* Broodstock of the copepod *Tisbe* have also been held in mesh-bottomed trays floating in larval culture systems. When the eggs carried by the female copepods hatch, the nauplii simply fall through the mesh into the culture water. A production of 132,000 nauplii per day from a 200 ml tray has been recorded.

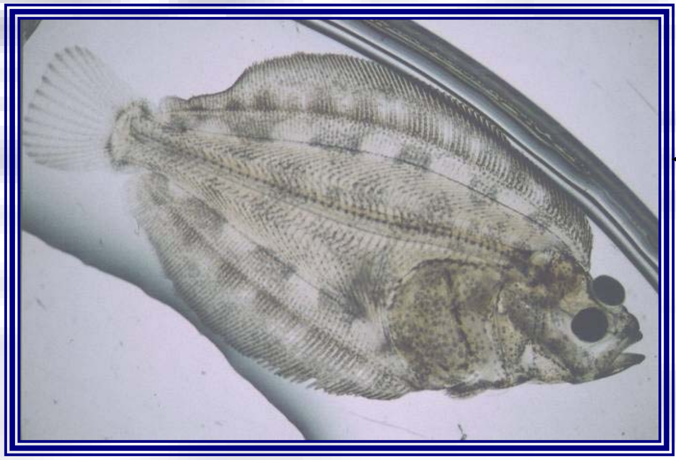
The copepods are fed on cultured marine microalgae species, particularly those with higher levels of essential HUFAs. Alternatively, nutrient rich water in ponds or lagoons can be used for growing algae as a natural food source for the copepods.

Return to main section

Hatchery - Weaning

Weaning is normally undertaken in shallow (<15 cm) tanks of 1 or 2 m2 surface area. Diets are commonly the dry crumb varieties which are available from commercial feed companies: Perla Marine from Trouw, Lansy from INVE, SSF from Norway. Artemia continues to be offered to the small halibut in the weaning tanks, on a slowly decreasing scale over a 2-3 week period. Survivals through the weaning stage are now quite acceptable, probably > 90%.





Halibut larvae at 2 stages of live feeding on Artemia, followed by a weaning-stage halibut

Hatchery - Nursery

Once the small halibut are fully weaned, it only remains for the hatcheries to grow them as speedily and safely as possible up to a size at which they can leave the hatchery. This will depend upon individual company policies and the requirements of customers, but 5g halibut are perfectly hardy animals, quite capable of being transported in much the same way as juvenile turbot. Allowing for some culling of runts and the occasional mortality due to aggression, nursery throughputs should now be > 85%.

There are two major factors to consider around this stage of halibut hatchery:

- The aggression mentioned above is more serious for halibut than for most other cultivated marine fin fish at this stage. Good feeding regimes and high stocking densities are thought to help overcome this problem.
- Halibut juveniles (weaning/nursery) have proved to be particularly susceptible to infection by IPN virus (Infectious pancreatic necrosis). Sterilisation of incoming hatchery seawater, and attempts to reduce any other sources of infection, are essential. Note that the IPN virus is particularly hardy, and high doses of sterilants such as UV or ozone are required. There is no evidence yet of vertical transmission of the virus (from the parents), but this possibility can not be ruled out.

Hatchery - Overview 1

A summary of the current challenges and opportunities facing halibut hatcheries would include:

Broodstock Numbers: Already discussed at some length, this issue is probably the most commercially important one facing any new hatchery producer of halibut. A ten-year wait to develop a full production capability has a very negative effect on cash flows and project acceptability from the point of view of investment decision.

Yolk Sac Rearing and Transfer to First Feeding: This phase is still the focus of some major research effort, and considerable efforts are being made to improve the 15% throughput commonly experienced.

Fish Quality: Incomplete metamorphosis and malpigmentation continue to affect a low but significant percentage of halibut reared in intensive, Artemia-only hatcheries. This problem is not considered too serious for the long term, since evidence suggests that increased overall success in halibut hatchery is bringing associated improvements in the quality of larvae. Anecdotally, the Icelandic hatchery in Akureyri (Fiske), which relies exclusively on Artemia, has achieved > 85% pigmentation and 85% perfect metamorphosis with its spring production run of 150,000 fish in 1998 - a highly acceptable result.

Handling and Husbandry Systems: Many hatchery operators are finding that tank hygiene during the protracted larval rearing phase is a difficult husbandry challenge. There is a need to clean debris from the tank bottoms regularly, but the use of a manual siphon system is both time consuming and overly intrusive to the larvae in the water column of the tank. Efforts are underway to develop a more automated system for this task.

Susceptibility to Disease: Halibut appear to have a non-specific immune system which becomes highly competent once they reach a size of >2g. However, at the weaning and early nursery phase there have been incidents of serious disease outbreaks which have led to massive mortalities. This has been particularly prevalent in Norway, where the use of wild plankton (perhaps !) has led to the introduction of a variety of diseases. IPN and Nodavirus appear to pose a particular threat. Studies are underway on the potential for maternal vaccination and early vaccination during the live food stages.

Aggression and Behaviour: Small halibut juveniles display considerably different behavioural characteristics to other flatfish species such as turbot. Notably they are much more aggressive towards each other during the weaning and early nursery phase, and there is considerable “fin-nipping”. This is not affecting overall survivals, but the ragged appearance of the fins of juveniles leaving the hatcheries is not only unsightly, but may predispose them to disease incidence in the nursery phase of ongrowing. Eye biting is a much more serious problem. Academic studies are underway into halibut aggression, and some practical husbandry solutions may be emerging (use of high densities, for example).

THE PRODUCTION PROCESS

Hatchery - Overview 2

The cumulative survival from hatched egg to final juvenile currently runs at some 5-10% in typical Artemia-only hatcheries, and may be slightly higher in Norwegian hatcheries. With a 50% success in egg incubation and an 80% incubation rate from stripped eggs, we can estimate that a minimum scale of commercially profitable hatchery (say 200,000 juveniles p.a.) would require an annual egg supply of c.11 million. With some 45,000 eggs per litre and each broodstock female giving 6 L of good quality eggs per annum, the hypothetical hatchery needs at least 40 top quality spawning females.

Experience shows that not all the female halibut which are captured from the sea will finally adapt to become good quality spawners, so a safe conservative goal for the hypothetical 200,000 juvenile commercial hatchery would probably be closer to 60 female fish. In addition there would be a requirement for at least 60 male fish, i.e. a total need to have some 120+ large broodstock halibut in captivity at the earliest possible time. It is possible to develop spreadsheet-based models (example on the right), to calculate hatchery scaling and broodstock issues.

Figure 1 Halibut Hatchery Throughput Model

MODEL ASSUMPTIONS	***200,000***	Juveniles Per Annum	
EGG PRODUCTION & INCUBATION			
Vol. Eggs/Fem/Season (L)	10	Percent Viable Eggs/Strip	75%
Duration of Spawn Season (Wks)	10	Number Eggs/L	40,000
Volume of Egg Incubators (L)	400	Egg Stock Density (Numb./L)	80
Egg Incubation Duration (Days)	13	Percent Survival of Eggs	50%
Number of Seasons per Year	2		
YOLK SAC INCUBATION			
Volume of YS Vessels (L)	400	YS Stock Density (Numb/L)	25
YS Incubation Duration (Days)	38	Percent Survival of YS	40%
		Percent Deformed YS Larvae	20%
FIRST FEEDING & LARVAL REARING			
Volume of FF Tanks (L)	2000	Larval Stock Density (Numb/L)	5
Percent Actual First Feeders	20%	Percent Survival thru' LR	80%
LR Duration (Days)	56		
WEANING & NURSERY			
Volume of Wean Tanks (L)	800	Weaning Stock Density (Numb/L	5
Weaning Duration (Days)	21	Percent Survival of Weaning	85%
Area of Nursery Tanks (m2)	4	Final Nursery Mkt Weight (g)	5
Final Stock Density (kg/m2)	8	Nursery Duration (Days)	100
Percent Survival in Nursery	95%		
MODEL OUTCOMES			
Total Egg Vol. Reqd./Season (L)	161	Number Female BS Required	32
Number Egg Incubators Required	28	Number YS Incubators Required	131
Number FF/LR Tanks Required	62	Number Weaning Tanks Reqd.	9
Total Numb. Nursery Tanks Required	16	Vol Eggs Needed per Week (L)	16
Yield Larvae per YS tank	3200		

Hatchery to Ongrowing Transition

The cumulative time taken to produce 5-10g weaned juvenile halibut in the hatchery is somewhere between 7 and 8 months. This compares with around 4 months to produce juvenile turbot of a similar size.

Traditionally, marine fin fish hatcheries have to focus on the difficult live food and larval rearing stages in order to achieve success. The final hatchery-nursery phase from weaning up to 5-10g is relatively undemanding from a biological standpoint - but it does occupy considerable physical space within the hatchery. It also occupies staff time, and critically it interferes with "pulse" production principles (where a hatchery operates on a distinct "all-in, all-out" seasonal pattern of production).

For these reasons, marine fin fish hatcheries need to get fish off site as early as possible.

For species such as turbot, where ongrowing production takes place in land-based systems, this is not a problem. The ongrowing farm would have a dedicated "nursery" or "pre-ongrowing" system - small tanks, usually under cover. Juvenile flatfish tend to remain at their most vulnerable to diseases (e.g. Vibrio, IPN) or behavioural problems up to a size of about 100g. At that point, they are relatively hardy, and can be placed into any "main" ongrowing system. The problem for cage ongrowing of halibut is that there is no "nursery" option on the ongrowing site.

Nursery Ongrowing 1

The “middle phase” which has emerged for halibut production in Scotland is the so-called “nursery phase”. Fish are typically taken from the hatchery and placed in another separate land-based unit, to be grown from 5-10g to 100g or even bigger.

Such units represent a “cost centre”, and should either be built alongside hatchery units, or alongside a large cage operation shore base. In both cases there is the opportunity to share overheads and manpower.

As a broad rule of thumb the costs of changing a 5-10g fish into a 100g fish relate to the following areas:

1) The cost of "purchasing" the 5-10g fish
2) The fixed asset cost (as a depreciation charge) involved in providing the physical system to grow the fish
3) The input costs the grow the fish from 10g to 100g, including:
   a) Feed costs b) Energy costs c) Manpower cost allocation
   d) Other consumables costs e) Share of overheads costs

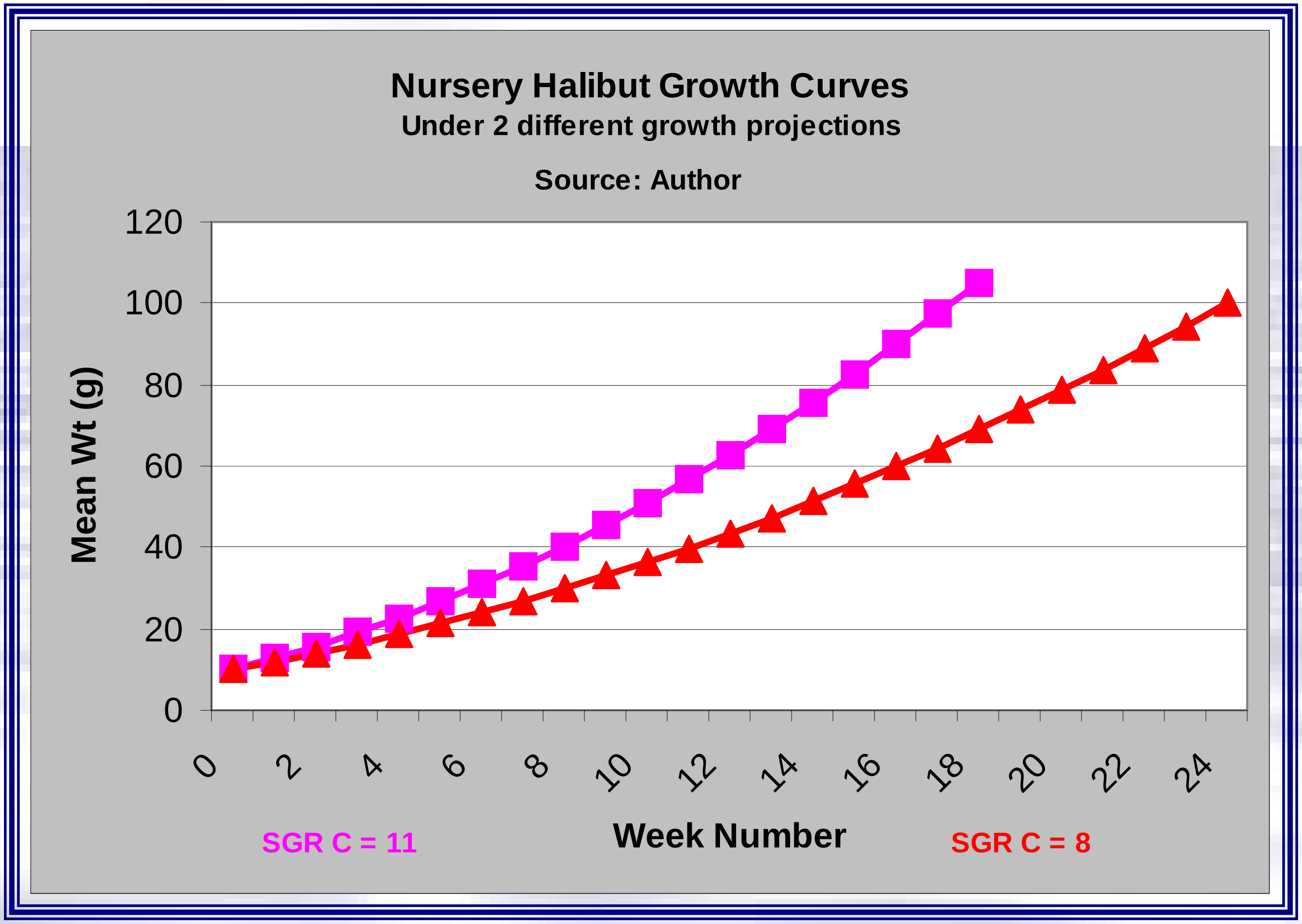
Speed of throughput in a nursery system will be of the essence - which means a focus on optimising growth rate.

Nursery Ongrowing 2

The expectation of growth rate can be numerically calculated, and can relate to several parameters. However, temperature of the rearing water is probably the main deciding factor.

The issue of water temperature is critical. If it is maintained at a near perfect level (e.g. 13 Deg C), then halibut should reach 100g in 17 weeks. If it is allowed to follow natural west of Scotland temperatures, then the average growth period might be extended to around 24 weeks.

The point about this is that with the faster growth a "nursery" could put 3 crops through per year. With the slower growth, only 2 crops per year are possible.



Nursery Ongrowing 3

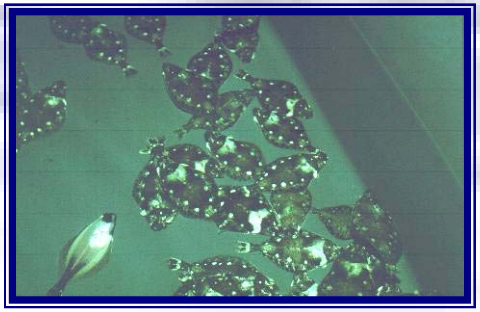
Halibut nursery units are primarily an issue of technical design and operation - and so they are discussed in the TECHNOLOGIES section of this Hyperbook.

From a production process standpoint, there are 3 principle options:

- **Simple ambient temperature flow-through systems**
- **Temperature control by way of heat reclamation**
- **Temperature control by way of recirculation systems**

Other than achieving different rates of growth, the halibut biology and husbandry is relatively consistent. The following parameters are important:

- **Feed (see SUPPLIERS) should be offered properly**
- **Feed conversion target should be in the region of 0.8:1 dry:wet**
- **Care must betaken to avoid disease introduction - particularly IPN**
- **Grading should be frequent to avoid aggression**
- **Stocking densities should be high - in the region of 10-20 kg/m2**



Ongrowing in Cages 1

Halibut ongrowing floating sea cages is essentially the same as salmon ongrowing in cages, with the following key differences:

- **A “standard” cage needs to have a modified flat bottom, to provide a resting surface**
- **This can be achieved by stretching a trampoline-like base from a sub-surface rigid frame**
- **The bottom material could be tarpaulin or fine mesh - both options are in use**
- **The cage base could in the region of 4 m below the water surface**
- **Such cages require sheltered sites (see TECHNOLOGIES section)**

Halibut cages in operation on the Isle of Uist

Ongrowing in Cages 2

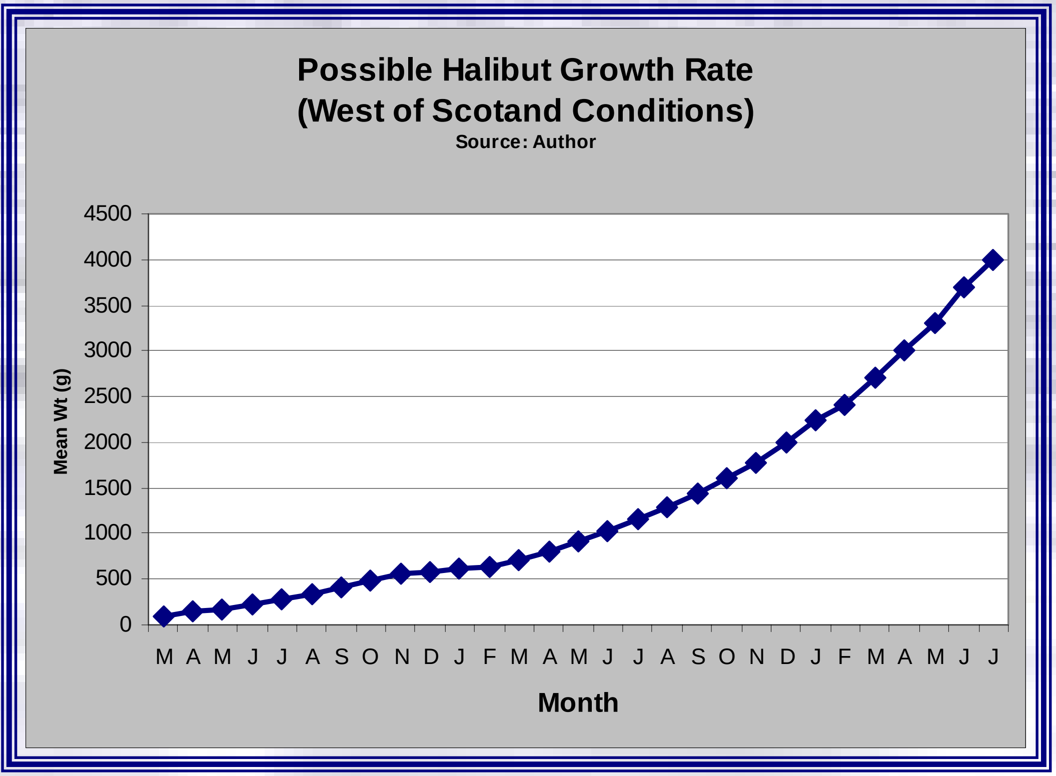
Halibut growth rate in sea cages will depend upon the ambient temperature range in the location chosen, but also upon good husbandry and feeding practices. The duration of the growth cycle will depend upon the company's harvesting strategy. Overall cage utilisation will depend upon stocking densities. There is also the choice of working with single or multiple "year class" sites. This Hyperbook can not provide you with all the answers in this new and developing field, but you may find the following pages useful.

Growth Rate expectation in Scottish conditions:

The target would be 4 kg after 27 months in the sea

This equates to a Specific Growth Rate constant (SGRC) of 12.2

For discussion about growth measurement, press here



Specific Growth Rate Equations and Constants

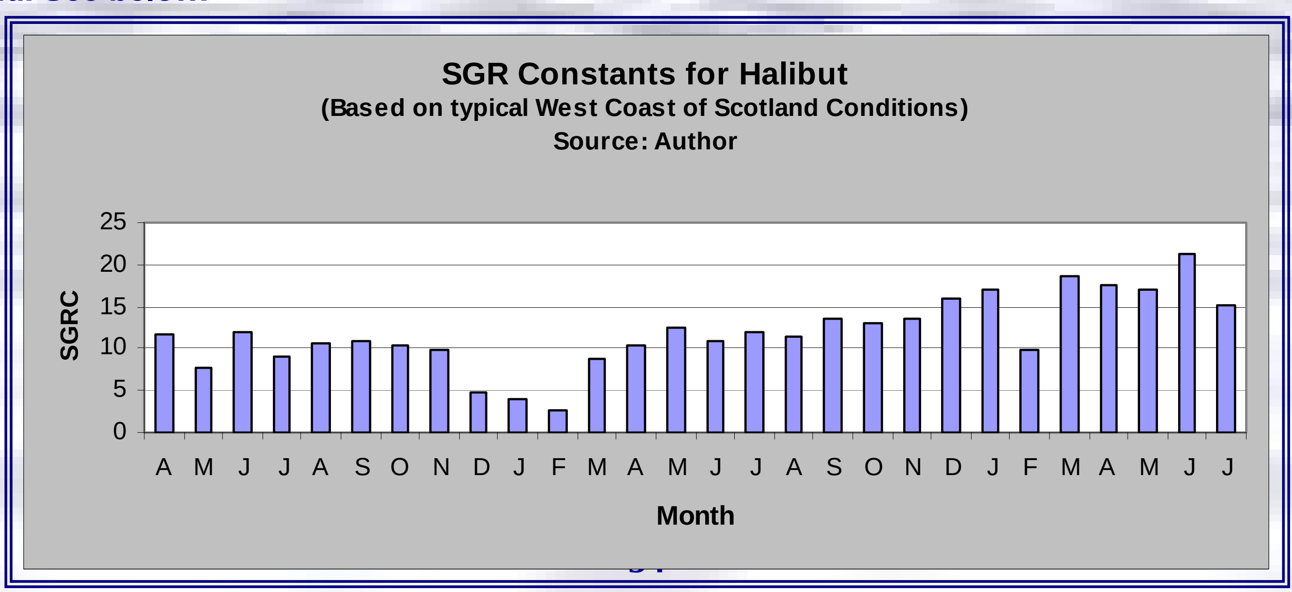
The growth rate of any fish is determined by a number of factors, such as food supply, suitable water chemistry, gender etc. However, if all these other factors are at or near optimum, the key factor is water temperature. Different species of fish have different "preferred" temperatures (which may vary slightly with fish size).

Growth rate can be numerically studied in two principal ways: the Specific Growth Rate (SGR) and the "GF3". This Hyperbook uses the SGR methodology, with SGR being defined as percentage change in body weight per day. SGR changes as fish get bigger, and of course it also varies with temperature.

The method utilises the equation:

$$SGR = (\text{Constant} \times \text{Weight}^{-0.5})/100$$

This is basically a way of "smoothing out" the effects of fish sizes over a time period. Unlike GF3, this method does not take account of factors such as temperature, diet etc. In practice there would be a range of different SGR "constants" (SGRC) during the life of a halibut growing under ambient conditions in Scotland. See below.



Ongrowing in Cages 3

Other considerations about halibut cage ongrowing:

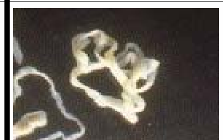
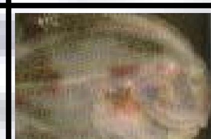
- **Feeding - follow the feed suppliers guidelines, but be prepared to experiment with feeding rates and frequencies**
- **Stocking densities have not yet been fine-tuned for halibut - but one should probably be thinking of 50 kg/m2 (of cage floor) as a maximum for larger fish, and 20 kg/m2 as a starting point for 100g juveniles**
- **Stock observation and mortalities removal is essential, but difficult if water clarity is not good - consider using divers or ROV-technology**
- **Malpigmented halibut may suffer from UV damage, so are probably not so suitable for cage ongrowing**
- **Stock handling and net changing procedures will have to be adapted from salmon farming - the flat cage bottom and its support frame can prove cumbersome**
- **Halibut appear quite hardy (in disease terms) so far, but regular observation for ectoparasites such as Trichodina or Caligus would be appropriate**

For information about disease issues, press here

Disease Issues

In addition to the health threats illustrated in the figure, there is one rather unique threat to malpigmented halibut in shallow tanks or cages. Direct sunlight appears to cause sub-cutaneous lesions and eruptions in the fatty tissues along the fin margins of some fish. These eruptions can become infected with secondary bacteria, and are therefore a potential risk to the fish. In addition they leave unsightly scarring even when healed, which could affect the final fish quality at the end of the farming process.

The exact cause of this syndrome is unknown, but it is almost exclusively seen in malpigmented fish, and does not seem to occur if fish are shielded from strong natural sunlight. There are not yet clear guidelines as to, for example, depth of water in various coastal conditions which would provide adequate shielding. The best solution so far, apart from trying to avoid the use of malpigmented fish, is to provide a high level of sun screening in the form of tank covers. However, lateral transmission of light in the cage environment means that this solution may not be so effective in cages. A guideline depth of 4 m is normally recommended for halibut cages.

ORGANISM	IMAGE	COMMENT
PARASITES Trichodina sp.		Not uncommon with halibut Treat with Formalin Not a serious threat if controlled
Tapeworms		Status unclear with halibut Probably not a serious threat
Entobdela sp.		Monogenean skin parasite Treatment techniques currently being developed. Can be heavy infestations
BACTERIA Aeromonas sp		Furunculosis-type problems Could potentially affect halibut, and can probably act as carriers Vaccination, Antibiotics
Vibrio sp		Can certainly affect big halibut, but probably on if weakened Vaccination, Antibiotics, Good Husbandry & Nutrition
VIRUS IPNV		Can certainly affect <2 g halibut and 20-100g halibut. Probably can also act as carriers. Avoid challenge
VHSV		Halibut seem to be v. resistant to this virus - but a new strain could cause problems. Avoid risks (eg no wet fish feeds)
Nodavirus		A problem in Norway. Vertical transmission. Cull suspect broodfish

Ongrowing in Land Based Systems - 1

There are two overwhelming implications of any land-based farming operation for growing marine fish species, and a third one for growing flatfish species:

- The cost of building the land-based fish containment system is invariably considerably higher than the cost for containing a similar biomass in floating structures in the sea (cages).
- The cost of keeping the fish in good quality water is also inherently higher in land-based units, since all the seawater must be pumped ashore, against the force of gravity. By contrast, natural (and free) tidal currents provide the water refreshment capability of cage systems.

Any building costs are primarily two-dimensional - they relate to the cost of putting tanks, buildings etc on the surface area of the ground. The additional cost of the third dimension is much less important, i.e. it does not cost much more to build a farm with 3 m deep tanks than to build a farm with 1.5 m deep tanks. It follows, therefore, that fish species which can utilise three dimensions can occupy a given amount of total fixed asset investment much more efficiently. In other words, flatfish, because they only use two dimensions, are inherently the least cost-effective species in terms of occupying costly land-based farms, on a kg-per-fixed-asset-cost basis.

From the above analysis, it follows that successful land-based farming has to attempt to optimise certain parameters:

- The farm must be built as cheaply as stock safety permits.
- The water pumping bill must be minimised by some means.
- The crop cycle and thus first positive cash flow must be made as rapid as possible (to minimise the finance cost burdens of the expensive up-front fixed asset investment)

Despite these caveats, land-based farming for high value species offers much more stock control than cage farming - and offers the opportunity for environmental impact control.

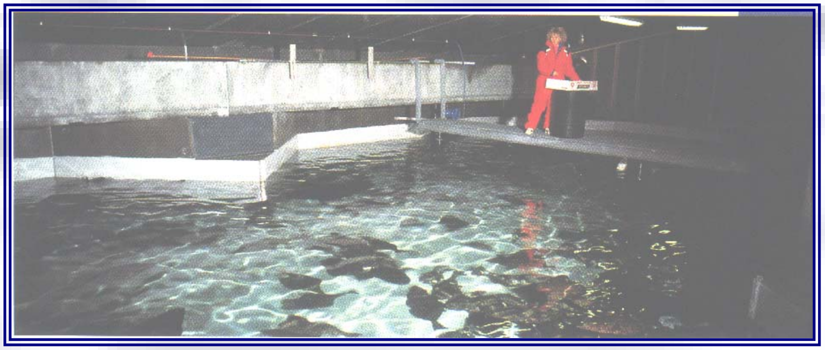
Ongrowing in Land Based Systems - 2

If both the fixed asset and operating cost burden are higher "per kg of fish held" in land based farms, it follows that the aquaculture plan must aim to minimise the amount of time which any fish spends in the farm (i.e. have fast growth), and optimise the use of all the expensive tank space (i.e. have efficient stocking in every tank at all times). These two requirements are self-evident, but can cause problems when species such as halibut are being contemplated:

- .The traditional wild halibut market size range is variable, but is generally for fish of >5 kg. This size of fish would take a long time to produce in the farming cycle, and there might be issues of poor growth due to spawning cycles along the way. Nevertheless, current halibut ongrowing practice is indeed to try to grow the fish as large as possible.

- .The most efficient way to stock a land based fish farm is to input several sub-annual crops, equally spread throughout the year. Such a strategy also helps to provide a more regular output of product at the end of the farming cycle. Unfortunately, even in the most established halibut producing countries (Norway and Iceland) there is not yet year-round photoperiod controlled egg production. There is progress in this area, and the species is certainly capable of photoperiod control. However, since the other main limitation in halibut hatcheries is controlled low temperatures, there is a tendency for hatcheries to avoid rearing in the summer season, even in these warmer countries.

One Norwegian company's approach to land-based halibut farming



Ongrowing in Land Based Systems - 3

One interesting opportunity for land-based halibut cultivation is the use of shelves in tanks. This relates to the obvious economic vulnerabilities for flatfish species discussed in a previous section, and is entirely sensible as a basic concept. However, as any experienced husbandryman will know, there is an inevitable danger of not being able to observe and manage the stocks of fish properly on the lower level shelves.

Practical experience has been limited so far - but it certainly seems that halibut are more likely to utilise shelves that other flatfish species such as turbot. For this reason, effective stocking densities in land-based halibut cultivation might be quite high on a "per m3" basis. Having two half-shelves at different depths within a tank (plus the bottom) would amount to an effective doubling of stocking density per unit "footprint".

A very simple approach to land-based halibut farming in Norway

Ongrowing in Land Based Systems - 4

The main considerations about halibut land-based ongrowing include:

- **Feeding - follow the feed suppliers guidelines, but be prepared to experiment with feeding rates and frequencies. Expect good feed conversion efficiencies, since wastage should be low**
- **Stocking densities have not yet been fine-tuned for halibut - but as a rule of thumb one should probably be thinking of 50 kg/m2 (of single layer floor) as a maximum for larger fish, and 20 kg/m2 as a starting point for 100g juveniles. If shelves were in use in a 1m deep tank, the maximum density might equate to 100 kg/m3 - and one would have to be concerned about good oxygenation**
- **Stock observation and mortality removal is essential - and much facilitated in tanks**
- **Malpigmented halibut may suffer from UV damage, but they could be grown in light-screened tanks. If the final product is fillet, the original skin colour is of little consequence**
- **Stock handling is easier in a land-based farm - but since it is important to maintain near-optimum stocking densities at all times, this is just as well**
- **Halibut appear quite hardy (in disease terms) so far, but regular observation for ectoparasites such as *Trichodina* or *Caligus* would be appropriate**
- **Control is easier than for cage farming - but the system integrity is important. Care is required to engineer water and oxygenation systems with sufficient redundancy and backup, and to have good alarm systems and staff on-call procedures**

Environmental Aspects of Halibut Cultivation - 1

Any form of aquaculture shares a natural resource (water) with a number of other users and stakeholders. The effect of aquaculture on the aqueous environment differs depending upon the species and the farming system:

- Shellfish are thought to be "benign" because they do not use artificial feeding, and thus do not add nitrogen, phosphorous or new solid material into the environment. On the other hand, they actually remove nitrogen from the marine environment, and carrying capacity for their production in some countries is limited by this very factor. They also do produce solid waste (faeces and pseudo-faeces) which deposits on the sea bed in their vicinity in a way which would not happen in a "natural" environment. In addition, current shellfish production technologies have some visual impact on the foreshore and general coastal waters.
- Fin fish farming does involve the addition of artificial feed - and this results in both solid and dissolved waste material (faeces and nutrients such as nitrogen and phosphorous). Furthermore, there may be the use of antifoulant chemicals in sea cage farms, and chemo-therapeutants in all types of fish production:
  - In cage farming there is little or no way to prevent these by-products of the process from entering the general aqueous environment
  - In traditional land-based farming there are some prospects for screening effluents for some waste materials (at a cost), but since flow rates are very high there is little prospect of much more "treatment" at any reasonable cost
  - In modern high-tech "recirculation systems" there are much lower flow rates, and therefore more prospects for water treatment. However these systems are expensive to install and operate, and are unlikely to form the mainstream of aquaculture prospects for Scotland in the future (although their use in land-based "nurseries" for halibut, cod and haddock may be practical)

In truth the physical "footprint" of all aquaculture in Scotland is very low - about 0.2 % of the entire coastal waters. Nitrogen input from the industry in year 2000 is calculated to be around 6,500 tonnes - a tiny percentage of the nitrogen running into the sea from towns, farms and forestry. Combining these inputs with the natural nitrogen flux into and out of our coastal waters, some scientists have estimated that aquaculture contributes only a tiny fraction of the total.

Environmental Aspects of Halibut Cultivation - 2

Halibut is a fin fish, much like salmon, and many of the environmental considerations are the same. The main differences or points to note include:

- **Estimated environmental input of nitrogen for halibut is 48 kg N per tonne of fish produced**
  - **Based upon an overal feed conversion ratio (FCR) of 1.3:1**
  - **If FCR's reduced to what the fish is capable of (with improved husbandry), 0.8:1, then the nitrogen figure would drop to around 22 kg N per tonne of fish**
- **Halibut cage farms will probably remain small (in production terms) compared with modern large salmon farms - 500 tonnes per annum, for example. They might therefore suit sites which have become inappropriate for salmon farming**
- **Visual impact at the surface will remain very similar to salmon farms (except for the issue of scale)**
- **Anti-foulant treatments for nets will probably be similar to salmon farming**
- **Halibut do not "host" the salmon sea louse - and thus are not part of the sea lice/riparian owners debate. There will thus be no requirement to treat halibut with anti-lice medications**
- **Hatcheries, land-based nurseries and traditional land-based ongrowing farms will be able to screen effluents for solid waste, and will be amenable to "end of pipe" discharge consent controls**
- **Any application of recirculation technology (if it proves to be viable in other regards) will mean even more discharge treatment - but one form of nitrogen or another will still be the final nutrient input of relevance to the marine environment**

Environmental impact - real or perceived - of aquaculture is a very complex subject. This Hyperbook can not go into any more detail than that shown above at the present time.

THE TECHNOLOGIES AND EQUIPMENT EMPLOYED

Introduction

This section of the Hyperbook will "mirror" the previous section (PRODUCTION PROCESS), but will focus on the hardware and systems aspects of halibut production.

Hatchery - Broodstock 1

A “typical” halibut broodstock tank might be:

- 4m in diameter - or larger
- 1m deep water (at least)
- Temperature controlled - at least near spawning
- Photoperiod controlled - therefore in a partitioned building or with its own light-proof cover
- Capable of being partially drained quickly in order to allow staff access in waders on a regular basis
- Secured in terms of broodstock fish “jumping” out of the water
- Secured by the general alarm system, for water level, flow rate, oxygen etc

A 5m diameter circular tank being installed, with its own light-proof cover

Hatchery - Broodstock 2

An egg stripping operation will require access to:

- A purpose-built stripping table - possibly with a hoist system
- Chest waders for staff
- Pit-tagged fish - and a pit-tag reader (alternative would be dye-marking, freeze branding or sheep tags)
- A selection of clean, dry polypropylene lab vessels e.g. 2L and 12L jugs, 50 & 100 ml beakers
- Egg handling vessels e.g. 13L clear plastic rectangular fish “tanks”
- Fine hand meshes
- Laboratory and microscope (for assessing sperm motility and egg division progress)

Setting up stripped halibut eggs in incubation

Hatchery - Egg Incubation

Halibut egg incubation lasts for about 14 days, and requires:

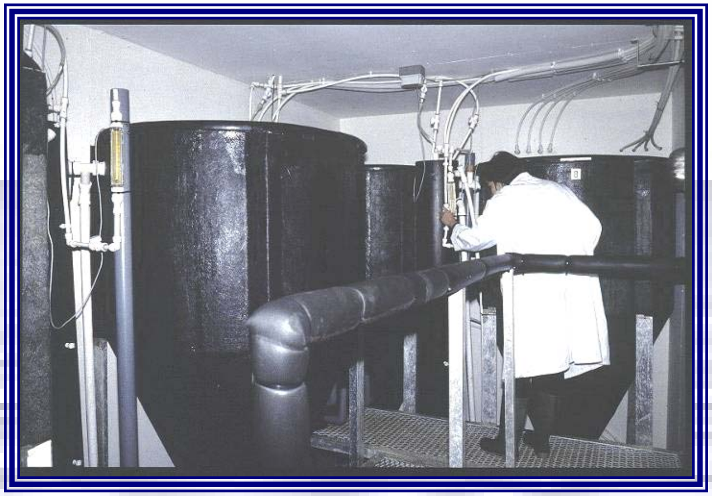
- Conical-shaped upwelling incubation vessels - kept largely in the dark. 70L “Paxtons” have been used, but better results are obtained with 450L vessels
- 1 Micron filtered and UV sterilised seawater at full salinity and a stable temperature of 6 Deg C
- Accurate flow-controls
- Record-keeping protocols and facilities
- Normal hatchery equipment:
  - Hand nets
  - Siphon
  - Jugs and beakers
  - Chemicals for egg sterilisation (gluteraldehyde or “kick-start”)

Typical 450 L fibreglass conical vessels, suitable for halibut egg incubation

Hatchery - Yolk Sac Incubation

Halibut yolk sac incubation lasts for about 45 days, and requires:

- Conical-shaped upwelling incubation vessels - in the dark. 450L vessels can be used, but 900 L or even larger vessels are also appropriate
- 1 Micron filtered and UV sterilised seawater at full salinity and a stable temperature of 6 Deg C
- Accurate flow-controls
- Record-keeping protocols and facilities
- Normal hatchery equipment:
  - Hand nets
  - Siphon
  - Jugs and beakers
  - Inspection lamps



Typical 900 L fibreglass conical vessels, suitable for halibut yolk sac incubation

"Banjo" mesh outlets in use in egg and yolk sac incubators

Hatchery - Larval Rearing

Halibut larval rearing (live feeding) lasts for about 45-65 days, and requires:

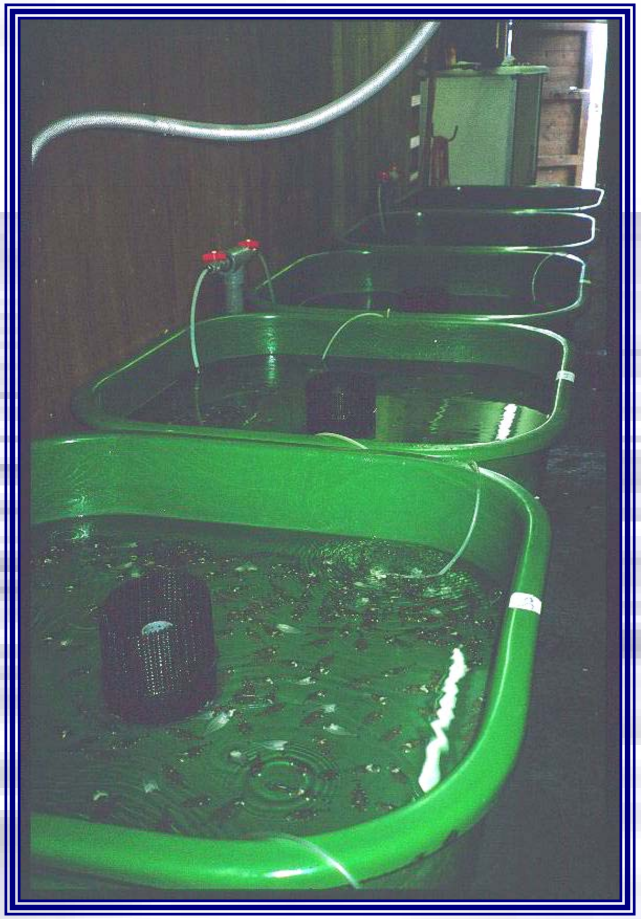
- **Flat-bottomed plastic rearing tanks of 1000L or larger**
- **Equipped with:**
  - Low level lighting
  - Temperature controlled filtered seawater flow (c. 10 Deg C)
  - Mesh screen outlets
  - Aeration
- **Normal hatchery tools, monitoring systems and record-keeping protocols**

Typical small 1000 L fibreglass halibut larval rearing tanks

Hatchery - Weaning

Halibut weaning involves transfer of the larvae to shallow tanks, and requires:

- **Flat-bottomed shallow fibreglass tanks - 1 m or 2 m across, by 0.2 - 0.5m deep**
- **Provision of temperature-controlled water flow (12-14 Deg C)**
- **Equipped with:**
  - **Medium level lighting**
  - **Mesh screen outlets**
  - **Aeration**
- **Normal hatchery tools, monitoring systems and record-keeping protocols**
- **Automatic feeders may be used - but regular hand-feeding and cleaning is probably preferable**



Typical shallow 1m fibreglass halibut weaning tanks

Hatchery - Nursery

Halibut nursery in the hatchery requires:

- Flat-bottomed shallow fibreglass tanks - 2 m across, by 0.5m deep
- Provision of temperature-controlled water flow (12-14 Deg C)
- Equipped with:
  - Medium level lighting
  - Mesh screen outlets
  - Aeration
- Normal hatchery tools, monitoring systems and record-keeping protocols
- Automatic feeders may be used - but regular hand-feeding and cleaning is probably preferable

Typical shallow 2m fibreglass halibut nursery tanks

Nursery Facilities - 1

A stand-alone land-based halibut nursery is effectively a small ongrowing farm. Typical tank sizes would tend to be 4-5m diameter, and the design should be as simple as possible.

An example of a simple tank layout - with the addition of some sun-screen covers, this would be a near-perfect halibut ambient temperature nursery unit - but if a temperature controlled nursery was required … see next page

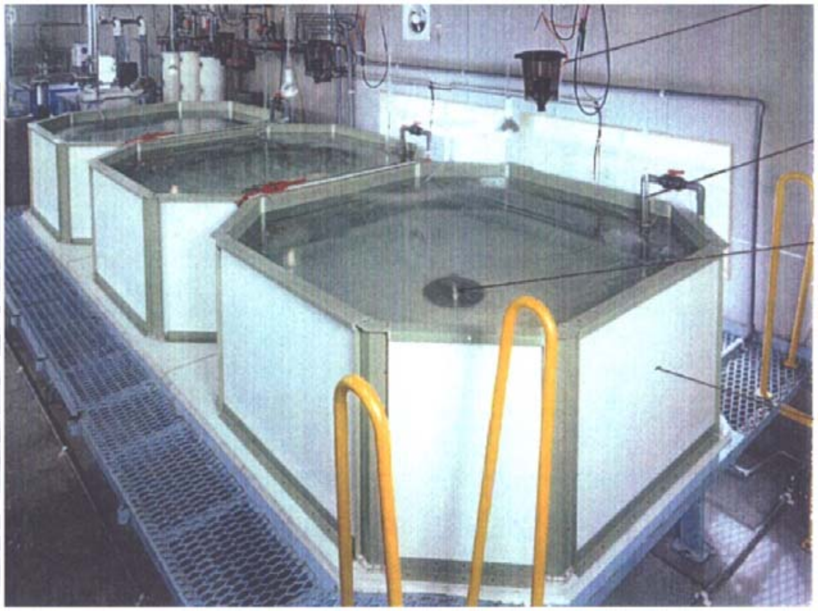
Nursery Facilities - 2

A temperature-controlled halibut nursery would provide faster growth and therefore throughput - and so allow more “crops” per unit time. The disadvantage would be higher construction and operating costs. Some sort of thermal insulation would be required, whether for a recirculation system or a heat-reclamation system. This could be achieved in a rigid building, or in individually-covered tanks & treatment units.

An example of a simple individually insulated fish tank, with a water recirculation system within a shed in the background - note the shed would be capable of housing treatment units for several tanks

Nursery Facilities - 3

There are several companies which will offer high-tech recirculation units, housed in insulated buildings and working on the highest standards of water quality.



An example of a very high-tech recirculation system - this was actually designed for small Japanese flounder, but the principle would be much the same as that on offer to would-be purchasers of halibut nursery recirculation systems

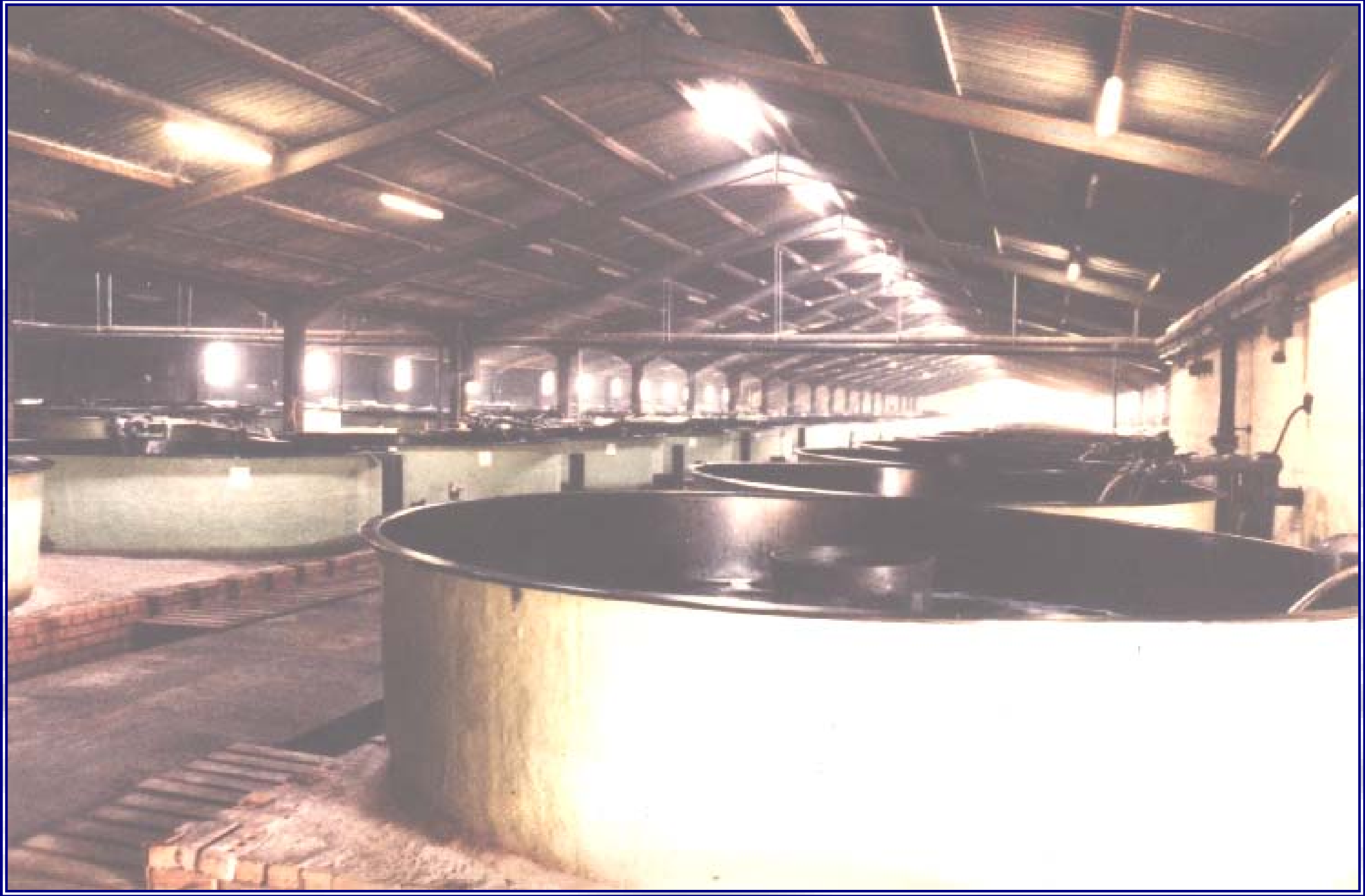
Land Based Ongrowing - 1

A typical marine fin fish land-based ongrowing unit. Located near the sea, with a large seawater pumping and screening system. Water is distributed to the tanks via a large open “flume” system, and effluent is discharged from the farm as far away from the seawater intakes as possible. Oxygen and aeration systems help to minimise the total pumping requirement.

Land Based Ongrowing- 2

Another marine fin fish land based ongrowing unit, using a combination of circular and rectangular tanks, 0.8 m deep. All tanks have light-shading covers to prevent UV damage. Seawater is pumped on to the farm via submersible pumps at sea, coming into the header tanks on the left of the picture. It is then distributed by gravity to the main farm, via a network of PVC pipes.

Land Based Ongrowing- 3



Farms can be located inside rigid buildings, although these are costly. This image shows a farm which is mainly utilising 6.3 m circular fibreglass ongrowing tanks, but in the foreground is the "nursery" area, with smaller 4m diameter tanks.

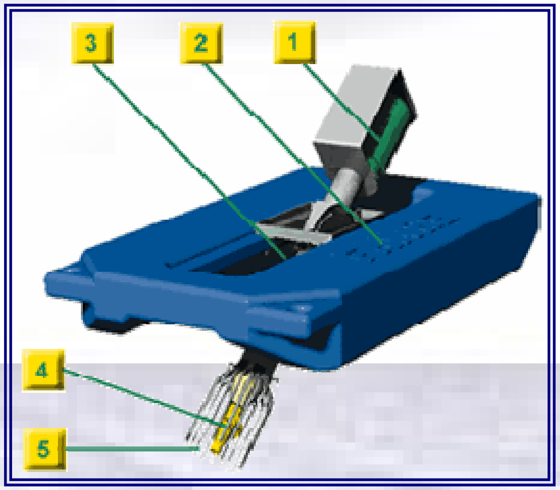
Land Based Ongrowing- 4

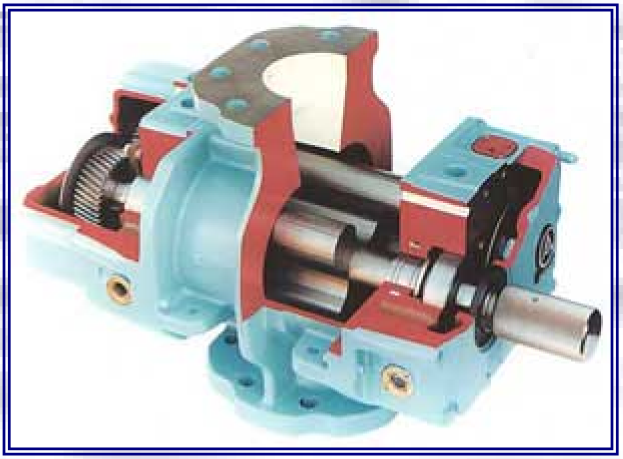
Cheaper forms of covered ongrowing units can be achieved by using “greenhouse” technology, but with rigid and opaque paneling. This unit also utilises concrete as the main construction material.

Land Based Ongrowing- 5

Seawater pumping is one of the main costs of land-based ongrowing - and also one of the most vital components of the system. Large, efficient and reliable pumps are required (either submersible or suction-based). Back-up pumps, alarm systems and contingency plans are essential.

Land Based Ongrowing- 6





Seawater pumping is minimised by providing extra oxygen for the fish by way of either aeration (using low-pressure blowers) or direct oxygen injection. Typical units are illustrated above.

Sea Cage Ongrowing- 1

Flatfish Cage Guidelines

The cages are generally constructed as modified salmonid cages, with the net bottom being replaced by a PVC or similar sheet, stretched across a rigid outer frame along the lines of a trampoline, and suspended from the surface flotation collar.

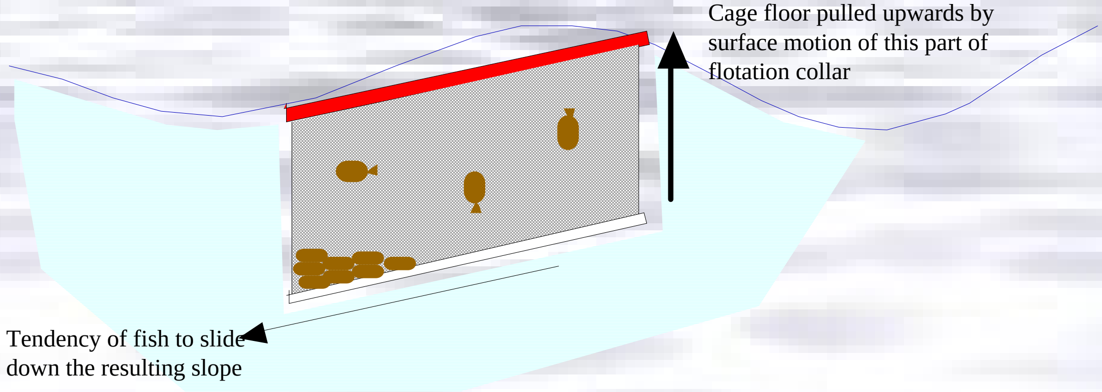
Cages range in shape from square (c.10 x 10 m or smaller), to hexagonal units with 35 m2 bottom areas.

Surface floatations have always been rigid metal structures with standard buoyancy packs (inflatable or solid), although there is now some experience of putting flat bottoms on circular HDPE collar cages

Cage bottoms are located at some 4-6m below the sea surface, in order to reduce the effects of UV light and to reduce biofouling on the bottom areas.

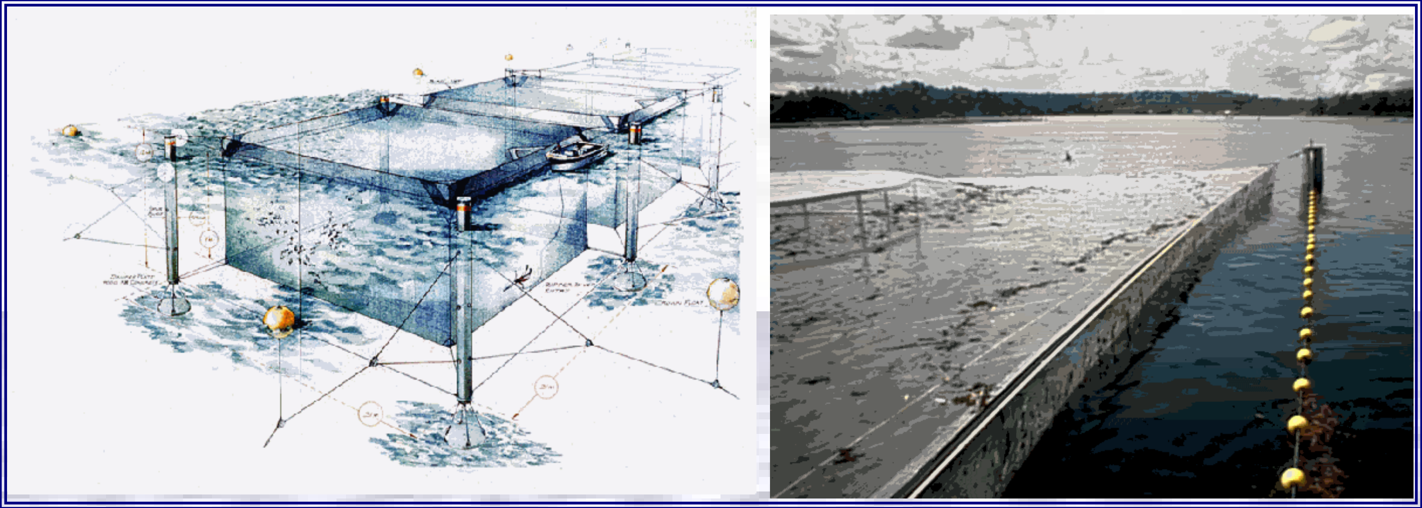
Some method of winching up the cage bottoms should be included, to allow access to the fish stocks, and to provide a method for cleaning the side walls of the cage netting.

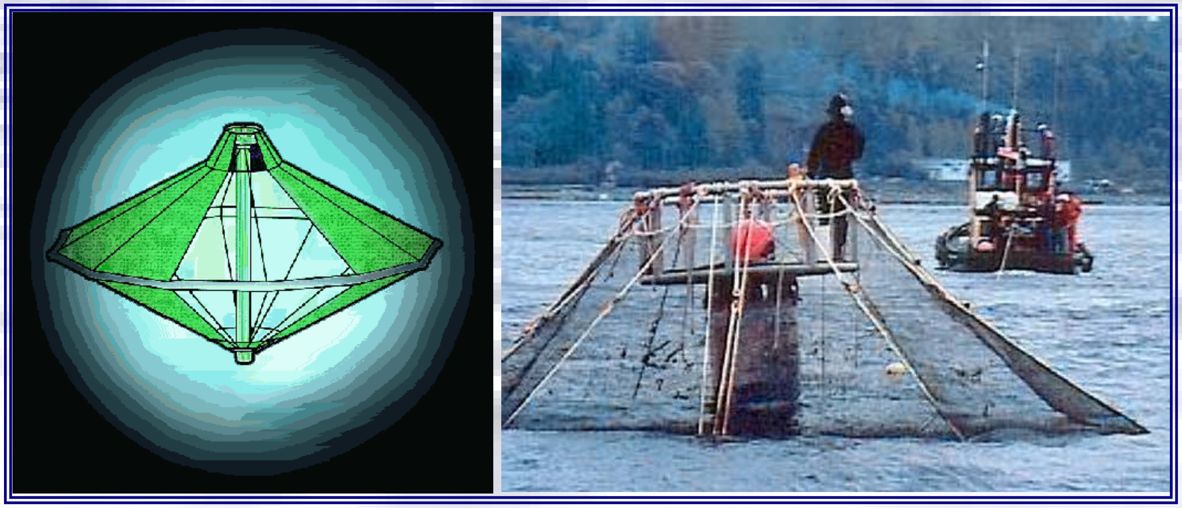
Cages should be located in very sheltered areas, since it had been recognised very early that surface wave motions would create mirroring “rocking” motions in the cage bottom structure (see below), and that this would be likely to stress the fish stocks.



The effect of wave action on flat-bottomed cages

Sea Cage Ongrowing- 2





Innovative cage designs which may have some application for species such as halibut: Ocean Spar (top) and Sea Station (bottom)

(Images from the excellent company Web sites)

Sea Cage Ongrowing- 3

A group of halibut cages in Scotland, and an example of the type of ROV technology which might be appropriate for use in such systems.

Sea Cage Ongrowing- 4

As a general guide, halibut cage cultivation technology closely mirrors that already in use in the salmon farming sector – many of the same developments used in salmon may find application with halibut

SITE SELECTION

Introduction

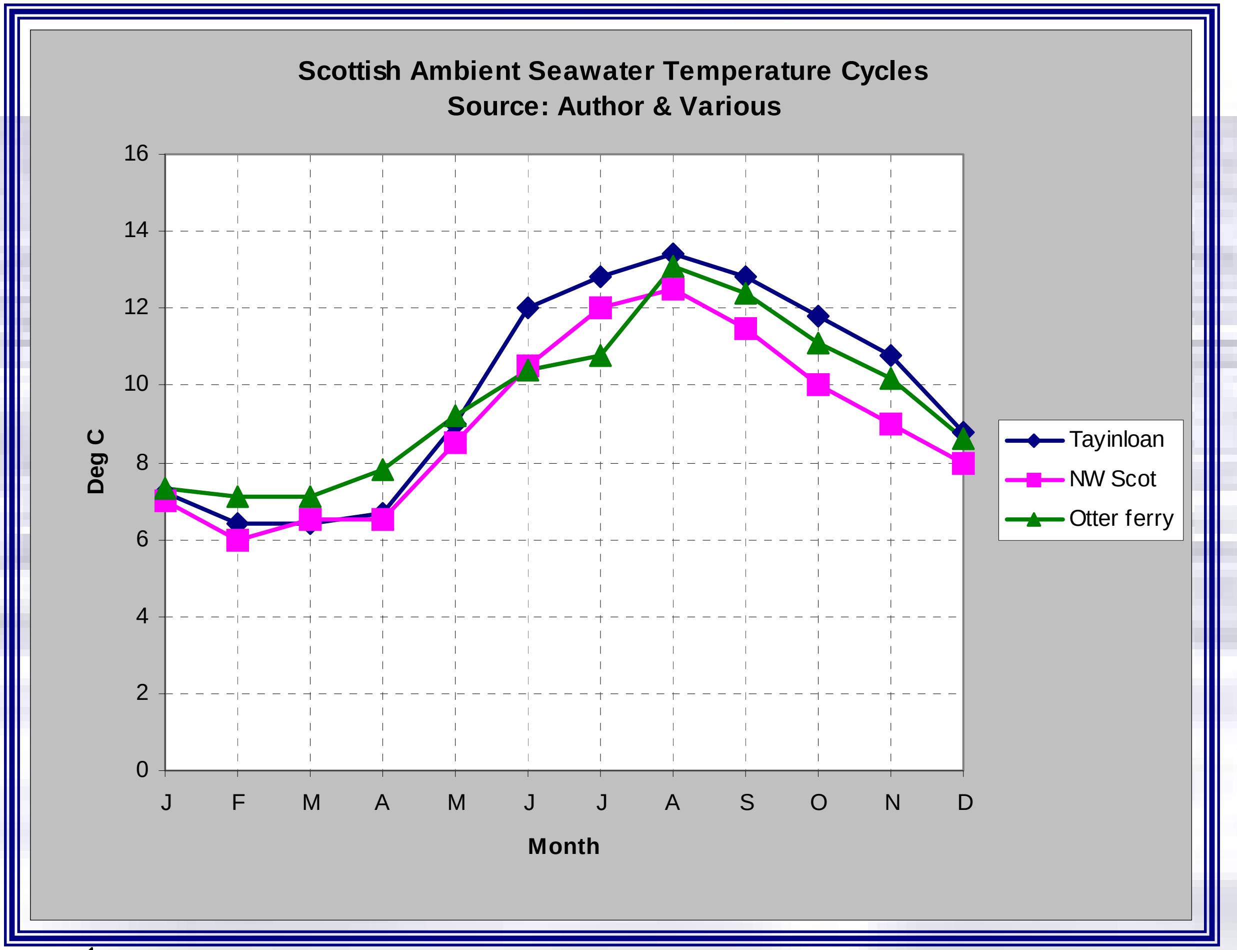
This section of the Hyperbook will consider how locations for halibut cultivation projects might or should be chosen. Good site selection is critical to the success of any aquaculture venture, and there are some obvious considerations:

- Choosing a location with the wrong ambient seawater temperature for the species may mean that they grow too slowly - or may even suffer mortality in the extremes of winter or summer
- Sites near industrial facilities, with the risk of water pollution incidents, should be avoided
- Sites without reasonable access (whether sea sites or land-based) for staff and supplies are clearly impractical - although the cost of providing access can always be considered in the outline business plan
- Sites have to be "feasible" from the point of view of the regulatory and planning authorities who have statutory obligations in the area - but this issue is discussed in the Legal and Administrative section

SITE SELECTION

Seawater Temperature Profile - 1

Halibut in ongrowing farms can probably survive in areas where the temperature varies between 2-3 Deg C in the winter and 17-18 Deg C in the summer. However, for best growth rate over most size ranges of halibut, it is probably better for the temperature to remain above 8 Deg C and below 15 Deg C.



The figure shows the ambient seawater temperature cycle for some aquaculture locations in Scotland - and they are clearly <u>almost</u> ideal for Atlantic halibut

Seawater Temperature Profile - 2

Halibut Hatcheries may also be dependent upon a good temperature regime, but the main elements here are:

- Cool temperature profiles if possible
- Stable daily temperatures (i.e. deep oceanic water locations)
- Alternatively, hatcheries should be seeking areas where there is saline ground water

A saline borehole

Halibut Nurseries require temperature profiles similar to ongrowing sites, or perhaps even a little warmer. However, by using some recirculation or water reuse and heat reclamation technology in the winter months, a wide range of locations could be accommodated.

Halibut appear to grow faster in land-based farms than in cages under similar temperature conditions, so potential cage sites should really seek to be in the best possible area from the point of view of temperature regime.

Topography

Land-based sites are inherently expensive to construct and to operate, compared with cage sites. This is less critical to the economics of hatcheries (and they are usually small units), but it is of major importance to nurseries and ongrowing farms. Issues to consider are:

- The land area should be relatively flat and therefore cheap to develop
- The site area should be as low-lying as possible in relation to the mean sea level - as a guideline, sites lying about 6-8m above mean high water spring tide are probably near the upper limit for water pumping costs
- The site should be as close to the sea as possible
- Areas where the tidal range is low are better - which also usually means areas where the horizontal distance of the sea from the foreshore is not too extreme at low water. Typical acceptable tidal range would be 2.5-3.5 m.
- Pumping seawater from sandy areas creates water quality problems, particularly in rough weather. Sites should be located on rocky foreshores, or near rocky promontories.
- Sites should facilitate the maximum separation between the location of the water intakes and the drainage water outlet - and the former should be located on the “up” side of the prevailing coastal currents
- Access has already been mentioned. There are probably many “ideal” land based sites around the UK, but if they lie more than a few hundred metres from an existing road access, they will be expensive to develop
  - (Consider also existing power lines, telephones, freshwater etc)

Sea Cage Sites

Cage sites for flatfish cages require to be more sheltered than for salmon. Good road access for the shorebase is essential.

LEGAL AND ADMINISTRATIVE ISSUES

Introduction

This section of the Hyperbook will consider the nature of the regulatory framework within which halibut cultivation takes place. Regulations and the legislation which underpins them (“statutory instruments” or “SI’s”) are a matter for individual jurisdictions, and this Hyperbook will focus upon the situation in Scotland.

It is important to stress that the regulatory framework and the European and national legal instruments are changing and evolving all the time, and that this Hyperbook is being written at a time of great flux in this regard. Consequently readers should make significant use of the internet links within this section in order to obtain up to date information. This section will provide a “picture” of some of the issues which would-be aquaculturists ought to consider, but there is no substitute for current investigation in this area.

The other point to consider is that regulation of the industry is intended to ensure that it co-exists with the environment and other stakeholders in a sustainable way - good regulation is good for aquaculture.

Main issues - 1

A focus on the main regulatory bodies would be the most useful approach. These are most easily identified during the process of application for a new aquaculture site (and in particular a cage site at sea). Once an application has been granted, and fish farming operations commence, the number of regulators with a significant ongoing operational concern reduces further.

For an aquaculture site application, the following decision making bodies are involved:

- The Crown Estate (CEC). Effectively the "landlord" in terms of ownership of the seabed, the Crown grants a lease and issues development consent to the operator, and levies a "rent" which is based upon tonnage of production
- The Scottish Environmental Protection Agency (SEPA). Considers issues including site location, proximity of other fish farms, water quality, authorisations of medicinal and other discharges and the hydrographic conditions prior to issuing a discharge consent. A maximum permissible biomass of fish on site is stipulated, together with limitations on discharges from the site
- Local Authorities. Considers applications and issues opinions to the Crown (and will eventually be the lead body in this regard). Also provide planning permission for any on-shore facilities
- Scottish Executive Environment and Rural Affairs Department (SEERAD). All marine fish farms must be registered with SEERAD, and the department is particularly concerned with its statutory obligations with respect to control of diseases and parasites, as well as having an interest on the impact of the project on the inshore marine environment
- Scottish Executive Development Department (SEDD). Considers the siting of all fish farms from a marine safety and navigation point of view
- Scottish Executive Inquiry Reporters Unit (SEIRU). Provides a further route for reconsideration of an application which is initially refused
- Health and Safety Executive. Concerned with health and safety

Main issues - 2

In addition, there are the statutory consultees, who will pass their views on the local authority for consideration:

- Scottish Natural Heritage (SNH). Have an interest in the natural environment
- SEERAD. As above
- SEPA. As above

Other groups and individual also have an opportunity to comment upon aquaculture applications:

- Maritime and Coastguard Agency
- Northern Lighthouse Board
- Local communities
- Private individuals
- Other groups e.g. FOE, WWF, RSPB

Once fish farms are up and running, they have to be concerned with ongoing interaction with some of the groups above - and with others such as:

- Food Standards Agency (FSA)
- Environmental Health Offices (EHO's)

Useful Internet Links

Before proceeding any further with this Hyperbook, you could quickly review the current position of various organisations *vis-a-vis* aquaculture (*click on the blue buttons, and "exit" your browser to return to this page*):

- **The Crown Estate (CEC)**
- **The Scottish Environmental Protection Agency (SEPA)**
- **Scottish Executive Environment and Rural Affairs Department (SEERAD)**
  - **Fisheries Research Service (FRS)**
- **Scottish Natural Heritage (SNH)**
- **Maritime and Coastguard Agency(MCA)**
- **Northern Lighthouse Board**
- **Health and Safety Executive (HSE)**
- **Food Standards Agency (FSA)**

Note that you should be "on-line" during this part of the Hyperbook session, if you want these internet links to function automatically. You may have to do some searching within each organisation's website to find material relevant to aquaculture - use their search engines and common sense about their site maps.

Main Issues - 3

This Hyperbook can not go into all the issues surrounding aquaculture regulation in great detail, and you are urged to do your own research. However, at the time of preparation of this Hyperbook, the "hot topics" facing the halibut sector were:

- Locational guidelines for aquaculture in Scotland - where new sites might be developed
- Environmental impact of halibut farming - as part of overall carrying capacity and discharge consent debates, but in the context of uncertainty about the science which pertains to "new species" such as halibut
- Fish health regulations with respect to IPN and VHS - based on outdated EC Directive 91/67 EEC
- Discharge consents for medicines - but particularly the use of FORMALIN as a traditional anti-parasite treatment for marine flatfish species

In the longer term, in conjunction with all fin fish species, attention is/was being paid to:

- Coastal zone management and the development of local framework plans for coastal water users
- Welfare issues (debated at the Council of Europe) relating to all aquaculture - but potentially delivering numeric restrictions to operating parameters such as stocking density
- Disposal of waste - mortalities on site are "hazardous waste" and require special treatment

Use of Divers

When divers are engaged in any work around a fin-fish cultivation site all diving operations must be carried out in accordance with the relevant national legislation (Health and Safety at Work Act 1974 and Diving at Work Regulations 1997 or subsequent revisions) and the most appropriate Approved Code of Practice (ACoP). Generally, this will be that for 'Commercial diving projects inland/inshore', but others may be applicable under specific circumstances. Compliance with the regulations is checked by the Diving Inspectorate of the Health and Safety Executive (HSE).

Particular attention should be paid to preparation of the dive plan and risk assessment which, in turn, will indicate the minimum number of persons (usually 4) required in the dive team for the particular operation. Failure to fulfil these requirements is the most common complaint made by the HSE against those involved in any form of diving related to fin-fish cultivation. Infringements frequently result in prosecution and those who contract-in divers are equally liable in these circumstances.

SUPPLIERS

Introduction

This section of the Hyperbook covers suppliers to the industry who might be able to support halibut cultivation operations. The list is not exhaustive, nor does inclusion within the list denote any particular endorsement of the company in question by Seafish or Epsilon Aquaculture Ltd. Wherever possible the supplier's website address is the main reference - readers can access these sites directly from this Hyperbook if they are "on line" during the Hyperbook session.

This list includes only some of the companies that supply to the aquaculture industry. Reference to these companies should not be construed as an official endorsement of these companies, nor is any criticism implied of similar companies that have not been mentioned.

Suppliers of aquaculture equipment can be found advertising in the trade papers and journals. The annual 'Fish Industry Yearbook' contains an aquaculture supplier section. Suppliers can also be contacted at conferences and trade exhibitions, such as the biannual Aquaculture International exhibition in Glasgow.

Suppliers are broadly grouped into:

- Biological Suppliers (hatcheries, feeds)
- Hardware suppliers (equipment)
- Services suppliers (advisors, utilities, financial)

Suppliers

Biological Suppliers

Halibut Hatcheries

- Otter Ferry Seafish Ltd. Tel: 01700 821226 Email: seafish@otterferry.com
- Mannin Seafarms Ltd. Tel: 01624 824698 Email: ManninFish@aol.com
- Orkney Marine Hatcheries Ltd. Tel: 01856 741216

Live Feed Suppliers

- CCAP (Cambridge collection of algae and protozoa). Tel: 01631 362244
- INVE (Artemia and enrichments): Tel: 00 32 52259070 Web:
- Biomarine/Aquafauna (Artemia and enrichments). Tel: 00 1 3109735257 Web:
- (Instant Algae) Reeds Web:
- Catvis (Artemia, larval diets). Web:
- Argent (Algal nutrients etc). Web:

Dry Feed Suppliers

- Trouw UK
- Ewos UK
- Biomar UK
- Danafeed

Medicines

For advice on medicines, you should contact your own veterinary advisor.

Alternatively, try:

Institute of Aquaculture, Stirling: Tel: 01786 467878

Web:

Hardware Suppliers

General Aquaculture Equipment

- Dryden Aqua
- C&H Plastics
- Red Rooster
- Tropical Marine Centre
- FOR A GOOD TOTAL LIST OF SUPPLIERS, SEE:

• Cages & Associated

- Irish Seafood contacts
- W&J Knox (nets)
- Fish Farming Online contacts
- Fusion Marine
- Alexander Noble & Sons (boats) Ayrshire Tel: 01465 712223

• Land Based Ongrowing

- Brice Baker & Co (tanks) Tel: 01480 216618
- Flygt (submersible pumps)
- Air Products (oxygen generators)
- Aerzen (roots-type air blowers)
- Everyvalve Equipment Ltd (valves, pipework) Tel: 01707 642018 Web:

Services Suppliers

Insurance

Aquaculture Risk(Management) Ltd., The Esplanade, Sunderland, SR2 7BQ. (Tel: 0191 5682000; Fax: 0191 5658625).

Aquarius Underwriting Agencies Ltd., 60 Mark Lane, London, EC3R 7ND.

Trade Associations

British Marine Finfish Association. Dr J S Buchanan (Tel: 0131 440 2116; e-mail: jim.buchanan@onyxnet.co.uk). Richard J Slaski (email: RichardSlaski@aol.com)

Training

Scottish Aquaculture Training Association, Mountview, Ardvasar. Skye. IV45 8RU Tel/Fax: 01471 844324 E-mail: DouglasMcleod@aol.com

North Atlantic Fisheries College (see information next page)

Scottish Association for Marine Science (see information next page)

Inverness College, 3 Longman Road, Longman South, Inverness. IV1 1SA Tel: 01463 273000 Fax: 01463 273001 E-mail: admissions.officer@inverness.uhi.ac.uk Web: www.uhi.ac.uk/inverness

Services Suppliers - Continued

Information, technical advice etc

Sea Fish Industry Authority, Aquaculture Development Service, Marine Farming Unit, Ardtoe, Acharacle. Argyll. PH36 4LD Tel: 01397 875000 Fax: 01397 875001 E-mail: aquaculture@seafish.co.uk Web: www.seafish.co.uk

Sea Fish Industry Authority, Technology Division, Seafish House, St Andrew's Dock, Hull. HU3 4QS Tel: 01482 327837 Fax: 01482 223310 E-mail: technology@seafish.co.uk Web: www.seafish.co.uk

C-Mar, Centre for Marine Resources and Mariculture, Marine Biology Station. The Strand, Portaferry. Co Down. BT22 1PF Tel: 028 4272 9648 Fax: 028 4272 9672 or 8902

Cross-boarder Aquaculture Initiative Team, Unit 14-15, Gray's Lane, Park Street, Dundalk, Co Louth. Ireland. Tel: ++ 353 42 9385074 Fax: ++ 353 42 9352490 E-mail: cbait@oceanfree.net

North Atlantic Fisheries College, Port Arthur, Scalloway. Shetalnd. ZE1 0UN Tel: 01595 772000 Fax: 01595 772001 E-mail: admin@nafc.ac.uk Web: www.nafc.ac.uk

Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban. Argyll. PA34 4AD Tel: 01631 559000 Fax: 01631 559001 E-mail: marine.science@dml.ac.uk Web: www.sams.ac.uk

Suppliers

Services Suppliers - Continued

- The Centre for Environment, Fisheries and Aquaculture Science (CEFAS)

  Specifically: www.cefas.co.uk/fhi

- Department of Environment, Food and Rural Affairs (DEFRA)

  Specifically: www.defra.gov.uk/fish

  www.defra.gov.uk/corporate/regulat/forms/fish

- Department for Agriculture and Rural Affairs, Northern Ireland (DARDNI)
- English Nature
- Northern Ireland Environment and Heritage Service (NIEHS)
- Foyle, Carlingford and Irish Lights Commission (FCILC)

- General Guide to Government Websites

Services Suppliers - Continued

Government Departments

Scottish Executive Environment and Rural Affairs Department, Fisheries Research Service, Marine Laboratory, PO box 101, Victoria Road, Aberdeen. AB11 9DB. Tel: 01224 876544 Fax: 01224 295511

Department of Agriculture and Rural Development, Fisheries Division, Annex 5, Castle Grounds, Stormont Estate, Belfast. BT4 3PW Tel: 028 9052 0100 Fax: 028 9052 3121 Web: www.dardni.gov.uk

National Assembly for Wales, Agriculture Department, Fisheries Division, New Crown Buildings, Cathays Park, Cardiff. CF10 3NQ Tel: 029 2082 5111 Fax: 029 2082 3562 Web: www.cymru.org.uk/subiagriculture

Department for Environment, Food and Rural Affairs, Centre for Environment, Fisheries and Aquaculture Science, Weymouth Laboratory, Barrack Road, The Nothe, Weymouth. Dorset. DT4 8UB Tel: 01305 206600 Fax: 01305 206601 Web: www.cefas.co.uk

Development agencies

For access to a network of local development agencies in Scotland contact:

Highlands & Islands Enterprise, Cowan House, Inverness Retail & Business Park, Inverness. IV2 7GF Tel: 01463 234171 Fax: 01463 244469 E-mail: hie.general@hient.co.uk Web: www.hie.co.uk

Scottish Enterprise, 150 Broomielaw, Atlantic Quay, Glasgow G2 8LU Tel: 0141 248 2700 Fax: 0141 221 3217 Web: www.scottish-enterprise.com

For Northern Ireland:

Department of Agriculture and Rural Development, Northern Ireland (DARDNI) (see government departments)

For Wales:

Welsh Development Agency, Principality House, The Friary, Cardiff. CF10 3FE Tel: 08457 775577 Fax: 01443 845589

Additional local or regional development initiatives may be operational in your area. To check the current position consult the agencies above or local council development departments. Organisations providing technical advice and support may also be able to advise (see Information etc).

BUSINESS PLANNING

Introduction

This section of the Hyperbook covers the development of business plans to support halibut cultivation. The section will provide an overview of business planning, but mainly introduces the Halibut Economic Models - a series of Microsoft Excel-based planning tools. The overview and the models must be seen as a starting point only - they do not replace the need for professional technical and financial planning, but might assist that process.

Seafish and Epsilon Aquaculture Ltd can take no responsibility for any business decision based upon this section (or other sections) of the Hyperbook, and readers are urged to seek professional and experienced assistance if they wish to proceed towards investment in this sector of aquaculture.

However, readers who are investigating initial scenarios within this sector might find the economic modelling tools within this section useful - they may serve to “scope” discussions with other professional advisors or suppliers.

General Principles

Readers should be clear at this point what their purpose is:

- To simply use this Hyperbook in order to improve their general understanding of halibut cultivation
- To use this Hyperbook to inform them about other people's plans concerning halibut cultivation
- To use this Hyperbook to help them plan an expansion or diversification of their existing business
- To use this Hyperbook to help them plan a new halibut cultivation plan

Products which might arise from use of this Hyperbook will depend upon the purpose - but there are certain basic truisms about cultivation of any aquaculture species:

- Aquaculture is a business - it needs to make sufficient profit to continue to develop and to repay its shareholders or investors
- Any successful business needs a good initial plan - and whilst the reality of operations might diverge from that plan, a good business will continually review those operations in the context of the initial plan
- Aquaculture is considered to be a "high risk" business in financial terms - and the history of the spectacular failures within the industry over the last three decades confirm that judgement
- An aquaculture business plan needs to be robust:
    - any technical uncertainties must be highlighted and numerically quanitified
    - a realistic view of the short, medium and long term market prospects must be taken
    - the Management Team must demonstrate capability to carry the plan to fruition
- Raising new finance for aquaculture is not easy. The sector's profitability potential normally falls below the criteria for true Venture Capital, and therefore requires more conventional bank finance - which means the provision of full security for any debt capital. Aquaculture is probably more readily financed from industrial sectors (either other aquaculture or related businesses) than from any other source.

Readers are urged to contact their Local Enterprise company, a qualified consultant or their financial advisor for guidance in business plan preparation

ECONOMIC MODELS

The core Economic Models for Halibut Cultivation are contained within your HALIBUT HYPERBOOK Folder. Access the READ ME FIRST file once again, just to remind yourself how to use these models.

Just press "Esc" on your keyboard at any time if you want to leave this Hyperbook show

Back to
Markets
Section

Spiced Halibut Steaks

4 x 225g (8oz) halibut or cod steaks, fresh or defrosted
4 x 15ml spoon (4 tablespoons) sunflower oil
1 small onion, finely chopped
15g (one half oz) fresh green and red chillies, deseeded and sliced
2 x 5ml spoon (2 teaspoons) curry powder
0.5 x 5ml spoon (one half teaspoon) cumin powder
salt and black pepper
2 x 15ml spoon (2 tablespoons) lemon juice

Preheat the grill

Heat the oil in a pan and cook the onion and chillies with the spices and seasoning for 2-3 minutes. Add the lemon juice.

Place the steaks in a dish and brush with the spice mixture.

Cover and leave to marinate in the refrigerator for 1-2 hours.

Place the steaks on a grill pan and cook under a moderate to hot grill for 10-12 minutes, turning once. Brush with the remaining marinade.

Serve hot with a selection of vegetables such as new potatoes and green beans. Garnish with lemon wedges.

Serves 4

NUTRITIONAL VALUES PER PORTION (APPROX) 380 Kilocalories;
57g Protein; 16g Fat; 1g Carbohydrate; 0g Fibre.

See a
picture

Back to Markets Section

Spiced Halibut Steaks

Next recipe

Halibut with Yellow Pepper and Coconut Sauce

4 x 170-225g (6-8oz) halibut or cod steaks, fresh or defrosted
3 x 15ml spoon (3 tablespoons) olive oil
1 small onion, chopped
3 yellow peppers, deseeded and chopped
150ml (5 fl oz) 88% fat free coconut milk
55g (2oz) butter
2 cloves garlic, crushed
salt and black pepper

Heat the oil in a large non-stick frying pan. Cook the onion and peppers for about 10 minutes. Add the coconut milk and continue to simmer for a further 5 minutes.

Pour the contents into a food processor or blender and process until smooth. Pour into a small saucepan and season.

Heat the butter and garlic in a pan. Add the halibut or cod steaks and cook for 3-4 minutes on each side. Heat the sauce.

Serve the fish covered with a little sauce and with steamed cabbage or spinach leaves and sautéed sweet potatoes.

Serves 4

Back to
Markets
Section

Halibut with Yellow Pepper and Coconut Sauce

Next
recipe

Back to Markets Section

Halibut Steaks with Champagne and Peppercorn Sauce

2 x 4-6oz (115-170g) halibut steaks, fresh or frozen and defrosted
40g (1 and a half oz) butter
salt and black pepper
150ml (5 fl oz) pink champagne or rose wine
4 x 15ml spoon (4 tablespoons) double cream or crème fraiche
1 x 5ml spoon (1 teaspoon) mixed whole peppercorns
1 x 15ml spoon (1 tablespoon) freshly snipped chives

Place the steaks onto a grillpan. Dot with 15g (half an oz) butter and season.

Cook under a preheated grill for 8-10 minutes, turning once.

Meanwhile, prepare the sauce: Heat the remaining butter in a pan and add the
champagne. Bring to the boil and reduce the liquid by half.

Stir in the cream, seasoning and chives.

Arrange the halibut steaks onto a plate, pour over the sauce and serve on a bed of cooked green and white tagliatelle.

Serves 2

See a picture

Back to
Markets
Section

Halibut Steaks with Champagne and Peppercorn Sauce