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COASTAL AQUACULTURE SYSTEMS FOR FISH AND CRUSTACEA IN THE MEDITERRANEAN

by

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TABLE OF CONTENTS

1. INTRODUCTION

The purpose of this paper is to show the possibilities of developing fish culture in salt or brackish water in the Mediterranean area. To this end, we think it is advisable to proceed as follows:

(a) first of all, to clarify the basic concepts for accurate interpretation of some terms normally used in fish culture;

(b) to describe the features and potential of some types of fish culture;

(c) to examine the commercial feasibility of various production systems;

(d) to examine their soundness also in relation to energy, and

(e) to present a plant model that is sound from the commercial and energy points of view and can be applied in Mediterranean countries.

2. DEFINITIONS

2.1 Fish Culture in Fresh, Salt or Brackish Water

There are fish species which live and breed well in fresh water and in salt or brackish water, as for example, some varieties of mullet, eel, trout, carp and bass. What, then, is the borderline between fresh, salt or brackish water? This is difficult to say if we take as a criterion the salt concentration of the water, all the more so as in the same water area salinity varies quite considerably with the season, even from zero to high concentrations. This happens, for example, in many basins in estuarine zones near the mouth of rivers or seasonal streams. Furthermore, fresh-water and salt-water species may live in the same environment.

It is much more practical to refer to a precise biological characteristic that links species to different environments. Thus fresh-water fish culture refers to species that breed in fresh water, salt-water or brackish-water culture would refer to species that breed in salt or brackish water.

2.2 Fisheries and Fish Culture

Particularly when extensive fish culture is carried on in lagoon areas, it may be asked what the difference is between fishing and culture. The fact that organization, methods and fishing gear are almost always different in the two activities is not enough to distinguish between them.

But seeding is certainly a criterion. Fishing is confined to catching and requires no preliminary operations except those closely coordinated with it. Culture, on the other hand, presupposes seeding as a productive operation, i.e., the introduction of young fish into the area from which the finished product will be taken later on. Catching in this case is merely the final phase of the production process.

2.3 Intensive, Extensive and Semi-Intensive Fish Culture

Before dealing with fish culture in detail, it is useful to clarify the terms intensive, extensive and semi-intensive. Those who deal with the subject define culture systems with a high stocking density as intensive, but they do not indicate the limit below which culture is no longer intensive. Extensive is used to define culture with a low stocking density, but again no limit is given above which culture is no longer extensive. Since semi-intensive describes an intermediate situation, it may be assumed that it covers the whole range, with admittedly fairly vague boundaries, that is not defined by intensive and extensive.

In actual fact, the stocking density is but a secondary, albeit striking, characteristic of the various types of culture. The fish biomass depends on the quantity of feed available in the environment, and it is inevitable that, if we intend to exceed the stocking density limits typical of a given environment, we have to provide additional feed to achieve the expected results.

The feeding regime can therefore be taken as the distinguishing characteristic of a given type of culture. Culture is intensive if all feed is provided from outside; it is extensive if the feed is supplied exclusively by the environment; it is semi-intensive if it is furnished by the environment with supplementary feed from outside. Such supplementation may be simultaneous, that is, provided throughout the production cycle, or it may be coordinated; that is, furnished as a substitute during some phases of the production cycle (normally in the first and second phases of culture).

2.4 Culture Methods with Stagnant Water, Running and Semi-Running Water

The stagnant-water method is used when fairly small quantities of relatively cold water are available. It is marked by the following conditions:

(1) very slight exchange from time to time with water at a temperature much lower than the optimum for culture (almost always groundwater at 12-14°C is used);

(2) the thermic regime of the water basin is directly related to atmospheric conditions;

(3) oxygen production relies on the environment (phytoplankton).

The running-water method can be adopted where abundant relatively warm water is available. The characteristics of this method are:

(1) intensive and continuous water exchange;

(2) thermic regime of the basin is directly related to the temperature of the circulating water;

(3) oxygen requirement is supplied by the flow of water.

The semi-running water method is a compromise or rather a combination between the stagnant and running-water methods. It is preferred when an abundant supply of cold water is available or warm water in slightly insufficient quantity. In both cases, the environmental factor is essential. The semi-running water method integrates environmental and water resources because each of them alone cannot sustain culture.

Depending on whether there is more or less circulation, the type of culture shifts toward the stagnant-water regime or to the running-water regime.

3. EXTENSIVE CULTURE

Extensive brackish-water fish culture is carried on in lagoon areas or in coastal areas subject to flooding and cannot be confused with fishing in view of seeding which is the basis of the production process.

Seeding can be done by (a) favouring the ascent (anadromous migration) of young fish from the sea and preventing their descent (catadromous migration), (b) catching fry in more or less distant marine areas and introducing them into the controlled areas, or (c) resorting to induced reproduction. Independently of the production it can yield, culture is defined as extensive if its feed comes from the environment.

The main features of an extensive culture system are enclosing structures for the water areas to be controlled, controlled communication with the external environment, and facilities for catching the product. Extensive systems in cold zones must have installations for protecting the fish against winter cold.

Extensive plants in the Mediterranean region mainly cultivate the following species:

- Sparus aurata (gilthead sea bream)[1/]
- Dicentrarchus labrax (sea bass)
- Mugil auratus (golden grey mullet)
- Mugil chelo (thicklip grey mullet)
- Mugil cephalus (flathead grey mullet)
- Mugil saliens (leaping grey mullet)
- Mugil capito (thinlip grey mullet)
- Anguilla anguilla (eel)

All of them are euryhaline and eurythermic, each with its specific tolerance to salinity and temperature. While in general we may say that salinity ranging from 15 to 25 percent and temperature from 18 to 25°C are the optimum for practically all these species, it should be pointed out that S. aurata and M. auratus do not adapt to fresh water and that a temperature of 4 to 5°C is lethal for S. aurata whereas D. labrax withstands a temperature down to 2°C, Mugil 3 to 4°C and Anguilla 0 to 1°C. All these species tolerate rather high temperatures (34 to 35° C), but their culture in these conditions is difficult.

In favourable climates, culture is almost continuous, the production cycle is reduced to the minimum, and harvesting is not dependent on the seasons.

In the typical extensive system, the feeding area is stocked with fingerlings and the product is collected when it is of marketable size. In a cold climate, on the other hand, the culture season is fairly short (5 to 6 months). In this case, the culture cycle is is longer and comprises various operations. Seeding is carried out in spring; in autumn the fish are collected and transferred to wintering ponds, and in the following spring they are transferred to the feeding areas. These last two operations are repeated until the product is of marketable size.

Production obtainable in extensive plants ranges from 100 to 500/kg/ha/year, depending on the geographic site and the climatic and ecological conditions.

The cost of constructing an extensive plant may vary greatly owing to many factors such as extent and type of enclosing structures for the ponds (in some cases, such structures may involve major coastal works), nature and conformation of the land, wintering installations for fish, pumping systems to supplement or replace tidal flow, etc. All this will affect the cost per hectare more or less in accordance with the ratio between the size of the structures and the area involved.

It is therefore very difficult to indicate costs in general. But by calculating the maximum amortization charges compatible with operations it is possible to indicate the limits of expenditure that should not be exceeded.

1/ Common names of species (except eel) in this document are those used in "FAO Species Identification Sheets for Fishery Purposes - Mediterranean and Black Sea (Fishing Area 37), FAO, 1973

An extensive system of 400 ha producing an average of 100 kg/ha/year may have the following profit and loss account (in U.S.$)1/.

		Expenditure	Income
- Management and administrative staff		28 000	
- Labour		47 000	
- Board and lodging for personnel		6 000	
- Overhead expenses (taxes, financial charges, administrative expenses, postage, telephone, etc.)		5 000	
- Seeding Gilthead sea bream		15 000	
- Sea bass		14 000	
- Eel		6 000	
- Other species		35 000	
- Grey mullet	50 kg/ha/year		50 000
- Eel	30 kg/ha/year		70 000
- Sea bass	10 kg/ha/year		33 000
- Gilthead sea bream	10 kg/ha/year		33 000
- Miscellaneous			6 000
		156 000	195 000
Profit		39 000	
Total		195 000	195 000

Construction costs of an extensive culture system mostly refer to structures whose amortization can be distributed over a period of 30 years. They comprise dikes, dams, sluices, fishing facilities, buildings, canals, etc., which are stable and durable works if they are properly maintained. Only up to 20 percent of all investments is spent on machinery, equipment and implements which are amortized in five to ten years. On the whole, therefore, annual amortization may be put at about 5 percent of costs including cost of the land.

If we allocate an amortization quota of 50 percent of the profits to the profit and loss account, we could justify investments up to U.S.$ 388 000 and up to U.S.$ 776 000 if we decide to forego profits in the first 20 years. The cost per hectare would thus be U.S.$ 970 or U.S.$ 1 940. The ratio of fixed capital assets to annual production potential would be U.S.$ 10 or 20/kg.

For a 400-ha extensive plant producing an average of 500 kg/ha/year, we may assume the following profit and loss account (in U.S.$):

1/ Expenditure and income are based on average prices on the European market. It may be assumed that in countries where the product is sold at lower prices, costs are also lower; therefore the ratio in the balance sheet would not change

		Expenditure	Income
- Management and administrative staff		35 000	
- Labour		94 000	
- Board and lodging for personnel		12 000	
- Overhead expenses (taxes, financial charges, administrative expenses, postage, telephone, etc.)		7 000	
- Current supplies, energy, transportation		19 000	
- Maintenance		14 000	
- Seeding: Gilthead sea bream		115 000	
Sea bass		28 000	
Eel		12 000	
Other species		247 000	
- Grey mullet	350 kg/ha/year		370 000
- Eel	60 kg/ha/year		141 000
- Sea bass	20 kg/ha/year		66 000
- Gilthead sea bream	70 kg/ha/year		247 000
- Miscellaneous			12 000
		583 000	836 000
Profit		253 000	
Total		836 000	836 000

The profit obtained in fish culture on this scale allows for fairly considerable investment. If we allocate 50 percent of the profit to amortization, we could cover a capital of U.S.$ 2 534 000 or U.S.$ 6 350 per ha, and still have a sufficient margin to achieve a satisfactory profit. The ratio of fixed capital assets to annual production potential would be about U.S.$ 12 per kg.

We have deliberately given two extreme examples - a low variant and a much higher variant. The former applies to fish culture in an unfavourable climate, the latter to a favourable climate.

If brackish-water fish culture develops in the southern Mediterranean area, it would operate in climatically and ecologically favourable conditions, hence with high productivity. It would seem that the commercial feasibility of such undertakings cannot be disputed.

4. INTENSIVE CULTURE

In the past decade satisfactory techniques have been developed and tested for the intensive culture of mullet, sea bass, gilthead sea bream and eel. With appropriate installations these techniques can produce 1-3 kg of grey mullet/m^2, 5-20 kg of sea bass/m^2, 3-5 kg of gilthead sea bream/m^2 and 2-8 kg of eel/m^2 1/. Culture techniques and type of installation vary with the species as well as for the same species if they have to be adapted to the land and water conditions. Production obviously increases with more favourable conditions (climate, water resources, type of soil) and more sophisticated installations.

1/ Hyper-intensive installations with a production potential of up to 100 kg/m^2 are being tested for eel

Installations for the intensive culture of grey mullet and gilthead sea bream do not require large investments (from U.S.$ 1 200 to 6 000/ha) whereas installations for sea bass and eel call for tens of thousands of dollars (from U.S.$ 60 000 to 350 000 for sea bass and from U.S.$ 47 000 to 94 000 for eel).

Food conversion rates for dry feed may be estimated as follows: 3-4:1 for grey mullet, 2-3:1 for gilthead sea bream and 1.5-2-5:1 for eel.

Grey mullet is reared with low cost feeds or waste from other intensive cultures. Gilthead sea bream, sea bass and eel, on the other hand, need feed with a high animal protein content. Where possible and suitable, fresh fish mixed with fish meal is also used.

The most recent technical trend, however, is to utilize the intensive culture of grey mullet only as an instrument in optimizing production in large areas (see p. 15), not to practise intensive culture of gilthead sea bream because this species produces very good results in extensive culture (therefore the cost of artificial feeding is not justified), and to carry out intensive culture in the case of eel and sea bass (see p. 15).

Two examples of a profit and loss account are given below for the intensive culture of eel and of sea bass.

1. Profit and loss account for intensive eel culture with a production potential of 200 t/year (in U.S.$).

	Expenditure	Income
- Management	18 000	
- Labour, 1 worker for 25 t	94 000	
- Energy and fuel	40 000	
- Seeding (purchase and transport of elvers)	24 000	
- Feed	280 000	
- Current supplies	24 000	
- Maintenance	12 000	
- Overhead	24 000	
- Miscellaneous	12 000	
- Depreciation (10% per annum)	94 000 1/	
- Reserve account	60 000	
	682 000	940 000
Profit	258 000 2/	
	940 000	940 000

1/ An installation of this type comprises about 60 000 m^2 of rearing ponds supplied by a first-stage installation totalling about 1 250 m^2 which is covered and has controlled temperature. The cost of the installation, excluding land, may be put at about U.S.$ 940 000. Fixed capital assets would be about U.S.$ 5/kg of production capacity. If the market can supply small eels of about 4-5 g which are already accustomed to artificial feed, the first-stage sector is not needed. In this case, the seeding item in the account would increase to about U.S.$ 118 000, the depreciation item would drop by about 40 percent, and the ratio of labour to production would be one worker for 40 t. Other expenses would also decrease by about 10 percent, for instance, energy, feed, current supplies, maintenance and the reserve account

2/ This is a gross figure before taxes and any financial charges

2. Profit and loss account for intensive breeding of sea bass, with a production potential of 100 t/year (in U.S.$).

	Expenditure	Income
- Management	18 000	
- Labour, 1 worker for 25 t	47 000	
- Energy and fuel	40 000	
- Seeding (purchase of fingerlings	175 000 1/	
- Feed	118 000	
- Current supplies	12 000	
- Overhead	18 000	
- Miscellaneous	6 000	
- Depreciation	76 000 2/	
- Reserve account	30 000	
	541 000	823 000
Profit	282 000 3/	
	823 000	823 000

The economic data set out above indicate the commercial advantage of intensive culture installations for eel and sea bass, emphasizing their high production capacity and consequently a relatively low incidence of fixed capital assets in relation to potential production.

1/ If the installation has a sector for artificial reproduction, the seeding item would disappear and depreciation would increase by about 50 percent, labour costs by about 60 percent, and the costs of energy, maintenance and current supplies by about 10 percent. One million fingerlings 2.5 to 3 cm in length are required to produce 100 t of sea bass of average weight 350 g

2/ Intensive culture installations for sea bass may have a mixed structure (cement-earth) or be entirely of cement. The latter may be in the open air or covered, but in all cases, a covered hatchery is required. The cost of the installation therefore may vary considerably in relation to climatic conditions and the stocking density planned. It should be remembered that less expensive installations have a smaller carrying capacity and that the culturing period is extended in protected installations. One may therefore conclude that fixed capital assets per kilogramme of production capacity are about U.S.$ 7 to 8 for a plant without a sector for reproduction and about U.S.$ 10 to 12 for a plant with such a sector. All these calculations exclude the cost of land

3/ This is a gross figure before taxes and any financial charges

5. THE ENERGY ASPECT OF FISH CULTURE

It is certainly necessary to examine carefully the commercial feasibility of the various forms of fish culture, but it is also necessary to examine their soundness from the energy point of view. We may in fact have a sizeable commercial profit with a considerable energy deficit. While this may not worry the individual entrepreneur the resultant imbalance may have an adverse effect at the national level particularly when a national community has to balance the deficit with other communities.

Three types of energy will be dealt with here - primary, subsidiary, and auxiliary energy. By primary energy is meant the energy reaching the ecosystem directly from the sun (solar radiation); subsidiary energy, is the energy one ecosystem can draw from another (tides, winds, water temperature, nutrients, etc.); auxiliary energy means the energy obtained through man-made circuits from fossil or nuclear sources of energy (thermal or electrical energy).

Extensive fish culture systems undoubtedly have a clearly positive energy balance sheet. Although positive energy balance sheet with reference to natural processes is an inappropriate and even absurd term, it is used to stress the fact that extensive fish culture generally does not employ appreciable quantities of auxiliary energy in its production process. Its contribution to production may be considered a balance between the various components which as a whole achieve the productivity of the culture environment regarded as an ecosystem.

Man intervenes only to coordinate and confines himself to introducing into the environment a tiny part of energy mainly in the form of seeding which, in weight, covers 0.3-0.6 percent of the energy produced and at any rate is an expression of the natural productivity of the marine ecosystem.

Brackish-water fish culture is or can be carried on nearly always in estuarine zones and sometimes in coastal areas that are completely or partly above water but are always in controlled communication with the external ecosystem. Such fish culture systems therefore can function as satellite ecosystems which can draw subsidiary energy from outside in the form of nutrients, thermal energy, mechanical energy, etc.

The input of subsidiary energy helps to strengthen the self-enrichment mechanism in the culture environment to a greater or lesser degree and therefore to determine the productivity of the extensive system. It is then up to man to intervene in the system, simply by coordinating and controlling in an effort to intensify natural productivity as much as possible, and by employing auxiliary energy if this can bring about profitable increases in production. Firstly he should:

(1) raise energy input by using subsidiary energy from the external ecosystem 1/;

(2) reduce to a minimum (or eliminate, if possible) the quota of stored energy through accurate control, matching and distribution of fish populations;

(3) speed up the rate of production as much as possible (in line with market requirements);

(4) prevent the outflow of organic substances from the system he controls.

Secondly, he should undertake the following culture operations:

(1) water regulation;

(2) soil work;

1/ This aspect of operations is very important when it is possible to utilize warm industrial effluents

(3) fertilization;

(4) feeding.

An example of an extensive 400-ha culture facility with an average output of 500 kg per ha per year has already been given (see p. 5). A hypothetical energy balance sheet for that model is given below:

Primary energy + Subsidiary energy =	kcal produced	kcal of auxiliary energy supplied
200 000 kg of fish	400 000 000	
Water regime (12 mil/m^3/year)1/		51 677 000
Auxiliary services		5 000 000
Supplementary feed, first stages		3 000 000
Soil work on pond bottoms1/		33 600 000
Totals	400 000 000	93 277 000

Let us now consider the energy balance sheet of an intensive culture installation with an annual production of 200 t, an average productivity of 5 kg per m^2 and food conversion rate of 2:12/:

	kcal produced	Subsidiary energy	Auxiliary energy
200 000 kg of fish	400 000 000		
Feed (an average of 4 000 kcal/kg)		800 000 000	
Water flow (1 m^3/sec) 31 536 m^3 (50 hp) = 37.30 kWh x 860 kcal = 32 078 kcal/h x 8 760 h of operation per year3/			281 000 000
Other services for a total of 50 kW of power used occasionally			100 000 000
Totals	400 000 000	800 000 000	381 000 000

1/ Just as a good production potential is attributed to the model, so a high energy expenditure for water regulation and work on the pond bottoms is also applied though it is not always needed to such an extent. On the other hand, fertilization is excluded because it would result in higher production than that under discussion

2/ Productivity and food conversion rate are based on average values of various types of intensive culture for eel and seabass

3/ The water flow carries also a highly important quota of subsidiary energy drawn from the external ecosystem (temperature, oxygen, etc.), which is not calculated because it would vary considerably with the type of installation (running water or semi-running water) and with the characteristics of the water used. On the other hand, the application of auxiliary energy needed to maintain flow remains virtually constant

If fresh fish instead of balanced feed is used, the energy situation would be as follows:

kcal produced	400 000 000
subsidiary energy	1 000 000 000
auxiliary energy	381 000 000

The importance of energy supplied by feed is a striking feature of the energy balance sheet for an intensive culture installation. It represents a contribution from the natural productivity of other ecosystems and should therefore be put under subsidiary energy 1/.

But it should be noted that, in the intensive culture of carnivorous fish, for every kilogramme of product we sacrifice about 2 kg of other fish with a diet of artificial feed and about 5 kg with a fresh fish diet. Thus the food chain lengthens and the system's loss of potential energy increases quite considerably.

The fact of considering as subsidiary energy what actually is a product that can be used for human consumption is a commercial and political option rather than an operation of energy recovery. For communities which depend on others for such a source of energy, the soundness of this production process would be questionable also from the commercial point of view, unless the finished product is exported with profit. If the community consumes the product, it would have to be admitted that it has chosen the most costly way of feeding itself. From the energy angle, therefore, intensive fish culture cannot compare with extensive culture, especially if the latter obtains satisfactory quantities of subsidiary energy.

In an attempt to find a technology for high production in a small area and to make fairly large areas productive, successful experiments have been made in the past few years with a type of fish culture based on functional integration of intensive and extensive culture. It has been established than an extensive plant suitably supported by an intensive sector can increase and rationalize its production. In practice, the intensive installation, in addition to its own production, serves as the first stage for the extensive plant, which becomes semi-intensive through this link. Moreover, all waste 2/ produced by the intensive sectors serves to fertilize the semi-intensive plant.

In our opinion, this type of integrated fish culture is an efficient and balanced instrument of production because, while the intensive sectors are supplied with a considerably quantity of energy, they in turn furnish a considerable quantity of energy to the semi-intensive plant in the form of water flow, waste material and semi-cultured fish which are transferred under optimal biological and operational conditions with respect to the productivity of the environment.

1/ Such subsidiary energy is, however, obtained at the cost of an adequate supply of auxiliary energy (fishing organization and effort, fish meal production, etc.)

2/ "Waste" means all materials derived directly and indirectly from the biological activity of fish. The effluent of a carnivorous fish plant operating with an average load of 150 t and a feed ration of 3 percent, discharges the following approximate quantities during 180 days of culture:

24 t	of ammonia nitrogen
20 t	of nitric nitrogen
14 t	of phosphorus
421 t	of suspended solids
486 t	of BOD
1 600 t	of COD

The total energy balance will be more positive when the production cycle is characterized by an accelerated turnover, and all organic substances present within the system are used. This requires:

- a rational proportioning between the intensive and semi-intensive sectors;
- the adoption of appropriate culture operations;
- the accurate assessment of the quantities of auxiliary energy required to produce the desired result.

A purely indicative ideal energy balance sheet for a 400-ha integrated fish culture model with a 4-ha intensive sector is given below:

	kcal (million)	Subsidiary and auxiliary energy
Estimated basic production of extensive plant: 300 kg/ha/year	240	
Intensive production: 160 t	320	
Energy expenditure		1 024.8 1/
Energy recovered by fertilized semi-intensive sector (production increase of 881 kg/ha)	804.8	
Totals	1 264.8	1 024.8

This credit balance corresponds to the energy the extensive plant can obtain while the energy loss in the intensive sector is offset by the greater productivity of the extensive plant which has become semi-intensive through energy recovery. On the whole, the volume of production achieved is more than four times the basic production of the extensive plant.

6. DESCRIPTION OF A MODERN BRACKISH-WATER FISH CULTURE MODEL

6.1 Introduction

Considerations on the commercial feasibility and energy efficiency of various brackish-water fish culture methods have directed us toward a productive structure designed to achieve high output in a small area and to make large or very large areas productive. It is useful to illustrate a model along these lines. Figure 1 represents a 400-ha estuary area bounded by installations (earth dikes, locks, screens) which can isolate it and connect it to the external ecosystem, depending on circumstances. Its water regime makes use of tidal movements and a river current 2/. Two pumping stations provide or support water movement when natural conditions fail to meet these needs entirely or in part.

The production complex consists of facilities for artificial reproduction hatchery, a sector for intensive culture (seabass, eel and mullet) and ponds for semi-intensive culture.

1/ Mean value between artificial feed and fresh fish feed

2/ It is useful but not indispensable to have fresh water available in a fish culture plant

Fig. 1 - <u>Légende/Captions</u>

1. Ecluse à la mer et pompes au vent
   Sea sluice and pumps facing prevailing winds

2. Logements du personnel
   Staff quarters

3. Atelier, magasin, frigorifique
   Workshop, stores, cold storage

4. Bassins d'hivernage
   Overwintering ponds

5. Hangar pour préparation des aliments
   Shed for feed preparation

6. Centre d'alevinage
   Hatchery

7. Elevage intensif des loups
   Intensive culture of seabass

8. Elevage intensif des anguilles
   Intensive culture of eel

9. Elevage intensif des mulets
   Intensive culture of mullet

10. Bassin de récolte des boues provenant des élevages intensifs
    Storage for mud collected from intensive culture ponds

11. Hydrocultivateurs
    Hydrocultivators

12. Canaux de récolte sub-lagunaires
    Lagoon bottom harvesting channels

13. Chambres de capture
    Fish capture tanks

14. Bassin de récolte des élevages semi-intensifs
    Fish capture tanks for semi-intensive cultures

15. Pompes sous le vent
    Pumps sheltered from prevailing winds

16. Canal d'adduction d'eau aux élevages intensifs
    Water supply canal to intensive cultures

17. Bassin de mélange des eaux douce et salée
    Tank for mixing fresh and sea water

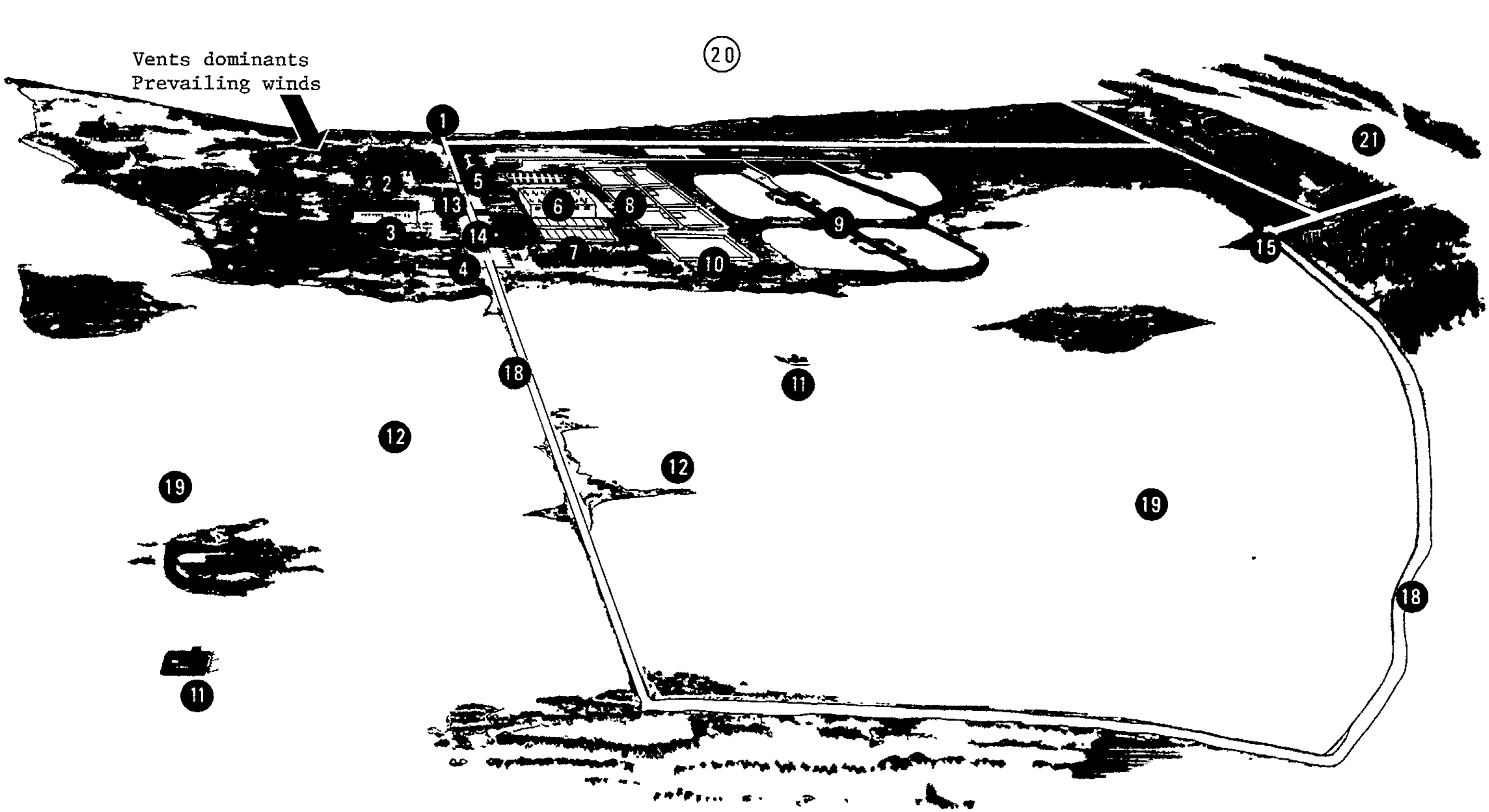
18. Canaux d'irrigation
    Water supply canals to lagoons

19. Lagunes closes d'élevage en semi-intensif
    Enclosed lagoons for semi-intensive culture

20. Mer
    Sea

21. Cours d'eau
    River

Fig. 1 - MODÈLE DE PISCICULTURE MODERNE EN EAU SAUMÂTRE (légende sur la page opposée)
MODEL OF MODERN BRACKISHWATER FISHCULTURE (captions on opposite page)



There are also wintering ponds (needed for fish culture in cold areas), basins for collecting the product of the semi-intensive operation, basins for harvesting, processing and distributing waste from the intensive sector, and facilities for working the pond beds. The infrastructure and services necessary for operating the whole plant are also included.

The intensive culture sector consists of a section for eel, with a production capacity of 200 t per year, a section for seabass with a capacity of about 100 t per year, and one for mullet which can deal with the entire semi-intensive operation.

Modern techniques tend to employ extremely compact intensive installations, therefore a relatively small space is reserved for eel and seabass (not more than 4 ha). Larger areas have to be provided for mullet because in the intensive culture of this fish the method adopted relies partly on the environment. The productivity of the semi-intensive plant closely depends on ecological and climatic conditions, and the size of the intensive sector which supports it varies accordingly.

The effectiveness on production of fertilization in the ponds also has to be assessed. In general, however, the production of a semi-intensive plant arranged in this way may range from 300 to 1 000 kg per ha depending on the climate. The minimum values given here refer to conditions of low productivity, also to areas where the culturing period is fairly short (for instance, this applies to valliculture in the Veneto region). In this case, the quantity of semi-cultured mullet from the intensive sector should be at least 50 percent of the finished product by weight, whereas in a more favourable and therefore more productive situation seeding may be limited to a maximum of 30 percent.

The semi-intensive plant in the model (which covers about 350 ha of water surface) requires an input of 52.5 t in the first case and about 105 t in the second case.

The intensive sector producing mullet would therefore have an area of 2.63 or 5.25 ha, respectively.

6.2 Description

This fish culture model is complete in structure because it comprises all operational stages, from artificial reproduction to commercial size of the product, including the genitors required to maintain the cycle. It is also based on a pattern applicable to a large number of fish species and can be established in large geographic areas and certainly throughout the Mediterranean.

In existing models, the species chosen for culture are always the traditional ones:

- *Sparus aurata* - English: gilthead sea bream
  French : daurade
  Italian: orata
  Spanish: dorada

- *Dicentrarchus labrax* - English: seabass
  French : loup (bar)
  Italian: spigola (branzino)
  Spanish: lubina

- *Mugil cephalus* - English: flathead grey mullet
  French : muge cabot
  Italian: cefalo
  Spanish: pardete

- *Mugil chelo* - English: thicklip grey mullet
  French : muge à grosses lèvres
  Italian: cefalo bosega
  Spanish: lisa

- Mugil capito	- English:	thinlip grey mullet
	French :	muge porc
	Italian:	cefalo calamita
	Spanish:	morragute
- Mugil saliens	- English:	leaping grey mullet
	French :	muge sauteur
	Italian:	cefalo verzelata
	Spanish:	galúa
- Mugil auratus	- English:	golden grey mullet
	French :	muge doré
	Italian:	cefalo dorato
	Spanish:	galupe
- Anguilla anguilla	- English:	eel
	French :	anguille
	Italian:	anguilla
	Spanish:	anguila

D. labrax and A. anguilla are raised in the intensive sector; Anguilla and all other species in the semi-intensive sector. This arrangement is arrived at for the following reasons:

- D. labrax is a commercially very valuable fish, gives excellent response to intensive methods, and is definitely not suited to semi-intensive culture because it would feed on other species cultured in the semi-intensive sector (this would therefore have a negative effect on the energy and commercial balance sheets).

- A. anguilla gives considerably better results in intensive culture than in the semi-intensive system, especially as far as the duration of the productive cycle is concerned. Commercial demand for this fish is much more sustained than for the other species and in this respect the production of large quantities is fully justified. This does not mean that A. anguilla could not and should not be raised also in the semi-intensive sector where its trophic level is not affected by great competition from other species.

- S. aurata gives good results if cultured by intensive methods but they are not better than those normally obtainable with the semi-intensive system as far as growth and survival are concerned (even the extensive system would achieve the same results). The cost of special facilities, especially for artificial feeding, therefore does not seem justified. The natural food chain of gilthead sea bream involves mainly molluscs; it may be strengthened by means of modest measures and has a valuable function of depuration and production in the environment.

- The five mugilid species are the true protagonists of semi-intensive culture because of their highly waste-consuming habit. They are expected to be responsible for the energy recovery on which the integrated fish culture model is based. As consumers they shorten the trophic chain also in regard to herbivorous species because they can use waste even before it undergoes subsequent processes of transformation. It is up to the fish farmer to ensure optimum waste use either through direct consumption by mullet (of at least part of the waste) or by initiating a rational fertilization process of the environment.

The supply of fry in quantities to meet the culture programme requirements is obviously a fundamental operation in fish culture, especially in intensive plants which are normally projected and constructed for monospecific culture and for a well defined economic and commercial purpose.

The sea has always supplied fry for traditional culture plants, but today this is an unstable and inadequate means of seeding; it is already very difficult to obtain supplies of high commercial value (S. aurata, D. labrax), which are of major interest at present. As a result, fish farmers have tackled the problem of artificial reproduction, first at research level, then on an industrial scale. The problem may now be regarded as solved for D. labrax, and there are good prospects for the other species as well. This is why the model provides for a sector for artificial reproduction. At present it produces D. labrax, but with the same facilities it will be possible to produce other species as the techniques are worked out or refined.

The projected production potential of this sector is about one million fry per year corresponding to the requirements of the respective culture sector. As it is a modular installation, it can be expanded without structural modifications.

The reproduction facilities cover about 4 000 m^2. They include sections for the production of phytoplankton and zooplankton (i.e., larval feed) and a section for the larvae, divided into an incubation-fecundation unit and a breeding unit. In addition, there is a section for the culture and preparation of genitors.

Artificially produced fry and fry taken from the sea are placed in special tanks during the first culture phase, which is the most delicate one. This phase varies according to the climate, season and species. For mullet and gilthead sea bream, it ranges from a few days to several weeks, for sea bass it is about three months, and for eel about eight months.

All these facilities comprise the hatchery; in the model we are describing it covers 500 m^2.

6.3 The Intensive Culture Sector

The intensive culture sector consists of sections for D. labrax, A. anguilla and the five mugilids. The sections differ considerably in structure and operation, and a section may also be changed to comply with the conditions in which it operates.

An intensive eel culture installation, for instance, may have running or semi-running water, depending on the quality and quantity of water available. An intensive sea bass installation may or may not have heated wintering facilities thermically controlled, depending on the climate.

An intensive mullet culture installation differs from those for eel and sea bass mainly because for its feeding it relies almost exclusively on waste from the intensive installations and because its structure is simple and so integrated with the environment that the borderline between intensive and semi-intensive is rather vague.

6.4 The Semi-Intensive Culture Sector

The semi-intensive sector is composed of water surfaces for feeding areas. The structures are adapted to local conditions and therefore vary considerably.

The most important conditions for a good semi-intensive sector are:

- division of the feeding areas into sub-basins of appropriate size;
- good controlled communication with the sea;
- the possibility of regulating the extent of the water surface as required;
- the possibility of regulating the salinity (and avoiding excessive concentration through intensive water exchange;
- a rational harvesting facility based on attraction of fish during drainage of ponds.

The principal semi-intensive culture operations are:

- the introduction of seed in a quantity proportionate to the biological capacity of the environment; seed should be of sufficient size to make for a high survival rate and a satisfactory weight increment;
- fertilization of the feeding area with waste from the intensive sector, with appropriate balancing if necessary;
- ploughing and harrowing of the pond bottoms;
- harvesting of the market-size fish.

6.5 The Water Circuit

The water circuit (Figures 2 and 3) also reflects the complementary nature of the whole production process. Water from the sea enters the intensive sector, whence it flows into the semi-intensive ponds for water renewal and feeding. If needed, this water can be reused in the intensive sector. Unfortunately, negative external conditions (pollution) often make it dangerous to use sea water. In this case, the semi-intensive ponds act as biological depurators.

6.6 Commercial and Energy Characteristics of the Model

Such a fish culture model would involve the following costs (in U.S.$)[1/]:

- Artificial reproduction facilities	282 000
- Intensive eel culture installations	306 000
- Intensive sea bass culture installations	236 000
- Semi-intensive culture sector (estimate based on medium effort)	470 000
- Headquarters and infrastructure	235 000
Total[2/]	1 529 000

The annual profit and loss account of the operating plant might be as follows (in U.S.$):

- Labour (about 20 workers)	240 000
- Energy and fuel	82 000
- Seed and genitors	350 000
- Feed	410 000
- Current supplies	60 000
- Miscellaneous	60 000

1/ Excluding cost of land

2/ See Annex 1

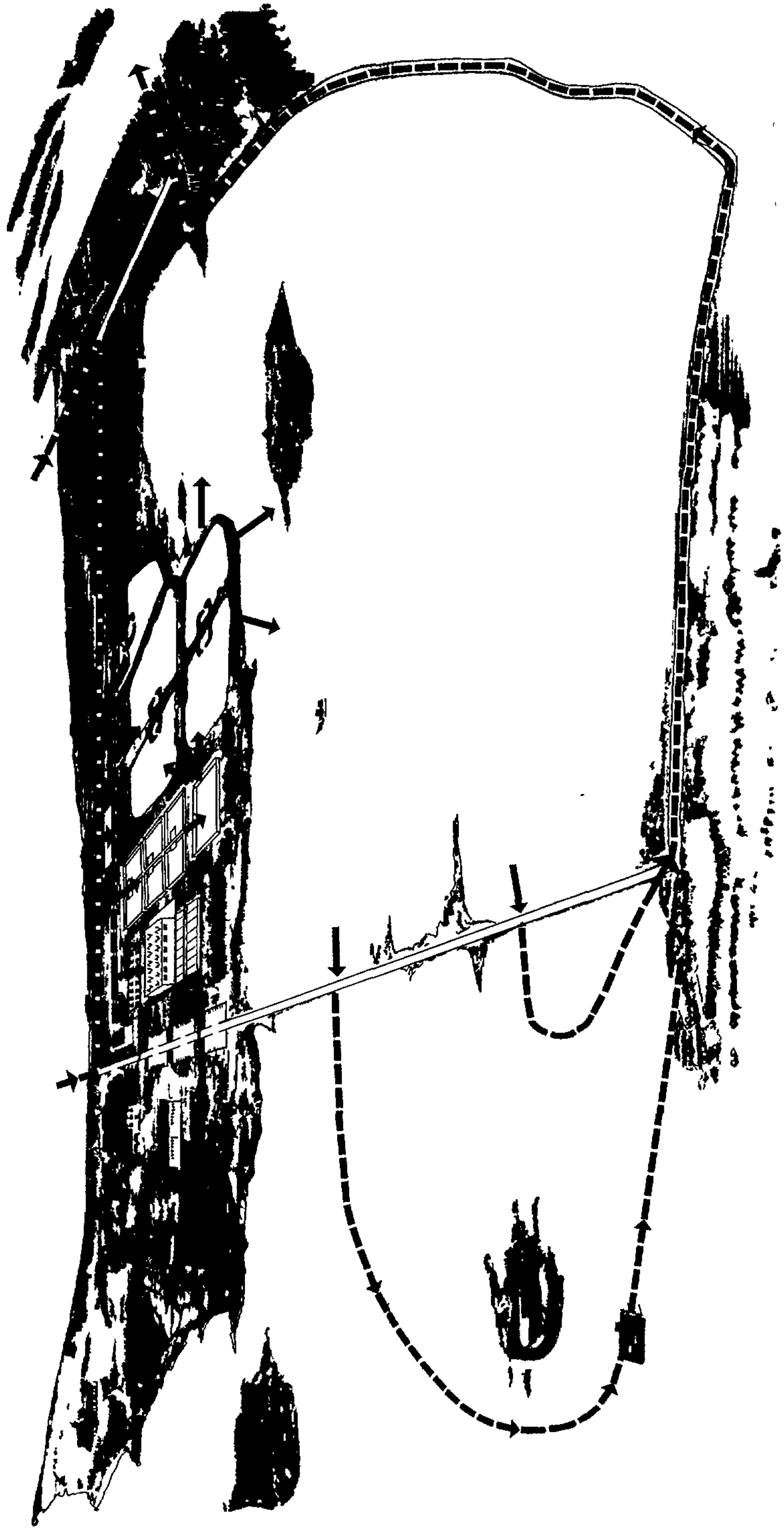
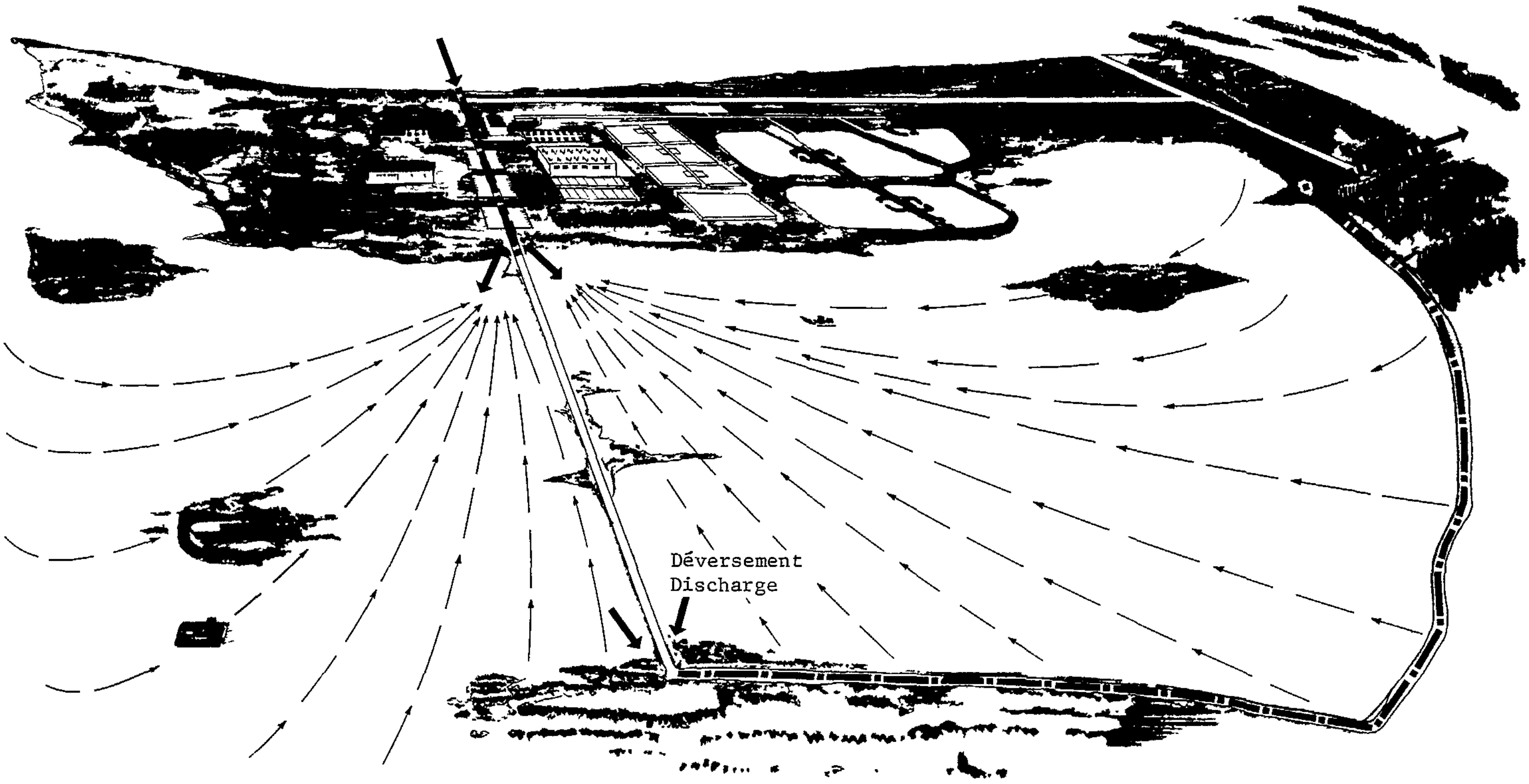


Fig. 2 - CIRCUIT DE L'EAU POUR L'ÉLEVAGE
WATER CIRCULATION DURING REARING PERIOD

Fig. 3 - CIRCUIT DE L'EAU POUR LA PECHE (⟶)
DIRECTION OF WATER FLOW DURING FISH CAPTURE
MOUVEMENT DU POISSON (⟶)
FISH MOVEMENT



- Overhead	94 000	
- Depreciation	155 000	
- Reserve account	240 000	
- Income: from intensive culture (300 t)		1 411 000
from semi-intensive breeding (350 t)1/		823 000
	1 691 000	2 234 000
Profit	543 000	
Totals	2 234 000	2 234 000

The energy balance sheet would be along these lines:

- kcal produced: intensive culture	600 000 000	
semi-intensive culture	700 000 000	
- kcal of subsidiary energy: feeding		1 200 000 000
- kcal of auxiliary energy: electricity, fuel, etc.		571 500 000
Totals	1 300 000 000	1 771 500 000

The profit and loss account and the energy balance sheet in this case would show that integrated fish culture tends to be a sound proposition from the commercial and energy points of view. But the launching of big plants of this type encounters difficulties in obtaining supplies of seed. Our model would annually need:

- Elvers	approximately	4 000 000
- Sea bass	approximately	1 000 000
- Gilthead sea bream	approximately	250 000
- Mullet	approximately	4 800 000
Total		10 050 000

Elvers fortunately do not present serious difficulties; sea bass can be supplied through artificial reproduction. But supply is problematic in the case of gilthead sea bream or large numbers of mullet.

The development prospects of brackish-water fish culture therefore rest on artificial reproduction. At any rate, this does not mean that modern culture techniques, appropriately exploiting the quantities of seed available at present, cannot result in a considerable increase in production.

1/ While this production is possible in climatically favourable areas, only about half of this can be achieved in unfavourable areas (northern Adriatic). On the other hand, some items of expenditure, e.g., reserve account, seeding, labour, etc., can be reduced

7. OTHER CULTIVABLE FISH SPECIES

Our attention has so far focused on traditionally cultured species of fish for which therefore considerable experience has been gained. But other species can be introduced in our model, in which they could be cultured in special intensive or semi-intensive sectors or in both, for example, flatfish, especially Solea vulgaris (sole) and Psetta maxima (turbot).

Sole, for instance, is already being cultured where temperature conditions permit. A limiting factor for this species at present is the difficulty of obtaining fry. We may also list salt-water trout, tilapia and sturgeon which is perfectly suitable for large areas and can be cultured in intensive and semi-intensive systems.

In some areas, certain species of crustaceans can be successfully cultured in the integrated fish culture model, especially Penaeus kerathurus and P. japonicus. Annex 2 gives some details on this point.

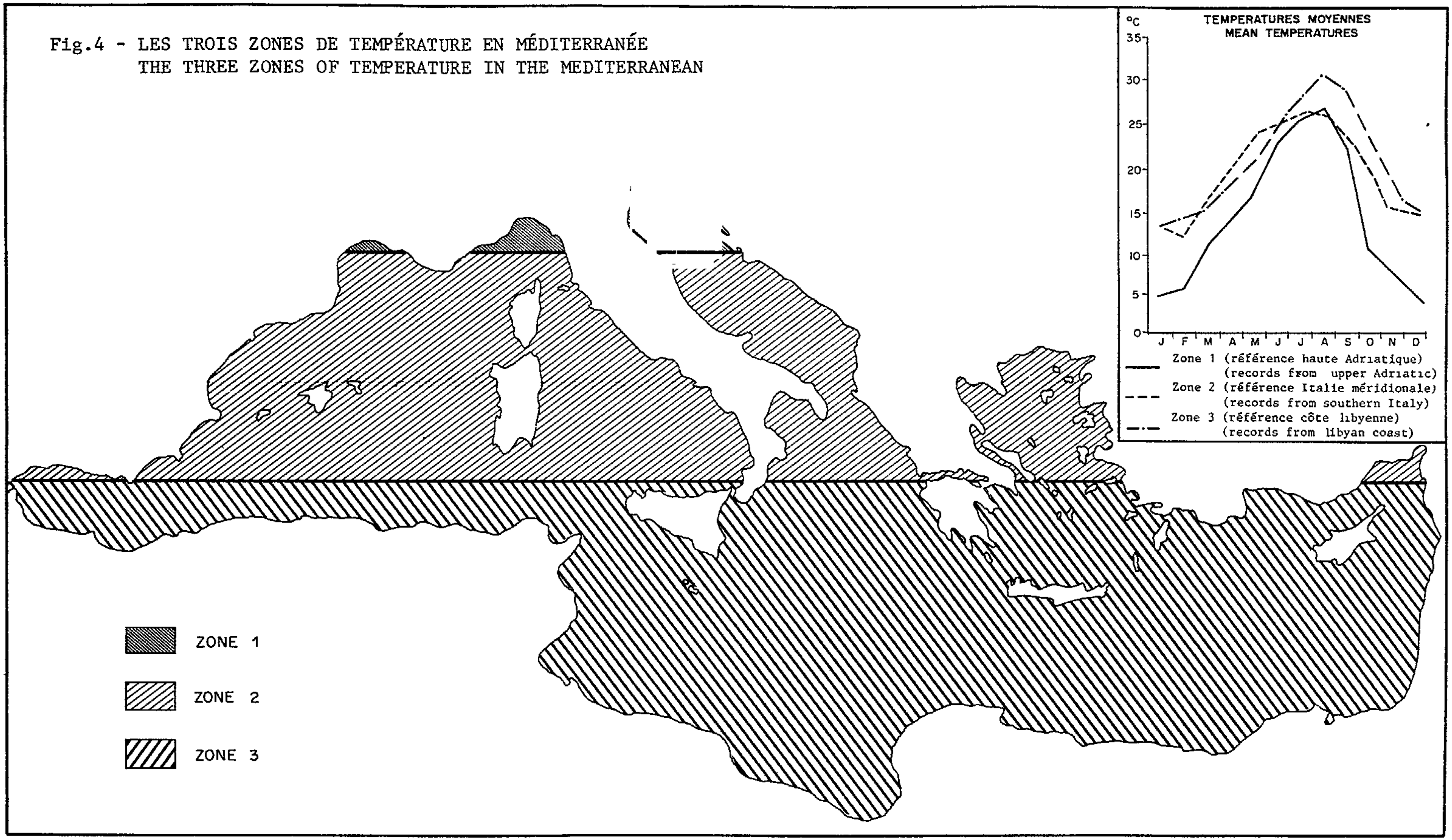
8. CONCLUSION

The brackish-water fish culture model described above combines traditional experience with modern techniques in a synthesis that can achieve quite a high production in a small area and can make very large bodies of water productive.

Where this model can be applied, fish culture can be carried on in its most comprehensive form. Where some of the necessary conditions (economic, ecological, territorial, commercial or other conditions) are lacking, one or several components of the model may be chosen. Thus the extensive or semi-intensive or intensive system may be adopted, according to the species to be cultured and the technique to be applied (stagnant water, running water, semi-running water, etc.).

This aspect is of importance especially since conditions and interests vary greatly from one country to another in the Mediterranean area.

Fig.4 - LES TROIS ZONES DE TEMPÉRATURE EN MÉDITERRANÉE
THE THREE ZONES OF TEMPERATURE IN THE MEDITERRANEAN



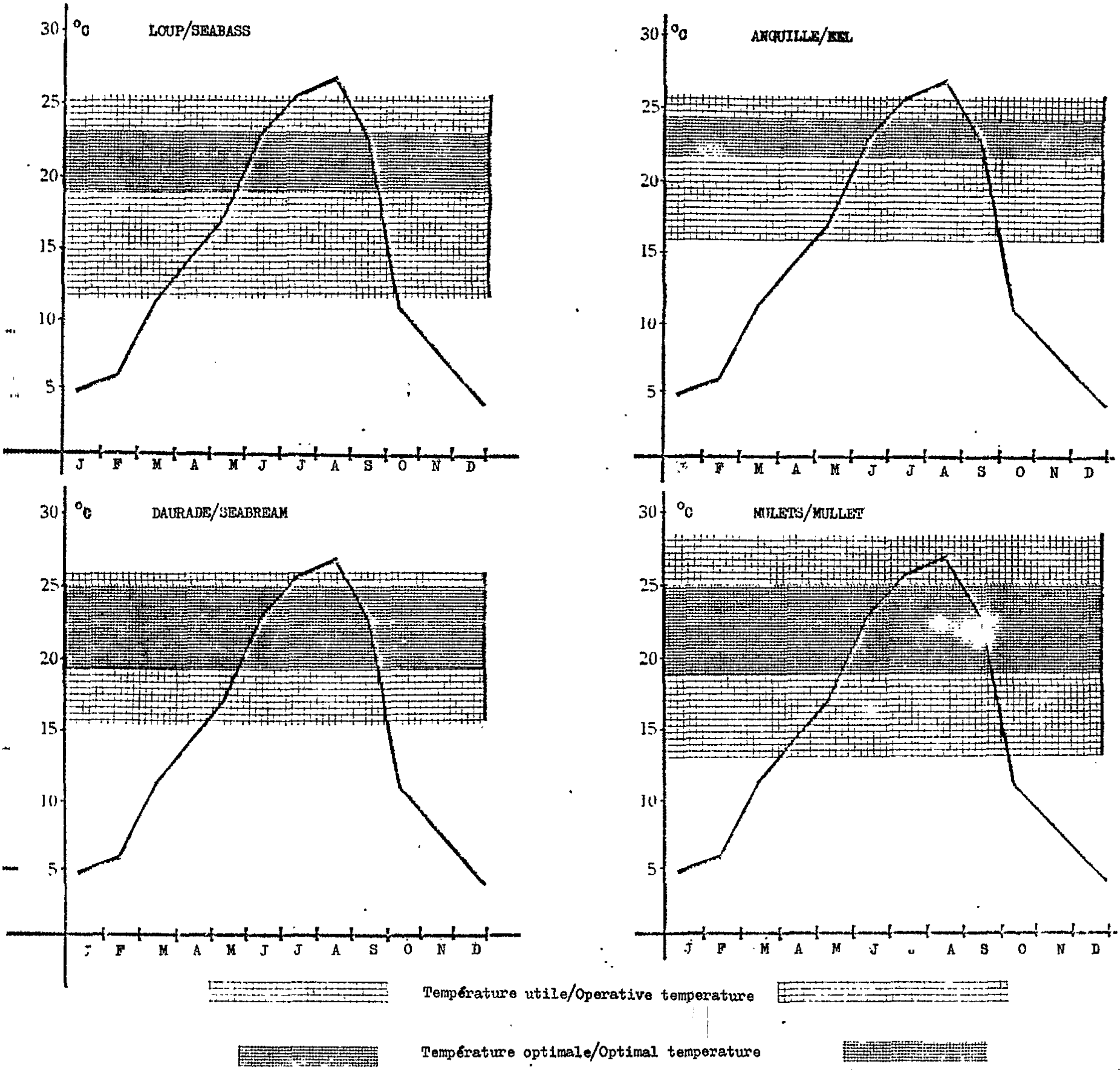


Fig. 5 - Zone 1 - Distribution des périodes de température utile et optimale pour le loup, l'anguille, la daurade et les mulets
Distribution of operative and optimal temperature periods for seabass, eel, seabream and mullet

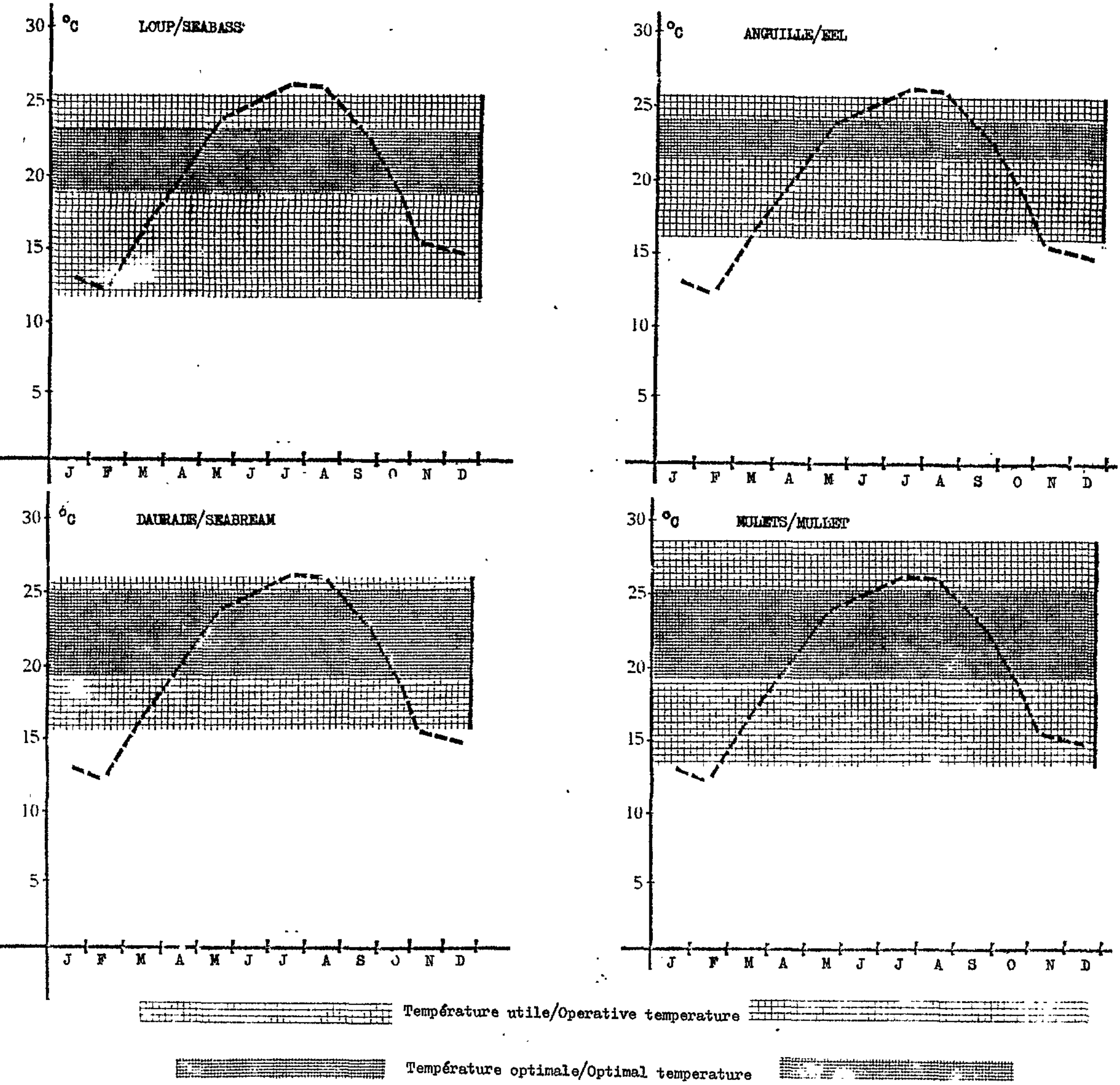


Fig. 6 - Zone 2 - Distribution des périodes de température utile et optimale pour le loup, l'anguille, la daurade et les mulets
Distribution of operative and optimal temperature periods for seabass, eel, seabream and mullet

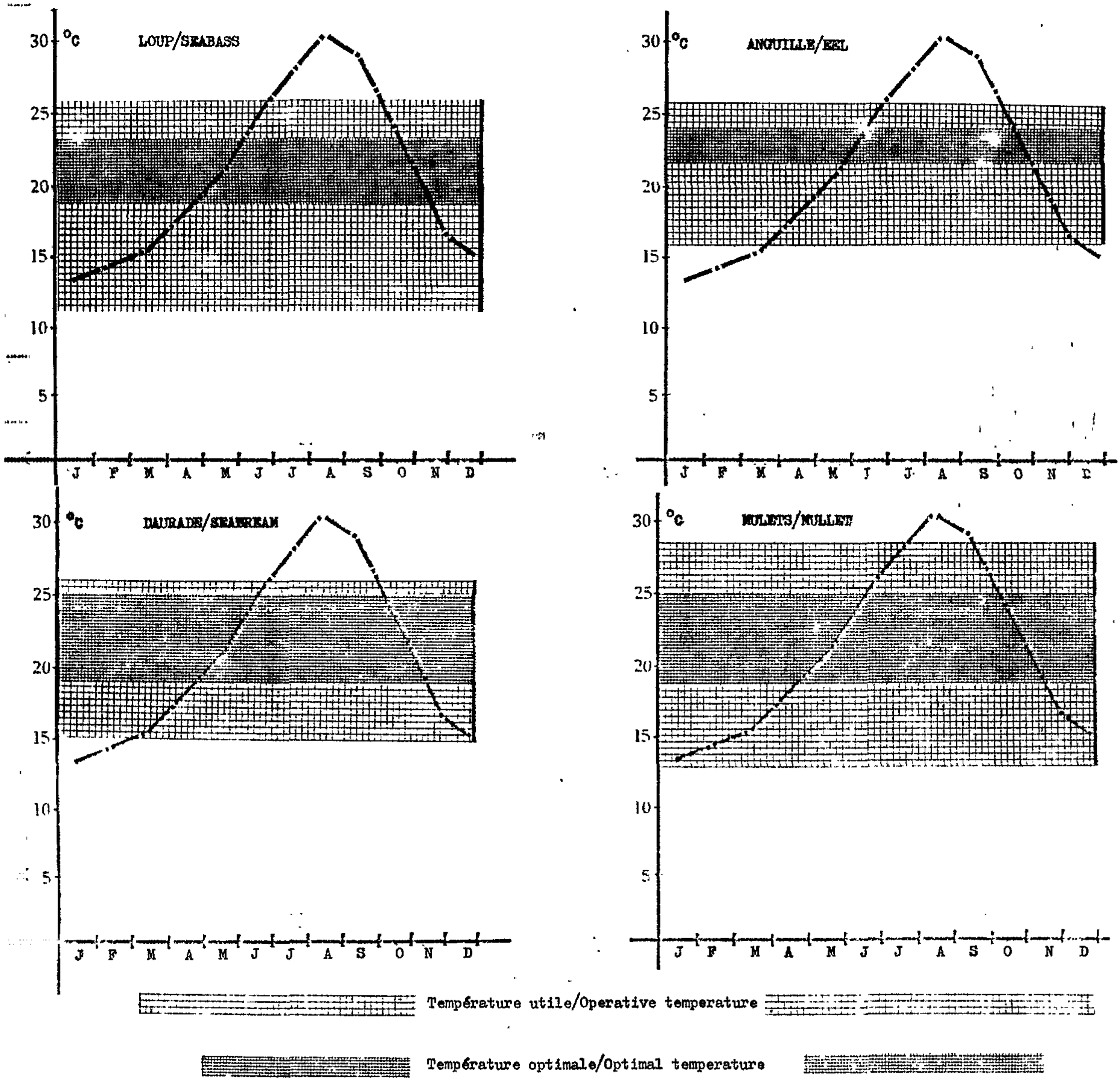


Fig. 7 – Zone 3 – Distribution des périodes de température utile et optimale pour le loup, l'anguille, la daurade et les mulets
Distribution of operative and optimal temperature periods for seabass, eel, seabream and mullet

Annex 1

DETAILED COSTS OF FISH CULTURE INSTALLATIONS (IN U.S.$)

1. Reproduction Centre and Hatchery

(a) Structures

- Laboratory and services	50 000
- Shed	89 000
- Basins for genitors	6 000
- Basins for first-stage eel	7 000
- Basins for fry	8 000
- Basins for fecundation	2 000
Total	162 000

(b) Miscellaneous

- Resino-vitreous basins for larvae	32 000
- Filters, exchangers, heating plant	12 000
- Passage grilles	4 000
- Pumps	2 000
- Lighting equipment	7 000
- Monorail for transporting zoo-phytoplankton	4 000
- Tip trucks for feeding larvae	3 000
- Automatic feeders	1 400
- Office and laboratory furniture	2 600
- Scientific instruments	18 000
- Basins for food chain	12 000
- Air-water distribution system	22 000
Total miscellaneous	120 000
Total structures	162 000
Grand total	282 000

2. Intensive Eel Culture (3 ha)

(a) Structures

- Basins	175 000

(b) Miscellaneous

- Posts	14 000
- Fish locks	4 000
- Basin inlet screens	24 000
- Outlet screens	11 000

- Inlet sluices	19 000
- Outlet sluices	9 000
- Basin partitioning	9 000
- Feed holders	6 000
- Aerators	35 000
Total miscellaneous	131 000
Total structures	175 000
Grand total	306 000

3. Intensive Sea Bass Culture (4 000 m^2)

(a) Structures

- Basins	165 000

(b) Miscellaneous

- Posts	9 000
- Fish locks	5 000
- Screens	30 000
- Sluices	19 000
- Basin partitioning	7 000
Total miscellaneous	71 000
Total structures	165 000
Grand total	236 000

4. Semi-intensive Culture Installation

(a) Structures

- Earth work	35 000
- Buildings for equipment	26 000
- Reinforced-concrete structures	35 000
- Cement for foundations, fill, etc.	18 000
Total	114 000

(b) Miscellaneous

- Wintering tunnel	21 000
- Water-conditioning equipment	27 000
- Instruments and automatic equipment	14 000
- Miscellaneous pumps	18 000

- Blocking and screening material (stakes, screens, etc.)	14 000
- Valves and piping	21 000
- Mud-working machines	18 000
- Pumping station	129 000
- Blow boats	94 000
Total miscellaneous	356 000
Total structures	114 000
Grand total	470 000

5. <u>Ancillary Installations</u>

- Building for storage and feed preparation	38 000
- Building for vehicles, workshop, etc.	54 000
Total	92 000

6. <u>Infrastructure</u>

- Generator	26 000
- Power network	46 000
- Fish sorters	19 000
- Feed-handling machines	21 000
- Cold-storage facilities	31 000
Total infrastructure	143 000
Total ancillary installations	92 000
Grand total	235 000

<u>Recapitulation</u>

	Structures	Miscellaneous
- Reproduction centre and hatchery	162 000	120 000
- Intensive eel culture	175 000	131 000
- Intensive sea bass culture	165 000	71 000
- Semi-intensive culture installation	114 000	356 000
- Ancillary installations and infrastructure	92 000	143 000
Totals	708 000	821 000

<u>Percentages</u>

	Structures (%)	Miscellaneous (%)
- Reproduction centre and hatchery	57.5	42.5
- Intensive eel culture	57.7	42.3
- Intensive sea bass culture	70.0	30.0
- Semi-intensive culture installation	24.25	75.75
- Ancillary installations and infrastructure	39.0	61.0

9. SPECIAL NOTE ON CRUSTACEANS - CULTURE INSTALLATIONS FOR *Penaeus kerathurus* AND *P. japonicus*

Consolidated experience regarding the culture of penaeids on a commercial scale is not available in the Mediterranean area at present.

But there is some experience regarding induced reproduction of these crustaceans and their culture on an experimental scale.

Some commercial-size pilot installations are about to be set up, and several projects have been considered.

Three types of installation will be briefly described here. The first two are based on Japanese culture techniques while the third type is a hyper-intensive experimental and avant-garde operation.

The production parameters of the first two models use the data given by Japanese penaeid farmers. It should be emphasized that they involve levels of production that can only be achieved in optimal environmental conditions and with long experience.

It should also be pointed out that, as said earlier, installations for penaeid culture can be easily fitted into the integrated fish culture model described above.

The assessment of costs excludes land.

9.1 Intensive Culture Installation in Earthen Basins or Adapted Natural Basins

This type of installation is usually called extensive but actually it is an intensive installation (see classification criteria on p. which is marked by a low stocking density and hence by low output (maximum 0.3 kg per m^2) compared with intensive installations for other species.

The installation has a reproduction sector and a culture sector. The reproduction sector comprises a water treatment unit, a reproduction unit and a larval rearing unit. The culture sector consists of a number of earthen basins or adapted natural basins in which the postlarvae are raised until they are of marketable size.

The maximum production obtainable with this type of installation is usually put at 3 000 kg per ha per year.

The costs of constructing an installation with earthen basins yielding an annual production of about 18 t, with a capacity of 3 000 kg per ha per year, may be listed as follows (in U.S.$):

(a) Reproduction sector

- Water treatment and conditioning unit	36 000
- Unit for reproduction, incubation and larval rearing	61 000
- Miscellaneous	41 000
Total	118 000

(b) Culture sector

- Earthen basins (about 60 000 m^2)	118 000
- Water inlet and outlet structures	24 000
- Miscellaneous	33 000
- Infrastructure	59 000
Total	234 000
Grand total	372 000

The profit and loss account may be outlined as follows:

- Management		18 000
- Labour (1 worker for 9 t)		24 000
- Artificial feed 1/		64 000
- Energy		12 000
- Maintenance		12 000
- Depreciation		34 000
- Overhead		12 000
- Miscellaneous		6 000
Income: 18 000 kg x U.S.$ 15 2/	270 000	
Total	270 000	182 000
Profit	88 000	
Reserve account (10% of gross production)	27 000	
Net profit (23% of income) (cost of product U.S.$ 10.06/kg)	61 000	

1/ The cost of feeding penaeids may vary greatly with the type of feed used. The conversion rate for live feed is 10-15:1. If waste of fish or bivalves of low commercial value is available, the cost may be U.S.$ 2-2.5 per kg of penaeids whereas the cost increases and may become untenable if such supplies are unavailable. Artificial feed has the function of stabilizing these costs within acceptable limits. In view of this solution we have applied a cost of U.S.$ 3.5 per kg of product in the calculations

2/ The sales price listed here is not an average quotation taken from the real market but a price the product should fetch to enable the installation to be profitable. This price can be assumed to be a basic index in the accounts with respect to all types of installation in order to give a comparative picture of their commercial feasibility. In the European region the wholesale market for crustaceans is strongly influenced by the influx of products from the Far East and at present prices are lower

If the culture sector consists of adapted natural basins instead of earthen basins, construction costs would decrease considerably. Under the obvious assumption that the site is chosen because conditions are particularly favourable, the costs of constructing the basins would be comparable to those considered acceptable for the establishment of extensive fish culture installations.

In principle, even though the area may have to be increased to produce 18 t per year - owing to a lower productivity, we may expect a saving of about 80 percent for the culture sector as compared with the construction costs of earthen basins. As a result, the profit and loss account might be as follows (in U.S.$):

- Management		18 000
- Labour (1 worker for 8 t)		28 000
- Artificial feed 1/		63 000
- Energy		12 000
- Maintenance		12 000
- Depreciation 2/		24 000
- Overhead		12 000
- Miscellaneous		6 000
Income: 18 000 kg x U.S.$ 15	270 000	
Total	270 000	175 000
Profit	95 000	
Reserve account (10% of gross production)	27 000	
Net profit (25% of income) (cost of product U.S.$ 9.73)	68 000	

9.2 Intensive Culture Installations in Cement Basins

The only difference in this model concerns the rearing basins for postlarvae.

In this case they are made entirely of cement, with a layer of sand and gravel covering the bottom.

This type of intensive installation can produce up to 6 000 kg per ha per year.

Apart from higher production, other advantages include better control and less labour.

The cost of constructing an installation yielding about 18 t per year may be as follows (in U.S.$):

(a) Reproduction sector

- Water treatment and conditioning unit	36 000
- Unit for reproduction, incubation and larval rearing	61 000
- Miscellaneous	41 000
Total	138 000

1/ See footnote 1 on p. 32

2/ A saving of 80 percent is estimated on the cost of the culture sector leaving the costs of the infrastructure unchanged, but these would tend to decrease

(b) Culture sector

- Basins (about 30 000 m^2)		570 000
- Facilities and miscellaneous		67 000
- Infrastructure		60 000
Total		697 000
Grand total		835 000

The profit and loss account may be given as follows:

- Management		18 000
- Labour (1 worker for 12 t)		18 000
- Artificial feed[1/]		64 000
- Energy		12 000
- Maintenance		12 000
- Depreciation		84 000
- Overhead		12 000
- Miscellaneous		6 000
- Income: 18 000 kg x U.S.$ 15	270 000	
Total	270 000	226 000
Profit	44 000	
Reserve account (10% of gross production)	27 000	
Net profit (6% of income) (cost of product U.S.$ 12.54)	17 000	

Comment

Examination of the costs and balance sheets for crustacean culture installations leads to the conclusion that this activity, though of great interest, still faces same difficulties.

It can be seen that, in contrast with the other types of culture, the commercial feasibility of penaeid culture decreases when we pass from extensive to intensive culture systems. It may be stated that at present only an installation involving very low investment costs can ensure a return.

This presupposes that operations are carried on under very special ecological, geographic and social conditions and that postlarva seed can be obtained from other installations, for instance from centres belonging to cooperatives or from government centres. In this case, depreciation costs would tend to disappear, as would the costs of highly skilled and therefore expensive labour.

1/ See footnote 1 on p. 32

Installation costs for culture in natural basins would decrease to about U.S.$ 120 000 (or much less if certain infrastructures could be omitted), and the profit and loss account might therefore be as follows (in U.S.$):

- Labour		28 000
- Artificial feed		64 000
- Energy		6 000
- Maintenance		4 000
- Depreciation		12 000
- Miscellaneous		2 000
- Income: 18 000 kg x U.S.$ 15)	270 000	
Total	270 000	116 000
Profit	154 000	
Reserve account	27 000	
Net profit (47% of income) (cost of product U.S.$ 6.47)	127 000	

By limiting net profit to 20 percent of income the normal profitability of the installation could be maintained even if the sales price is lowered to about U.S.$ 9.17 per kg.

The economic significance this activity may have if it is introduced in suitable social conditions should also be considered.

When artisanal fishermen, small-scale fish farmers and shellfish farmers are involved as direct operators, thereby making a living or improving their economic situation, this alone is a notable result.

But it must be acknowledged that, because of the particular conditions required, such a type of culture cannot be applied in most parts of the Mediterranean area.

The development of the sector is therefore linked to research and experimentation on much more perfected and productive systems than the present ones.

This leads us to present a hyper-intensive model that is worth experimenting on an appropriate scale.

9.3 Hyper-Intensive Culture Installation

The objectives of this installation are:

- To reach a culture density of about 40 penaeids per m^2 (density in intensive culture is 25 per m^2);

- To work on superposed culture levels up to the limit of optimal operation; this limit depends on the type of structures and equipment used, and an eight-level structure would be within this limit;

- On this basis, to achieve a production very close to 10 kg per m^2 of surface area of the installation;

- To establish penaeid culture in a very large geographic area;

- To mechanize and (where possible) automate culture operations;

- To maintain continuous and full control of conditions (temperature, light, water exchange, etc.);
- To use warm industrial effluents, attaining a continuous cycle of production independent of seasonal conditions.

The success of this method requires above all:

- The working out of techniques which eliminate or prevent the cannibalism typical of penaeids;
- A satisfactory solution to the problem of feeding crustaceans (dry pellets with a good conversion rate);
- An adequate technology for the whole system.

The cost of construction of a hyper-intensive installation with a total culture area of 40 000 m^2 divided into eight levels of 5 000 m^2 each, may be roughly as follows (in U.S.$):

(a) Reproduction sector	
- Water treatment and conditioning unit	36 000
- Unit for reproduction, incubation and larval rearing	61 000
- Miscellaneous	41 000
Total	138 000
(b) Culture sector	
- Structures	747 000
- Basins	470 000
- Facilities and miscellaneous	270 000
- Infrastructure	60 000
Total	1 546 000
Grand total	1 685 000

In setting out the profit and loss account, we assume that it is possible to operate at a density of at least 40 penaeids per m^2 and that the plant works at optimum thermal regime throughout the year (which depends on the possibility of using free thermal energy, otherwise conditioning costs would be untenable)1/.

If these conditions are met, the installation could produce about 60 000 kg per year.

The profit and loss account would therefore be as follows:

- Management	18 000
- Labour	34 000

1/ Unless a satisfactory water recycling could be achieved

- Artificial feed[1/]		212 000
- Maintenance		12 000
- Energy		34 000
- Depreciation		172 000
- Overhead		12 000
- Miscellaneous		6 000
- Income: 60 000 kg x U.S.$ 15	900 000	
Total	900 000	500 000
Profit	400 000	
Reserve account (10% of gross production)	90 000	
Net profit (34% of income) (cost of product U.S.$ 8.33 per kg)	310 000	

Experimental Unit

A hyper-intensive pilot culture installation operating on an experimental basis would be very useful in working out new culture techniques for penaids and establishing their feasibility.

It could be fairly small and, at the same time, offer a basic unit for commercial-type plants. As seeding material can be obtained from specialized centres, it is not considered necessary to provide a reproduction sector.

Therefore the cost of constructing the unit may be as follows (in U.S.$):

- Building (about 200 m^2)	18 000
- Rearing batteries on superposed levels	6 000
- Equipment	12 000
- Heating plant	2 000
- Miscellaneous instruments	12 000
- Miscellaneous	6 000
Total	56 000

Annual costs of experimentation:

- Specialized technical personnel (2 men)	36 000
- Operators (3 men)	36 000
- Energy and fuel	23 000
- Current supplies and artificial feed	28 000
- Maintenance	6 000
- Consultancies and travel	12 000
- Miscellaneous charges	12 000
Total	153 000

Experimentation is expected to take 2-5 years.

1/ The costs of feeding penaids may vary greatly with the feed used. The conversion rate for live feed is 10-15:1. If waste of fish or bivalves of low commercial value is available, the cost may be U.S.$ 2-2.5 per kg of penaeids whereas the cost increases and may become untenable if such supplies are unavailable. Artificial feed has the function of stabilizing these costs within acceptable limits. In view of this solution, we have applied a cost of U.S.$ 3.5 per kg of product in the calculations here

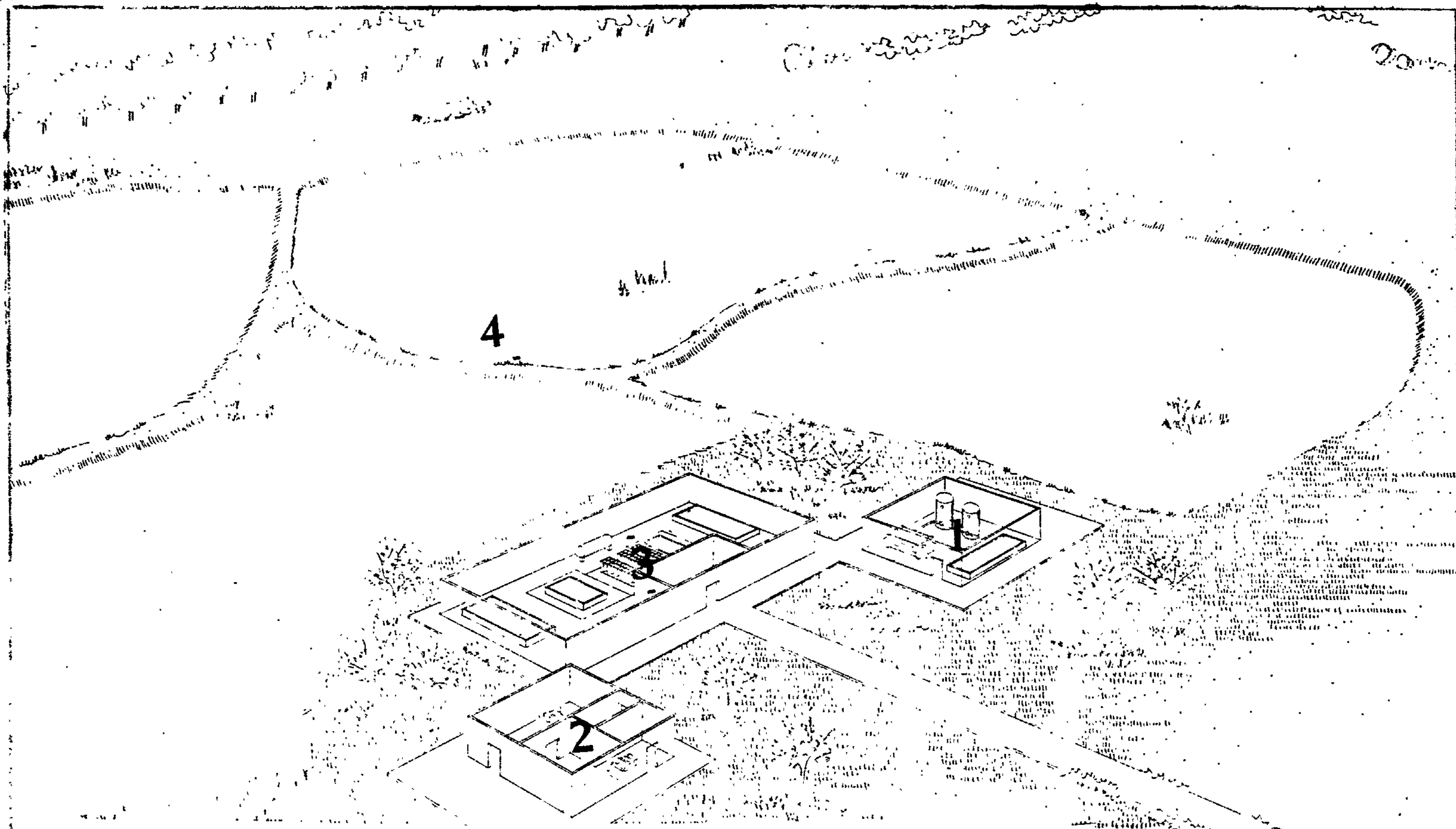


Fig. 8 – Schéma d'une installation de type extensif avec bassins naturels pour crustacés
Layout of an extensive culture system with natural ponds for crustaceans

1. Installation de traitement et de conditionnement de l'eau
   Water treatment and conditioning plant
2. Infrastructures
3. Ecloserie/Hatchery
4. Bassins d'élevage des post-larves
   Post larval nursery ponds

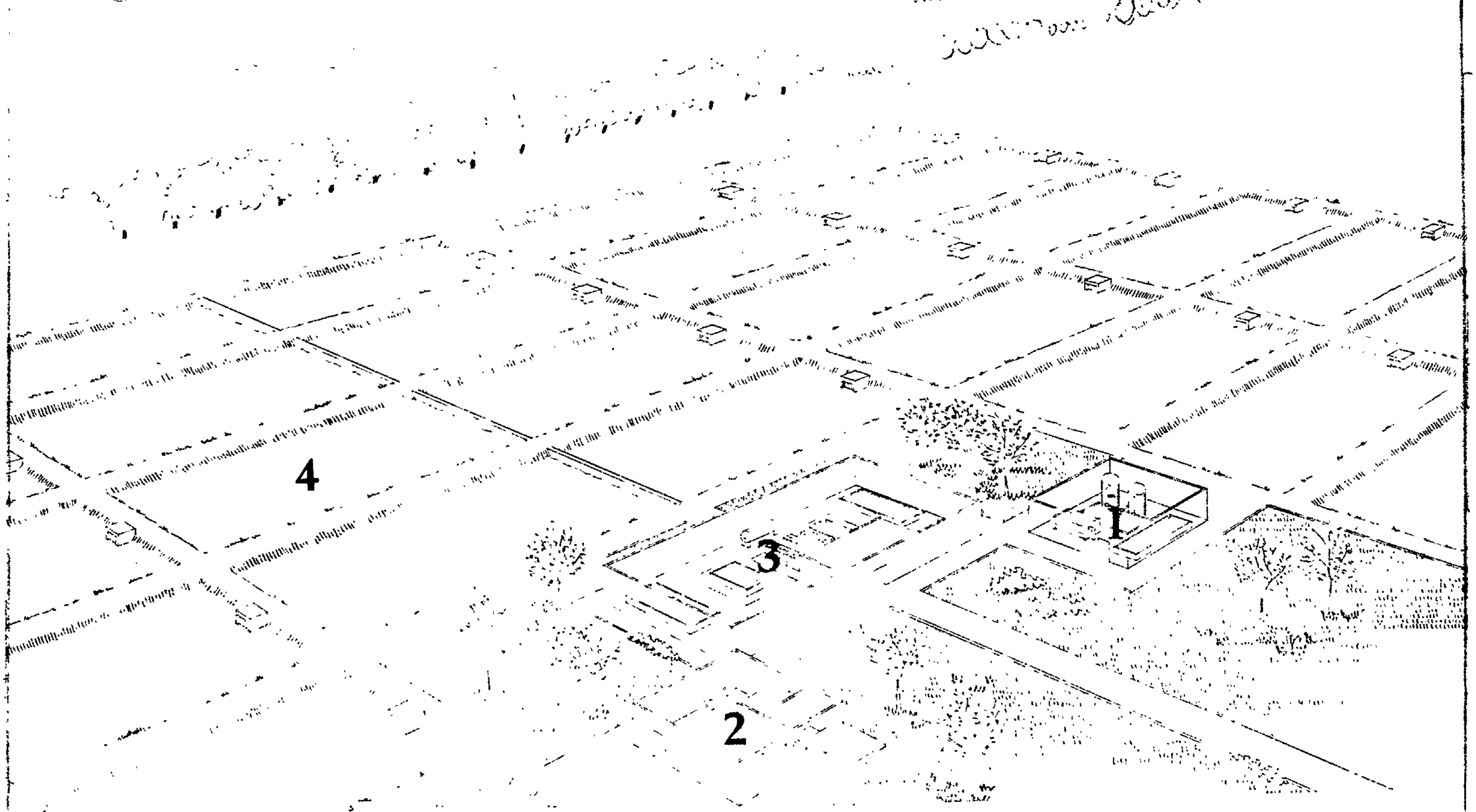


Fig. 9 - Schéma d'une installation de type intensif avec bassins en terre pour crustacés
Layout of an intensive culture system using earth ponds for crustaceans

1. Installation de traitement et de conditionnement de l'eau
   Water treatment and conditioning plant
2. Infrastructures
3. Ecloserie/Hatchery
4. Bassins d'élevage des post-larves
   Post larval nursery ponds

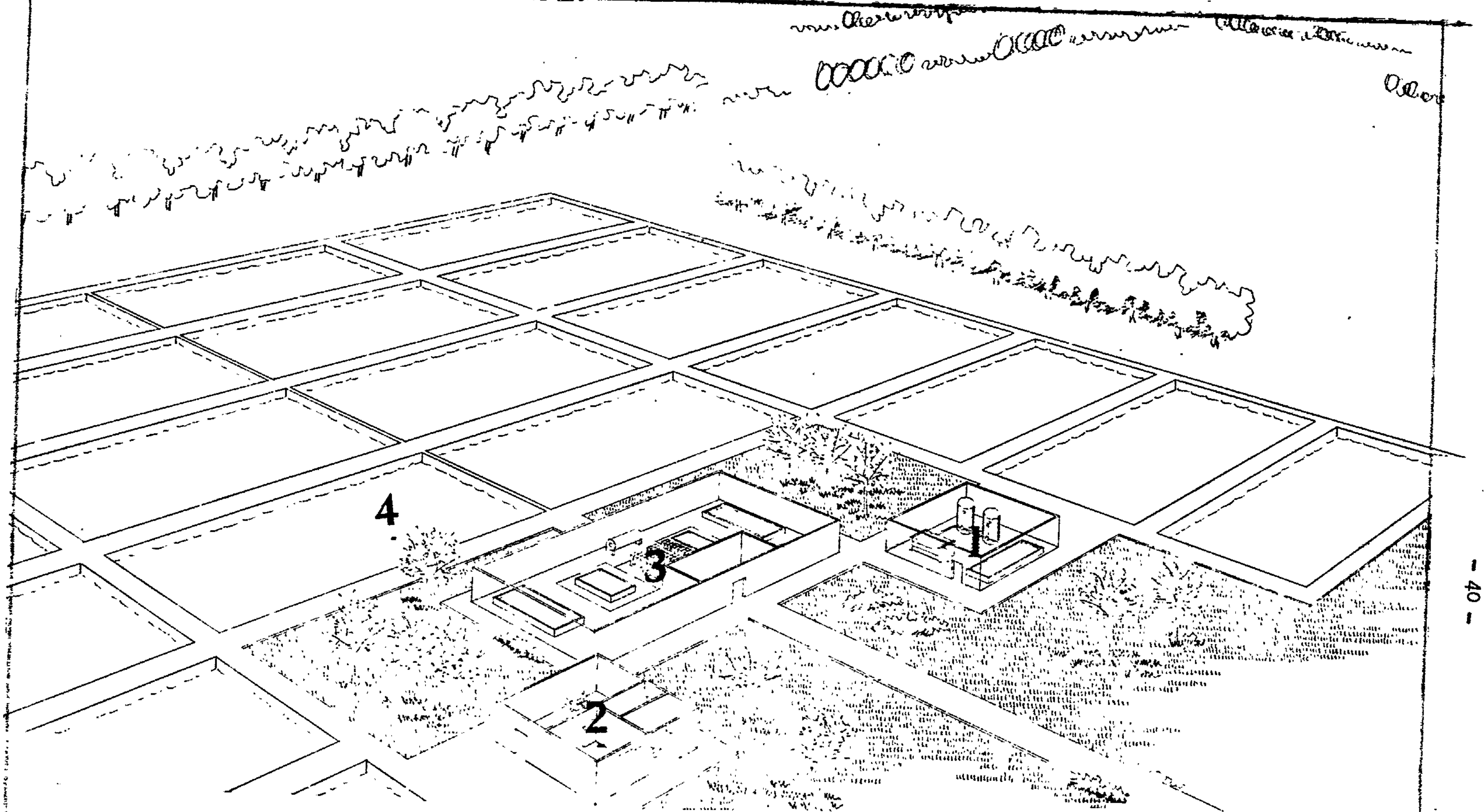


Fig. 10 – Schéma d'une installation de type intensif avec bassins en ciment pour crustacés
Layout of an intensive culture system using cement ponds for crustaceans

1. Installation de traitement et de conditionnement de l'eau
   Water treatment and conditioning plant
2. Infrastructures
3. Ecloserie/Hatchery
4. Bassins d'élevage des post-larves
   Post larval nursery ponds

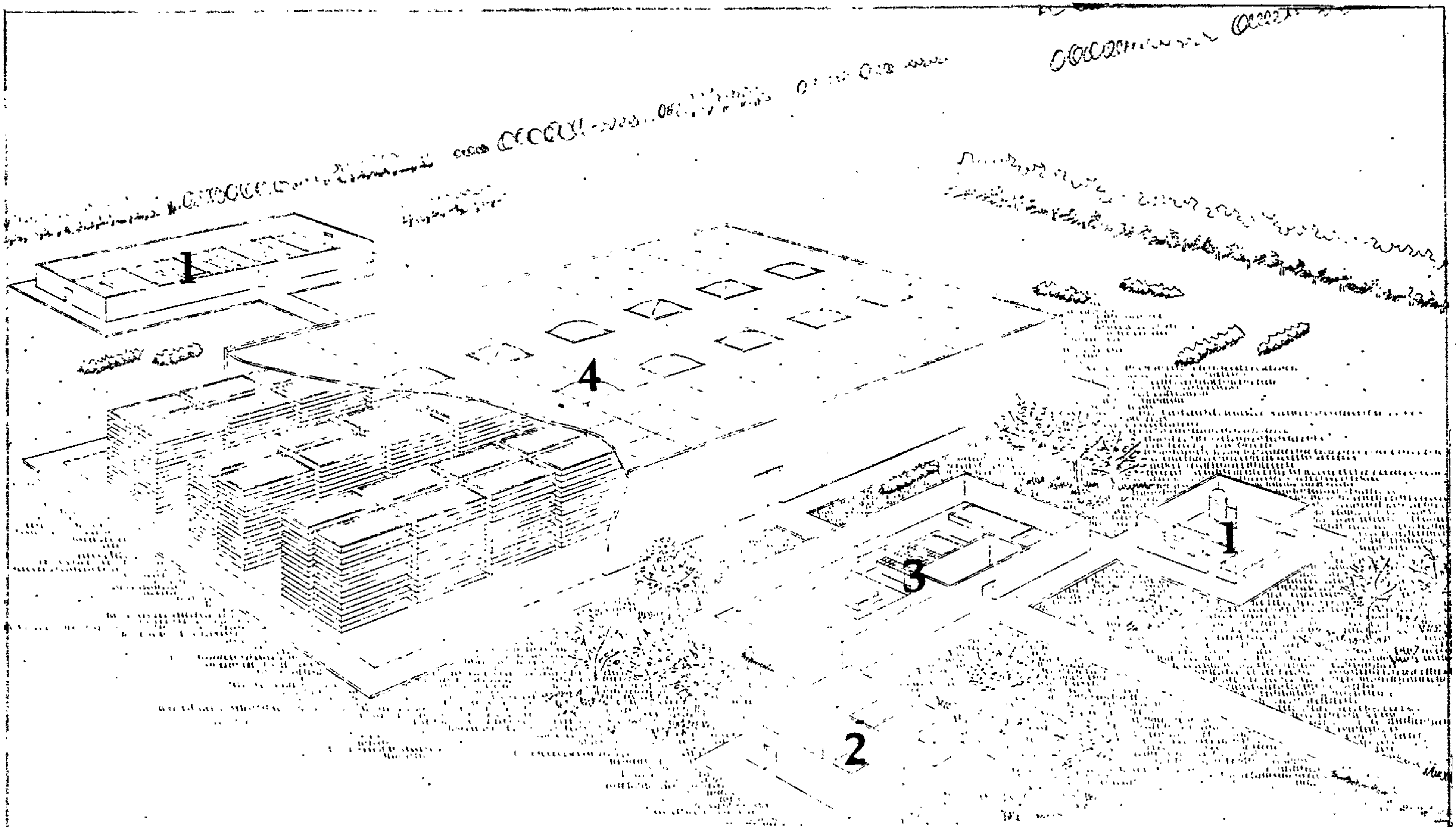


Fig. 11 - Schéma d'une installation de type hyper-intensif pour crustacés
Layout of an hyper-intensive culture system for crustaceans

1. Installation de traitement et de conditionnement de l'eau
   Water treatment and conditioning plant
2. Infrastructures
3. Ecloserie/Hatchery
4. Bassins d'élevage des post-larves
   Post larval nursery ponds

Annex 2

DETAILED COSTS OF BASIC INSTALLATIONS FOR THE CULTURE OF CRUSTACEANS (IN U.S.$)

1. Water Treatment and Conditioning

Structures

(1)	Land preparation and connecting roads	6 000
(2)	Shed	9 000
	Total structures	15 000

Miscellaneous

(1)	Sedimentation tank	2 000
(2)	Filters	7 000
(3)	Water heating plant	4 000
(4)	Pipes	2 000
(5)	Automatic equipment and miscellaneous instruments	2 000
(6)	Pumps	4 000
	Total miscellaneous	21 000
	Total structures	15 000
	Grand total	36 000

2. Reproduction, Incubation, Larval Rearing, etc.

Structures

(1)	Land preparation and connecting roads	10 000
(2)	Shed	32 000
(3)	Reinforced-concrete basins	4 000
(4)	Sliding walls	13 000
	Total structures	61 000

Miscellaneous

(1)	Furniture and fittings	4 000
(2)	Scientific instruments	18 000
(3)	Resino-vitreous tanks	2 000
(4)	Autoclave and accessories	6 000
(5)	Electrical plant	1 000
(6)	Water and air distribution plant	2 000

(7)	Hydro-thermo-sanitary plant	6 000
(8)	Miscellaneous equipment (trolleys, feed holders, etc.)	2 000
	Total miscellaneous	41 000
	Total structures	61 000
	Grand total	102 000

3. <u>Warehouse, Aeration, Cold Storage</u>

Structures

(1)	Land preparation and connecting roads	7 000
(2)	Shed	18 000
	Total structures	25 000

Miscellaneous

(1)	Generator	14 000
(2)	Cold store	18 000
(3)	Blowers	2 000
(4)	Electrical plant	1 000
	Total miscellaneous	35 000
	Total structures	25 000
	Grand total	60 000

4. <u>Additional Costs for Extensive Culture</u>

Structures

(1)	Earth work	117 000
(2)	Reinforced-concrete water inlets and outlets	24 000
	Total structures	141 000

Miscellaneous

(1)	Screens	9 000
(2)	Sluices	6 000
(3)	Miscellaneous equipment (feed holders, nets, etc.)	18 000
	Total miscellaneous	33 000
	Total structures	141 000
	Grand total	174 000

5. Additional Costs for Intensive Culture

Structures

(1)	Earth work	10 000
(2)	Reinforced-concrete for pond slopes	118 000
(3)	Cement for pond bottoms	428 000
(4)	Water inlet and outlet structures	12 000
	Total structures	570 000

Miscellaneous

(1)	Fish locks	5 000
(2)	Sluices	3 000
(3)	Pipes for water inlet and outlet	47 000
(4)	Miscellaneous equipment (feed holders, nets, etc.)	12 000
	Total miscellaneous	67 000
	Total structures	570 000
	Grand total	637 000

6. Additional Costs for Hyper-Intensive Culture, Shed, Basins for Postlarvae

Structures

(1)	Land preparation and connecting roads	41 000
(2)	Shed	706 000
(3)	Basins	470 000
	Total structures	1 217 000

Miscellaneous

(1)	Water and air distribution plant	175 000
(2)	Automatic equipment and miscellaneous instruments	60 000
(3)	Miscellaneous equipment (trolleys, feed holders, etc.)	35 000
	Total miscellaneous	270 000
	Total structures	1 217 000
	Grand total	1 958 000

Recapitulation and Percentages

	STRUCTURES		MISCELLANEOUS		TOTAL	
	'000 U.S.$	%	'000 U.S.$	%	'000 U.S.$	%
Extensive Installation	242	60.7	130	39.3	372	100
Intensive Installation	571	76.3	139	23.7	835	100
Hyper-Intensive Installation	1 121	78.2	312	21.8	1 685	100