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A socioeconomic cost-benefit analysis of the use of glass eel

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Contents

Introduction

European eel farming has developed strongly over the recent years, not least in Denmark. The development of the technology makes it possible to produce eel intensively taking into account environmental, quality, and efficiency demands.

The decline in the Japanese eel *Anguilla japonica* and the strong demand from the Japanese market has turned the Japanese demand towards Europe and the European eel *Anguilla anguilla*. The consequence is that European glass eel is exported to Japan via China where it is grown and used for kabayaki-production. The kabayaki-eel is then exported from China to Japan. The increasing demand for glass eel has put the European eel stock in jeopardy, and because eel cannot be hatched artificially the raw material demanded for the European eel farm has been affected in particular on the price. Recently, the glass eel prices have decreased but worries about future development in demand for glass eel still prevail because of the large size of the far-east production volume relative to the European volume.

The International Council for Exploration of the Sea (ICES) has declared the eel spawning stock outside safe biological limits (ICES, ACFM report Coop. Res. Rep. 229, 1998). Therefore, it has become important to manage the European eel with the aim to restore the stock and avoid shocks and possibly demolition of the European industry. In the recent advice (January 2000) to the EU Commission the Scientific, Technical and Economic Committee for Fisheries (STECF) recommends that “countries should be encouraged to stop the direct consumption of glass eel and to ban export of glass eel to countries outside ht EU” as an act to protect the eel stock (STECF 1999, pp. 11-12).

The general objective is, therefore, to arrive at a state where sustainable and balanced development of the eel sector in Europe is secured. The objective of this study is to carry out a cost-benefit analysis with the aim to compare the economic benefits to society from different use of the glass eel. This analysis is based on biological information about the relationship between the glass eel and the adult eel.

Danish Eel Farmers’ Association has commissioned the study and the following economists have carried it out:

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Michael Ingemann Pedersen, the Danish Marine Institute, Department of Freshwater, Silkeborg has been associated the project as referee on chapter 4.

The report is work out in Danish Crowns but a few figures are stated in Euro. The exchange rate between DKK and Euro is; app. 7.45 DKK: 1 Euro.

The Danish Institute of Agriculture and Fisheries Economics, July 2000

Jørgen Løkkegaard
Research director

1. Summary of findings

Catches of European glass eel (*Anguilla anguilla)* is estimated at about 500 tonnes a year. The catches mainly take place in the area of Biscay. The glass eel is used for:

- Restocking and commercial fishery
- Aquaculture (intra European)
- Aquaculture (overseas exports)
- Direct consumption

Very high growth rates are recorded from the glass eel stage to adult eel stage. The highest rates appear in eel farming implying that one kilo of glass eel is raised to about 385 kilos of adult eel (cf. e.g. table 5.3), whereas wild eel is raised to a little less than 100 kilo but over a much longer period (cf. chapter 4 e.g. figure 4.1). Only a smaller share of the glass eel is used in Europe for farmed eel production and restocking into lakes, rivers and streams. With an annual production level at about 10 000 tonnes of adult eel for the European eel farms the potential for a production increase is obvious. Price drops and shortage of demand for adult eel will, however, put a limit to the magnitude of this increase.

Restocking and commercial fishery

Restocking of glass eel make basis for annual additional catches of 96 tons at a value of 4.9 million DKK per ton of restocked glass eel, cf. diagramme 4.1. This assumes, however, that restocking is done on a continuous basis that makes eel available all the time. It is assumed that fishing is commenced when the eel is 6 years old. The first 4 years from that stage the eel is caught as yellow eel at an average price at DKK 46.5 per kilo. When the eel is 10 years old it is assumed that it starts silvering and the price increases to DKK 60 per kilo. The value of the landing is not discounted to present as is prescribed in theory. Or alternatively, the rate of discount is fixed at zero from the point of view that it is of benefit to society that the eel stock is restored. The loss of catches because of increased predation from the eel is not subtracted from the above value.

If there is excess capacity in the fishery for wild eel no extra resources are required to catch the extra quantity caused by increased stock abundance. This is probably the normal case. If further effort is required the contribution from 1 ton of glass eel is lower, cf. table 1.1. The figures are exclusive of catches of other species that would be the result from the extra effort. The other species only constitutes about 4% of the landing value of the target eel fish-

ery and most of the species are subject to quotas and is therefore transferred from other fishermen. As a consequence, these catches are excluded from the cost-benefit analysis.
It is assumed that the living of the eel in the environment is costless to society until the eel is being caught. The volume of glass eel that could be transferred is dependant on the carrying capacity of the lakes and streams into which the eels are launched.

The highest contribution to society, value added, and assuming excess capacity is estimated at DKK 4.9 million minus restocking costs, cf. table 1.1. This is because nature, so to speak, pays the costs of bringing up the eel. The increase in income generates more employment. The crew share is 23% of the turnover. That increases crew salary with DKK 1,1 million equal to an increase at about 4 persons per tonnes glass eel.

It must be emphasized that calculations are carried out with the assumption of fixed prices. Increase in production to a larger extend will entail price increase on raw material and price reductions on adult eel products reducing the economic gains. This applies to fisheries as well as to farming. At the available information it is not possible to assess price changes. Possible consequences are evaluated by sensitivity analyses.

Eel Farming.

Assuming a well-functioning and well-adapted eel farming industry, the calculations from chapter 5 for year 5-6 serve as basis for the conclusions.

The input of one tons of glass eel in eel farms produces about 200 tonnes a year at a value of DKK 21.2 millions. The sales price is fixed at DKK 55/kilo as the eel from farms are yellow eel but more uniform than wild yellow eel and it is possible to deliver large quantities at a continuous basis.

The calculations are based on full capacity use. Therefore an increase in production requires more production resources. The result based on a single year shows that one additional ton of glass eel produces revenue net of costs at DKK 1.2 million dependant of the size of capital depreciation (average of year 5 and 6), cf. table 5.6.

The value added contribution: the remuneration of capital and labour is DKK 11 millions per tonne glass eel and the increase in labour is 7-8 persons.

The figure that is applied in a cost-benefit analysis for comparison of the four scenarios is calculated as well. These figure show the net profit generated from one ton of glass eel, and the net profit is revenue less all costs but before interest, tax and depreciation payments. These results are summarised in table 1.1.

TABLE 1.1: **Value added per gear in EU of the use of 1 extra tonnes glass eel in four scenarios**

Scenario	Cost-benefit Contribution per year Million DKK	Value added Million DKK	Employment Number of persons
1. Commercial fishery after adult eel			
- Eel fishermen 2	1.6 – 3.7	2.9 - 4.9	4
2. Glass eel used by the aquaculture sector in Europe		2.2	
- Glass eel fishermen 3	9.5	11.4	7-8
- Eel farmers		13.6	
- Total			
3. Aquaculture overseas (extra EU export of glass eel)	-	2.2	-
- Glass eel fishermen 3			
4. Final consumption of glass eel			
- Glass eel fishermen 4	-	0.75	-

Note: 1. The value added does not include derived industries, traders and consumers.
2. The lowest level is reached if increase in output requires further input of production factors.
3. Based on a price on 3,300 DKK/kg and that production costs are 1/3 of turnover.
4. Based on a price of 750 DKK/kg and that production costs are 1/3 of turnover. The price is chosen, as Spanish consumers of glass eel are only willing to buy at this low price. When the price is higher, this market is not supplied.

Remark:
Cost-benefit contribution is surplus before remuneration of capital
Value added is remuneration of all capital and labour

Some conclusion may be drawn from the table. The cost-benefit contribution provides information about the annual net profit before remuneration of capital (interest and depreciation. Given assumptions, when this figure over a number of years is discounted to present value it shows the magnitude of investment that could be undertaken to increase production., one extra tonnes of glass eel in EU creates value added of between 2.9-4.9 to the fishery. The interval reflects that it is uncertain to what extend extra production input such as gear and piles are required. For eel farming, however, the figure is more than DKK 11 millions in value added per ton glass eel. Scenario 3 and 4 results are uncertain. Estimates indicate that consumers are not willing to pay more than 750 DKK per kilo glass eel, and the estimate for scenario 3 assumes that is not free of costs to catch glass eel, cf. table note 3. Therefore, subject to the market's capability to absorb the eel, the value added created by use of glass eel on eel farms in EU can be increased by increasing the eel farming sector in

EU and at the same time decrease the use according to the other three scenarios, particularly decreasing the use for final consumption.

However, the analysis includes not value added in derived industries and among traders in EU as well as it does not include gain to EU consumers of a possibly increased supply because it has not been possible to obtain information required for such calculations. If value added in derived industries and among traders in EU were included in the analysis, scenario 1, 2 and 4 would be more advantageous to EU than obtained from the analysis. Correspondingly, if EU consumers were included, scenario 1, 2 and 4 would be more advantageous to EU.

The estimates of cost-benefit contribution and value added are point estimates. If production of adult eel is increased price will fall. The consequence of expansion of the industry is not subject for investigation in this context and such an investigation requires price formation studies.

On this basis it can be concluded that scenario 2 and thereafter 1 are the most advantageous for the EU as a whole. As a consequence introduction of policies aiming at increasing the use of eel for aquaculture in EU, or increasing the commercial eel fishery, can increase value added in EU considerably.

Production viability

Rather substantial gain can be obtained by using glass eel for further production in the EU. If glass eel is consumed as such, a consumer surplus at about DKK 1 million per tonne (DKK 0.75 million plus some more), estimated as the consumer price plus willingness to pay more by some consumers minus the catching price, is lost. This loss is smaller than the gain from further growing, processing and consumption of the eel. The consumer surplus from consumption of large eel is not included here. From society's point of view, that is the EU and the Member States, it is of benefit to use the glass eel for further production either in restocking or in eel farming compared to consumption of glass eel or exports.

The possible benefits are, however brought into jeopardise because company viability is a constraint that has to taken into account. Restocking activities benefit small fishermen who normally do not possess the resources to organise restocking alone. Because the enterprises are small and the changes in catches are counterweight by change in income among the fishermen this group is not, in the short run at least, susceptible to changes.

Contrary to that, the eel farms often carry high capital burdens that make them very sensitive to changes in sales prices and input prices as well of changes in input volume of glass eel. As soon as the size of the production plant is fixed it is very important for the viability of the company that prices are stable and that there is access to stable and continuous quantities of glass eel.

As shown in the sections about aquaculture (overseas) the sheer size of the Chinese aquaculture sector and the variability in prices by itself put threats to a stable development of the European eel farming industry that uses closed re-circulating systems. Change in glass eel prices and the prices of big eel makes the industry very vulnerable in particular if these prices go in opposite directions. This is presumably the normal case the way the market is organised currently in Europe. High Japanese demand for kabayaki increases the demand and the prices for European glass eel, and the higher supply of kabayaki eel means price reductions on adult eel on this market. The European consumer market for eel does not seem to be linked with the Japanese market. This entails that the European consumer prices may go in any direction relative to the glass eel price.

In particular, if the glass eel price and the price for big eel go in opposite direction the margin for profitability in the European eel farming is very small. As that development at the same time is linked with shortage of glass eel supply, sustainable development of the European eel farming industry is endangered.

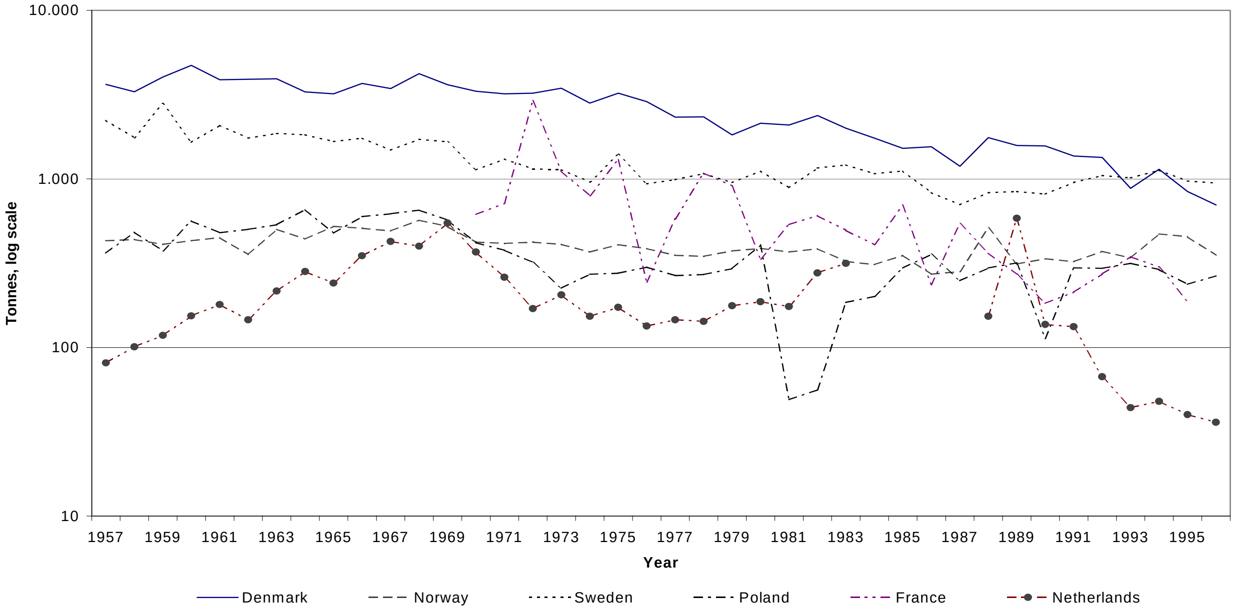
The European direct consumption of glass eel is reported to be relatively low and presumably the prices are lower for these glass eel than for the share used in further production. This market is not price leader, and the development here is not a threat to the same extend as the overseas market.

2. Identification of objectives

Eel landings have for many years shown a downward trend and growing attention has been given to management of the stock. For many local areas such as the Baltic Sea, the Ijsselmeer and the Lough Neagh in N. Ireland fishing for silver and yellow eel used to be of significant importance. The lack of knowledge about the spawning and hatching process and the highly migratory behaviour of the eel put a number of limitations to the development of a proper management scheme. The EIFA/ICES working group on eels (ICES CM 2000/ACFM:6) held its eleventh session in September 1999 and has produced much valuable information although without being able to reach the same level as known for other species.

Information about eel catches is unreliable because of lack of recording catches of part-time and leisure fishermen. There is no doubt, however, that landings have gone down over the last 40 years as shown in diagramme 1. The log scale on the vertical axis allows for comparison of the trend although the volume of landings is different between the countries. If the decline in the landings is parallel, the relative decrease in the landings is the same.

Diagramme 2.1: **Landings of eel in selected important eel countries**



Source: ICES

Although the reasons for this development is not fully known it has caused concern within the EU, and this has lead to initiatives about management actions for restoration of the stock. At the meeting in November 1999 The Scientific and Technical Committee for Fisheries (STECF) has recommended that fishing mortality be reduced to the lowest possible level until a management plan for recovery of the eel stock has been worked out and implemented (STECF, 1999, pp. 11-12).

The eel culture in Europe has been growing. Unofficially it is estimated that the total production is about 10 000 tons at the end of the 90'es. Table 2.1 shows an estimate of the distribution of farmed eel production in Europe on countries.

The magnitude of the farmed eel production is now close to the level of the landings of wild eel, and although these two industries are not competing for glass eel considerations have started of how to secure a continuous and sustainable development of the whole industry.

The limiting factor for this development is the catches and distribution of glass eel. The main living site for glass eel is the Biscay area from the Atlantic coast of Portugal, Spain, France and the UK. Catches at about 500 tonnes is reported from this area (Dekker 1999a). In these countries only minor quantities of large eel are caught. Apart from the use in further production such as restocking and eel culture glass eel is exported out of the EU and, within the EU, consumed directly as cooked glass eel.

Table 2.1 Intensive eel culture production in Europe, 1998

Country	Number of farms	Production in tonnes
Belgium	3	160
Denmark	28	2500
Germany	5	300
Greece	9	500
Ireland	1	100
Italy	70-75	3100
Luxemburg	1	50
Spain	2	340
Sweden	3	230
The Netherlands	55	3000
Total		10280

Source: Curt Gelin, Scandinavian Silver Eel AB, Helsingborg, Sweden

Therefore, the purpose of this study is to shed light on the economic profitability of using glass eel for the purposes:

- Restocking and commercial fishery
- Aquaculture (intra European)
- Aquaculture (overseas exports)
- Direct **c**onsumption

3. Scenario analysis

Scenarios

The cost-benefit methodology is briefly described in Annex 1.

Four scenarios of the use of glass eel are considered. It is assumed that all the glass eel can be used to all four purposes. If the market for glass eel is divided, so some quality of glass eel is not sold for some specific purpose then the alternative possibilities of the use of glass eel is less than four.

The first scenario is the normal fishery of adult eel. In this case the eel is simply left in the sea. In the other three scenarios the glass eel is harvested.

In the second scenario the glass eel is sold to the aquaculture sector of EU.

In the third scenario, the glass eel is sold for final consumption in Southern Europe.

In the fourth scenario, the glass ell is sold to the aquaculture sectors in the East, mainly China and Japan.

Scenario 1: Commercial fishery for adult eel

Here the cost and earnings statistics of the eel fleet is used (SJFI). An average cost-benefit ratio per kilo eel[1] (or ton) is calculated using all the private costs except the capital costs (transfers and sunk cost). The implicit assumption is that the eel fleet's fixed costs do not change as a function of changes in the allocation. If the fleet size increases substantially then the investment cost will have to be included.

The cost-benefit ratio per kilo eel is transformed to a ratio per unit of glass eel. This requires information on natural mortality and the age of adult eel. If the allocation of glass eel changes then the changes for the commercial fishery after adult eel will take place a number of years later when the glass eel has grown to the fishable size. The cost-benefit analysis has to take this feature into account.

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[1] This is an approximation to producer surplus that can be justified if relatively small changes in the allocation are considered.

Scenario 2: Glass eel used by the aquaculture sector in Europe

The basis for the calculations is the aquaculture sector located in Denmark. Two calculations are made possible: a cost-benefit ratio for Denmark (Scenario 2a) and one for the whole EU sector (Scenario 2b).

Information on the costs in the glass eel fishery is not available. In scenario 2a this information is not required as the price of glass eel reflects the real costs. The aquaculture sector processes the glass eel and sell the adult eel as different products. For our purpose, information on the costs and sales prices for an average product mix is sufficient if detailed information is not available. Based on this, a cost-benefit ratio per kilo (ton) adult eel or glass ell is estimated. The transformation from glass eel to the final product requires information on the link between glass eel and adult eel. This is described more in detail in chapter 4.

In principle, in scenario 2b the cost-benefit ratio of the glass eel fishery has to be added to the ratio obtained in scenario 2a. Given that no information is available to calculate the 2b-ratio, we assume as a baseline that the average sales price of the adult eel reflects the opportunity cost of the fishery and vice versa if sales prices are not available for farmed eel but available for wild eel. The concept opportunity costs is used to estimate what the enterprise could earn if the product was sold to the same price as a competing product: in this way the revenue from another comparable product is the cost in the relevant production. Sensitivity analysis is performed to test how significant this assumption affects the economic results.

Scenario 3: Aquaculture overseas

In this scenario the cost-benefit ratio can be based on the sales price of glass eel and the cost in the glass eel fishery. None or very little information about overseas aquaculture is available; therefore a cost benefit-ratio for this sector is based on European information. Clearly, if the sales price of glass eel is equal in scenario 2 and 3 and if the cost-benefit ratio in scenario 2 is positive, then aquaculture production of the glass eel in EU is an advantage.

Scenario 4: Final consumption of glass eel

To calculate the cost-benefit ratio in the case where the glass is processed (cooked or fried) directly and sold for consumption information is required on the costs of the processing and the final consumer price. This information is not available and some assumptions about mark-up pricing have to be made.

4. The biological basis[2]

Approach

The basic model used in the calculation of this report is a dynamic pool model (often referred to as a Beverton-Holt model). The model describes the development of a cohort throughout its life from recruitment to death. Simultaneously describing several cohorts, recruited in consecutive years, the catches or production in a specific year is calculated. The model is applied for calculations of catches in "wild" fishery including re-stocking and eel-farm production. The parameter values are different, however, for "wild" production and farmed production. The model is based on differential equation (Dekker 1999a):

$$\frac{dN_t}{dt} = -(F_t + M_t) * N_t$$

Integrating this equation yields:

$$N_t = N_0 * \exp^{-(Ft+Mt)*t}$$

N: Number of fish
F: fishing mortality rate
M: Natural mortality rate

In order to transform the model into a production model information is required about:

Recruitment (number of fish)
Life stages (number of years and growth)
Natural mortality
Fishing mortality
Weight of the eel at age

Catches/production in terms of weight for each age group is then calculated:

$$W_t = N_{t-1} * (1 - \exp^{-(Ft+Mt)}) * w_t * \frac{F_t}{F_t + M_t}$$

[2] This chapter has been reviewed by Michael Ingemann Pedersen (M.S. biology), Danish Marine Institute, Silkeborg, for which he is gratefully acknowledged. He has forwarded valuable comments. However, the responsibility for the contents of the chapter relies solely upon the authors.

W_t: Weight of catches/production for each age group t
w_t : Weight per eel in age group t

When the catches/production in terms of number calculated from this equation is combined with weight per eel and prices, total revenue in terms of value is obtained. When the costs of producing the revenue is known, economic indicators such as net profit, cash flow (total revenue-operating costs) and employment based on salary expenses could be calculated.

The model allows calculations of catch volumes with known parameter values of $N_{0,}$ F, M and w. The model parameters describe different types of production (sea fishery, lake fishery, farm production). The initial values are derived from Dekker (1999a). In the bio-economic calculations weight per eel in each age group is calculated based on known information about average weight in different age groups. For wild eel is used a smooth growth from initial weight to final weight, whereas for farmed eel a discrete growth path as a function of eel size, based on information from Danish Eel Farmers Association, is transformed into a growth path as a function of time. This growth path shows a declining growth rate with the age of the eel but the change in weight measured in absolute value is increasing. Prices and costs are retrieved from other sources.

Life cycle

The basic biological description concerns the European eel *(anguilla anguilla*). The description is carried out with the aim to prepare input to the economic calculations and analyses that are the main subject for this report.

Eel fisheries and eel culture distinguish from almost all other fisheries because of the life cycle of the eel. First of all it has not yet proven possible to hatch and breed eel artificially in a commercial scale, which is the basis for culture production of other fish species. Secondly, the life cycle of the eel is extremely migratory:

1) Spawning takes place in the Sargasso Sea in the Northern Atlantic Ocean
2) After larval state the eel turns into glass eel (transparent eel) and hits the coast of Europe from Northern Africa and to Norway
3) The glass eel turns into fingerlings (elvers) after pigmentation occurs
4) The fingerlings turn into yellow eel (yellow back) feed in brackish or fresh water
5) The yellow eel turns into silver eel (dark blue back and silver underside).
6) The silver eel migrates to the Sargasso Sea from the European waters to spawn.

This life cycle with extensive migration and going from salt water with high salinity to fresh water (rivers and lakes) makes biological assessment very difficult. In addition to that the eel is caught in nature in many different ways in lakes, rivers and at sea by a number of different group of people ranging from full time fishermen to part time fishermen and leisure fishermen. Reliable statistics on landings are therefore difficult to get. There is no doubt that the landings have gone down but there is some uncertainty about the variation in the downward trend.

From a production point of view the stages. Glass eel, yellow eel, and silver eel that is of interest. The fingerling stage is of minor interest because the eel is not used for production or consumed in this stage. Within farming, however, some fingerlings are produced for further growth at other producers. The period of time the eel spend in each stage is associated with some uncertainty or put in another way there is a substantial variation in growth time around the mean value. The following estimates in table 4.1 is from Dekker 1999a:

TABLE 4.1. **Stages in the life span of an eel.**

Stage	Duration in years 1)	Mean weight per eel
Glass eel	0.25	0.3g
Fingerlings	1-2	8g
Yellow eel	(4) 6 (20)	200g
Silver eel	(5) 10 (20)	200g

1) The figures in brackets are the shortest and the longest recorded.

In subsequent calculation about the economic benefits of the catches of wild eel and benefits from restocking the two areas are treated as one. The fishery commences on yellow eel at age 6 and on silver eel at age 10. Based on communication with Michael Ingemann Pedersen, the Danish Marine Institute, the average estimated weight used for the yellow eel and the silver eel are 100 grammes and 500 grammes respectively due to estimated changes in the sex composition of wild eel over the last years. A relative large share is now big female eel.

From a biological point of view diversity in production and catching of eel is based on the fact that, irrespective of the lack of progress in artificial hatching and breeding, a society objective is to preserve species in the natural environment. From an economic and consumer point of view it does not matter that much what type of production is carried out and what type of species is landed as long as the price is low and the quality is good.

But in the case of eel the biological and economical objectives are simple necessities to maintain a divers production ranging from catches of wild eel and production of cultured eel. Glass eel used for breeding or restocking in lakes does not produce silver eel and in the lakes the escapement rates is possibly low although not fully known. Restocking into areas where the yellow eel can grow to silver eel preferably females which require good feeding areas, would enhance the possibilities for producing a larger mother stock. But the wild eel are subject to catches and therefore the stock is diminished in this way.

Stocking

Transferring glass eel from one environment, typically France, to another, typically European lakes and the Baltic area is named stocking. The best-known area where stocking takes place is Lough Neagh in Northern Ireland where the effects of stocking have been subject to several investigations (Knights and White 1998; Klein Breteler 1999). The conclusions are that stocking has declined since the late 70's. The possible reason for that is the growing demand for glass eel and subsequently higher glass eel prices. Restocking is considered a cost-effective way of increasing catches for local fishermen, in particular, in lakes where natural inflow is constrained. Thereby restocking plays a socio-economic role. There is a financial problem, however. Who is benefiting and who is paying. Careful restocking and exploitation increase the benefit because the growth of the eel is density and temperature dependant. The time span from restocking to harvest is long. Overstocking may lead to change in sex ratios. The sex ratios should be maintained. The harvest should take place in rather limited seasons to harvest the more valuable silver eel. Yields per recruit between 20-90 g are reported. That implies a ration between glass eel and adult eel at 60-273, cf. also chapter 5.

There are uncertainties and drawbacks of restocking effects on the environment. Inter-catchment stocking may reduce the successful migration to the spawning ground of the silver eel. Stocking has negative effect on the crayfish population but not on other fish populations.

Growth rate

Although the magnitude of the intrinsic growth rate has some importance in nature, it is not that important as long as the recruitment does not fail for several consecutive years. In lakes or culture the growth rate is important because the production volume is a function of space. The faster the eel reaches a marketable size the higher the turn over per time period.

In nature eel is compared to other species a very slow growing fish. It will take between 5 and 20 years for an eel to mature (silver eel), and further it will (probably) only spawn one time. Other species spawn several times.

When an eel has turned into a silver eel the growth stops. In nature an eel grow from approximately 0.3 g to around 98 +/- 17.7 g (standard deviation) for male silver eel and 829 g +/- 285 g for female silver eel (Pedersen 1999).

The growth of eel is calculated using a Von Bertalanffy growth equation (Rasmussen and Therkildsen, 1979).

Natural mortality and fishing mortality

A species with a slow growth rate is not able to sustain a high fishing mortality relative to fast growing species. The highest yield per recruit is obtained by rather low fishing mortality rates. Therefore, the mortality among wild eel is important both with respect to the yield and the escapement in order to sustain the spawning stock.

The natural mortality is inflicted by diseases, pollution, predators like birds etc. The natural mortality affects the yield that can be achieved from a cohort of eel. Estimates of natural mortality rates (M) are found in Dekker (1999b) reporting that 75% of the eel dies from natural causes over the whole life span. This is equal to a M-value at 1.4 over the whole life span. This transforms to an annual mortality rate at 0.1-0.2 with a life span at 14 or 7 years respectively. With estimates of "spawning biomass per recruit" (SPR)[3] between 23% and 33% a total fishing mortality rate at 1.47-1.12 is estimated.

The mortality rates that are used (reported) are relatively low. Fishing mortality is inflicted on every year class depending on the mesh size or type of gear. For a large number of captured and subsequently released silver eel Pedersen (1999) reports that 37.8% 26.2% and 19% were recaptured in commercial (or part time) fishery. The highest recapture rate (37.8%) was recorded for the eel released in the inner part of a rather narrow fiord while the lowest rate was recorded for eel released in open sea. The eel were released in the beginning of October that is the high season for migration and the high season (high fishing effort) for the silver eel fishery. If the recapture rates are transformed into fishing mortality rates 19% is equal to 0.2 and 37.8% is equal to 0.48. While 0.2 is a relative low fishing

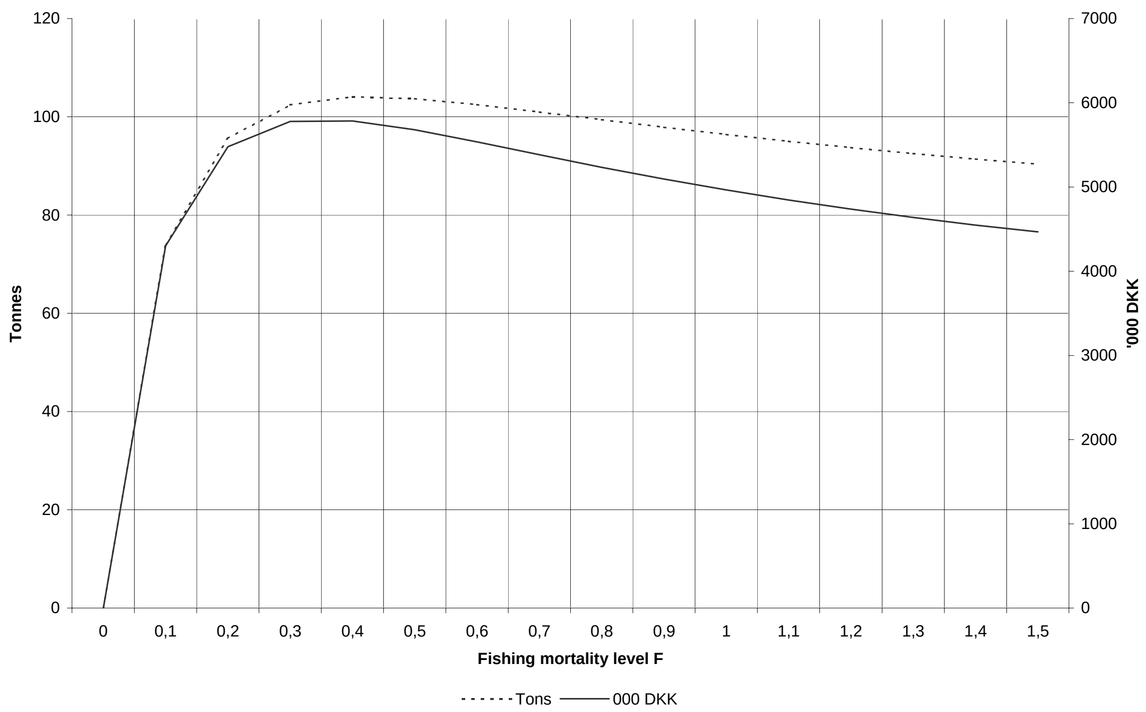
[3] Log (replacement% SPR)=2.69-0.51*log (WTmax)+0.38*log (WT50%mature)+3.52*M. WT is the weight at maximum and the weight where 50% of the cohort is matured

mortality rate, 0.48 is relatively high for a slow growing species. Only a very small quantity of yellow eel is caught in the open sea. But if it is assumed that the fishing mortality rate at 0.48 also could be applied to yellow eel living in fiords the exploitation rate must be considered relatively high for yellow eel.

Pedersen (1999) points out that fishing mortality on silver eels is highly correlated with fishing effort in terms of pound nets. In 1978 a survey estimated the number of pound nets at 4144 while in 1997 this was reduced to 947. Tag-capture experiments in 1960 showed a recapture rate at 80% for eel released in the same fiord as for which the recapture rates were 37.8 and 26.2% in the recent study.

The production relationship between recruits (glass eel) and yellow and silver eel is indicated in diagram 4.1. The calculation is based on the data from Annex table 1 with the adjustments mentioned in the above text. The prices used for yellow and silver eel are DKK46.5 and DKK 60 respectively in order to calculate the revenue in economic terms. If more fish is recruited, the production curve will shift upwards. If fishing is delayed until the old ages of the eel the right hand side of the curve shifts upwards.

Diagramme 4.1: **Catches of yellow and silver eel from 1 ton of glass eel as a function of fishing mortality level F**



5. Results of scenario analysis

Restocking and commercial fishery

The purpose in the following is to put light on the impact on the economic performance of the fishery from a change in stock. The analysis is accomplished by use of a model that describes the revenue and cost structure of a representative stationary gear (pound net) fishing vessel that operates in the eel fishery. The economic fishery model forms the necessary basis to estimate the profit and costs on the European level and, moreover, the model embodies information to accomplish a partial costs and benefit analysis of the eel sector.

The information is extracted from the Danish eel fishery that is the largest in Europe (cf. diagramme 2.1). It is representative for the Baltic Sea fishery that is the most important fishery for silver eel in Europe.

The section is organised in tables with associated comments to way the different items are calculated. The basic source of information is a recent report about the Danish pound net fishery (Bundgarnsfiskeri i Danmark, 1998).

The cost of producing 1 ton of output (silver eel) is shown in table 5.1. Detailed information is shown in Annex table 2. The sales price per kilo silver eel is DKK 60.33. Total variable operating costs are DKK 21.96 per kilo silver eel, and total variable costs including nets and piles are DKK 43.54. This entails a gross profit at DKK 38 and DKK 17 respectively. If higher catches are achieved without having to increase effort (nets and piles) the first number applies. If higher effort is required the second number applies.

TABLE 5.1 **Variable costs in the production of 1 ton of eel in the pound net fishery (during the autumn season). 1997**

In average 3 nets should be employed to produce 1,000 kilo of eel during the autumn (1)

Variable operating costs	DKK
Salary and crew costs (2)	13695
Oil costs (3)	2232
Sales costs (4)	6033
Total variable operating costs	21960
Total variable operating costs per kilo produced eel	21.96
Gear costs (5)	
Depreciation costs nets (6)	13083
Depreciation costs piles (7)	8493
Total gear depreciation costs (8)	21576
Total variable costs per kilo of produced eel	43.54
Price per kilo eel	60.33

(1) The average catch of a pound net vessel during the autumn season is 325 kilo per net. This means that 3.067 nets should be used to catch 1000 kilos. Additional the 3.067 nets will produce 1677 kilo of other species during the autumn season (3.067 nets*547 kilo, price per kilo is 7.26 DKK) and 380 kilo miscellaneous catches (24 kilo * 3.067 net/2 seasons, (price per kilo 6.83 DKK).
(2) Salary to the crew is defined to be 22.7% of the revenue from the eels, which is based on Table 33 and 38 in Fiskeriregnskabsstatistik 1997.
(3) Oil costs are defined to be 3.7% of the revenue from the eels, which is based on Table 33 and 38 in Fiskeriregnskabstatistik 1997.

(4) Sales costs are defined to be 10.0% of the revenue from the eels, which is based on Table 33 and 38 Fiskeriregnskabsstatistik 1997.

(5) Based on assumptions that are specified in Annex 6 of the report of the gill fishery (Bundgarnsrapporten). The depreciation on net and pile are assumed linear based on expected user period of perceptively 12 and 6.5 years. Replacement value per net 51189 DKK, replacement values per pile 375 DKK. In average there is used 48 piles per net. The nets are only used during the autumn season and the user period is assumed to be 12 years.

(6) Depreciation costs nets = 3.067 nets * price per net (51189 DKK)/ user period of nets (12 years).

(7) Depreciation costs piles = 3.067 nets * piles per net (48)*price per pile (375 DKK)/user period of piles (6.5 years).

(8) Total deprecation costs = depreciation costs nets + depreciation costs piles.

The following calculations are based on an estimated relationship between catches and number of nets (pound nets), cf. table 5.1 note 1. The calculations are not calibrated to the volume of the total Danish eel fishery but to the number of enterprises (vessels) included in "Bundgarnsrapporten". The first calculation is the base case. The second one a 10% increase in stock abundance that does not require larger effort to catch 10% more. Finally, the third one is up-scaled 10 times to reflect a possible situation for the whole European eel sector catching wild eel. The up scaling assumed that more gear (pound nets) is needed and that the fishery takes place with diminishing returns to scale.

TABLE 5.2. **Base case and sensitivity analysis of eel production at the national and European level (*)**

1. Estimation based on actual production in 1997 (abundance index=100)	Numerator	Figure
Produced quantity of 952 nets in the autumn season (1)	Tonnes	310
Contributed revenue from the eel production (2)	Million DKK	18.7
Est. Variable cost of the eel production (3)	Million DKK	13.5
Est. short-run profit from the eel production (4)	Million DKK	5.2
Est. salary to crew in eel production (5)	Million DKK	4.2
2. Consequences of 10% increase in eel abundance		
Produced quantity of 952 nets in the autumn season (6)	Tonnes	341
Contributed revenue from the eel production (7)	Million DKK	20.6
Est. Variable cost of the eel production (8)	Million DKK	14.2
Est. short-run profit from the eel production (9)	Million DKK	6.4
Est. salary to crew in eel production (10)	Million DKK	4.7
3. European eel production (eel abundance index =1000)		
Produced quantity of 9520 nets in the autumn season (11)	Tonnes	4138
Contributed revenue from the eel production (12)	Million DKK	249.6
Est. Variable cost of the eel production (13)	Million DKK	97.6
Est. short-run profit from the eel production (14)	Million DKK	152.1
Est. salary to crew in eel production (15)	Million DKK	56.7

(*) The production of eel is assumed to follow the logarithmic model: y = constant * index * log (x), where y is the catches of eel, x is the number of employed nets, and constant >0, and index is an index that measures the abundance of eel. Given constant >0 the logarithmic production function is characterised by dy/dx > 0, dy2/dx2 <0.

1. y= constant * index * log (x), x=952 nets, constant=1040, index=100.
2. Revenue from eel = price per kilo eel (60.33 DKK) * production quantity (1).
3. Estimated variable costs of eel production: 0,364*revenue from eel production (2) + (952 nets* 51189 price per net/ user period per net (12 years) + (48*952 piles * 375 price per pile /user period per pile (6.5 year).
4. Estimated short run profit = revenue of eel production (2) – est. variable cost in eel production (3).
5. Estimated salary to crew is 22.7% of the revenue from the eel production (2).
6. y= constant * index * log (x), x=952 nets, constant=1040, index=110.
7. Revenue from eel = price per kilo eel (60.33 DKK)* production quantity (6).
8. Estimated variable costs of eel production: 0,364*revenue from eel production (7) + (952 nets* 51189 price per net/ user period per net (12 years) + (48*952 piles * 375 price per pile /user period per pile (6.5 year).
9. Estimated short run profit = revenue of eel production (7) – est. variable cost in eel production (8).
10. Estimated salary to crew is 22.7% of the revenue from the eel production (7).
11. y= constant * index* log (x), x=952 nets, constant=1040, index=1000.
12. Revenue from eel = price per kilo eel (60.33 DKK)* production quantity (11).
13. Estimated variable costs of eel production: 0,364*revenue from eel production (12) + (9520 nets* 51189 price per net/ user period per net (12 years) + (48*9520 piles * 375 price per pile /user period per pile (6.5 year).
14. Estimated short run profit = revenue of eel production (12) - est. variable cost in eel production (13).
15. Estimated salary to crew is 22.7% of the revenue from the eel production (12).

Aquaculture (intra European)

Eel farming is a growing activity, in particular in The Netherlands and Denmark. The production depends on the availability of glass eel imported from France, Spain and England. In order to value the economic impact of changes in the availability of glass eel, calculations are carried out based on cost and earning of a farm with a production capacity of about 200 tons.

The calculations include information about the growth in the farmed eel from glass eel to consumption eel and the associated costs. This type of calculation makes it possible to investigate the impact on employment, value added and profitability per normalised volume of glass eel input measured in kilo and in number. Further the calculations allow for sensitivity analyses such as the impact of prices changes on glass eel or other important variables.

Eel farm production is very sensitive to changes in the intrinsic growth in the eel and the natural mortality. The growth information in table 5.3 is transformed into information that is a function of time instead of eel size. The result is shown in annex table 3 in terms of net growth that is the product of the intrinsic growth and natural mortality. The transformation makes it possible to construct a biological production model as basis for the economic calculations.

TABLE 5.3. **Intrinsic growth and natural mortality rates for farmed eel**

Size	Intrinsic growth rates	Natural mortality rates
Gram	% day	% of survivors
Glass eel	3.0	30
1 – 5	2.0	10
5 – 20	1.3	5
20 – 60	1.0	0.5
60 – 100	0.8	0.20
100 – 130	0.5	0.10
130 – 160	0.3	0.10

Note: It is known that on average the weight of a glass eel is 0.33 gram, and the weight of an adult eel is about 150 grams after 18 month.
Intrinsic growth- and mortality rates are smoothened over the intervals by the equations:

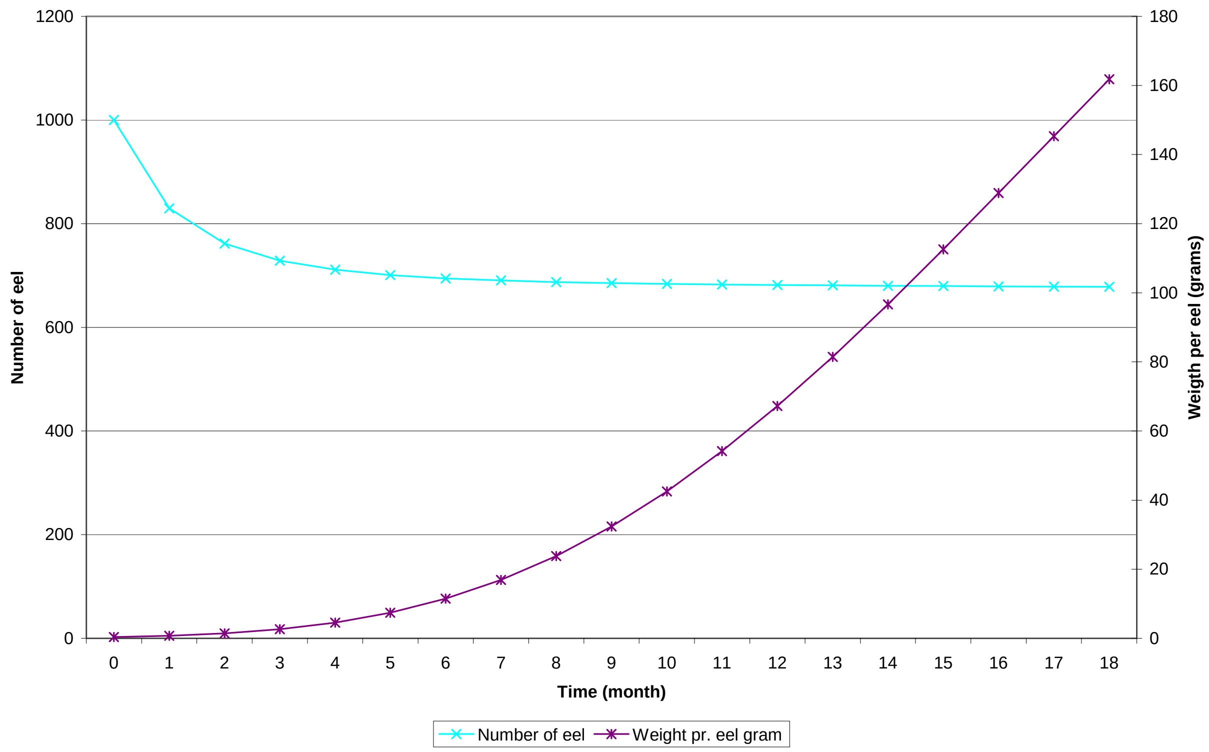
Intrinsic growth = -0.0037*LN(size)+0.022

Natural mortality = 0.06*size^(-0.94)

The intrinsic growth- and mortality rates are then calculated pr. day as a function of time (month).
See annex 4.
Source: Consultant Chr. Graver, The Association of Danish Eel Producers.

The natural mortality is large when the glass eel are small. On the other hand the intrinsic growth is very big at this stage. Then natural mortality gradually decreases and when the eel is growing bigger almost none of the eels die. The intrinsic growth rate decreases as well. After about 12 month the eel has reached a marketable size at about 100 gram on average, and sales starts. This information is shown in diagramme 5.1.

Diagramme 5.1. **Intrinsic growth and natural mortality in a cohorte of far med eel**



Source: Annex 4

Earnings are calculated taking the market price estimated at DKK 55 and multiply with the production. The earnings are dependent on the sales prices and the growth in particular. The faster the eel grow the shorter is the stay in the pools and the faster they are ready for new production.

Costs are more complicated to estimate and the availability of information is limited. One of the problems in eel farming is to get started because the capital demand is rather high and the earnings appear not until one or two years after commencement. The basis for the calculations is a farm that is being operated over a long life span, 10 years. For such farms information about variable, fixed and capital costs are collected. The costs are calibrated to a farm size at about 135 tons measured in eel carrying capacity. A farm of this size produces about 200 tons output a year.

Investments and financing schemes may differ considerably from farm to farm, and the investment and financing scheme shown in table 5.4 are indicative. Production site, buildings, and production equipment are necessary and the estimates are based on rules of thump from information provided by the industry. The size of the plant is scaled relative to the production volume, and this is shown in the first part of the table. The total investment is about 23 million DKK including the investments in the fish stock. The investment in the fish stock is calculated taking the size of the stock at the end of the second year multiplied by the output price. The fish stock does not require full financing but is included in the equity or own capital in the financing scheme.

The financing scheme assumes that equity is 30% of the total investment costs. It is assumed that the short-term working capital is 6 %. The interest rate is fixed at 12% p.a. but the rate could be changed. The major part of the financing capital is long term, 64% at 8% p.a. in interest rate. The composition of the financing scheme is important with respect to capital costs.

TABLE 5.4. **Eel farm with 200 tons production capacity, investments and financing**

Item	'000 DKK
Investment per 10 tonnes production	
Production plant	320
Auxiliary equipment	50
Building site	350
Actual investment	
Production plant	6,400
Auxiliary equipment	1,000
Building site	7,000
Fish stock	6,500
Total	20,900
Financial scheme	
Equity	6,300
Loans	13,400
Working capital	1,200
Total	20,900
Additional working capital to cover 1'st years deficit	10,000
Financial scheme composition	%
Equity (own capital)	30
Loan long term	64
Loan short term	06
Total	100

Source: The Danish Eel Farmers' Association

The sales prices of eel for consumption and the purchase price for glass eel are subject to market fluctuations. In the calculations these prices are changed in order to investigate the sensitivity to profit of such changes. The variable production factors are relative stable and in table 5.5 most of the factor prices are expressed in terms of production output.

TABLE 5.5. **Prices and variable production factors relative to production output**

Item	Coefficient	Numerator and comments
Sales price	55	DKK/kilo
Price glass eel	3300	DKK/kilo
Feeding coefficient	1.70	Allocated feed pr. kilo produced fish
Electricity	0.4	DKK/kilo produced fish
Heating	0.3	DKK/kilo produced fish
Feeding stuff	8	DKK/kilo feed
Oxygen	2.25	DKK/kilo produced fish
Chemicals	1	DKK/kilo produced fish
Wages	280,000	DKK/employee. One employee per 100 tons production capacity
Water consumption	0.5	DKK/kilo produced fish
Maintenance	1.5	DKK/kilo produced fish
Producers' ass'ation fee	0.2	DKK/kilo kilo produced fish plus 3000 DKK/plant
Salary manager	0	Included in profit and wages
Insurance/Adm'stration	2	DKK/kilo produced fish

Source: The Danish Eel Farmers' Association

The information is used in a model that simulates over ten years the economic and production performances for a 200 tons plant. The investment in the farm is profitable over a ten years period of time at a discount rate at 7%. The first year the farm runs with substantial deficits but at the end of the period the earnings are high. This deficit is covered by a short term loan in the calculation. It could also be covered by share capital. The net result for the farm is very much dependant of the financing scheme, depreciation rates and tax payments.

To illustrate the economic performance of the "model farm" the results for year 4, 5 and 6 are shown in the Annex table 4. From this table important features are extracted and shown in table 5.6. The results are not presented in NPV-terms as prescribed in annex 1, but rather by choosing specific years. It is anticipated that this way makes it easier to relate to the results because they are presented in a normal "balance sheet" mode.

TABLE 5.6. **Cost and earnings for a 200 tons production capacity eel farm. 1999**

Year	4	5	6
Farm balance			
Purchase of glass eel, Tons	0.52	0.52	0.52
Sales of eel, Tons	200	200	200
Sales of eel, '000 DKK	10,980	10,980	10,980
Total operating costs '000 DKK	6,064	6,064	6,064
- Wages	559	559	559
- Purchase of glass eel	1,287	1,287	1,287
- Feeding stuff	2,583	2,583	2,583
Total interest payment, '000 DKK	1,951	1,779	1,594
Depreciation, '000 DKK 1)	2,511	2,134	1,814
Profit, '000 DKK	453	1,002	1,506
Value added, '000 DKK	5,921	5,921	5,921
Employment 2)	3	4	5
Per tonne glass eel			
Sales of eel, Tons	385	385	385
Sales of eel '000 DKK	21,115	21,115	21,115
Total operating costs '000 DKK	11,662	11,662	11,662
Profit '000 DKK	871	1,927	2,896
Value added '000 DKK	11,387	3,489	3,489
Employment 2)	6	8	10

1) Depreciation is arbitrarily fixed at 15% (year 1: 0%; 2 and 3: 10%) and hence tax payments
2) Employment is calculated according to the share left for remuneration after all costs, interest payments, depreciation and tax payments. This employment does not compare to the technological employment, which is 1 person per 100 tonnes production output.
Note: Value added is remuneration of labour and capital
Source: Annex 5.

From the table it appears that the total value added from 1 ton of glass eel is about 11 million DKK. The value added includes total wages and remuneration of all invested capital (foreign and own). The employment that is generated is about 8 people per ton glass eel if employment is based on possible remuneration at DKK 280000 per person on average. The technological employment is about 4 persons equal to 400 tonnes production output.

These results are based on sales prices at 55 DKK per kilo, and glass eel purchase prices at 3300 DKK per kilo. From the table it is noted that 1 ton of glass eel can produce around 138 tons of eel for consumption.

The figures are associated with some uncertainty, in particular because very accurate growth rate and mortality figures are required. Some improvements take place all the time. That tends to improve the results. However, the "model farm" used here perform slightly better, measured on total revenue and profit, than actual farms for which cost and earnings figures are available.

The profitability of the farm is not very sensitive to the volume and the price of the glass eel. It is extremely sensitive to changes in the sales prices.

Looking at year 5 only, a price increase at 75% to 5800 DKK per kilo glass eel makes the farm unprofitable. The employment is 2 persons and the value added is DKK 5.0 millions. The whole investment becomes unprofitable over a 10 years period if the glass eel price increases with 10% to DKK 3600.

A reduction in sales prices at 10% to 50 DKK per kilo has the same effect on profitability in year 5 as the 75% increase in glass eel price. A 3% reduction in sales prices makes the whole investment unprofitable. The employment is 2 persons and the value added is DKK 4.9 millions.

A reduction at about 50% in the volume of glass eel has the same effect on the profit in year five as the price increase at 75% (employment down to 1, value added down to 3.0 millions). The reason for the different effect is that a decrease in volume will reduce employment, feed and other variable production factors. Therefore the impact on the farm is not as strong as the impact on value added and employment.

6. The overseas eel market

Aquaculture (overseas exports) and glass eel consumption

In this section the international eel market is described and analysed. The description is based on available information covering recent years and focuses on trends as a base for predictions of the future. As available information about eel markets contains a limited amount of details, conclusions should be regarded with a degree of uncertainty.

Information on the eel market was obtained primarily by searches in the GLOBEFISH Databank, according to FAO (1999), for the period 1995-99. The Databank is specialised in fisheries and the purpose is to provide precise and updated information on the fishery sector with special emphasis on international trade with fish and fishery products. Moreover, information from 1999 was obtained from eel market reports from Fish-Info Service (1999).

The international eel market consists of Japanese and European eel (the species anguilla japonica and anguilla anguilla)[4]. Other eel species are also known, for example from the US East-coast (anguilla rostrata) and from Australia (anguilla australis), but these species form an insignificant share of the global market and will not be described in details here. Both wild and farmed eel supplies the market. However, as eel farmers have not succeeded in the development of commercially interesting methods to raise eel spawns in farms, production of farmed eel have to be based on catches of live, wild glass eel. Therefore, markets for both glass eel and ell for final consumption exists and is described separately below.

[4] The terms Japanese and European glass eel refers to the species anguilla anguilla and anguilla japonica and not to area of living, despite the fact that the species actually live in waters around Japan and in European waters.

Glass eel

The international glass eel market is supplied by Japanese and European glass eel. Japanese and Chinese fishermen catch Japanese glass eel in the waters around Japan, whereas French, Spanish, Portuguese and British fishermen catch European glass eel in the Bay of Biscay. Glass eel are demanded for farming primarily in China and to a lesser extend in Japan and the EU. Therefore, China is the main eel farming country, where Japan and the EU are glass eel supplying countries. However, eel farming also exists in Japan and the EU on a smaller scale than in China. Moreover, the EU exports large and increasing quantities of glass eel to China.

With China as the main purchaser on the international glass eel market an overview of the market could be obtained by looking at the Chinese market, given that reliable data are available from China. But this is not the case. Therefore, indications of glass eel market relations are obtained indirectly from other sources, wherever they are available. On this basis, international markets for Japanese glass eel, used in China and Japan, and for European glass eel, used in EU and China, are described separately.

Japanese and Chinese as well as other Asian fishermen catch Japanese glass eel. However, reliable catch statistics are only known from Japan and it is given in table 5.7.

TABLE 6. **Catch and price of glass eel in Japan 1990-97**

Year	Catch /tonnes	Price ECU/kilo
1990	57.8	1,540
1991	46.7	1,120
1992	44.5	1,460
1993	40.3	2,190
1994	29.0	4,620
1995	34.8	4,010
1996	31.0	4,680
1997	20.0	7,680

Source: Aquaculture Europe (1997).

From the table it appears, that catches of glass eel in Japan are decreased from 57.8 tonnes in 1990 to an expected level of 20 tonnes in 1997, corresponding to a decrease on 65%. Catches are decreasing over the whole period, except in 1995. Moreover it appears, that prices have increased fivefold from 1,540 ECU/kilo to an expected level of 7,680 ECU/kilo. Apart from 1995, prices are increasing over the whole period. Therefore, the situation on the Japanese market until 1997 is that, due to limited supply, prices are increasing. However, part of the price increase is explained by the appreciation of yen in relation to ECU, as prices only increase 3.7 fold if measured in yen.

After 1997 Sea-World (1999b) reports considerable increasing Japanese glass eel catches in December 1998 and January 1999, compared to the year before[5]. Moreover, Fish-Info Service (1999) assess that 38 tonnes of Japanese glass eel are stocked in ponds in Japan in the 1998-99 season, corresponding to an increase of 50% compared to the year before. The reason for this development is not known, but it can be favourable oceanographic conditions. However, the consequence is very clear as prices decreases from 6.833 ECU/kilo in December to 1.367 ECU/kilo in mid February and 860 ECU/kilo in March. In December 1999 the market has recovered slightly, with a price of 1.375 ECU/kilo in the beginning of the 1999-2000 season. This development expects to cause oversupply of eel for final consumption when the glass eel grow up and are marketed within 1-2 years.

The level of glass eel catches in China is not known exactly. Aquaculture Europe (1997) estimate Chinese catches of glass eel to around 20 tonnes in 1996, based on the requirement for glass eel to fulfil an assumed production level of eel for final consumption on 140.000 tonnes. Fulfilment of this production level demands glass eel of 140 tonnes and with imports of 120 tonnes, 20 tonnes is assessed caught domestically in China. Sea-World (1998b) reports that the total catch of Japanese glass eel by Japan, China and Taiwan in 1998 until date is less than 30 tonnes, which is one of the worst seasons ever. Assuming that Japanese catches in 1998 is not above the 1997-level on 20 tonnes, which is reasonable given that both seasons are bad, this leaves room for Chinese and Taiwanese catches of less than 10 tonnes. Infoyu (1999c) assess that 20 tonnes glass eel are caught in China in January and February 1999 and Fish-Info Service (1999) assess that around 30 tonnes are stocked in ponds in China in the 1998-99 seasons. Therefore, the development of glass eel catches over time in China and Japan seems to follow the same pattern.

The aggregate level of Japanese glass eel catches is rising and is estimated to 80-100 tonnes in the 1998-99 season. However, as data are lacking and as some sources reports that the Japanese export ban is violated, as an illegal export from Japan through Hong Kong to China and Taiwan exists, the origin of the Japanese glass ell used is not known exactly.

The price level of Chinese glass eel catches is not known exactly either. However, Infofish (1993) reports that prices of glass eel in China were 1,320 ECU/kilo in 1985, increasing to 5,998 ECU/kilo in 1993, corresponding to a 4.5 fold increase. Moreover, Sea-World

[5] The glass eel season typically run from December to April.

(1998a) reports that prises of Japanese glass eels in China in March 1998 increase from 7 to 10 yuan, corresponding to an increase on 43%. Finally, Infoyu (1999c) reports that Chinese catches are sold domestically for around 3,100 ECU/kilo, which is an increase from 2,768 ECU/kilo in the same period in 1998. Therefore, something is known about Chinese prices. However, the reliability and comparability of this knowledge is not assessed to be large, as prices are given on random time periods for random parts of the market, which may not be comparable and useable as a base for prediction of future prices.

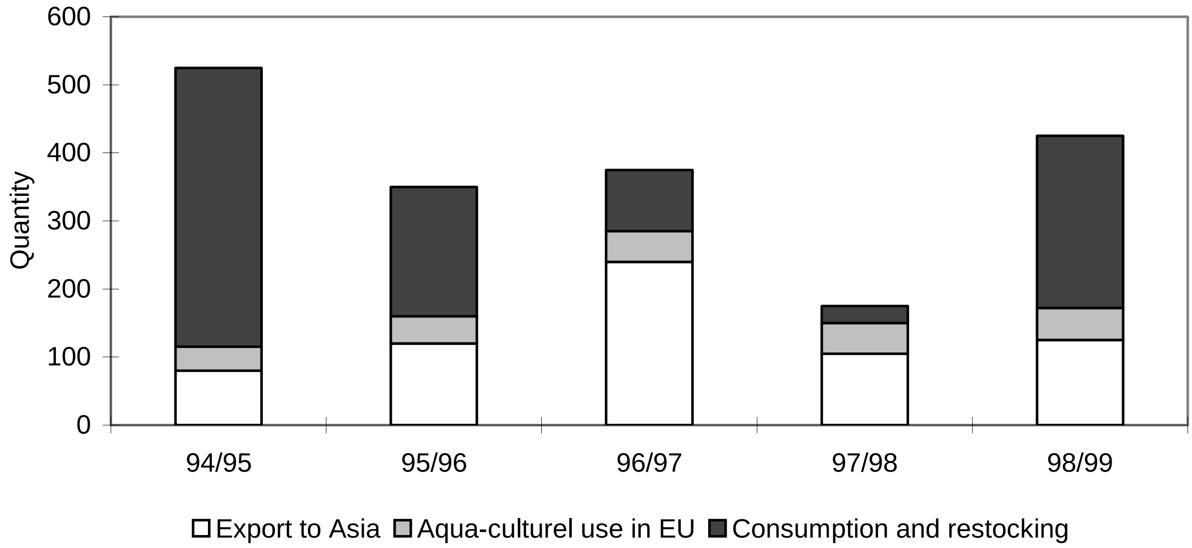
Therefore, the best indication of prices of Japanese glass eel caught in China may be prices of Japanese glass eel caught in Japan, as glass eel probably are traded if price differences are significant. That this approach can be used is supported by the fact, that China, despite the Japanese export ban, actually is importing large quantities of glass eel from Japan. According to Infoyu (1999b) this level is expected to be 60-70 tonnes in 1999. Given this knowledge it is supposed, that Japanese and Chinese glass eel markets are integrated, meaning that prices follow the same pattern over time in the two countries. Prices can fluctuate according to random shocks in the short run, but will be brought together again after an adjustment process. The implication is that the Japanese and Chinese glass eel markets can be considered as an aggregate market.

Considering the market for Japanese glass eel on an aggregate basis for Japan and China, catches are decreasing from 1990-97, trough in 1997-98 and increase in 1999. Prices follow the inverse pattern with increases from 1990-97, peak in 1997-98 and decrease in 1999. Whether the 1999 development continue in the coming years depends on future catch levels of Japanese eel, which again depends on oceanographic conditions, the state of the Japanese eel stock and on regulatory initiatives.

Some regulatory initiatives have been discussed in China, which can affect the market for Japanese glass eel in the coming years. The situation is according to Infoyu (1999j), that the large catches of Japanese glass eel in 1999, combined with increasing import of European glass eel to China, is expected to create excess supply in the next 1-2 years. This development will affect the Chinese eel farmers negatively, as prices of eel for final consumption will decrease. The result can be a crisis in the Chinese eel farming industry. Limitations of eel production, aiming at increase prices of eel for final consumption is discussed, according to Sea-World (1999a) and Infoyu (1999k), as Chinese eel farmers with coordinated sale holds monopoly power on the main Japanese market for ell for final consumption. Among others a ban on glass eel fishing in China and coordination of production has been suggested.

The catch level of European glass eel is not known exactly, but estimates of catches and uses, obtained from Aquaculture Europe (1997) and Fish-Info Service (1999) are summarised in figure 5.2.

FIGURE 5.2: **Catch and use of European glass eel, 1994-99, tonnes.**



Source: Aquaculture Europe (1997) and Fish-Info Service (1999).

From the figure it appears, that the total catches of European glass eel on 350-525 tonnes annually are relatively stable over the 1994-99 period, except for the trough on 175 tonnes in 1997-98.

The trough in 1997-98 is not caused by economic factors, as prices on glass eel are high at the international market at that time. Therefore, economic factors do not affect catches of European glass eel significantly. Moreover, according to ICES (1996), there is no evidence of that the high price of glass eel at the international market have caused larger catches of European glass eel. It is probably the other way around; catches of European glass eel determine prices of the international glass eel market together with catches of Japanese glass eel, as only few substitutes exists[6]. Therefore, other factors are assessed to have caused the trough. Oceanographic conditions as water temperature and tide affect migration of glass eel and thereby catch potential. Moreover, according to Sea-World (1998c), fishing in former years as well as water pollution affect catch potential.

[6] American and Australian glass eel are potentially substitutes. However, Australia has imposed an export ban and in 1999 American glass eel are not exported to Asia, due to low prices. American glass eel is not the preferred specie in Asia, but is interesting to Asian eel farmers in periods with lacking supply.

Uses of European glass eel also appear from the figure. European glass eel is used for eel farming in EU and Asia, for direct human consumption in Spain and for re-stocking in Europe.

It is estimated that demand for glass eel for use in European eel farms, mainly in Italy, The Netherlands and Denmark, is 35-45 tonnes annually and is slightly recovering in the period. Around 10,000 tonnes of eel for final consumption is produced on EU eel farms annually.

Export to Asia of European glass eel is stabilised at 110-120 tonnes in the 1997-98 and 1998-99 seasons, probably due to the introduction of a Chinese import quota on this amount. Sources from the Danish eel farming sector, however, estimates that the export in 97-98 was rather 250 tonnes and in 98-99 140 tonnes. In the years before, EU glass eel export increase sharply with the rising demand from the developing Chinese eel farming sector combined with decreasing catch levels of Japanese glass eel. In this period export prices rises from 100 ECU/kilo to 330 ECU/kilo. Afterwards, the price went down to 223 ECU/kilo in the first half of 1998, followed by an increase to 410 ECU/kilo in the first half of 1999. The latter increase is probably due to continuously increased demand combined with the imposed import quota.

The use of glass eel for re-stocking and for direct human consumption also appears from the figure. Together, use for these purposes decreased from 410 tonnes in the 1994-95 season to 25 tonnes in 1997-98. According to ICES (1996) the reason for this development is, that the high price on the international market causes a shift from re-stocking and direct human consumption to export to Asia. As a consequence, re-stocking programmes in EU has been threatened. In the 1998-99 season this development is turned, due to decreasing prices on the international market, to the introduction of the Chinese import quota and to the increased catches of European glass eel. On this basis, the present re-stocking level is assessed to be high, but as the consumption and re-stocking category in the figure cannot be split, the state of the re-stocking programme in recent years is unclear.

In 1997, for example, around 20 tonnes were used for direct human consumption in Spain, sold for an average price of 100 ECU/kilo. It should be noted that part of the glass eel consumed directly were separated as dead glass eel in association with the glass eel fishery. However, the market for direct human consumption in Spain is unstable by nature, as consumers are willing to purchase only below some fixed price of around 100 ECU/kilo. If prices at the international market are higher, the Spanish market is not supplied.

The money spend on re-stocking over a time period can with advantage be based on price trends on the international market, maximising the utility of the amounts used in the long run. In other words, large quantities of glass eel can be re-stocked when prices are low, and small quantities when prices are high.

International markets for glass eel are ruled by two different trends in recent years. Catches of Japanese glass eel are decreasing until the trough in 1997-98 and are increasing afterwards. Prices of Japanese glass eel follow the inverse pattern and are increasing until a peak in 1997-98 and are decreasing afterwards, as price changes are extremely sensitive to changes in catches, as for example, a 10% decrease in catches of Japanese glass eel will cause a 15.9% price increase on Japanese glass eel[7]. Catches of European glass eel are more stable, except for the trough in 1997-98. However despite this fact prices of the Chinese imports of European glass eel are increasing. Therefore, an internationalisation is taken place on glass ell markets, with EU export to China as the driving force.

The internationalisation has developed since Chinese eel farmers started to use European glass eel in a large scale as substitute for Japanese glass eel in 1997, after a number of years with decreasing catches of Japanese glass eel. After the successful introduction of European glass eel on the Chinese market in a larger scale, Chinese demand for European glass eel have increased continuously since, as well as prices paid to the EU exporters have. The main reason for this development is the price advantage of European over Japanese glass eel.

According to that, the price of Japanese and European glass eel in Asia was 4.620 and 100 ECU/kilo respectively in 1994, where the price was 7.680 and 330 ECU/kilo, in 1997[8]. Therefore, the price difference is decreasing from 1994 to 1997. Moreover, despite that no comparable price data are known, the internationalisation is expected to have decreased the price difference further afterwards.

However, for a number of reasons the price difference will not disappear. Firstly, because European glass ell are larger at time of sale, implying that out of one kilo European glass eel can only be produced ¼ of the weight obtained out of one kilo Japanese glass eel. Secondly, because the long transport from Europe stresses the small eel, more European than Japanese glass eel dies under transport and afterwards in the ponds. Finally, higher trans-

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7 See Annex 4.

8 The Japanese glass eel price from Japan is used, as Japanese glass eel prices from China are not available.

portation costs, import tariffs, license fees and other costs implies, that a price difference will be maintained.

The price level of glass eel at the international market is expected to rise in the near future, as prices of Japanese glass ell, due to decreasing catch levels, is expected to rise. However, the imposed Chinese import quota as well as an expected gradually disappearance of the price advantage of Japanese over European glass eel, caused by the internationalisation, can limit this development. But the future price trend is very sensitive to variations in future catches of Japanese glass eel.

Production of big eel and trade

The international market for eel for final consumption is supplied with farmed and wild caught Japanese and European eel. Japanese eel is farmed in Japan, Taiwan and China and is caught by fishermen from a number of Asian countries, presumably Japanese, Chinese, Taiwanese and South Korean fishermen. European eel is farmed in China and in several EU countries, primarily Italy, the Netherlands and Denmark and is caught by fishermen from several EU countries, including Italian, Dutch and Portuguese fishermen.

The size of total supply at the international market is not known, as detailed information is lacking. Therefore, an overview of the international market can only roughly be obtained.

Catches of Japanese eel are 150,000 tonnes in 1994, according to FAO (1997), of which the Chinese fishermen caught 110,000 tonnes and also Taiwanese fishermen have a significant share. After 1994, total catches is expected to have decreased considerably, but due to lack of data the exact level is not known. However, decreasing catches of eel by Taiwanese fishermen, as well as decreasing catches of Japanese glass eel, support the truth of this development. Catches of European eel are assessed to 15,600 tonnes in 1994, according to Moriarty and Dekker (1997).

Production on eel farms is 39,304 tonnes in 1994 in Asia excluding China. Japan raise around 2/3 of this amount, but in Taiwan eel is also raised. However, production on eel farms in Japan and Taiwan have decreased in the 1994-98 period, due to lack of supply of glass eel and due to extra cost of labour and land in Japan and Taiwan in relation to the gradually more opened China. Therefore, Chinese eel farming has increased until 1997, where Aquaculture Europe (1997) estimates eel production on Chinese farms to 140,000 tonnes, which makes China to the main eel farming country in the world. After 1997 the development in total Asian eel supply is not known exactly, but the increasing catches of glass eel in the 1998-99 season is expected to have caused increased production on Asian eel farms.

Production on eel farms in EU is 8.214 tonnes in 1994, increasing until today to around 10,000 tonnes. Production on eel farms in USA and Australia is very small.

On this basis total international eel supply can be estimated at 350,000 – 400,000 tonnes annually. However, this can be an overestimation, as the level of catches of wild Japanese eel is not known precisely, in particular for China; it is not known whether figures for production include both wild and farmed eel, or whether the figures are separate estimates. The estimate obtained from Infoyu (1999 l), indicates production in China is assessed to be 163,000 tonnes farmed eel in 1998, corresponding to 70% of global eel production in aquaculture. Based on this information the global eel production from farms is 232,000 tonnes in 1998.

Japan and Taiwan use primarily Japanese glass eel for production, China use both Japanese and European glass eel and EU use only European glass eel. Traditionally, the Asian eel farmer preference order in relation to species is Japanese, European and American glass eel. Japanese eel is raised for use primarily for sale as live eel of a relatively large size to restaurants and fishmongers, where European eel is raised for sale as Kabayaki in Japan and for sale as smoked eel in EU[9]. Therefore, Japanese eel is traditionally raised for the high quality market, where European eel in Asia is raised for the lower quality Kabayaki market.

In recent years preferences have shifted, as Chinese farmers now base the majority of their production on imported European glass eel. There are a number of reasons for this shift. Japanese glass eel has been undersupplied over a period, European glass eel has had a price advantage and Chinese eel farmers are gradually developing better farming methods for European eel, which makes it possible to raise European eel in a larger scale. Today, therefore, European eel is just as much preferred as source for Kabayaki production, as Japanese eel is. In 1998, production of European eel in Chinese farms is around 50,000 tonnes in live weight, corresponding to 30,000 tonnes Kabayaki.

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9 Kabayaki consists of small gutted and filleted eel (5-6 pieces per kg), which are fried, boiled and dipped in special soy sauces and thereafter quickly frozen.

Supply of eel at the international market is predicted to rise in the near future, as catches of glass eel in both Asia and Europe have been high in the 1998-99 seasons and large quantities, as a consequence, have been stocked in ponds.

In the long run, supply is not easily predicted, as it is affected by two contradictionary trends. On the one hand, production in aquaculture is expected to develop further, due to improved farming methods, particularly, if methods to rear eel from eggs are developed once in the future. On the other hand, catches are expected to decrease due to low stock levels of Japanese eel observed from many years with continuously decreasing catches of Japanese glass eel. The large 1999 cohort does not affect the stock level significantly. Supply is expected to decrease in the long run. However, this will be the result only if future cohorts do not develop as positive as the 1999 cohort did.

International eel trade pattern is not easily overviewed, as data in many cases are not available. However, the main parts of the trade can be overviewed by describing imports of baked eel, including kabayaki, and live eel to Japan, as these are the main products and as Japan is the main consuming market. Moreover, data of this trade is relatively reliable. Japanese import of baked eel is shown in table 6.2.

TABLE 6.2. **Japanese import of baked eel, 1993-99**

Year	Quantity /tonnes	Price /ECU/kilo
1993	38,340	17.5
1994	39,012	18.5
1995	36,159	19.7
1996	44,502	16.6
1997	54,357	15.3
1998	52,001	11.2
January 1999	5,701	10.6
January – June	30,600	10.9
December 1999 *	na	7.4

Note: Imported Kabayaki.
Source: Infoyu (1999abdeghi), Infofish (1997) and Fish-Info Service (1999).

From the table it appears, that import of baked eel is relatively stable in 1993-95, are increasing in 1996-97 until a stable level is reached in 1997-98. Import prices are also stable on a high level in 1993-95 and are decreasing continuously since. The price of imported Kabayaki in December 1999 is, due to oversupply, the lowest price ever seen.

The developing Chinese eel farming sector combined with the opening of China drives the increase in imported quantities to Japan in 1996-97. The reason is that Chinese eel farmers have a comparative advantage over Japanese eel farmers, due to lower cost of labour and land. Moreover, Chinese eel farmers have successfully introduced European glass eel in Chinese farms in a period with falling catches of Japanese glass eel.

The developing Chinese eel sector has also a comparative advantage over Taiwanese eel farmers, which traditionally has exported large quantities of eel to Japan. The result is, that China counts for 91% of the Japanese import of baked eel in 1998 and Taiwan only counts for 6%[10]. In 1995 the corresponding figures were 76% and 20%, respectively. Therefore, supply of the Japanese baked eel market has gradually shifted from Japanese and Taiwanese to Chinese eel farmers.

The decreasing prices from 1996 and onwards is caused by several factors. Supply has increased considerable, due to the successful introduction of European glass eel on Chinese farms; however, partly meet by falling catches of Japanese glass eel. At the same time demand has been falling in Japan, due to the Asian crisis and the weakening of the Japanese economy. The decrease in December 1999 indicates, that excess supply is present in 1999-2000, due to large catches of both Japanese and European glass eel in the 1998-99 season.

Recently, Japan has started to import baked eel from EU in small quantities, as 120 tonnes Kabayaki were imported from Denmark in January 1999. These Kabayaki eel was sold at the Japanese market for an average price of 14.6 ECU/kilo corresponding to a price premium over the average import price on 38%. The reason for this premium price could be that Danish Kabayaki is of higher quality than the Chinese Kabayaki. On this basis it cannot precluded, that European glass eel can be produced and utilised more efficiently in EU, instead of exporting them directly to China.

Data for the Japanese import of live eel has not been accessible for recent years, but in 1994 it was 46,000 tonnes, imported for 4.9 ECU/kilo from Taiwan among others. However, as Taiwanese catches of eel, according to Infoyu (1999f), have decreased considerable over several years, Japanese import of live eel have probably decreased. The price of Japanese import of live eel was in the first half of 1999 6,2 ECU/kilo, 43% lesser than the price of imported baked eel. The reason for this price difference is, that the exporter creates value added on baked eel, where the purchasing restaurants and fishmongers create value added on live eel.

[10] Malaysia counts for 2%-points of the rest.

Trade pattern of eel is expected to change in the near future, as the Japanese and Taiwanese eel sectors are recovering, due to increased catches of Japanese glass eel in the 1998-99 season. On this basis Chinese exporters are expected to face decreasing market shares on the international market and the Chinese government has, according to Infoyu (1999jk), reduced the export tariff in order to meet the increased competition. Moreover, due to expected overproduction in Asian eel farms, caused by the large quantities of glass eel stocked in ponds from the 1999 glass eel cohort, farmers can possibly begin to export baked eel to EU. Finally, Japanese import can possibly be affected by the inspection programme for drug residues in eel, introduced in January 1999.

In the long run trade patterns are more unpredictable, but depends on whether the increased catches of glass eel in the 1998-99 season are permanent or not. If the increase is permanent, Chinese eel farmers will face stronger competition on the international market for baked eel from Taiwanese and domestic Japanese eel farmers. Moreover, Taiwanese and domestic Japanese eel farmers is expected to increase supply on the live eel market in Japan. However, the increase is not expected to be permanent and the recovering of the Japanese and Taiwanese eel farms is expected to last for only a short period, due to lack of supply of Japanese glass eel. Japanese and Taiwanese farmers could under these circumstances purchase European glass eel at the international market, but as Chinese eel farmers has developed methods of raising European glass eel and thereby possess a competition advantage, this is not expected to happen.

Consumption of big eel

Eel is consumed in many areas around the world in various forms. However, the most important consuming areas are Japan, China and EU.

In Japan, ITN (1995) assess that the total consumption of eel as final products is around 120,000 tonnes in 1995 and that this level is decreasing, due to limited supply caused by falling catches of glass eel and eel. Seafood International (1997) assessed in 1997 that 70,000 tonnes of baked eel including Kabayaki are consumed annually, leaving 50,000 tonnes for consumption of live eel.

After 1997 consumption of baked eel have increased, where consumption of live eel has decreased. The reasons are lack of domestic supply, which is the most obvious source of supply of live eel, and increased supply of Chinese Kabayaki eel rose of European eel.

Moreover, the weakening of the Japanese economy and thereby the stagnating incomes moves demand from expensive live eel, typically consumed on restaurants or purchased in expensive fishmongers, to cheaper Kabayaki products.

Furthermore, decreasing prices of Kabayaki, combined with more constant prices of live eel, due to a more sluggish price formation on restaurants and in fishmongers, moves consumption form live eel to Kabayaki. The more sluggish price formation in restaurants and in fishmongers is caused by that large live eel have to be raised on farms in longer time than small Kabayaki eel.

Finally, as Kabayaki is a more convenient product than live eel and as convenience gradually is becoming more important to consumers, consumption is moved from live eel to Kabayaki.

Japanese consumers consider eel as healthy and tasty and particularly the healthy oil content is an important reason for purchase of eel. The largest quantities of eel are consumed in the summer when temperatures exceed 26 degree C.

Consumption patterns are not expected to change considerable in the future, as the identified trends are expected to continue. That is, Kabayaki consumption is expected to rise and consumption of live eel is expected to fall. Moreover, consumption of Kabayaki is expected to be very high in the near future, due to low prices caused by oversupply, and the most important competition parameter in the near future is expected to be price.

In the longer run consumption is stronger affected by the development in incomes, as eel is a luxury good. Thereby, future consumption is affected by the strength of the Japanese economy, which today is recovering slowly from the Asian crisis. On this basis OECD (1999) forecasts moderate growth in Japan in 2000-2001 with private consumption growing 1.5–2 % annually. As a consequence, eel consumption is expected to increase slightly.

In China around 40,000 tonnes live eel and very little baked eel is consumed annually, according to Infoyu (1999l). However, South China Morning Post (1996) expects, that demand for baked eel will rise, due to the growing economy and the fast increasing domestic production of Kabayaki.

In EU around 25,000 tonnes of eel is consumed annually, assuming that foreign trade is insignificant. Germany has the highest per capita consumption of eel, covering half of all EU consumption and consumers prefer smoked eel. Presently, domestic farmers and fishermen supply EU, however, in the future Asian farmers may, due to their overproduction, export to EU.

German consumers consider taste of eel, taste of smoke, colour and firmness of meat as the most important reasons for purchase of eel, according to Bech et al (1995).

Eel is also consumed in significant quantities in a few other countries, including Taiwan.

Conclusion about the impact of overseas aquaculture

These findings may be concluded in the following items:

- Global catches of glass eel decreases until 1998, increase in 1999 and is expected to decrease again. Prices of Japanese glass eel follow the inverse pattern with increases to a high level in 1998 followed by decreases afterwards. Prices of European glass eel have increased almost continuously in recent years, due to rising demand in China, but on a lower level than prices on Japanese glass eel.

- Re-stocking programmes in EU have been threatened in recent years until 1999, as prices on the international glass eel market have increased. In 1999 rising catches of both Japanese and European glass eel results in lower prices thereby probably increasing the level of re-stocking.

- The global eel supply source has shifted in recent years from fisheries to farms, with China as the main producing country and Japan as the main consuming country. Three eel products are sold at the international market in significant quantities with Kabayaki as the most important, followed by live and smoked eel. Prices at the international market have decreased since 1996, where the first European glass eel raised in China, was marketed in significant quantities. In December 1999 prices of Kabayaki are the lowest ever recorded.

- Overproduction is expected in Asia in the near future and in connection with low demand for eel in Japan, caused by the weak economy, prices is expected to continue decreasing and consumption to continue increasing. For Asia as a whole over production is not expected. In particular, increasing consumption is expected in China but not increasing production. In the long run, however, consumption is expected to decrease and prices to increase, as the large catches of glass eel in 1999 are not expected to happen permanently.

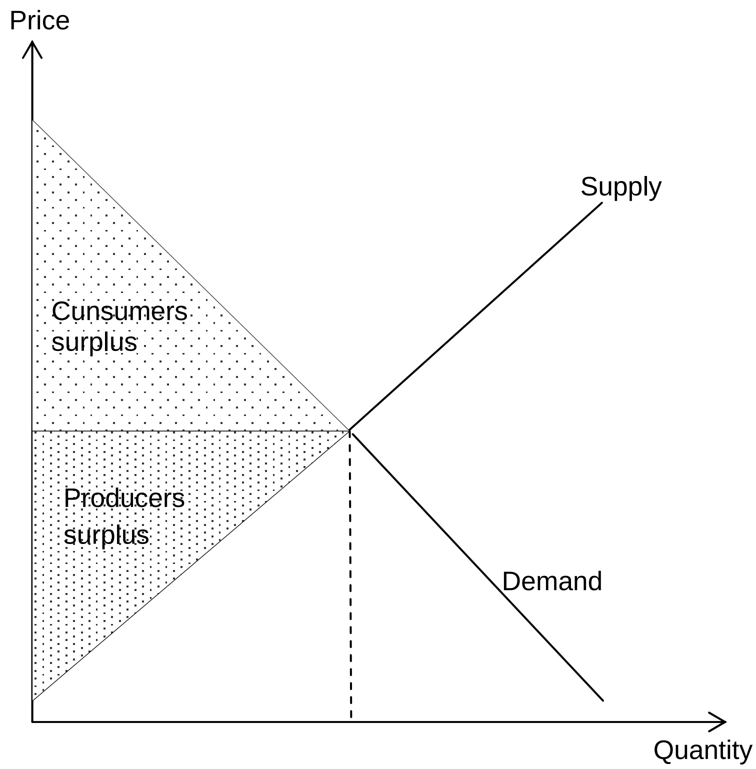
Annex 1. Cost-benefit analysis

The purpose of a cost-benefit analysis is to measure the net national economic benefits or losses that would follow from alternative public policies such as allocations of fish resources to different user groups or different use. The selection of a proper baseline scenario is important. The allocation without the policy is the proper comparison rather than before the policy.

Method

In cost-benefit analysis the net benefits are measured as the sum as the consumer and producer net benefits less of management and enforcement cost. In economic terms these net benefits are called surplus. Consumer surplus is the differences between the price consumers are willing to pay for a product and the price they actual pay. Producer surplus is the differences between the actual price and the price that producers are willing to supply a product. Changes in consumer and producer surplus and management and enforcement cost provide the net benefit to the nation of an allocation.

FIGURE 3.1 **Consumer and producer surplus**



Cost-benefit analysis frequently uses a budgeting approach, allowing analysis on spreadsheets (e.g. Excel). Cost-benefit is an economic analysis and not a financial. Hence, the focus is on real resource use by the society and the costs and benefits connected, measured at the actual time of expenditure or receipt. Financial analysis focuses on the costs and benefits faced by private firms and individuals.

Normally financial costs and benefits are available and several adjustments are necessary to estimate economic cost and benefit. First, some payments are from the point of the society merely transfers from one sector to another. This includes taxes, interest payments and depreciation. Also benefits to foreign firms are not included in the cost-benefit analysis. Secondly, external costs must be included. An external cost arises if the actions of one producer adversely affect other producers or consumers. Thirdly, a more broad view on benefits and costs are applied in the economic analysis. For example, management and enforcement cost are included which is not a part of a financial analysis. Fourthly, it can be relevant to adjust the market price because they do not reflect the marginal willingness to pay or the opportunity cost. Market prices must also be adjusted for inflation. If the market is heavily distorted then it can be relevant to calculate shadow prices. In fisheries, it has often been argued that the labour has limited employment opportunities outside fishery and hence a low shadow price or wage rate should be used. However, often these calculations lack credibility and in general market prices should be used. Fifthly, only avoidable cost matter in the analysis, i.e. cost incurred before the policy change could be excluded including capital cost of vessels and processing plant if these investments have already been made. However, new investment and terminal (scrap) value of vessel or plant can be included as real economic costs. Sixthly, the cost-benefit analysis places equal weight to all the considered individuals or groups. For some reasons, the society could place a higher weight to some groups than others. The argument for using equal weight is that when the net benefit of a policy change is positive, then the winners could compensate the losers and the society is still better off. However, in reality this kind of compensation does not take place.

The fundamental issue in cost-benefit analysis is that cost and benefit occurs at different point in time. Hence, to value the cost and benefits a single term the present value is calculated by the formula:

$$NPV = \frac{\sum_{t=0}^{T}(B_t - C_t)}{(1+r)^t}$$

Where NPV= net present value, t=0 is current time, T is terminal time, B_t is the value of benefit at time t and C_t is the value of cost at time t.

The allocation that maximises the NPV gives the greatest net benefits to society and is optimal if the purpose is to maximise economic efficiency. Distributional concerns may also count and the benefit and cost may be divided following the different user groups.

In fisheries, considerable uncertainty about central parameters might be present, because of fluctuations in the parameter from year to year or because only simple average is available which can hide the diversity of the sector. Therefore sensitivity analysis is often conducted in order to show the crucial relationships.

Sometimes it is not possible to collect all the required information to calculate and compare and interpret *NPV.* Therefore results are also presented as the relation between benefits and costs for the whole time period or for one properly selected year.

Consumers surplus

If an allocation changes the quantity, prise or quality of the product, the consumers can gain or lose. Consumer surplus increase if there is a lower price for the same product, if additional quantities is provided or if the allocation favours producers that creates a higher quality (higher valued) product.

The consumer surplus is often difficult to estimate because of lack of data. There are often several different markets and total consumer surplus is not simple the sum of the consumers surplus in each market (the problem is called path dependency). However, if the products are exported then there is no consumer surplus in the home country. If the products are sold in competitive markets with a lot of substitutes it is likely that the price is not determined by the supply and hence there will be no impact on consumer surplus.

Producer surplus

Producer surplus is increased if a producer have lower production costs, if a higher quality product is produced or if a greater quantity is produced.

ANNEX 2. **Information about eel at different life stages**

	------------Catches ------------			Natural mort	-- Fishing mort --		--------- Stock ---------	
Life stage	Tonnes	mill.	mEuro	M*dt	F/y	F*dt	tonnes	mill.
Bay of Biscaye								
Glass eel				0.25y		0.25y		
-fisheries	510	1530	33	0.04	12.59	3.15	538	1616
-restocking	0	0	0		0	0	22	67
Yellow eel								
-pre-exploited	0	0	0	0.14	0	0	547	67
-exploited	1090	5	7	0.14	0.105	0.63	3352	17
Silver eel	545	3	3	0.07	2.87	1.43	735	4
Escapees	0	0	0	??	0	0	164	0.8
Sum	2145	1538	43		0.29	5.21	5358	1771.8
Elsewhere Europe								
Glass eel								
-fisheries	72	216	5	0.04	4.25	1.06	167	502
-restocking	-125	-375	-12			-1.47	91	272
Yellow eel								
-pre-exploited	0	0	0	0.14	0	0	5286	648
-exploited	10599	53	64	0.14	0.105	0.63	32388	162
Silver eel	5299	26	32	0.07	2.87	1.43	7146	36
Escapees	0	0	0	??	0	0	1590	8
Sum	15845	-80	89		0.09	1.65	46668	1356
Sum excl. Restock					0.18	3.25		

Source: Dekker (1999a)

ANNEX 3. **Catch composition, revenue and costs of the pound net fishery in Denmark**

Est. catch per unit of effort (1) (2) (3)	Kilo per vessel	Kilo per net
Eel (spring)	103	17
Eel (autumn)	3008	325
Other (spring)	36521	5872
Other (autumn)	5058	547
Est. miscellaneous catches on annual basis	2078	248
Total annual catch quantities	43657	6667
Prices on a seasonal basis	DKK	DKK
Eel (spring)	46,48	46,48
Eel (autumn)	60,33	60,33
Other (spring)	4,16	4,16
Other (autumn)	7,26	7,26
Annual price on other species	6,83	6,83
Est. revenue per unit of effort	DKK per vessel	DKK per net
Eel (spring)	4787	790
Eel (autumn)	181465	19606
Other (spring)	151927	24428
Other (autumn)	36721	3971
Est. revenue miscellaneous catches, yearly	14195	1694
Total annual revenue	389096	50489
Variable operating costs	DKK per vessel	DKK per net
Salary and crew costs (4)	88325	11461
Oil costs (5)	14397	1868
Sales costs (6)	38910	5049
Gear specific cost (net investment costs) (7)	DKK per vessel	DKK per net
Depreciation costs net	35755	4266
Depreciation costs pile	23212	2769
Total gear depreciation costs	58967	7035
Unit effort costs	DKK per vessel	DKK per net
Total variable costs per unit of effort	259565	32448

(1) The sensitivity analysis builds on the assumption of constant output prices and composition of catches.
(2) Source: Bundsgarnsfiskeri i Danmark, Rapport fra Danmarks Fiskeriforening, 1998, pp 34.
(3) Source: Annex 2. In the report of the gill net fishery (Bundsgarnsfiskeri i Danmark, Rapport fra Danmarks Fiskeriforening, November 1998).
(4) Salary to crew is defined as 22.7% of the total revenue, which is based on Table 33 and 38 in Fiskeriregnskabsstatistik 1997.
(5) Oil costs are defined as 3.7% of the total revenue, which is based on Table 33 and 38 in Fiskeriregnskabsstatistik 1997.
(6) Sales costs are defined as 10.0% of the total revenue, which is based on Table 33 and 38 Fiskeriregnskabsstatistik 1997.
(7) Based on assumption specified in Annex 6. In the report of the gill net fishery (Bundgarnsrapport) that is the depreciation on net and pile are assumed linear based on expected user period of perceptively 12 and 6.5 years. Replacement values per net 51189 DKK, replacement value per pile 375 DKK. In average there is used 48 piles per net.

ANNEX 4. **Growth of a cohort farmed eel**

Time primo month	Natural mortality	Intrinsic growth	Number of eel	Weight pr. eel gram	Total kilo	Net growth per day
0	17.01%	2.61%	1000	0.33	0.3	
1	8.23%	2.32%	830	0.7	0.6	1.97%
2	4.30%	2.07%	762	1.4	1.1	2.03%
3	2.42%	1.84%	729	2.6	1.9	1.92%
4	1.44%	1.64%	711	4.6	3.2	1.76%
5	0.91%	1.46%	701	7.4	5.2	1.59%
6	0.61%	1.30%	695	11.4	8.0	1.43%
7	0.42%	1.15%	690	16.9	11.6	1.28%
8	0.31%	1.03%	687	23.8	16.4	1.14%
9	0.23%	0.91%	685	32.3	22.2	1.02%
10	0.18%	0.81%	684	42.5	29.0	0.91%
11	0.14%	0.72%	683	54.1	37.0	0.81%
12	0.11%	0.64%	682	67.2	45.8	0.72%
13	0.10%	0.57%	681	81.5	55.5	0.64%
14	0.08%	0.51%	680	96.7	65.7	0.57%
15	0.07%	0.45%	680	112.6	76.5	0.51%
16	0.06%	0.40%	679	128.9	87.5	0.45%
17	0.06%	0.36%	679	145.4	98.7	0.40%
18	0.05%	0.32%	678	161.8	109.8	0.36%
19	0.05%	0.28%	678	178.0	120.7	0.32%
20	0.04%	0.25%	678	193.7	131.3	0.28%
21	0.04%	0.22%	677	208.9	141.5	0.25%
22	0.04%	0.20%	677	223.3	151.2	0.22%
23	0.04%	0.18%	677	237.0	160.5	0.20%
24	0.03%	0.16%	677	249.9	169.1	0.18%
25	0.03%	0.14%	676	262.0	177.2	0.16%
26	0.03%	0.12%	676	273.2	184.7	0.14%
27	0.03%	0.11%	676	283.6	191.7	0.12%
28	0.03%	0.10%	676	293.1	198.1	0.11%
29	0.03%	0.09%	676	301.9	203.9	0.10%
30	0.03%	0.08%	675	309.9	209.3	0.09%

Source. Calculated from information provided by the Association of Danish Eel Farmers

ANNEX 5. **Full cost and earnings information for a 200 tons production capacity eel farm. 1999.**

Year	4	5	6
Sales of eel, Tons	200	200	200
Sales of eel, '000 DKK	10980	10980	10980
Fixed costs, '000 DKK			
Chemicals	200	200	200
Wages	559	559	559
Maintenance	300	300	300
Water consumption	100	100	100
Producers' association fee	48	48	48
Insurance and administration	339	339	339
Total fixed costs	1605	1605	1605
Variable costs, '000 DKK			
Purchase of glass eel	1287	1287	1287
Grading	0	0	0
Feeding stuff	2583	2583	2583
Heating	60	60	60
Electricity	80	80	80
Oxygen	450	450	450
Total variable costs '000 DKK	4459	4459	4459
Total operating costs '000 DKK	6064	6064	6064
Result before interest '000 DKK	4915	4915	4915
INSTALMENTS ON LOANS AND CAPITAL COSTS			
Instalment long term loan	1728	1658	1587
Instalment deficit cover loan	1770	1770	1770
Instalment working capital loan	182	182	182
Total instalments	3680	3680	3680
Dept long term before instalment	10581	9699	8817
Dept deficit cover loan before instalment	8077	7277	6380
Dept working capital before instalment	1128	1081	1029
Total dept	19786	18057	16226
Interest payment long term loan	846	776	705
Interest payment deficit cover loan	969	873	766
Interest payment working capital loan	135	130	123
Total interest payment	1951	1779	1594
Result before tax	2964	3136	3320
DEPPRECIATION AND TAXES, '000 DKK			
Depreciation rate % 1)	15	15	15
Depreciation	2511	2134	1814
Balance for depreciation	14228	12094	10280
Year profit	453	1002	1506
Result for taxation	453	1002	1506
Tax (50%)	226	601	753
Result after tax	226	601	753
LIQUIDITY AND STOCKS OF EEL			
Liquidity ultimo (million DKK)	1,1	1,9	2,5
Max. stock before sale Tons	136	136	136
Min. stock after sale Tons	63	63	63
Value added '000 DKK	5921	5921	5921
Employment 2)	3	4	5

1) Depreciation is arbitrarily fixed at 15% (year 1: 0%; 2 and 3: 10%) and hence tax payments

2) Employment is calculated according to the share left for remuneration after all costs, interest payments, depreciation and tax payments. This employment does not compare to the technological employment, which is 1 person per 100 tonnes production output.
Note: Value added is remuneration of labour and capital

Annex 6. Price estimation

This result is obtained from estimation of an inverse demand function for the Japanese glass eel market, based on the 8 yearly observations from 1990-97 given in table 1 with prices in yen, using a log-log model. The estimation result is:

$$\log(price) = 8.1 - 1.59 * \log(catch)$$

with a reasonable explanatory power (R^2) on 83%, with absence of autocorrelation, with rejection of the hypothesis that the explanatory variables does not contribute to the explanation of price variations, either single or together. As the model is estimated in log-log form, the price flexibility of – 1.59 are given directly in the equation. Therefore, if catches of Japanese glass ell increase 10%, prices will decrease with 15.9%. Given the knowledge, that no substitutes exist for glass eel, the high price flexibility seems reasonable.

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