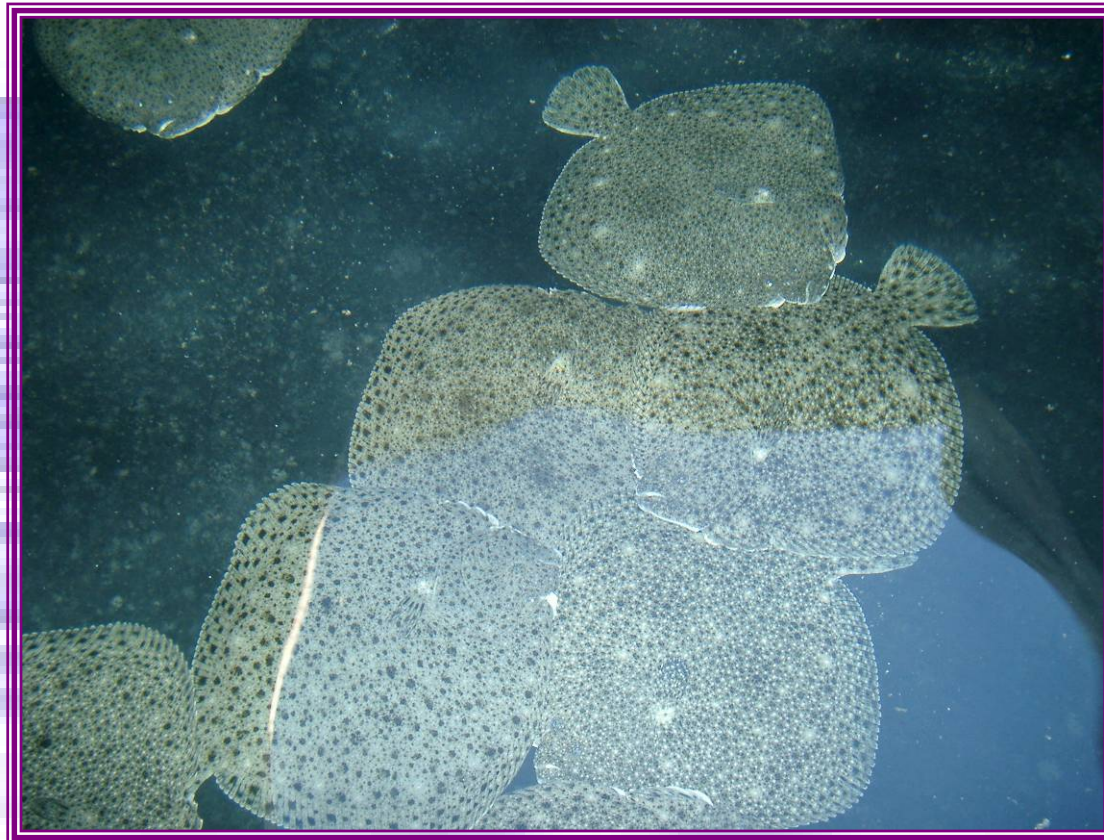


EPSILON  
AQUACULTURE LIMITED



## The Turbot Hyperbook®



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

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1

**PRESS FOR NEXT PAGE**

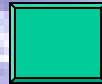
## HOW TO USE THIS HYPERBOOK

Navigating around this Hyperbook is easy:

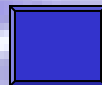
- If you just want to proceed to the next page, simply “left click” on your mouse
- If you want to use a “hyperlink” to jump to another part of the book, position your cursor over the appropriate button or text (a pointing finger symbol will appear), and left click

• You can practice this here

• Try clicking on this button



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

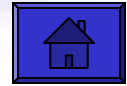


**You have completed your first “hyper-jump”**

**Click on this button to return**

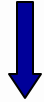










# MAIN MENU



## THE MAIN SECTIONS OF THE HYPERBOOK

(Press the appropriate action button)



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

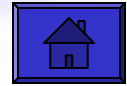
Useful internet links



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 TURBOT CULTIVATION



The Atlantic turbot (*Psetta maxima* L.) is one of 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.

Turbot is a European species in terms of natural distribution, although it is now also present in Chile and China (as a result of aquaculture).

Turbot is a relatively scarce “gourmet” fish, and is highly prized in the market. Aquaculture efforts have been undertaken with this species since the early 1970’s, and it is now firmly established as a niche aquaculture product in Europe.



Juvenile turbot



# INTRODUCTION TO TURBOT CULTIVATION - Continued



A species specification sheet for turbot

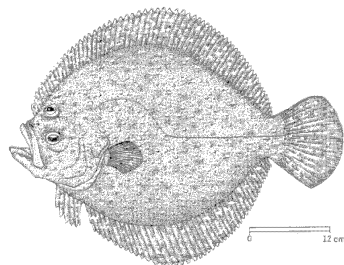
### SPECIES DATA

Common Name  
 Latin Name  
 Alternative Latin Name  
 Name in: France  
 Spain  
 Turkey  
 Germany

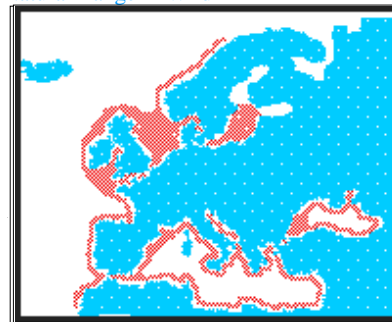
### TURBOT

Turbot  
*Psetta maxima*  
*Scophthalmus maximus*  
 Turbot  
 Rodaballo  
 Kalkan  
 Steinbutt

### Appearance



### Natural Range in Wild



Present European Wild Catch	7,000 tonnes - Principally North Sea
Present Turkish Wild Catch	1,600 tonnes - Principally Black Sea
Lethal Temperature (Max/min)	Max. 28-30 Deg C    Min. 1-2 Deg C
Growth Temperature (Max/min)	Max. 21-22 Deg C    Min. 7-8 Deg C
Optimal Temperature Hatchery	8-10 Deg C
Optimal Temperature Grow-out	14-16 Deg C
Euryhaline Tolerance	Max. 40 ppt                      Min. 12 ppt
Natural Feed in Wild	As Juveniles - Crustacea and polycheates

Maximum size:	As Adults - Small fish
	Farmed fish - 2 kg
	Wild fish - 40 kg (commonly 3-5 kg)





## INTRODUCTION TO TURBOT CULTIVATION - Continued

All teleost (bony fish) flatfish species have evolved to a life on or near the bottom of the sea. They are “flat” because they are actually lying on one side of their body, and the eye which would have been “underneath” has migrated around to the upper side during early development. All flatfish larvae are free-swimming and planktonic, and are oriented in a normal round-bodied fish way. The process of turning on one side and “flattening” is called metamorphosis, and in the case of turbot takes place between Day 14 and Day 25 after hatching.

There are actually 3 closely-related flatfish species in Europe, all belonging to the Bothidae family:

- Atlantic turbot
- Black Sea turbot
- Brill

Bothidae are distinct from the majority of other commercially important flatfish species in Europe in terms of their orientation - they lie on their right “side”, whereas the other groups lie on their “left” side.





## INTRODUCTION TO TURBOT CULTIVATION - Continued



The potential for farming of Atlantic turbot has been under investigation since the early 1970's, with researchers in Lowestoft reporting on the first successful attempts to rear larval turbot in captivity in 1973. Significant research and development continued in the UK and France in the late 1970's and early 1980's, and has been followed by more recent work on turbot cultivation in Spain, Holland 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 only surpassed by the effort on halibut, 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.

In the event, turbot cultivation has actually increasingly focused on regions of Europe which are *not* particularly strong salmon growing areas.



## INTRODUCTION TO TURBOT CULTIVATION - Continued



During the late 1970's and 1980's juvenile turbot supplies from hatcheries were the strategic bottleneck for the industry.

Luckily the on-growing industry was able to develop while hatchery problems were being researched, because we were able to obtain juvenile turbot from the wild. These were mainly taken (under special licence from MAFF) from sandy beaches around the coast of the UK in late summer - when the newly metamorphosed "O" group wild turbot came into the shore to feed. Capture was achieved by way of adapted sand-eel seine netting.

Hatcheries became effective suppliers of juvenile turbot by the mid-late 1980's, and wild juvenile collection ceased at that time.

Views of Borth beach, mid-Wales:  
the most productive UK turbot  
juvenile area



## INTRODUCTION TO TURBOT CULTIVATION - Continued



Turbot on-growing takes place in land-based tanks (with or without recirculation).

Turbot tend to feed and grow well at temperatures ranging from 12 to 18° C, and in areas where these temperatures are maintained for most of the year, turbot can reach a market size of 2 kg in 24 months “at sea”.

Female turbot grow faster than male turbot, 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 4 kg or more, there is a premium price for larger farmed turbot. Nevertheless, with farmed fish commonly available at size of 1-2 kg, the market has adapted rather well over the last decade.



A marketing brochure from one of the original turbot farming companies in Spain

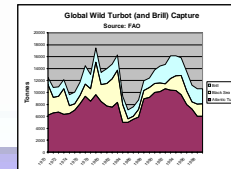


# THE MARKETS FOR TURBOT

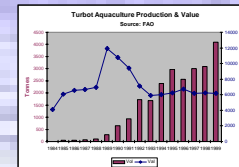


The global and regional “market” for Atlantic turbot is presently defined by the availability of supply from the wild fishery *and* from aquaculture.

Click on the thumbnail to see the global wild supply data



Click on the thumbnail to see the global aquaculture data



The wild landings of turbot show some annual variation, and there appear to be peaks and troughs. Late 1990’s combined landings of Atlantic and Black Sea turbot are in the region of 8,000 tonnes per annum.

Aquaculture production of Atlantic turbot has grown steadily since the late 1908’s, and by 1999 there were some 4,000 tonnes coming from aquaculture.

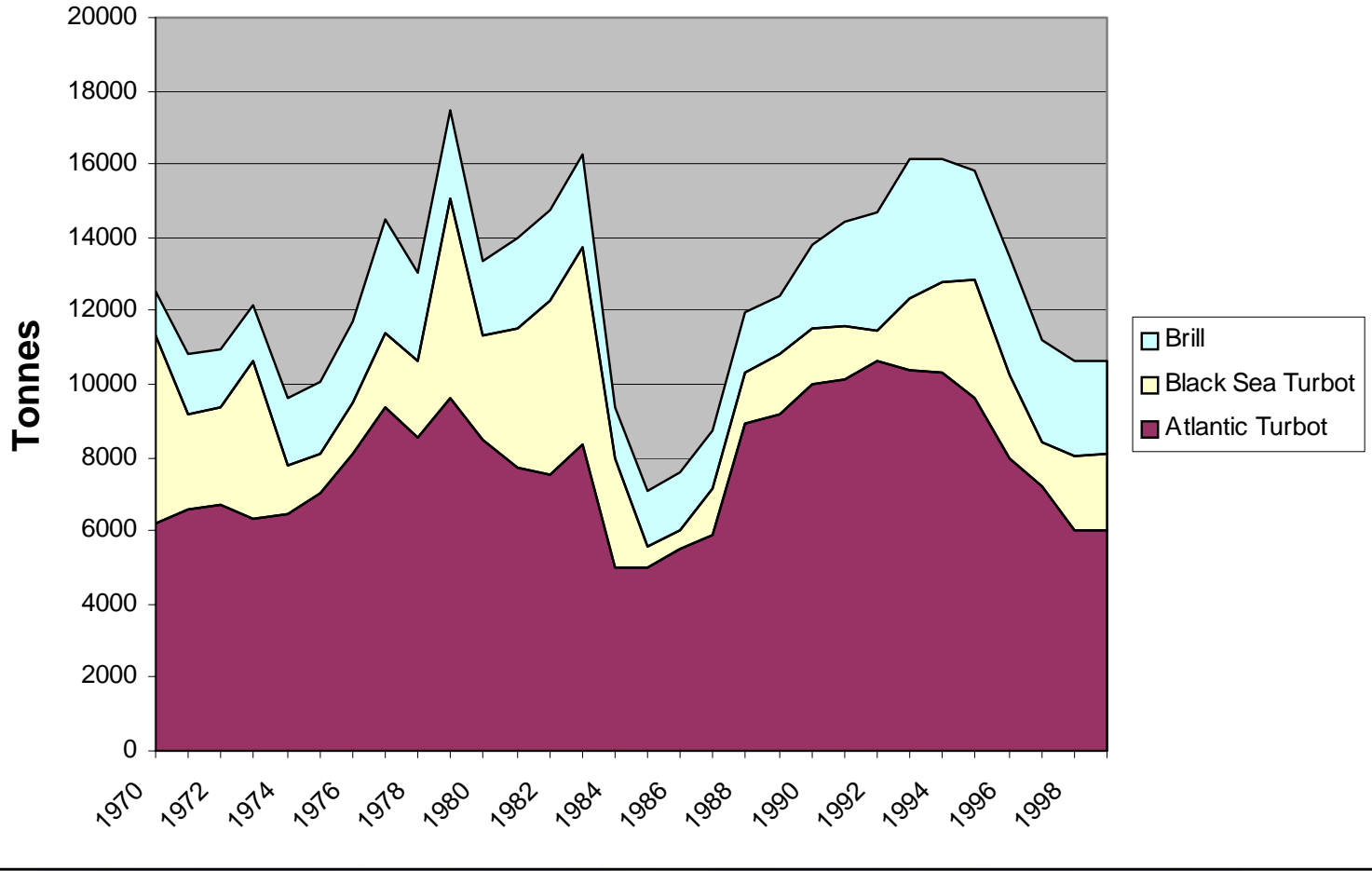
*Note: there is Chilean production of around 300 tonnes per annum of turbot, which does not appear in the FAO database*





# Global Wild Turbot (and Brill) Capture

Source: FAO

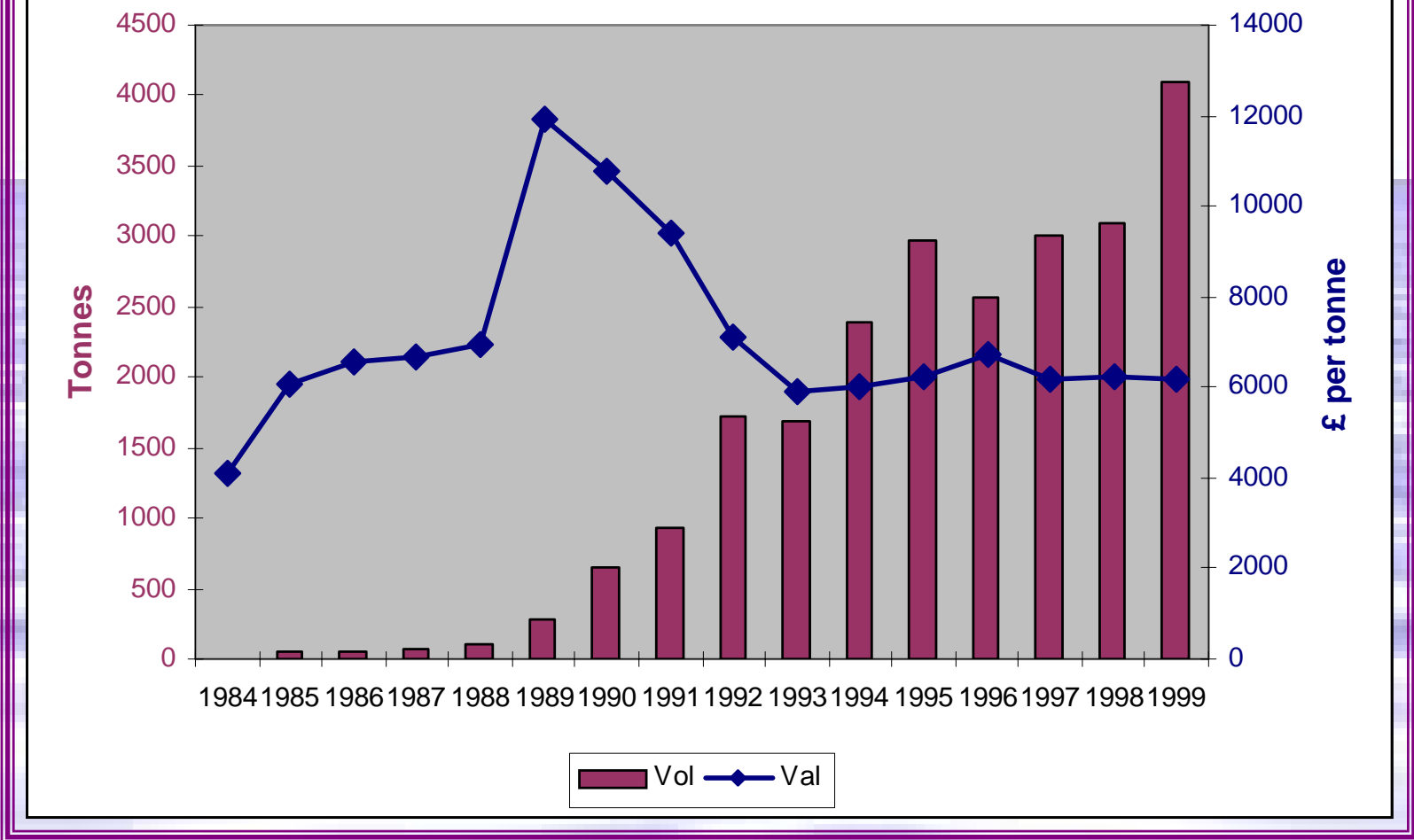






# Turbot Aquaculture Production & Value

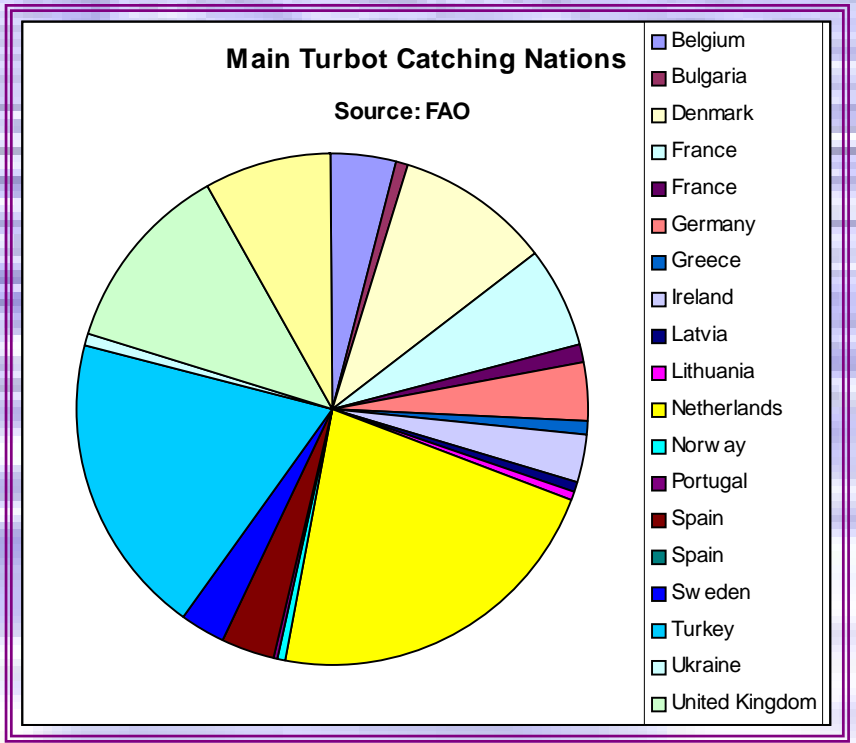
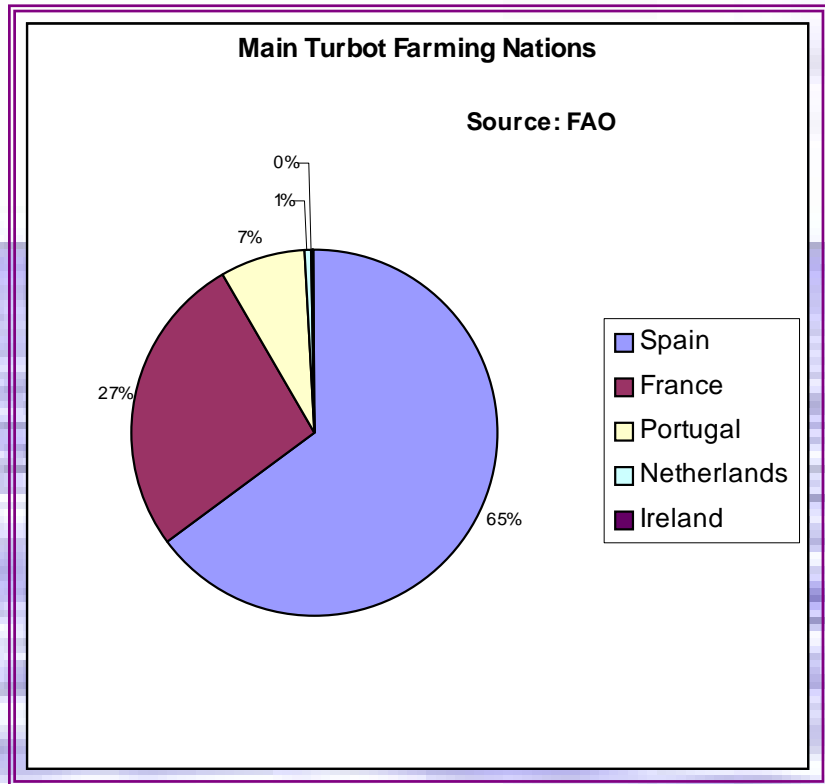
Source: FAO



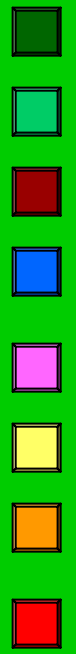


# THE MARKETS FOR TURBOT - Continued

The main aquaculture and fisheries production countries are:



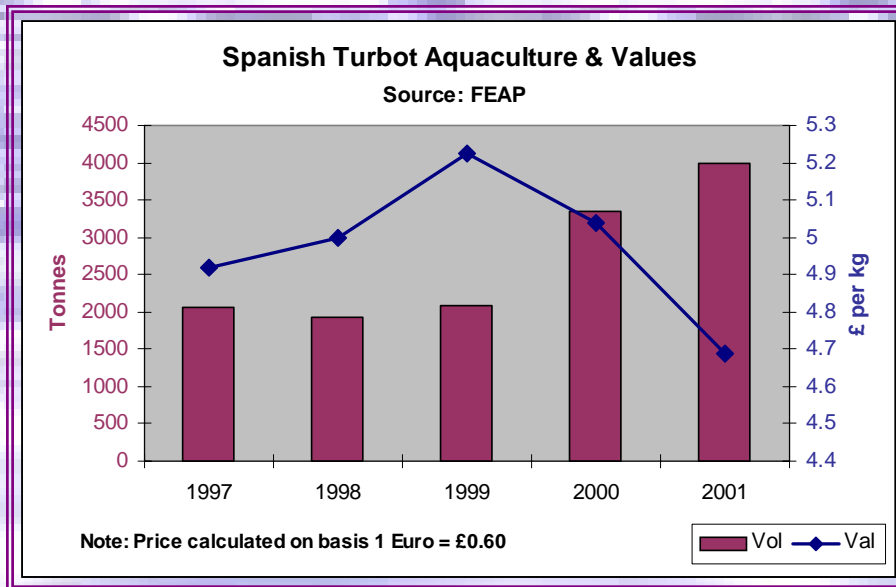
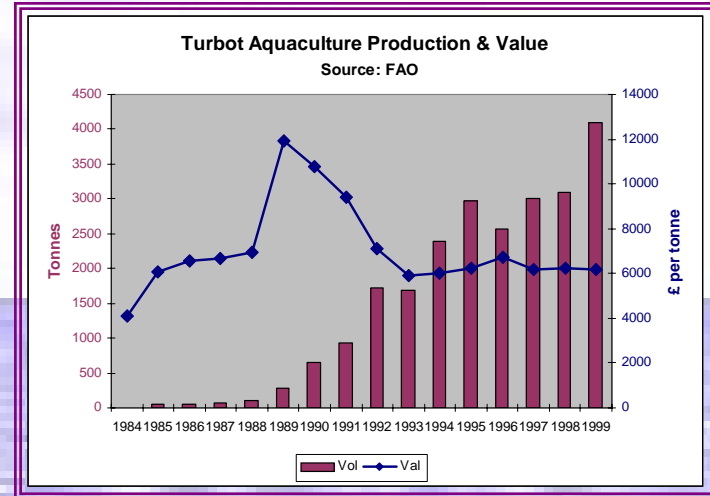
Data presented as 3-year average, 1997-99





# THE MARKETS FOR TURBOT - Continued

The market price for cultivated turbot has progressed through some relatively typical perturbations, in relation to the volume produced (the picture for seabass and gilthead bream is very similar). However, unlike bass and bream, turbot prices have apparently reached a stable plateau - with production slowly increasing.



Data for Spain, from the FEAP website, is rather more up to date than FAO, and projects a slightly different picture of absolute value at first-sale - and downward trend in value





## THE MARKETS FOR TURBOT - Continued

The UK and general European market for turbot 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

- There was not enough data from the survey to assess overall volumes of consumption
- This species is consumed in all the countries surveyed, with the UK and Irish markets being the least significant in volume terms
- Turbot sells into the mid –range of the market for:
  - United Kingdom £5.00 – £6.50 per kg (commonly £6.00)
  - Republic of Ireland £6.60 per kg
  - Spain £3.70 - £5.56 per kg (commonly £4.44)
  - France £5.68 per kg
  - Germany £5.35 - £5.91 per kg
- Turbot is perceived as too expensive for large volume utilisation in the UK market on the basis of whole fish cost and low fillet yield, and farmed product is seen as producing a relatively thin fillet
- There was very broad support from almost all the interviewees for further turbot production from aquaculture, with similar requests to those noted above for halibut. The need to possibly lower prices in order to sell significantly more turbot was highlighted by many respondents





## THE MARKETS FOR TURBOT - 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 TURBOT:

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







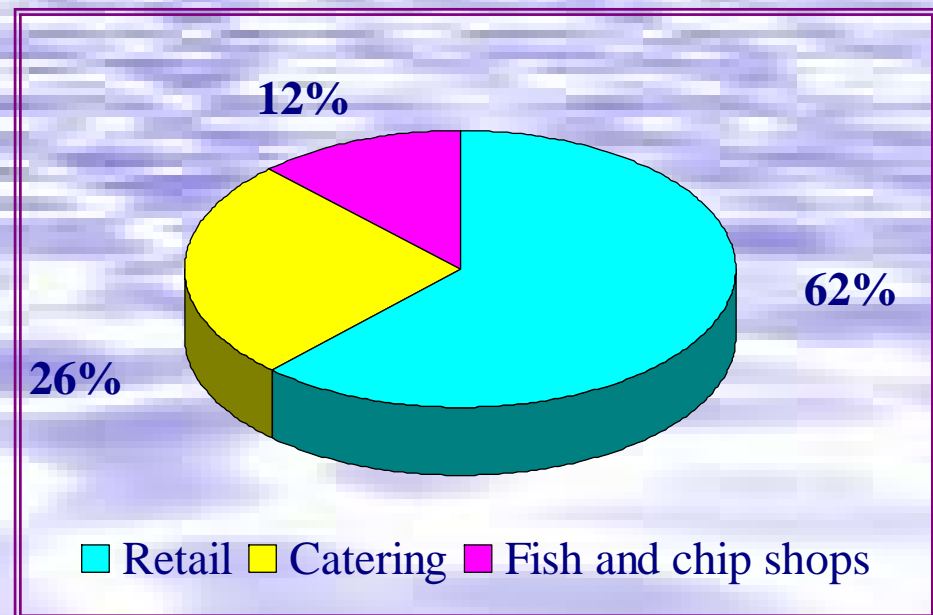
## THE MARKETS FOR TURBOT - Continued

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





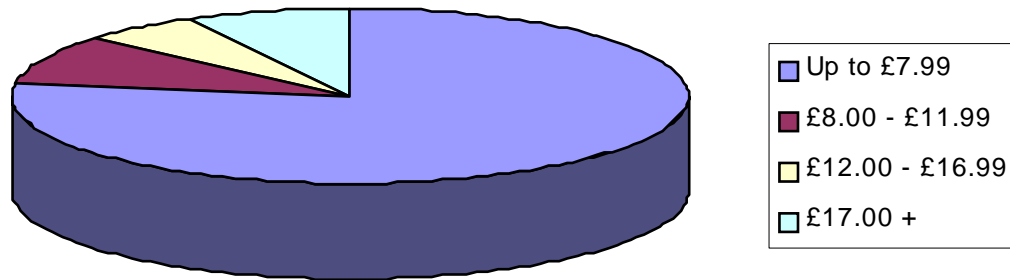
## THE MARKETS FOR TURBOT - Continued

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

### UK Seafood Meals by Price Band

Total Seafood Meals 338 million p.a.

Total Seafood Meal Value £2062 million p.a.



Source: Taylor Nelson Sofres & SFIA

- 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 TURBOT - 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 - turbot 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       |
| • Turbot fillet yield  | 30%             |
| • So restaurant can buy whole fish for   | <b>£5.25/kg</b> |
| • 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 |                 |
| • <i>(Note that the consumer is paying the equivalent of £35 per kg for whole turbot in this example!)</i>   |                 |





## THE MARKETS FOR TURBOT - Continued

The other important factor in considering the “real” value of cultivated turbot 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
- Turbot, unfortunately, has one of the poorest fillet yields of all the common edible marine fin fish species in the UK - estimated at some 30% of the eviscerated whole fish weight



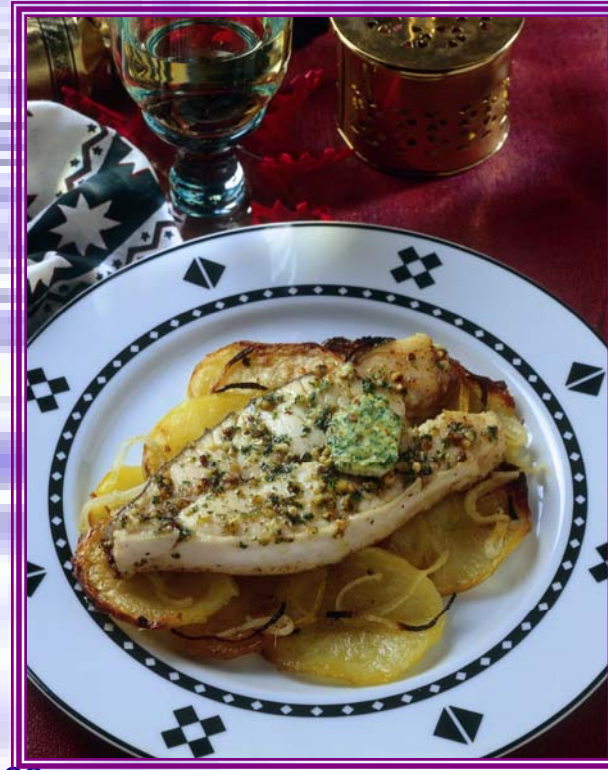


## THE MARKETS FOR TURBOT - Conclusion

The main turbot market messages from this section are:

- Atlantic turbot is already a successful niche aquaculture product - the market has become relatively familiar with it, and accepts it
- Market values have stayed reasonably high - although there is some recent evidence of declining prices as volumes continue to grow
- Turbot suits an end-user who demands whole fish, or at least skin-on cross-cut steaks
- Turbot is not so suited to consumers who demand boneless fillets, since the fillet yield is not very high

A turbot recipe







# 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 turbot:  
hatchery and land-based ongrowing

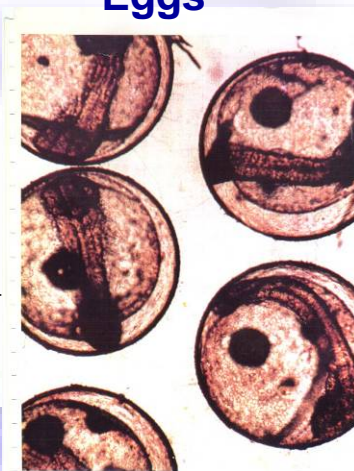


### Broodstocks



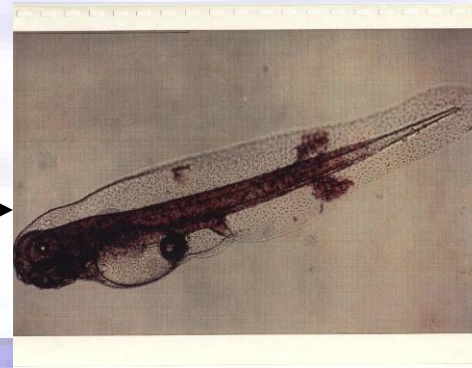
Repeat spawning

### Eggs



5 days

### Larvae



90-110 days in hatchery

Rotifers



Dry pellets



Artemia

3-4 years for good broodstock recruitment

24 months in ongrowing

Market



Land-based ongrowing



Weaned juveniles



## THE PRODUCTION PROCESS

### Hatchery - Broodstock 1



In the wild, mature turbot gather every year in early spring in distinct spawning grounds. The North Sea is the most important spawning area for turbot, but there are spawning populations in the Irish Sea, Baltic, Bay of Biscay and in the Mediterranean (as well as the Black Sea).

Spawning is once per year, and the exact time depends upon the exact stock. However, it is generally assumed that “most” turbot spawn in April, May and June in the North Sea. Spawning takes place over several weeks, since turbot are repeat “batch” spawners.

Turbot eggs are small - around 1mm diameter - and many are released (for large female turbot, an egg production of 1 million per kg of body weight per season is the “norm”)

Although the large numbers involved in egg release are indicative of a rather “shotgun” approach to reproduction, there is actually a relatively complex behavioural between individual males and females during ovulation - one which is apparently difficult to encourage in captivity.



## THE PRODUCTION PROCESS

### Hatchery - Broodstock 2



In captivity, broodstock tanks for turbot range from 4 to 10 m<sup>3</sup> in volume, and are typically stocked with fish at densities of up to 10 kg/m<sup>2</sup>, with a male:female ratio of 2:1. Tanks are supplied with temperature-controlled water in order to maintain optimum conditions: typically mirroring North Sea ambient conditions. Water exchanges are generally quite low, but the active chilling of water is rarely necessary for turbot broodstocks in most European hatcheries. Warming of part of the hatchery broodstock water supply is probably more likely to be needed.

Broodstock turbot can be subjected to photoperiod control of spawning in a fairly easy and predictable manner. Each photoperiod stock will produce eggs for about 10-12 weeks. It is not difficult to establish several photoperiod stocks in a hatchery, such that viable egg production can be maintained on a year-round basis.





## THE PRODUCTION PROCESS

### Hatchery - Broodstock 3



Turbot 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 (mainly in halibut), and there were further refinements of the diet.

Some hatcheries are still concerned about broodstock nutrition, and supplementation with frozen natural feeds would still be feasible if the diets could be sterilised.

Other feed suppliers can provide turbot broodstock “mixes”, which are intended to supplement the main diet

The other development which would be welcomed by industry is an appropriately-sized high quality dry pellet broodstock diet - with all the correct nutrients included

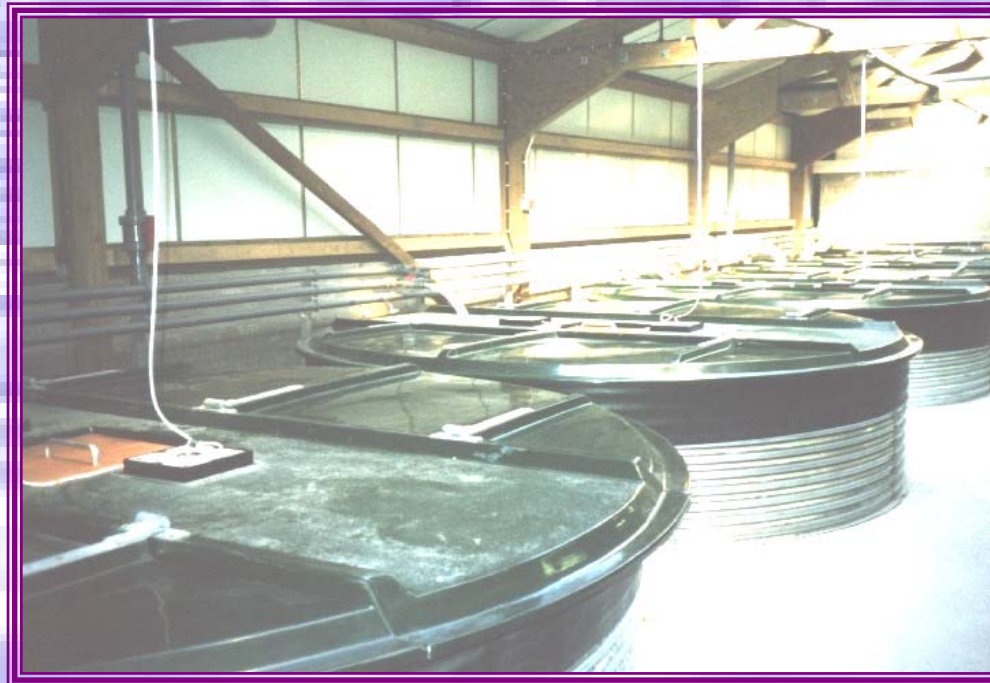


## THE PRODUCTION PROCESS

### Hatchery - Broodstock 4



Turbot 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 2.5-3 days. Broodstock individual weights vary considerably, and males are usually smaller than females. Stripping is usually undertaken outside the broodstock tank due to the ease of handling adult turbot. Fertilisation takes place immediately after egg collection, and both wet and dry techniques can be used.



Turbot  
broodstock  
tanks





## THE PRODUCTION PROCESS

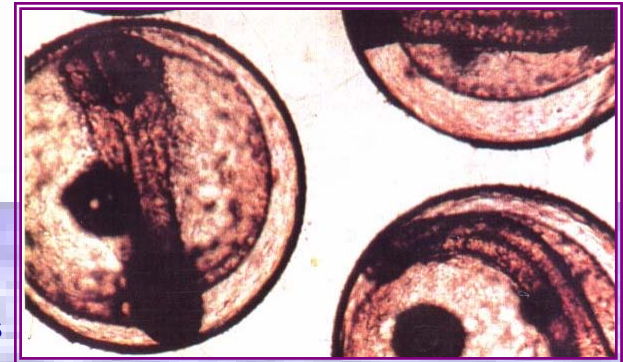
### Hatchery - Egg incubation

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 of around 70 L in volume. Control of water temperature and cleanliness is vital during this stage - optimum temperature appears to be around 12° C, and the water is usually filtered and UV sterilised. There is some tendency for eggs to clump together, and so gentle aeration in the conical is commonly used to prevent this.

Survival through the 5 days of the egg incubation phase is variable, but tends to average 30-50%. 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 can be equipped with bottom-flushing mechanisms, but a simple siphon tube from the surface will remove any dead eggs very efficiently

Near the end of the egg incubation, (day 4) the eggs can be gently netted out and surface sterilised with peroxyacetic acid.

Turbot eggs tend to hatch very synchronously, and it is perfectly feasible to allow hatching to take place in the incubation conical. Newly-hatched turbot larvae are quite robust, and can be “jugged” into the larval rearing tank. Alternatively, eggs can be transferred to larval rearing tanks just pre-hatch.



Turbot eggs - close to hatch

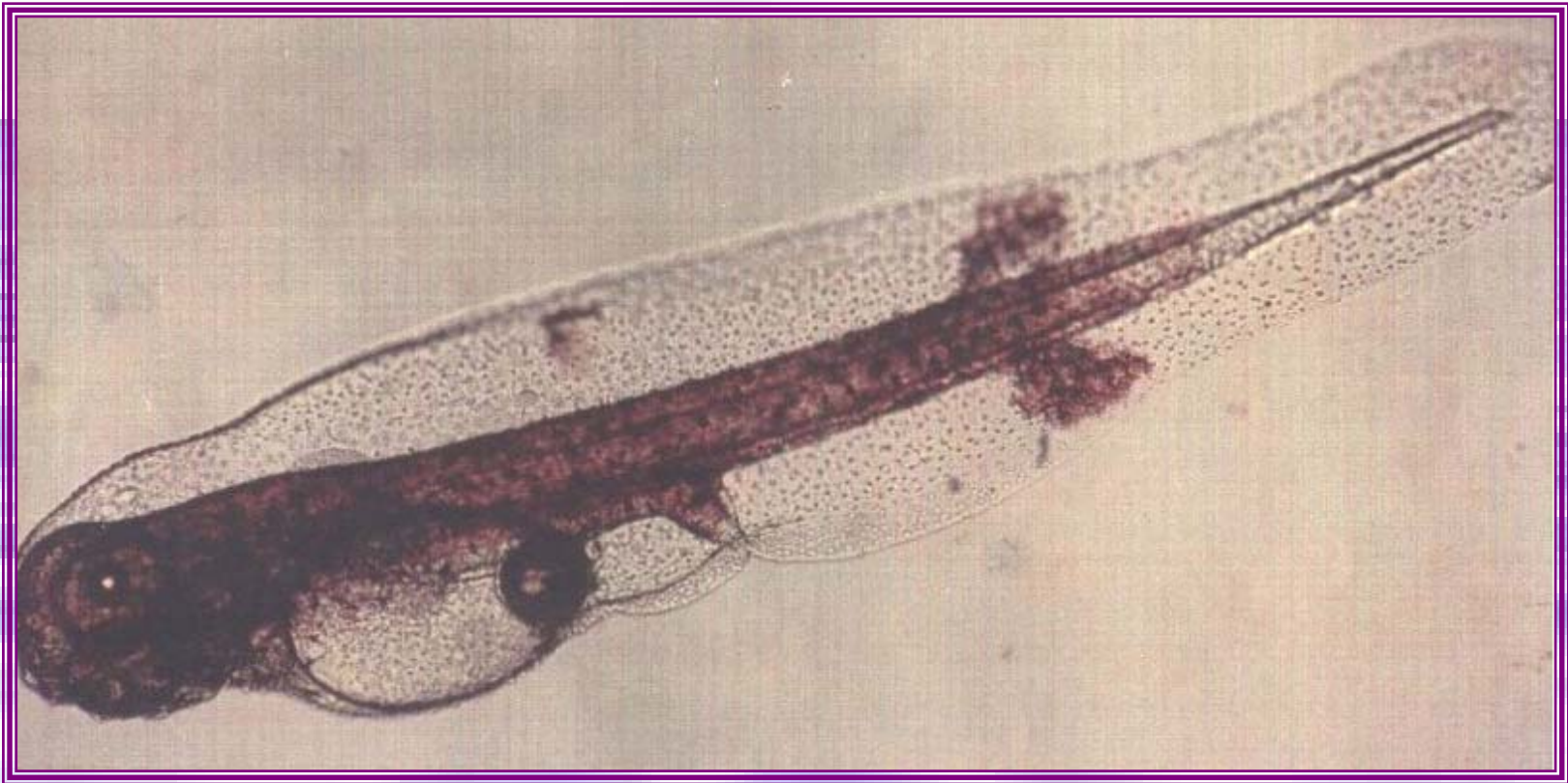




## Hatchery - Early Larval Rearing 1



Turbot larvae are around 3.5 mm long at hatch, and have an initial endogenous nutrition from their yolk sac. Unlike halibut, however, turbot larvae use up their yolk-sac very quickly, and are ready to start feeding on live plankton on day 3 or 4 post-hatch.



Turbot larva - about 60% through yolk-sac utilisation





## THE PRODUCTION PROCESS

### Hatchery - Early Larval Rearing 2

Turbot larval rearing in a range of different tanks (in terms of volume), but vessels of 2000 L capacity are not uncommon. This Hyperbook can not provide full turbot hatchery details (in most cases these details rest within commercial companies), but there are some guiding principles which are common:

- Early turbot larval rearing requires offering live food in the form of enriched rotifers
- Best results are obtained with water temperatures above 15 Deg C
- “Green water” techniques are quite common (the addition of cultured microalgae to the tank, as well as the actual zooplankton prey)
- Tanks are lighted artificially, commonly 24 hours per day
- The water is gently aerated in several places around the tank, in order to prevent any layering or stagnation
- It is quite common to have “static” water flow conditions for the first 10 days of turbot rearing - i.e. there is no introduction of a water flow
- The larvae should be offered freshly enriched rotifers 2 or 3 times per day, and prey levels within the main tank should be regularly observed - a level of 2-3 prey per mL would be desirable
- Rotifers are usually offered between Day 3 and Day 15 post-hatch
- Enriched brine shrimp (*Artemia*) is first offered around Day 6-8
- Great care is required to provide well-enriched live feed items
- Great care is also required to maintain good hygiene conditions in the hatchery during this phase



## THE PRODUCTION PROCESS

### Hatchery - Late Larval Rearing



Turbot in Late Larval Rearing - around Day 23 post hatch

Turbot larval rearing is still a somewhat problematic sector in terms of large scale reliability, and only 2-3 hatcheries in Europe could claim to have truly reliable production.

Serious problems can occur during the changeover from rotifer feeding to Artemia feeding - commonly around Day 10-13 post hatch. Although *live feed nutrition* is probably essential for correct skin pigmentation with turbot juveniles, and also important in terms of larval survival, it is not likely to be at the heart of this particular problem. Poor hatchery hygiene is most likely to be the cause of this sort of mortality.

For more detailed information on [live food production](#), press the button



# 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 carboys – 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 plicatilis* 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.



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[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 availability 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 energy loss.



## 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.

## THE PRODUCTION PROCESS

### Hatchery - Weaning



Weaning turbot on to inert pelleted diets is no longer a major problem area. It can safely start around Day 35 post hatch, and is usually complete within 2-3 weeks. Weaning is normally undertaken in either shallow (<15 cm) tanks of 1 or 2 m<sup>2</sup> surface area, or it can even be started in the larval rearing tanks themselves. 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 turbot 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%.



Grading part-weaned turbot juveniles





## THE PRODUCTION PROCESS Hatchery - Nursery

Once the small turbot 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 turbot are perfectly hardy animals, quite capable of being transported to on-growing farms. Allowing for some culling of runts and the occasional mortality due to aggression, nursery throughputs should now be > 85%.

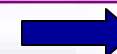
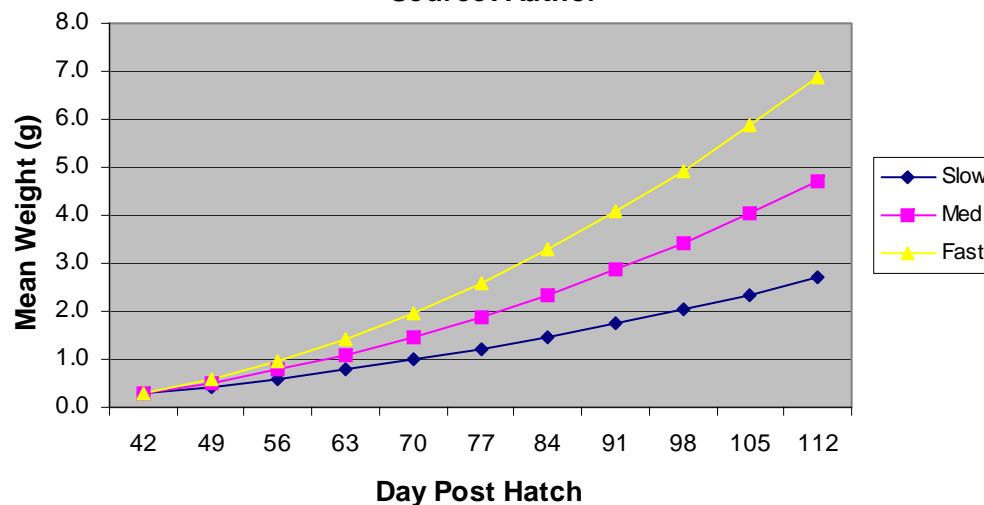
Nursery rearing in hatcheries is undertaken as speedily and efficiently as possible. Tanks of 4 to 12 m<sup>2</sup> floor area, and anything from 30 to 60 cm deep would be common. Feeding is on commercially available dry pellets (refer to feed manufacturers recommendations - See Suppliers). Best temperature is c. 18-20 Dec C.



**Growth of turbot juveniles in the "nursery" phase of the hatchery**

**Targets For Turbot Nursery Growth in a Hatchery**

Source: Author



## THE PRODUCTION PROCESS

### Hatchery - Overview 1



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

**Broodstocks:** Not a major problem for turbot hatcheries, but there is the need to ensure good nutrition. Selection programmes to encourage development of strains of fish with favourable characteristics will become important

**Yolk Sac Rearing and Transfer to First Feeding:** Not a difficult area for turbot hatcheries

**Larval Rearing:** Still the most problematic phase, particularly Day 10-15 post hatch. Expect average 10-15% survival from hatch to Day 25

**Fish Quality:** Incomplete metamorphosis and malpigmentation continue to affect a low but significant percentage of turbot reared in intensive, Artemia-only hatcheries..

**Handling and Husbandry Systems:** Many hatchery operators are finding that tank hygiene during the 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:** Turbot 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 turbot juveniles do not display any significant aggression, and nursery stages are relatively problem-free





## THE PRODUCTION PROCESS

### Hatchery - Overview 2

The British Marine Finfish Association (BMFA) takes the view that there will not be a large development of more turbot farming in the UK, due to our less than perfect ambient seawater temperatures. Nevertheless, there are projects based upon water recirculation techniques, and these need to acquire juvenile turbot.

Suppliers of juvenile turbot will be listed in the Suppliers Section of the Hyperbook, but in summary:

- There are probably some 5-6 million turbot juveniles being reared per annum in Europe at the present
- (Plus some 500,000 per annum in Chile, and new hatcheries in China)
- UK farmers can purchase turbot juveniles from:
  - The hatchery on the Isle of Man
  - The European hatcheries which have “approved zone” status under the terms of 91/67 EEC

The whole question of disease regulations and freedom of trade in terms of aquaculture products is an important and evolving issue - See Legislative Section

In conclusion, it is likely that juvenile turbot *can* be obtained by anyone in the UK who wishes to commence a turbot ongrowing operation.







## THE PRODUCTION PROCESS

### Hatchery to Ongrowing Transition

The cumulative time taken to produce 5-10g weaned juvenile turbot in the hatchery is somewhere between 3 and 4 months. This compares with around 8 months to produce juvenile halibut 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 PRODUCTION PROCESS

### Nursery Ongrowing 1

There is a very clear requirement to treat small turbot, arriving on an ongrowing site, with great care. They are still potentially vulnerable to diseases such as vibriosis (even if vaccinated) up to a size of at least 50g, and they require special care in feeding and grading. Typically an ongrowing farm will have a dedicated system of “nursery” tanks, which will be smaller than the main ongrowing tanks, and quite possibly housed in a building or other covered area.

As a broad rule of thumb the costs of changing a 5-10g fish into a 50g fish in this sort of combined ongrowing farm is not teased out of the main operating economics of the overall system. Nevertheless, speed of throughput in a nursery system is still of the essence - which means a focus on optimising growth rate.

**The world's first full scale turbot ongrowing farm at Hunterston, Scotland.**

**The nursery tanks are housed in the black-clad polytunnels**







## THE PRODUCTION PROCESS Nursery Ongrowing 2

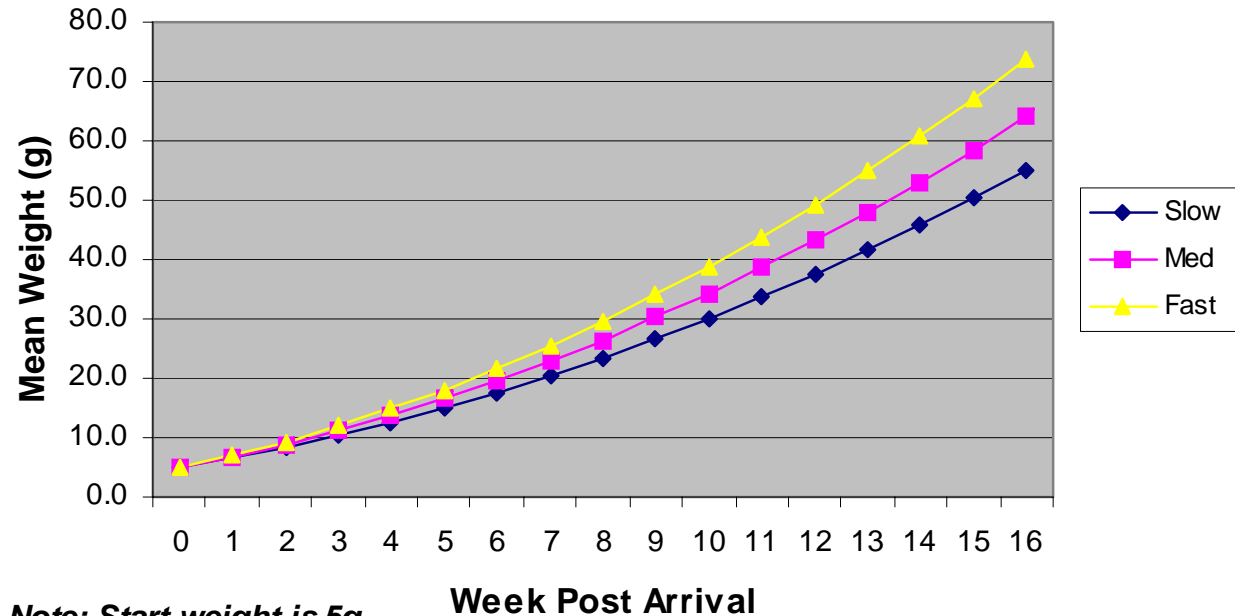
The expectation of growth rate can be numerically calculated, and can relate to several parameters. However, *temperature* of the rearing water is probably the main deciding factor.

The issue of water temperature is critical. If it is maintained at a near perfect level (e.g. 18 Deg C), then turbot should reach 50g in 13-14 weeks.

The point about this is that these temperatures do not occur naturally in the UK for very long in the sea - some heating would be required to obtain this sort of performance.

### Targets For Turbot Nursery Growth in Ongrowing

Source: Author



Note: Start weight is 5g





## THE PRODUCTION PROCESS

### Nursery Ongrowing 3

Turbot nursery units - if needed by UK aquaculture - 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 turbot 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 be taken to avoid disease introduction - particularly IPN
- Grading should be undertaken
- Stocking densities should be high - in the region of 10-20 kg/m<sup>2</sup>





## 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.



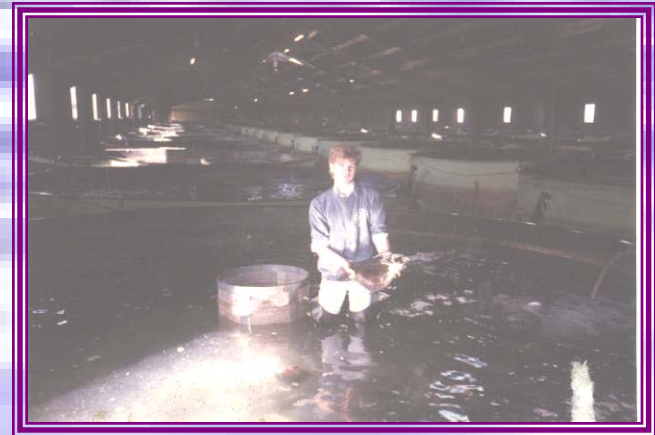


## Ongrowing in Land Based Systems - 2

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 turbot market size range is variable, but is generally for fish of >3 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. The author is of the opinion that farmed turbot can not be grown to such a large size in a profitable fashion - or at least that only a *proportion* of the crop can be carried through to this size
- 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. Happily, this is quite possible with turbot in Europe, since hatcheries are producing juveniles on an almost year-round basis

Turbot ongrowing at Hunterson,  
Scotland



## THE PRODUCTION PROCESS

## Ongrowing in Land Based Systems - 3

One interesting possibility for land-based turbot 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 does not appear that turbot adapt to shelves as readily as halibut



Turbot tanks have traditionally been built quite shallow - even if shelves were to be utilised, they might not be appropriate for some current farms





## THE PRODUCTION PROCESS

## Ongrowing in Land Based Systems - 4

The main considerations about turbot 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 are reasonably well-defined for turbot - as a rule of thumb one should probably be thinking of 50 kg/m<sup>2</sup> (of single layer floor) as a maximum for larger fish, and 20 kg/m<sup>2</sup> as a starting point for 50g juveniles. If shelves were in use in a 1m deep tank, the maximum density might equate to 100 kg/m<sup>3</sup> - and one would have to be concerned about good oxygenation (as well as the welfare lobby)
- Stock observation and mort. removal is essential - and much facilitated in tanks
- Malpigmented turbot 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
- Turbot 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







## THE PRODUCTION PROCESS

### Environmental Aspects of Turbot 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 Turbot Cultivation - 2

Turbot 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 turbot has not yet been formally established for UK aquaculture - but it is likely to be similar to that for halibut (48 kg N per tonne of fish produced)
- Turbot on-growing farms will probably remain small (in production terms) compared with modern large salmon farms - 2-400 tonnes per annum, for example.
- Visual impact will be a coastal land planning issue, rather than a marine issue
- Turbot do not “host” the salmon sea louse - and thus are not part of the sea lice/riparian owners debate.
- Hatcheries, land-based nurseries and traditional land-based on-growing 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.

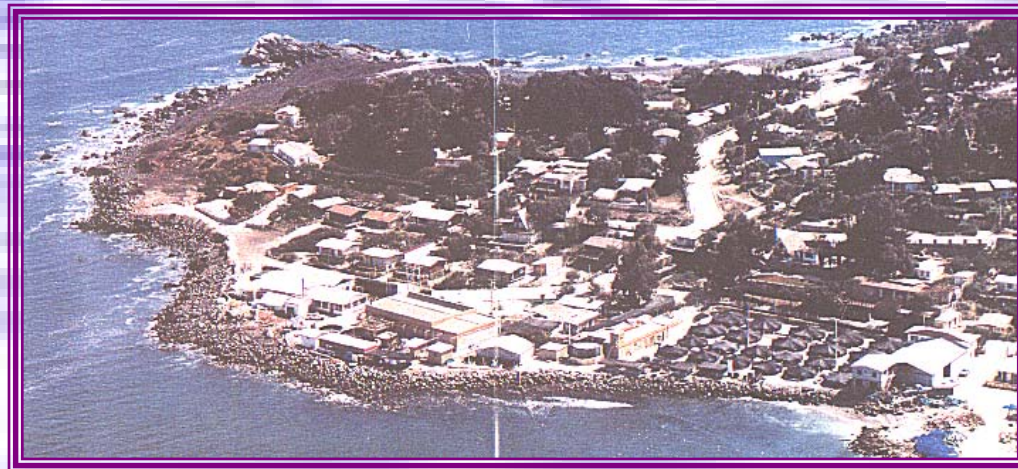




# THE TECHNOLOGIES AND EQUIPMENT EMPLOYED

## Introduction

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



## THE TECHNOLOGIES

### Hatchery - Broodstock 1

A “typical” turbot broodstock tank might be:

- 4m in diameter - or larger
- 0.7 m deep water
- 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 - located near the main tank
- Chest waders for staff
- Pit-tagged fish - and a pit-tag reader (alternative would be dye-marking or freeze branding)
- 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)



## THE TECHNOLOGIES

### Hatchery - Egg Incubation

Turbot egg incubation lasts for about 5 days, and requires:

- Conical-shaped upwelling incubation vessels - kept largely in the dark. 70L “Paxtons” are commonly used
- 1 Micron filtered and UV sterilised seawater at full salinity and a stable temperature of 12 Deg C
- Accurate flow-controls
- Record-keeping protocols and facilities
- Normal hatchery equipment:
  - Hand nets
  - Siphon
  - Jugs and beakers
  - Chemicals for egg sterilisation (“kick-start”)



Typical 70 L conical vessels, suitable for turbot egg incubation, with a simple recirculation system, sand filters and 1 micron cartridge filter





## THE TECHNOLOGIES

## Hatchery - Larval Rearing

Turbot 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. 18 Deg C)
  - Mesh screen outlets
  - Aeration
- Normal hatchery tools, monitoring systems and record-keeping protocols



Typical 2000 L polyethylene turbot larval rearing tanks - commercially available



## THE TECHNOLOGIES

## Hatchery - Weaning

Turbot weaning can be started within the main larval rearing tank, and is normally largely completed by the time the small fish are moved to nursery tanks (at around Day 45 post-hatch).

It is important to keep the tank clean during weaning, and a proper design of tank outlet is essential.



Turbot in late larval rearing, ready to be weaned on to commercially available crumb diets



## THE TECHNOLOGIES

### Hatchery - Nursery

#### Turbot nursery in the hatchery requires:

- Flat-bottomed shallow fibreglass tanks - 2 m across, by 0.5m deep
- Provision of temperature-controlled water flow (18-20 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 turbot nursery tanks



## THE TECHNOLOGIES

**Ongrowing Nursery - 1**

A turbot nursery within an ongrowing farm would have typical tank sizes of:

- 2 m fibreglass tanks (identical to hatchery nursery tanks)
- 3-4 m diameter circular tanks



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





## THE TECHNOLOGIES

### Nursery Facilities - 2

A temperature-controlled turbot 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





## THE TECHNOLOGIES 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.

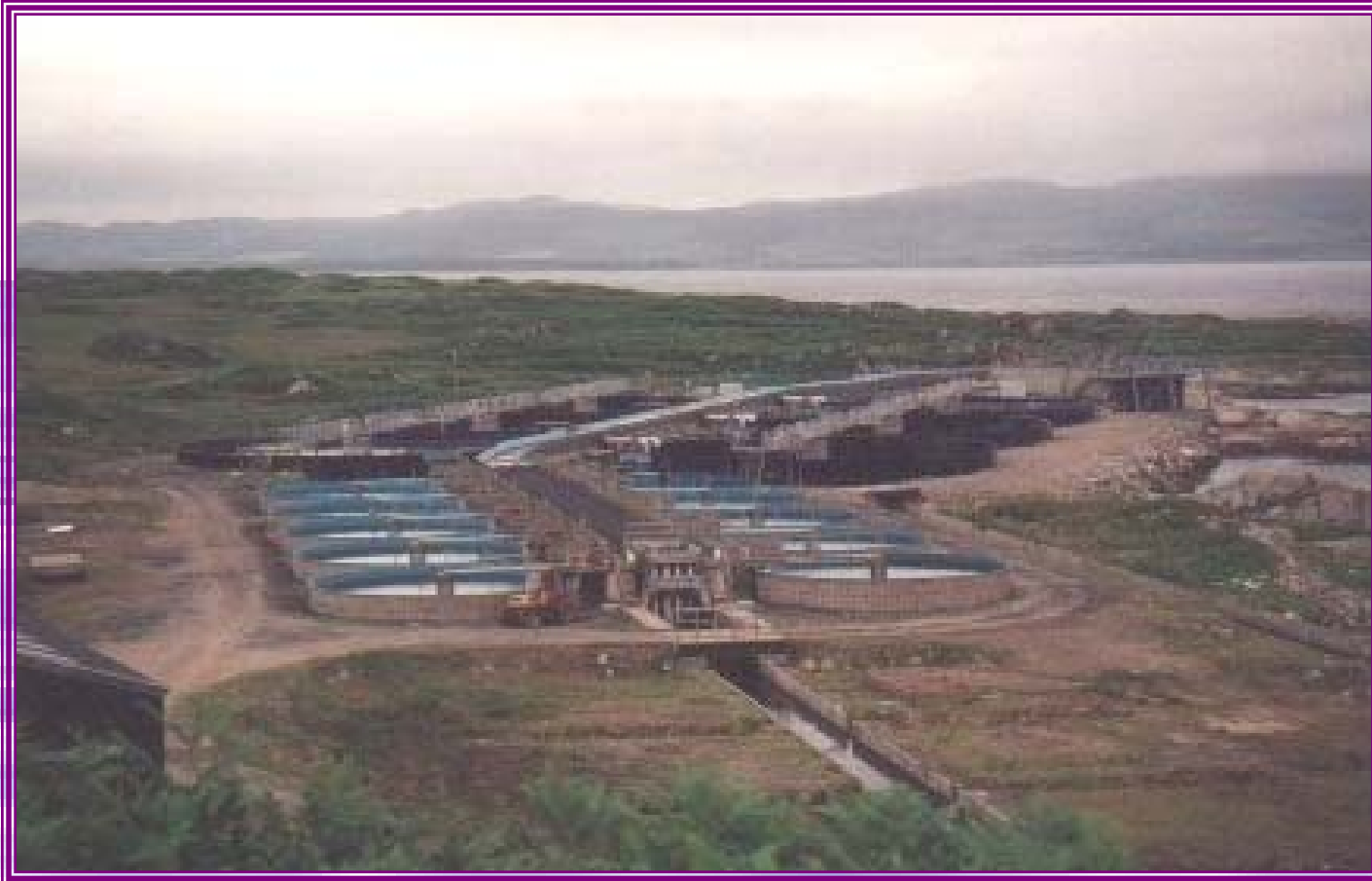


An example of a very high-tech recirculation system - this was actually designed for small Japanese flounder, but the principle would be much the same as that on offer to would-be purchasers of turbot nursery recirculation systems



## THE TECHNOLOGIES

### 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.



## THE TECHNOLOGIES

### 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.





## THE TECHNOLOGIES

### 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 on-growing tanks, but in the foreground is the “nursery” area, with smaller 4m diameter tanks.



## THE TECHNOLOGIES

### Land Based Ongrowing- 4



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





# THE TECHNOLOGIES Land Based Ongrowing- 5



- Green
- Light Green
- Red
- Blue
- Pink
- Yellow
- Orange
- Red



Industrial sites with heated seawater resources are sometimes used for turbot ongrowing



## THE TECHNOLOGIES

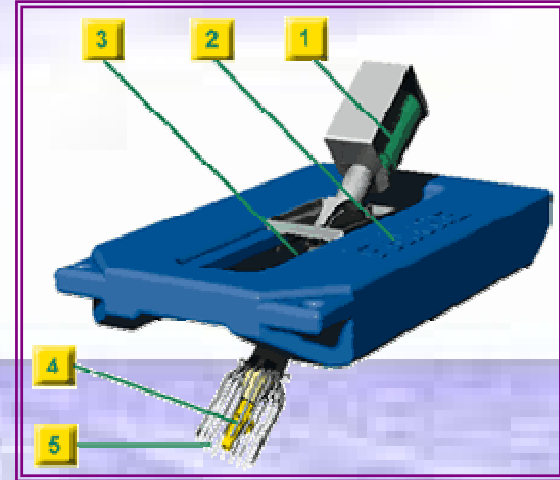
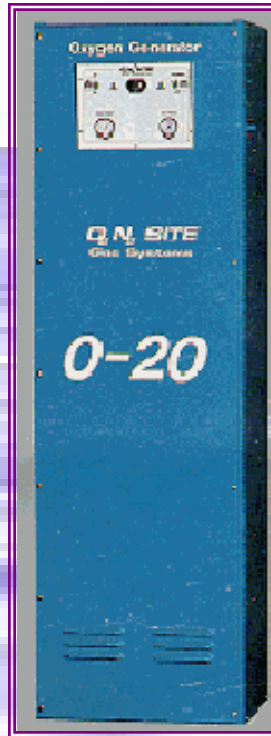
### Land Based Ongrowing- 6



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.



# THE TECHNOLOGIES Land Based Ongrowing- 7



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.



## THE TECHNOLOGIES Land Based Ongrowing- 7

As a general rule, flatfish are not so easy to handle as round fish in terms of mechanised tools. This situation is changing, and there are now some flatfish grading machines on the market.



Grading and moving  
part-grown turbot







# SITE SELECTION

## Introduction

This section of the Hyperbook will consider how locations for turbot 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.

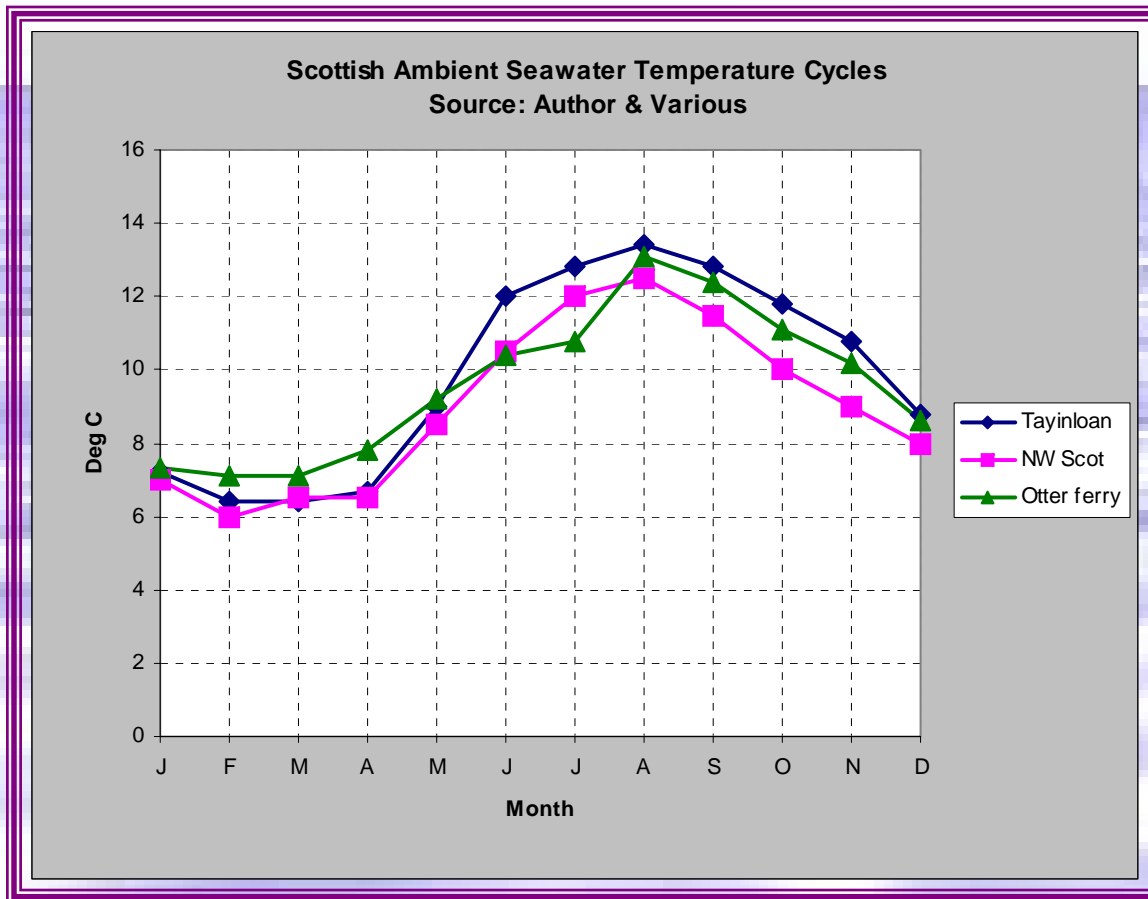




## SITE SELECTION

### Seawater Temperature Profile - 1

Turbot in on-growing 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 turbot, it is probably better for the temperature to remain above 12 Deg C and below 20 Deg C – which explains why turbot is not a mainstream choice for ambient temperature UK locations.



The figure shows the ambient seawater temperature cycle for some aquaculture locations in Scotland - and they are clearly not ideally suited for turbot



## SITE SELECTION

## Seawater Temperature Profile - 2

Turbot 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



## SITE SELECTION

### 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)





## Introduction

This section of the Hyperbook will consider the nature of the regulatory framework within which turbot 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.



## LEGAL AND ADMINISTRATIVE

### 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







## LEGAL AND ADMINISTRATIVE 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)





## LEGAL AND ADMINISTRATIVE 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.





## LEGAL AND ADMINISTRATIVE 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 turbot sector were:

- Locational guidelines for aquaculture in Scotland - where new sites might be developed
- Environmental impact of turbot 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 turbot
- 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





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 turbot 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

#### Turbot Hatcheries

- France Turbot (France)
- Mannin Seafarms Ltd. Tel: 01624 824698 Email: ManninFish@aol.com
- Maximus (Denmark) Tel: 00 45 98 944903

#### 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:



## Suppliers 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: 





## Suppliers 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: [jm.buchanan@onyxnet.co.uk](mailto:jm.buchanan@onyxnet.co.uk)). Richard J Slaski (email: [RichardSlaski@aol.com](mailto:RichardSlaski@aol.com))

### Training

Scottish Aquaculture Training Association, Mountview, Ardvassar. Skye. IV45 8RU Tel/Fax: 01471 844324 E-mail: [DouglasMcleod@aol.com](mailto: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](mailto:admissions.officer@inverness.uhi.ac.uk) Web: [www.uhi.ac.uk/inverness](http://www.uhi.ac.uk/inverness)





## Suppliers 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](mailto:aquaculture@seafish.co.uk) Web: [www.seafish.co.uk](http://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](mailto:technology@seafish.co.uk) Web: [www.seafish.co.uk](http://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](mailto:cbait@oceanfree.net)

North Atlantic Fisheries College, Port Arthur, Scalloway. Shetland. ZE1 0UN Tel: 01595 772000 Fax: 01595 772001 E-mail: [admin@nafc.ac.uk](mailto:admin@nafc.ac.uk) Web: [www.nafc.ac.uk](http://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](mailto:marine.science@dml.ac.uk) Web: [www.sams.ac.uk](http://www.sams.ac.uk)





## Suppliers Services Suppliers - Continued

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

Specifically: [www.cefasc.co.uk/fhi](http://www.cefasc.co.uk/fhi) 

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

Specifically: [www.defra.gov.uk/fish](http://www.defra.gov.uk/fish) 

[www.defra.gov.uk/corporate/regulat/forms/fish](http://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 







## Suppliers

### 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](http://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](http://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](http://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](mailto:hie.general@hient.co.uk) Web: [www.hie.co.uk](http://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](http://www.scottish-enterprise.com)

#### **For Northern Ireland:**

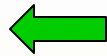
Department of Agriculture and Rural Development, Northern Ireland (DARDNI) (see government departments)

#### **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).





Back to  
Markets  
Section



## Turbot in Nutty Herb Butter

4 x 170g (6oz) turbot or halibut steaks, fresh or defrosted

Nutty Herb Butter

115g (4oz) butter, softened

2 cloves garlic, crushed

2 x 15ml spoon (2 tablespoons) fresh chopped parsley

2 x 5ml spoon (2 teaspoons) whisky or brandy

few drops lemon juice

55g (2oz) chopped hazelnuts

lime and lemon slices, to garnish

Mix together the ingredients for the nutty herb butter. Place onto cling film, roll into a sausage shape and chill for 2-3 hours.

Slice the flavoured butter and heat for 3-4 minutes in a pan. Add the fish and cook for 6-8 minutes, turning occasionally. Add more butter if necessary.

Garnish and serve with potato wedges and a green salad.

Serves 4

NUTRITIONAL VALUES PER PORTION (APPROX) 471 Kilocalories;  
32g Protein; 37g Fat; 2g Carbohydrate; 1g Fibre.

Tip: Make the flavoured butter in advance and freeze. The butter can be used with a variety of fish such as cod, swordfish or shark for a quick and easy supper.

See a  
picture



 [Back to Markets Section](#)



**Turbot in nutty herb butter**





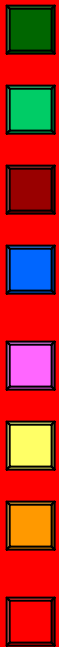
# BUSINESS PLANNING

## Introduction

This section of the Hyperbook covers the development of business plans to support turbot cultivation. The section will provide an overview of business planning, but mainly introduces the Turbot 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.





## Business Planning 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 turbot cultivation
- To use this Hyperbook to inform them about other people's plans concerning turbot 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 turbot 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 quantified
  - 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 Turbot Cultivation are contained within your TURBOT 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

