FEASIBILITY STUDY AQUACULTURE

Sponsoring Agent :
MINISTERIE VAN DE VLAAMSE GEMEENSCHAP, ADMINISTRATIE VOOR EKONOMIE
IMPULSGEBIED OOSTENDE-BLANKENBERGE

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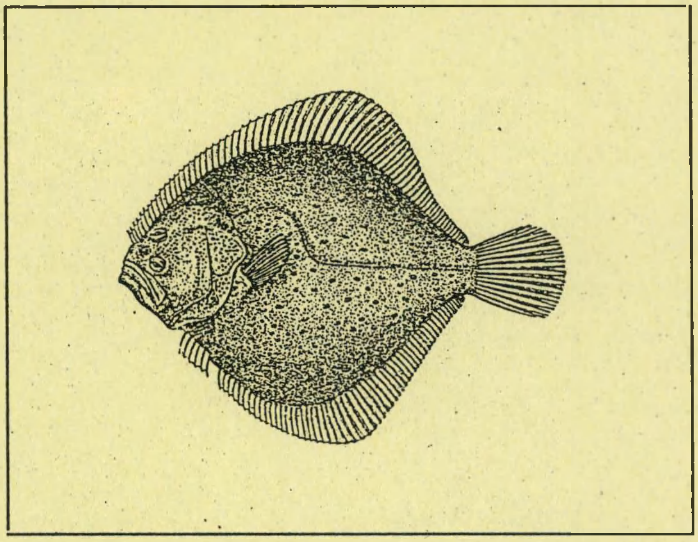

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Table of contents

1. BACKGROUND

OBJECTIVES

On 14th February 1990 the "Vlaamse Executieve" decided to take a number of selective measures to the areas of concern on the basis of relevant regional socio-economical indicators. One of these problem areas - called "areas for impulses" was the **Oostende-Blankenberge area**, especially the municipalities between Middelkerke, Oostende, Bredene, De Haan, Zuienkerke and Blankenberge.

Within this programme for stimulation called "Implementatie van selectieve maatregelen in de impulsgebieden " an agreement for co-financing was signed on 26th January 1993 between the "GOM-West-Vlaanderen" and the "Fisheries Research Station" in view of the research project "Feasibility Study Aquaculture". The Fisheries Research Station" acted as promotor of a group of scientists. The scientists were recruited from Ghent University (P. Sorgeloos, P. Lavens, P. Dhert, D. Delbare), the KU-Leuven (F. Ollevier en B. Denayer) and the French society "Aquaconseil" (J. Perrot). De coordinates of the scientific participants are given in annex.

Co-sponsoring of the study was obtained from the private sector, viz. de "Beroepsvereniging der Visgroothandelaars", het "Waarborg- en Sociaal Fonds voor de Zeevisserij" en het "Pieters Visbedrijf N.V.".

The total cost of the project was fixed at the amount of 1.200.000 Belgian Francs.

The purpose of the project was to investigate the possibilities for aquaculture in the **region Oostende-Blankenberge** in view of the production of larvae and the grow out of sea- organisms. The specific objectives were as follows:
1. the determination of the technical, commercial and financial aspects related to these projects.
2. the feasibility of these conditions in the **region Oostende** or outside the region.

The final report consists of two parts. First of all a detailed study in English was published containing all technical data, secondly a shortened and more easily accessible version in Dutch for a wider public.

Finally it must be stressed that the results of this study must be considered as a product of its time. The final feasibility of aquaculture depends on the current situation of the market situation. Negative conclusions could be altered thoroughly in the future if different market and culture conditions should arise.

2. INTRODUCTION

Although more than 70 % of our planet "earth" is covered by water, the main source of food for the human population is generated through terrestrial farming: agriculture and animal breeding.

Aquatic production yields only about 100 million tons annually, with the biggest share coming from capture fisheries.

Aquaculture or the controlled farming of aquatic plants, shellfish and finfish was initiated thousands of years ago. However, over the centuries it remained a largely artisanal practice, with a few exceptions in Asia and SE-Asia where for example the farming of carp in China and India, and of milkfish in Indonesia and the Philippines constituted a major source of animal protein for the local people.

The big change in aquaculture production has occurred in recent decades when innovative methods were developed for the artificial propagation in captivity, the mass production of quality seed, and the ongrowing/fattening up to commercial size, of several species with commercial interest.

With some fish and shrimp species, spectacular results have been achieved; for example in less than two decades a salmon farming industry has been developed that yields over 200 000 metric tons annually; salmon which are being produced in cages in Norway, Chile, Scotland, etc. Also within a period of less than 20 years the countries of Ecuador, the People's Republic of China, and Thailand developed methods to produce more than 100 000 metric tons per year and per country of Penaeid shrimp (also called "gambas"). Worldwide shrimp consumption approximates 2 million metric tons per year: today about 30 % of the marketed shrimp are grown in aquaculture ponds!

Less than 10 years ago reliable production methods were developed for the European seabass ("loup de mer") and the European seabream ("dorade"). Within that period several farms were set up in the Mediterranean basin and production outputs for 1993 are estimated at about 100 million fry (sold at about 20 BEF per piece) and some 15 000 metric tons of marketable fish (size in the 300 to 400 gram range, ex-farm price about 400 BEF per kg).

Techniques for the farming of turbot have now reached the stage of technical and commercial feasibility, and several farms are being set-up in N-Spain, France, UK, Denmark, Norway, etc.

Where suitable temperatures might not be available for year-round ongrowing of marine fish (f.ex. seabass and seabream) in cages set-up in protected coastal areas (in Greece, Spain, Italy, etc.), land-based tank systems have been designed for the intensive fattening of fish using thermal effluents (cooling waters from power stations, cokes-plants, etc.) as cheap sources of heated water. This has made it possible to consider commercial production of aquaculture species in Northern countries, f.ex. the 600-ton per year commercial unit "Aquanor" for the farming of seabass and seabream near Gravelines in N-France where the cooling waters from the nuclear power station ensure year round availablity of seawater with an optimal temperature for the farming of these species.

Aquaculture is clearly emerging as a successful new bio-industry. At a moment that capture fisheries are stagnating or even decreasing, aquaculture production experiences annual growth rates of more than 10 % and has depassed the 15 million tons per year. Aquaculture products can better meet market demands in terms of freshness, size, and timely availability. It is now widely accepted that in future years increased market shares of aquatic products will be generated through aquaculture as farming techniques are being developed for several more species, f.ex. halibut, cod, wolffish, and several tropical, sub-tropical species.

Although Belgium has only a very limited coastline, and does not have a very favorable climate, it is certainly a timely decision to explore the potential for the implantation of one or more aquaculture production units.

3. SITE SELECTION

Introduction

In general a limiting factor for aquaculture development with warm water species in North-western European countries, and especially in Belgium, are the climatic conditions resulting in low water temperatures during the winter period. Also is site selection probably the most important decision to be taken when you envisage to set up a fish farm, because the whole life of a project is depending on the accurate suitability of the selected site.

With those conditions in mind, to start a marine aquaculture project at economical scale at the Belgian Coast is rather complex, since one has to manage a solution dealing with special constraints :

a) - Due to the Belgian coast characteristics, and the winter cold temperatures of the sea, not allowing use of cages, the farm is to be a land-based farm.

b) - The capacity of the farm (which must be in the range 200/400 tonnes per year to secure the project profitability) leads to select a flat area with a minimum surface of 4 ha.

c) - Supply of water of good quality, in a range of 4 000/6 000 m^3/h with a flow-through system, coming either from the sea or from ground water, will have to be heated in winter using low cost calories taken from an industrial plant in order to be able to obtain an economically acceptable growth rate.

If a hatchery is integrated in the project, water salinity must be kept between 29 and 35 ppt.

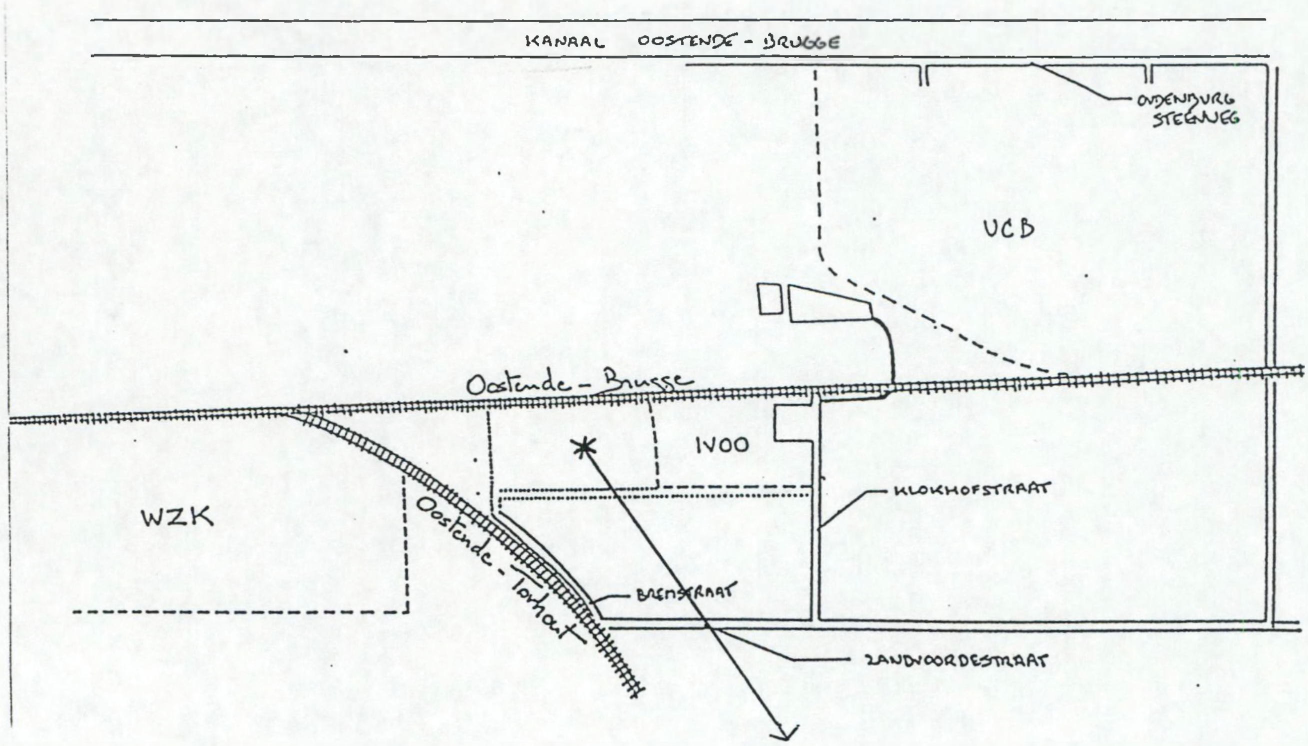
Taking these prerequisites into consideration, the following review of potential sites has been made.

3.1. SITE No 1 : **Cheap calories - Acquifers**

Introduction

Site No 1 is located in Zandvoorde, approximately 5 km inland the coastal area, between the junction of the railroads Oostende-Brugge and Oostende-Torhout.

This site has been chosen here because of the presence of cheap calories produced by the IVOO (incineration plant for household refuse), which produces steam as waste product. This steam could be used for heating the aquaculture installation. Nearby the site (700 m) the facilities of a water treatment plant (WZK - Waterzuivering Kustbekken) could be used to drain the effluent water. The existing effluent pipeline running from IVOO to the water treatment plant is located on a large area of the available industrial zone and could possibly be shared with the IVOO for the intake of warm water and the drainage of effluent water (Figure 1).



POTENTIAL AQUACULTURE SITE

Figure 1 : Location of the aquaculture site at Oostende near IVOO (incineration plant for household refuse).

3.1.1. Ecological factors

A. Saltwater properties:

Since the side is located ± 5 km inland and has no direct connection with the sea, all the water has to be pumped from so called underground "acquifers". These acquifers are spread along the Belgian coastline up to 10 km inland (Figure 2.).

Due to the fact that this water is pumped up from underground, the temperature of the saltwater is relative constant throughout the year and varies between 9 and 12 °C. The salinity of the water, however, is unpredictable and varies between 2 and 25 ppt, depending on the depth of the well. Saltwater of approximately 30 ppt should be found at a maximal depth of 30 m (Table 1).

	Oudenburg	Spuikom	Zandvoorde	Adinkerke
depth	10-20 m	32 m	12 m	2.5-7 m
salinity	16-26 ppt	20-23 ppt	16-25 ppt	
pH		7.0-7.2		7.0-7.9
temp.		12 °C	9-11 °C	9-10 °C
flow rate		5-6 m3/h	10 m3/h	

Table 1 : Physical parameters of underground saltwater on different sites.

The water obtained from underground acquifers has an optical density between 0.00 and 0.04 and a white to light brownish colour, depending on the underlayers (Figure 3). Even at this turbidity problems with precipitation on the gills of the fish may occur. As a safety precaution settlers will be necessary as a first treatment for the influent water.

As the acquifers are not directly fed by seawater, the chemical composition of the saltwater is quite different from that of natural seawater and possibly not suited for all marine fish species. Due to the presence of peat in the underlayers high H_2S-concentrations of up to 50 ppm are found. This is far above the maximum acceptable level of 0.002 ppm given by Terver (1989). In the present case a packed column for H_2S removal will be necessary.

The pH of the saltwater varies between 7.0 and 7.8, compared to seawater this is quite low, but the buffer capacity of the water could be increased by adding calciumhydroxide or calciumoxide until an acceptable pH (7.8-8.4) is reached.

The average concentrations of dissolved nutrients and gases found in the underground aquifers are given in table 2.

The concentrations of N, P and Si are too high for direct use as culture medium and should be reduced by using biofilters (not for Si). However for removing such high concentrations of nutrients, the dimension of the purification installation will become very high and not cost effective. The high concentration of Fe^{3+} (above 0.1 ppm) will give problems with precipitation on the gills if it is not removed from the water.

The bacteriological content of the saltwater is onknown.

	Oudenburg	Spuikom	Zandvoorde	Adinkerke
Na^+			8000	6806-8272
Mg^{2+}			1011	802-1120
Ca^{2+}			740	250-407
K^+			300	203-366
Fe	2-12	3-12	2-11	0-19
Cl^-			15200	12067-15670
SO_4^{2-}			928	1339-2452
SiO_2	16-24	7-11	16-24	
NH_4^+	21-49	10-18	20-49	2-22
NO_2^-		0		0.03-0.31
NO_3^-		0		0.67-2.31
POD	5.1	0.3-1.1	5.14	0.46-6.88
O_2		0.5-1.9		

Table 2 : Dissolved nutrients and gases of underground saltwater (in ppm).

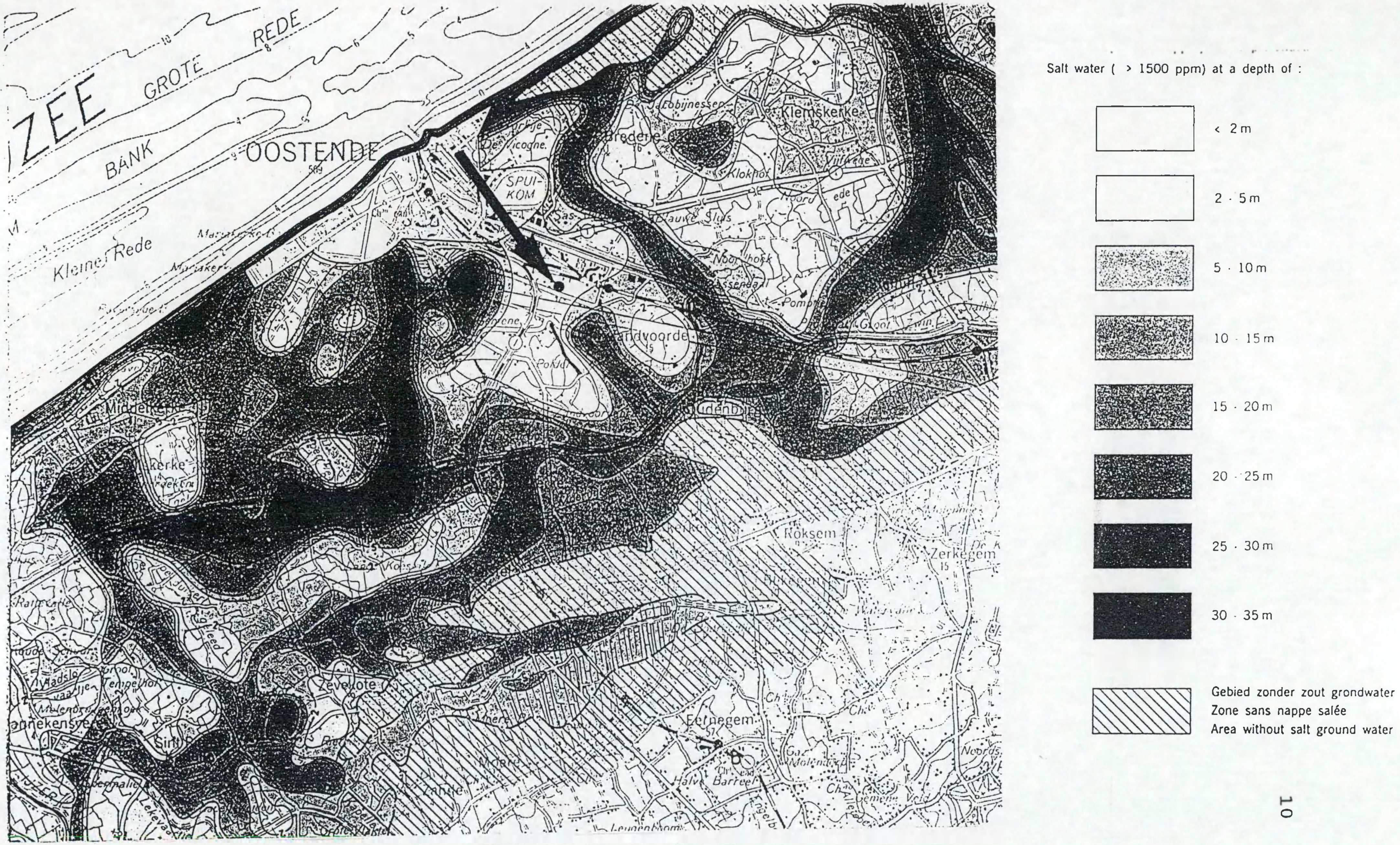


Figure 2 : Depth of the fresh-salt water interface in the unconfined aquifer of the Belgian coastal area.

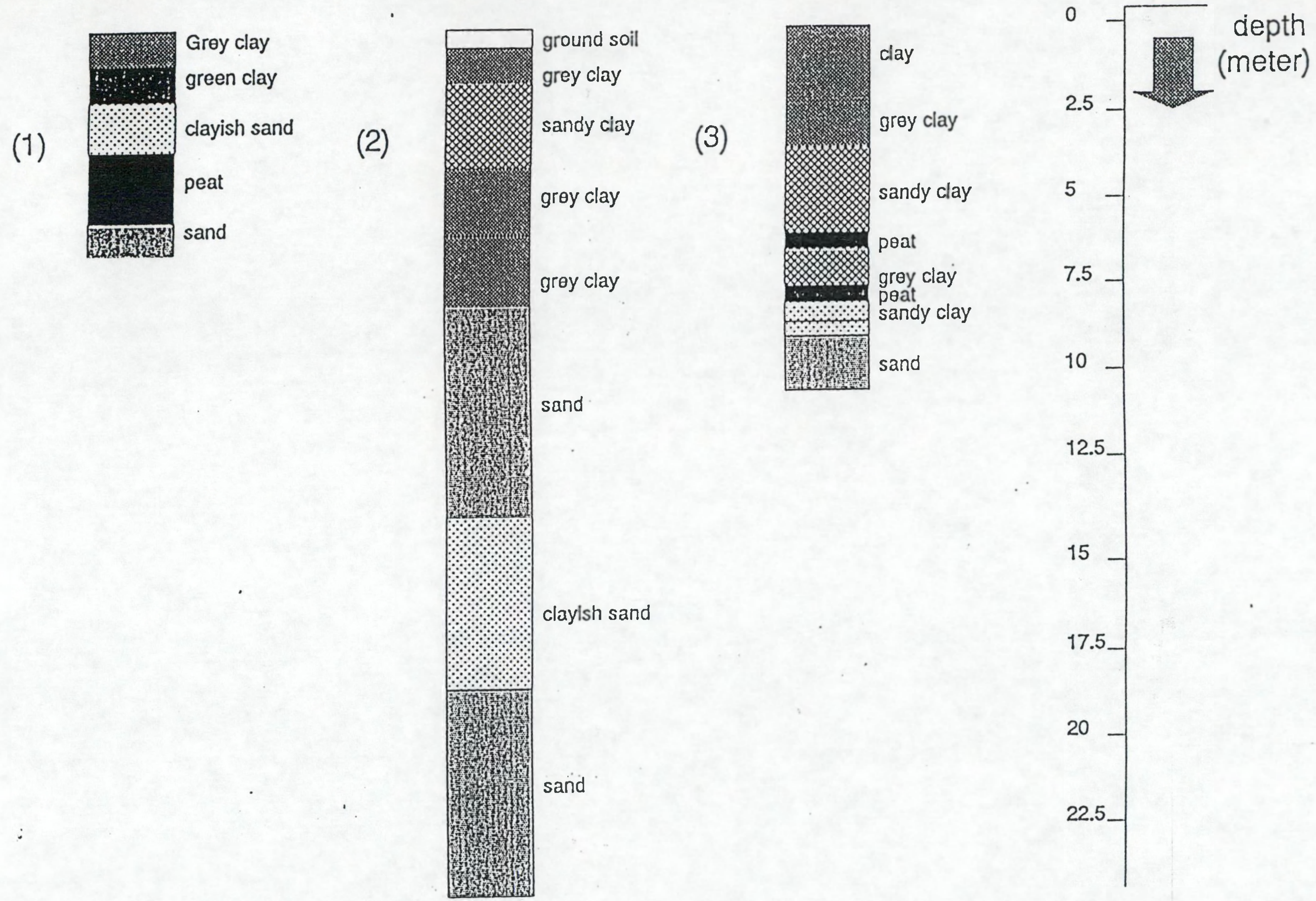


Figure 3 : Subsoil composition - 1. Oudenburg
2. Spuikom
3. Zandvoorde

B. Freshwater availability:

Fresh ground water is not found in the underground on the site, but as the site is located in industrial area, tap water should be available. On the other hand effluent water from the treatment plant (W.Z.K.- Waterzuivering van het Kustbekken) could also be used.

C. Soil characteristics

The water quality will depend on the first place on the nature and texture of the sediment in the underground. This can vary a lot from one well point to an other (Table 2).

Once again the presence of peat in the underground has a negative influence on the water quality (high H_2S and CH_4 concentrations). Peat can also induce soil sagging when large volumes of water are pumped. The instability of the soil may cause damage to surrounding facilities or cause cracks in the pipelines or fish tanks.

3.1.2. Human activities

A. Logistic factors

Zandvoorde can easily be reached via the highway E40 (Brugge-Oostende), exit Zandvoorde. The site is accessible via the Zandvoordestraat, the Klokkehofstraat and the Bremstraat (Figure 1). The Zandvoordestraat gives acces to the WZK and has a junction with the Bremstraat, which follows the railroad Oostende-Torhout. The Klokkehofstraat has a dead end: the IVOO. A path runs across the site forming a connection with the IVOO (Klokkehofstraat) and the Bremstraat.

Since the area is allocated for industrial uses and several plants are already in full operation, electricity and telephone are already present and the unit has only to be connected on the existing electricity and telephone network.

The nearest main city is Oostende at approximately 3 km from the site. Oostende (Raversijde) is a harbour city with a national airport nearby.

B. Human activities in the area

Although great precaution has been taken by the IVOO to purify the exaust fumes, air pollution may still occur. The chemical plant UCB is also a potential air pollutant. Pollution by infiltration of toxic products in the acquifers, coming from UCB is another possibility.

C. Restrictions - regulations

Since some cities do only allow aquaculture activities in semi-industrial area's, a specific demand for Oostende was undertaken. Apparently such regulations are not followed in Oostende and semi-agricultural activities are allowed in industrial area's.The land price per ha for industrial area is estimated at 5 000 000 BEF. On the site, the available land area is restricted to 8 ha of industrial area and is located in between the IVOO, the water treatment plant (WZK) and the railroad. However, due to the industrial activity in the area the possibilities for futher expansion are very limited and nearly unexistant.

Taking into consideration the high salinity and organic load of the effluent water, it is primordial that the effluents are properly drained and comply with the legislation on effluent waters. For this only one possibility remains and consists in draining the effluent water to the treatment plant (WZK), using the existing pipeline shared by IVOO and UCB. The diameter of this pipe is 1 m which should be sufficient. Herefore further negotiations with the concerned parties (WZK, IVOO and UCB) have to be undertaken. Before construction a detailed MER (Milieu Effect Rapportering) will be requested.

3.1.3. Evaluation:

Positive:

1) Cheap heat source:

The incinerator at the IVOO consists of two ovens each with a capacity of 5.6 ton per hour. At a minimal working capacity of 75% for the ovens, and a caloric content of 9 200 kJ (2 200 kcal/kg) for each kilogram of household refuse, 1.8 10^9 kJ (0.4 10^9 kcal) are produced daily. The largest part of the heat is used in a steam circulation system wich is converting the energy in electricity. This electricity (3.5 to 5.5 MW) is sold to a local electricity company (W.V.E.M.).

However, a part of the heat, approximately 960 10^6 kJ (230 10^6 kcal) per day is not converted to electricity and is discharged from the condensor into the open air at a rate of 569 000 m^3/h. During this process the ambient air is heated by 15°C. It is this energy source that might be used for aquaculture purposes. Based on the formula: $Q = c \cdot m \cdot dt$ it can be calculated that with the available heat source approximately 1 000 m^3 water can be heated by 10°C every hour. In this calculation, however, no consideration is made for energy losses from one medium to another. If seawater has to be heated by hot air, losses may be important.

2) Offset and distribution of the products:

Direct offset of the fish is possible in the fish-mine of Oostende. The distribution of the different products (eggs, larvae, fingerlings, adults and smoked products) can easily be done by road (highway E40 nearby), by airplane (Raversijde) or by ship, even jetfoil (Harbour of Oostende).

Negative:

1) Insufficient availability of a constant heat source:

With the available heat source the water can be sufficiently heated to maintain a standing crop of approximately 50 ton (flow through system). From marketing studies, however, it appears that rentability for grow-out of marine finfish is obtained at a minimal size of 200 ton. The previous figures are based on 960 10^6 KJ (2 ovens in function), which is produced by the IVOO for only 240 days per year. For the rest of the year (110 days) 417 10^6 KJ is produced (1 oven in function). Furthermore the IVOO is not operating during two short periods when the plant is repaired and when maintenance activities are scheduled (maximum 6 days, generally in March and October). During these periods the tanks have to be isolated to prevent against heat losses or heated with an auxiliary heating system. The costs of such emergency heating and pipelines is estimated at 28 % of the total installation cost.

2) Insufficient availability of sufficient saltwater:

The flow-rates obtained from the well points are rather low (maximum 10 m^3/h), due to the soil texture (see above). This means that more well-points have to be digged (50 000 BeF/well), if the plant is operated on a flow through (open) system.

Since acquifers are not supplied by the sea, it is very likely that on the long term the saltwater will be diluted by infiltration of freshwater. Excessive pumping from these aquifers will cause a decrease in flow-rate of the well and enhance the risk of soil sagging.

The low flow-rate of the well-points and the insufficient heat source for a flow-through production plant, necessitate a system with a closed or semi-closed system, which makes recirculation imperative. This recycling system requires:

- o pumps to recirculate the water (seawater resistant)
- o settlers
- o biological filters

The technique of using recirculated water is well known and many hatcheries are recirculating up to 80 % of their water every hour (80 % recycling per hour could be possible in the near future). Under these conditions it is obvious that the requirements for a heat source and large quantities of saltwater are less important.

3) Poor water quality

Due to the poor water quality (high concentrations of N, P, Si, CH_4 and H_2S) an additional treatment on the incoming saltwater and continuous monitoring of the water quality will be necessary.

3.2. Site No 2 : Pure seawater - Logistic facilities.

Introduction

Among the very few sites suitable for aquaculture on the Belgian coast, which can become available in a near future, we have to consider the NIEUWPOORT site.

This site is located at the extreme mouth of the IJZER river, on the right bank (East side) and was previously used as a slipway (Figures 4 and 5).

The above surface is bordered directly by the sea to the North, a large dock to the South, and the river to the West.

At this point the river is about 150 meters wide at high tide. Towards the open sea, two long wooden piers delimit the entrance of a channel leading to the harbour. This channel is permanently dredged down to at least five meters.

The site is currently occupied by the ARMY (Navy), but it is envisaged to transfer it to the economic sector in a near future and will become available in accordance with the saling of military properties by the Federal Ministry of Defence.

Even if this transfer is still unprecised, especially as far as time is concerned the location of this part of land is so attractive for aquaculture purposes that it is of interest to watch up the moving of the situation and stand as candidate for its utilisation.

The main factors related to the suitability of the site are briefly reviewed below.

3.2.1 Metereological factors

The meteorological conditions in the NIEUWPOORT area are very similar to those prevalent all along the Belgian coast.

A. Air temperature

The main annual air temperature is about 10°C, with a mean maximum of 20°C in August and a mean minimum of 2°C in February.

Extreme temperatures can reach -13°C in winter and 34°C in summer.

B. Precipitations

The mean annual height of the precipitations in the NIEUWPOORT area varies between 600 and 800 mm, with a maximum in November and a minimum in July.

Long periods with a light rain are observed, mainly during winter.

Storms are rather frequent from November to March. Winds reaching 40 knots, and sometimes speeds up to 60 knots are not rare, starting generally from South-West and turning progressively to North-West.

3.2.2 Ecological factors

A. Seawater properties

a) Physical

Currents run alongside the coast and change their direction with tides. From 1 knot during low tides, they reach 2 knots in spring tides.

Swell at seashore is not very important, due to the sand shoals which break the sea, except when the wind is North-East.

Mean sea temperatures vary from 6°C in February to 17,5°C in August, with differences of 2°C to 3°C more or less according to the year.

Surface salinity is steady in open sea, around 34 ppt, but decreases in the vicinity of the estuary, when the river is in spate. Salinity fluctuations can occur in the estuary.

Turbidity is rather strong due to the sea movements on the shoals, near the coast line and the sluicing activities at the river IJZER.

b) Chemical

No water quality analysis has been performed. It is supposed that data are very similar to those obtained in the neighbourhood of ZEEBRUGGE.

B. Biological Environment

Due to the constant agitation of the sea and the strong currents, the risk of eutrophication and red tides is very low.

C. Soil Characteristics

Soil is made of sand. The area is surrounded by dunes on the North and East sides. Detailed topography has not been examined, but it is obvious that the most part of the site is raised and leveled, slightly higher than high tides.

Some buildings have been built by the NAVY along the dock. They have to be visited to evaluate their usability for aquaculture activities.

3.2.3 Human activities

A. Logistical factors

The site is located inside a zone of strong residential and leisure activities, with a very important yachting base 1 km South at the river IJZER.

Access and availability of any service is easy on the site.

B. Restrictions

As a counterpart, it is to fear that using this site will be submitted to severe restrictions when the site should be destinated for recreational or touristical activities in the future.

CONCLUSION ON THE NIEUWPOORT SITE

A detailed study would be necessary to assess the overall suitability of the site, especially as far as availability of ground seawater is concerned.

However, it is clear that the NIEUWPOORT site appears as the only one where pure seawater can be obtained, either directly from the sea (for example by constructing a pumping facility nearby the entrance pier) or from boreholes or draining pipes into the sand.

In view of the availability of full strenght seawater this site is suited to install a hatchery.

Moreover, the site is large enough to allow the setting up of growing facilities with a production capacity of several hundreds tons per year. This opportunity is linked and restricted to the possibility of using large quantities of heated water to keep, during winter, an acceptable temperature of the culture water (flow through system), or waiting for the good running of recirculation systems.

Due to its exceptional situation, directly on the seashore, this site will certainly be disputed between a lot of competitors. It should be observed that an aquaculture project does not need the usage of the total area, and that, for example, the setting up of a "marina" in the dock would not be a real constraint.

For all these reasons, it is recommanded to seriousely keep an eye on the expected change of status of the military complex, and act as a candidate for establishing a model farm on this site.

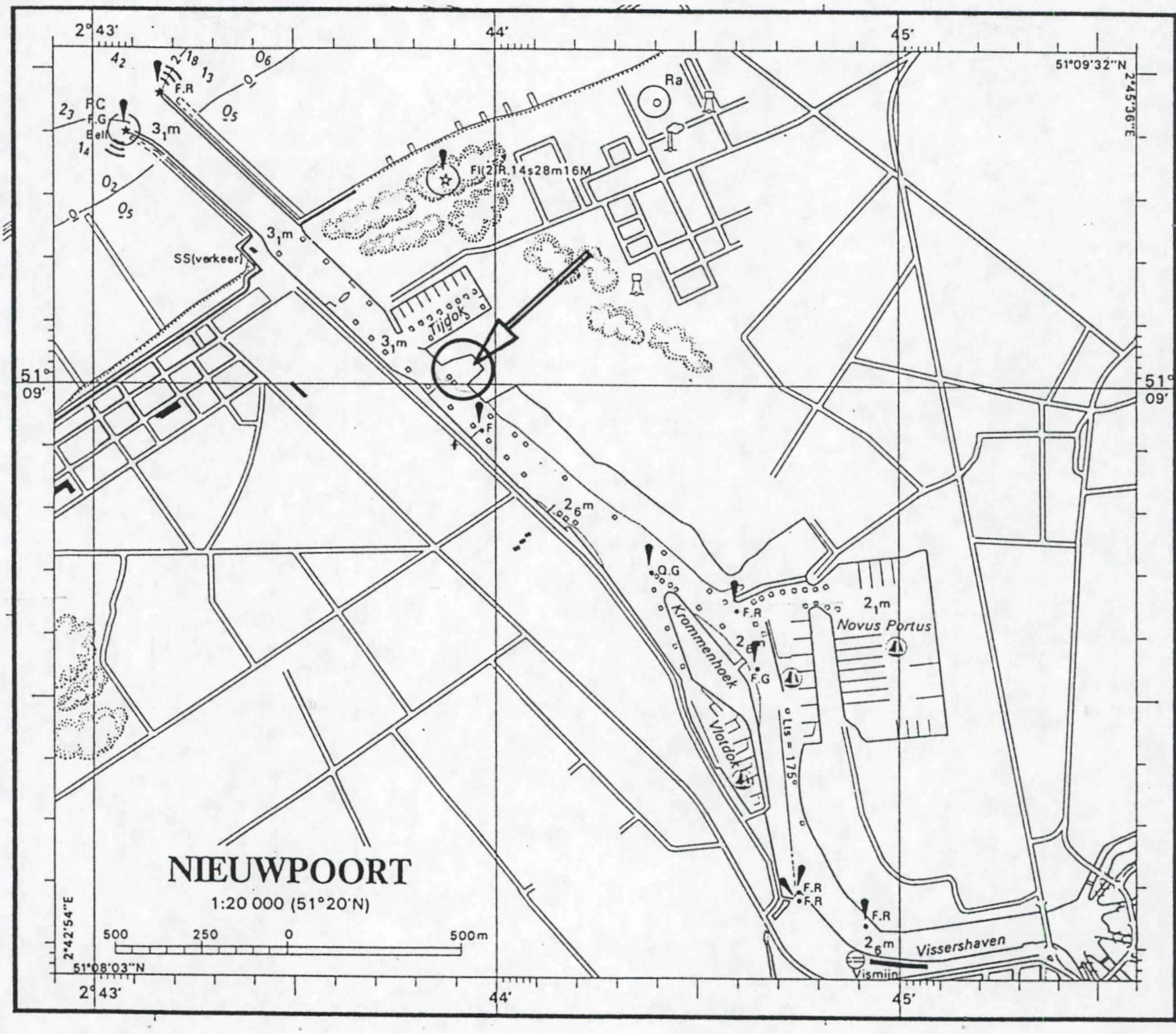


Figure 4 : Location of the site.

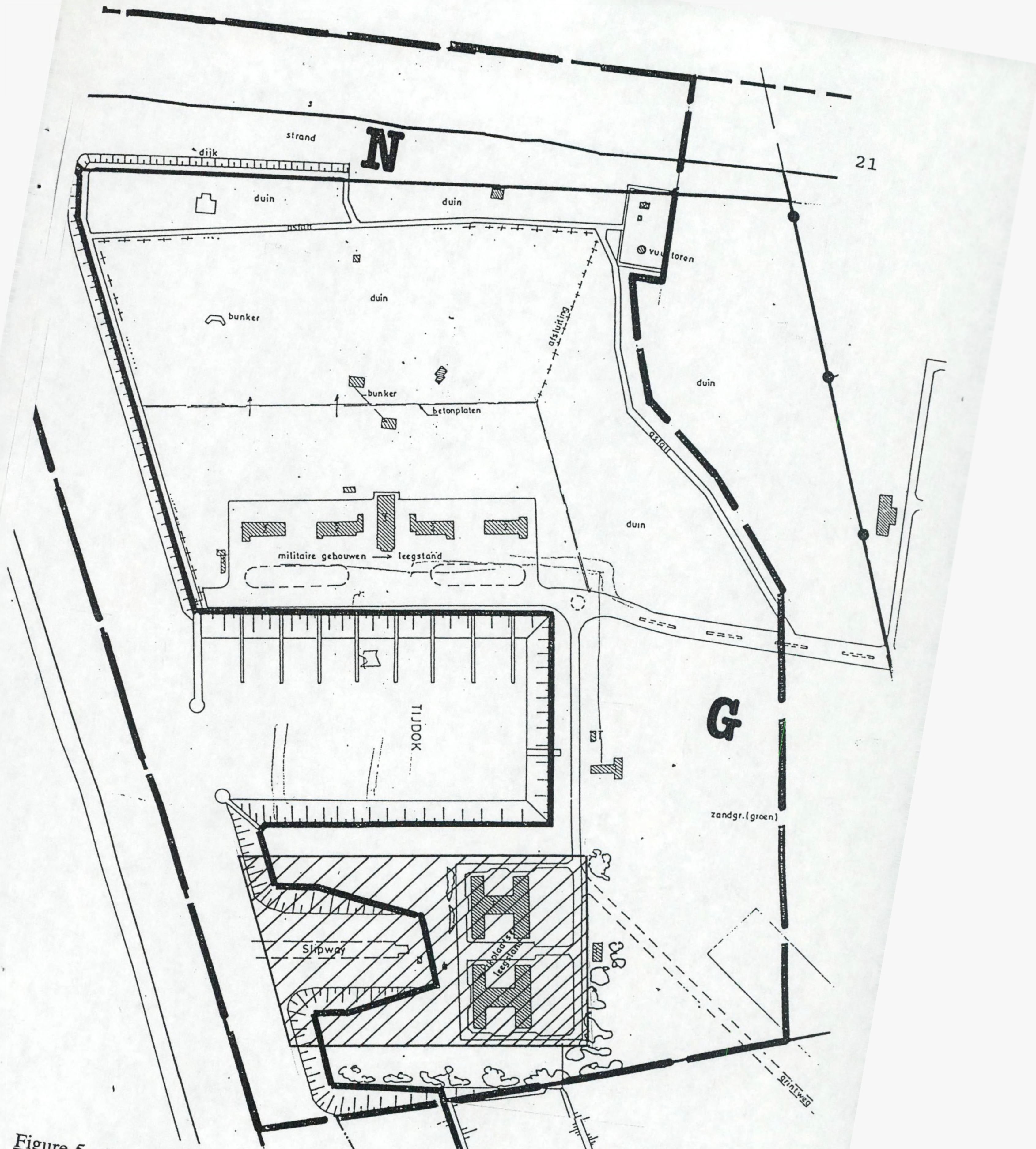


Figure 5 : Location of the site (shaded area).

3.3. Site No 3 : Power plant - Logistic facilities - Brackish water.

Introduction

One of the suited sites in Flanders with a continuous availability of a vast amount of cooling water is the nuclear power station at Doel.

At the initiative of ELECTRABEL (Electricity Producing Company), GIMV (Investment Company for Flanders), K.U.Leuven Research and Development and the Laboratory for Ecology and Aquaculture of the University of Leuven, research started in 1983 to investigate the possibilities for aquaculture in the thermal effluents of the power station at Doel.

A pilot plant using cooling water from the power plant and water of the river Scheldt was constructed. Since the cooling water used is brackish water from the river Scheldt, several trials with euryhaline species (i.e. sea bass, sea- bream, eel) showing promising market perspectives, have been conducted.

3.3.1. Tidal range in the river and river flow.

The fluvial zone of the Westerscheldt estuary is characterized by a rapid and large penetration of the tides. The tidal range near Doel is on average +1.13 m, with a minimum level at -2.20 m and a maximum level at 5.67 m. Equinoctial high tide is situated at a level of 6.12 m.

The river Scheldt nearby Doel has an average flow of about 130 m^3/s. The discharge from the river basin depends essentially on the rainfall.

3.3.2. Physical water quality.

a) Temperature range.

The major benefit for intensive aquaculture in thermal effluents is the elevated temperature promoting a faster growth of cold blooded organisms. Table 3 gives a view on the minimum and the maximum values of the water quality variables during the consecutive years of research. Minimum water temperature values are recorded in winter periods when environmental temperature is low, resulting in low cooling water temperature. Short term maximum water temperatures are recorded in the summer. Appropriate manual mixing of water sources (cooling water, condensor water, water of the river) reduces these periods with minimum and maximum temperatures of the culture water.

The temperature of the water of the river Scheldt (average 13.3°C ; S.D. 5.0°C) fluctuates considerably over the year. The minimum weekly average temperature recorded is 6.0°C, the maximum temperature is 22°C.

An appropriate mixing of the different water supply sources (cooling water, condenser water, river water) available for aquaculture purposes results in a culture water temperature stabilized in the range which allows optimum growth of sea bass. The average temperature of the culture water over the research period was 24.1°C (S.D. 2.5°C). The mean weekly temperatures vary between 19°C and 27°C. Short term daily fluctuations in the cooling water temperature can occur due to influences from climatic conditions.

In figure 6 the weekly averages of the culture water temperature can be compared with the temperature of the water of the river Scheldt over the period March 1987 to July 1991.

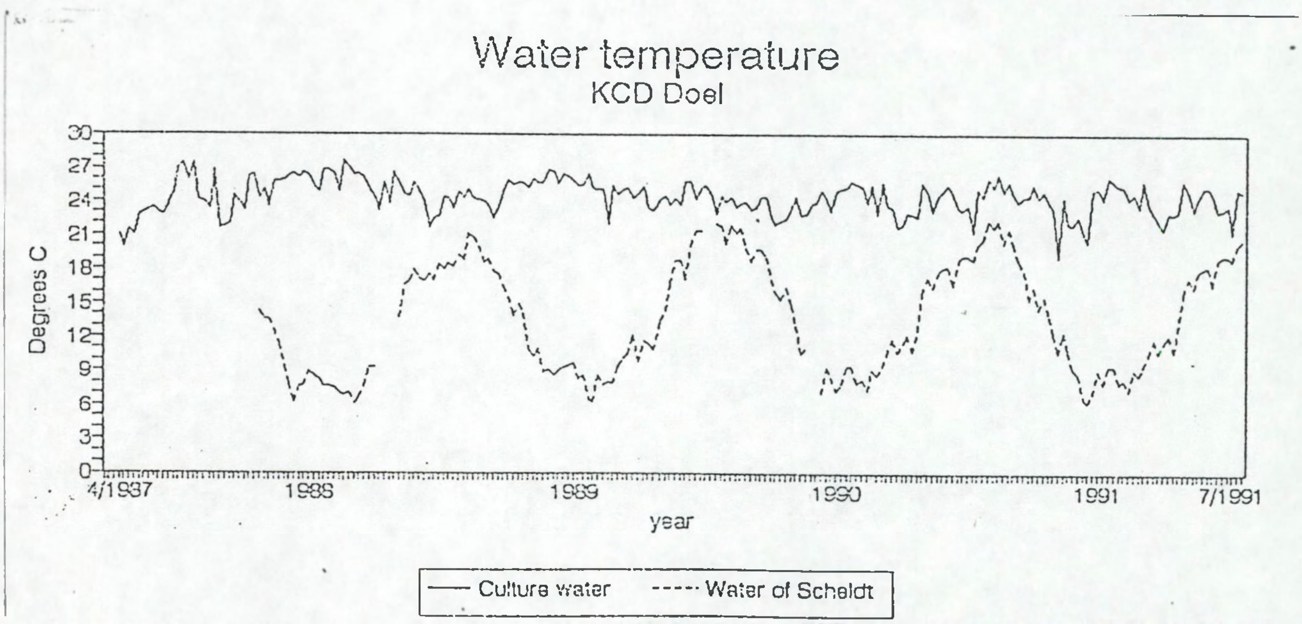


Figure 6 : Mean weekly temperature of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

		Culture water in [illegible] tank							Water of river Scheldt						
		Temp. C	pH	D.O. mg/l	Sal. ppt	NH4-N mg/l	NO2-N mg/l	SS mg/l	Temp. C	pH	D.O. mg/l	Sal. ppt	NH4-N mg/l	NO2-N mg/l	SS mg/l
1987	Min.	10.00	7.25	3.50	3.60	0.01	n.d.	70	5.10	7.31	-	-	0.15	0.04	50
	Max.	30.30	8.50	12.10	12.90	2.20	1.00	175	19.90	7.99	-	-	3.50	2.70	209
1988	Min.	15.50	7.10	3.70	1.90	0.01	n.d.	20	4.90	7.12	-	-	0.04	0.01	40
	Max.	30.20	8.42	11.80	16.50	1.80	1.00	310	22.00	7.67	-	-	7.50	0.55	390
1989	Min.	13.10	7.30	4.10	2.40	0.05	n.d.	20	4.00	7.25	-	1.70	0.01	n.d.	20
	Max.	39.40	8.44	11.20	18.20	1.75	0.45	310	25.20	7.76	-	17.80	3.70	0.32	390
1990	Min.	15.20	7.28	3.10	4.20	n.d.	n.d.	17	4.90	7.18	1.00	3.00	n.d.	n.d.	20
	Max.	28.90	8.40	9.40	20.00	0.84	0.95	440	23.10	8.10	7.80	20.00	4.20	0.95	440
1991	Min.	14.60	7.30	6.00	0.00	0.04	n.d.	50	6.00	7.10	1.70	0.00	0.10	0.02	60
	Max.	30.50	8.30	9.70	10.00	2.70	0.25	240	16.30	7.70	7.40	11.00	4.50	2.40	240

Table 3 : Minimum and maximum water quality variables of the culture water and water of the river Scheldt during the research period 1987-1991.

b) Salinity range.

An annual periodicity is observed in the salinity of the Scheldt water near Doel. The fluctuation of the salinity is related to the water flow, which in turn is influenced by the amount of rainfall. In winter, when the surface flow rate is high, the salt gradient will be displaced down-river. In summer, when river flow is low, the salt gradient displaces up-stream and the local salinity at the Doel site increases. Minimum and maximum values recorded are mentioned in table 3. In figure 7 the weekly averages of the culture water salinity can be compared with the salinity of the water of the river Scheldt over the period March 1987 to July 1991. The decrease of the salinity of the Scheldt water in the winter and spring as a result of increased river flow didn't affect seabass. Periods of several days with approximately freshwater in 1991 had no observable effect on the cultured fishes.

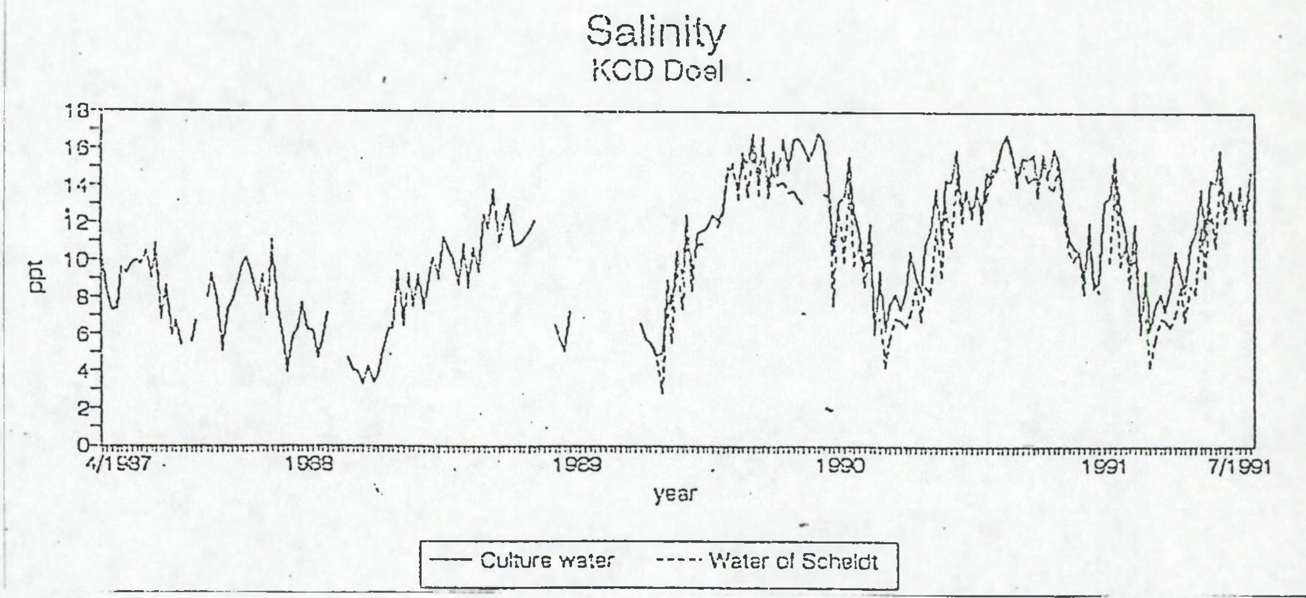


Figure 7 : Mean weekly salinity of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

c) Suspended solids.

The annual periodicity observed in the suspended solids concentration of the Scheldt water near Doel is shown in figure 8. In the river Scheldt, the mixing area of salt-water en freshwater is located between Antwerpen and Doel and is characterized by high amounts of suspended solids (flocculation zone). The fluctuation of the amount of suspended solids over the year is related to the water flow, which in turn is influenced by the amount of rainfall. In contrast with salinity, in winter periods, when the river flow rate is high, the mixing area displaces down-river resulting in high suspended solid concentrations near Doel.

In summer, when river flow is low, the mixing area displaces up-stream and the suspended solid concentration at the Doel site decreases. Minimum and maximum values recorded are mentioned in table 3. In figure 8 the weekly averages of the suspended solids concentration in the culture water can be compared with the salinity of the water of the river Scheldt over the period March 1987 to July 1991.

The suspended solids in the culture water had no observable effect on the cultured seabass.

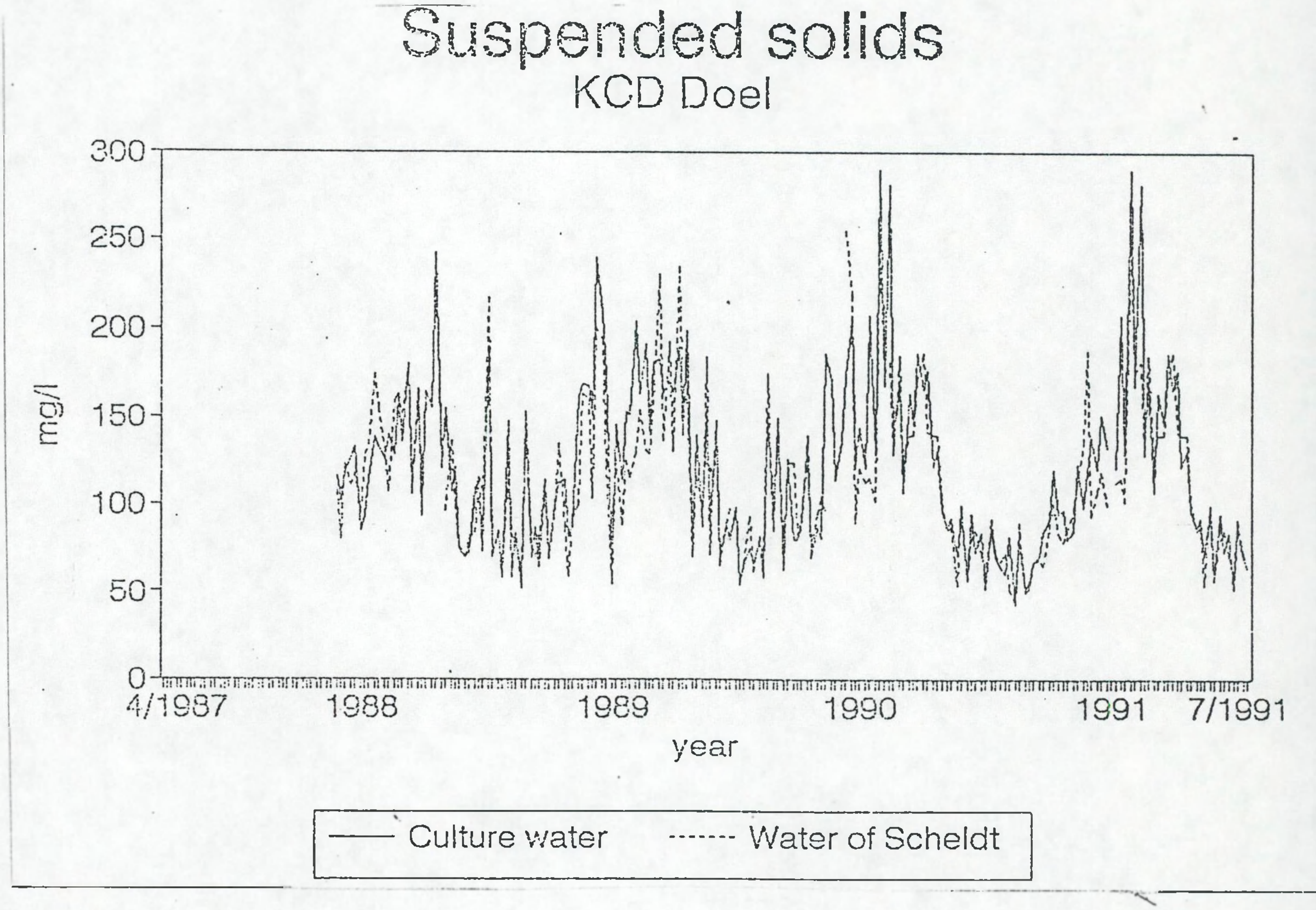


Figure 8 : Mean weekly suspended solids concentration of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

3.3.3. Chemical water quality.

a) pH

The average of the daily measured pH values of the river water is 7.5 (S.D. 0.1). Passing the cooling tower results in a stripping of carbon dioxide from the cooling water. Due to this stripping the culture water pH increases to 8.0 (S.D. 0.3 ; average of the daily measured pH values). Minimum and maximum values recorded are mentioned in table 3.

In figure 9 the weekly averages of the daily measured pH values in the culture water can be compared with those from the water of the river Scheldt over the period March 1987 to July 1991.

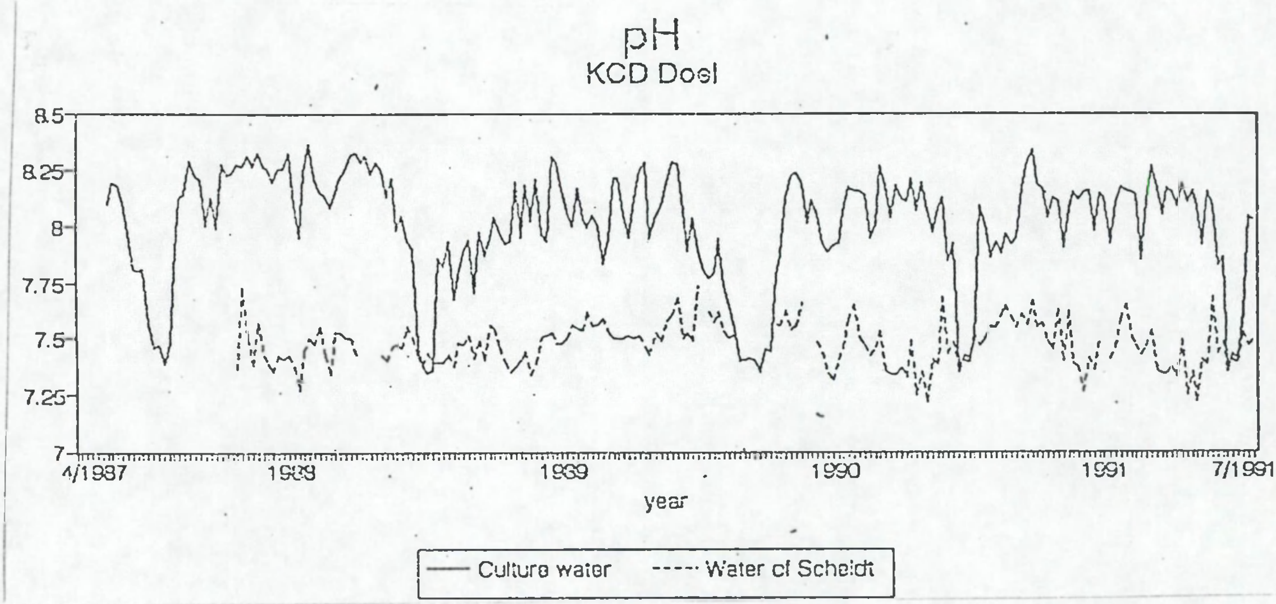


Figure 9 : Weekly average of the daily measured pH values of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

b) Dissolved oxygen.

The improvement for aquaculture purposes of the Scheldt water after passing the cooling tower is obvious. Dissolved oxygen concentrations are increased due to the aeration of the water when distributed in the cooling tower.

The dissolved oxygen concentrations, with an average of 4.6 mg/l (S.D. 1.5 mg/l) in the water of the river Scheldt increase markedly after passing the cooling tower. In the culture water an average D.O. concentration of 7.6 mg/l (S.D. 1.5 mg/l) is measured (figure 10). These oxygen concentrations in the culture water with additional tube aeration in the rearing tanks supported fish densities up to 60 kg/m^3. The lower D.O. concentrations (table 3) are recorded during summer periods when water of the river with low D.O. concentrations is mixed.

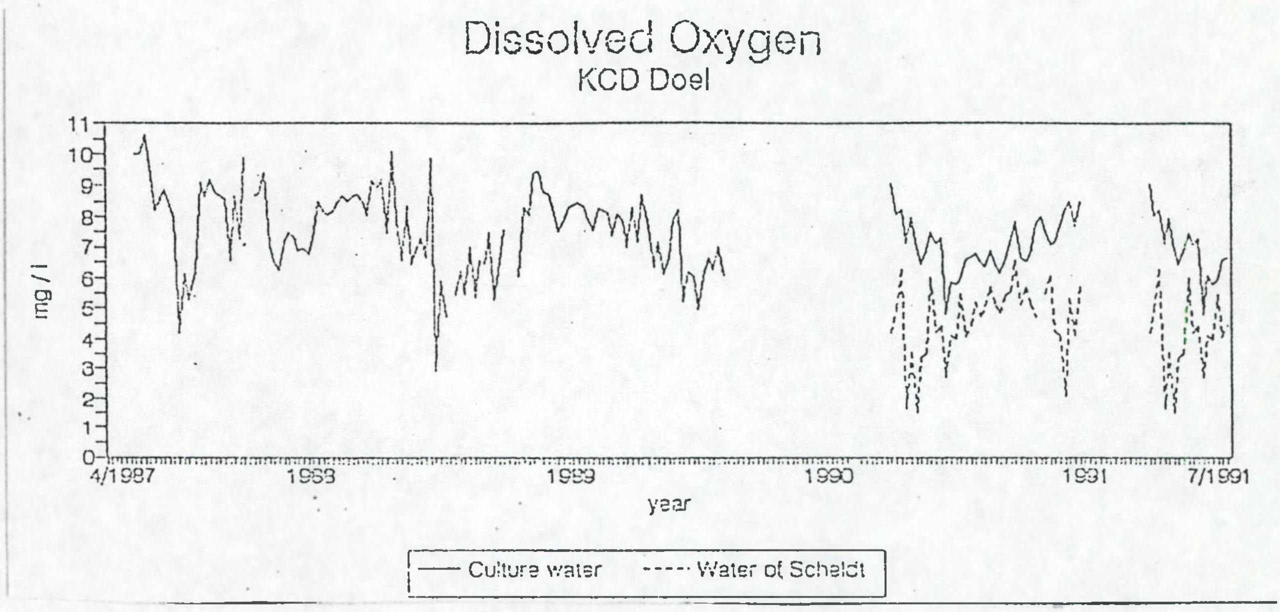


Figure 10 : Mean weekly dissolved oxygen concentration of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

c) Total ammonium.

Ammonium, especially the un-ionized ammonia, entering water systems from a.o. industrial wastes, sewage effluents and agricultural input, can be a serious toxicant to fishes. The total ammonium concentration, correlated to increased D.O. concentrations in the river water, have decreased steadily since 1972. The average total ammonium concentration in culture water is 0.29 mg/l (S.D. 0.32 mg/l) and 1.09 mg/l (S.D. 1.12 mg/l) in river water (figure 11). High NH_4-N concentrations in water of the river Scheldt are observed in winter periods as a result of reduced biopurification. Higher concentrations in the culture water (table 3) are recorded when water of the river is mixed with water of the cooling system. Total ammonium concentrations in the cooling water are decreased due to the stripping effect in the cooling tower.

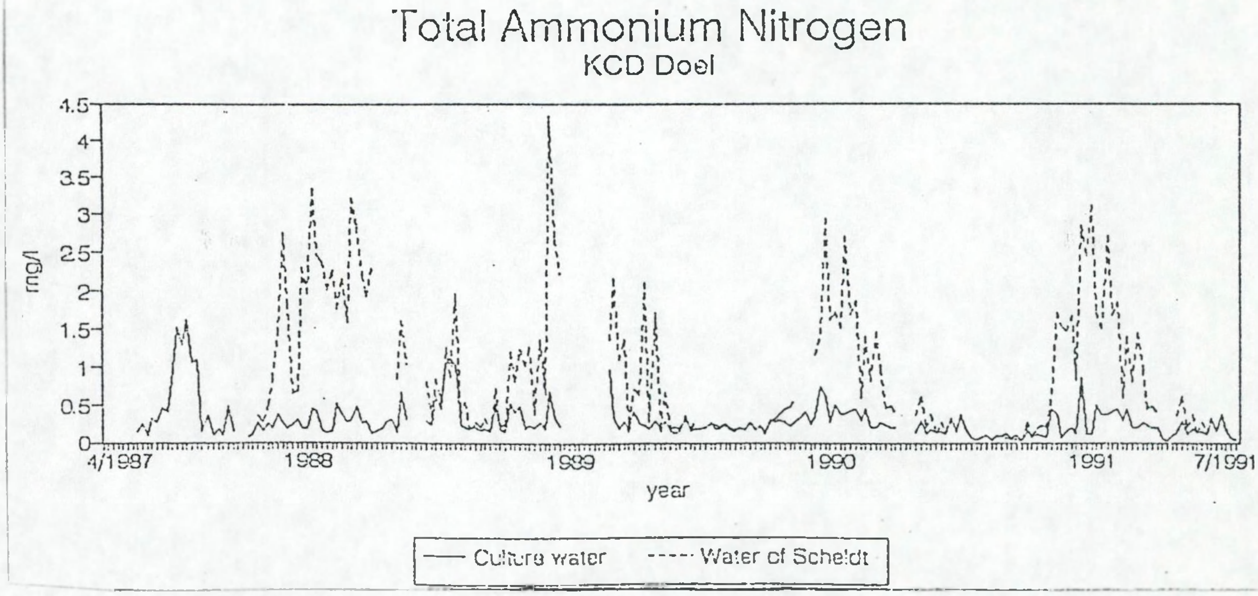


Figure 11 : Mean weekly total ammonium concentration of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

d) Nitrite.

In the culture water at Doel the average nitrite nitrogen recorded is 0.11 mg/l (S.D. 0.13 mg/l). In the river water the average nitrite nitrogen recorded is 0.14 mg/l (S.D. 0.16 mg/l) (figure 12). Nitrite toxicity in brackish- and marine water is low. The presence of chloride reduces the toxicity of nitrite. For aquaculture in marine environments a maximum of 1 mg/l NO_2-N is mentioned.

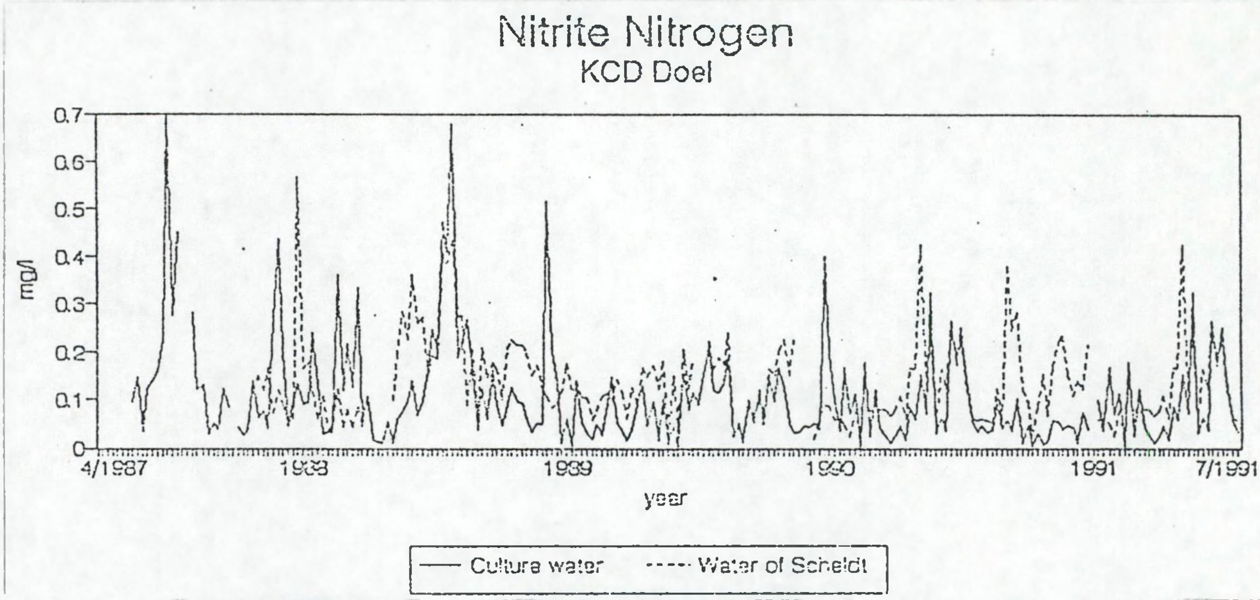


Figure 12 : Mean weekly nitrite concentration of the culture water and water of the river Scheldt at Doel from March 1987 to July 1991.

3.3.4. Ground water availability.

The Geological Institute of the University of Gent is conducting research to map the ground water reserves and their salinity in the area. At the moment no detailed information is available about depth and quality of the ground water.

3.3.5. Seed occurrence of wild populations of fishes.

The abstraction of cooling water at the nuclear power station at Doel leads to impingement of fish and crustaceans. The community structure of the brackishwater area of the Scheldt was investigated by monthly sampling of the impinged fish and crustaceans from September 1991 to February 1992.

24 species of fish and crustaceans were found in the samples. The most abundant species were *Crangon crangon* (common shrimp), *Palaemonetes varians* (prawn), *Carcinas maenas* (common shore crab), *Pomatoschistus minutus* (sand goby), *Pomatoschistus microps* (common goby), *Pomatoschistus lozanoi* (lozano's goby), *Sprattus sprattus* (sprat), *Clupea harengus* (herring), *Syngnathus rostellatus* (Nilsson's pipefish), ***Dicentrarchus labrax* (seabass)**, *Anguilla anguilla* (eel) and *Gasterosteus aculeatus* (3 spined stickleback).

The natural occurrence of seabass in estuaries is also observed at the river Scheldt. The abundance of seabass at Doel is highest during the autumn, decreases over the winter period and is absent in February.

3.3.6. Soil and subsoil characteristics.

The subsoil characteristics at the formerly called "Doelse Polder" (between +2 and +3 m) is characterized by the numerous parcels for peat winning and wet soils with heavy clay, sandy clay and loam.

At present the soil of the nuclear site is raised (at +9 m), leveled and consists of sand.

3.3.7. Human activities - presentation of the site.

The Doel nuclear power station is situated in an industrialized area on the left bank of the River Scheldt in the port area of Antwerpen at 65 km of the North Sea. The station consists of four production units (Doel 1, 2, 3 and 4) with a total electrical output of 2 685 MWe. The accessibility by road is excellent with a distance from Antwerp of about 20 km, from Brussels 50 km and from Zaventem (airport) 45 km.

The generation of electrical energy in nuclear (as well as conventional) power stations requires copious quantities of cooling water, since it must be possible to dissipate 2/3 of the thermal output during the production process. In the nuclear production process at Doel, steam produced in the sealed secondary circuit is used to generate electricity. In order to recondense this steam, cooling water is drawn from the Scheldt and circulated around the tertiary cooling water circuit. During the condensation process, heat is transferred from the secondary to the tertiary circuit. Figure 13 shows an overview of the tertiary cooling water circuit of the power station.

The tertiary cooling circuits of the nuclear power station are open (unit Doel 1 and Doel 2) or semi-closed recirculation (unit Doel 3 and Doel 4) systems.

The water used in the tertiary cooling circuits (30 m^3/s) is drawn from the river Scheldt via two water inlets. From the oldest water intake the water is pumped to the condensers of Doel 1 and Doel 2 (4 circulating pumps, 22 500 m^3/h each, 2 per condenser). After passing through the condensers, this water is returned to the Scheldt via the effluent cooling water channel.

The cooling water for the Doel 3 and Doel 4 units is obtained from the in 1990 newly constructed water intake structure. Using the principle of the communicating vessels, the water enters the site via a subgrounded gallery. From the pumping station on the site, water is then pumped to the cooling circuits of Doel 3 and Doel 4, respectively (1 auxiliary pump per circuit, 45 200 m^3/h). Before being discharged again to the river the cooling water passes the cooling tower constructed on each circuit.

This thermal energy in the cooling water can be optimally valorized for aquaculture purposes either directly or indirectly by heat exchange. The temperature of the water, in combination with a saturation with oxygen, allow a fast growth of fishes.

3.3.8. <u>Presentation of the aquaculture site.</u>

a) General topography.

At the Doel nuclear power station a surface of 1 ha is available for aquaculture purposes on a raised (+9 m) and leveled site (figure 14). The surface is situated at the site of the nuclear power station. The demands towards an aquaculture facility at this site are : to have their own access, to prevent overflow of the nuclear site, to be total autonomous (i.e. electricity, telex and telephone), to right the site when stopping aquaculture activities. Further North along the river Scheldt, the possibilities exist to enlarge the aquaculture facilities to a surface of 5 ha.

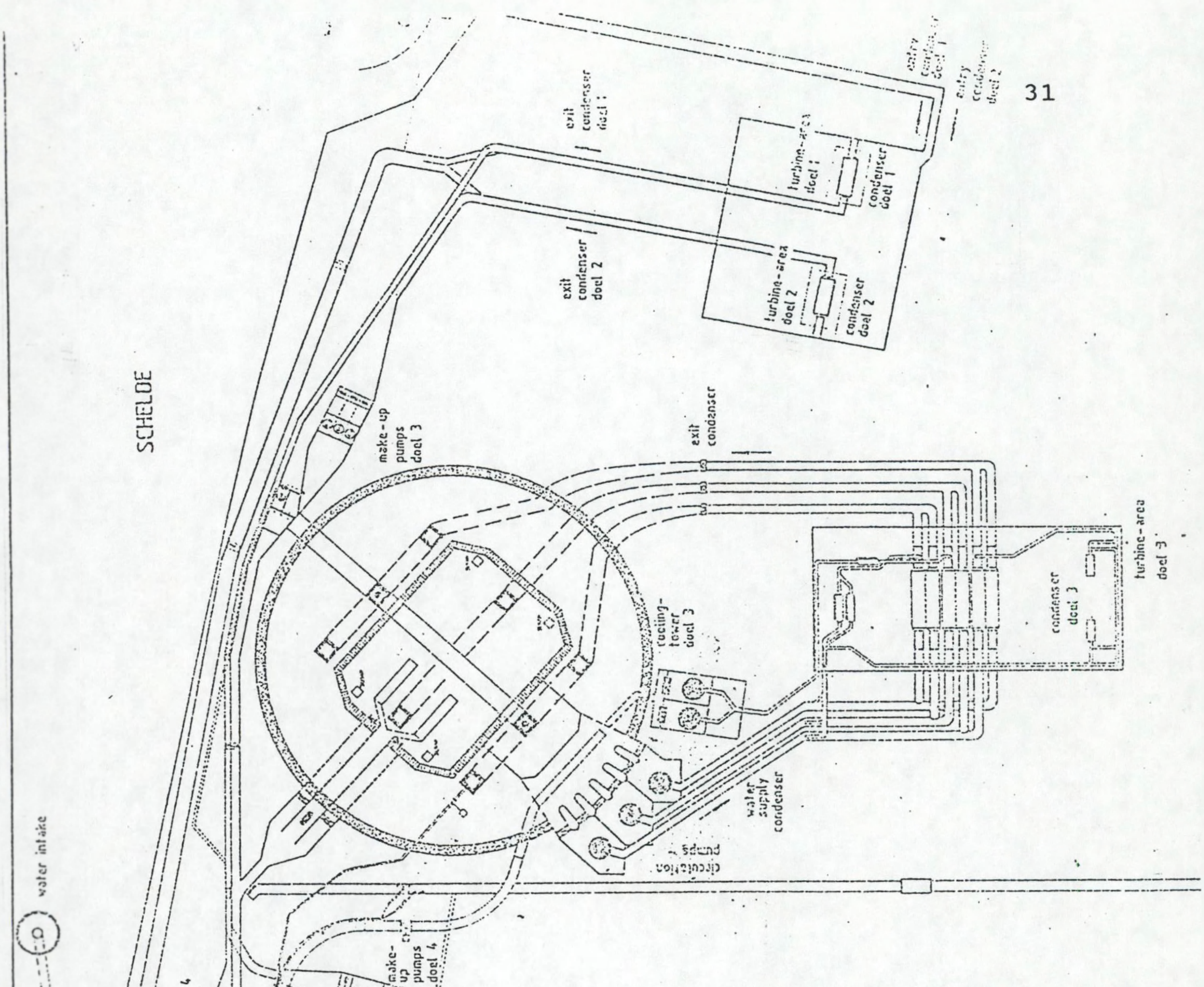


Figure 13 : The tertiary cooling water circuit in the nuclear power station at Doel.

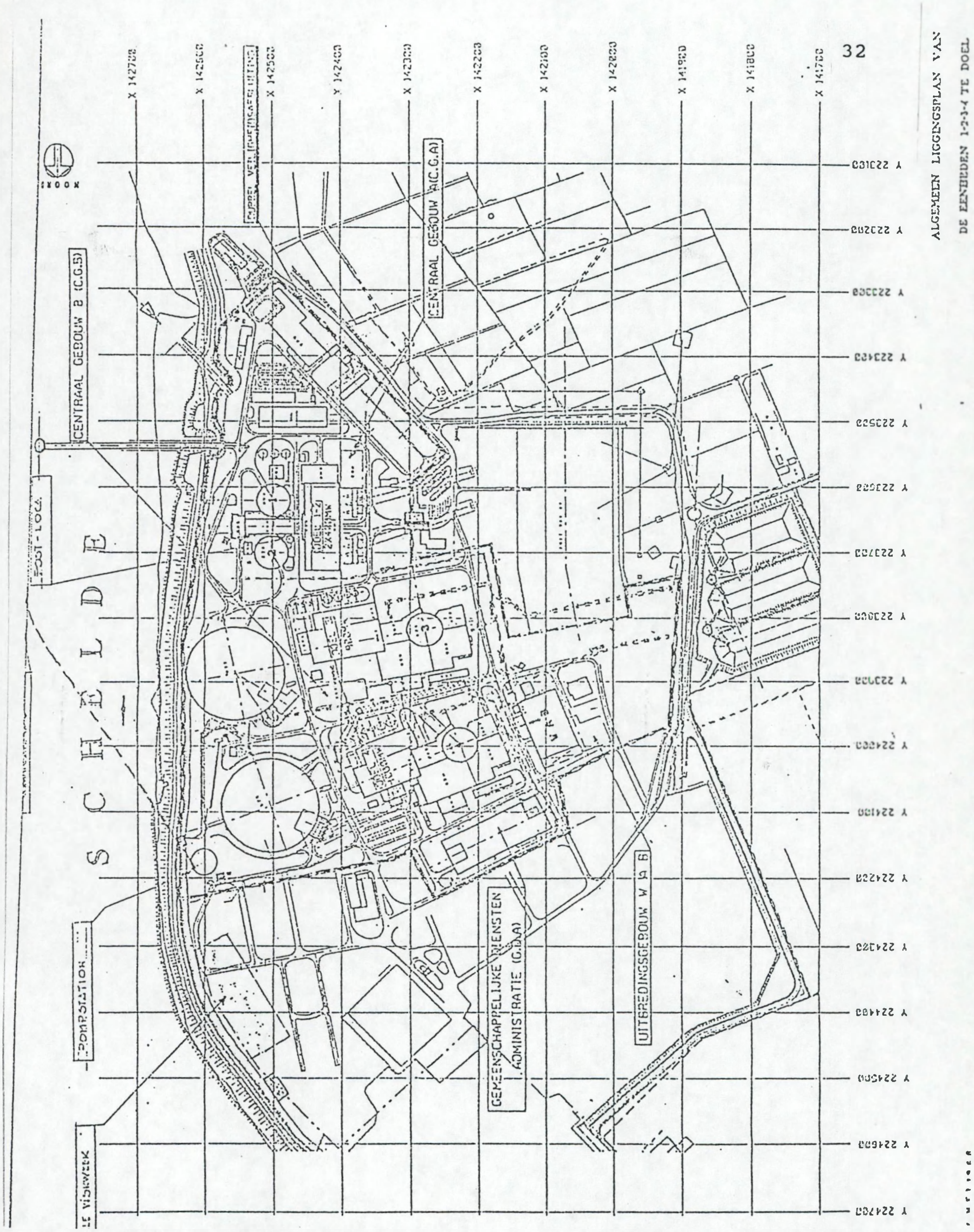


Figure 14 : Location of a leveled site (1 ha) at the nuclear power station at Doel with possibilities for aquaculture activities.

b) Water availability.

Considering the water supply conditions to an aquaculture facility, the major characteristics of the site are :

1. three separate circuits can be used to supply an aquaculture facility with water :

a) water of the river Scheldt is available at the in 1990 newly constructed water intake vessel on the site of the nuclear power plant, at a distance of about 100 m of the aquaculture site. The salinity varies from 0 ppt to 20 ppt. The temperature varies over the year from 4 to 25°C.

b) overflow water from the cooling circuits D1 and D2 (in case of emergency).

c) water from the outlet of the condensor (primarily used at an aquaculture facility), at about 100 m of the aquaculture site. 5 000 m^3 can be supplied by gravity.

An appropriate mixing of these three water types allows an optimum rearing temperature the whole year round.

2. the absence of a short circuit between intake water and the effluent water of an aquaculture facility.

Considering the discharge of effluent water from an aquaculture facility :

1. the dikes along the river Scheldt, as well as the effluent canals at the nuclear site, are raised up to +12 m to prevent overflow of the nuclear site. Discharging effluent water in the discharge canals of the nuclear power station has to be negotiated with the responsables of the nuclear power station.

2. from the environmental point of view, when discharging the brackish effluents of an aquaculture facility constructed outside the nuclear site in surface waters, the general regulations for discharging water have to be followed (VLAREM I and II). Licenses for discharging effluents are to be treated by the Environmental Licenses Board (Administration for the Environment, Nature and Land Use).

c) Pollution sensitivity.

The generation of electrical energy in both nuclear and conventional power stations requires copious quantities of cooling water, since it must be possible to dissipate 2/3 of the thermal output during the production process. If this cooling water is not subject to any quality requirement, it is drawn directly, and untreated, from the surface water. Some of the organisms which have their habitat in this surface water find the pipelines and channels of the cooling circuit to be an ideal environment (suitable temperature, oxygen concentration, etc.) in which to establish themselves and reproduce. These are the cause of biofouling.

Two types of biofouling can be distinguished. The first type is caused by micro-organisms which attach themselves to the walls of the condenser, where they form a slimy deposit. Subsequently, macroscopic fouling organisms find this slime layer to be an ideal environment on which to establish themselves.

Fouling is combated preventively and curatively using a combination of chlorine, biofilm wetting agent and dispersing agent. This treatment of the cooling circuits, depending on the season applied every two weeks up to every month removes the fouling and keeps the cooling circuits free of organisms.

Considering the water supply conditions to an aquaculture facility during treatment of one of the cooling circuits it should be mentioned that as well water from the outlet of the condensor of Unit Doel 3 as water from the outlet of the condensor of Unit Doel 4 can be used separately. When one of the circuits is treated, the aquaculture facility can be supplied with water from the not treated circuit. As a safety measurement automatic monitoring of incoming water for chlorine detection during cooling circuit treatment will be necessary.

3.3.9. The experimental aquaculture project at Doel.

At the initiative of ELECTRABEL (Electricity Producing Company), GIMV (Investment Company for Flanders), K.U.Leuven Research and Development and the Laboratory for Ecology and Aquaculture of the University of Leuven, research started in 1983 to investigate the possibilities for aquaculture in the thermal effluents of the power station at Doel.

A pilot plant using cooling water from the power plant was constructed. Since the cooling water used is brackish water from the river Scheldt, several trials with euryhaline species (i.e. seabass, seabream, eel) showing promising market perspectives have been conducted.

The first period of the research project (1983-1986) was focused on the exploration of the possibilities at Doel. During this period the goals were :

- to select the candidate species for intensive culture taking into account growth, the economical interest and the adaptation at the culture conditions at Doel,
- to determine the biotechnical characteristics,
- to evaluate the demands towards a technical installation,
- to gain experience with intensive aquaculture activities.

In view of the research efforts and the high market value in Mediterranean countries, research at Doel was focused on the culture of the European seabass (*Dicentrarchus labrax*). In 1986 the pilot plant at Doel was optimized (water supply and aeration). During the next period (1987-1991) research was focused on maximizing production capacity and rentability :

- the water quality was evaluated in detail,
- the intensive rearing technology of seabass (*Dicentrarchus labrax*) was revealed,
- the maximum production capacity of the pilot installation was evaluated by application of appropriate rearing schedules and high rearing densities.

a) Fish species cultured at Doel.

During the first research period (1983-1986) several potential fish species were cultured. In view of the existing market in Belgium and its natural appearance in the river Scheldt near Doel, trials with eel (*Anguilla anguilla*) were carried out, as well as trials with sea- bass, seabream, trout, catfish, exotic carp species and sturgeon.

In the second period of the research period (1987-1990) the ongrowing of seabass (*Dicentrarchus labrax*) was intensively researched. Considering the experiments with other fish species, seabream and sturgeon culture is applicable at Doel.

b) Intensive culture of seabass.

Under natural conditions seabass juveniles migrate from coastal waters into estuaries attracted by local favourable conditions, i.e. higher water temperature and food supply. Wild seabass juveniles are frequently observed in catches at the river Scheldt what makes it a species well adapted to the water quality conditions encountered in the river near Doel. The optimum temperature for seabass growth is about 22°C to 24°C. Under these temperature conditions and supplied with a high-energetic food that completely covers the nutritional needs of the cultured fish, seabass attains a marketable weight (350 g) in 19 to 21 months.

The culture of seabass started with juvenile seabass fry, having an average weight of 1.3 to 9.5 g and obtained from the Laboratory for Ecology and Aquaculture (University of Leuven) or from French commercial hatcheries (AQUANORD, Gravelines).

During the research period, seven culture cycles with sea bass were completed. In the first period (26/10/84 to 9/12/86) seabass grew from 4 g to 360 g over a period of 25 months. Food conversion ratio was 3.0 on a dry weight base, while specific growth rate varied between 1.2 for the smallest and 0.2 for the largest fishes. The average specific growth rate over the whole period was 0.6. The daily food ratio varied between 1% and 2.5% of the total body weight depending on the fish size and the water temperature. The stocking density obtained at the end of the experiment was 31 kg/m^3.

In the second period (1987-1990) 6 batches of sea bass were grown up to a marketable size (350 g) in 19 to 21 months. Under the culture conditions at Doel, seabass reach a marketable size of 350 g in 19 to 21 months depending on the weight at the start of the ongrowing cycle. The overall specific growth rates (% weight increase/day) to grow the different batches from start to end weight vary from 0.592 to 0.800. The mean specific growth rate of the different growth stanza is the highest (2.2%/day) for seabass juveniles between 1 and 5 g. With increasing fish weight the specific growth rate decreases to 0.21%/day for fishes in the growth stanza between 300 to 400 g. Detailed zootechnical data of sea bass culture are mentioned in section 4.2.

c) Production capacity and performances.

During the research period 1989-1990 the goal of the project was to evaluate maximum capacity and rentability of the pilot plant. During 1990 the overall stocking density at the pilot plant varies from 22.5 kg/m^3 to 30.7 kg/m^3. The biomass production in 1989 is 21.5 kg/m^3 and 29.9 kg/m^3 in 1990. The maximum stocking densities obtained in the rearing tanks reach 60 kg/m^3. A summary of the input/output data for the experimental plant during 1989 and 1990 show overall yearly food conversions of 2.4 to 2.7. The sea bass produced was sold to local wholesalers at 580,- Bef. ex-farm. The production results, in relation to the available rearing volume, are comparable with the performances of other industrial aquaculture facilities with comparable culture conditions.

Conclusions.

The frequent occurrence of seabass on the river Scheldt and the results of 8 years of experimental work indicate the **suitability of using thermal effluents of the nuclear power station at Doel for seabass culture**. Using different sources of water, optimum culture temperature conditions can be maintained in order to grow up seabass with an **economically acceptable growth rate**. A marketable size (350 g) is reached in 19 to 21 months.

Using a pelleted food covering the nutritional requirements of seabass, overall food conversions of 2.4 to 2.7 are obtained. As the production schedules were optimized, fish densities in the culture tanks can attain 60 kg/m^3 in order to produce 30 kg/m^3 per year.

Since those results are **comparable with the performances of industrial aquaculture plants** with comparable culture conditions, the intensive culture of seabass at commercial scale (**flow through or recirculation system with heat exchange**) at Doel is worthwhile to be considered.. Production can possibly be enhanced in a recirculation system (with heat exchange) due to a better control of environmental conditions, i.e. water temperature.

The **experience with intensive aquaculture** gained during the consecutive years of research at Doel **can be used in other intensive aquaculture project located elsewhere** under comparable environmental conditions.

Other potential species for being cultured at Doel are sea bream and sturgeon.

The **important advantages** of an aquaculture site at Doel are :

- the possibility to culture seabass, seabream and sturgeon,
- the presence of a leveled site,
- the possibility to obtain cooling water directly from the cooling circuits and to supply it by gravity to the aquaculture site,
- during winter periods, the cooling water has a minimum temperature of 20°C,
- the possibility to discharge the effluent water by gravity to the river Scheldt,
- the absence of the return of effluent water of an aquaculture facility to the water intake structures at the river Scheldt, reducing the sanitary risks,
- the agreement of ELECTRABEL and K.U.Leuven to co-operate in an industrial aquaculture application,
- the experience of 8 years with an experimental pilot plant showing excellent production performances.

The **disadvantageous drawbacks** for an aquaculture project at Doel are :

- the absence of the possibility to culture turbot, due to the low salinity during winter periods,
- the absence of a suited water source to supply a hatchery,
- the security measures to prevent overflow of the nuclear site, resulting in high investment cost to supply and discharge high amounts of water to and from an aquaculture plant.
- the incorporation of righting cost in the financial plan, hypothecating the feasibility of an aquaculture project at the nuclear site.
- the environmental considerations and water supply investments when constructing an aquaculture facility outside the nuclear site.

3.4. Site No 4 : Geothermical salt water.

Introduction

The temperature of the earth increases, i.e. in mines, with depth. In Flanders this increase is about 3°C per 100 m and is called the geothermal gradient.

Valorizing the heat of the earth is only possible by bringing it to the surface by mean of a carrier. Water is most appropriate to function as a carrier and is available in certain rock-formations in the subsoil.

The existence of such a reservoir in the cretaceous layers of the Viseaan (Under-Karbon) has been proved at different locations in the Antwerpse Kempen (Turnhout, Poederlee, Loenhout,...)(figure 15). Since at Merksplas (Beerse) this reservoir is found at a sufficient depth, it could be interesting to valorize the geothermal heat and evaluate the possibilities for aquaculture.

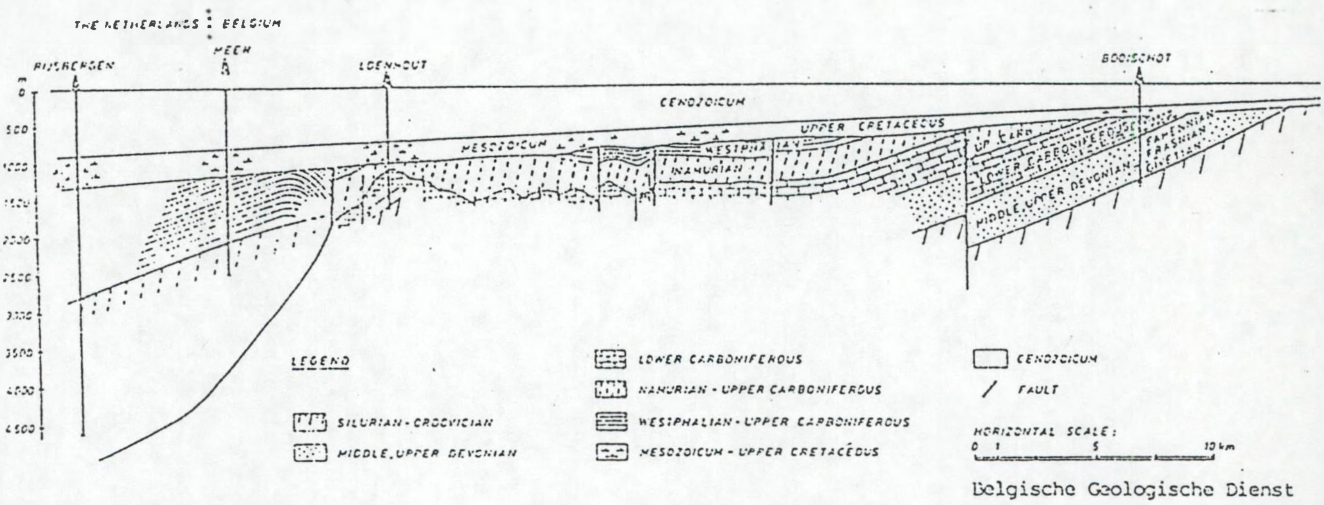


Figure 15 : Geological North-South section from the border of the Netherlands up to the center of Belgium.

A. The availability of geothermal water at Merksplas.

At the initiative of GOM-Antwerpen and the Belgian Geological Office a feasibility and rentability study of a geothermal plant has been carried out in 1987. As a part of the study the geothermal water properties were determined in detail. In figure 16 it is shown that the cretaceous layers at Merksplas (Beerse) are found at a depth of 1 636 m. The geothermal water has a temperature of 75°C and is pumped at a flow rate of 75 m^3/h. The cooled water (32°C) is reinjected at 700-800 m. The reinjection of the cooled water is necessary since it is a brine. The salinity reaches up to 135 g salt per liter, almost 4 times the salinity of seawater. The geothermal well is a property of the state.

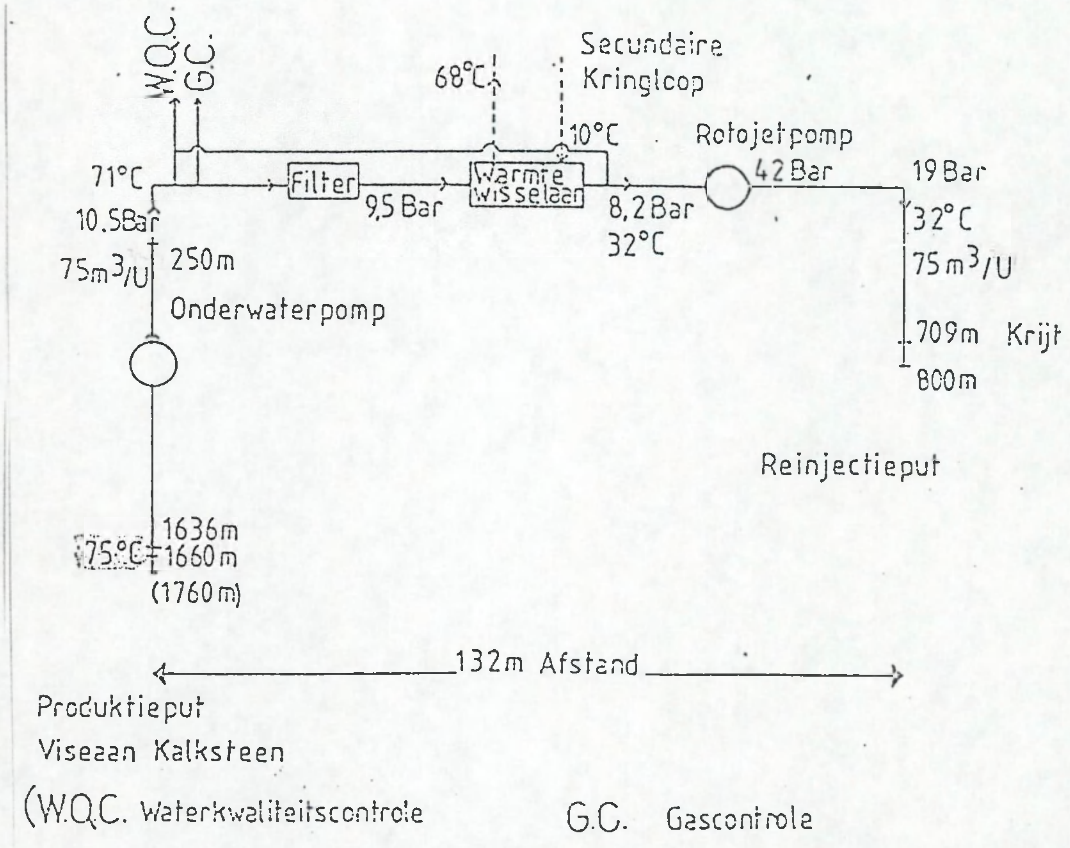


Figure 16 : The geothermal water circuit with heat exchanger to valorize the geothermal heat.

B. Water quality properties.

In order to evaluate the possibilities for marine aquaculture the water quality properties of the geothermal brine itself, obtained in the 1987 tests, are studied.

a) Temperature range.

The temperature of the brine water at the wellhead is 72°C. The temperature can be considered as a constant.

b) Salinity range.

The salinity (sodium chloride) of the brine water reaches 120 g/l. The total dissolved solid contents is constantly high and varies around 130 to 147 g/l dried at 105°C. The dry residue is mainly composed of sodium, calcium and potassium chloride, with presence of magnesium and sulphate ions. Detailed chemical and physical analysis results of the brine are mentioned in table 4. The ion composition of the brine (Na/Mg, Ca/Mg, Na/K, Na/Cl) doesn't reflect the ion composition of natural seawater.

ELEMENT	CENTRAL Laboratory (Min.Economic Affairs)							Core Lab (Scotland)	Labofina	Labofina
	Airlift 6.6.87 15hr20 after 1 hr	Airlift 6.6.87 17hr20 after 3 hrs	Airlift 6.6.87 23hr55 after 10hrs	Airlift 7.6.87 10 hr after 20hrs	ESP 8.6.87 02hr20 after 1 hr	ESP 8.6.87 04hr30 after 2hrs	ESP 8.6.87 07hr30 after 5hrs HCl treatm.	ESP 8.6.87 05hr30 after 3 hrs	ESP 8.6.87 08hr30 after 6Hrs	Downhole sample at 772 m 16.6.87
Na^+ (mg/l)	4020	4730	5120	5070	5050	5070	5090	5370	5004	6100
K^+ (mg/l)	85	91	92	93	93	93	93	93	225	245
Mg^{++} (mg/l)	135	160	178	176	176	176	176	190	181	306
Ca^{++} (mg/l)	500	300	230	214	228	230	232	235	228.9	337.3
cations(mg/l)	214	238	252	249	249	249	---	263	---	---
HCO_3^- (mg/l)	210	340	420	400	440	440	---	455	445.3	355
Cl^- (mg/l)	7020	7960	8310	8430	8410	8410	8360	8390	8500	9800
F^- (mg/l)	---	---	3.9	---	---	---	4.3	---	---	---
$SO_4^=$ (mg/l)	375	433	489	493	475	491	483	485	486	379
anions(mg/l)	209	239	251	255	254	254	---	254	---	---
Ba (mg/l)	---	---	0.09	---	---	---	0.085	0.3	0.068	0.272
Sr (mg/l)	25	27	28	28	28	28	30	31	30.31	42.62
Fe (total)	---	---	7	---	---	---	13	9.3		
Fe(dissolved)	---	---	---	---	---	---	---	<0.02	0.037	0.040
Carbonate	---	---	---	---	---	---	---	Nil	Nil	Nil
Hydroxide	---	---	---	---	---	---	---	Nil	Nil	Nil
B (mg/l)	---	---	5.2	---	---	---	0.056	8.6		
Al (mg/l)	---	---	3.1	---	---	---	3.1	<0.2		
Si (mg/l)	---	---	---	---	---	---	---	7.5		
P (mg/l)	---	---	0.44	---	---	---	0.39	<0.06		
Pb (ug/l)	---	---	40	---	---	---	<20	---		
Cd (ug/l)	---	---	15	---	---	---	10	---		
Cu (ug/l)	---	---	120	---	---	---	140	---		
Zn (ug/l)	---	---	565	---	---	---	50	---		
Mn (ug/l)	---	---	250	---	---	---	65	---		
Cr (ug/l)	---	---	7	---	---	---	<4	---		
Mo (ug/l)	---	---	65	---	---	---	160	---		

Table 4 : The chemical analysis results of the Merksplas brine (1987).

c) Colour, particle count and precipitation.

The original brine appears as a crystal clear water and becomes slightly pale yellow at laboratory observation, which indicates oxydizing phenomena.

The particle count and the determination of size and distribution, as shown in table 5 and analysed with coulter counter, indicates that about 74 to 90% are concentrated in the small size, inferior to 2 micron. The maximum total count is 2.6 10^6 particles/ml solution brine. Particles larger than 4.5 micron were not found.

CRETACEOUS WATER - MERKSPLAS II

Particles diameter size (μ m)	Water pumping	Pressure cylinder 772m	Airlift	Airlift + Hcl
1.00 - 1.25	42.11%	82.29%	46.34%	66.7%
1.25 - 1.50	23.82%	12.50%	20.73%	16.7%
1.50 - 2.00	21.88%	3.13%	19.51%	16.7%
2.00 - 2.50	8.03%	2.08%	7.72%	-
2.50 - 3.00	3.05	-	3.25%	-
3.00 - 3.50	0.83	-	1.22%	-
3.50 - 4.00	0.28	-	0.81%	-
4.00 - 4.50	-	-	0.41%	-
Total particles */ ml solution	912.000	3.429.500	2.337.000	57.000

* Average value on three tests

Table 5 : Particle count on brine water.

d) pH

The continuous pH monitoring during 24 days shows a rather stabilized pH curve. The average value is 5.7. The values found in the early stage of the test may correspond to the impurity of the brine. The difference of the pH value in the upstream (hot side) and the downstream (cold side) is relatively small and may be affected by the temperature, pressure and the dissolved carbon dioxide (figure 17).

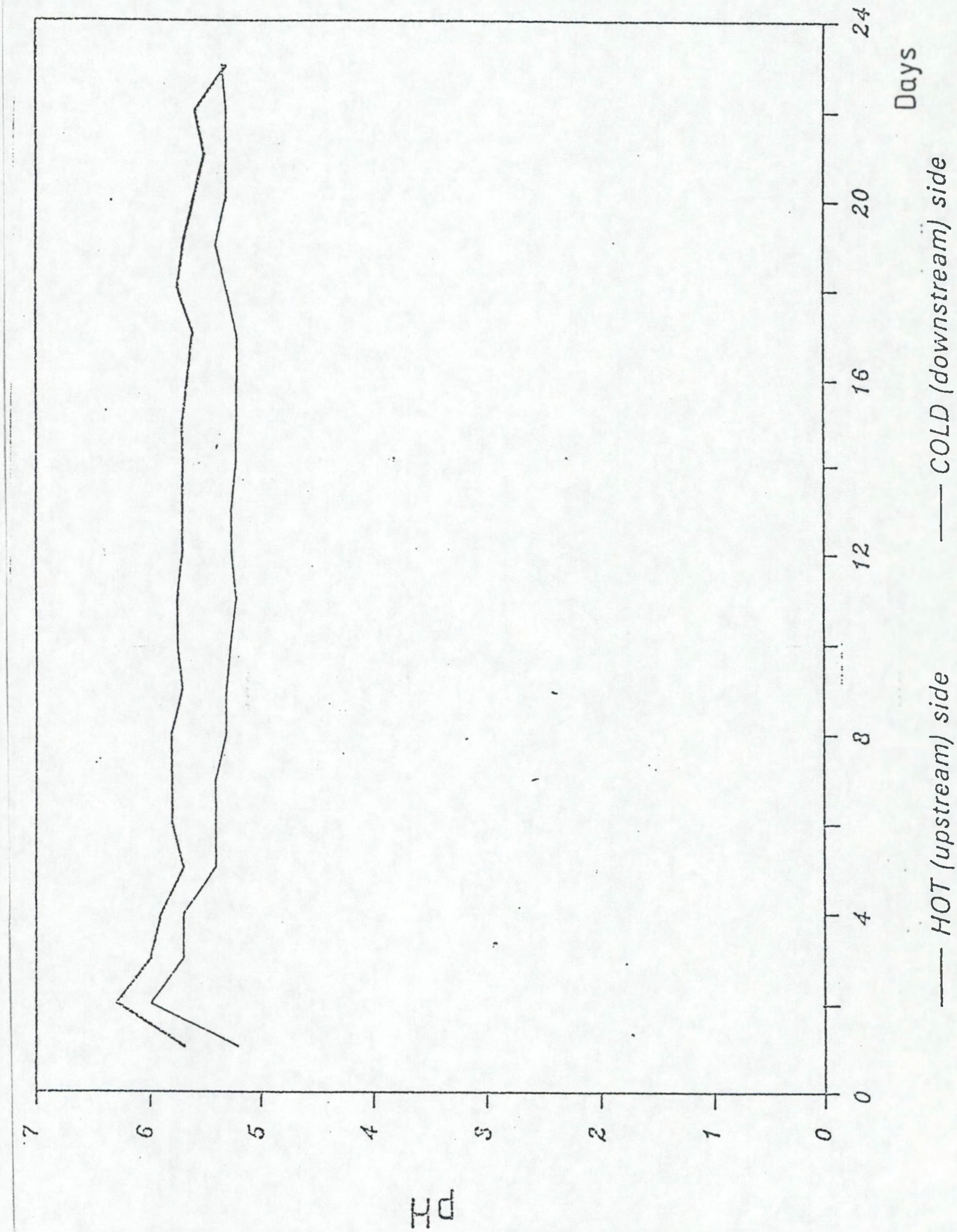


Figure 17 : pH value of the brine water during a continuous water quality monitoring program over 24 days.

e) The dissolved gases.

1° The dissolved oxygen.

The dissolved oxygen concentration of the brine is low. The geothermal brine reaches a stable oxygen content of less than 20 ppb. In the early stages of the monitoring program the oxygen level on the downstream line shows high readings in comparison with the upstream level, probably due to leakage of the closed piping system.

2° Other dissolved gases.

The analysis of dissolved gases during the monitoring program shows the presence of oxygen (O_2), nitrogen (N_2), methane (CH_4) and carbon dioxide (CO_2). The results show a constantly read of CO_2 >50% during the test period (table 6). H^2S was not detected in any tested sample.

Description	wellhead 11 bars 70°C		downstream 9 bars 31°C	
	mol %	mg/l	mol %	mg/l
O_2	0.6422	2.915	0.7267	3.279
N_2	29.5529	117.414	26.2425	103.659
CH_4	18.4130	41.895	16.5534	37.446
CO_2	51.3919	320.775	56.4774	350.478
GLR (m3/m3)	0.317		0.315	
Mol mass (kg/kmol)	34.056		35.095	
Density	1.216		1.180	

Table 6 : The analysis of dissolved gases in the brine.

f) Bacteriological contents.

The microbiological analysis of brine samples on different days show one positive detection at July 7th 1987 when neglectible amounts of sulphate reducing bacteria (30 colonies/ml) were detected. No more bacteries have been found both on the sample at the wellhead of the high temperature side as well as on the low temperature side in the samples of July 10th (table 7). The native brine is probably free from bacteria in the closed system.

	Water pumping	Pressure cylinder 772m	Airlift	Airlift + Hcl
Total bacteria	10^6	$< 10^3$	10^6	nd
Gram -	10^5	$< 10^3$	10^6	nd
Pseudonomas	nd	nd	nd	nd
Yeast	nd	nd	nd	nd
Fungi	nd	nd	nd	nd

Table 7 : Bacteriological analyses of brine water (colonies/ml).

C. Restrictions and regulations.

From the environmental point of view, discharging the effluents of an aquaculture facility using geothermal brine will create environmental problems. For fish farm effluents the general regulations for discharging water have to be followed (VLAREM I and II). Licenses for discharging effluents are to be treated by the Environmental Licenses Board (Administration for the Environment, Nature and Land Use).

D. Examination of soil characteristics, topography and human activities.

Based on the water quality characteristics, the possibilities for aquaculture using the geothermal brine can be evaluated. In this regard no further examination of the site was carried out.

E. Final evaluation.

Looking at the water quality properties of the brine water, aquaculture applications will demand a dilution of the brine in order to bring the salinity and the temperature of the water at an acceptable level.

The effect of gases (i.e. CH_4) on cultured organisms, even after treatment of the water (degassing), is yet not predictable. In an aquaculture installation, the carbon dioxide release caused by degassing can cause serious precipitation and scaling problems. The dissolved oxygen concentration of the brine is low and an oxygenation of the diluted brine will be necessary for aquaculture application.

The waterflow of the excisting well will only be sufficient to supply a marine hatchery. However, the water quality will not allow rearing the extremely vulnerable marine larval fish species and/or the live food species. The ion composition of the brine (even after dilution) does not reflect the ion composition of natural seawater.

Based on water quality properties, it can be stated that it will be questionable using geothermal brine for aquaculture applications. However, only a small scale, short term rearing/survival test can give a decisive answer.

Getting an effluent discharge permission for an aquaculture facility using the brine will be problematical due to either the high salinity (when discharged in surface water) or the nutrients (when reinjected into the soil).

Using artificial seawater in a secondary circuit heated by heat exchange is not considered since the rentability would not allow such an aquaculture project.

3.5. Site No 5 : Power plant (?) - Logistic facilities.

Introduction

Since a few years ELECTRABEL (Private Electricity Producing Company) and SPE (Public Electricity Producing Company) have the intention of constructing two electricity production units at the industrial site in the backport of Zeebrugge (figure 18). The project "Centrale-Zeebrugge" consists of :

- a conventional coal unit with a net electrical capacity of 750 MW,
- a combined gas- and steam turbine-unit (STEG unit) with a net electrical capacity of 460 MW.

To cool the steam circuits, the power plant will make use of seawater obtained in the outport and will discharge the cooling water again in the backport of Zeebrugge.

The proposed project at Zeebrugge, with a continuous availability of a vast amount of marine cooling water, offers a lot of opportunities with respect to intensive aquaculture with marine organisms. The implementation of an aquaculture project from the designing stage of the electricity plant on could for instance reduce water supply investments to an aquaculture plant. In regard to the proposed electricity plant the water quality criteria of seawater at the outport of Zeebrugge are studied.

During the study of screening potential aquaculture sites the ultimate permission to construct the power plant was not yet obtained from the authorities.

3.5.1. Tidal range at Zeebrugge.

The outport at Zeebrugge is influenced by the tides at sea. The mean minimum tide is 0.51m T.A.W., the mean maximum tide is 4.19m T.A.W..

Influences of marine tides in the backport are prevented by the Vandamme seasluice. The waterlevel in the docks and the "Boudewijnkanaal" is situated at 375 cm Hz.

The water quantity control in the backport is mainly dominated by the ship traffic through the Vandamme seasluice, allowing seawater to flow inland, and the freshwater flow via the "Boudewijnkanaal", coming from Brugge and its seawage plant, creating a brackishwater environment in the backport at Zeebrugge.

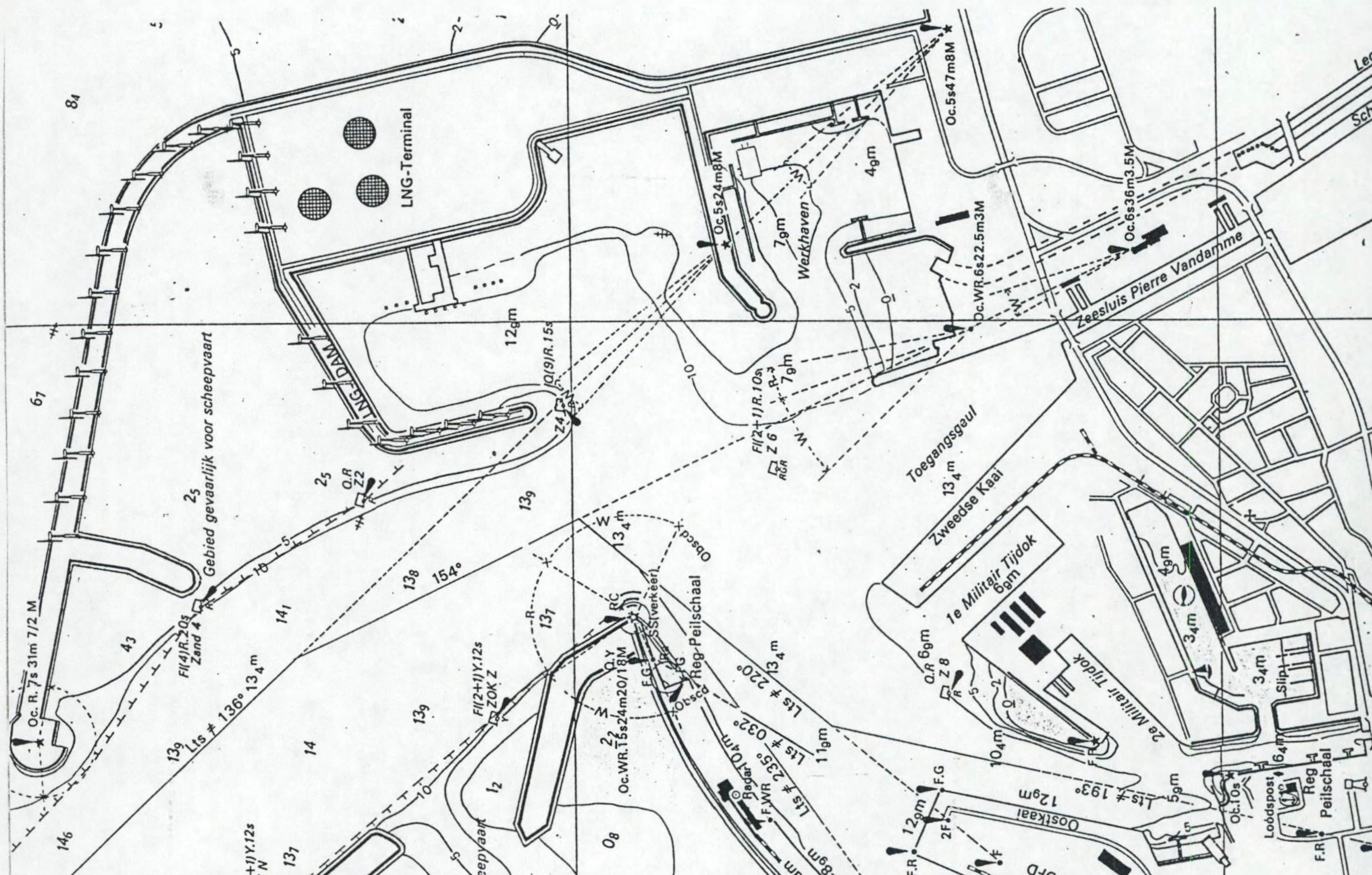


Figure 18 : Site location.

3.5.2. Physical water quality at the outport.

A. Temperature range.

Mean monthly seawater temperature near Zeebrugge from 1988 to 1992 is shown in figure 19. To reduce heating costs, an aquaculture facility should use a cheap heating source to warm up the seawater to an appropriate temperature during cold periods.

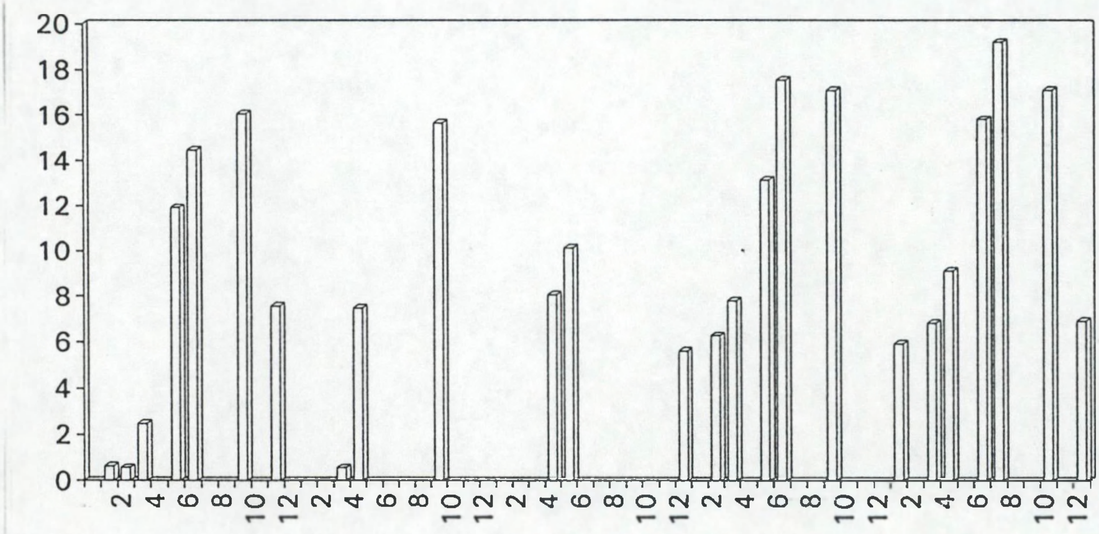


Figure 19 : Mean monthly temperature of the seawater at Zeebrugge from 1988 to 1992 registrated nearby the coast.

Mean monthly seawater temperatures registrated from the lightvessel West-Hinder at a distance from the coast of about 20 nautical miles are shown in figures 20 and 21. It is clear that these mean monthly temperatures of the seawater fluctuates considerably over the year. Minimum mean monthly seawater temperature recorded during January and February is 3.6°C (February 1987), the maximum mean monthly temperature is 9.1°C (January 1990) (Figure 20).

Minimum mean monthly seawater temperature recorded during July and August is 14.6°C (July 1978), the maximum mean monthly temperature is 19.3°C (August 1990) (Figure 21).

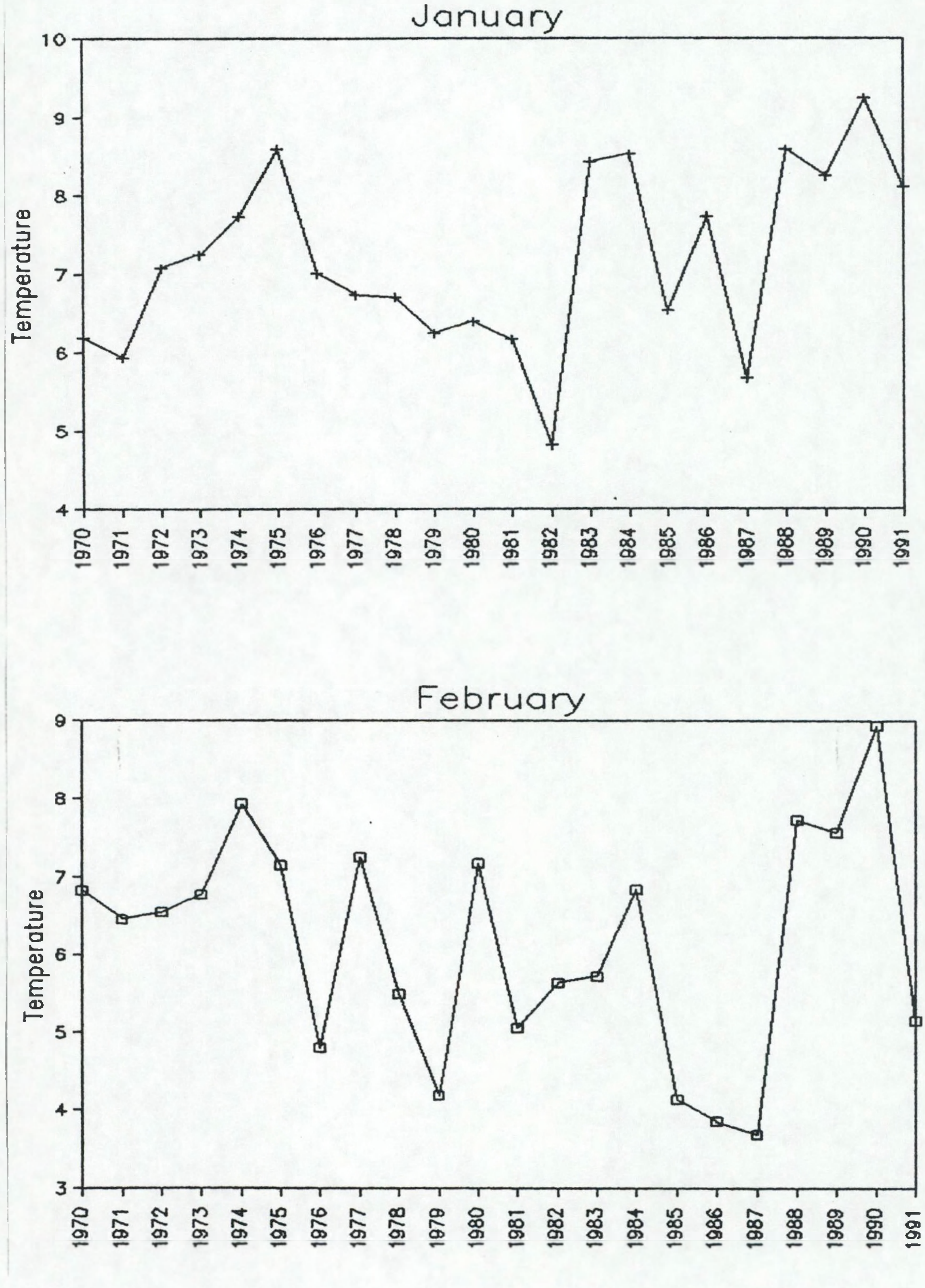
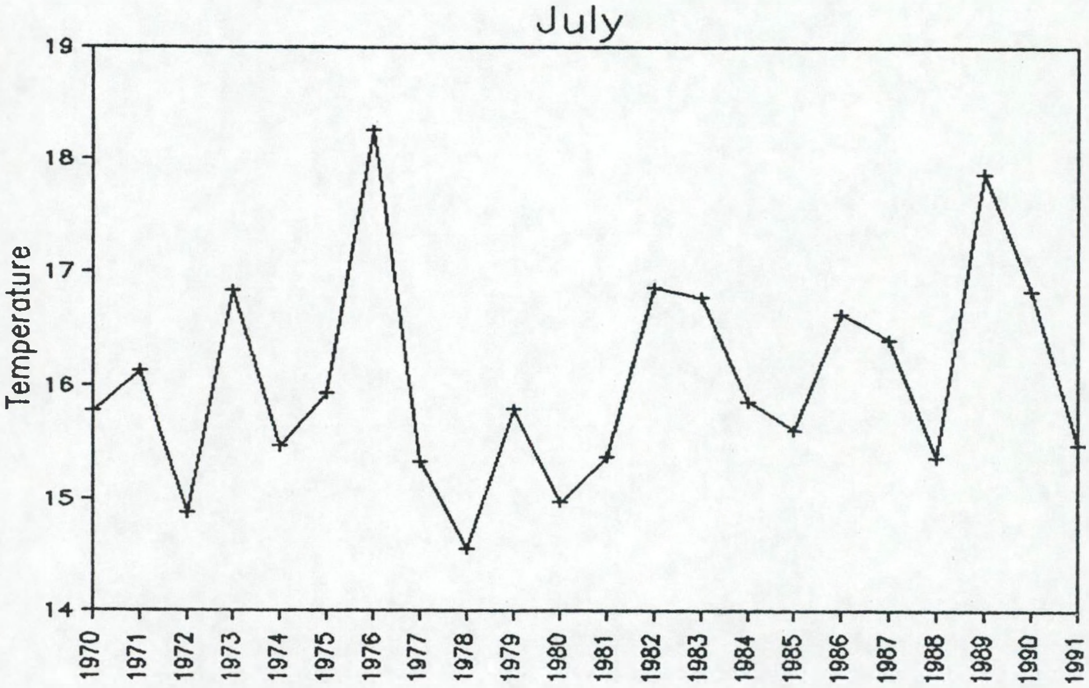


Figure 20 : Mean monthly temperature of the seawater in January and February registrated at the lightvessel West-Hinder.



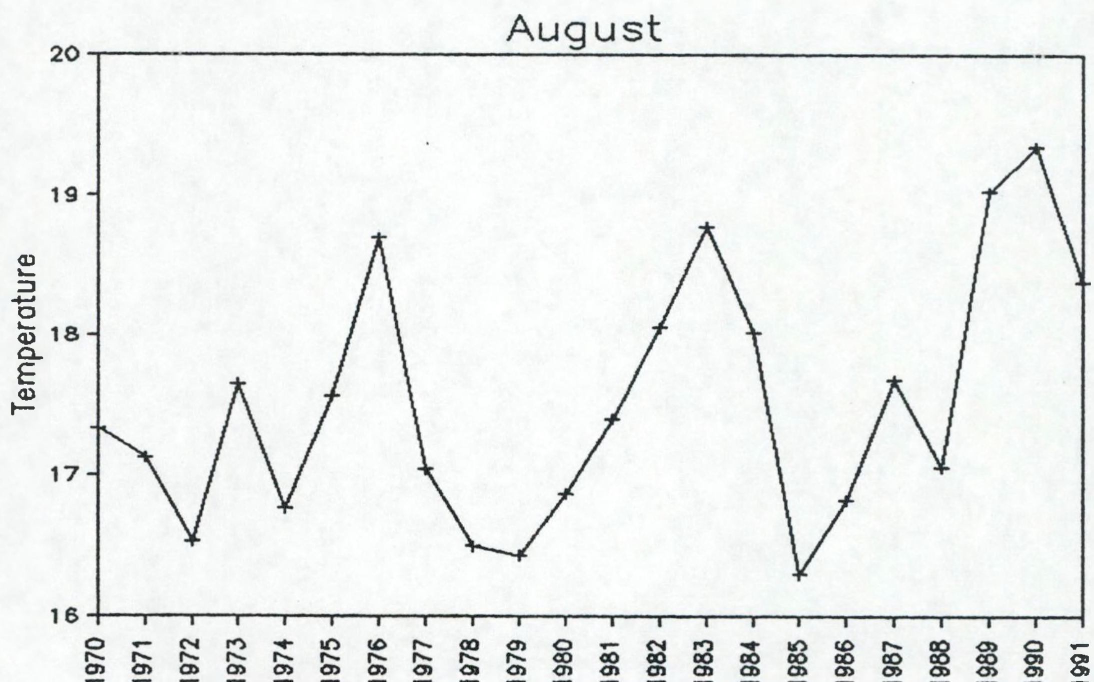


Figure 21 : Mean monthly temperature of the seawater in July and August registrated at the lightvessel West-Hinder.

B. Salinity range.

The salinity of the seawater at Zeebrugge is fairly constant with minor fluctuations between 29 and 34 ppt. Mean monthly salinity data from 1988 to 1992 are shown in figure 22. The stability of the salinity and the full strength seawater allow marine hatchery, nursery and on-growing aquaculture activities.

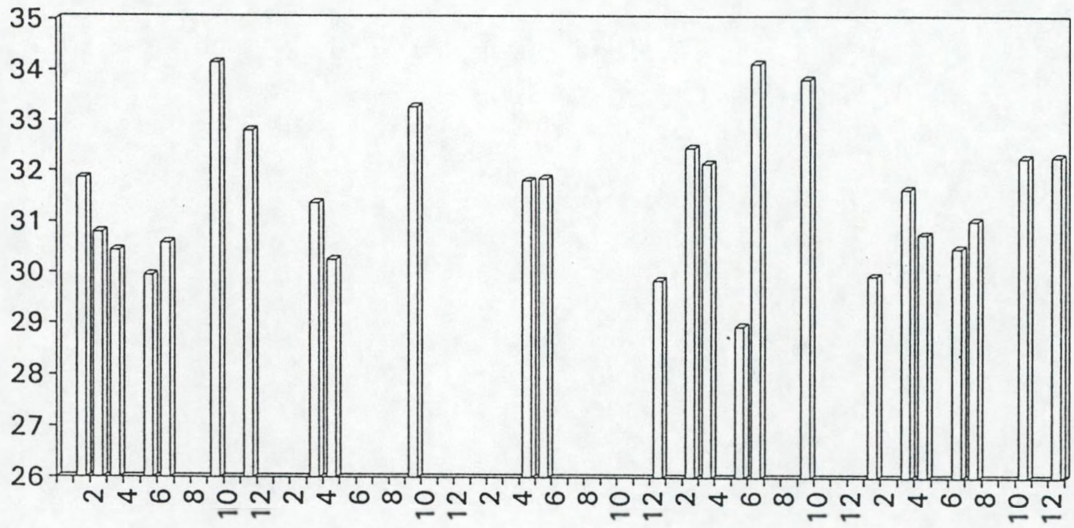


Figure 22 : Mean monthly salinity of the seawater at Zeebrugge from 1988 to 1992.

3.5.3. Chemical water quality at the outport.

A. Total ammonium.

Ammonium, especially the un-ionized ammonia, entering water systems from a.o. industrial wastes, sewage effluents and agricultural input, can be a serious toxicant to fishes.

In the outport total ammonium concentrations are low. Mean monthly total ammonium concentrations are shown in figure 23. The minimum mean monthly total ammonium concentration is 2 μM/l (April 1992), the maximum mean monthly total ammonium concentration is 40 μM/l (May 1990).

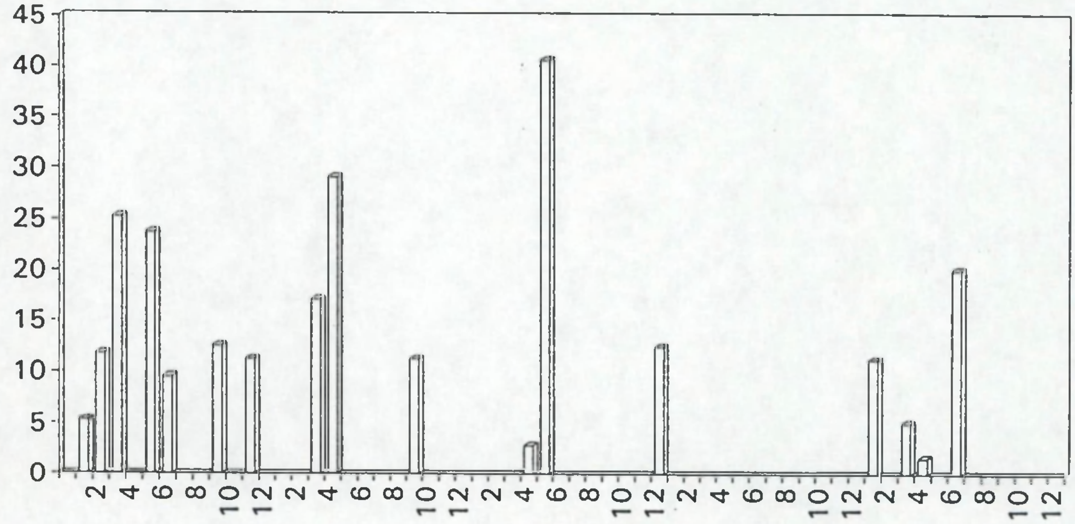


Figure 23 : Mean monthly total ammonium concentrations of the seawater at Zeebrugge from 1988 to 1992.

B. Nitrate.

In the seawater near Zeebrugge the minimum mean monthly nitrate concentration recorded is 1 μM/l, the maximum mean monthly nitrate concentration recorded is 78 μM/l. The mean monthly nitrate concentrations at Zeebrugge are shown in figure 24.

Nitrate is less harmful to fish species and the recorded nitrate concentrations will not interfere with aquaculture activities.

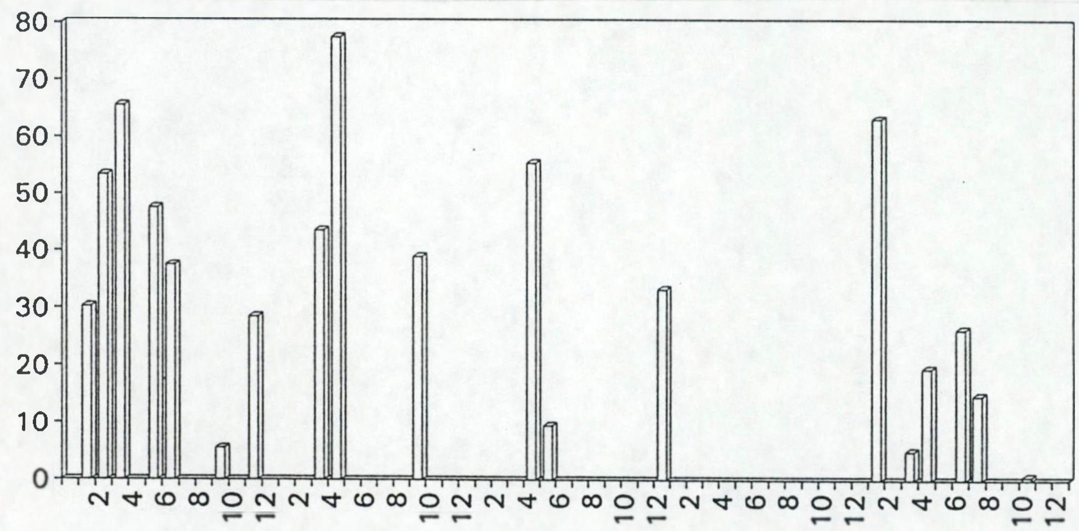


Figure 24 : Mean monthly nitrate concentrations of the seawater at Zeebrugge from 1988 to 1992.

C. Silicate.

In the seawater near Zeebrugge the minimum mean monthly silicate concentration recorded is 1 μM/l, the maximum mean monthly silicate concentration recorded is 23 μM/l. The mean monthly silicate concentrations at Zeebrugge are shown in figure 25.

Silicate is less harmful to fish species and no interference with aquaculture activities is to be expected.

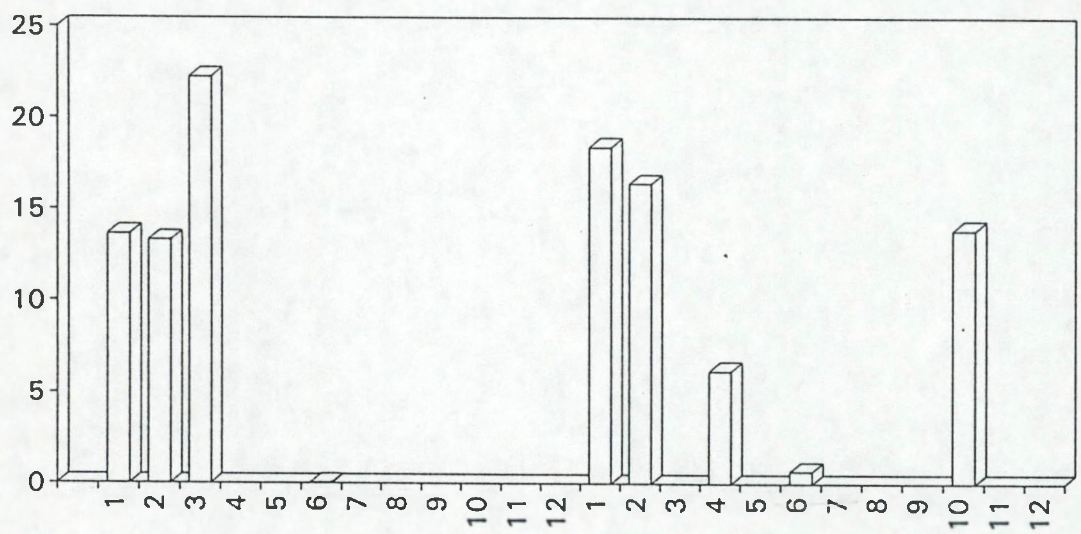


Figure 25 : Mean monthly silicate concentrations of the seawater at Zeebrugge from 1988 to 1992.

D. Phosphate.

In the seawater near Zeebrugge the minimum mean monthly phosphate concentration recorded is 0.2 μM/l, the maximum mean monthly phosphate concentration recorded is 3 μM/l. The mean monthly phosphate concentrations at Zeebrugge are shown in figure 26.

The phosphate concentrations in the seawater near Zeebrugge are low and no interference with aquaculture activities is to be expected.

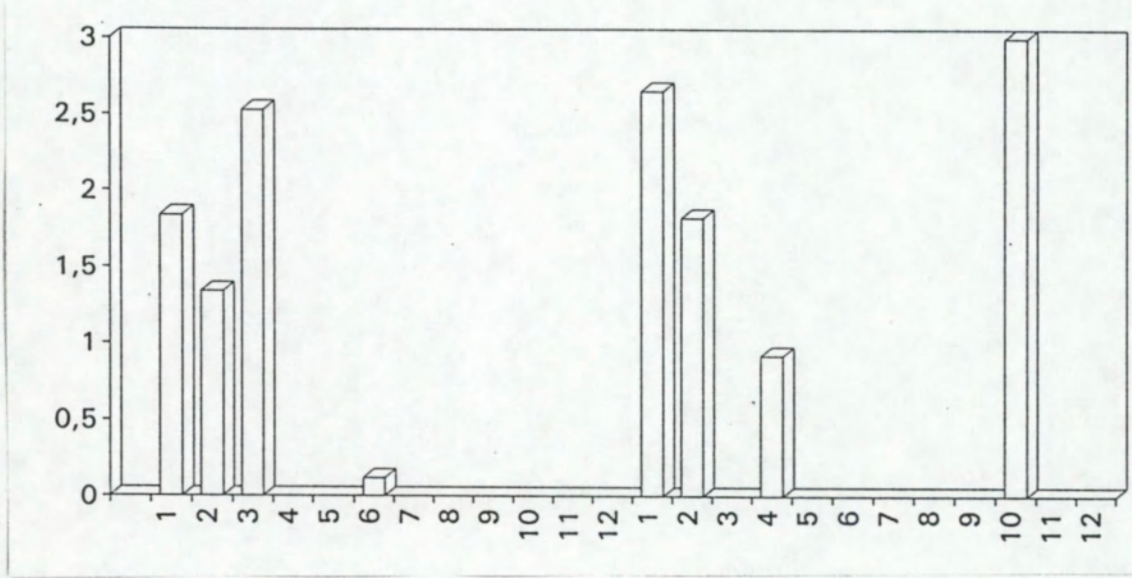


Figure 26 : Mean monthly phosphate concentrations of the seawater at Zeebrugge from 1988 to 1992.

E. pH

pH of the seawater in the outport varies around 8.00.

F. Disolved oxygen.

In the outport the dissolved oxygen concentration is >5mg/l.

3.5.4. Water quality of the backport of Zeebrugge and the Boudewijnkanaal.

The implantation of an electricity plant more inland (i.e. near Brugge, 8 km or more inland) should also be considered. An electricity plant situated more inland will probably use water of the backport of Zeebrugge or water of the Boudewijnkanaal as cooling water. In view of the possibilities for aquaculture the water quality characteristics from the backport and the Boudewijnkanaal can be compared with those of outport water in table 8.

parameter		1,2,5	3,4	6,7,8	11 tem 16
temperatuur	°C	19.16	18.88	18.24	17.73
zuurstof	mg/l	6.88	5.12	7.49	6.72
geleidbaarheid	µS/cm	32173	29183	32289	35478
zuurtegraad	-	8.03	7.86	8.09	8.00
COD	mg O2/l	26.27	30.17	28.33	18.62
BOD	mg O2/l	4.26	4.61	3.67	1.93
fosfaat	mg PO4/l	1.45	1.90	1.24	0.33
nitraat	mg N/l	1.12	0.90	1.47	1.18
ammoniak	mg N/l	0.54	1.61	0.40	0.22
Kjeldahl	mg N/l	1.16	2.20	1.85	0.41
chloride	mg/l	15256	14034	15206	17394
sulfaat	mg/l	2111	1961	2108	2417
bez. stof.	ml/l	0.10	0.10	0.15	0.10
zwev. stof	mg/l	105.00	94.50	89.94	77.21
cadmium	mg/l	0.062	0.053	0.060	0.063
koper	mg/l	0.000	0.000	0.001	0.000
lood	mg/l	0.407	0.348	0.364	0.381
zink	mg/l	0.093	0.355	0.105	0.081

Table 8 : Water quality characteristics at the backport of Zeebrugge (1,2,5 and 6,7,8), at the Boudewijnkanaal (3,4) and at the outport (11-16).

The chloride concentration of the Boudewijnkanaal varies between 13 and 16 g/l. At the backport chloride concentrations vary between 14 and 18 g/l, at the outport between 17 and 18 g/l. At the Boudewijnkanaal conductivity is higher than 25 000 µS/cm and increases with depth due to the inland penetrating salinity gradient at the bottom of the canal (salination). At the backport the conductivity varies from 30 000 to 40 000 µS/cm. In the outport conductivity of the water is situated around 35 000 µS/cm with a maximum of 40 000 µS/cm.

The salinity of the Boudewijnkanaal is about 80-90% of seawater and allows marien aquaculture (supposed that the salination of the Boudewijnkanaal is not altered in the future).

Water quality analyses at Zeebrugge and at the Boudewijnkanaal date from the summer of 1991. Natural water temperature varies around 18-19°C.

Dissolved oxygen near the Vandamme seasluice (6, 7, 8) and in the backport (1, 2, 5) is rather high due to the sluicing of water. The D.O. in the Boudewijnkanaal decreases considerably more upstream.

PH of the water varies between 7.5 and 8.5.

The chemical pollution (COD) increases upstream at the Boudewijnkanaal. COD varies between 10 and 50 mg O_2 /l and is comparable with the COD in the backport.

The organical pollution (BOD) is rather low and varies between 1 and 8 mg O_2 /l at the outport, the backport and the Boudewijnkanaal.

Ammonium nitrogen concentration at the Boudewijnkanaal can reach a maximum of 3 mg N/l. At the backport ammonium nitrogen concentrations are lower than 1 mg N/l. At the outport ammonium nitrogen concentration is always lower than 0.5 mg N/l.

In VMM reports (Flemish Environmental Control Company) of 1991 the water quality of the Boudewijnkanaal is estimated as polluted up to very heavily polluted. At the moment a sanitation program for the Boudewijnkanaal is carried out, but, unless a detailed study on the water quality of the canal proofs the opposite, it will be questionable whether or not the water quality of the canal (and quality of the silt) shall allow aquaculture activities using canalwater in the future.

Conclusively, when an electricity plant would be constructed at a more inland location, and not regarding any environmental restriction on the effluents, it would be advisable to supply sea water from the outport via a pipeline to the aquaculture facilities. The more-investment cost is estimated at 12 million Bef/km.

3.5.5. Human activities - presentation of the site.

The port of Zeebrugge is situated at the Belgian coastline of the North Sea. The nearest cities are Oostende (32 km) with a national airport and Brugge (15 km). The access to the motorway E40 is situated at 20 km. The harbour of Zeebrugge consists of an outport and a backport (figure 18) with developing industrial activities (i.e. LNG terminal, Distrigas, Glaverbel, Carcoke).
The location of the power plants in the backport of Zeebrugge is not yet determined and no specific aquaculture site can be proposed. The port of Zeebrugge is exploited by M.B.Z. (Maatschappij der Brugse Zeevaartinrichtingen).

3.5.6. General topography and soil characteristics of the backport.

The backport of Zeebrugge is situated between the "Boudewijnkanaal" and the "Afleidingskanaal van de Leie". In the North it is bordered by the "Verbindingsdok" and in the South by the railroad Brugge-Knokke.

At present some parts of the backport of Zeebrugge are raised and leveled at +6.3 m with sand. The subsoil under the raised parts shows the characteristics of formerly creek soils and peat winning grounds with clay, loam and sand. Not raised parts have a groundlevel of +1.25 to +4.00 m.

Groundwater is situated at a depth of 2 to 5 m with a salinity of >1 500 mg/l.

Conclusions.

Water quality of seawater at the outport of Zeebrugge is excellent. If water of the outport would be used for aquaculture activities, the quality will not interfere negatively with those activities. The temperature of the water will reduce the growth rate of aquatic cold-blooded species during cold periods. A heat source to warm the water at an appropriate temperature could reduce heating costs of an aquaculture facility when using seawater of the outport. Considering the water supply conditions to an aquaculture facility, it should be mentioned that, the combination of a water supply conduct to a power plant with an aquaculture site nearby, could considerably reduce water supply investments for an aquaculture facility.

In the course of the study (May 1993) ELECTRABEL and SPE decided to postpone the project of the electricity power plants at Zeebrugge. Due to this decision no concrete aquaculture site can yet be proposed.

At the moment possibilities for marine aquaculture at other companies using water of the back- or outport of Zeebrugge, with an excess of heat and using water with an appropriate salinity as cooling water, are not evident. Although no detailed study was carried out, at the moment the water quality of the backport and the Boudewijnkanaal is not optimal for aquaculture purposes. With the development of the port of Zeebrugge and the industrial activities in the backport, possibilities may occur in the future.

The **important trumps** of an aquaculture site at Zeebrugge are :

- the salinity of the outport water allowing the culture of turbot, seabass and seabream,
- the excellent water quality allowing ongrowing, nursery and hatchery activities,
- the presence of leveled industrial sites in the backport,
- the absence of the return of effluent water of an aquaculture facility in the backport to the water intake structures when using outport water, reducing the sanitary risks,

At the moment, the **major disadvantages** for an aquaculture project at Zeebrugge are :

- the absence of a cheap heat source to warm the water during cold periods,
- the absence of water supply conducts to an aquaculture site,
- the lack of a detailed study and practical experience about the possibility of using backport water for aquaculture purposes,
- and the absence of interest for aquaculture of companies in the backport with an excess of marine cooling water.

4. Potential species

Introduction

This part of the study presents, as far as their zootechnical aspects are concerned, the species (fishes and crustaceans) which we consider as candidates for setting up a profitable marine aquaculture project at the Belgian coast. In this regard freshwater species like eel and catfish, which have potentials for aquaculture are not considered. Neither are the relatively "new" marine species like halibut, cod or wolffish, of which the zootechnical details are been researched now.

surface seawater temperature

In fact, at the Belgian Coast, coastal seawater temperatures would **only** have normally allow to take into account cold tolerant species (salmonids) for which, unfortunately, on-shore pumped systems, the only ones suitable for this kind of coast, are poorly cost efficient.

The reason why this major criterion has not been kept is that, from the beginning, it is clear that viability of any fish or crustacean culture project in this area cannot be envisaged unless is available, under any form whatever, **an outer thermic resource at a very low cost.**

Availability of low cost calories, coming for example from cooling water flowing out from an industrial facility, must allow to enlarge the scope of our search and take into consideration very high value species with grow out techniques more adapted to the environment.

We mention hereafter criteria which have led to select high quality species. Among them, in an apparently paradoxical way, one of the main factors usually used for the selection of suitable species in a given environment, i.e. water temperature, has been neglected. Beside the temperature requirements, conditions to be met by potential species can be summarized as follows :

1° The convenient species must have demonstrated their suitability to be cultured, in on-shore systems, using **intensive process**. (In this case, the word "intensive"" does not mean only addition of food, but is also directly related to a high rearing density).

2° For these species,rearing technology must be completed, and totally under control in production structures at a commercial scale.

3° Last, but not least, a good prospect of selling on the European market is necessary. This aspect will be fully examined in a further part of this report.

In a first approach, the species meeting these requirements are :

SEABASS

SEABREAM

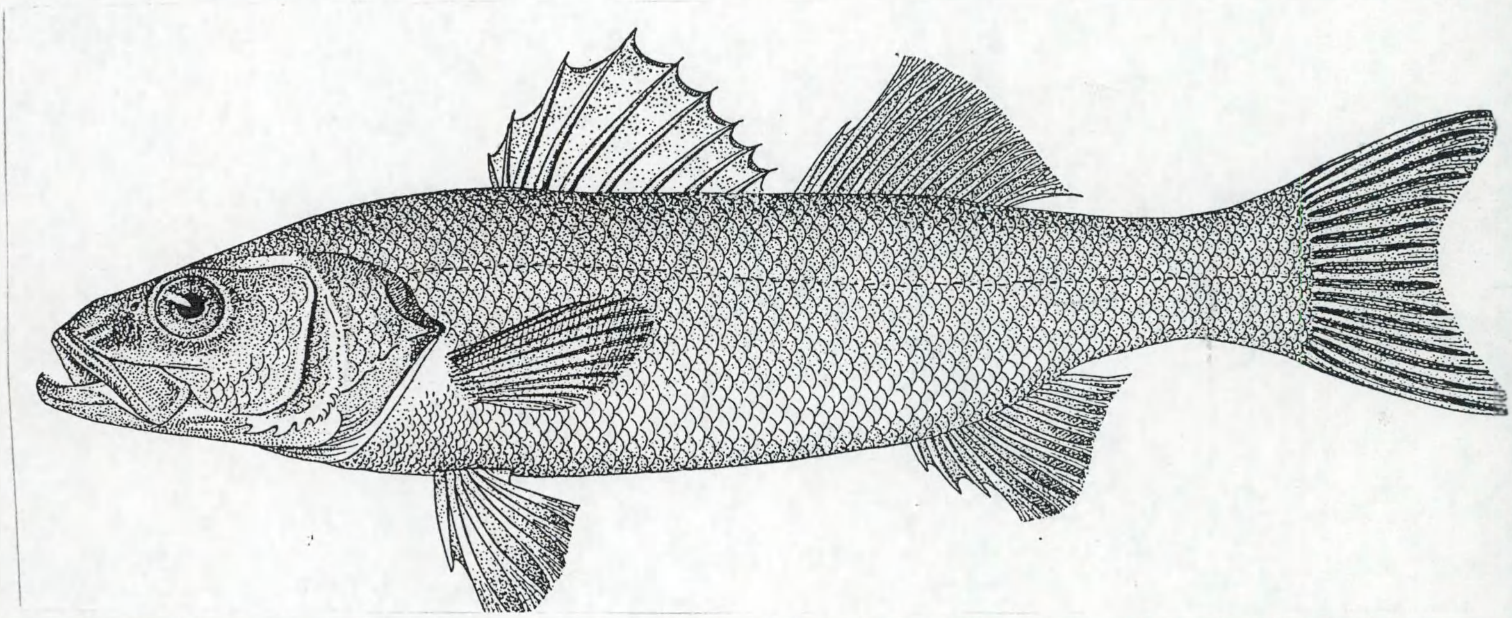
TURBOT

STURGEON

SHRIMP (penaeids)

The review of their main characteristics, from a zootechnical point of view, will help to support this preselection.

SEABASS



CLASS : Osteichthyes

ORDER : Perciformes

FAMILY : Serranidae

SPECIES : *Dicentrarchus labrax*

4.1. SEABASS

Introduction

SEABASS, *Dicentrarchus labrax*, is a carnivorous demersal fish relatively abundant on the East Atlantic coasts of Europe and North Africa, in the North Sea and the Baltic Sea, as well as in the Mediterranean Sea.

Seabass live in coastal shallow waters and are common (mainly during juvenile stages) in brackishwater lagoons and estuaries. They can reach one meter in length (usually O.5m) and 12 to 15 kg in weight (usually 5 to 6 kg).

It is a highly valuable commercial fish either in Western Europe as well as in countries bordering the Mediterranean Sea.

Traditional methods have been used for a long time to extensively culture seabass, with juveniles captured from the wild and kept in enclosures.

Intensive farming is now well developed due to the availibility of fry produced through a lot of efficient hatcheries.

The main zootechnical parameters of seabass culture are :

4.1.1. BROODSTOCK MANAGEMENT

The large scale production of eggs and larvae in hatcheries is today entirely dependent on captive spawners. Useful fishes range from 1 kg in weight to 4 kg. At the end of each spawning season, the highest weight class of fish is replaced by a younger class carefully selected, to give an annual renewal of around 2O% for the whole group.

The sex ratio is 1 male to 2 or 3 females.

The stocking density is working from 4 to 1O kg/m^3.

The water quality is carefully controlled, in a completely open circulation system.

The fish is fed ad libitum with a diet consisting of compound food and trash fish.

The temperature and photoperiod are manipulated in order to obtain maturations and spawnings throughout the year. The maximum number of eggs is obtained with temperatures during spawning between 13°C and 16°C.

Hormone injection (LHRH) is practiced to accelerate the last stage of the maturation and ovulation processes and synchronize the spawning of several females. Natural spawning and fertilization are generally used.

Each female spawns about 350 000 eggs/kg.
The average hatching rate is 80% of the viable eggs.

Just after hatching, larvae are transferred to the larval rearing room.

4.1.2. LARVAL REARING

The main characteristics are the following :

- Period : 40 days.

- Density : Initial 100 larvae per liter.

- Water temperature : starting at 13°C increasing to 20°C.

- Water renewal : 20/100% per hour in most cases recirculating.

- Light : After a first darkness period, the duration and intensity of artificial illumination deserve special attention as well as the cleanness of the water surface that must be clear of oils. This care allows to maintain at a minimum level number of juveniles with abnormal swimbladder (less than 10%).

- Food : *Artemia* sequence with enrichment.

- Weight at the end of the period : 30 to 40 mg.

- Average survival rate : 50% (min. 35%, max 65%).

4.1.3. NURSERY PHASES

The nursery phases are not as sophisticated as larval rearing. We may consider two stages : weaning and pregrowing.

A. Weaning

The weaning is carried out in small tanks (0.5 to 1 m^3) in a water at a temperature of 20°C, with salinity close to 35 ppt and natural lighting photoperiod.

Stocking densities are about 4 000/m^3.

Water renewal : 40 to 100% per hour.

Feeding : After the first five days, the *Artemia* ration is progressively reduced until complete deletion one week later .
A compound food is used (mini pellets) rich in oil, vitamins, and attractant. Daily feeding rates are 5 to 10% of the biomass.

During this period, the fry weight increases from 40 mg to 1 g. A peak of mortality may occur after 10 days reaching 25% or even up to 40% of the initial numbers of fish. One week later, it becomes negligible.

B. Pregrowing

According to the kinds of facilities, pregrowing is limited to a fry weight of 5 g (common selling weight 1/5 g) or continued up to 20/50 g in the same farm department, especially when the whole farm is land-based.

From 1 g, the fish weight reaches 5 g in 2 to 3 months, and 20 grams after 5 additional months in Mediterranean conditions.

The rearing tanks - either raceways or cylindrical tanks are managed as follows :

- Initial density : 3 kg/m^3; final density : 10 kg/m^3.

- Survival rate : 90%.

- Seawater temperature : optimal 24°C range 18/27°C.

- Salinity : range 5 ppt to 40 ppt.

- Water renewal : 100% per hour.

- Food : Commercial pellet.

At the pregrowing stage the main concern is **pathology**. Seabass have been shown to be susceptible to bacterial diseases, mainly *Vibrio anguillarum*, currently the major pathological problem for the rearing of young seabass, and also to some viral diseases :

- Infectious pancreatic Necrosis (IPN)
- Viral hemoragic Septicemia (VHS)
- Seabass virus (SBV) (Whirling disease)

C. GROW OUT (figure 27)

Seabass can be grown out either in floating cages, or in land-based farms, in tanks of accurated dimensions. In this case, seawater is obtained by pumping or tidal flow.

In all cases, water temperature has the major influence, since mortality is observed below 6°C and above 33°C, whereas maximum growth is obtained between 18°C and 25°C.

The zootechnical criteria related to land-based intensive farming of seabass are :

Environmental conditions

- Optimal seawater temperature : 22°C.

- Salinity : 5 to 40 ppt.

- Oxygen : minimum level is 4.5 mg/l. In onshore tanks, additional oxygen is provided by aerators or intake of pure oxygen.

- Nitrogen compounds : the resistance of seabass to ammonia is rather high with an upper limit of 4.5 mg/l at pH 7.5.

- Water exchange : a maximum biomass of 30 to 35 kg/m^3 needs a water renewal of 80 to 150 %/h or supplementary oxygen.

- Diets and nutrition : Commercial seabass feed are available from several European suppliers, with different pellet sizes.
  Daily rations depends i.e. on seawater temperature, size of fish, water turbidity.

  Conversion rates range from 2 to 3

- Grading : Grading is necessary at all stages. It prevents cannibalism during the juvenile phases, and then maintains a good access to food for every fish.

Growth time to market

Under Mediterranean conditions, where the annual average water temperature is 18°C and the average temperature of the coldest and the warmest months are 11°C and 25°C respectively, fish reach 80 g in one year and 250 to 350 g at the end of the second year. To make larger sizes, it will be necessary to stop maturation or use transgenic animals.

A survival rate of 70% can be expected during the ongrowing stage.

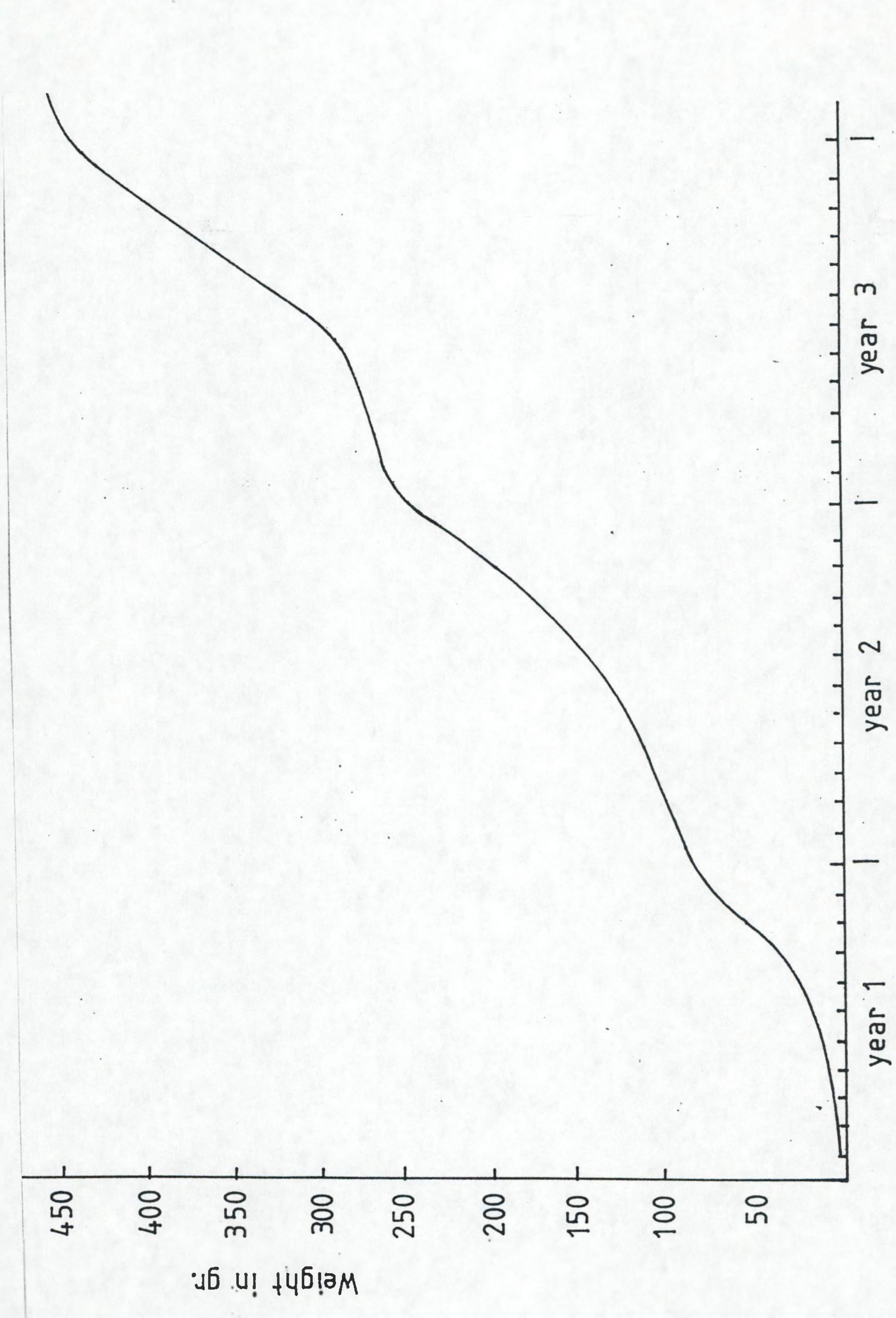


Figure 27 : Seabass growth curve (Mediterranean condition, seawater temperature 11°C/25°C).

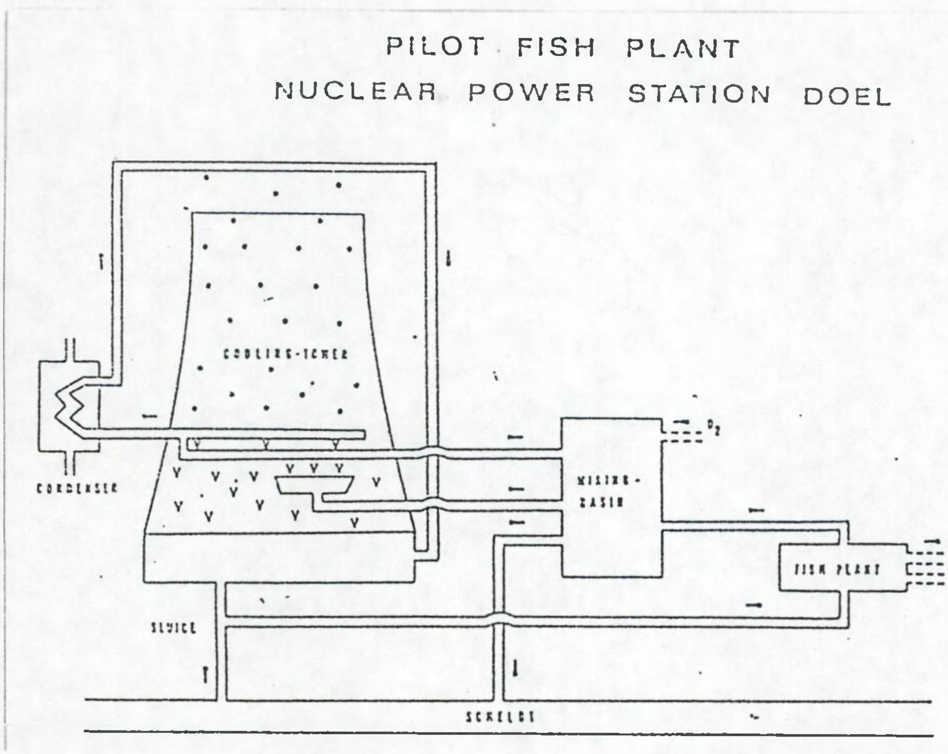
4.2. <u>Seabass culture : **biotechnical results of the experimental project at Doel.**</u>

Research from 1983 to 1991 at an experimental aquaculture plant using the thermal effluents of the nuclear power station at Doel indicates the possibilities to culture seabass (*Dicentrarchus labrax*).

In the period between 1987 and 1991, six batches of seabass were grown up to a marketable size (350 g) in 19 to 21 months using the thermal effluents of the nuclear power station at Doel. Dry feeds were developed and production schedules maximized. The overall food conversion varied from 2.4 to 2.7. Production attained 29.9 kg/m^3/ year. The improved dissolved oxygen concentration in the cooling water, after having been distributed in the cooling tower, supported a fish biomass in the culture tanks up to 60 kg/m^3.

A. Description of the experimental aquaculture plant at Doel.

The pilot-plant of 500 m^2 is situated near the cooling tower from nuclear unit 3. The total tank surface attains 100 m^2, covering a total rearing volume of 60 m^3. Due to the availability of a sufficient amount of cooling water, the pilot-plant has been designed as a single flowthrough system. Three sources of water are available : warm water derived from the condenser, water from the cooling tower and colder water from the river Scheldt (figure 28). Cold water from the river Scheldt can also be supplied separately to each tank, providing the possibility to maintain different water temperatures in each tank if desired. Using "tube" aeration (3 bar) dissolved oxygen concentrations can be maintained at an optimum level.



<u>Figure 28</u> : Water supply to the aquaculture plant at Doel.

The rearing tanks are supplied by gravity with 100 m^3/h of cooling water. From a mixing tank (diameter 3.6 m ; h 2.5 m) this water is distributed to the culture tanks. The available rearing facilities are :

-6 square tanks of 4 m^2 (water depth 0.3 m)
-3 circular tanks of 5 m diameter (water depth 0.8 m)
-1 circular tank of 3 m diameter (water depth 0.5 m)
-1 circular tank of 2 m diameter (water depth 1.0 m)

Fish are fed a commercial dry pelleted food distributed using demand feeders. Juvenile seabass fry having an average weight of 1.3 to 9.5 g are obtained from the Laboratory for Ecology and Aquaculture (University of Leuven) or from French commercial hatcheries (AQUANORD, Gravelines).

B. Growth of seabass at Doel.

The growth data of 6 batches of seabass are mentioned in table 9. Batch 1,2,3 and 4 were sold to local wholesalers at the mean end weight mentioned in table 9. At the end of the experimental period (May 1991) batch 6 attained a mean end weight of 171 g. Figure 29 shows the growth curves of batch 2,4,5 and 6 derived from the morphometric measurements carried out monthly. Under the culture conditions at Doel, seabass reach a marketable size of 350 g in 19 to 21 months depending on the weight at the start of the ongrowing cycle.

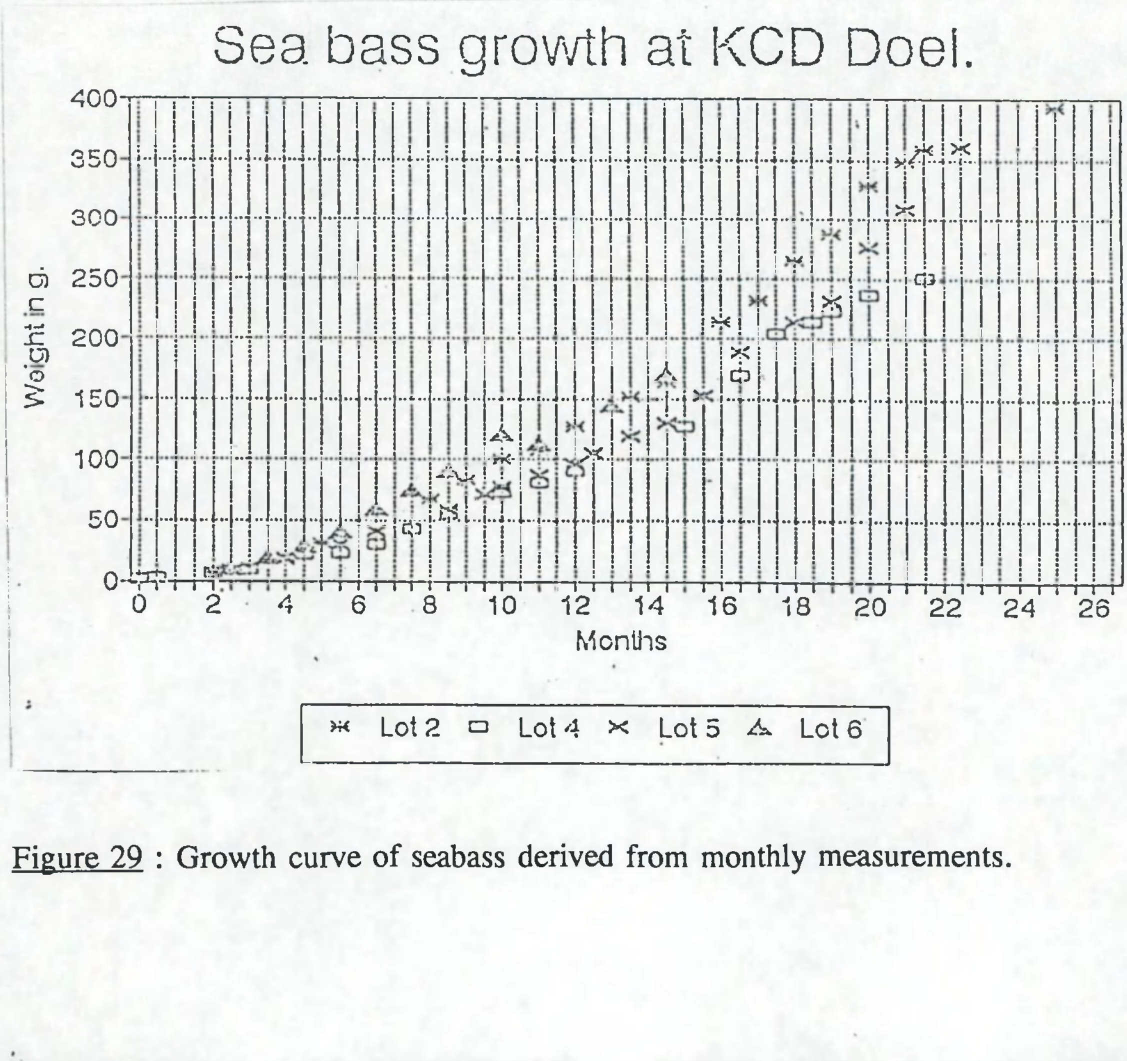


Figure 29 : Growth curve of seabass derived from monthly measurements.

The overall specific growth rates (% weight increase/day) to grow the different batches (with exception of batch 1) from start to end weight vary from 0.592 to 0.800 (table 9). The mean specific growth rate of the different growth stanza is the highest (2.2%/day) for seabass juveniles between 1 and 5 g (table 10). With increasing fish weight the specific growth rate decreases to 0.21%/day for fishes in the growth stanza between 300 to 400 g. During 1990 the overall stocking density at the pilot plant varies from 22.5 kg/m^3 to 30.7 kg/m^3. The biomass production in 1989 is 21.5 kg/m^3 and 29.9 kg/m^3 in 1990 (table 13). The maximum stocking densities obtained in the rearing tanks reach 60 kg/m^3.

	Origin	Period	Weight (in g) at start	end	day's	S.G.R.	Regression equation of growth	r2	Max. stocking density (kg/m3)
Lot 1	Gravelines	19/01/88 - 01/09/8	135	224	227	0.225	ln G = 4.88 + 0.0024 T	0.97	17
Lot 2	Gravelines	25/08/87 - 17/07/8	6.5	393	693	0.592	ln G = 2.73 + 0.0060 T	0.89	24
Lot 3	K.U.Leuven	28/04/88 - 13/11/8	2.9	232	575	0.756	ln G = 2.15 + 0.0074 T	0.86	21
Lot 4	K.U.Leuven	02/06/88 - 20/03/9	1.3	250	657	0.800	ln G = 1.51 + 0.0075 T	0.89	33
Lot 5	Gravelines	20/04/89 - 17/12/9	8.2	360	597	0.633	ln G = 2.86 + 0.0055 T	0.94	58
Lot 6	Gravelines	18/04/90 - 25/04/9	9.5	171	373	0.775	ln G = 2.82 + 0.0075 T	0.89	60

Table 9 : Growth data of 6 batches of seabass grown at Doel (G = weight in g ; T = time in days).

	Weight in g.							
	1-5	5-10	10-20	20-50	50-100	100-200	200-300	300-400
S.G.R.								
Mean	2.20	1.82	1.53	0.84	0.55	0.46	0.40	0.21
N	6	8	14	34	33	40	12	4
Min.	1.17	1.12	0.63	0.34	0.27	0.18	0.11	0.16
Max.	3.03	2.97	2.11	1.80	0.93	0.76	0.73	0.27
S.D.	0.72	0.55	0.49	0.34	0.16	0.17	0.18	0.04

Table 10 : Specific growth rate (% weight increase/day) in relation to fish weight.
(N = number of growth stanza from which the mean is derived)

	Weight in g.							
Size	1-5	5-10	10-20	20-50	50-100	100-200	200-300	300-400
pellets		1	2	2	3	4.5	4.5	4.5
crumbles	1							
Food ratio								
Mean	4.12	3.78	3.16	1.71	1.29	1.00	0.89	0.58
N	6	8	14	36	38	40	12	4
Min.	3.60	3.00	2.40	1.00	0.90	0.50	0.50	0.40
Max.	4.70	4.60	3.80	2.60	2.00	1.70	1.20	0.80
S.D.	0.37	0.56	0.43	0.39	0.23	0.18	0.17	0.18

Table 11 : Food ratio (% of body weight) and food size (mm) in relation to fish weight.
(N = number of growth stanza from which the mean is derived)

	Weight in g.							
	1-5	5-10	10-20	20-50	50-100	100-200	200-300	300-400
Food conversion								
Mean	2.22	2.22	2.56	2.35	2.60	2.62	2.71	2.64
N	6	8	14	36	38	40	12	4
Min.	1.30	1.30	1.22	1.01	1.02	1.21	1.26	1.70
Max.	4.00	3.10	5.70	4.23	4.06	7.40	4.97	3.63
S.D.	1.06	0.53	1.16	0.84	0.85	1.40	1.15	0.77

Table 12 : Food conversion in relation to fish weight.
(N = number of growth stanza from which the mean is derived)

C. Food and feeding of seabass.

Under culture conditions, sea bass adapt well to artificial diets. The high culture densities in the rearing tanks prevent loss of food when feeding with demand feeders.

A food covering the nutritional requirements of seabass was formulated. The gross composition of the food distributed to the cultured fishes contains 51% protein, 13% fat, 13% carbohydrates, 9.1% crude ash, 1.2% crude fibre and 9.1% water.

A protein content of 50-52% and a total fat content of 12% in the food is found to be the optimum for seabass growth. Food experiments at Doel show the highest growth with diets containing 51.5% to 56.5% protein and 10% to 15% lipid in the diet. Considering the standard energy value (SEV) and protein-energy ratio (P:E) of the diets tested, a dietary SEV range from 3 527 to 3 680 Kcal/kg combined with a dietary P:E ratio from 160 to 172 mg protein/Kcal supports a good seabass growth.

The food is distributed at the ratio (% food weight/fish biomass) mentioned in table 11 and takes into account the temperature regime of the culture water and the fish weight. The minimum and maximum ratios are supplied at respectively the lower and higher water temperatures encountered. In relation to an increasing fish weight the size of the pelleted food increases (crumble size and pellet diameter in mm).

The mean food conversions (weight food pellets distributed/ wet weight fish biomass increase) of the different growth stanza (N) increase slightly with the weight of the fish (table 12). A summary of the input/output for the experimental plant during the years 1989 and 1990 show overall yearly food conversions of 2.4 to 2.7 (table 13).

	1989		1990	
	kg	kg/m3	kg	kg/m3
Sea bass stock begin	426	7.1	1348	22.5
Sea bass stock end	1348	22.5	1842	30.7
Biomass sold	319	-	1206	-
Mortality	33	-	34	-
Samples (analyses, PR)	13	-	58	-
Biomass produced	1287	21.5	1792	29.9
Food distributed	3075	-	4800	-
Food conversion	2.4	-	2.7	-

Table 13 : Overall yearly input/output data of the experimental aquaculture plant at Doel.

D. Mortality of seabass.

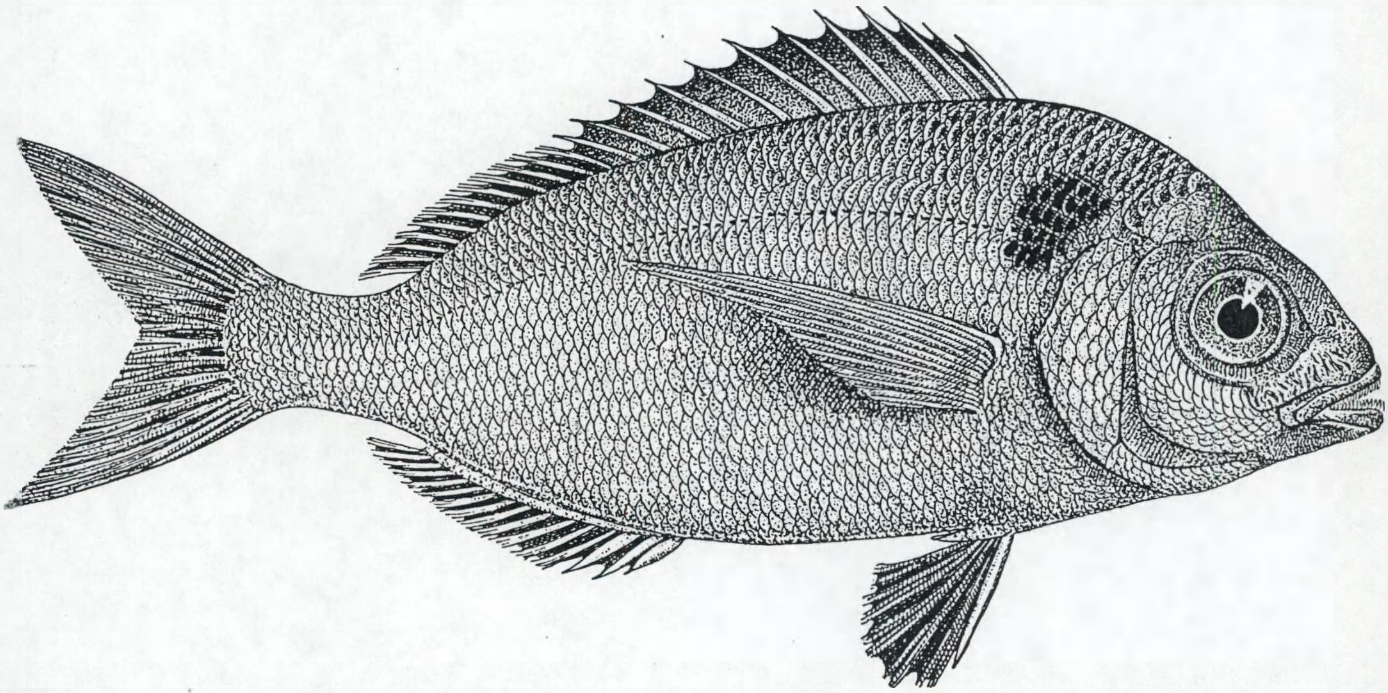
Mortalities of juveniles are observed in the first month after arrival at Doel and are caused by transport and acclimation stress. Later during the culture cycle minor mortalities are sporadically observed due to handling stress.

In batch 2 the observed mortality due to transport and acclimation during the first month is 8.8%. Sporadic mortality during the rest of the rearing cycle is 1.7% calculated on the initial number of fishes stocked. In batch 4 observed mortality during the first 2 months (growth from 1.3 to 6.2 g) is 1.2%. During the rest of the cycle the observed mortality is 2%. In batch 5 the calculated mortality during the first 7 months (growth from 8.2 to 80 g) is 4% based on counted numbers of fish at the beginning and the end of the growth stanza. During the rest of the cycle the observed mortality is 3.2%. In batch 6 the observed mortality is 2.1%.

E. Conclusions.

The biotechnical results with seabass obtained at Doel are comparable with the growth and production performances found in commercial fish farms with comparable culture conditions.

SEABREAM



CLASS : Osteichthyes

ORDER : Perciformes

FAMILY : Sparides

SPECIES : *Sparus auratus*

4.2. SEABREAM

Overview

SEABREAM, (*Sparus aurata*), is present in the coastal waters of the Mediterranean sea, as well as on the Atlantic European coasts, from England to Mauritania . It is encountered on all types of bottom substrates, in depths ranging from littoral down to 40 to 80 meters. Eurytherm (6°C-32°C), and euryhalin, seabream use also to stay in the coastal lagoons during summer.

The name of "royal seabream" is due to the gilded headband which adorns its head between the eyes. The body, grey coloured with glints of gold, is laterally compressed. The jaws are very strong, allowing the animals to crush shellfishes.

In the wild, spawning occurs either in November (Mediterranean conditions), or in the summer (North Atlantic Sea) at depths ranging between 5 and 25 m. The female productivity is 1 to 3 millions of eggs/kg. Larvae are pelagic and live on zooplankton. Juveniles use to stay close to the coast line, eating algae and shellfishes.

The species is hermaphrodite. The animals are first male, then female. First maturation appears when they are around two years old.

The young fish have a behaviour very similar to that of the juvenile seabass. When growing adult, seabream put out to open sea and live on the bottom, feeding on molluscs, small crustaceans and polychetes.

Seabream culture has been studied and experimented together with that of seabass and presents many similarities. A lot of farms carry out the rearing of the two species in the same facilities.

The main zootechnical parameters of intensive rearing are :

4.2.1. BROODST0CK MANAGEMENT

Captive broodstock has to be constituted with animals taken from the wild for a part, and from reared animals for another part. Wild animals are acclimated during a six months period before being put into the maturation tanks.

A 25% annual replacement is made with young animals (2 years old males and 4 years old females).

Food is made of dry pellets five days per week with an additional fresh food, mussels and crabs, the two other days.

Sex ratio, stocking densities, water exchange are similar to those used for seabass.

Spawning periods, year round, are obtained through manipulation of thermoperiod and photoperiod cycles. Seabream spawns during the decreasing photoperiod phase at temperatures ranging from 20°C down to 16°C.

Production of eggs is between 1 and 3 million per kg of female, and per year.

Fecundation is natural. Spawning and fertilization are spontaneous

Incubation is achieved in special small tanks. Hatching occurs after 48/72 hours according to water temperature. Rate of hatching is generally higher than 80%.

4.2.2. Larval rearing

The main zootechnical characteristics of larval rearing are :

- Period : 40 days.
- Tank volume : 2 to 4 m^3.
- Initial density : 100 larvae per liter.
- Water temperature : from 16°C to 20°C.
- Water renewal : 20% per hour, with careful cleaning of water surface for obtaining functional swimbladders.
- Light : Seabream larvae never feed in the dark.
  Standard is 24 h of light (artificial) 600/1 500 lux.
- Food : in a first stage enriched rotifers, in a later stage then enriched *Artemia.*
- Weight at the end of the period : 5/10 mg.
- Average survival rate : 25% (min 10%; max 40%).

4.2.3. Nursery phase

As for the seabass, the nursery phase is made of two stages : weaning, and pregrowing.

A. Weaning

At the end of the larval rearing period, the animals are transferred in new tanks (circular or rectangular) with recirculation of water through a biological filter.

Seawater temperature is kept to 20°C, with a salinity close to 35 ppt.

During 5 days, larvae are fed mainly on *Artemia* with a linear reduction of the quantities, related to an increased distribution of a compound food crumbled pellets.

Inert food containing a high rate of protein (protein 55 to 60%; lipid 15 to 20%) is commercially produced.

Survival, after ten days of weaning, ranges from 8O to 95%.

B. Pregrowing

Up to the first grading, seabream culture generally goes on in the same tanks with a first grading of the animals when they reach an average weight of 1 g. Beyond this weight, pregrowing may be practiced either in tanks, or in small cages.

During the pregrowing stage, stocking densities increase from 10 kg/m^3 to 20 - 30 kg/m^3.

In tanks, seawater renewal is 100% per hour. 0xygen level is maintained at 5 mg/l at a temperature ranging from 16°C to 22°C.

Food is a commercial pellet with 50% protein and 12% lipid .

Animals reach a weight of 5 g in 3 months.

4.2.4. <u>Grow out</u>

Seabream can be grown, as seabass, either in floating cages or in tanks.

When dealing with cages, attention must be made to use very resistant nets to resist the "browsing"' habit of the seabream. A twin net is often necessary.

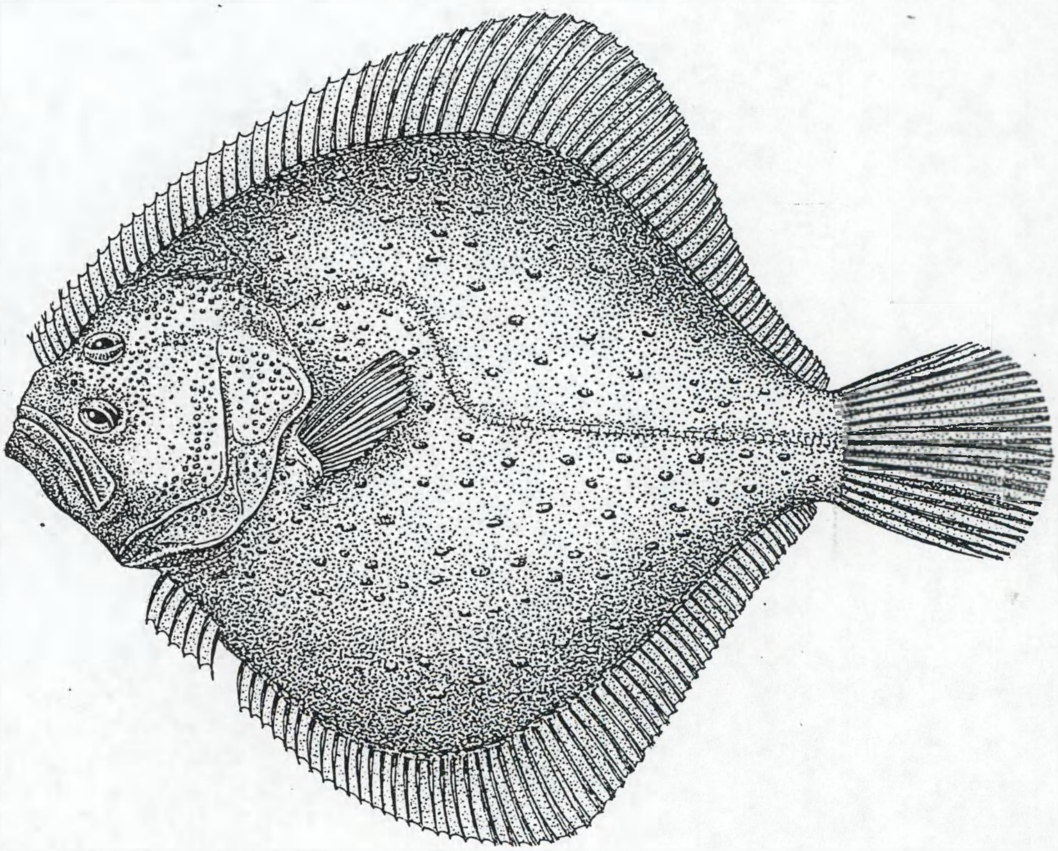
When grow out is achieved in land based tanks, the main parameters to be considered are :

- Optimal seawater temperature : 22°C-26°C.
- Salinity : 15 - 38 ppt.
- Oxygen minimum level : 4.5 mg/l.
- Stocking densities : up to 35 kg/m3.
- Water exchange : 100% per hour.
- Diets : suitable commercial feed are available, containing roughly 50% protein, 12% lipid. Rate of conversion is 2 to 2,5.

- Growth : growth is faster than that of seabass when temperature exceeds 18°C.
  It is possible , in the Mediterranean conditions to obtain fishes weighing 350 g after only one year (from 5 g).

- Survival rate : a survival rate of 80 to 90% is observed.

TURBOT



CLASS : Osteichthyes

ORDER : Pleuronectiformes

FAMILY : Scophtalmidae

SPECIES : *Scophtalmus maximus*

4.3. TURBOT

Introduction

The **turbot** (*Scophthalmus maximus*) is one of the most appreciated flatfish within Western Europe.

Wild turbot is a carnivorous fish relatively abundant in the North- East Atlantic from South-Norway down to the West coast of Portugal (with a particular species in the Black Sea). Turbot lives on the bottom of the sea, at depths going from 20 m to 200 m.

It use to stay quiet, hidden under sand or gravel, and just springing up to seize its prey with its large mouth.

The animal can reach up to 15 kilos after about 15 years. It feeds on small fishes passing around, and especially small sandeels which share the same habitat.

Wild turbot spawn at the end of spring, or early summer, according to the sea temperature. Maturation occurs as soon as the third year, when the fish reach a weight ranging between 1.5 and 2.5 kilos. The female spawn several hundred thousands of eggs, close to the coast line where fry spend their first summer in shallow waters to benefit from the high productivity of this area. Adult turbot then migrate to more deep waters.

After 15 years of research and development, conducted mainly in England and France, commercial turbot farming is now a reality in Europe, especially in England and France, as far as hatchery techniques are concerned, and in Spain where the major grow-out developments are found.

Turbot is close to ideal for farming purposes.

The fish is calm, hardy towards disease and pollution (it can tolerate 20 to 30 times more ammonia than salmonid fish), and easily domesticated.

The major problem has been the reproduction of turbot. Considerable progress has been made in hatchery techniques, and, right now, good quality fingerlings are produced in satisfying quantities.

A review of the main zootechnical aspects of turbot culture shows several stages, starting from broodstock constitution to grow out management.

4.3.1. BROODSTOCK

Setting a broodstock is the first and essential operation for an autonomous working hatchery. This setting is to be undertaken with animals from several sources (wild and farmed), and carefully identified and marked after their acquisition in order to allow, as soon as possible, the launching of a genetic selection program.

Useful animals range in weight between 2.5 and 6 kilos (beyond handling becomes difficult). They are stocked at a density of 3 kg/m^3.

Water quality is very important, either ground saltwater or natural seawater filter 50μ. Salinity ranges from 28 to 35 ppt.

Seawater temperature must be kept between 12°C and 14°C.

Maturation is induced and manipulated through photoperiod adjustments with artificial light.

Water exchange rate is 10% of the volume per hour.

Food is made of fresh fish with accurate supplementation.

Sex ratio : 25% males, in the same tank with females

Mature females are stripped for eggs. Fecundation is artificially made. Rates of hatching range from 30 to 90% .

4.3.2. LARVAL REARING

Larval rearing requires very particular conditions, rather different according to each hatchery, which cannot be described in detail at this stage.

Let us indicate briefly that they require a perfect seawater quality (salinity 29/35 ppt) - with U.V. sterilization and filtration $1/5\mu$.

Water is distributed through a thermoregulated network to several specialized airconditionned rooms in order to provide right flows at suitable temperatures (with additionnal filtrations when necessary).

Life food cultures are required :

- algae (the more often)
- enriched rotiferes
- *Artemia* from nauplii to metanauplii, also with special enrichments

Duration of this phase : more or less 30 days.

Average survival rate : 10% (maximum 30%).

At the end of this stage, fry is weighing about 75 mg with normal pigmentation in 80/95% of the total.

4.3.3. WEANING

The weaning is achieved in water at a temperature of 16/20°C, still protected by U.V., since outbreaks of *Vibrio* are dangereous at this stage (unless ground water is used).

Stocking densities are about 2 300/2 500 fry/m^2 (4 0O0/m^3).

Water renewal : 35% per hour.

Survival rate 80 to 90%, after 30 days.

Artemia are progressively replaced by special mini-pellets whose formula vary with each supplier. Results are also quite different.

The fry weight increases from 75 mg to 700 mg during this phase, with a starting weight dispersion needing a first sorting.

4.3.4. PREGROWING

We regroup under this item what is often separated in 2 or 3 phases, but generally achieved in very similar facilities , called "nurseries".

During this phase, fry grows from 700 mg to 20 gr in 5 or 6 months, as follows :

700 mg - 2.5 g	30 days
2.5 g - 5 g	2 months
5 g - 20 g	2 to 3 months

Rearing densities progressively increase from 1 to 2 kg/m^2 (initial density) to 10 kg/m^2.

Survival rate is 90%.

The main zootechnical parameters are :

- water height : 40 to 60 cm.

- water temperature : 14/20°C optimal 18°C.

- water renewal : 50% per hour.

- aeration : O.3 m^3 per m^3 of water, with a minimum outlet oxygen concentration of 5 mg/l.

- feeding : commercial extrusion pellets with a main content of protein 45%, fat 20% and vitamins

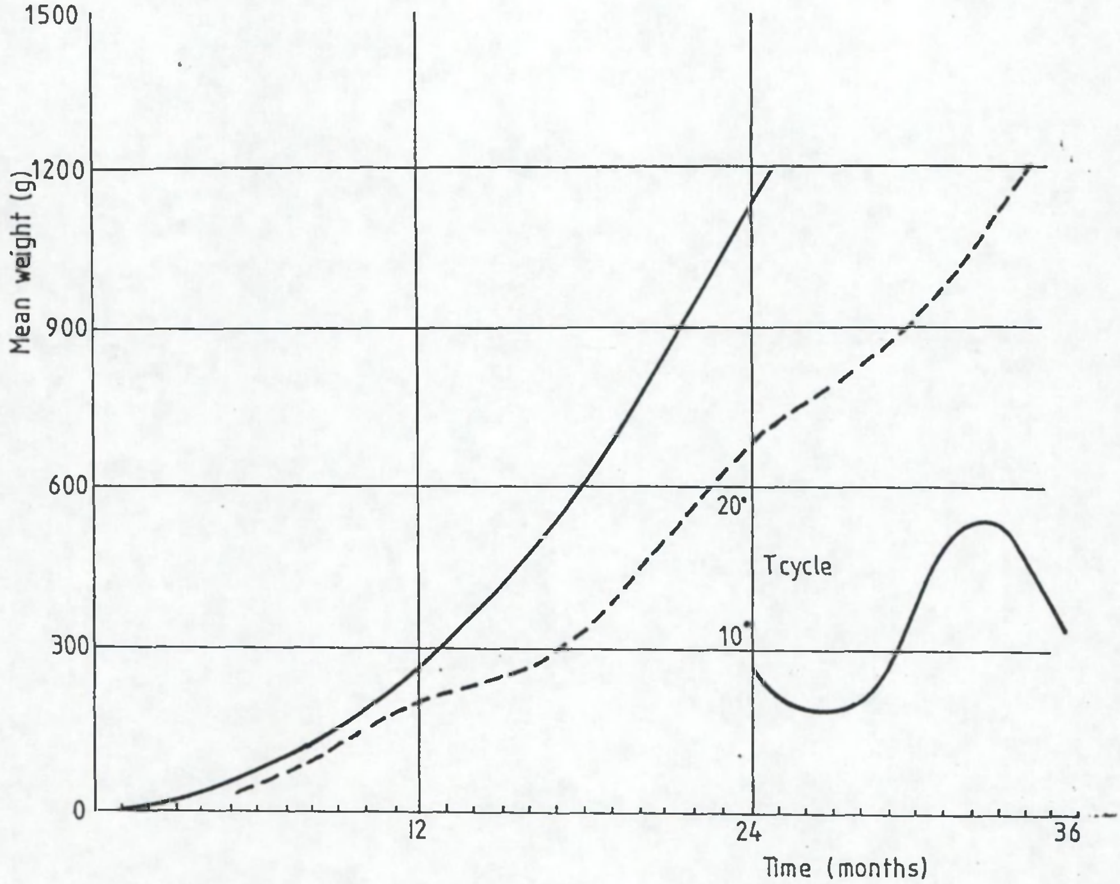
Feed conversion rate is around 1. Detailed turbot feed composition and feeding schedules are given in tabel 1 and 2.

4.3.5. GROW-OUT

Grow-out of turbot is also often practiced in several phases in the commercial farms, with at least two following stages : growth from 20 g to 300 g and growth from 300 g to 1 500 to 2 500 g.

The average duration of each stage depends mainly on water temperature. Optimal growth is reached with temperatures between 14°C and 18°C. The minimum water temperature tolerated is 5°C. The maximum water temperature tolerated is 22°C.

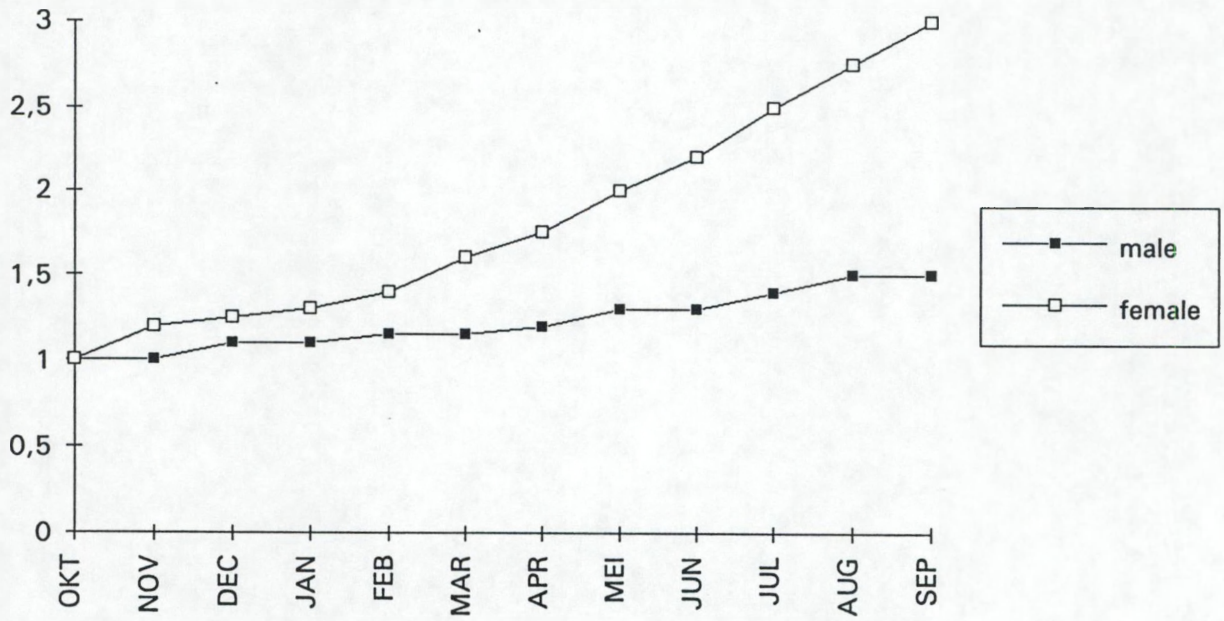
Under the conditions existing in the French North Brittany, which are rather close to those of the East Channel, the grow-out periods are 9 months from 20 g to 300 g, 15 months from 300 g to 1 500 g, and about 6 additional months to grow to 2 000 g (figure 29).



A : Growth process till 1.2 kg.

——————— Steady temperature 18°C (experimental)

---------------- Seasonal temperatures
Natural seawater North Brittany



B : Growth process from 1 - 3 kg.

Figure 29 : Turbot growth curve

These figures are **mean figures**, because growth dispersion is very important. It starts with larval rearing and goes on all over the rearing period, in spite of frequent sortings.

An additional factor of differentiation appears with sexual activity. Males are growing less rapidly than females of the same batch, with a continuously increasing gap.

Figure 30 shows the dispersion observed in a batch of 30 000 turbots,after 22 months of rearing (from the egg) in natural seawater (North Brittany).

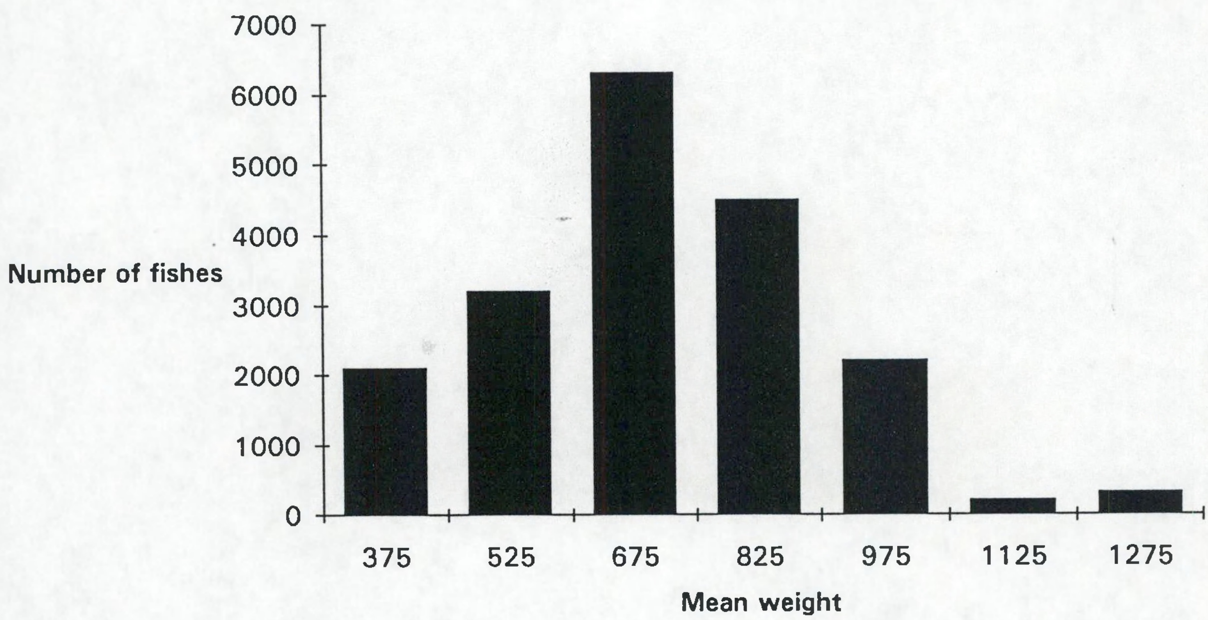


Figure 30 : Turbot weight dispersion within a batch of 30 000 animals after a 26 months commercial rearing in natural seawater North Brittany - 1989)

The suitable **densities** range from 15 kg/m2 to 30 kg/m2 during the first stage (20/300 gr) and from 30 kg/m2 to 50 kg/m2 during the final stage.

Survival rate for the whole ongrowing stage about 90%.

Water depth inside the tanks : 1 m.

Water renewal : 50% per hour

Aeration : 0.3 m^3 per m^3 of water
(minimum outlet oxygen concentration 4 mg/l)

Food : As for the previous stages, a special turbot extruded pellet is available from several suppliers. (Protein 45/50 % - Fat 15/20 %). Pellets are usually distributed by hand in 2 or 3 meals each day.

Rate of conversion is around 1 from 2O to 3OO gr, and increases up to 1.4/1.5 in the final stage with a mean rate of 1.2/1.3 for the whole grow-out stage.

Feed mean analysis		Vitamins per Kg of feed	
Crude Protein	45 %	Vit. A.	6 000 UI
Crude Fat	20 %	Vit. D3	3 000 UI
Crude Ash	8,6 %	Vit. E	110 mg
Crude Fiber	1,8 %	Antioxydant : Ethoxiquin	
Moisture	10 %		

Table 14 : Composition of turbot feed

Weight of fishes in grams	ECOLIFE 17	Water temperature 6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
3 - 10	1,5 mm	1,0	1,2	1,4	1,6	1,9	2,2	2,5	3,0
10 - 50	2 mm	0,7	0,8	0,9	1,0	1,2	1,4	1,7	1,9
50 - 100	3 mm	0,5	0,6	0,6	0,8	0,9	1,0	1,2	1,4
100 - 300	4 mm	0,3	0,4	0,5	0,5	0,6	0,7	0,8	1,0
300 - 700	5 mm	0,2	0,3	0,3	0,4	0,4	0,5	0,6	0,7
	AQUA 17								
700-1300	7 mm	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,6
1300-2000	9 mm	0,2	0,2	0,2	0,2	0,3	0,3	0,4	0,5
+ de 2000	9 mm	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,4

Table 15 : Feeding ratio of turbot and pellet size related to fish weight and water temperature.

4.3.6. SUMMARY OF ZOOTECHNICAL PARAMETERS OF TURBOT REARING

Currently it is possible to synthetize the status of turbot rearing as follows :

- Reliability of hatchery techniques, although the average larval rearing survival rate is still poor.

- The weaning and the ongrowing stage to commercial sizes are totally under control, with very low mortality rates.

- Availibility of a high quality commercial scale food for grow-out phases.

- Optimal growth at temperatures between 14°C and 18°C (large animals prefer 14°C to 15°C and the smallest 18°C)

- Commercial size is reached within 24 to 36 months, with an important dispersion of sizes.

In the near future, a conscientious control of rearing water temperature will ameliorate the growth rate and reduce the grow out period to commercial size. Research to the genetic improvement of turbot strains resulting in higher growth rates or in retarding maturation, will also substantially improve production performances of turbot farms.

4.3.7. ORGANOLEPTICAL TESTS

Organoleptical evaluation were carried out with a taste panel. Turbot from three different origins were tasted, viz. one sample from a Dutch fishery vessel, one sample from a French aquaculture plant and one sample from a French fishing vessel (table 16).

The panel scores were rather high in all samples. No significant differences could be found between the three samples. The cultured turbot was equally appreciated as the fishery products. One member could (rightly) identify the cultured sample, while another member was of the opinion that all three samples were real fishery products.

The general conclusion was that the noted differences in external appearance, texture, taste and general impression were rather small between the wild fish and the cultured fish.

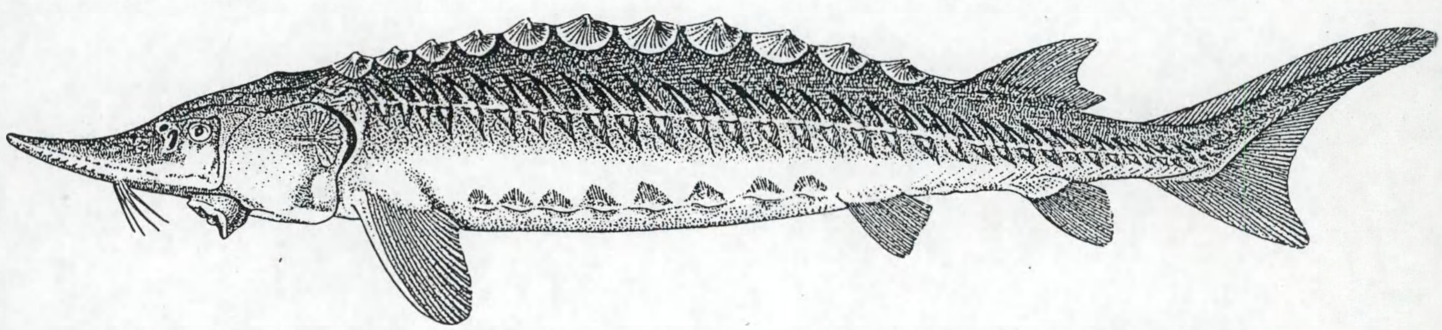
TEST TRIANGULAIRE "C"

	ASPECT			TEXTURE			GOUT			IMPRESSION GENERALE		
	1	2	3	1	2	3	1	2	3	1	2	3
VOLTOLINA	7	7	8	7	7	8	7	7	8	7	7	8
PENZO E.	8	8	8	8	8	8	8	8	8	9	9	9
BARBIERI	8	8	8	8	8	8	8	8	8	8	8	8
RAVAGNAN	8	7	7	8	7	8	7	8	7	8	7	7
PENZO G.	9	8	8	8	9	9	9	9	9	9	9	9
MORETTI	8	7	8	7	7	8	7	7	8	7	7	8
MAIGNON	8	7	7	7	7	8	7	7	7	7	7	8
LOIX	8	8	8	8	8	6	8	8	7	8	8	7
.DESANTA												
CORBARI	8	5	7	8	8	8	7	8	7	8	8	8
GIRSEPE	6	5	7	8	8	8	7	8	7	8	8	8
LESTRADE	7	6	5	8	8	7	8	7	6	8	7	6
TIMSIT	8	7	6	6	8	8	8	8	8	8	8	8
MOYENNE	7.7	7.0	7.2	7.5	7.7	7.6	7.5	7.5	7.4	7.8	7.6	7.6

1. Turbot de pêche (Hollande).
2. Turbot d'élevage (France).
3. Turbot de pêche (France).

Table 16 : Evaluation of the organoleptical tests of wild and cultured turbot.

STURGEON



CLASS : Osteichthyes

ORDER : Acipenseriformes

FAMILY : Acipenseridae

SPECIES : *Acipenser sturio*

4.4. STURGEON

Overview

Until the late 1970's, there has been little interest in the Western countries on sturgeon culture.

In Russia, the native sturgeon stocks were managed due to human activity. In this regard the Soviets undertook an ambitious hatchery research project to enhance the native stocks, and were successful in overcoming earlier problems with the artificial reproduction which is the bottle-neck for sturgeon farming.

Since 1980, several countries. Canada, Italia, and mainly Hungary, U.S.A. and France conducted sturgeon culture programs, particularly with the two species :

- White sturgeon (*Acipenser transmontanus*) in U.S.A.

- Siberian sturgeon (*Acipenser baeri*) in Europe.

The zootechnical information mentioned is related to the Siberian sturgeon, a freshwater fish whose culture management was supposed to be easier than that of amphihalin sturgeon species.

4.4.1. Broodstock management

The impossibility in Western Europe of basing any production on a regular supply from abroad makes it necessary to master the reproduction of the species.

Consequently, the first task to be achieved is to set up a generation of breeders. This operation takes a lot of time since fish puberties are still observed in animals older than seven years.

The second task is to obtain synchronisation of the ovulation of females with the spermiation of sperm from the males.

The accurate management of a Siberian sturgeon broodstock contains:

- Animals are stocked at a density around 5 kg/m^3 in tanks with a water depth close to 1m.

- Temperature is manipulated with a drop in winter to obtain a satisfactory spawning.

- Hormonal stimulation is practiced.

- Collection of ova is usually done by stripping as well as removal of sperm. Nevertheless at least one hatchery is using injection with hormones analogues before taking sperm and eggs.

- Eggs are artificially fertilized and treated against stickiness , usually with a chalk solution.

- At 14°C to 15°C, the eggs hatch in about one week. The newly hatched larvae are quite large, about 12 mm long. After consuming their yolk sac, they reach more than 20 mm.

4.4.2. Larval rearing and weaning

The process of larval rearing of *Acipenser baeri* is now performed on a routine basis, although only one commercial hatchery is currently in operation in FRANCE.

The main features of the larval rearing and weaning stage are :

- Period : 45-50 days.

- Initial density : between 35 and 6O larvae per liter.

- Water renewal : 100% per hour.

- Temperature : 17°C.

- Food : First feeding is with *Artemia* or chopped *Tubifex* worms and/or special compound minipellets during the first 20 days. Then a dry artificial food (trout food) can be used for the weaning stage.

- Rate of survival : about 80%.

- Mean weights : Day 0 = 25 mg
Day 30 = 350/450 mg
Day 50 = 1.5 / 3 g

During the larval rearing stage, the main problem is cannibalism, probably resulting from a diet not totally covering the nutritional requirements of sturgeon larvae.

4.4.3. Grow-out

Grow-out is practiced in tanks of various forms and dimensions commonly used in aquaculture and according to the size of the fish.

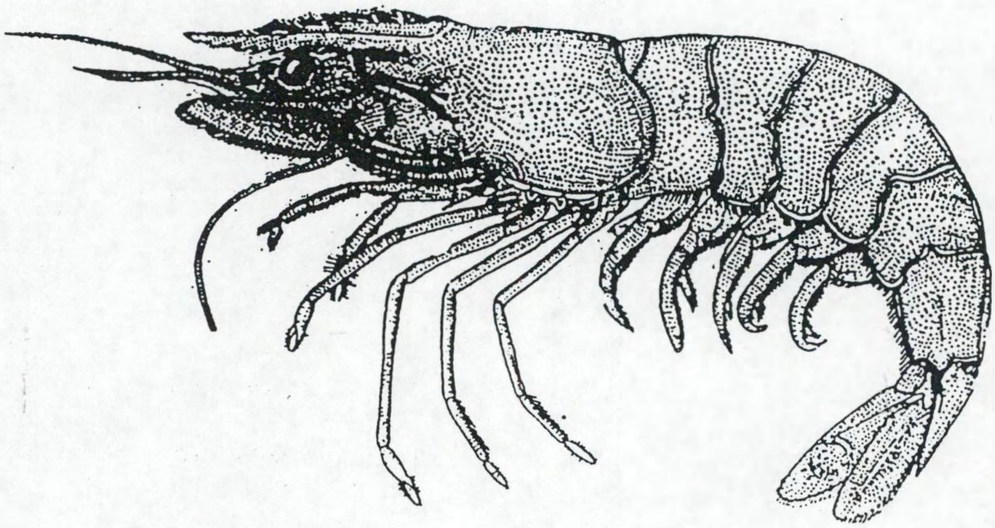
The suitable water temperature for sturgeon ongrowing ranges from 15° to 22°C.

With a stable temperature of 17°C, the fish reaches 500 g at 12 months and 2 kg in 24 months.

The main zootechnical parameters of sturgeon ongrowing are :

- Initial stocking density : 10 kg/m^3 (average weight 5 g).
- Final stocking density : 35 kg/m^3.
- Survival rate : 70%.
- Water renewal : 100% per hour.
- Oxygen : minimum level 4 mg/l.
- Food : until a special food for sturgeon is commercially produced, the currently used food is a rainbow trout food, with a rate of distribution of about 1.5 % of the live weight at 17°C.
- Conversion rate : 1.6 to 2.4 according to the size of the fish.

SHRIMP



CLASS : Crustaceans

ORDER : Decapods

FAMILY : Penaeides

SPECIES : *P. Vannamei - P. Japonicus*

4.5. SHRIMP

Shrimp culture has attracted considerable attention in recent years, not only because of its value as food supply, but also of its high potential as a foreign exchange earner in developing countries.

All the species considered for culture belong to the Penaeid family, due to their very rapid growth at large sizes. Nearly all of them are originated from tropical and subtropical areas and require to be farmed at high seawater temperatures.

Currently the world's shrimp farmers produce an estimated 700 000 to 800 000 metric tons of whole shrimp per year, what is approximately 30% of the shrimp placed on the world market. Consequently, international market prices have began to drop.

If we consider, in addition, that shrimp is mostly farmed in tropical countries, in large clay ponds with yields referred not to cubic meters of water, but to hectares of soil, it seems difficult to conceive the achieving of a profitable shrimp culture in BELGIUM where climate and sites are not suitable.

Nevertheless we may envisage two particular options.

- A first one would be based on a **superintensive** rearing of the species ***Penaeus vannamei***, due to the proven results at a very high density in artificial structures (provided a suitable seawater temperature is available).

- A second one would be also a **superintensive** process, using the only Penaeid species which can remain alive at least 24 hours after harvesting : ***Penaeus japonicus***. Although less easy, this rearing would allow to market the product at a better price.

In the two cases, it must be clear that such a venture would have the character of a technical challenge probably more than that of an economic opportunity.

4.5.1. Superintensive rearing of *Penaeus vannamei*

Penaeus vannamei is originated from the East-coast of the Pacific Ocean, and is currently farmed on a large scale in subtropical and tropical countries bordering this ocean from North Peru to Mexico, using post-larvae from the wild and/or produced by commercial hatcheries.

The superintensive rearing method of this species has been set up in French Polynesia by the team of AQUACOP (IFREMER).

The main zootechnical aspects are summarized below :

A. Reproduction in captivity

The breeders are reared at low density ($5/m^2$ till 20 g, and less than $1/m^2$ at high weight) in small ponds. Within 8 months, 60 to 70 g females and 45 to 50 g males can be obtained.

The maturation techniques comprises :

- eyestalk ablation of the females
- artificial photoperiod
- adjusted temperature
- artificial insemination of the females ready to spawn

B. Larval rearing

They are conducted till Pl 3 stage in 5/10 m3 tanks at an initial density of 100 nauplii/liter at 29°C.

The larvae are fed on :

- algae (Zoe 1)
- algae + microparticulated diets (Z2-Z3)
- *Artemia* + microparticulated diets after Mysis 1

After P 3 (15 days of larval rearing), the post-larvae are gradually acclimatized to the outside conditions, then P 5 larvae are transferred to the nursery for pregrowing .

C. Nursery stage

The goal is to produce well conditionned larvae to be seeded in the growing tanks.

The main characteristics of the nursery stage are :

Tanks volume : 10 m^3, depth : 1 m.

Density : 15 000 to 20 000 P 5 larvae /m^3.

Period : 14/17 days.

Seawater temperature : 28°C to 33°C - salinity : 25 to 35 ppt.

Water renewal = 30 to 50% per day.

Aeration : permanent aeration to maintain saturation.

Food : microparticules.

Survival rate : 60 to 75%.

Final mean weight = 10 to 15 mg.

D. Grow-out

Grow-out is made in concrete tanks with bottom surfaces going from 100 to 1 000 m^2, rectangular or circular shape, with water depth 0.5 to 1 m.

- Initial density : 100 Pl 2O - Pl 30 per square meter

- Water : usually seawater at salinity 25-35 ppt, but grow-out can also be carried out working with low salinity waters down to 8 ppt.

- Water renewal is linked to the biomass :

Biomass (g/m^2)	0/250	250/500	500/800	>800
Renewal (% per day)	10	2O	30	40

In addition, it is necessary to make bottom flushes to evacuate wastes and facilitate control of algae blooms. Flushing rate increases from 1 to 2 per week at the beginning of the rearing, to 1 per day at the end.

- Aeration : a strong aeration is necessary, about 4 CV/100 m^3.

- Food : special compound pellet.
  50% protein up to 2 g
  35% - after 2 g

- Period of growing : 5 to 6 months.

- Mean weight at harvest : 15 to 20 g.

- Survival rate : 65 to 75%.

- Yield : 1 000 to 1 500 g per square meter.

- Food conversion rate : 1.9 to 2.4.

4.5.2. Superintensive rearing of *Penaeus japonicus*

Penaeus japonicus is a temperate water species. Its reproduction and grow out have been studied for many years and have been brought to completion in commercial aquaculture operations in Japan, Korea, France, and more recently Italy and Spain.

In Southern Europe, reproduction is achieved using captive breeders and intensive hatchery process called "clear water process " .

Superintensive grow-out is practiced only in Japan where very high market prices balance the rather heavy cost of the process.

The main features of *Penaeus japonicus* rearing are :

A. Broodstock constitution and management

Future spawners are selected and reared at low density up to a weight of 40/70 g for females and 30/40 g for males.

They are placed in maturation tanks 60% females 40% males, and fed on fresh food (calamar-mussels) supplemented with high protein and vitamin compounds.

Photoperiod and temperature are manipulated.

Exchange of water is 150 to 200% per day.

Spawning is induced by thermal shock. The number of eggs collected from each female ranges from 100 0O0 to 200 00O.

B. Larval rearing

Larval rearing is achieved according to the following parameters
Seawater :Temperature 24 to 28°C
Salinity 32 to 36 ppt
Renewal 80% day
Aeration 100% volume/hour

Biological standards :

Period : 15 days from nauplii to Pl 5 larvae
Stocking density : 100 larvae per liter
Final density : 50 to 60 Pl per liter.
Food : in a first stage unicellular algae, replaced in a later stage by *Artemia* and microparticulated diets.

Fungal and bacterial infections have to be eliminated or reduced by using Treflan and antibiotics.

C. Pregrowing (nursery stage)

From Pl 5 to Pl 30 the juvenile shrimp are kept in nursery ponds (volume 100 m^3) at densities starting at 12 Pl per liter decreasing to 6 Pl per liter.

Suitable temperature is 22°C to 26°C. - Salinity ranges 20 to 35 ppt.

Animals are fed on micropellets with a protein rate of 60%.

Water exchange : 100 to 150% per hour.

D. Grow out

Superintensive grow out of *Penaeus japonicus* is practiced only in Japan, in the Kagoshima area. Post-larvae are transferred to large circular tanks (1 000 m^2) at initial density of 100/120 per m^2.

Tanks have double bottoms, with a layer of sand forming the first bottom, *Penaeus japonicus* burrow in the sand during the day and feed at night.

Water exchange is very important (4 times a day). The incoming water creates a circular flow which concentrates wastes in the center of the pond where they are drained out through a central drain device under the pond.

A part of the water pass continuously through the layer of sand, supplying enough oxygen to the shrimps when they are burrowed. With this method, it is necessary to use an excellent digestible dry food (52 to 54% protein) to minimize remains of feed and faeces in the tanks.

According to the seawater temperature (optimal 18°C to 26°C), production in a four or five months culture reaches 1.5 to 2 kg per square meter, with about 3O shrimps per kilo.

4.6. Short note on the use of trash fish as food in an intensive aquaculture facility.

Trash fish is only used as food for grow-out in fish production units with a rather artisanal character. It is still used in Spain as a grow out feed for turbot. At the Aquaculture conference in Torremolinos (Spain, may 1993) it was revealed that out of 12 turbot farms, 4 of them were administering fish directly (Blue Whiting and sandeels), 4 farms were using home made moist pellets consisting of 50% trash fish and 50% fish meal, only the other 4 farms used artificial diets.

Altough trash fish could easily be obtained in the harbours of Nieuwpoort, Oostende and Zeebrugge, its use in aquaculture is not recommended. The main constraints in the use of trash fish reside in the fluctuations of the nutritional composition of the food, which may vary with seasons (different fat content, protein content, etc.) and the difficulty of controlling water and hygienic conditions. Trash fish has a higher food conversion rate (>3:1) than commercial diets (1:1-1.5 for turbot), which means that more food and thus more nitrogen has to be brought into the system, resulting in a higher pollution of the cultere medium. Trash fish may also be contamined with pathogens which could easily be transferred to the fish cultures. Besides this, fresh fish has a high thiaminase activity, which breaks down thiamine (causing deficiency diseases). Therefore trash fish has to be treated by heat (80°C) to desactivate the thiaminase and to kill off the pathogens, resulting in extra costs (treatment plant and cold storage).

5. TECHNICAL INSTALLATION, EXPLOITATION AND FINANCIAL ANALYSIS

This part of the study is devoted to the definition of the technical installations constituting a production farm, with the exploitation and financial analysis associated.

We should have logically to deal separately with all the cases related to the different species evocated in the previous chapter.

However, due to the similarity of many equipments and installations taking place in any intensive farm, as well as the same scheme of exploitation, it would have been without interest to repeat some descriptions and evaluations.

For this reason it is preferable to give rather detailed information on a model farm project regarding one species, for example turbot, which is the species requiring the more sophisticated technology (at least as far as hatchery technique is concerned), and then to indicate the differences to be contemplated when farming other finfish species.

We shall treat successively :

5.1. - Production targets

5.2. - Description of the installations

5.3. - Water flows and quality of water

5.4. - Exploitation and financial analysis

5.5. - Data adjustment for other finfish species

Since at the moment no particular site can be selected, the proposed technical installation and the exploitation and financial analysis are pure indicative estimations and have to be updated (engineering, architectural and economical aspects) when a specific site is selected.

5.1. PRODUCTION TARGETS

We consider an **integrated project** with a production capacity of 300 tons of turbot per year. This production capacity is likely to be the lowest capacity allowing to make a profit venture when using intensive systems in Western Europe.

Weight of the commercial product will range between 1.5 and 2 kilos. It results that the number of fishes to be sold will be approximately 175 000 per year.

Taking into account a rate of mortality of 20% during a growing cycle of thirty months, the number of juveniles needed when leaving the nursery to be transferred to the grow-out sector is about 210 000.

Consequently, the hatchery production to be contemplated must be at least 250 000 juveniles, after weaning and elimination of bad pigmented animals. This means a production of about 300 000 juveniles after 30 days of larval rearing.

The rate of success of larval rearing being currently around 10%, and the number of cycles per year being 8, it will be necessary to start each cycle with about 400 000 larvae, let say 3 200 000 larvae per year.

5.2. DESCRIPTION OF THE INSTALLATIONS

5.2.1. Building and special units

To construct an integrated farm, producing 300 ton turbot/year, a total surface of 3 to 4 ha is necessary.

Out of the general facilities (roads - water and energy networks, etc.), the farm comprises :

- the hatchery building properly so called, covering an overall area of 1 400 square meters and made of industrial construction, and sheltering the following units :
    - the broodstock maturation unit
    - the larval rearing unit
    - the weaning and pregrowing unit
- the nursery greenhouse with a total surface of 300 m²
- the grow-out unit in six modules 1 800 m² each
- the technical building gathering all the energy equipments

- the servicing building with offices, sanitaries, storehouse, workshop and processing plant

5.2.2. Rearing tanks and volumes

A. Hatchery

Maturation unit : The broodstock is distributed in 6 tanks, 40 m^3 each, in 3 pairs with 2 of them under controlled condition (photoperiod and temperature)

Hatching unit : 16 hatching tanks (small volume)

Larval rearing unit :

Rotifers : 6 cylindro-conical tanks total volume 10 m^3

Artemia : 4 tanks of 2 m^3 (nauplii); 6 tanks of 4 m^3

Larval rearing : 12 tanks of 2 m^3

Total volume for broodstock and larval rearing = 306 m^3

B. Pregrowing unit

The pregrowing unit is equiped with 12 circular weaning tanks - surface 7 m^2 each (depth 0.5 m), and 8 subsquare tanks, 16 m^2 each (depth 0.5 m).

Total surface : 212 m^2 Total rearing volume : 106 m^3

C. Nursery

The nursery consists of a set of 16 tanks sheltered under a greenhouse similar to agricultural greenhouses. Piping or canalization outside the greenhouse is insulated to reduce thermal energy losses.

Tanks are made of concrete, with a square shape and a surface of 20 m^2 each.

Height of the water inside the tanks is 60 cm.

The total water volume is 16 x 20 x 0,6 = 192 m^3

5.2.3. Grow out facilities

The grow-out facilities are made of separated modules with a production capacity of 50 tons per year.

Each module is sheltered under a greenhouse covering a surface of 1 800 m^2 and designed in a way to allow using of structure and woof of agricultural multichapelled greenhouses, in conformity with the European normalization rates.

The process permits to add jointly and laterally as many units as it is wanted.

A. Tanks

Each module comprises 32 tanks of 4O m^2, out of which 2 are used for the transfers, and 30 devoted to the successive rearing phases (total water surface of 1 280 m^2).

These tanks are subsquare shaped (square with cut angles), self-cleaning and made of ferro-concrete with surface water intake and bottom central outlet. Prefabrication can be used.

Due to a water height inside the tanks of 90 cm, the total circulating volume is : 32 x 40 x 0.9 = 1 152 m^3 for each module.

For 6 modules, the total volume will be :

1 152 x 6 = 6 912 m^3 # 7 000 m^3

5.3. WATER FLOWS - Quality of water - NETWORKS

5.3.1. Seawater

It is supposed, for a first calculation, that a recirculation system is used only for the hatchery and the nursery, and that the grow-out modules are supplied with seawater, using a flowthrough system.

The seawater requirements are :

Hatchery/Nursery 500 m^3/h recirculation 50%	250 m^3/h
Grow-out modules 900 x 6 (renewal each 60 to 90 mn)	5 400 m^3/h
TOTAL	5 650 m^3/h

Whatever the system of seawater supply, either directly from the sea, from boreholes, or from cooling water taken from an industrial plant, the farm will have to construct and manage a package of pipes and pumps capable to sypply about 6 000 m^3 per hour of circulating water and subsequently evacuate it.

At the moment, it is unrealistic to give more details about the water supply construction until a site has been definitively selected. However an approach of the related investment and exploitation costs is made, extrapolating them from similar projects already constructed.

About the quality of water it can be mentioned that intake water has to be carefully filtrated, either through sand filters or mechanical filters, up to 50/100 μ. Seawater used for the hatchery is then sterilized by U.V. and filtrated again up to 1 to 2 μ.

Recirculation water is relieved from particles of feed and solid excrements through a mechanical filter, then passed through a biofilter for nitrification and returned to the rearing tanks with an appropriate addition of oxygen.

It has been previously stated that an aquaculture project at the Belgian coast is viable only if calories are available coming from external sources, or if ground water is available. In these two cases, either quality of the water allows to use it directly, or it is necessary to transfer heat through heat exchangers. When cooling water of power stations is used, water temperature is maintained by mixing. When the culture water has to be heated by an outer thermal energy source in a primary circuit, heat exchangers have to be used.

Anyway, mechanisms have to be installed for controlling and maintaining a suitable temperature of the circulating water.

5.3.2. Other networks

Two other networks have to be considered.

The first one deals with electricity supply. Out of heating, energy needs for a 300T turbot farm are estimated to 400 to 500 KVA. The best way is to be directly connected to a mean voltage line through a transformer.

However, due to the high value of the fish stock, there is an absolute necessity to maintain a continuous electric supply under all circumstances. Equiping the farm with at least two generating sets in order to have always one of them ready to work is a necessity.

Another network is the aeration network.

In the hatchery, air needs are estimated to 200 m^3/h under a 400 mbr pressure.

In the nursery, the useful air output is about 100 m^3/h at 150 mbr.

As far as grow-out is concerned, aeration needs are calculated according to 0.3 $m^3/h/m^3$ of seawater. The total air volume for each module is 400 m^3/h. For 6 modules, air volume will be 2 400 m^3/h at 150 mbr.

Air is produced through a central device with three blowers located in the technical building.

5.4. INVESTMENT-EXPLOITATION and FINANCIAL ANALYSES

5.4.1. Investment costs

The following estimates are taken out from similar recent existing realizations in France and in Spain, and must be considered only as an order of magnitude. A precise evaluation can only be made on a definitively selected site and through a detailed engineering study.

Table 17 hereunder gives round figures for the main components of the farm with costs expressed in thousands of Belgian francs (transformation factor 1 FF = 6.1 Bef).

TYPE OF FACILITY	COSTS (x 1 000 Bef.)
- Earth works and roads	5 000
- Hydraulic works	18 000
- BUILDINGS	
Hatchery	12 000
Nursery	3 000
Grow-out modules	35 000
Exploitation and processing	9 000
- TANKS	
Hatchery	5 000
Nursery	1 500
Grow-out modules	25 000
- EQUIPMENTS	
Hatchery	16 000
Nursery	1 500
Modules	6 000
Exploitation and processing	6 000
- Electricity	2 500
TOTAL	145 500
Contingency (10 %)	14 550
TOTAL COST	160 050

Table 17 : Investment costs summary for a 300 ton turbot farm.

Annual depreciation

Taking into account a depreciation period of 20 years for the general installations (hydraulics, roads,...), buildings and tanks, and a depreciation period of 7 years for the equipment and greenhouses, the annual depreciation (straight line method) will be 13 300 thousand Bef.

However, due to a 35% subsidy granted by the EEC and national government, the depreciation in the accounts will be limited to 13 300 000 x 0.65 = 9 750 000 Bef.

5.4.2. Operating expenses

To calculate the operating expenses, the following assumptions are made :

- Juveniles are all taken from the hatchery

- Food conversion rate is 1.5 using commercial pellets

- Labour

  The total number of employees is 27, divided as :

Management	3
Hatchery/Nursery	6
Grow-out	13
Processing	3
Maintenance	2

- Energy (including external calories purchase)

  20 BeF per Kilo of Fish

- Maintenance

  1% of building costs

  3% of the equipments

- Insurance

  3.5% of the stock value

- Processing and packing

  20 BeF per Kilo of fish

In table 18 the figures related to the operating expenses in a routine year (in thousands of Bef.) are mentioned.

- Grow-out feed	15 100
- Hatchery feed and sanitary products	1 800
- Salaries	29 000
- Energy	6 000
- Maintenance	1 500
- Insurance	3 200
- Processing and packing	6 000
TOTAL	62 600

Table 18 : Operating expenses of a 300 ton turbot farm during a routine exploitation year.

The exploitation expenses of the two first years can vary considerably according to the starting-up strategy applied. For an integrated farm with a fast starting-up, the operating expenses during the first and second year are respectively estimated at 2/3 and 3/4 of a routine year.

5.4.3. Exploitation balance

Considering that the average selling price ex-farm for the turbot of commercial size is 335 Bef, the exploitation balance during routine exploitation and out of interests in financing needs, is as follows, in thousands of Bef :

Production costs		Receipts	
- Operating expenses	62 600	- Sales	
- Depreciation	9 750		300 (t) x 335 = 100 500
Total	72 350		
Result	28 150		
	100 500		100 500

5.4.4. Employment

Modern aquaculture companies are highly sophisticated and capital intensive industries. Aquaculture activities not only generate a direct employment, but also an indirect employment related to development, services, suppliers and market activities for the business.

In the next section some particularities about qualifications wanted for the people serving directly in an aquaculture farm, as well as an estimation of indirect employment that aquaculture is capable of generating, are mentioned.

A. Direct employment

An integrated farm, such as that described, with a production target of about 300 tonnes turbot/year, and including a hatchery needs a staff of 27 to 30 people.

The wanted qualifications for these people are :

1) Management

Management people comprises first the General Manager, responsible for the good working of the farm, one secretary and one accountant.

The General Manager will be preferably a biologist with a PhD or MS degree, and a ten years or more experience in the field of aquaculture. An additional knowledge in management, administration and marketing is useful.

The accountant is an employee mastering the commercial book keeping and knowing how to use computers and software applied to accounting and management.

The secretary work needs a good professionalism, with an easy use of modern typing devices. The job also requires to be fluent in several languages, especially English.

2) Hatchery/Nursery

The person responsible for the hatchery/nursery activity must be a good biologist with a M.S. degree or a senior technician with a proven experience in the hatchery work.

The other employees consist of technicians coming from professional schools with a good level (bac + 2) and/or skilled workers with a prior experience of hatchery techniques.

3) Grow out

To run the grow out department of the farm, a young biologist or senior technician with some years of experience in the field is needed.

Out of the ten other people (in a 300 tonnes/farm), half of them will be technicians coming from professional schools and the other ones workers with a C.A.P. level.

4) Processing

The employee in charge of processing will be responsible not only for the processing operations, but also for the good working of the selling tasks :

- communication with the clients
- good organisation of the carriages, in strictly convenient sanitary conditions
- primary accountance (setting of invoices and associated documents)

This person will be preferably a technician coming from the agrobusiness sector with a good knowledge on the cold chain and conditioning methodology.

The two other employees in this department will be ordinary workers. Seriousness and capacity to serve automatic mechanisms are more important than a theoretical background.

5) Maintenance

The team "maintenance" will comprise two or three people having a practical good knowledge of mechanical and electrical equipments.

The team leader has a very essential task in the farm. He has to face any technical problem which threatens the continuous supply of the major components (energy - seawater - heating - etc.) as well as to conceive and to improve the equipments which are permanently needed by the production teams.

A very good experience for this job is f.e. that of chief engineer of a ship.

B. Indirect employment

Since indirect employments cannot be evaluated with the same precision, the mentioned indirect employment will merely be indicative for the gross employment creating effect of aquaculture activities.

1) Upside employment

When an aquacultural activity is set up in an area, it generally raises up an additional research effort from specialized institutes and universities.

This effort is directed towards the major problems related with the culture of the selected species. It ranges from genetics to physiology of the main vital functions (reproduction, growth, nutrition) and pathology.

Applied research can also be conducted on some particular aspects of rearing cycles or culture technology which are not yet mastered for 100%, or need to be improved.

When research is made on species having important development potentials, it may benefit of subsidies from national research foundations and/or CEE. By this the number of scientists involved will increase.

As an example, aquaculture research occupies in France more than 200 scientists and technicians (half of them in the IFREMER structure).

We may also account among the upside employments those devoted to professional education. Aquaculture may become a part of many programs of education and training in schools of different levels, from the agro high-schools to the more modest ones giving a practical training on marine cultures.

2) Joint employments

We call joint employments the employments resulting of the demand of supplies and services made by the farms to the economic sector.

We shall quote, as an exemple, the people contributing to the building of the farms, but mainly those who provide regular supplies, especially food supplies.

Another joint employment comes from the veterinary service which is indispensable for any farm.

3) Downside employment

Finally, we have to take into account the downside employments, especially all those linked to the transformation and the commercialization of the product.

It is currently estimated that employments resulting of transformation, conditioning and distribution of the raw product coming from fisheries is in Europe about twice of the fishermen number.

This ratio is probably reached only for some aquaculture species (especially salmon), but it certainly remains significant. In Belguim, one employment in fisheries supplies covers a downside employment of 3 to 4 places in distribution and transformation activities.

To conclude, next to the basic activity of aquaculture several other activities belonging to the primary production sector are stimulated. Aquaculture creates an induced employment that can be evaluated at three to four times the direct employment in a project. So an integrated aquaculture project, producing 300 tonnes turbot/year, will create at least a global employment up to 120 to 160 people.

5.4.5. Financial study

The financial study is related to a turbot farm with a 300 tonnes/year production capacity, an investment cost mentioned in table 17 and an exploitation balance mentioned in section 4.3.

To elaborate a financial study, the following assumptions are made

1) The investment is made within two years.

During the first year, engineering, general facilities, hatchery-nursery and the first ongrowing module are realised.

During the second year, the five other on-growing modules are realised, in such a way that the hatchery production is regularly absorbed.

2) In order to simplify the calculation, it is supposed that the sales start at the normal rythm at the beginning of year 4 after starting construction.

It is also assumed that operating expenses are one third of a routine year expenses in year 1, and two thirds in year 2.

A. Financing of material investment.

An investment subsidy granted by the EEC and the national government has been obtained up to 35% of the investment cost, say 56 000 000 Bef.

The remaining financing is supplied as follows :

one third : company assets	34 700 000 Bef
two thirds : Long Term Loan	69 300 000 Bef

The Long Term Loan is taken with an interest rate of 8.5%, on 15 years, with an exemption of two years, and fixed reimbursements, at the rate of 5 330 000 BeF year.

B. Financing of operating expenses.

We shall suppose that half of the total assets are applied to the financing of the operating expenses, which gives a contribution of 34 700 000 Bef (and a total of company assets of 69 400 000 Bef).

The remaining needs will be supplied through short term loans with an interest rate of 9.5%.

C. Renewal of equipments.

Equipments renewals start as soon as year 8. It is assumed that they are of the same value each year (8 300 000 Bef per year).

The total depreciation is increased by :
8 300 000 x 0.35 = 2 905 000 Bef to take in account that equipment renewals do not benefit of subsidies.

The detailed data of the Gross Exploitation Balance and the Financing Means and Using on a 15 year period are given in table 19 and 20.

D. Conclusions.

The production cost of turbot is estimated at 251 to 291 Bef/kg related to a proposed selling cost of 335 Bef/kg.

During a routine exploitation year (i.e. year 2000), the important production costs are grow-out feed (15% of the annual turnover), salaries (29% of the annual turnover) and depreciations (10% of the annual turnover). Results before taxes are calculated at 22% of the annual turnover.

Break even period for het proposed project is 4 years 8 months and the IRR of the investment is 25.85% (on a 15 year period).

	1994	1994 in %	1995	1995 in %	1996	1996 in %	1997	1997 in %	1998	1998 in %	1999	1999 in %	2000	2000 in %
REVENUES														
Sales (t)	0		0		300		300		300		300		300	
Price/kg	335		335		335		335		335		335		335	
Turnover	0,00	100	0,00	100	100,50	100	100,50	100	100,50	100	100,50	100	100,50	100
EXPENCES														
Purchase raw material														
- Juveniles	-	-	-	-	-	0	-	0	-	0	-	0	-	0
- Feed (grow-out)	10,07	-	11,33	-	15,10	15	15,10	15	15,10	15	15,10	15	15,10	15
- Hatchery products	1,20	-	1,35	-	1,80	2	1,80	2	1,80	2	1,80	2	1,80	2
Various														
- Insurance	2,13	-	2,40	-	3,20	3	3,20	3	3,20	3	3,20	3	3,20	3
- Maintenance	1,00	-	1,13	-	1,50	1	1,50	1	1,50	1	1,50	1	1,50	1
- Energy	4,00	-	4,50	-	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6
- Processing and packing	0,00	-	0,00	-	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6
- Various	-	-	-	-	-	0	-	0	-	0	-	0	-	0
Salaries	19,33	-	21,75	-	29,00	29	29,00	29	29,00	29	29,00	29	29,00	29
Depreciation	5,36	-	9,75	-	9,75	10	9,75	10	9,75	10	9,75	10	9,75	10
Trading-results	-41,89	-	-50,86	-	29,95	30	29,95	30	29,95	30	29,95	30	29,95	30
Financ. costs	-	-	8,79	-	13,94	14	15,01	15	11,81	12	10,41	10	7,73	8
Taxes and rates	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-
Results before	-41,89	-	-59,65	-	16,01	16	14,94	15	18,14	18	19,54	19	22,22	22
Taxes														
Cash flow	-36,53	-	-49,90	-	25,76	26	24,69	25	27,89	28	29,29	29	31,97	32
Production cost/kg					288		291		281		276		267	

	2001	2001 in %	2002	2002 in %	2003	2003 in %	2004	2004 in %	2005	2005 in %	2006	2006 in %	2007	2007 in %	2008	2008 in %
REVENUES																
Sales (t)	300		300		300		300		300		300		300		300	
Price/kg	335		335		335		335		335		335		335		335	
Turnover	100,50	100	100,50	100	100,50	100	100,50	100	100,50	100	100,50	100	100,50	100	100,50	100
EXPENCES																
Purchase raw material																
- Juveniles	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
- Feed (grow-out)	15,10	15	15,10	15	15,10	15	15,10	15	15,10	15	15,10	15	15,10	15	15,10	15
- Hatchery products	1,80	2	1,80	2	1,80	2	1,80	2	1,80	2	1,80	2	1,80	2	1,80	2
Various																
- Insurance	3,20	3	3,20	3	3,20	3	3,20	3	3,20	3	3,20	3	3,20	3	3,20	3
- Maintenance	1,50	1	1,50	1	1,50	1	1,50	1	1,50	1	1,50	1	1,50	1	1,50	1
- Energy	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6
- Processing and packing	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6	6,00	6
- Various	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
Salaries	29,00	29	29,00	29	29,00	29	29,00	29	29,00	29	29,00	29	29,00	29	29,00	29
Depreciation	12,66	13	12,66	13	12,66	13	12,66	13	12,66	13	12,66	13	12,66	13	12,66	13
Trading-results	27,04	27	27,04	27	27,04	27	27,04	27	27,04	27	27,04	27	27,04	27	27,04	27
Financ. costs	5,45	5	3,38	3	2,27	2	1,81	2	1,36	1	0,91	1	0,45	0	0	0
Taxes and rates	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-	p.m.	-
Results before	21,59	21	23,66	24	24,77	25	25,23	25	25,68	26	26,13	26	26,59	26	27,04	27
Taxes																
Cash flow	34,25	34	36,32	36	37,43	37	37,89	36	38,34	38	38,79	39	39,25	39	39,70	40
Production cost/kg	269		262		258		257		255		254		252		251	

Table 19 : Exploitation account of an integrated turbot producing aquaculture facility (in 1.000.000,-BeF).

	YEARS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Investment	82 500	77 550													
Inv. renewal								8 300	8 300	8 300	8 300	8 300	8 300	8 300	8 300
Total investment	82 500	77 550	0	0	0	0	0	8 300	8 300	8 300	8 300	8 300	8 300	8 300	8 300
Gross exploit. balance	-20 900	-41 800	-62 600	37 900	37 900	37 900	37 900	37 900	37 900	37 900	37 900	37 900	37 900	37 900	37 900
Long term interests		- 5 890	-5 890	-5 437	-4 531	-4 078	-3 642	-3 172	-2 719	-2 266	-1 813	-1 360	-907	-454	
Short term interests		-2 896	-8 052	-9 571	-7 276	-6 365	-4 085	-2 280	-663						
Depreciation		-5 360	-9 750	- 9 750	-9 750	-9 750	-9 750	-12 655	-12 655	-12 655	-12 655	-12 655	-12 655	-12 655	-12 655
Total	-20 900	-55 946	-85 692	13 142	16 343	17 707	20 423	19 793	21 863	22 979	23 432	23 885	24 338	24 791	25 245
Taxes															
Net result	-20 900	-55 946	-85 692	13 142	16 343	17 707	20 423	19 793	21 863	22 979	23 432	23 885	24 338	24 751	25 245
Cash flow		5 360	9 750	22 892	26 093	27 437	30 173	32 448	34 518	35 634	36 087	36 540	36 993	37 446	37 900
Cash flow after															
Reimbursement of loans									6 910	22 004	22 457	22 910	23 363	23 816	29 600
Long term loans		69 300	63 970	58 640	53 310	47 980	42 650	37 320	31 990	26 660	21 330	16 000	10 670	5 340	0
L.T. interests		5 890	5 890	5 437	4 531	4 038	3 642	3 172	2 719	2 266	1 813	1 360	907	454	
L.T. reimbursements			5 330	5 330	5 330	5 330	5 330	5 330	5 330	5 330	5 330	5 330	5 330	5 340	0
Short term loans		63 961	118 091	100 521	79 766	57 639	32 796	13 978	0						
S.T. interests		2 896	8 052	9 571	7 276	6 365	4 085	2 280	663						
S.T. reimbursements				17 562	20 763	22 127	24 843	28 818	13 978						
Assets	34 100	35 300													
Long term loans	69 300														
Subsidies		28 875	27 142												

Table 20 : Means / Using in thousand of BeF.

5.5. DATA ADJUSTMENTS FOR OTHER FINFISH SPECIES

5.5.1. Seabass

The adjustments to be considered for a seabass farm instead of a turbot farm, as far as installations, costs and turnover are concerned can be summarized as follows :

Investment :

A. Hatchery

On one hand, the number of fry to obtain the same production (300 tons per year) is higher :

with marketing fish at 300/350 g = 1 200 000

with marketing fish at 600/700 g = 650 000

This requires more tanks since the rearing densities are pretty similar. On the other hand, equipments are more simple. There is no need for algae and rotifers. Finally, hatchery investment is not very different as for turbot.

B. Grow-out facilities

With an intensive system at a land based farm, the general lay-out of the farm is rather similar whatever species is cultivated.

Differences may concern for example the shape of the tanks. Seabass is preferably reared in raceways or circular tanks instead of square tanks used for turbot.

But the main factor to take into consideration to fix the total volume of the tanks is the duration of the rearing cycle which depends itself on the seawater temperature.

This period itself is different according to the commercial selling size.

For example, it is possible to make a 350 g seabass within 22 to 24 months with an average temperature of 24°C, but due to the first maturation occuring after two years, and the resulting decreasing growth, it will take 12 months more to make a 600 g fish.

If we choose the small size (300/350 g), then it is possible to reduce the total volume and consequently the number of the tanks versus a turbot farm of the same capacity. Investment costs related to tanks and their equipments will be reduced by about 30%.

Economy will be about 18 000 000 Bef.

C. Operating expenses

As regards operating expenses, the main change is related to the feed cost.

As a matter of fact, the rate of conversion for seabass is higher than for turbot and reaches 2.5, and even 3 if large size fish are reared.

Since the unit price is about the same, grow-out feed expenses will be at least one third more (20 500 000 instead of 15 100 000).
Energy cost is also likely to increase since a higher water temperature is necessary.

D. Balance

Assuming that the selling price of the produced seabass (300/350 g) remains the current price 355 Bef per kilo, the exploitation balance would be as follows (in thousands of Bef).

Operating expenses	68 000	Sales 355 x 300 (t)	
Depreciation	7 600		
Total	75 600		106 500
Result	30 900		
	106 500		106 500

5.5.2. Seabream

A similar analysis may be laid regarding seabream.

Though a little less sophisticated, the seabream hatcheries need the same equipment as the turbot hatcheries (with a production of algae and rotifers).

In comparison with seabass, growing up to commercial size needs less time, what makes it possible to reduce the total volume and surface bottom of the tanks to obtain the same production weight.

Investment cost decreases to 133 000 000 Bef and annual depreciation to 5 540 000 Bef.

However, it is to fear that the selling price of seabream does not stay at its current level (about 335 Bef) leading to a decreasing result.

5.5.3. Conclusion

Selection of the best species (from an economic point of view) do not depend on technical or methodological particularities, but on the availibility of heated water and on the market prospects.

6. MARKET STUDY

Introduction

With the increased development of aquaculture facilities in recent years, it becomes more and more evident that the main problem facing any aquaculture development in the long term is market capacity to absorb the production at a profitable and steady price.

After solving technical problems in the early days when aquaculture facilities were started, today, marketing is by far the main concern of farmers.

In a study devoted to examine the prefeasibility of a large intensive farm in BELGIUM, it is necessary to review and discuss all the information available on the current situation of the markets for the species which are contemplated.

The content of this part of the study will be the following :

6.1. - Review of production

6.2. - Market situation and prices

6.3. - Commercialization of products

6.1. Review of Production

This review will proceed in regrouping together all the information concerning each species, whether it is related to aquaculture or fisheries, in order to have an overall view of the supply and trends species by species.

From an aquaculture point of view seabass and seabream will be considered together because they are very often cultured jointly in the same farm.

6.1.1. Seabass and seabream

Seabass *(Dicentrarchus labrax)*, and seabream *(Sparus aurata)* whose production cycle has been totally mastered, are now cultivated in nearly all the countries bording the Mediterranean Sea.

The aquaculture commercial product is mainly a fish weighing 250 to 350 g. and for a small part reaching 600 to 700 g.

In the wild, sizes of seabass range up to 10-12 kg/piece, whereas the size of wild seabream is smaller, with a maximum of 6 kg/piece.

The development rate of seabass and seabream aquaculture which occurs in the warm waters of Spain, France, Italy, ex-Yugoslavia, Greece, Turkey, Israël, Cyprus, Malta and Tunisia has been very rapid.

The very early research began in 1970, and the predevelopment stage occurred in the 1980's. In 1992, production reached 14 000 tonnes and is estimated to reach 35 000 tonnes by 1995.

Detailed figures of aquaculture production of bass and bream in the Mediterranean from 1989 to 1992 (in tonnes) are mentioned in table 21.

	1989	1990	1991	1992
Greece	600	1 600	3 300	7 000
Spain	370	1 760	1 800	3 500
Italy	500	1 000	1 150	1 300
France	240	380	600	1 300
Portugal		150	250	300
Tunisia	150	330	350	450
Turkey	50	180	250	450
TOTAL	1 910	5 400	7 700	14 200

Table 21 : Bass and bream production (tonnes),in Mediterranean countries. (Data from Cephalonia Fisheries).

Meanwhile, supply from fisheries have remained relatively steady.

The figures in table 22 show that the catches of bass and bream remain stable year after year in the main fishing countries.

Some 100 to 150 tonnes are caught by English fishermen and more or less 300 tonnes by Italian.

	1985	1986	1987	1988
Total WORLD	3 808	4 346	4 612	3 601
France	3 166	3 481	3 867	3 066
Spain	364	388	402	402
Portugal	310	462	325	115

Table 22 : Fisheries landings of seabass *(Dicentrarchus labrax)*.
(in tonnes. Source : FAO).

However quantities consumed from the wild are almost certainly higher than statistics would indicate. Local landings often do not appear in official statistics, especially in France.

	1987	1988
Total WORLD	4 985	4 349
France	183	292
Spain	83	35
Portugal	578	197
Italie	2 379	2 027
Turkey	1 019	1 000

Table 23 : Fisheries catches of seabream (*Sparus aurata*).
(in tonnes. Source : FAO).

Table 23 shows the fisheries landings for seabream. Those figures have to be taken with carefulness because there are several other bream species (as *Dentex, Pagellus,* etc.) wich are easily mingled with royal bream *(Sparus aurata).*

However, as for salmon ten years before, on the one hand the supply from fisheries is steady at a relatively low level. On the other hand the supply from aquaculture is increasing very rapidly in such a way that as early as 1995, cultivated fish will be two times (as far as tonnage is concerned) more important than fish from the wild.

Is that trend likely to go on ?

The answer is given by the number and the size of existing aquaculture projects or projects under construction, and especially integrated projects including hatcheries.

The exact number of hatcheries set up in the Mediterranean countries is not significant because a lot of them do not work year round (without controlled maturation).

The more important factor is the continuous increase of production capacity of the dozen very large hatcheries. Two of them are located in France, three in Spain, four to five in Greece and two in Tunisia.
Hatcheries such as "Thalassa foods" in Greece, or "Cupimar" in Spain, "Sepia international" in France are capable of producing each about 10 to 15 million juveniles per year. The precise data given for France in figure 31 and 32 show the impressive rate of increase for both juveniles and fishes of commercial size in the two last years.

In 1993, the estimated number of juveniles produced by hatcheries will be between 95 and 100 millions, with a forecast of 130-140 millions in 1995 (60 to 70% seabass and 30 to 40% seabream). Selling price of juveniles has consequently dropped from about 0.60 US Dollar to 0.40 US Dollar.

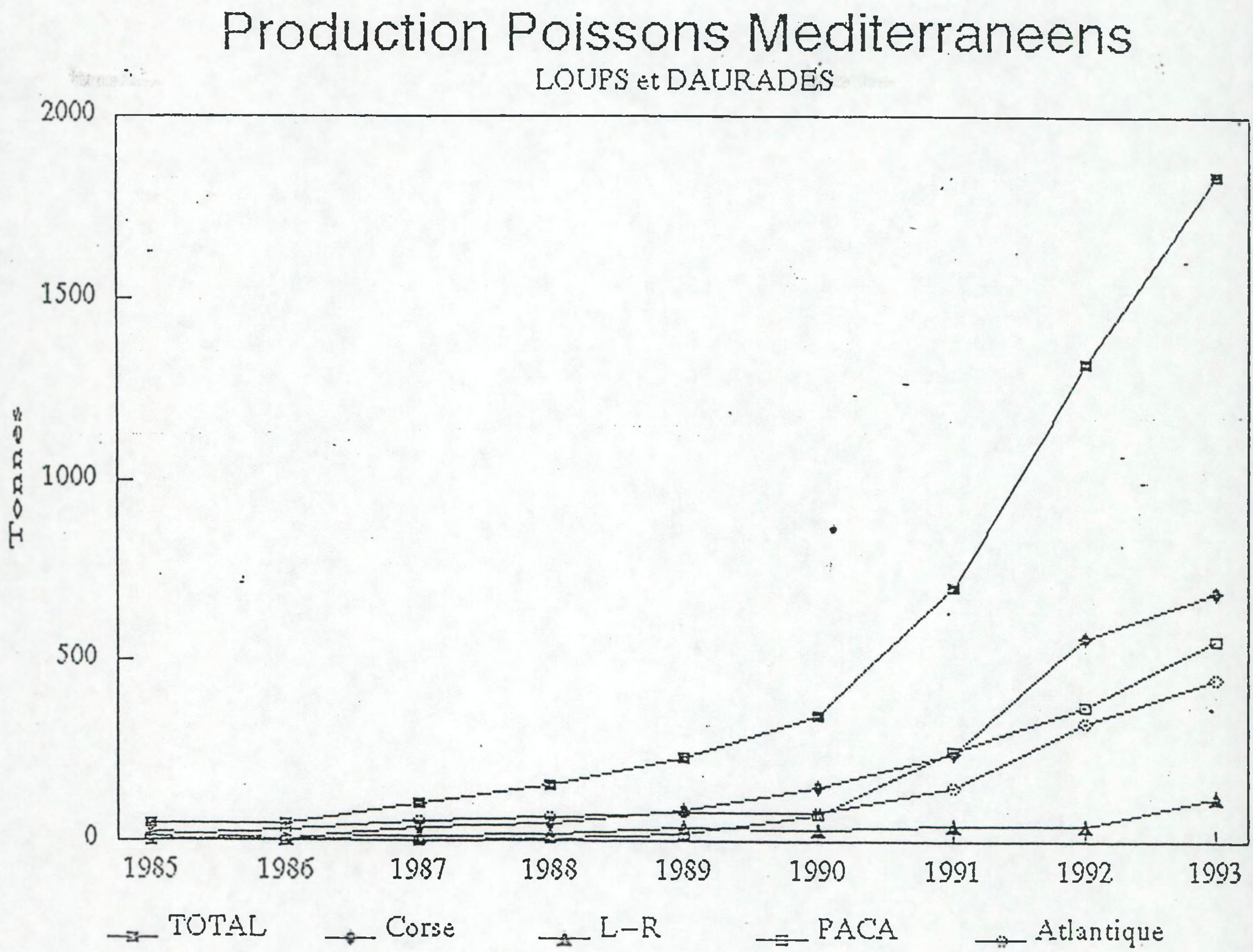
Regarding the farms, the situation is contrasted.

In some countries, as France, Italy and Spain, legal and administrative constraints as well as environmental problems and price decrease lead to limit the setting up of new farms. New projects are developing in other countries, especially in Greece and Turkey.

Greece has doubled its annual production every year over the last five years which reached 7 000 tonnes in 1992. Forecasts for 1995 are 15 000 tonnes.

However such an increase cannot last at the same speed. It is likely that after 1995, production will level of, at least till selling prices are stabilized and the market is enlarged .

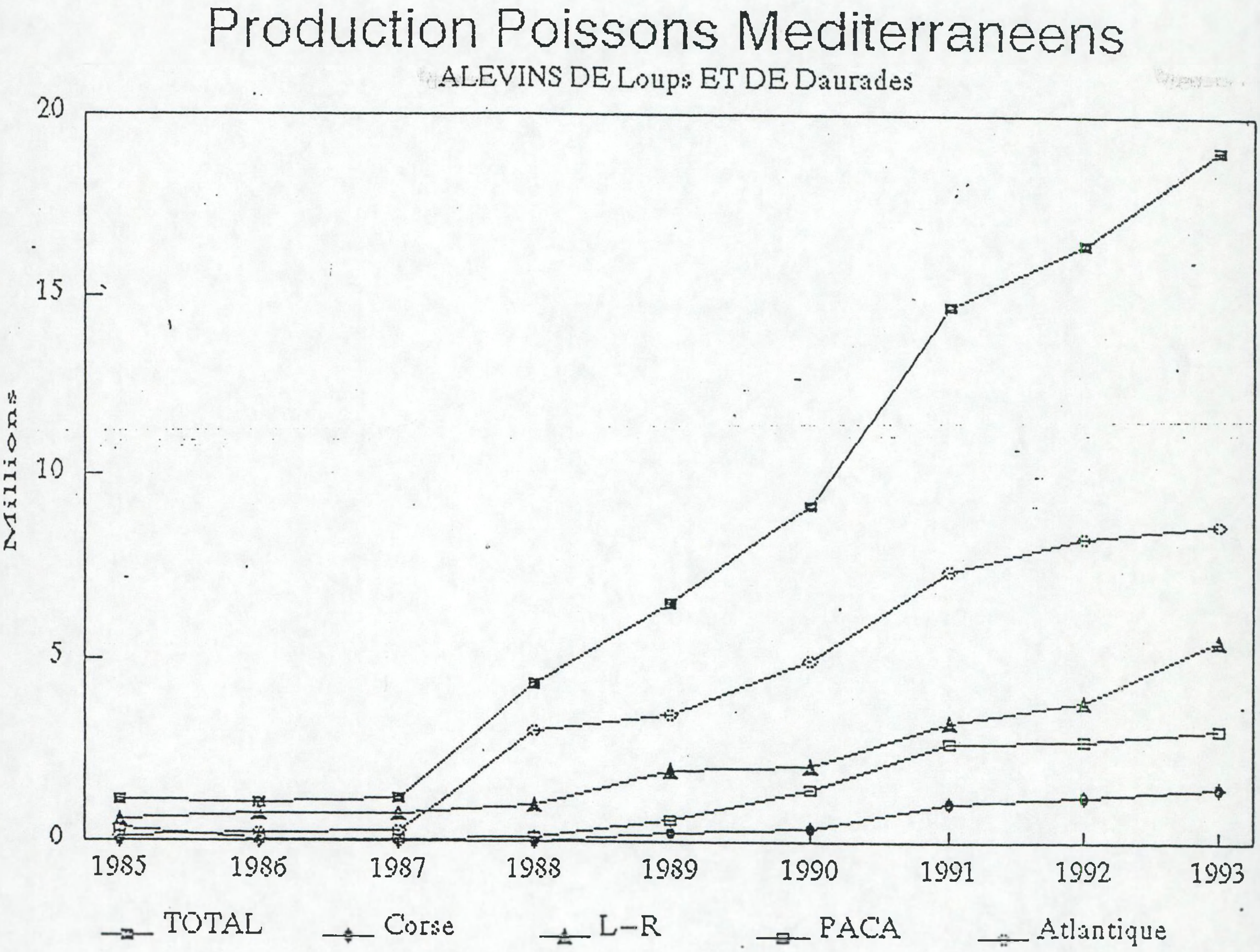
PISCICULTURES MARINES EN FRANCE : PRODUCTION POISSONS MEDITERRANEENS



	1985 Tonnes	1986 Tonnes	1987 Tonnes	1988 Tonnes	1989 Tonnes	1990 Tonnes	1991 Tonnes	1992 Tonnes	1993 Tonnes
TOTAL	54	52	111	160	234	347	703	1320	1830
Aquitaine	0	0	0	0	0	0	0	0	0
Bretagne	0	0	0	1	2	3	4	6	5
Charentes	2	0	0	0	0	0	6	17	25
Corse	12	10	38	54	89	154	250	565	690
Langedoc-Rou.	26	7	13	24	38	35	47	47	130
Nord	15	35	58	74	84	79	140	300	400
PACA	0	0	3	8	22	76	253	378	560
Loire	0	0	0	0	0	1	3	7	20
Atlantique	17	35	58	75	86	83	153	330	450

Figure 31 : Seabass and seabream production (tonnes) in France from 1985 to 1993.

PISCICULTURES MARINES EN FRANCE : PRODUCTION POISSONS MEDITERRANEENS



	1985 Alevins	1986 Alevins	1987 Alevins	1988 Alevins	1989 Alevins	1990 Alevins	1991 Alevins	1992 Alevins	1993 Alevins
TOTAL	1200000	1190000	1275000	4380000	6531000	9197000	14708000	16460000	19020000
Aquitaine	0	0	0	0	0	0	0	0	0
Bretagne	0	0	0	0	0	0	30000	0	0
Charentes	160000	260000	340000	1550000	2350000	2924000	3400000	4000000	4000000
Corse	0	0	0	0	250000	433000	1151000	1330000	1600000
Langedoc-Rou.	660000	830000	835000	1130000	2071000	2200000	3350000	3950000	5550000
Nord	0	0	0	1550000	1220000	2100000	3900000	4200000	4500000
PACA	380000	100000	100000	150000	640000	1540000	2827000	2880000	3200000
Loire	0	0	0	0	0	0	50000	100000	170000
Atlantique	160000	260000	340000	3100000	3570000	5024000	7380000	8300000	8670000

Figure 32 : Production of seabass and seabream juveniles production in France from 1983 to 1993.

6.1.2. Turbot

Turbot catches from the wild have remained quite stable over the years at 7 000 - 8 000 tonnes. Including estimates for underreporting, total European catches are about 10 000 tonnes/year .

The Netherlands is the main turbot catching country with about 3 500 tonnes/year. The second major catching country is Denmark (2 000 tonnes). Turkey is the only non EEC turbot producer and reports a surprising increase reaching 1 200 to 1 500 tonnes since 1990.

The culture of turbot is a relatively recent aquaculture development. Technology, especially as far as hatchery technology is concerned, has been built up in England and France. Grow-out is located mainly in Spain (Galicia) where natural conditions are excellent for this species.

Spain has thus become the main turbot culturing country, importing juveniles from Norway, England and France.

Cultivated turbot production has been increasing, since 1988 (table 24). Turbot size produced through aquaculture is generally 1 500 - 2 000 g. Production expected in 1995 is about 5 000 tonnes.

	1988	1989	1990	1991	1992	1993
Spain	97	271	640	825	1.400	2.000
France			30	80	120	400
TOTAL	97	271	670	905	1.520	2.400

Table 24 : aquaculture turbot production in Europe (in tonnes).

Efficient hatcheries are very few. They are located in Norway (1), England (2), France (2), Denmark (1) and Spain (4).

The total production capacity is about 2.5 million juveniles per year, with 1 million in France.

This capacity will remain more or less unchanged in the next years, because construction of new farms has been practically stopped due to the uncertainty of price fluctuations.

The number of farms is also limited. In Spain, 13 ongrowing facilities are working (4 farms have been shut in early 1993) and several projects have been cancelled.

In France, 4 farms are operating. New projects are delayed.

Two or three projects are planned in Portugal, but their setting up encounters many difficulties.

It seems that, especially in Spain where natural conditions are the best in Europe, potential investors are waiting for a better view of the general economic situation as well as a price stabilization.

Out of Europe turbot farming is starting in Chile, where one commercial hatchery and growing facility (capacity 200 tonnes/year) have been built recently. According to the Chilean people involved, they will produce for the North American market.

6.1.3. Sturgeon

Sturgeon culture for wild stock restauration, as well as fisheries, is dominated by ex-U.R.S.S. and Iran.

In 1988, fisheries landings in those two countries are estimated at about 25 000 tonnes, representing 90% of the total world sturgeon production.

Catches from the wild in Europe, especially from the Garonne river in France have turned to nothing.

Sturgeon aquaculture production in Europe is small and rather marginal. Four countries are involved in sturgeon culture. In Italy 500 to 800 tonnes *Acipenser transmontanus* are produced. In Hungary and ex-Yugoslavia, sturgeon is cultured extensively in ponds at small scale. Germany is involved in sturgeon culture research.

One hatchery has been built in France, and a large farm is in course of construction with a capacity of 200 - 300 tonnes per year.

6.1.4. Shrimp

Total world production of shrimp placed on the world market, is about 2 000 000 metric tonnes per year.

From this production, 720 000 tonnes come from aquaculture in 1992 (100 000 tonnes in 1982).

Shrimp farming countries are located in the tropical and subtropical areas. Today, more than fifty countries have shrimp farms.

A large part of juveniles (post-larvae) is produced by hatcheries. Shrimp hatcheries are found in three sizes : small scale - medium scale and large scale. The great number of small scale hatcheries in the developing countries (backyard hatcheries) explain the impressed total existing in the world (table 25).

	Production	Ha in production	Kg per ha	Number of hatcheries	Number of farms
W. Hemisphere	129 500	144 947	893	203	1 798
E. Hemisphere	591 500	856 200	691	2 792	46 940

Table 25 : World summary shrimp production in 1992.(Source : World shrimp Farming).

The European production is very small. Tentatives have been made in France and Spain with the cold-tolerant shrimp "*Penaeus japonicus*", but results are deceiving. Production is decreasing, even in Spain where climatic conditions are satisfiable. From 87 tonnes in 1989, shrimp production has dropped to 30 tonnes in 1992.

The prospect for a new shrimp production development is not clear.

6.2. Market structures and prices

6.2.1. Seabass and seabream

The main markets for seabass and seabream are those of France, Italy and Spain.

Seabass

France landings of seabass and output of farming have been increasing over the past years. Nevertheless, seabass currently represents a very low percentage of total landings of finfish. Imports cannot be identified in trade statistics, but they are believed to be relatively small.

Prices are very high compared with other species, but fluctuate over the year. Cultured seabass (300 g) is not yet sold in large quantities in France because the market prefers sizes from 500 g to 1 kilo/piece which are not the common size of cultured seabass.

In 1990, average price on the Rungis market was 100 - 120 FF per kilo. In 1992, average price on the Rungis market has dropped to 80 FF per kilo.

The Italian market is the best market for aquaculture products. Out of a consumption of about 2 500 tonnes per year, about 1 000 to 1 200 tonnes are currently coming from aquaculture.

In Italy imports come from Greece, France, Tunisia and Spain.

Prices, as in other European markets, are high, but are just losing about 25% of their value with recent monetary adjustments. Current market price is not higher than 10 to 11 US dollar instead of about 14 US dollar in 1992.

Preferred sizes are situated in the range 300 - 500 g/piece which can perfectly be supplied by aquaculture products. Seasonal demand peaks at Christmas and to a lesser extent during summer months (touristical season).

In Spain, cultured seabass is mainly consumed through the restaurant sector. The preference is for a large fish, so that seabass farmed in Spain is the more often exported to Italy.

The former strongly demanding markets of Spain, France and especially Italy, with high prices, have evolved over the last two years to free markets. The recent trend of increasing production and a price reduction of about 20% to 30% (compared to 1990) seems to level off. In the future the price of seabass will probably be situated around 70 FF/kg with fluctuations of 10% and high prices during certain periods of the year (Christmas, holiday months). The exceptional situation on the Italian market (high prices) probably will disappear and prices will be equal to the French and the Spanish market.

<u>Seabream</u>

In France, seabream consumption has fluctuated between 1 000 and 2 500 tonnes annually over the past nine years.

Seabream is primarily a Mediterranean fish. The main markets are situated in the South of France. Demand is somewhat seasonal, peaking in the summer and during holiday periods.

Breams are bought by both restaurants and through the retail sector.

Prices are generally erratic, reflecting both demand and supply variations. They are finally 4 to 5 US dollars below seabass prices.

In Italy, wild landings of breams amount to about 5 000 tonnes per annum while about 1 500 to 2 000 tonnes consist of farmed bream.

Prices of imports are relatively high compared with other markets. Although no official market statistics are available, a price of 14 US dollar (now 10 US dollar) has been usual in the wholesale markets over the past years.

The Italian market has a strong preference for sizes 200 - 500 g/piece, with 300 g/piece particularly suitable for restaurants.

Seasonal demand peaks at Christmas and to a lesser extent at Easter and in the summer. During these periods prices are twice those during the rest of the year.

This market offers considerable potential for expansion and is likely to be a prime target for increased volumes expected from farming.

The Spanish market for seabream is also a major market although, compared with Italy, the demand is less strong and prices are lower.

For all markets, prices have started a decreasing trend linked with the difficulties of fisheries, the monetary adjustments and the increasing production.

6.2.2. Turbot

Turbot is generally sold fresh and gutted.

In a recent aquaculture congress at TORREMOLINOS (Spain - May 1993), the current market demand for turbot has been estimated (table 26).

Spain	2 500 tonnes
Netherlands	1 000
France	2 000
Turkey	1 000
Italy	1 500
U.K.	800
Germany	1 000
Denmark	200
TOTAL	10 000 tonnes

Table 26 : The market of Turbot in European countries.

The total market demand represents more or less the catch from fisheries.

When looking at the forecasted cultured turbot production (5 000 tonnes/year towards 1995), it becomes obvious that the influx of cultured products will upset the stable and high priced market unless demand is increased by a strong effort of marketing.

Regarding consumption, France appears to be the best market for turbot in Europe, if not for quantities, at least for prices.

The French market fully appreciates the special taste of turbot and is willing to pay a relatively high price.

The bulk of consumption is made through the restaurant sector.

The Spanish market is rapidly developing. At present, most of the supply comes from the aquaculture industry. But 1991, prices began to drop. From 1 600 Pta/kg, they have progressively decreased down to 1 100 Pta/kg. To face this drop, Spanish turbot farmers look now for foreign markets for their products, especially the French market.

In Italy, turbot is mainly consumed in the north. The market is rather limited and the Italian consumer is not disposed to pay the premium price for turbot.

The main size used in Italy is relatively small (turbot of 0.5 - 1.5 kg/piece) as the Italian restaurant customer prefers a plate-sized fish.

Other markets, i.e. Germany - Denmark, are of less importance though in Denmark the prices are high and stable throughout the year.

Landings of turbot in Belgian ports during the period 1988-1992 are given in table 27. Landings increased considerably in 1990 and are highest during the period from Septembre to January. The Belgian market is estimated at 1 500 tonnes/year. Beside the landings, turbot is imported from the Netherlands and Denmark. It is not clear whether the increased landings or the economic conjuncture caused a minor price decrease of turbot < 3 kg (figure 35).

	1988	1989	1990	1991	1992
January	15263	16417	26098	26380	36708
February	15355	17572	17442	20851	31871
March	15806	11975	17077	30995	21245
April	14665	11077	11525	24721	15662
May	14055	18708	16605	25892	21184
June	11745	11548	18403	17866	17062
July	11689	15654	17638	23023	19786
August	11567	18073	29227	23035	24955
September	17270	35321	35898	50243	39002
Oktober	31279	38553	72057	48455	37041
November	33774	32926	46073	52941	34148
December	26796	32543	46466	54766	38791
Total	219264	260367	354509	399168	337455

Table 27 : Landings of turbot (in kg) from 1988 to 1992.

Turbot prices in Belgian fishports depend on the size of the fish. The mean price of turbot > 4 kg is highest and is situated around 600,- Bef/kg. The mean price of turbot from 3 to 4 kg is situated around 450,- Bef/kg, average turbot price < 3 kg is situated around 320,- Bef/kg (figures 33 to 35). The prices fluctuate over the year with maxima during winter periods (Christmas) and minima in June for turbot > 4 kg, and maxima during winter and summer periods for turbot < 3 kg.

The current mean European price for cultured turbot is around 10 US dollars /kg, but this price is fluctuating, resulting from the more or less abundance of fisheries landings in the Netherlands. Since fisheries supply of turbot is much higher than turbot production, the production increase due to farmed turbot will have a minor influence on the price.

Figure 33 : Turbot prices in Belgian fishports from 1988 - 1992 (kat 1 : > 4 kg).

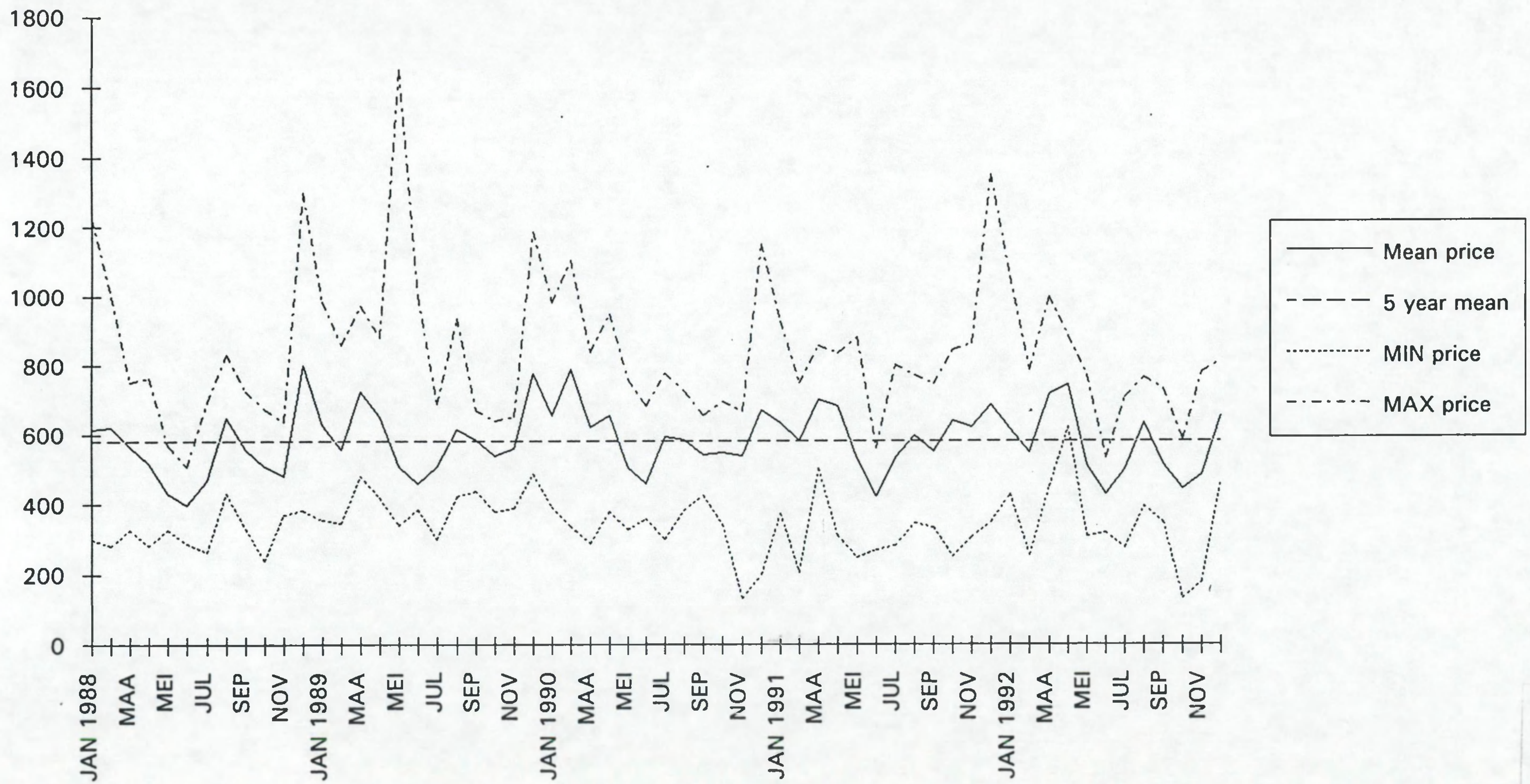


Figure 34 : Turbot prices in Belgian fishports from 1988 - 1992 (kat 2 : 3 kg - 4 kg).

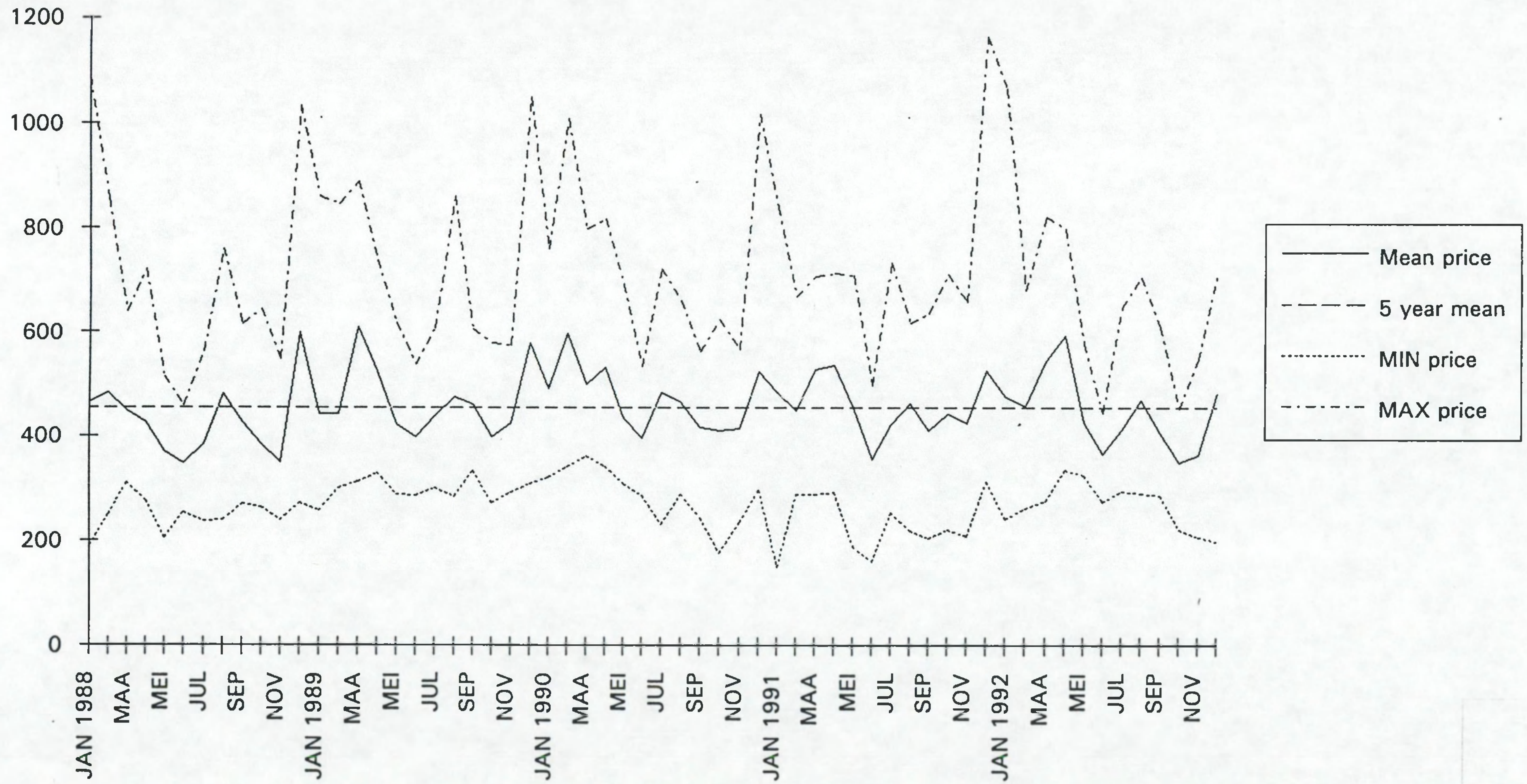
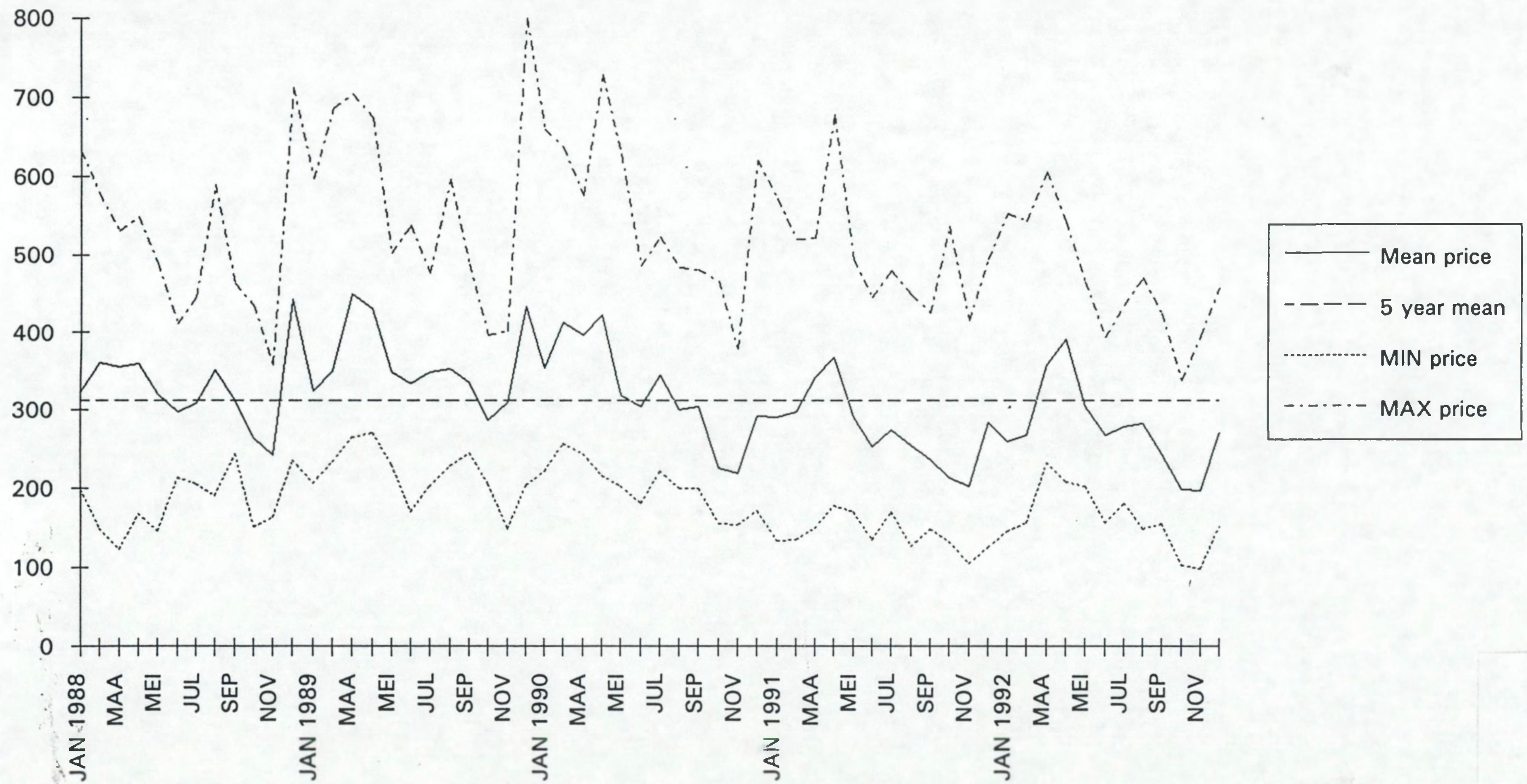


Figure 35 : Turbot prices in Belgian fishports from 1988 - 1992 (kat 3 : < 3 kg).



6.2.3. Sturgeon

There is no structured market in Europe for sturgeon. Farmed sturgeon is sold fresh on ice at 2 kg/piece. In France, when production was limited to some ten tonnes/year, prices of farm were situated around 100 FF/kg (restauration sector). In 1991, the future French market was estimated at 400 - 500 tonnes and prices of 85 FF/kg of farm were suggested. Now that the first farmed production (about 100 tonnes in France) is available, 100 FF/kg is clearly an overestimation. At the moment, there is no clear view on the market demand and the price which can be obtained. In the future, to market fresh or smoked sturgeon, a substantial effort to develop and to promote the product will be necessary.

At the Belgian market, sturgeon appears sporadically at wholesalers but the demand from the restauration sector is low and unstable.

6.2.4. Shrimp

Shrimp market is an international market.

The main consumers are Japan (303 OOO tonnes in 1992) - U.S.A.
(130 0O0 tonnes) and Europe (80 000 tonnes).

Prices vary according to the species, and mainly the size. Sizes are characterized by the number of pieces in a kilo. For exemple, the class 30-40 means between 30 and 40 shrimps in a kilo (33 to 25 g/piece).

There is of course a very great difference of price between the larger sizes (10-20) and the smaller sizes (100-120). The current average price is around 10 US dollars per kilo ex-farm.

6.3. Commercialization of products

Due to the increasing production, commercialization of products has become one of the major concerns of farmers involved in marine aquaculture.

The main parameter to be considered for all the species (with the exception of sturgeon since this market is just starting to develop) are :

- The increase of farmed production exceeds already or will exceed very soon the fishery supply, and no increases in wild landings of these or comparable species appear likely.

- There is a strong current demand for quality fish.

- Aquaculture will allow regular supplies. The case of salmon illustrates the demand creation effect if distributors are assured of regular supplies of a good species at relatively constant price.

- The impact of standardisation will be stimulating for the market. If farmed output is available in standardized sizes and of consistent quality, this will stimulate demand, particularly from the supermarket sector.

Some aspects are different according to the species.

For example, seabass and seabream are traditionnally traded in whole form and fresh. It will be very difficult to make changes and/or to bring added value by new processing options (especially because the selling size of farmed fish is limited).

On the contrary, turbot, and particularly large turbot (more than 1.5 kg) can be processed in different ways, opening new distribution channels.

It is however obvious that to maintain the current prices after the 20 to 40% reduction occurred in constant money value at the end of 1992, it will be necessary for all the species contemplated, to extend the market to new consumers through a very important and sustained marketing promotion.

In this approach, it appears that the main competition will not be versus wild catches, but with salmon because this species is more and more promoted as supplies increase.

Finally fish consumption and prices are sensitive for the market tendency and the economic conjuncture. Prospects are good for higher consumption as soon as economic recession in Europe is ended. To enlarge the markets and keeping pace with production, it will be necessary that:

- producers set up professional associations in order to define and guarantee quality of the products as well as availibility year round.

- a marketing strategy is adopted, comprising not only an extension of markets to new consumers, providing them with information and education, but also applying new processing options, especially for turbot whose relatively large size currently dissuades the housekeeper.

7. COMPILATION OF SITE CRITERIA

SITE No : 1

		Surface	Water quantity		Water quality		Thermal energy	Market conditions	Discharge	Technical installation	Status culture technology				Final evaluation
				Temperature	Sallinity	Pollutans									
SEABASS	1. BROODSTOCK	+	+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY	+	+	-	+	o	+	o	+	+	+				F -
	3. ON-GROWING	+	-	-	+	o	+	o	+	+	+				F -
SEABREAM	1. BROODSTOCK	+	+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY	+	+	-	+	o	+	o	+	+	+				F -
	3. ON-GROWING	+	-	-	+	o	+	o	+	+	+				F -
TURBOT	1. BROODSTOCK	+	+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY	+	+	-	+	o	+	+	+	+	+				F+
	3. ON-GROWING	+	-	-	+	o	+	+	+	+	+				F -
SHRIMPS	1. BROODSTOCK	+	+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY	+	+	-	+	o	+	o	+	+	+				F+
	3. ON-GROWING	+	o	-	+	o	+	o	+	+	o				F -
STURGEON	1. BROODSTOCK	+	+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY	+	+	-	+	o	+	o	+	+	o				F+
	3. ON-GROWING	+	-	-	+	o	+	-	+	+	+				F -

Estimation quotations

+ : satisfactory conditions
o : can be improved
- : severe limiting conditions

F+ : Feasable
F - : Feasable but requiring higher investments
MF : Not feasable

SITE No : 2

		Surface	Water quantity		Water quality		Thermal energy	Market conditions	Discharge	Technical installation	Status culture technology				Final evaluation
				Temperature	Salinity	Pollutans									
	1. BROODSTOCK	+	+	-	+	o	-		+	+	+				F -
SEABASS	2. HATCHERY + NURSERY	+	+	-	+	o	-	o	+	+	+				F -
	3. ON-GROWING	+	+	-	+	o	-	o	+	+	+				F -
	1. BROODSTOCK	+	+	-	+	o	-		+	+	+				F -
SEABREAM	2. HATCHERY + NURSERY	+	+	-	+	o	-	o	+	+	+				F -
	3. ON-GROWING	+	+	-	+	o	-	o	+	+	+				F -
	1. BROODSTOCK	+	+	-	+	o	-		+	+	+				F -
TURBOT	2. HATCHERY + NURSERY	+	+	-	+	o	-	+	+	+	+				F -
	3. ON-GROWING	+	+	-	+	o	-	+	+	+	+				F -
	1. BROODSTOCK	+	+	-	+	o	-		+	+	+				F -
SHRIMPS	2. HATCHERY + NURSERY	+	+	-	+	o	-	o	+	+	+				F -
	3. ON-GROWING	+	+	-	+	o	-	o	+	+	o				F -
	1. BROODSTOCK	+	+	-	+	o	-		+	+	+				F -
STURGEON	2. HATCHERY + NURSERY	+	+	-	+	o	-	o	+	+	o				F -
	3. ON-GROWING	+	+	-	+	o	-	-	+	+	+				F -

Estimation quotations

+ : satisfactory conditions	F+ : Feasable
o : can be improved	F - : Feasable but requiring higher investments
- : severe limiting conditions	NF : Not Feasable

SITE No : 3

		Surface	Water quantity		Water quality		Thermal energy	Market conditions	Discharge	Technical installation	Status culture technology				Final evaluation
				Temperature	Salinity	Pollutans									
SEABASS	1. BROODSTOCK	+	+	-	-	o	+		+	+	+				NF
	2. HATCHERY + NURSERY	+	+	-	-	o	+	o	+	+	+				F -
	3. ON-GROWING	+	+	-	+	o	+	o	+	+	+				F+
SEABREAM	1. BROODSTOCK	+	+	-	-	o	+		+	+	+				NF
	2. HATCHERY + NURSERY	+	+	-	-	o	+	o	+	+	+				F -
	3. ON-GROWING	+	+	-	+	o	+	o	+	+	+				F+
TURBOT	1. BROODSTOCK	+	+	-	-	o	+		+	+	+				NF
	2. HATCHERY + NURSERY	+	+	-	-	o	+	+	+	+	+				F -
	3. ON-GROWING	+	+	-	-	o	+	+	+	+	+				NF
SHRIMPS	1. BROODSTOCK	+	+	-	-	o	+		+	+	+				NF
	2. HATCHERY + NURSERY	+	+	-	-	o	+	o	+	+	+				F -
	3. ON-GROWING	+	+	-	-	o	+	o	+	+	o				NF
STURGEON	1. BROODSTOCK	+	+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY	+	+	-	+	o	+	o	+	+	o				F+
	3. ON-GROWING	+	+	-	+	o	+	-	+	+	+				F+

Estimation quotations

+ : satisfactory conditions
o : can be improved
- : severe limiting conditions

F+ : Feasable
F - : Feasable but requiring higher investments
NF : Not Feasable

SITE No : 4

		Surface	Water quantity	Water quality			Thermal energy	Market conditions	Discharge	Technical installation	Status culture technology				Final evaluation
				Temperature	Salinity	Pollutans									
	1. BROODSTOCK			+	?	o	+		-	+	+				F -
SEABASS	2. HATCHERY + NURSERY			+	-	o	+	o	-	+	+				NF
	3. ON-GROWING			+	?	o	+	o	-	+	+				F -
	1. BROODSTOCK			+	?	o	+		-	+	+				F -
SEABREAM	2. HATCHERY + NURSERY			+	-	o	+	o	-	+	+				NF
	3. ON-GROWING			+	?	o	+	o	-	+	+				F -
	1. BROODSTOCK			+	?	o	+		-	+	+				F -
TURBOT	2. HATCHERY + NURSERY			+	-	o	+	o	-	+	+				NF
	3. ON-GROWING			+	?	o	+	o	-	+	+				F -
	1. BROODSTOCK			+	?	o	+		-	+	+				F -
SHRIMPS	2. HATCHERY + NURSERY			+	-	o	+	o	-	+	+				NF
	3. ON-GROWING			+	?	o	+	o	-	+	o				F -
	1. BROODSTOCK			+	?	o	+		-	+	+				F -
STURGEON	2. HATCHERY + NURSERY			+	-	o	+	o	-	+	o				NF
	3. ON-GROWING			+	?	o	+	-	-	+	+				F -

Estimation quotations

+ : satisfactory conditions	F+ : Feasable
o : can be improved	F - : Feasable but requiring higher investments
- : severe limiting conditions	NF : Not Feasable

SITE No : 5 (*)

		Surface	Water quantity		Water quality		Thermal energy	Market conditions	Discharge	Technical installation	Status culture technology				Final evaluation
				Temperature	Salinity	Pollutans									
SEABASS	1. BROODSTOCK		+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY		+	-	+	o	+	+	+	+	+				F+
	3. ON-GROWING		+	-	+	o	+	+	+	+	+				F+
SEABREAM	1. BROODSTOCK		+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY		+	-	+	o	+	+	+	+	+				F+
	3. ON-GROWING		+	-	+	o	+	+	+	+	+				F+
TURBOT	1. BROODSTOCK		+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY		+	-	+	o	+	+	+	+	+				F+
	3. ON-GROWING		+	-	+	o	+	+	+	+	+				F+
SHRIMPS	1. BROODSTOCK		+	-	+	o	+		+	+	+				F+
	2. HATCHERY + NURSERY		+	-	+	o	+	o	+	+	+				F+
	3. ON-GROWING		+	-	+	o	+	o	+	+	o				F+
STURGEON	1. BROODSTOCK		+	-	+	o	+		+	+	+				F-
	2. HATCHERY + NURSERY		+	-	+	o	+	+	+	+	o				F-
	3. ON-GROWING		+	-	+	o	+	-	+	+	+				F+

Estimation quotations

+ : satisfactory conditions	F+ : Feasable
o : can be improved	F - : Feasable but requiring higher investments
- : severe limiting conditions	NF : Not Feasable

(*) conditions : 1. pipeline to beach
2. powerstation

8. Conclusions

Flanders has already proved his merits in marine aquaculture research. At the moment, the state of the art of intensive aquaculture know how allows an economical feasible project at industrial scale. The essential technologies are sufficiently advanced to enable an adequate production from an aquaculture facility. However, concrete marine aquaculture applications at economical scale are not that evident. In assessing the feasibility of a marine fish farming project in Flanders, several prerequisites should be examined. First of all, prospects for marine aquaculture applications should focus on the salt or brackish water availability, appropriate for aquaculture purposes. Moreover, due to the climatic conditions in Flanders, a commercial aquaculture project producing fish at an economical acceptable growth rate should be located near a thermal energy source in order to valorize waste calories (thermal effluents) by means of aquaculture. In this regard five sites with salt water and/or thermal energy wastes and five marine or euryhaline species were evaluated.

At the Nieuwpoort site marine aquaculture is possible, but the site has the limitation of possessing no cheap energy source nearby to realize an optimum rearing water temperature in an aquaculture facility.
At the Oostende site, a vast amount of sheap energy is available from the incineration plant (IVOO). Groundwater supplies have an appropriate salinity, but the quality and quantity will not allow a large industrial aquaculture project. The available water quantity will allow a hatchery project, which needs smaller amounts of water, but treatment and probably adjustment of the ion composition and salinity will be necessary to obtain an appropriate water quality to culture the vulnerable marine fish larvae.
At the Doel site, an experimental aquaculture project already proved the possibilities for aquaculture at that site. Due to salinity restrictions only the culture of euryhaline (tolerating salinity changes, i.e. seabass, seabream, sturgeon) species is applicable at Doel. A marine hatchery cannot be integrated in an industrial farm at this site since for those activities full strength seawater is needed. The high investment cost (security measures) at the nuclear site hypothecates the feasibility of an aquaculture project.
At Merksplas, geothermal saline groundwater is available but the quantity is yet not known. Unless a detailed study proves the opposite, the brine water at the site would probably not allow marine aquaculture activities since its chemical composition doesn't reflect seawater composition. Moreover, environmental obstructions will occur for the disposal of saline groundwater in a fresh surface water environment.
Water quality at the outport of Zeebrugge is good. The seawater, in combination with the thermal waste energy produced in an electricity plant would offer a unique opportunity for marine aquaculture in Flanders.

Considering the species, the study was focused on the culture of high quality marine species, showing a promising market potential, which have already been cultured at an economical feasible and industrial scale abroad. Making this objective, freshwater species such as catfish and eel were not studied, but these species certainly offer possibilities for aquaculture projects in a fresh water environment. Neither relatively "new" marine species in the aquaculture bussiness, i.e. halibut, cod and wolffish, have been studied, although they could appear on the scene in the future.

From the species studied turbot is the most promissing. Culture technology is controled and the species has a promissing market potential, especialy in Belgium. Sea bass and sea bream culture technology is controled and the species can be cultured at Doel. However, the market potential in Belgium and the market prospects at European scale should urge investors to prudence. Sturgeon could probably be the species of the future. The Doel site is perfectly fitted to culture this species but at present the market demand would not be able to absorb a relatively large sturgeon production. At first sight, live shrimp species have very promissing market potentials. However the grow out technology is yet not totally under control and the live shrimp market will have to compete with the rather cheap froozen shrimps, imported from tropical countries.

In the course of the study several sites in Flanders were evaluated for their aquaculture potential. Since the objective of the study was to inform potential investors about the possibilities at each site, no particular site has yet been selected to elaborate an aquaculture project in situ. Nevertheless, it was found valuable to include a computation of the investment and exploitation cost of an integrated farm with an annual production of 300 ton turbot. These calculations show that the state of the art of intensive aquaculture allows an economical feasible project at industrial scale. An aquaculture site at Zeebrugge, valorizing the thermal enriched cooling water of a power plant, being the most apropriate for this kind of activities. If favourable sites with thermal effluents will not become available in the near future, intensive aquaculture activities in Flanders should focus on closed recirculation systems of which the technology is now been developed and will become available in a few years.

Last but not least, in a period of economic recession, an industrial aquaculture project would create a supplementary emploiment and will have an amplifying effect, not only for starting other aquaculture projects in Flanders, but also for activities related to fish processing and distribution (marketing, trading, export of products), services and suppliers activities (feeding technology, prophylaxis,...). Towards the future, stimulation of aquaculture research, aiming to develop know how and to optimize applied technology, should further enhance productivity and reduce production cost of farms by optimization of rearing technology and production cycles. In the long term, an integration of know-how of aquaculture companies, supply industries, engineers and constructors, distributors, financers and insurers in a Flemish Aquaculture Association could valorize and export aquaculture know-how by export of products or consultancy activities abroad.

In this regard, an aquaculture project shall carry a major positive profit at different levels and in several sectors of economy. Aquaculture will contribute in employment, is complementary with fisheries activities, will contribute significantly to national goals by creating rural employment, generate high value foods, create export or import substitutes that can contribute to an improved balance of payments and justify infrastructure development, thus enabling aquaculture to become a wealth creating activity.

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