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The Propagation of Cod *Gadus morhua* L.

DOES COD FARMING HAVE A COMMERCIAL FUTURE? A TECHNICAL AND ECONOMIC ASSESSMENT

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ABSTRACT

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Cod is a traditional favourite with British consumers, but supplies have fallen dramatically through the 1960's and 70's as a result of imposed fishing limitations. Maintenance of supplies for the future will depend on efficient stock management or perhaps fish farming.

Cod larvae can now be reared in the hatchery using techniques similar to those developed for turbot and sea bass. Growth to market size is rapid at ambient temperatures in the range 5-15^{o}C. Technically cod farming is possible, but economic projections indicate a production cost above the current quayside price for cod and suggest it would not be profitable. Small operations with access to cheap food and specialisist markets exist and appear viable.

INTRODUCTION

Cod has always been a low priced traditional favourite with British consumers, but supplies from United Kingdom landings have fallen dramatically from around 300,000 t in the early 1970's to some 100,000 t in 1982. This decline has occurred because of fishing limitations imposed on British vessels and also falling catch rates, consequently the U.K. now relies heavily on imports to meet the market demand for cod.

Looking to the future, an increase in our domestic cod supplies can only come through improved stock management or perhaps some form of farming or ranching. In this paper an attempt has been made to evaluate the potential of farming cod by considering firstly whether it is technically feasible and, secondly, whether it could be profitable. This study is confined to evaluating the feasibility of intensive farming methods for cod production. Natural stock replenishment by fry release and sea ranching, although valid alternatives, have not been covered.

FRY PRODUCTION

In recent years considerable progress has been made in the development of methods for mass rearing of European marine fish fry, especially species such as sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*) and turbot (*Scophthalmus maximus*) (Jones and Houde, 1981). Marine fish characteristically produce large numbers of small pelagic eggs which at hatching release larvae of only a few milimetres in length. It is the problems associated with solving the environmental and feeding requirements of these tiny larvae which makes their rearing so difficult compared, for example, to salmonids. Cod produce eggs ranging from 1 to 1.5 mm diameter, giving rise to newly hatched larvae measuring around 3.5 mm in length. Some biological characteristics of cod compared with other marine species are shown in Table 1.

Cod can now be reared in hatcheries using methods similar to those developed for other marine fish species. Recent experiments in Norway (Huse et al., 1982) and in the U.K. (Howell, 1979) have resulted in the production of several thousands of fry. In the trials conducted by Howell, larvae were first offered a diet of rotifers (*Brachionus plicatilis*) for the first 30 days after which they were transferred to a diet of *Artemia* metanauplii. The metanauplii were grown on a mixture of two species of unicellular algae, *Isochrysis galbana* and

TABLE 1

Comparison of fecundity, egg and larval size of selected marine species.

	Annual Fecundity Eggs/kg Thousands	Egg Diameter mm	Length of larvae mm	Wet Weight of larvae mg
Bass (*Dicentrarchus labrax*) (Girin, 1979)	300	1.2-1.4	7.0-8.0	0.4
Bream (*Sparus aurata*) (Person-Le Ruyet and Verillaud, 1980)	500	0.9-1.1	3.5-4.0	-
Turbot (*Scophthalmus maximus*) (Jones, 1972)	1000	0.9-1.2	2.7-3.0	0.3
Sole (*Solea solea*) (Girin, 1979)	700	1.0-1.4	3.2-3.7	0.6
Milkfish (*Chanos chanos*) (Chaudhuri et al., 1978)	200C	1.1-1.25	3.2-3.4	-
Grey Mullet (*Mugil cephalus*) (Nash and Shehadeh, 1980)	850	0.9-1.0	2.2-3.5	-
Grouper (*Epinephelus tauvina*) (Hussain and Higuchi, 1980)	250	0.77-0.9	1.4-2.4	-
Cod (*Gadus morhua*)	450	1.0-1.5	3.6	-

Pavlova lutherii, for two days. Survival of the larvae was in the region of 5-7% to 72 days old. The larval survival curve is reproduced in Fig. 1 and can be seen to compare very favourably with the level of survival achieved in rearing trials with other marine species.

Ignoring for the present economic criteria, the rate of development of cod farming will be governed to a great degree by the availability of fry for ongrowing. Parallels can be drawn with sea bass, sea bream and turbot farming in Southern Europe where fry availability is currently a major factor in

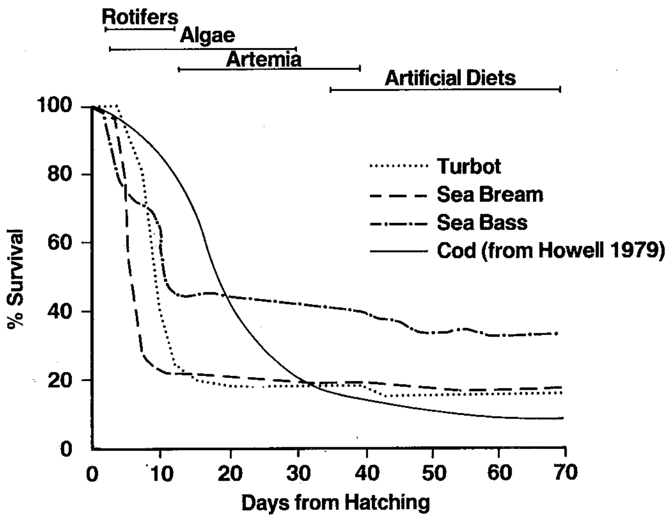

Fig. 1. Larval survival curves for four species of marine fish. (Figures for turbot, sea bream and bass from Jones et al., 1980).

controlling the rate of growth of these industries. However, commercial hatcheries are becoming established and output is increasing as rearing methods become more reliable. The emphasis in these hatcheries is on mass rearing with production capacities of 1 to 2 million fry per year. Larval rearing is conducted in tanks up to 20 m^3 in capacity which are stocked at levels of 20 larvae per l.

Provision of adequate broodstocks is also an important factor in commercial hatcheries. Ten years ago, when emphasis was on determining how to feed and maintain larvae under artificial conditions for the first time, the high fecundities of marine fish meant that egg supplies were not limiting for this work. However, now that larval rearing rechniques are more developed, the main objective is mass production, and so reliability of spawning and egg availability is now vital to ensuring that a hatchery's productive capacity is fully utilised. Progress in the regulation of spawning time by photoperiod control and the use of hormones to stimulate ovulation has played a prominent role in extending the fry production season for many species. Using these techniques it is now possible to spawn turbot, bass or bream at any time of the year. Cod will spawn naturally in captivity, and this is an advantage from the hatchery management viewpoint. Turbot are usually hand stripped and bass are induced to ovulate and spawn using HCG extracts. Both these activities impose an extra burden on hatchery staff. Assuming that cod could be induced to spawn at any time of the year with photoperiod control, their ability to spawn naturally would make fertile egg recovery from the spawning ponds a simple process using surface overflow collectors.

ONGROWING

The production of cod fry on a large scale appears to be feasible and presents no more technical problems than the rearing of other marine fish. Growth trials with hatchery reared cod have produced increases in mean weight from 12 g to 470 g over a 42 week period at temperatures ranging from 6 to 16°C (Howell and Bromley, 1983). This temperature range is similar to that of a Scottish loch or Norgwegian fjord, so it is reasonable to presume that year round growth would be obtained under natural conditions. In the above trial the cod were fed on a diet of industrial fish (sandeels, whiting and Norway pout) and conversion rates ranged from 2:1 to 3:1. Being a round fish, cod would adapt readily to cage farming and indeed in Scotland and Norway, there are some pioneering farmers who are producing small quantities of marketable cod using naturally caught juvenile stock. The growth rate of cod is shown compared with that of turbot in Fig. 2. These growth curves are those that would be expected in ambient conditions on the west coast of Scotland. This rate of growth would produce a cod of 2 kg weight 18 months from stocking at 5 g. Clearly a very acceptable rate of growth for commercial operations. In comparison the slow growth rate of turbot illustrates what we already know to be true, that this species requires temperatures in the range 15-18°C for optimum performance (Jones et al., 1981).

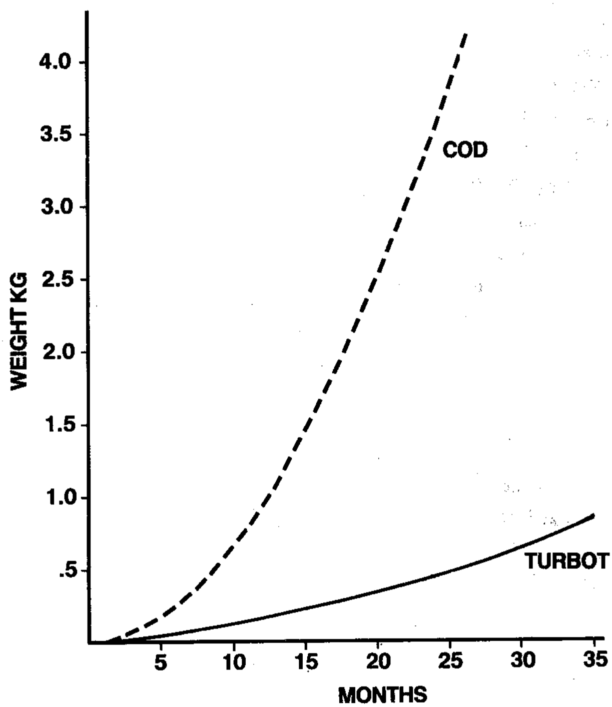

Fig. 2. Estimated growth rates of cod and turbot at ambient temperatures off the West Scottish coast.

PRODUCTION COSTS

The technical data and trial results discussed so far indicate that there are no major obstacles to fry production and ongrowing. If this is the case, then cod farming is possible, but would it yield acceptable returns on investment? The economic case has been assessed by projecting the costs of fry production and ongrowing, drawing on experience in related fields of commercial fish farming.

Fry Production Cost

As fry production is more technically involved than ongrowing, it has been assumed for the purpose of this analysis that fry would be produced by specialist hatcheries and sold to cod ongrowers. In Table 2 are some projections on likely capital for a hatchery unit capable of producing one million cod fry per year.

TABLE 2

Cod farming - cost of fry production based on a unit with annual output of one million fry.

		£
Capital		
Buildings		150,000
Equipment		130,000
Vehicles		20,000
	Total	300,000
Annual Operating Cost		
Labour		73,000
Power		
1) Heating		8,000
2) Pumping/General		11,500
Feed		
1) Artemia		31,000
2) Weaning/Fry		4,000
Repairs, Motor, Telephone/Telex, Insurance		16,250
Sundries		2,500
Depreciation		21,000
	Total	167,250

Production Cost = 16.7 p/Fingerling
N.B. All costs before interest charges.

The capital cost of the hatchery is estimated at £300,000, comprising £150,000 on buildings, £130,000 on equipment and £20,000 on vehicles. The larvae would be reared in ten 20 m^3 circular tanks.

It has been assumed that survival from yolk sac larvae to metamorphosed fry would be 10% and that fry would be grown on in a nursery facility until they reached a mean weight of 5 g at which size they would be sold to the ongrowers. Production cost is estimated at 17 pence per fingerling with a minimum sale price to the ongrower of 23 pence. Operating costs assume a staff of seven persons plus a part-time secretary and book-keeper. The larvae will be reared at 12^{o}C and heating costs have been calculated assuming an ambient temperature range of 5-16^{o}C. The total quantity of pumped water required for the hatchery and nursery will be 54 m^3 per hour. Fee, which is a significant percentage of total operating costs, assumes the use of 750 kg of *Artemia* annually.

Ongrowing Cost

Ongrowing costs have been estimated for a hypothetical 100 t per annum sea cage unit in Western Scotland. Ongrowing costs are set out in Table 3. The capital costs assume an 18 cage unit of 315 m^3 capacity cages with minimal onshore facilities Total capital investment is estimated at £78,000 and would be

TABLE 3

Cod farming - ongrowing costs for a 100 t/annum cage unit.

Capital		£
Cages		43,000
Buildings		17,000
Equipment		18,000
	Total	78,000
Annual Operating Cost		
Labour		30,000
Feed		56,700
Stock (Fry)		13,800
Other		14,000
Depreciation		9,400
	Total	123,900

Production Cost = 55p/lb (£1.21/kg)
N.B. All costs before interest charges.

complete three years from start up. The annual operating costs shown in Table 3 are projected typical annual costs when the site is on stream. The site would operate with a workforce of four. The farm would produce 2 kg cod and require 60,000 fingerlings for stocking each year, (allowing a 20% mortality over the grow out phase) to maintain an annual production of 100 t. Food requirements have been estimated using a dry diet at a cost of £315 per tonne and assuming a conversion rate of 1.8:1. On the basis of these assumptions, production cost is 55 pence/lb (£1.21/kg) for a whole cod.

Return on Investment

The projected production cost of 55 pence/lb (£1.21/kg) is low when one considers the relatively high cost of fingerlings at 23 pence each and is mainly due to the rapid growth rate and efficient conversion rates which have been achieved in trials. However, the main factor which will determine whether cod farming could be profitable is the market price the finished product will sustain.

The first quayside values of U.K. cod landings are shown in Table 4. These figures suggest that if farm product were sold into the same markets as wild fish, it would only command a price of 28 pence/lb (£0.62/kg), still well below the 55p/lb production cost of farmed fish.

In the U.K. whole cod are marketed headless and gutted. Removal of the head, guts, liver and roe results in a reduction weight of the whole fish by approximately 37% (Wateman, 1981). This, therefore, means that the production cost for farmed cod is equivalent to 87p/lb (£1.92/kg) in the headless gutted form.

The retail price that farmed cod would need to sustain has been calculated on the basis of what would constitute a reasonable return on investment to the producer. For many commercial operators a reasonable rate of return is at least 30%. Return on investment has been calculated using the following ratio:

$$\frac{\text{Profit}}{\text{Total Investment (Fixed + Current Assets)}}.$$

Profit is defined as gross profit after all operating ex-

TABLE 4

Cod - quantity and value of U.K. landings for selected years.

	Weight Tonnes	Value £000	Value p/lb (£/kg)
1972	301,819	46,000	7 (0.15)
1975	242,440	61,000	11 (0.24)
1976	212,110	80,200	17 (0.37)
1977	147,699	77,000	23 (0.51)
1978	126,391	67,300	24 (0.53)
1979	109,255	63,600	26 (0.57)
1980	104,307	58,300	25 (0.55)
1981	115,733	60,800	23 (0.51)
1982	108,222	67,400	28 (0.62)

(Source: M.A.F.F. Sea Fisheries Statistical Tables 1982)

penses but before interest charges. Total investment is defined as fixed assets net of accumulated depreciation plus current assets (net receivables plus stock). The results of this analysis are set out in Table 5 and this shows that a return on

TABLE 5

Projected return on investment for a cod cage unit producing 100 tonnes per year (63 tonnes headless gutted).

	Year 1	Year 2	Year 3	Year 4
	(all figures £'s sterling)			
Plant Equipment	52000	64750	62600	54000
Current Assets	1702	44797	78323	78390
Total Investment	53702	109547	140923	132390
Labour	23500	29000	29000	29000
Feed	6200	41900	56700	56700
Stock	13800	13800	13800	13800
Other	10000	12500	15000	15000
Depreciation	0	7000	9400	8600
Total Expenses	53500	104200	123900	123100
Sales at £1.15/lb (£2.53/kg)	0	69552	162288	162288
Profit	-53500	-34648	38388	39188
Return on Investment	-100%	-32%	27%	30%

investment of 30% could only be ahieved with a retail sales price of £1.15/lb (£2.53/kg).

To summarise the current assessment of the profitability of cod farming we can refer to Table 6. These figures clearly show that, according to this analysis, farmed cod would need to yield a 35p/lb (£0.77/kg) premium over its wild counterpart in order to give an acceptable rate of return.

TABLE 6

Market, wholesale and retail prices of wild cod versus farmed cod.

	Wild Cod		Farmed Cod	
	p/lb	£/kg	p/lb	£/kg
Market Price (Heads on, gutted)	28	0.62		
*Retail Price (Headless, gutted)	80	1.76		
Production Cost				
1) Whole Cod			55	1.21
2) Headless, gutted			87	1.92
Retail Price (Headless, gutted)			115	2.53

*Source: Household fish consumption in Great Britain quarter ended 1982. Published by the Sea Fish Industry Authority.

CONCLUSIONS

It is apparent that cod has many attributes which make it an attractive species for farming. These may be listed as follows:

(a) Its fry can be reared artificially at commercially acceptable levels of survival.

(b) It grows rapidly at low ambient sea temperatures encountered around the Scottish and Norwegian coasts.

(c) It accepts artificial diets and is an efficient converter.

(d) There is a large and ready market for the product.

Despite all these attributes it must be concluded that it is difficult to envisage at present a strengthening of the market price which would enable a profitable farming business on a large scale similar to that of salmon and trout in Northern Europe and Scandinavia. However, there may be localised opportunities where there are supplies of cheap food, or where local markets offer premiums which could make for profitable operations. Some of these situations already exist in Norway and are being exploited on a small scale. However, unless there are changes in the availability of wild product through further declines in the landings it does not seem likely that cod farming on an industrial scale will attract investment in the foreseeable future.

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