SITUATION OF FRESHWATER CRAYFISH IN FRANCE, AND RESULTS CONCERNING THE PROBLEM OF MORTALITY OF ASTACUS ASTACUS (L.) IN INTENSIVE CULTURE.

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Summary

We can find in France several species of native freshwater crayfish: Astacus astacus, Austropotamobius pallipes, Orconectes limosus, and foreign species: Astacus leptodactylus, Pacifastacus leniusculus and Procambarus clarkii. The development of freshwater crayfish farming can be attributed to the economic situation: the annual consumption of 2,000 t is based on importation, and to the preoccupation of restocking the depopulated waters.

Foreign species generally present biological characteristics more suitable for culture than native species. A definitive choice of species for farming has not yet been done, but it seems judicious to keep native species, ecologically adapted to French waters, for restocking. One of the obstacles in the development of culture is the mortality rate in farming situations, and this has been the emphasis of our investigations.

The influence of different factors: the use of prophylactic treatments, the type of production area, the source of animals, upon the survival rate of Astacus astacus, was studied. The survival rate considerably changes with the farming site.

The environmental characteristics of several production areas did not explain the occurrence of pathological phenomena preferentially in certain sites. A protection against the Saprolegnia sp. mycosis can be expected from the use of mixed prophylactic treatments with malachite green (5ppm) and quaternary ammonia (2ppm), right from the start of the stocking.

With A. astacus fished in France (Haute-Marne) shortly before stocking ponds, the results obtained were little different from those observed with crayfish imported from Eastern Europe for human consumption.

1. Situation of Freshwater Crayfish Farming in France

General presentation

The freshwater crayfish in France is traditionally a very appreciated delicacy. Consumed in restaurants, or at home for special occasions, it has also been the object of family fishing. This pastime is almost no longer possible, because the native populations of freshwater crayfish has considerably decreased in the France waters, as in most of European waters.

The disappearance of freshwater crayfish is generally attributed to a heavy epidemic of the freshwater crayfish plague, the Aphanomyces astaci (Schickorea) mycosis. But other factors have also played a part: notably pollution, and overfishing.

Moreover, the consumption of freshwater crayfish in France continues to stay at a high level. The market is supplied with importation, chiefly of Astacus leptodactylus (Escholtz), the Eastern Europe freshwater crayfish, from Turkey (Table 1). Turkey has sizable natural populations of this crayfish in the big lakes of Anatolia.

The amount of imported freshwater crayfish over the past years has been approximately 1,800 to 2,000 t per year, reaching 2,076 t in 1979, at a cost of 34,227,000 FF. The export numbers are very low, and refer only to those crayfish which pass through France to other destinations (Table 2, Fig. 1). For a food product of secondary importance, freshwater crayfish is thus responsible for a noticeable imbalance in foreign trade.

Table 1. Sources of importation of freshwater crayfish in France

Origin and species	% of total importation quantity 1980	1981	1982
Greece (A. leptodactylus)	1.5	1.0	1.0
Turkey (A. leptodactylus)	97.0	96.2	95.3
Spain (P.clarkii)	–	1.5	2.5
Kenya (P.clarkii)	–	–	0.7
Various origins *	1.5	1.3	0.5
TOTAL	100.0	100.0	100.0

* Importations of A.astacus from Poland and Yougoslavia, and others.
Source: French foreign trade statistics

Table 2. Foreign trade of freshwater crayjish in France

YEAR	Import Quautity (t)	Import Value (1,000 FF)	Export Quautity (t)	Export Value (1,000 FF)
1973	1034	10127	8	168
1974	1036	12508	6	161
1975	1021	14363	10	194
1976	1091	16362	18	317
1977	1535	20021	20	480
1979	1985	28783	74	1296
1979	2076	34227	66	1662
1980	1948	32576	58	1492
1981	1961	35215	47	1326
1982	1753	32389	43	1260

Source: French foreign trade statistics

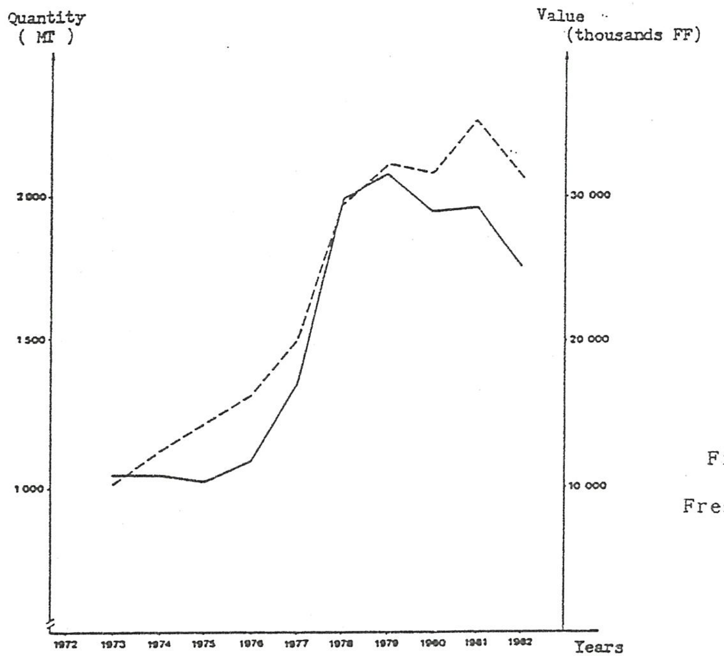

Fig. 1.

Freshwater crayfish importation in France

——— Quantity
- - - - Value

The desire to develop freshwater crayfish farming in France is then motivated for two reasons: (1) to restore the populations in the continental waters, (2) to assume an auto-production that will help to eliminate such large import.

Presentation of species

Consequently, the first question to answer deals with the choice of the species for farming. We can actually find six species in France. The native species are Astacus astacus (Linne) and Austropotamobius pallipes (Lereboullet). Orconectes limosus (Rafinesque), the "American Freshwater crayfish", was introduced from U.S.A. to Europe at the beginning of the century, spread in all the waters, and is now often considered a native species. This small-sized animal, which lives in low quality waters, is not often consumed. The foreign species are Astacus liptodactylus (Escholtz), Pacifastacus leniusculus (Dana), the "Californian freshwater crayfish", introduced because of its possible suitability for farming and restocking, and Procambarus clarkii (Girard), or "Louisiana crayfish", that represent only a small amount of the overall consumption.

The comparison of the biological characteristics of these species (Table 3 and 4) shows that the foreign species are more suitable for farming. They show a faster growth rate and are less exigent in water quality than the native species A. astacus and A. pallipes.

Another factor which should be considered with respect to restocking is the sensitivity to the fungus A. astaci S., agent of the crayfish plague. The stronger tolerance to this agent of P. leniusculus, whose biotope is similar to that of A. astacus, is the reason for the choice of this species as a replacement species in the waters where A. astacus disappeared. Such a policy has been applied in Finland and Sweden, where a national restocking program has shown very favorable results. In France, as the ecological impact of introduction in waters of foreign species is not known, priority is given to the native species for a restocking program. Consequently, the actual legislation prohibits the introduction of foreign species in other places than "closed waters" (Code Rural-art. 439-I). Closed waters refer to lakes, ponds, or piscicultural installations on a river closed upstream and downstream by fish-barriers. It is interesting to note that, as freshwater crayfish are able to leave the water and walk on land, a "closed water" system as used for fish, is not closed for freshwater crayfish. It is now well known that freshwater crayfish can often be found downstream of the farming sites. The unrestricted import of living crayfish for human consumption leaves many possibilities for using these animals for farming. The danger here is the accidental spreading of foreign species, from the farming sites.

A real protection of the continental waters with regard to an ulterior restocking program of native species, could only be carried out by totally prohibiting the import of living foreign freshwater crayfish. This has been decided by the Environment Agency* for Procambarus clarkii G., considered as a dangerous species because of its very aggressive behavior, and for the fact that it burrows deep holes in the banks. The existence of a market based on the purchase of living animals is preventing making such a regulation general for all foreign species.

Situation of freshwater crayfish farming

In Europe fresh water crayfish, and the possibilities of farming this animal, were considered as early as the 19th century (Huxley 1880, Carbonnier 1869, Chantran 1870). In 1867-1870, the cultivation of A. astacus was carried out by the Marquis de Selves in former watercress ponds at Melun, in the east of Paris.

The present situation in France is causing a renewal of interest in this field (Andre 1960, Clement and Durecu 1978, Arrignon 1981). In the last years, several attempts of freshwater crayfish farming in France have been undertaken by researchers and private individuals.

The main farms are as follows:

(1) At Guemene-Penfao (Loire Atlantique), Mr. Fournis did an intensive culture of Astacus leptodactylus E. from 1975 to 1981. The animals were reared in

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* Decision published in the Journal Official of 19/08/1983.

Table 3. Some data about biological characteristics of freshwater crayfish in natural environment

Species	Habitat	Enbironmental conditions				Size at complete development	Sexual maturity for 100% of population		Sensitivity to Aphanomycosis
		pH	D.O. (ppm)	Temperature (℃)	Calcium (ppm)		Male	Female	
Astacus astacus *	Quiet, pure water. Depth: 1.5-2m. Sandy and muddy bottom.	Min.6 Max.9 Opt.6.2-8.2	5-saturaion	Min.0 Max.30 Opt. in summer: 17-21		10 cm <	7-8 cm	8-9 cm	Sensitive
Austropotamobius pallipes *	Fresh flowing water (as trouts). Shallow depth. Gravels, stones on bottom.	Min.6 Max.9 Opt.6.2-8.2	6-saturaion	Min.0 Max.21 Opt.15	Min.5 Max.130 Opt.50-100	9 cm		6 cm	Sensitive
Orconectes limosus *	Quiet water. Low quality waters.	Min.6 Max.10 Opt.6.5-8	1-saturaion	Min.0 Max.30 Opt.20		6-9 cm	5-6 cm		Eventual healthy carrier
Astacus leptodactylus **	Quiet waters. Depth up to 7 m.	Min.6 Max.10 Opt.6.5-8	1-saturaion	Min.0 Max.35.5 Opt. in summer: 20-25	Min.5 Max.130 Opt.50-100	10 cm <	7.5 cm	7.5 cm	Sensitive
Pacifastacus leniusculus **	Quiet waters. Gravel and rocky substrate.		exigeant	Min.0 Max.25 Opt.18		10 cm <	6 cm	8-8.4 cm	Not sensitiv but healthy carrier
Procambarus clarkii **	Swamps. Burrows deep holes.		Resistant to low DO concentertions	Min.15 Max.35 Opt.21-29					Not sensitiv but healthy carrier

* native species ** foreign species
In: Clement and Durecu 1978, Laurent and Forest 1979, Arrignon 1981.

Table 4. Growth of different species of freshwater crayfish in natural (N) and restocked (R) populatons (Lenth rostrum-telson in millimeters)

Species	Place and author	Year * 0	1	2	3	4	5
Astacus astacus	USSR (N) Cukerzis (1970) in Laurent (1979)	Autumn 16 to 18	Summer 33 to 40	Summer 59 to 63	Summer 73 to 81	Summer 87 to 94	Summer 104 to 114**
〃	Sweden (R) Abahamson (1973)	Autumn 18 to 25	Autumn 35 to 55	Autumn 60 to 80			
Austropotamobius pallipes	Ireland (N) Morlarty (1973)		Autumn 43 to 57	Autumn 74 to 80	Autumn 77 to 85		
Orconectes limosus	France (N) Jestin (1978)		Autumn 60				
Astacus leptodactylus	Turkey (N) Tcherkashina (1977)						
〃	Turkey (R) Tcherkashina (1975)	Autumn 50	Autumn 98 to 106				
Pacifastacus leniusculus	Sweden (R) Abrahamson (1973)	Autumn 30 to 50	50 to 90	90 to 100			
Procambarus clarkii	Louisiana (USA) (R) (Rice-paddies) Gault (1978)	between Dec. and June 100					

* The lifeyear os coumpted from the hatching in July for all the species, except P. clarkii hatched in autumn.
** Marketable size (min 100 mm)

concrete race-ways and tanks, fed with natural food: algae were used for the pre-growth of youngs, then fish, rice and wheat for the growth period. With this farming system, marketing size animals (8 cm from rostrum to telson) could be expected in three years (CEMAGREF 1980). Mr. Fournis did also extensive culture of the same species in ponds. This farmer gave up this exploitation, because of heavy mortalities in intensive culture, attributed to pathological phenomena, and unexplained intoxications.

(2) The Pisciculture of Les Clouzioux (Indre) proposes young Pacifastacus leniusculus (1 month), produced in a hatchery, and fed during the first weeks with a humid paste made with salmonids pellets.

(3) Mr. de Malleray in Reignac (Loiret) is trying to perfect a suitable method for the breeding of native species A. astacus and A. pallipes, and to develop the restocking with these animals.

Much interest in developing this husbandry is shown by a group of private individuals, who call themselves "Association des Astaciculteurs de France" (French Freshwater Crayfish Farmers Association). Several people have made attempt at culturing, but the results have not been published.

As for the research, freshwater crayfish farming is being studied by several organizations: C.S.P.* (Superior Council for Fisheries in Continental Waters), I.N.R.A.** (National Institute for Agronomic Research), CEMAGREF*** (Center for Agricultural Engineering ,Waters, and Forests), and also various universities. Even if the biological cycle can be obtained in its entirety in farming conditions, numerous problems still remain for perfecting satisfactory culture techniques. For extensive culture, it is recommended to chose water with high calcium concentration, good oxygenation, and to provide shadow zones and shelters for the animals. But very little is known about the evolution of populations (Vigneux 1978), and the expectable production (minimum 500 kg/ha/year, Laurent 1982). In intensive conditions, specific problems linked with artificialization and higher density must be considered.

The problem of cannibalism, particularly important during the molting periods, seems to be overcome by limiting the stocking density, supplying food in sufficient quantity, and installing shelters for the animals.

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* C.S.P. : Conseil Superieur de la Peche.

** I.N.R.A. : Institut National de la Recherche Agronomique.

*** CEMAGREF : Centre du Mechinisme Agricole, du Genie Rural, des Eaux et des Forets.

The nutritional requirements of freshwater crayfish are not known exactly, and no artificial diet can yet be considered as suitable for growth. An increase of the survival rate of youngs could also be expected with an improvement in the alimentation at this phase.

Even if numerous techniques have already been used for rearing, e.g. closed and open systems, different types of tanks, ponds, of shelters, of density, our knowledge does not yet allow us to choose precisely the best technological conditions for farming.

Several diseases that are known to occur in natural environments, have been observed at a higher frequency in culture conditions. Most of them are now described, and can be recognized with laboratory techniques. Since two years ago, it has been possible for any farmer to obtain a diagnosis at the Departmental Veterinary Service. The last problem to overcome is to determine the cause of the appearance of pathology, and how to fight against these rapidly progressing phenomena. The importance of the problem in experimental and practical freshwater crayfish has motivated us in our choice of this subject for our study.

Possibilities of development and conclusion

Until now, freshwater crayfish farming in France has not been considered as an economically viable activity. As the price of imported animals is rather low (for A. leptodactylus imported from Turkey, 18 to 30 FF/kg in 1980, 24 to 25 FF/kg in 1982), competition can only be expected from a low cost system. The economic study based on the first results of intensive culture of A. leptodactylus farming in GuéménéPenfao gave a price of 0.62 FF for a one-year old animal, while the individual price of the imported animals (25-35 g) was 0.80 FF, with a whole sale price of 25 FF/kg. The conclusion of this study, as was A. pallipes (Clement and Durecu, 1978), is that freshwater crayfish farming in intensive culture is at present not economically worthwhile, but that good results could be expected from extensive culture. A further improvement in the situation of this crayfish production can of course be expected with an adjustment in suitable techniques by researchers and farmers, but also by a change in the economical situation. Turkey, the present source of supply, shows signs of decreasing its production, due to overfishing problems. A decrease of import, and an increase of price, could make the farmed freshwater crayfish system competitive with the importing system.

The conclusion drawn at present is that it is better to consider freshwater crayfish farming as a secondary activity, whose development must be handled with care.

2. Results concerning the problem of mortality of Astacus astacus L. in intensive culture

We shall give here the main results of our study (Mariojouls, 1984), which was presented in more detail during a recent Symposium of Astacology (Lund, Sweden, Aug. 1984).

In freshwater crayfish culture, high mortality rates can be attributed to cannibalism, pathology, intoxications, or interactions of these factors. The sensitivity to any of them is higher in weakened animals. The quality of the water and the initial state of animals at stocking time must thus be taken into consideration, as possible weakening factors.

The aim of our study was to investigate the influence of the origin of the animals and of the farming site, on the subsequent survival rate of cultivated A. astacus. Also to search for ways of fighting against pathology, the main apparent cause of mortality in farming conditions.

Two groups of animals were used: A. astacus imported for human consumption (length rostrum-telson 79 to 99 mm), having suffered transport and storage situations, and native A. astacus fished in France (80 to 130 mm), and brought to the place of farming in the shortest time possible.

The imported animals were stocked in different sites, which varied in the origin of their water (tapwater, river or pond water), the type of tank, the water system (recirculated or open). Stockage density was the same (15 to $20/m^2$), except for one site used as a reference for extensive conditions.

We tried different prophylactic treatments: with malachite green (5 ppm) for one 20 min. period per week, and quaternary ammonia (2 ppm) for one 20 min. period per fortnight. These treatments were applied alone, combined, and compared with untreated lots.

Test of the farming site

During the first experiment, a heavy epidemic of Pseudomonas sp. bacteriolysis provoked a 100 % mortality rate in two sites fed with the same source water, in intensive and extensive conditions (Gournay's site). The same lot in a recirculated system fed with dechlorinataed tapwater presented a 40 % survival rate at the end of the same period of 55 days.

Gournay's site thus appears to be characterized by a high pathological risk. The analysis of the environmental conditions of the different sites showed that Gournay presented (1) a low summer temperature (10 to 16°C), (2) a wide daily thermal amplitude (1.5 to 3.5°C), and (3) significant concentrations of total aerobic bacteria (10 to 100 germs/ml), and fluorescent Pseudomonas. The two last factors were also observed in sites were the survival rate stayed at a high level. The low summer temperature is thus the only specific characteristic of the high pathological risk site, and can be considered and responsible for an initial weakening of the animals, made then vulnerable to pathogenic agents. We can emphasize here that the optimum summer temperature range for A. astacus is 17 to 21°C (Cukerzis in Laurent et al. 1978). The two other characteristics of this site may also have played a part, in synergy with the former.

Our results concerning the physico-chemical parameters in the closed systems allowed us to presume there is a strong tolerance of A. astacus to a wide range of pH (5 to 8.4), and high concentrations in nitrogenic matters (up to 0.05 mg/l for NH_3, 7.9 mg/l for NO_2^- , 228 mg/l for NO_3^-).

Test of prophylactic treatments

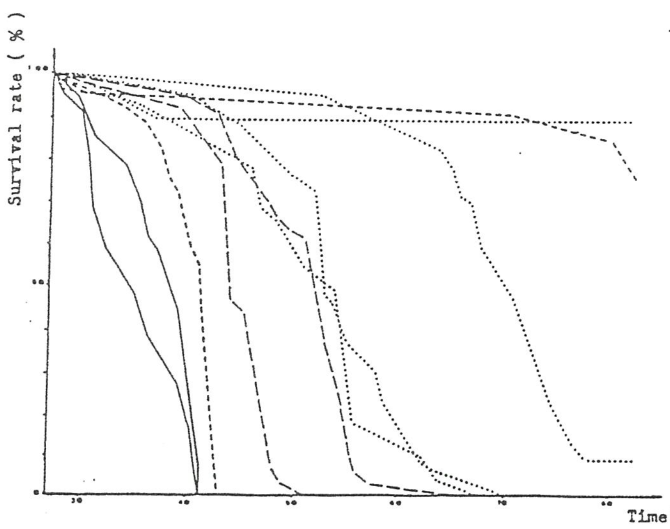
The application of prophylactic treatments in the intensive culture site of Gournay showed that:

(1) During the first experiment, none of the treatments applied after a five weeks quarantine had an effect on the unfolding of the Pseudomonas sp. bacteriolysis epidemic. The posology we used, with prophylactic aim, was certainly not able to fight an already begun epidemic.

(2) During the second experiment, the application of the same treatments right from the start of the stocking, showed that the double treatment with malachite green and quaternary ammonia was able to prevent or slow down a Saprolegnia sp. mycosis epidemic. Malachite green alone was also found to give more protection to those animals that were in better conditions, i.e. those issued from good transportation conditions (Fig. 2).

Test of the origin of the animals

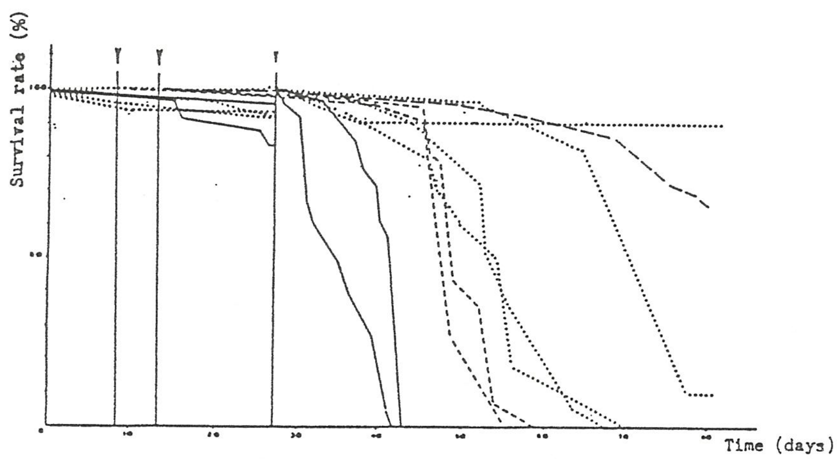
The native freshwater crayfish stocked in Gournay during the second experiment were also affected by the Saprolegnia sp. mycosis, even if they showed a better resistance to the infection (mortality beginning 35 to 42 days after the stocking,as opposed to 25 days for the imported animals). The protection against the epidemic, noticed with imported animals, was also found with these animals submitted to the same treatment with malachite green and quaternary ammonia (Fig. 3).



--------malachite green ....malachite green and quaternary ammonia

------quaternary ammonia ________no treatment

Fig. 2. EFFECT OF PROPHYLACTIC TREATMENTS ON THE SURVIVAL OF ASTACUS ASTACUS DURING THE SECOND EXPERIMENT.



———————— imported A.astacus receiving no treatment

.... imported A.astacus receiving a combined treatment (G.M. & Q.A.)

----------- native A.astacus receiving no treatment

——————— native A.astacus receiving a combined treatment (G.M. & Q.A.)

Y stocking of native A.astacus

ı refilling of the ponds of imported A.astacus

Fig. 3. EFFECT OF THE ORIGIN OF THE ANIMALS AND OF PROPHYLACTIC TREATMENTS ON THE SURVIVAL RATE OF ASTACUS ASTACUS.

Conclusion

This study brings up new considerations in our knowledge of pathology of freshwater crayfish in intensive culture conditions, and possible ways to fight against it. The use of imported animals for farming does not seem to be the cause of a specific vulnerability of the animals.

The obstacles we met in explaining the high pathological risk found in Gournay show also a need for further investigations concerning the sensitivity of A. astacus to environmental parameters. This would allow us to find criteria for the choice of suitable sites for farming, and thus open large possibilities to a development of this activity.

REFERENCES

ABRAHAMSON, S., 1973. The crayfish Astacus astacus in Sweden and the introduction of the American crayfish Pacifastacus leniusculus. Freshwater crayfish papers, 1st Int. Crayfish Symp., Austria, pp 28-40.

ABRAHAMSON, S., 1973. Methods for restoration of crayfish waters in Europe. Freshwater crayfish papers, 1st Int. Crayfish Symp., Austria, pp 203-210.

ANDRE, M., 1960. Les ècrevisses francaises, Ed. P. LECHEVALLIER and Maison Rustique, Coll. Savoir en histoire naturelle XXIV, p 293.

ARRIGNON, J., 1981. L'ècrevisse et son èlevage, Coll. Nature et Agriculture. Ed. Gauthiers and Villars.

CARBONNIER, P., 1869. L'ècrevisse: moeurs, reproduction, èducation. Ed. P. Dupont. p 179.

CHANTRAN, M., 1870. Observation sur l'histoire naturelle des ècrevisses. C.R.Ac. Sciences, 71, pp 43-45.

CEMAGREF-FORMA, 1980. Essai d'èlevage d'ècrevisses Astacus leptodactylus.

CLEMENT, J.L. and DURECU, A., 1978. Donnees actuelles sur l'astaciculture et ètude d'implantation en Ariege. DDA de ENSA Rennes. 2 tomes polycop.

GAULT, J., 1978. Ecrevisses de Louisiane. Publ. ADA, 5.

HUXLEY, T., 1880. L'ècrevisse. Bib. Scientifique Internationale.

JESTIN, J.M., 1979. Techniques d'èchantillonage, croissance et production de l'ècrevisse Orconectes limosus Raf., du Lac de Crèteil. These de Docteur Ingènieur. Universitè Pierre et Marie Curie.

LAURENT, P.J. and FOREST, J., 1979. Donnèes sur les ècrevisses qu'on peut rencontrer en France. La Pisciculture Francaise, 5.

LAURENT, P.J., 1982. In "La Pisciculture en etang", I.N.R.A..

MARIOJOULS, C., 1984. Freshwater crayfish intensive culture: contribution to the study of the survival of Astacus astacus (L). after stocking. Doctorate thesis (in French).

MORIARTY, C., 1973. A study of Austropotamobius pallipes in Ireland. Ed. S. Abrahamson. Freshwater crayfish papers, 1st Int. Crayfish Symp., Austria. pp 57-67.

TCHERRKASHINA, N.Y., 1975. Distribution and biology of crayfishes of genus astacus (crustacea, decapoda, astacidae) in the Turkmen waters of the Caspian sea. Ed. J.W. Avault. Freshwater crayfish papers, 2nd Int. Crayfish Symp., Baton Rouge, USA. pp 553-555.

TCHERKASHINA, N.Y., 1977. Survival, growth and feeding dynamics of juvenile crayfish (Astacus leptodactylus cubanicus) in ponds and river Don . Ed. O.V. Lindovist. Freshwater crayfish papers, 3rd Int. Crayfish Symp., Kuopio, Finland. pp 95-100.

VIGNEUX, E., 1978. Premiers resultats d'elevage d'Astacus leptodactylus en etang. Ed. P.J. Laurent. Freshwater crayfish papers, 4th Int. Crayfish Symp., Thonon, France.

SOME DATA ON THE LARVAL REARING OF TWO CRUSTACEAN SPECIES PALAEMON SERRATUS AND PENAEUS JAPONICUS

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In order to become better informed of those factors influencing larval mortality at the time of rearing, two crustacean species were investigated. The first is the common prawn Palaemon serratus and the second, the famous Japanese shrimp, Kuruma-ebi. The latter was implanted in France several years ago and is referred to as Penaeus japonicus. Both of these species are potentially susceptible for aquaculture development in Europe.

The mass rearing of penaeid larvae has already been accomplished in various parts of the world. There is, however, an important need for fundamental research, especially within the framework of an automated aquaculture program. This is already well under way in France and will hopefully become a total reality in the very near future.

As in the case for the common prawn, basic studies dealing with larval rearing date quite for back (Reeve, 1969; Forster, 1970; Wickins, 1972).

Results and discussion

The prawn represents a very important commercial species in France, particularly in the Mediterranean Sea, and on the North Atlantic coast, ranging from the Straits of Gibraltar to the Netherlands (Campillo, 1979). The salinity of the water in this region varies in relation to the specific locality from where it is sampled. In general it is about 38 ‰ in the Mediterranean Sea and approximately 36 ‰ on the Atlantic coast. This is slightly higher than the salinity reported from the Japanese coasts. On the basis of our experiments, P. serratus for example, is capable of metamorphosing to the postlarva stage (survival rate-10 to 20 %), even when the salinity of the water exceeds 40 ‰ (supersaline), see (Table 1). In contrast, it is very difficult for this species to metamorphose when the salinity is inferior to 19 ‰, that is to say, when the sea water is

Table 1. Combined effects of temperature and salinity on metamorphosis of larval *Palaemon serratus* (Pennant)

Temperature (°C)		SALINITY (‰) 13	19	25	31	37	43
13	PM*	0,0	0,0	0,0	20,0	12,0	4,0
	T**	—	—	—	65,90± 5,24	68,83 ±9,68	87,00± 5,66
17	PM*	4,0	16,0	68,0	76,0	58,0	54,0
	T**	31,0 ± 0,00	33,75± 8,19	36,21± 6,51	35,21± 4,39	38,69± 6,45	41,07± 7,89
21	PM*	24,0	86,0	86,0	86,0	86,0	58,0
	T**	23,00±2,45	29,72 ±3,30	19,37±3,34	26,26± 2,92	24,91± 2,86	28,62 ±4,39
25	PM*	8,0	78,0	84,0	90,0	72,0.	10,0
	T**	16,50±0,58	20,10± 2,52	21,40±2,72	20,22± 1,85	20,72±2,99	25,80± 3,70
29	PM*	0,0	24,0	26,0	32,0	0,0	0,0
	T**	—	18,83± 1,95	18,38± 1,85	18,44± 1,86	—	—

* PM :metamorphosis rate, ** T : larval period in days.

diluted with an equal volume of fresh water. This situation is apparently quite different from what we see with the Japanese species P. pacificus (Igarashi et al. in press), P. serrifer (no published), P. macrodactylus (no published) and P. ortomanni (no published), which metamorphose and survive relatively well, even when the salinity of the water is inferior to 10 ‰. When we consider the temperature, our results suggest that the optimal values for larvae of P. serratus vary between 17 and 25°C. This tolerant range is equal or narrower to that of the Japanese species mentioned above.

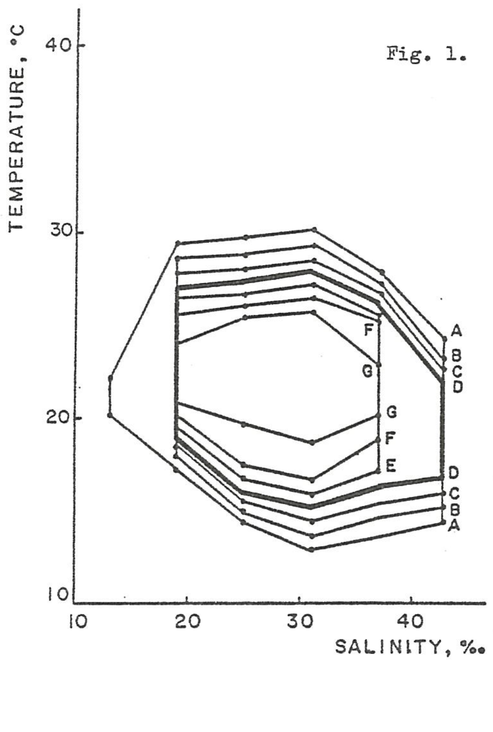

Fig. 1. Estimation of the metamorphosis rate of zoeal P. serratus based on the experimental results under 30 different combinations of temperature - salinity. Isopleths are shown at 20 % (A), 30 % (B), 40 % (C), 50 % (D), 60 % (E), 70 % (F), 80 % (G) and 90 % (H), respectively.

Table 2. Combined effects of temperature and salinity on metamorphosis of larval *Penaeus japonicus* Bate.
PM ; metamorphosis rate, T ; larval period in days.

Tempera-ture (°C)		SALINITY (‰) 19	25	31	37	43	48
13	PM	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0
	T	—	—	—	—	—	—
18	PM	0, 0	6, 0	100, 0	76, 0	30, 0	8, 0
	T	—	15, 67	15, 44	15, 44	17, 07	18, 00
23	PM	0, 0	62, 0	98, 0	94, 0	92, 0	24, 0
	T	—	8, 59	9, 39	10, 02	9, 59	8, 17
28	PM	4, 0	100, 0	96, 0	100, 0	100, 0	84, 0
	T	7, 00	6, 12	6., 13	6, 14	6, 72	8, 19
33	PM	0, 0	78, 0	44, 0	18, 0	0, 0	0, 0
	T	—	6, 00	6, 00	6, 00	—	—

On the basis of our work, it is possible to say that the survival rate, the metamorphosis, the respiration as well as the free swimming larval period is heavily influenced by such external factors as temperature and salinity. It is also very important to realize that the effects of these environmental conditions are heavily influenced by the interaction. P. serratus is capable of metamorphosing in water ranging salinity between 13 and 43 ‰ at temperatures ranging between 13 to 29°C. When we examine the threshold of metamorphosis of P. serratus characterized by a survival rate of more than 50 %, we note that the tolerant limit of the combinations of salinity and water temperature are 19 to 37 ‰ and 17 to 25°C. respectively (Fig. 1). The combinations of "low salinity - low temperature" and "high salinity - high temperature" are less favorable for the larval development. The optimum value of salinity-temperature combination on the basis of our experiments with P. serratus is 31 ‰ and 25°C. This ensured good metamorphosis and reduced duration of the free swimming larval period.

The several experiments were conducted for Penaeus japonicus. We determined that the nauplius stage of this species was capable of tolerating to great variation in temperature and salinity. The most favorable conditions which we found that ensure metamorphosis after the zoea and mysis larval stages, just were a temperature 18 - 33 °C in the salinity 19-48 ‰ (Table 2).

The limits of the salinity-temperature combination as the threshold "50 % survival rate" were found to be in 25 to 48 ‰ and 18 to 33°C respectively. This range is obviously much larger than that obtained for P. serratus.

An interesting observation was made for P. japonicus larvae, in that this species was able to show a high rate metamorphosis in every case of the salinity on condition that the temperature was "favorable". When, however, the temperature was low, for example 18 °C, metamorphosis occurred only at salinity of 31-37 ‰ . And high temperature for example 33 °C, normal metamorphosis can only be accomplished at a salinity of about 25 ‰. We observed that at temperature level of 13 °C, no metamorphosis occurred beyond the mysis stage.

The optimum conditions for metamorphosis for P. japonicus larvae was found when the salinity-temperature combinations are 25-43 ‰ and 28 °C respectively (Fig. 2). The larval growth (as measured by the total length) was not significantly influenced by salinity or temperature for P. serratus. In contrast, we found that the temperature significantly influenced the larval development of P. japonicus (as measured by total length).

As far as the growth rate is concerned, it is noteworthy but for both species, there is a tendency for postlarval metamorphosis to be delay in relation to increasing the temperature. A similar phenomenon is observed for salinity.

Finally, the respiration appears to be influenced by combined interaction of salinity and temperature. The oxygen consumption increases linearly as the temperature of the water goes up. It is characterized by maximum value at a optimum salinity. There is the decrease of oxygen consumption when the salinity is inferior or superior to the optimal point.

The perspective models, in point of our study, in three dimension, on based on the hypothesis of Alderdice (1972), we feel that this approach allowed larger comprehensions and better expressions of the observations.

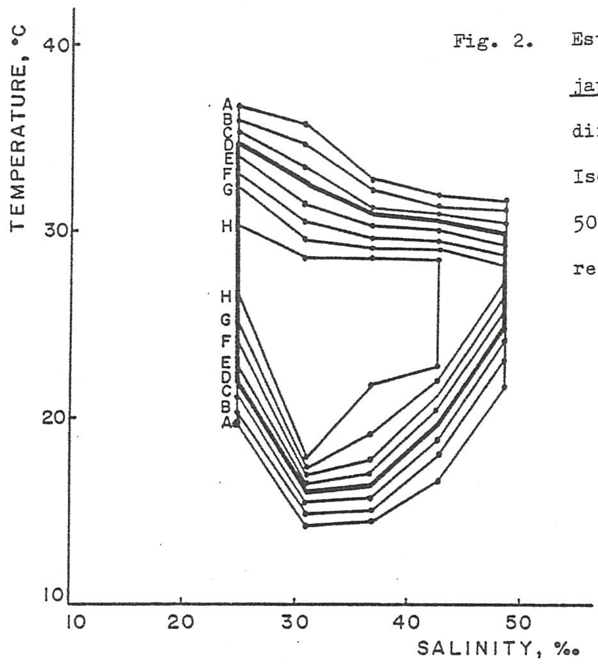

Fig. 2. Estimation of the metamorphosis rate of zoeal P. japonicus based on the experimental results under 30 different combinations of temperature - salinity. Isopleths are shown at 20 % (A), 30 % (B), 40 % (C), 50 % (D), 60 % (E), 70 % (F), 80 % (G) and 90 % (H), respectively.

References

ALDERDICE, D.F., 1972. Factor combinations. Responces of marine poiki-lotherms to environmental factors acting in concert. Marine Ecology, Edit. Wiley-Interscience, Lond., Vol. 1, part 3 : 1659-1722.

CAMPILLO, A., 1979. Contribution a l'etude de la ctevette rose Palaemon serratus (Pennant) exploitation biologie, elevage, epidemiologie. These Doct. Etat, Univ. Sc. Techn. Languedoc, Montpellier : 247pp.

Forster, J.R.M., 1970. Further studies on the culture of the prawn, Palaemon serratus Pennant, with emphasis on the postlarval stages. Fish. Invest. Ser. 2, 26 : 1-40.

IGARASHI, Y., YAGI, H. and UNO, Y., 1984. Influence de la combinaison des facteurs temperature et salinite sur la croissance larvaire de Palaemon pacificus (STIMPSON) (Palaemonidae, Decapodes crustace). La mer (in press).

Reeve, M.R., 1969. Growth, metamorphosis and energy conversion in the larvae of the prawn Palaemon serratus. J. Mar. Biol. Ass. U.K., 49: 77-96.

Wickins, J.F., 1972. Developments in the laboratory culture of the common prawn, Palaemon serratus Pennant. Fishery Invest., Lond., Ser. 2, 27(4): 1-23.

YAGI, H. and CECCALDI, H.J., 1983. Croissance, survie et respiration des stades larvairs de Palaemon serratus (Pennant), Crustacea Decapoda, a differentes combinaisons de salinite et de temperature. Rapp. Comm. int. Mer Medit, 28, 6: 345-348.

TRANSPLANTATION OF USEFUL ATLANTIC CRUSTACEANS INTO JAPAN

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The Sanriku coast is characterized by many sheltered bays and a variety of varied mariculture production. Oceanographic survey has shown the availability of space and food for many culture species along a complicated shoreline. However, since there are no useful indigenous species, culture of crustaceans has not been popular. Release of Penaeus japonicus was unsuccessful due to low water temperature, but from an oceanographic viewpoint, it seems possible to select a suitable culture species from the North Atlantic Ocean which is separated geographically from the Sanriku Coast. Palaemon and Homarus have been experimentally introduced since 1975.

Palaemon serratus

Introduction of Palaemon serratus

Twelve egg-bearing Palaemon serratus were transported from Concarneau, France, in January of 1976. The larvae hatched out from early February to early May. A total of 1,389 postlarvae were produced. These shrimp became mature in October and spawned in November. The hatching began in February of the following year. The larvae were successfully reared at water temperature 20°C, a Chlorella

Table 1. Larval rearing of Palaemon serratus at Sanriku

Year	No. of females used	Hatching Period	Number of 1st zoea	Number fo postlaral shrimp	Number of days for rearing	Survival rate(%)	Generation
1976	12	Feb 5-Mar 2	17,500	1,389	116	7.9	2
1977	44	Feb11-Jun23	31,890 (45,810)	2,350	52	7.4	3
1978	26	Feb 4-Aug15	23,887 (26,249)	7,256	49	30.3	4
1979	75	Mar13-Jul 5	73,449	11,479		15.6	5
1980	158		16,176 (113,935)	934		5.8	6
1981		Feb15-Mar28	51,789	5,902		11.4	7
1982		Apr 1-23	150,315	14,628		9.7	8
1983	62	Apr 5-May15	25,094	9,907	33	34.1	9
1984							10

density of 5 million cells/ml fed Artemia salina and Brachionus plicatilis. The larvae metamorphosed into postlarval stage after 6 moltings in 21 days at 20°C. Survival rate during the larval stage was 70 % in a 1,000 l tank using ecosystem method. We have cultured Palaemon serratus for 10 generations in outdoor tanks at Sanriku since 1976 as shown in Table 1. Survival rate after postlarvae was higher than 80 % as shown in Table 2. The problem in the culture of this species is considered to be the lower growth rate compared to Penaeus japonicus as shown in Table 3.

Table 2. Surval rate of Palaemon serratus in an outdoor tank

Tank	Date of		No. of P. serratus		Survival rate (%)
	Release	Harvest	at release	at harvest	
E	Jul 10, 1977	Nov 25, 1977	1,432	1,337	93.4
B	Jul 10, 1977	Aug 7, 1977	200	185	92.5
B	Aug 8, 1977	Dec 8, 1977	123	104	88.6
B	Jul 10, 1977	Dec 10, 1977	160	153	80.0

Dimensions of tank. E: 10m×6m×0.6m. B: 2m ×1m×0.6m.

Table 3. Growth rate of Palaemon serratus

Body weight (g)	Date							
	5/22	6/19	7/17	8/19	9/16	10/14	11/13	12/11
0.4-	52							
0.6-	44	4						
0.8-	4	34						
1.0-	12	28	14	2				
1.2-	4	16	30	4				
1.4-		10	16	8				
1.6-		4	6	4				
1.8-		4	10	20	6			2
2.0-			10	28	16	4		
2.2-			10	2	18	14	14	6
2.4-			4		18	28	18	10
2.6-					4	24	22	24
2.8-				2	4	10	12	6
3.0-				4	2	2	6	4
3.2-				4	2	0		0
3.4-				6		2		0
3.6-				4	4		2	2
3.8-				6	6		2	
4.0-					4		2	
4.2-					14			2
4.4-					2	6	2	4
4.6-				2		2	2	6
4.8-							4	8
5.0-						4	2	8
5.2-						2	8	4
5.4-								4
5.6-							2	6
5.8-								4
6.0-							2	
Total	50	50	50	50	50	50	50	50
Avg. Bw(g)	0.56	1.09	1.57	2.25	2.84	2.90	3.22	3.73

Reproduction

Female Palaemon serratus became mature in early October at the water temperature of 15.3-22.2°C (average 18.2°C). An egg-bearing female was first found in the middle of November at water temperature 7.6-14.5°C (average 13.2°C). The percentage of egg-bearing females to the total number of females was 6.7 % in the middle of November. Wintering of Palaemon serratus was experimentally successful in Okirai Bay using a cage. In a culture tank, heating was necessary because temperature becomes very low during winter. The hatching experiment showed that about 30 days was necessary from spawning to hatching at water temperature 20°C. Hatching was delayed in the outdoor tanks due to lower water temperature. A total of 19 egg-bearing females were placed individually in cages hung in an indoor tank on February 9. Water temperature was maintained at about 20°C. The following reproduction cycle was observed for an individual. The first hatching was done on February 21. After 5 days, the female molted, mated and spawned (the second spawning). 30 days after spawning, the larvae hatched out (the second hatching) on March 28. After 5 days, the third spawning was done on April 2. The female released eggs before hatching (the third hatching). The fourth spawning was done on May 4 and the fourth hatching was done on June 3. Thus one cycle of reproduction was found to occur almost every month. The female molted on June 4 but mating did not occur. The female molted 5 times, mated and spawned 4 times and carried out successful hatching 3 times. Number of females that spawned 1, 2, 3, and 4 times during the period from November to June was 2, 5, 6, and 6 individuals, respectively. The average frequency of spawning was 2.8. Releasing eggs before hatching was found 17 times in a total of 54 cases of egg-bearing. No egg loss was observed for the 1st spawning females. The egg loss increased with increase of spawning frequency. Hatching was not successful for 70 % of the females that carried eggs at the time of the 3rd spawning. Average body weight was 4.93 g in February and 5.10 g in May. This means that energy was used for maturation during reproduction period.

Mating was done very soon after the female molted. Time of copulation lasted for only a few seconds. The female spawned about 500-1,500 eggs for a few minutes within 24 hours after mating. The period from spawning to hatching was 30 days at 20°C. Hatching occurred from 22 p.m. to 1 a.m. at night time for about 30 sec.

The effect of water temperature and photoperiod on spawning were examined. 20 females and 10 males were placed in four 2-ton FRP tanks each. Two tanks were given short photoperiods (8 hours daylight and 16 hours darkness) and the other two tanks with long photoperiods (16 hours daylight and 8 hours darkness). Water temperature was controlled at 15 and 20oC in combination with short photoperiod and long photoperiod. Maturation and spawning occurred repeatedly under the long photoperiods while it was retarded under the short photoperiods. The results of the experiment is shown in Table 4.

Table 4. Effect of water temperature and photoperiod on maturation and spawning of Palaemon serratus

Photo-period	Water temp. (℃)	No. of shrimp	1st spawning		Days spawning to hatching	2nd spawning No.	Maturity	
			No.	Average date			Mature	Immature
Short daylingth	15	20	9	Jan 1.3	61	2	8	1
	20	20	9	Dec19.7	31	5	9	0
Long daylingth	15	20	15	Dec20.4	62	0	0	15
	20	20	13	Dec10.1	35	1	1	12

Short daylingth: 8 hr of light and 16 hr of darkness.
Long daylength: 16 hr of light and 8 hr of darkness.

Homarus gammarus

Introduction of Homarus gammarus

Lobsters are attractive species for culture because of their huge size. The characteristics of Homarus gammarus and H. americanus have been compared. Five egg-bearing Homarus gammarus were transported from Brest, France in May of 1977. The female released eggs in culture tanks before hatching. Only a total of 249 first larvae hatched out in early August. The season of transportation was changed to autumn and winter and the number of the released eggs decreased. After various larval rearing experiments, an outdoor octagonal tank with an air lift induced water current was chosen. In 1980, a total of 9,169 fourth stage larvae were produced from 5 males with the survival rate of 32.0 %. This is comparable to the survival rate 22.9 % for H. americanus. The duration from the 1st to 4th stage was an average 16.9 days and 17.9 days for H. americanus and H. gammarus, respectively. The latter showed larger size during the larval stage compared to the former. The total length and body weight for the 4th larvae was 18.3 mm and 65.5 mg for H. gammarus and 15.6 mm and 59.2 mg for H. americanus.

Growth and survival of Homarus gammarus in comparison with H. americanus

In the case of individual culture, as shown in Table 5, H. gammarus showed larger body weight from 4th to 11th stage and larger total length from 4th to

17th stage compared to H. americanus. H. gammarus became smaller in body weight after 12th stage and in total length after 18th stage. Duration of intermolt period is shown in Table 6. Monthly average of water temperature is shown in Table 7. Intermolt period was almost equal from 4th to 9th stage for both species.

Table 5. Comparision of growth between H. gammarus and H. americanus

Stage	Average body weight(g)		Average body weight(g)	
	H. gammarus	H. americanus	H. gammarus	H. americanus
4	0.0665	0.0592	18.32	15.64
5	0.1033	0.1025	20.14	18.27
6	0.1856	0.2072	23.91	22.94
7	0.3428	0.3326	28.81	26.74
8	0.6291	0.6064	34.43	31.50
9	1.0446	1.0303	40.51	37.31
10	1.705	1.650	45.82	40.78
11	2.749	2.491	52.67	46.95
12	4.261	4.540	60.20	56.29
13	7.550	8.656	71.76	67.95
14	13.67	13.85	84.93	79.91
15	19.77	22.98	98.14	94.34
16	30.94	38.33	110.24	109.53
17	48.55	62.42	127.04	126.87
18	71.45	94.29	143.66	145.56
19	99.93	146.64	158.36	166.11
20	140.00	223.00	174.94	192.07
21	198.56	290.00	191.31	200.16
22	315.20		220.94	

Table 6. Avarage number of days to pass through advanced stage for Homarus

Stage	H. americanus		H. gammarus		Hybrid	
	Mean(days)	Total(days)*	Mean(days)	Total(days)*	Mean(days)	Total(days)*
4	17.6	17.6	22.6	22.6	16.9	16.9
5	14.6	32.2	15.7	38.3	15.7	32.6
6	17.8	50.0	16.0	54.3	17.6	50.2
7	17.8	67.8	17.5	71.8	18.6	68.8
8	22.1	89.9	20.6	92.4	20.6	89.4
9	27.0	116.9	28.9	121.3	25.9	115.3
10	116.1	233.0	43.3	164.6	44.9	160.2
11	78.4	311.4	71.8	236.4	108.4	268.6
12	53.4	364.9	77.1	313.5	71.0	339.6
13	44.1	409.0	63.3	376.8	52.4	392.0
14	45.6	454.6	39.6	416.4	44.1	436.1
15	65.6	520.2	48.3	464.7	61.1	497.2
16	128.8	649.0	62.8	527.5	111.8	609.0
17	132.4	781.4	97.3	624.8	109.5	718.5
18	117.6	899.0	114.3	739.1	130.0	848.5
19	160.5	1059.5	151.9	891.0	169.2	1017.7

* Total(days): total number of days from hatching.

However, molting was delayed for H. americanus at 10th stage compared to H. gammarus when the water temperature decreased seasonally from 14-15 to 10.6-11.2 °C. Retarded molting was also observed at 16th and 17th stage for H. americanus during the following winter when water temperature decreased to 10.6-11.1 °C. As the result, H. gammarus showed better growth rate compared to H. americanus through the entire experimental period.

In the case of communal culture for each species, H. gammarus showed definitely poor growth compared to H. americanus. Average body weight of the 1977 year class H. gammarus was 0.06, 8.6, 24.3, and 39.0 at the end of the calendar year for 0, 1, 2, and 3 year-old, respectively, as shown in Table 8. Body weight

Table 7. Average water temperature for the individual culture tank (℃)

Month	1980	1981	1982
January		*11.02 (8.4-12.7)	**15.66 (12.1-19.4)
February		*11.29 (7.2-12.3)	**11.22 (9.5-13.0)
March		*10.81 (8.0-12.4)	**10.57 (6.6-13.7)
April		*11.84 (9.5-13.8)	**12.54 (8.6-17.1)
May		11.37 (9.8-12.5)	14.90 (12.2-18.2)
June	15.80 (15.3-16.7)	12.56 (10.4-15.6)	17.36 (12.6-18.3)
July	16.76 (15.3-18.6)	18.45 (14.3-21.2)	18.23 (16.4-21.6)
August	18.21 (17.0-20.2)	20.08 (18.5-21.1)	20.17 (17.3-22.0)
September	18.80 (17.3-20.0)	18.69 (17.3-19.7)	19.48 (18.0-21.4)
October	16.64 (12.5-18.7)	17.15 (15.0-19.9)	17.33 (13.9-19.4)
November	*14.67 (10.4-18.9)	**17.66 (14.3-20.4)	16.65 (13.1-18.5)
December	*14.13 (9.4-16.7)	**17.21 (13.2-20.4)	14.30 (11.7-17.6)

* and ** During these periods, majority of individuals were at 10th and 16th stage, respectively.

Table 8. Rearing experiment for Homarus gammarus

Age	Date	Tank	No. of lobster	Survival rate (%)	Avg.Bw (g)
0	Sept.16-Oct 13,1977	E	710	8.9	0.06
1	Apr. 23,1978	A	63	82.5	0.24
	Der. 22	A	55		8.6
2	Apr. 28,1979	C	52	32.7	9.6
	Nov. 27	A	18		24.3
3	Apr. 24,1980	B	17	47.1	21.7
	Nov. 27	B	9		39.0
4	May 16,1981	B	8	62.5	59.0
5	May 14,1982	B	5		206.0

Area of tank. A: 8 m^2, B: 2 m^2, C: 6 m^2, D: 60 m^2.

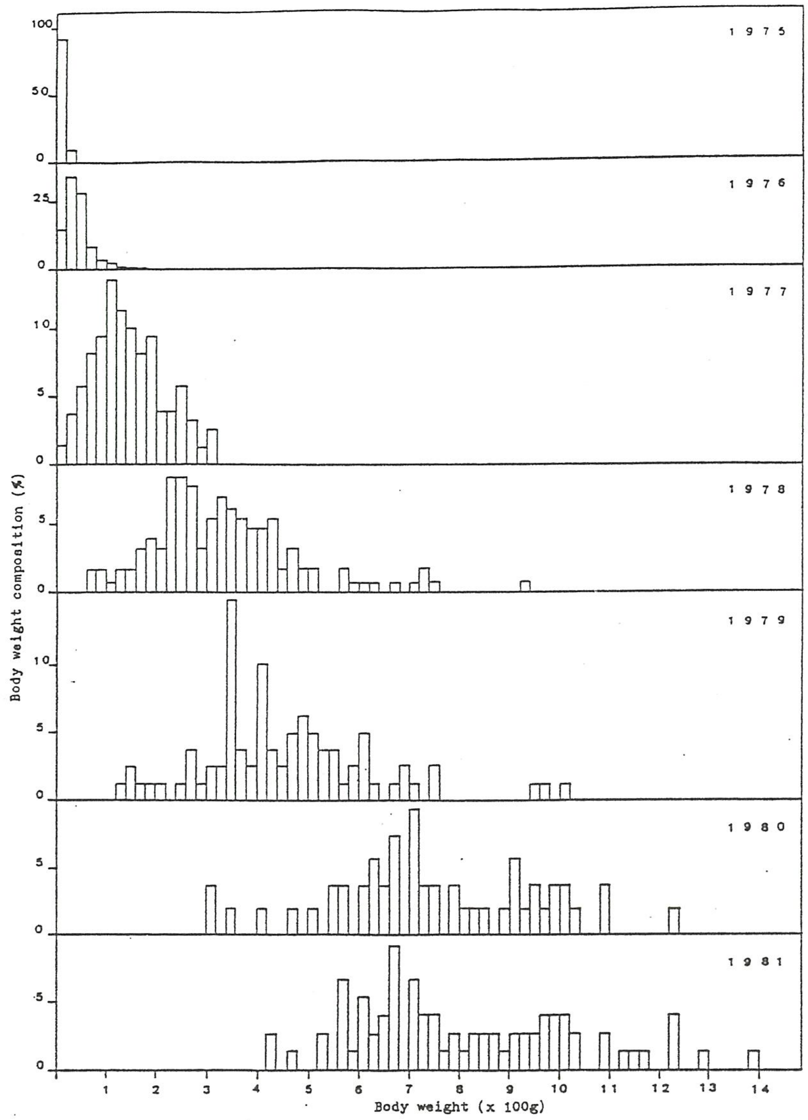

Fig. 1. Body weight composition of the 1975 year class Homarus americanus in the communal culture at the end of the calendar year.

composition of the 1975 year class H. americanus is shown in Fig. 1. Average body weight of the 1975 year class H. americanus was 8.1, 37.9, 172.0, 312.7, and 453.6 g at the end of the calendar year for 0, 1, 2, 3, and 4 year-old, respectively. A total of 16.7 % individuals of 1975 year class H. americanus grew to the matured stage at the end of 3 year-old while H. gammarus grew to the stage at the end of 5 year-old. In 1980, a total of 6,206 fourth stage H. gammarus and 9,208 fourth stage H. americanus were stocked separately in two tanks (dimensions of a tank: 10 m x 6 m x depth 0.6 m). After 2 years, 1,094 H. gammarus and 2,793 H. americanus were recovered. Survival rate was 17.6 % for the former and 30.3 % for the latter. The final average body weight of 2 year-olds was 5.1 g for the former and 14.5 g for the latter. Difference of survival and growth rate were more remarkable for H. gammarus cultured communally with H. americanus as shown

Table 9. Growth and survival of H. gammarus cultured communally with H. americanus

Species	H. gammarus	H. americanus
Date of stocking	July 2- Aug. 1, 1979	
No. of 4th stage larvae	5,008	3,509
Average body weight(g)	0.066	0.059
Average total length(mm)	18.3	15.6
Date of harvesting	May 30, 1980	
No. of lobster survived	240	957
Survival rate(%)	4.8	31.9
Average body weight(g)	0.14	5.35
Average total length(mm)	33.9	53.6

Dimension of tank: 10m× 6m × 0.6m

Note: H. gammarus and H. americanus were communally cultured in the separate tanks. The results were as follows:

	H. gammarus	H. americanus
Number		
4th larvae	618	2,748
in December	78	633
in May	50	562
Survival rate (%)		
4th larvae-December	12.6	23.0
December-May	64.1	88.8
Body weight (g)		
in December	0.5	2.8
in May	2.8	4.3

in Table 9 and 10. In 1979, the fourth stage larvae, both 5,008 H. gammarus and 3,059 H. americanus, were stocked in a tank (dimensions: 10 m x 6 m x depth 0.6 m). After one year, survival rate was 4.8 % and average body weight was 0.14 g for H. gammarus while these value were 31.9 % and 5.4 g for H. americanus. In 1978, 4th stage larvae of H. gammarus and H. americanus were stocked in a tank. After two years, the former grew to 14.6 g while the latter 62.6 g. Survival rate for 2 year was 7.0 % for the former and 62.6 % for the latter. H. gammarus showed definitely poorer results in communal culture compared with H. americanus.

Reproduction

It is important to establish controlled reproduction in captivity because there is of no natural population of Homarus in Japan.

(1) Individual culture method. About 16 % of the individuals of the 1975 year class Homarus americanus grew to the the matured size at 3 years old. Mating experiments were done in 1978 with 11 individually cultured females of body weight 232-739 g. A male was introduced in a cage (dimensions: 50 cm x 20 cm x depth 40 cm) or FRP tank (dimensions: 2.5 m x 1.2 m x depth 0.6 m) which con-

Table 10. Growth and survival of H. gammarus cultured communally with H. americanus

Species		H. gammarus	H. americanus
Number			
May 12-June 19, 1978	* 0 year	87	79
October 5, 1978		23	65
〃		32**	74**
April 28, 1979	1 year	29	71
November 27, 1979		9	62
〃		9	27**
April 24, 1980	2 year	8	27
Survival rate (%)			
0 year before wintering		26.4	82.3
during wintering		96.0	90.6
1 year before wintering		31.0	87.3
during wintering		88.9	100
0 and 1 year		7.0	65.1
Growth rater (g)			
0 year in October		2.9	12.4
1 year in April		3.0	11.8
in November		10.9	58.9
2 year in April		14.6	62.6

* 4th larvae.
** Lobster were transferred from/to another tank.
Dimensions of tank for 0 year: 10m × 6m × depth 0.6m.
〃 for 1 year: 4m × 2 × depth 0.6m.
〃 for 2 year: 2m × 1 × depth 0.6m.

Table 11. Mating experiment for 4 year old Homarus americanus grown up at Sanriku (May 1979-March 1980)

No.	Body weight(g)	Mating in 1979	Spawning in 1979	Hatching in 1979	Tank for mating
1	630	May 19	Aug 24	—	Indoor tank
2	597	May 28	—		〃
3	540	Jun 13	Aug 29		〃
4	563	Jun 29	—		〃
5	739	Jul 7	Aug 27	—	Indoor tank
6	630	Jul 18	Sep 13	—	Cage
7	502	Sep 24	—		Indoor tank
8		Oct 9	—		Cage
9	705	?	Sep 20 ? *	Nov 10-Dec 3 **	Outeoor tank
10	740	?	〃	Dec 25-Fed 9 ***	〃
11		?	〃	Jan 26-Mar12 ****	〃

* Egg-bearing female was found.
** No. of 1st larvae : 244, No. of 4th larvae : 27.
*** 〃 : 439, 〃 : 16.
**** 〃 : 8, 〃 : 0.

Table 12. Mating experiment for Homarus in 1980

No.	Date of mating	Date of spawing	Date of hatching	No. of 1st larvae	Days mating-spatching	Days spawnig-hatching	Total days
(Homarus gammarus)							
1	Feb 2	Jul 18	Dec 21	70	160	156	316
2	Feb 23	Sep 22	Jul 22, 1981	1167	211	303	514
3	Mar 23	Jul 31	No hatching	—	130		
4	Apr 29	Sep 4	No hatching	—	128		
5	Jun 8	Sep 5	No hatching	—	89		
6	Jul 27	Oct 5	No hatching	—	70		
7	Jul 28	Nov 26	Jul 24, 1981	5727	122	239	361
8	Aug 26	Nov 6	Aug 13, 1981	150	72	281	353
(Homarus americanus)							
1	Jul 22	Nov 26	Jul 13, 1981	14345	127	199	326
2	Jul 23		No hatching				
3	Jul 23	No spawning					
4	Jul 26	No spawning					
5	Aug 13	No spawning					
6	Aug 22	Aug 12, 1981	No hatching	—	365		
7	Aug 30	Oct 5, 1981	Mar 4, 1982	1401	401	150	551
8	Oct 19	Oct 5, 1981	Fed 27, 1982	175	352	145	597

Comarison between H. gammarus and H. americanus:

Species	Number	No. of mating	No. of spawning	No. of hatching
H. gammarus	8	8	8	4
H. americanus	8	8	5	3

tained a newly molted female. Copulation usually occurred within 1 hour. No spawning was found for these 3 year-old females. Mating experiments were repeated in 1979 with 8 females (No. 1-8) in cages or FRP tanks as shown in Table 11. Spawning was found for 4 females 51-97 days after mating, but hatching did not occur.

Reproduction experiments were done for both species by the individual culture method. The results are shown in Table 12. In 1980, each 8 females of both species were used for the experiment. Mating was successful for all individuals. Spawning was successful for all individuals of H. gammarus and only about 60 % of the H. americanus. Hatching was successful for 50 % individuals of H. gammarus and 38 % individuals of H. americanus. Mating is affected by behavioral characteristics of the species. The female H. gammarus is rather passive during mating compared to the female H. americanus. Hybridization was successful between female H. gammarus and male H. americanus but not yet successful between female H. americanus and H. gammarus. Spawning is affected by the nutritional condition of

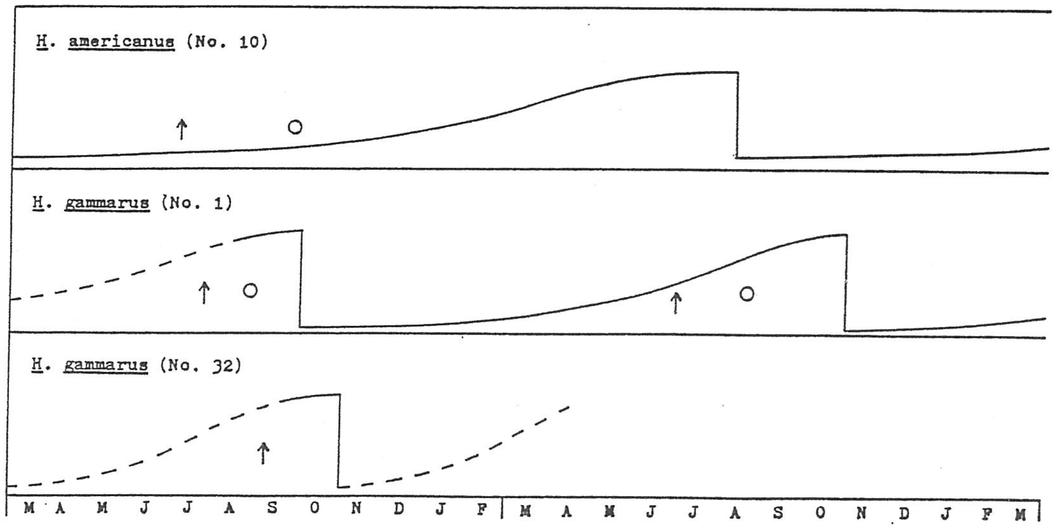

Fig. 2. Diagrammatic representation of reproductive cycle of adult female Homarus at Sanriku, Japan.

↑ Hatching, ○ Molting and mating
Curves indicate relative ovary development.
Vertical drop in the curve indicates spawning.

the female. The higher percentage of spawning success for H. gammarus is considered to be due to the fact that the ovary of H. gammarus matured rapidly compared to H. americanus. Fig. 2 shows illustratively seasonal change of ovarian development. Duration from mating to spawning is usually shorter for H. gammarus compared to H. americanus. Some individuals of H. gammarus were found bearing eggs without mating. H. gammarus showed better reproduction characteristics than H. americanus after they grew to the matured stage.

(2) Communal culture method. In an outdoor communal culture tank (dimensions: 10 m x 6 m x depth 0.6 m), 49 females and 56 males of 4 year old H. americanus were cultured after June 20, 1979. Nine berried females were found on September 20, 1979. These female were transferred in indoor FRP tanks for hatching. A total of 691 1st larvae hatched out from 3 individuals from November to March. Because of low water temperature, only 43 larvae metamorphosed to the 4th stage. However, these results suggest reproduction of Homarus is easier in the communal culture method using large-scale outdoor tanks rather than the small-scale individual culture method.

In May 1980, 46 females and 42 males of 5 year-old H. americanus were introduced in the large-scale outdoor tank (dimensions: 10 m x 6 m x 0.6 m). Thirty-one berried females were found in September 1980. These were transferred into another outdoor tank (dimensions: 4 m x 2 m x depth 0.6 m) with U-shaped concrete blocks as shelters. Twenty-seven females carried eggs until hatching in the following spring. Fifty-two thousand and six hundred eighty 1st larvae hatched out over a 31 day period beginning on May 15 of 1981. Survival rate from 1st to

4th stage was about 23 %. The result is shown in Table 13. The similar method was applied to breed 4-7 year old egg-bearing females in 1982. One hundred and twenty-four females and 51 males were introduced in April of 1982. On September 28 of 1982, 114 females and 32 males survived. The number of egg-bearing females was 11. Rate of egg-bearing females was 8.9 % for 1982 while it was 67.4 % for 1980. All egg-bearing females of 1982 released eggs without hatching.

The most remarkable difference of growing condition between 1980 and 1982 was feeding as shown in Table 14. In 1980, both mussels and shrimp pellet were used. Mussels were roughly converted to dry weight by multiplying total weight including shell by 0.04. At Sanriku, lobster grows rapidly from May to September and molting-mating is carried out during this period. The percentage of food used during this period was about 75 % from pellet and 25 % from mussels. After September, the percentage of mussels decreased to 10 %. Spawning was found in September. In 1982, pelletized food for shrimp was used exclusively through all the growing season. No mussels were used. Spawning was not successful in 1982. These results may suggest that the feeding condition before September has a direct effect on spawning. In the case of penaeid shrimp culture, shrimp pellet is effective in a pond with abundant diatom propagation. Lobsters become very active just after sunset for feeding. Feeding at the proper time will decrease loss of the pellet in the water.

(3) Hanging culture method. Water quality is also an important factor for reproduction, especially during the egg-carrying period. Twenty juveniles *H. americanus* were placed in individual cages which were hung from a raft in Okirai Bay in 1978. Mating was done in July of 1981 by placing a female together with a male several days before molting. In June of 1982, 5 females were found egg-carrying. From these females 10,767 first larvae hatched out in late June. In Okirai Bay reproduction is possible once a year.

Experimental release

Experimental release of *Homarus* was carried out at the Koshiki Islands in the south of Japan. *Homarus* placed under the shelter were monitored for about 10 days. All of the *H. americanus* dispersed from the releasing site and about 30 % of the *H. gammarus* individuals stayed under the shelter. This means that *H. americanus* is more active while *H. gammarus* is rather cautious. Such difference of behaviour may explain retarded growth and poor survival for *H. gammarus* in communal culture. Although the character of *H. gammarus* might be a demerit for consideration for commercial aquaculture, it may be better for coastal stocking programs because it may have less impact on the coastal ecosystem.

Table 13. Reproduction of 5 year old Homarus americanus communally cultred in an outdoor tank

Year	Date	Body weight(g)		Tank No.
0	May ,1975		Hatched out	
0	Dec ,1975	8.1	Communally cultured	
1	Dec 6, 1976	37.9	〃	
2	Nov 26, 1977	172.0	〃	
3	Dec 17-18 ,1978	312.7	〃	
4	Sep 20, 1979	453.6	〃	
5	May 10, 1980	556.0	46 females and 42 males were stocked in	E-1
5	Sep 18-19 ,1980		31 berried females were found in	E-1, E-2
5	〃		were transferred to	A-8
6	Apr ,1981		27 berried females were transferred to	A-11
6	May 15-Jun 15, 1981		52,680 1st larvae hatched out	A-11
6	Dec 10, 1981	867.2		

Dimension of tank. E:10m×6m×depth 0.6m. A:2m×1m×d. 0.6m.

Table 14. Record of feeding for matured Homarus americanus

Year	Month	No. of feeding days	Amt.of pellet (kg)	% of total feed.amt	Amt.of* mussles (kg)	% of total feed.amt	Total ** feeding amt. (kg)	Total weight (kg)	Daily feeding rate(%)
1980	Apr	26	2.380	(87)	8.448	(13)	2.726	48.93	0.21
	May	31	3.901	(84)	17.200	(16)	4.669	53.15	0.28
	Jun	27	3.621	(78)	25.800	(12)	4.653	57.38	0.30
	Jul	31	3.745	(72)	35.600	(28)	5.169	61.60	0.27
	Aug	30	3.570	(60)	60.200	(40)	5.978	65.83	0.30
	Sep	15	3.580	(79)	24.000	(21)	4.540	70.05	0.43
	Sub-total		20.797	(75)	171.248	(25)	27.735		
1981	Sep	10	4.990	(95)	6.500	(5)	5.250	49.05	1.07
	Oct	28	5.590	(92)	12.300	(8)	6.080		0.44
	Nov	27	8.595	(92)	18.800	(8)	9.347		0.70
	Dec	13	2.410	(85)	10.800	(15)	2.842		0.44
	Jan	4	0.120	(33)	6.000	(67)	0.360		0.18
	Sub-total		21.705	(91)	54.400	(9)	23.961		
1982	Apr	1	0.300	(100)	0	(0)	0.300	155.25	0.19
	May	15	3.960	(87)	0	(13)	4.560***		0.19
	Jun	15	7.290	(87)	0	(13)	8.350***		0.35
	Jul	16	11.040	(100)	0	(0)	11.040		0.44
	Aug	24	10.170	(100)	0	(0)	10.170		0.27
	Sep	24	3.600	(100)	0	(0)	3.600	84.47	0.17
	Oct	18	7.355	(100)	0	(0)	7.355		0.48
	Nov	17	5.810	(100)	0	(0)	5.810		0.40
	Dec	13	4.100	(100)	0	(0)	4.100		0.37
	Sub-total		53.625	(97)	0	(0)	55.285		

88 5 year old H. americanus were stocked in E-2 tank on May 10, 1980.
Spawning was checked on September 18, 1980.
175 4-7 year old H. americanus were stocked in E-2 tank on April 26, 1982.
Spawning was checked on Sept 20, 1982.

* Conversion factor: amount of mussles × 0.04 = amount of pellet.
** Weight of mussles was converted to pellet.
*** 3.00 and 5.30 kg frozen sardine were used in May and June, respectrvely.

References

J. KITTAKA: Report to the Ministry of Eduction, Culturte and Science (Overseas Scientific Survey No. 404152 and 504347), 1-77 (1981).

J. KITTAKA, Y. HENOQUE, K. YAMADA and N. TABATA: Bull Japan. Soc. Sci. Fish., 49, 1347-1354 (1983).

J. KITTAKA: Report to the Ministry of Eduction, Culturte and Science (Overseas Scientific Survey No. 56042009, 57041052 and 58043052), 1-118 (1984).

FRENCH MOLLUSC CULTURE:

Achievements and development prospects
Main constraints and research contribution

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In France, mollusc culture stands for an activity of high social and economical importance which generates about 25,000 continuous employments and lore than 30,000 seasonal jobs. The output of this activity means about 100,000 tons of oysters and 80,000 tons of mussels for the last five years which sets oysters at the top of all marine products for its turnover.

These cultures have been keeping developing since the middle of the last century and are now spreading to all the favorable coastal areas of France on the Channel, the Atlantic and the Mediterranean (Fig. 1). The exploited areas are actually 26,500 ha with 20,000 for oysters and 6,500 ha for the mussels. Technical improvements and innovations of exploitation have joined this rise although oyster and mussel culture have mostly kept a traditional aspect in France, with family exploitation on a small scale, and although the basic strategy of this culture has no changed, i.e. spat collecting and growing in natural environment, licensed on public property. However the success of filtering mollusc culture is precisely due to this secular strategy which makes use of the natural productivity of the sea and the normal behaviour of the species.

But in spite of these opportunities and economical success, mollusc culture reveals problems as to the existing level of output as well as to the development of its potentialities. Scientific research can especially resolve some of these problems: degradation of the quality of culture waters, epizootic diseases, lack of balance between the biotic capacity of environment and its load of biomass.

Quality of culture waters

The reasons as well as the result of degradation of culture waters are various, but they can be classified into three main categories: bacterial pollution, chemical pollution, and eutrophication phenomena.

Bacterial pollution requires a particular attention in France, as shellfish are mostly eaten raw. The development of the coastal urbanization has increased the risk of pollution, so that the sanitary control of sites and culture products had to be reinforced, and the collect and treatment of outgoing waters had to be systematized. In coastal zones where the water treatments are not efficient enough to guarantee the salubrity in culture waters, a purification of the products must be operated by water treatment installations with use ozone or chlorine. But it should be observed that these measures while preserving the consumer's health, mean a cost price increase for the producer, which is particularly due to the cost of purifying the shellfish but also to the financial contribution which the producer much assume for the official sanitary control of his own product. Further more it is possible that certain shellfish sites impoverfishment relatively closed, can be explained as the result of a lack of nutritive salt flow far from the places of out going waters.

The risks of chemical pollution are increasing with the rate of industrial development. For this reason a net of national monitoring stations has been created to control the contamination degree, especially by the heavy metals, and to observe whether this degree remains under the critical values for the marine fauna and the human nutrition. Some noxious effects of this sort of pollution on shellfish culture may be illustrated by the following example: scientists proved that certain anti-fouling paints (used for the protection of ship bottoms) were responsible for calcification anomalies and increase of oyster larval mortality. Consequently, these paints containing organostannic compounds are now prohibited in France.

As to eutrophication and discolored waters phenomena, if the knowledge of their appearance and evolution process increases, it will always be very difficult and even impossible to stop them because they depend on natural environment conditions. Nevertheless, an improvement of this status may be expected by a regulation of the nutritive salt flows. Anyway, these phenomena which seem to become more frequent in France, have always serious consequences for shellfish exploitation: mortality by anoxy of the whole shellfish stock, empoisonment of people eating molluscs contaminated by plankton. Regarding the latter, an abnormal multiplication of <u>Dinophysis</u> <u>acuminata</u> has been observed on two sectors of the French coasts, in 1983 and in 1984, leading to prohibit the sale and consumption of grown mussels, in these sectors.

Epizootic diseases

The French oyster culture has been meeting with a heavy loss (estimated at more than 1.5 milliard Francs) for the last twenty years caused by three epizootic diseases: a virus disease appeared in 1966 eliminated in the early seventies the whole Crassostrea angulata stocks. Thanks to the introduction of the Japanese oyster Crassostrea gigas the stocks have been reconstituted since then, and two protozoa parasite diseases, the first starting in 1968 Marteilia refringens and the second starting in 1979 Bonamia ostreae, are still raging on plate oyster stocks and have considerably reduced their output from 20,000 t to 2,000 t.

This very alarming status justified a revision of the French regulations concerning clauses and conditions of molluscs importation. The means of research on the pathogenic agents of oysters and their self resistance mechanisms have also been increased, specially by founding an experimental station for molluscs pathology and genetics.

Carrying capacity of the bay

In the very closed bay, the cultivated biomass can overload the capacity of the ecosystem which depend on the productivity of the waters but also on the velocity of the currents. If we look at the French production of oysters since the beginning of the culture (Fig. 1) it appears that the production never reaches a stable equilibrium but is always moving up and down. After each large increasing, the cultivated species are destroyed by diseases; it is the case for Ostrea edulis but also for Crassostrea angulata.

The success of acclimatization of the Japanese oyster Crassostrea gigas has permitted to give a new impetus to the oyster cultures. But we have to take into account the problems we met before and try to success to stabilize the production at a mean level of exploitation. Up to this date we can establish certain anomalies such as growing deficiencies and lack of spat collecting which seem to be due to an excess of cultivated biomass in relatively closed culture sites. Such an excess could also explain the decrease of production in certain mussel culture sectors. The state of over-stocking can cause direct mortalities which are not in relation with the expansion of pathogenic agents but depend on physiological state of the molluscan in relations with the lack of food; it is the case in the bay in the winter time for oysters in the Marennes-Oleron Bay (Heral et al., 1983) and also for oysters in the summer time in the Arcachon (Maurer, 1984).

For all these reasons, there is a large interest in acting on the regulation of biomass in terms of natural productivity of marine waters.

Two different ways of research are followed:

(1) A global approach can be practiced by following simultaneously the growth of the shell and of the flesh of the cultivated species in relation with the evolution of the stock of these species. The objective is to determinate when the biomass becomes too important by referencing with the rapidity of the growth and the quality of the flesh. This standard model can be considered as an empiric method for the management of a bay, but can, in a short term, give quite good results for the determination of the level of exploitation of a bay taking as an hypothesis that the biotic capacity of an ecosystem is constant and that the development of trophic competitors does not exist. This approach needs to have good historical data not only on the commercial production but also on the stocks and in another hand to follow the growth in length and in weight of the oysters, clams and mussels.

(2) The second approach is more analytical, using basic knowledge on the different acting parameters.

- Quantity of food which can be used by the molluscan: dissolved organic matter, particulate organic matter with an important effort on the potential available food for the molluscan (sum of the proteins, lipids, and carbohydrates) and on the phytoplankton biomass (Héral, 1985). The quantity of food is directly in relation with the velocity of the currents which bring and issue the food which can be used at an effective range by the molluscan.

- The seasonal demand in energy by the molluscan which can be described by the general equation of energy budgets (Crisp, 1971; Lucas, 1982).

$$C = P + R + F + U$$

with $P = Pg + Ps + Pr + Pe$ and $F = F' + F''$

where C is the consumption, P: production is composed of Pg: growth of somatic flesh, Ps: secretory products and particularly the organic part of the shell, Pr: energy of reproductive products, and Pe: eliminated products, R is the energy for the metabolism known by respiration, F is the energy content in the feces (F') and in the pseudofeces (F''), U is the energy of excretion products like urine (Deslous-Paoli, 1985).

After having determinated this parameters for the oysters, it is possible to put in relation the quantity of available food with the demand of one population of oysters to obtain the flux between primary and secondary production (Fig. 2).

After the obtainment of this data it is necessary to put this relations in term of equations in a model. Bacher (1985) proposes a review of the models which can be built for shellfish production. They need to take into account the physics with the current speed but also the diffusion, the advection and the residual path which can be very long (9 to 15 days for example in Marennes-Oleron Bay) particularly in the closed bay.

This analytical approach is quite a long job but is necessary to understand the operating mechanisms of the cultivated area, the evolution of their carrying capacity and the possible deterioration of the quality of the water and of the ground, the models show how to achieve efficient production patterns.

Development prospects

The actions to develop the French shellfish culture are conducted in two directions:

- extend cultivation towards yet unexploited sectors which are generally located in more remote and deeper waters than the existing culture places, as the latter spread over large zones. This extension of culture activities opens some interesting perspectives estimated up to a potential output of more than 100,000 t. But if the experiments carried out have been very successful on the biological produce level (growing, fattening), the extension of new sites in more remote waters faces technical and economical problems. Culture proceedings and structures added to bad weather conditions must be elaborated, and their cost price must not prejudice the exploitation profitability.
- promote cultivation of new species (Venerides, Pectinides) offering more advantages than an output increase, i.e. a better valorization of sites (making use of the complementary behaviour of species, especially on the trophic level), a decrease of epizootic risks (which are always more important for monospecific cultures), a better adaptation of the output to the requirements of the French and foreign market, a benefit increase (by the high trade value of select species). In this context the best successful example is the clam culture (Ruditapes philippinarum) which is just going to be developed after some research years of perfectioning technical and biotechnical proceedings.

References

BACHER, C., 1985. Development of shellfish production models. International Seminar on Shellfish Culture and Development. La Rochelle 4-8 mars 1985. Actes et Colloques IFREMER 17 p. (in press)

DESLOUS-PAOLI, J. M., 1984. Transferts energetiques entre l'huitre Crassostrea gigas de 1 an et la nourriture potentielle disponible dans l'eau d'un bassin ostreicole. Haliotis, 14,79-90.

DESLOUS-PAOLI, J.M., 1985. Assessment of energetic requirements of reared molluscs and of their main competitors. International Seminar on Shellfish Culture Development and Management. La Rochelle 4-8 mars 1985. Actes et Colloques IFREMER 33 p. (in press)

HERAL, M., DESLOUS-PAOLI, J.M., SORNIN, J.M., 1983. Transferts energetiques entre l'huitre Crassostrea gigas et la nourriture potentielle disponible dans un bassin ostreicole : premieres approches. Oceanis, 9, 3, 169-194.

HERAL, M., 1985. L'ostreiculture francaise traditionnelle in aquaculture : editeur Lavoisier Paris. (in press)

HERAL, M., 1985. Estimation of ecosystems carring capacity for molluscan. International Seminar on Shellfish Culture Development and Management. La Rochelle 4-8 mars 1985. Actes et Colloques IFREMER, 35 p. (in press)

MAURER, D., 1984. Recherches sur les mortalites estivales de l'huitre creuse Crassostrea gigas dans le bassin d'Arcachon. Rapport IFREMER, 49 p.

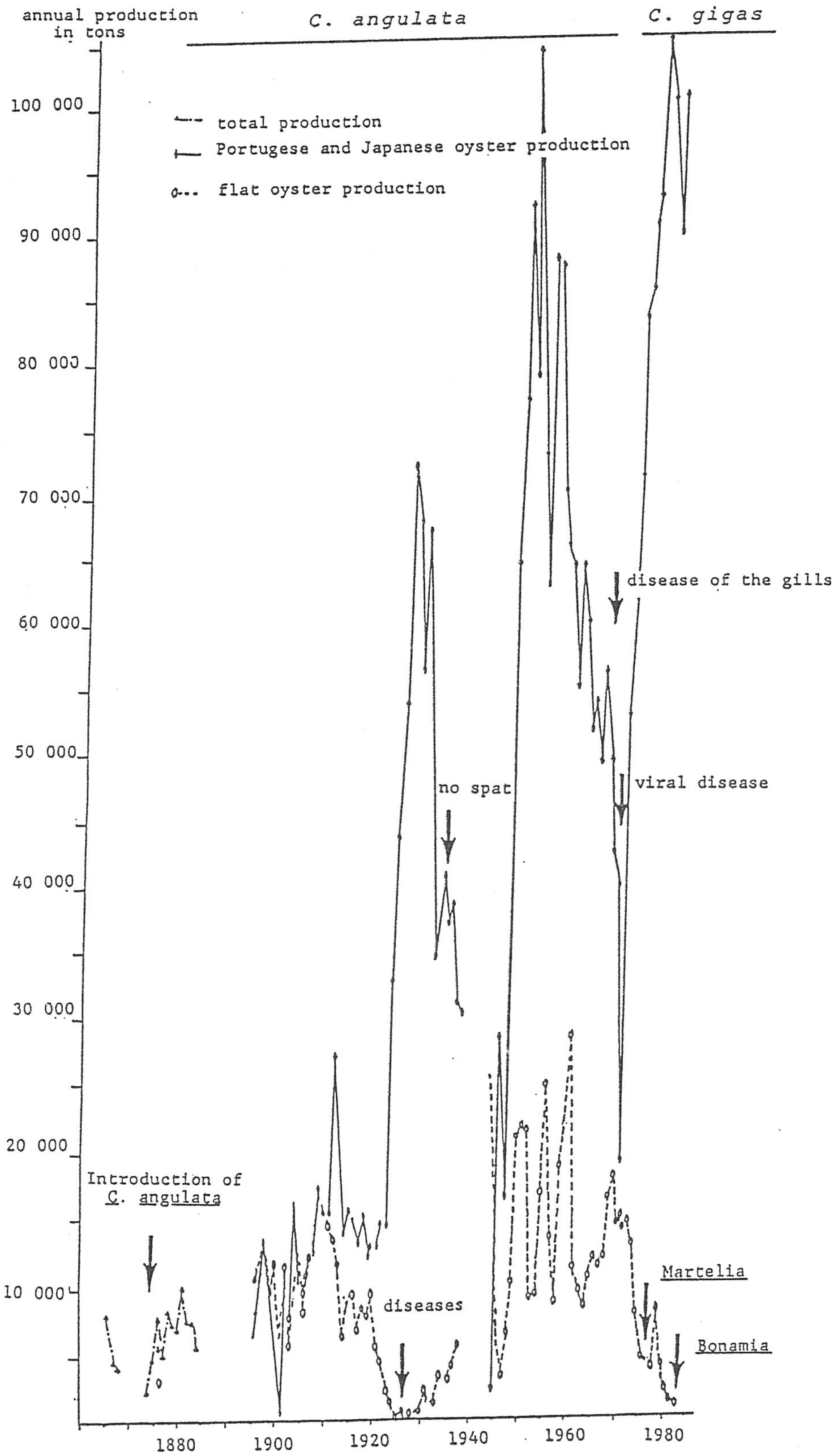
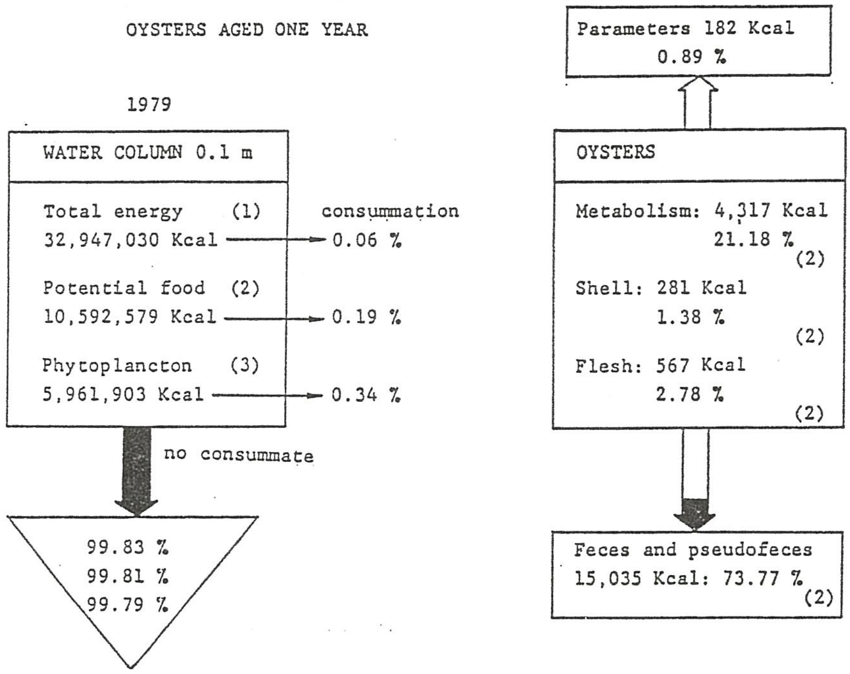


Figure 1 : Evolution of the oyster production in France from 1865 to 1983.
From Héral, 1985.



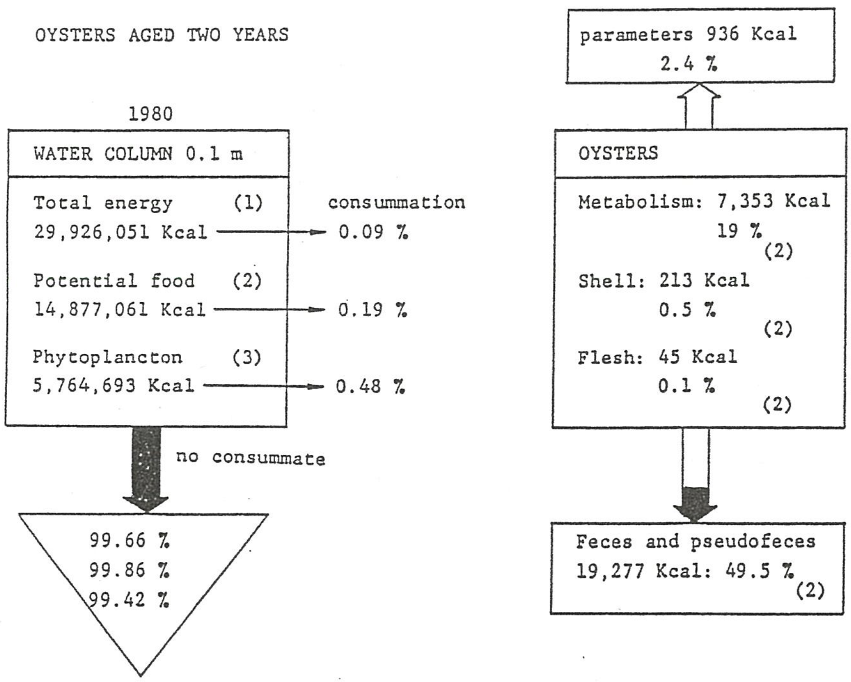


Figure 2 : Flux of the annual energy between a water- column of 0.1 m with a mean current of 0.3 ms^{-1} and density of oysters of 200 individuals by a square meter in the bay of Marennes-Oleron (France) (from Héral et al., 1983 and Deslous-Paoli and Héral, 1984).

PROGRESS OF MOLLUSCAN CULTURE TECHNOLOGY ALONG THE NORTHEAST COAST OF JAPAN

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In earlier days, molluscan mariculture production in Japan was limited to oysters. As the techniques of rearing the larvae of marine molluscs have been developed, many other marine molluscs have been cultured. Some of them occupy an important position in the mariculture industry today.

Generally, there are three phases in mariculture operations, based on the stages of development and growth of the animal. The first phase is to catch the juveniles at the moment of metamorphosis from swimming larvae into the sessile stage. The second phase is to rear these juveniles to the size desirable for culture or for release in the natural environment. The final phase is their cultivation to marketable size.

In this paper discussion is made about the present status of technical development of molluscan mariculture in northeast Japan, taking three of the representative species as examples, oyster, scallop and abalone.

The oyster

The mariculture of oysters Crassostrea gigas in Japan has a long history. However, really significant developments in the oyster culture have only occurred in the last 60 years.

Biological data based on research have been accumulating since about 1930. Studies concerning the life history of marine organisms important to mariculture, such as their feeding habits, reproductive cycle, environmental requirements, and so on, had to precede the exploration on the techniques for artificial breeding and culture in natural environment.

The advance of culture techniques is represented by the changeover from bottom culture to hanging culture. Further technical modifications in the hanging culture method arose from the stability factors of different regions. At present the method in general use is that of hanging strings of oysters either on racks, rafts, or long lines at a certain depth in the water. By this method, the

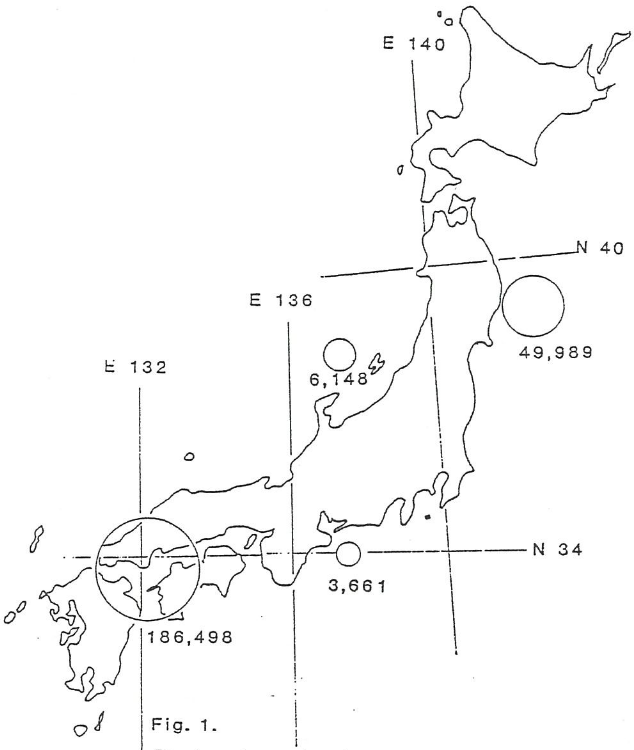

Fig. 1.
Regional production of oyster in Japan, in tons.

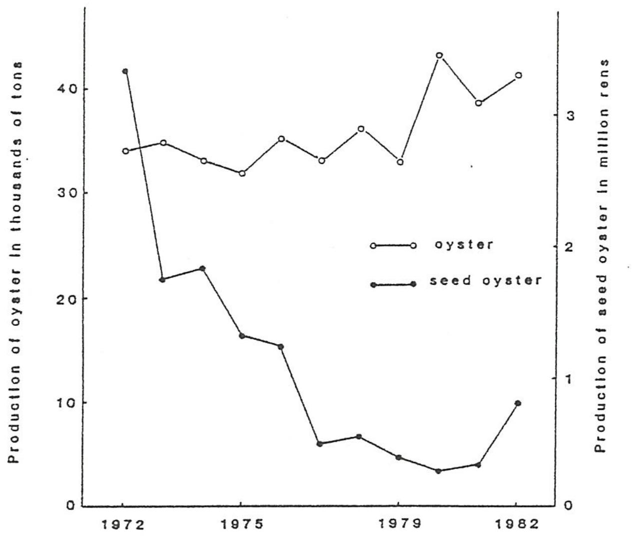

Fig. 2. Production of oyster and seed oyster in Japan,

culturist can made good use of water regardless of the depth or the nature of the bottom. In 1982, oyster production with shell in Japan was shown in Fig. 1. During the past 10 years, production of oyster meat by culture in Japan keeps the present level between 30,000 and 40,000 t (Fig. 2).

Along the coast of the northeast Japan, the second largest oyster center in Japan, the culture area has been expanded by the use of long lines, usually 50 m long. Especially in Japan, longline culture method has been used very often lately.

On the other hand, seed oysters are collected on shell collector in the natural bed. Miyagi Prefecture produces nearly 90 percent of the total seed. The large scale seed oyster production in Japan such as Sendai Bay of the Miyagi Prefecture is greatly influenced by biological and environmental conditions. Some of the favorable conditions are the amount of adult stock, a suitable rise in water temperature in summer, a healthy growth of larvae, and physical factors which contribute to the dispersion and accumulation of these larvae. The trend in seed oyster production has been decreasing year by year during the past 10 years, but now it has been increasing gradually (Fig. 2). At present the production not only satisfies domestic demand, but also supplies to some foreign countries for culture. Thus, there is no demand for the seed, which is artificially bred in tanks.

As long as the expansion of culture grounds into new offshore areas is continued, a further increase in the oyster production can be expected. Also, new types of oysters, such as the European flat oyster, Ostrea edulis, may be commercially produced in the future.

The common scallop

The common scallop Patinopecten yessoensis has been cultured recently in northeast Japan. Scallop production on natural grounds was subject to sharp fluctuations, which were particularly remarkable in Mutsu Bay of Aomori Prefecture. The mariculture production of scallops is shown a rapid increase since the raft and long line types hanging culture method was introduced into the coastal regions of northeast Japan. Consequently, high demand for seed from the culturist has stimulated the seed-catching industry, and now tremendous amount of seed are produced in Mutsu Bay.

At the same time, artificial breeding has been developed on a small scale, in the order of 1 million seed scallops, at the Aquaculture Center of Aomori Prefecture. The juveniles in the early stages are grown in net baskets with meshes of small size until their shells reach 3 to 4 centimeter and over in shell length, and then they are put into larger net bags with large meshes or they are connected to rope by nylon fiber strings through holes made in the ear part of shell. The latter method is prevalent among culturists in northeast Japan.

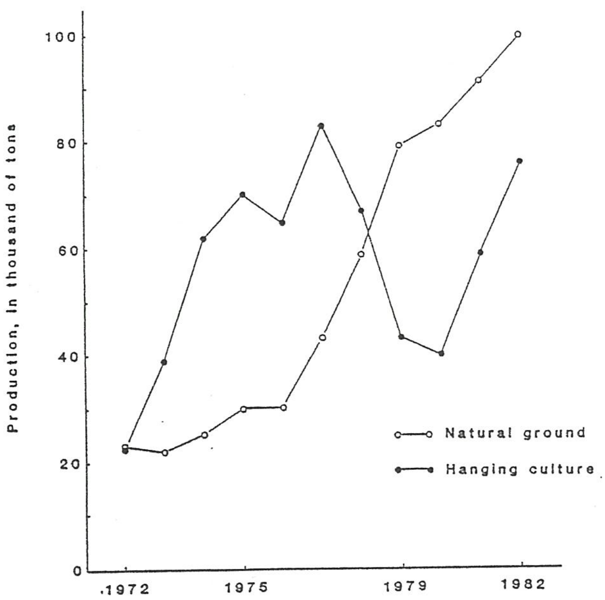

Fig. 3. Production of common scallop in Japan, 1972 through 1982.

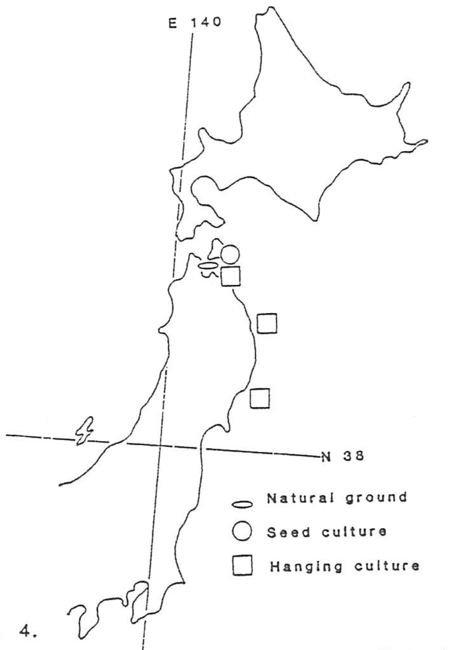

Fig. 4. Geographical distribution of scallop fisheries in northeast Japan.

These bags and ropes are hung from rafts or long lines. The scallops suspended in the water grow much faster than those resting on the bottom, and in a year and a half they reach marketable size: over 12 centimeter in shell length. They are free from the attacks of bottom predators, such as starfish, but their mortality during culture varied largely (Fig. 3). This phenomenon are supposed to due to unfitting use for the culture ground, culturing in over population and prevalence of some pests. The geographical distribution of scallop fisheries in northeast Japan was shown Fig. 4.

On the other hand, the larger juveniles of 4 to 5 centimeter in shell length can be released on the natural grounds and harvested in 2 years or so with a good return. A large scale sea-bottom farming of scallops shows a rapid rate of increase along the coast of the Okhotsk Sea of Hokkaido (Fig. 3).

Yet there still remain many problems to be solved related to the culture of scallop. One of the most important problems is in the first the development of techniques for the natural seed collection, in order to maintain a stable seed supply. The second is the management in order to obtain maximum production levels in bottom and hanging culture.

The abalone

It is well known that abalone Haliotis discus hannai is also one of the most important marine products in rocky areas along the northeast coast Japan. Its production in the past 10 years is shown in Fig. 5 and 6. The harvest is estimated to change maintaining the same level. Among four species of abalone harvested in Japan, H. discus hannai in cold water and H. discus in warmer water are the most important in quantity and quality.

Techniques have been developed for the production of abalone seed artificially in tanks at Mohne Bay Laboratory of the Oyster Research Institute established by our late professor Dr. Takeo Imai. The abalone spawns naturally when the sea temperature falls to 20°C in late

September or in early October. It is desirable to start the culture as early as possible in order to obtain larger juveniles before cold weather begins. Spawning can be induced by exposing the matured abalone to irradiated sea water with ultraviolet rays. The method was perfected by Dr. S. Kikuchi and N. Uki belong to Tohoku Regional Fisheries Research Laboratory. After a few days of swimming life, the larvae become sessile on the substratum. The minute juveniles start feeding on the diatom. And as the juveniles grow larger, they begin to browse on larger algae, such as Eisenia, Undaria, and Laminaria. They should be grown to 3 cm in shell length in 15 months after their spawning before they are

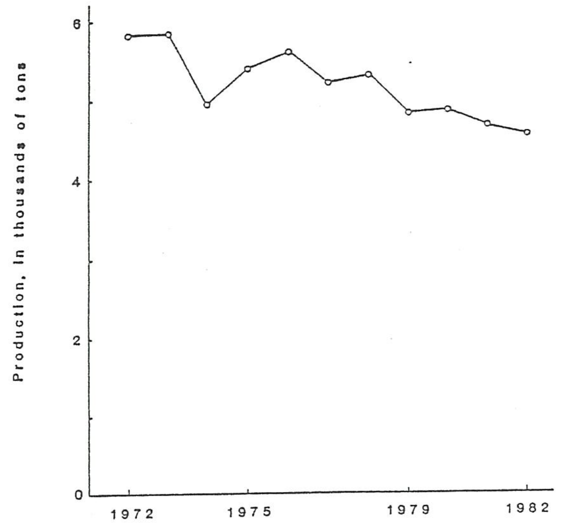

Fig. 5. Production of abalone in Japan, 1972 through 1982.

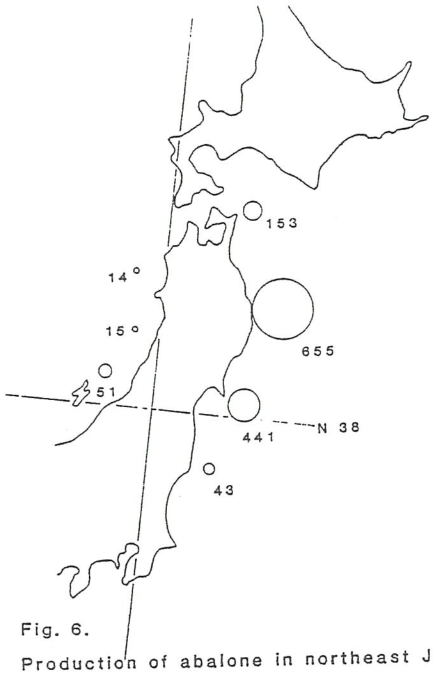

Fig. 6. Production of abalone in northeast Japan, in tons.

released on natural ground-rocky reefs with a rich supply of large algae, then a good return at harvest can be expected. The fate of released juveniles in natural rocky reefs and the positive effect of augmenting the natural production have not been proved yet, but the ecological research is now in progress. It is certain that by releasing a large quantity of the tank-bred juveniles, we can increase the abalone production significantly in the near future.

The abalone juveniles can be grown on large algae to marketable size under captive conditions, but such mariculture does not seem to be economically feasible at present.

In Japan, there are 60 hatcheries devoted to abalone seed production. At present the amount of good-sized juveniles produced is more than 20 millions, but the production may be doubled or tripled in a few years. When we have a large number of artificially bred abalone juveniles at hand, farming of abalone on rocky sea bottom will become a reality.

Conclusion

In the present paper, attention has been currently focused on just three of the marine molluscs under investigation through culture along the northeast coast of Japan. All these molluscs are endowed with biological characteristics proper to through culture, though their suitability for culture varies greatly. These molluscs include oysters, scallops whose culture has developed remarkably in recent year, and abalones, an important seashore resource for which artificial breeding is now being established. The status of the basic research and the technical achievements for each of these molluscs has been summarized.

From what we have seen in three examples of molluscan mariculture in northeast of Japan, we can conclude that the technical development in seed production and the developments in culture techniques as well as in ocean engineering have enabled us to culture many of the molluscs, such as octopus, cuttlefish, and clams, have been bred in tanks and their juveniles have been grown on a laboratory scale. What is expected in the future is the establishment of production systems of hatchery operation and of juvenile culture so that juveniles of desirable size can be produced economically on a commercial scale.

To this end, seed production in northeast coast of Japan, either artificial or natural, will be intensified in the future. When we can have a large number of juveniles of desirable size at hand, we will be able to start sea-bottom farming on a large scale for example, scallop and clam farms on sandy bottom, ark shell farms on muddy bottom, and abalone farms on the rocky reefs where seaweed is planted thickly. We are not far from that goal.

COASTAL PLANNING: an Example of Regional Development of marine culture in Provence-Alpes-Côte d'Azur

GEORGES CRISTIANI, JEAN-PIERRE LAMARE, and ALAIN SIRE

Office Regional de la Mer, Provence-Alpes-Côte d'Azur

The three regions of the South of France (Languedoc-Roussillon from Spanish Border to the Rhône to the Italian Border, and Corsica) are situated along the most westerly part of the Mediterranean Sea.

Because of our natural affinity for the sea and the richness and variety of our coasts, aquaculture developments in the areas are both numerous and diversified, both along the technical as well as the socio-economical level.

The development of aquaculture in Provence-Alpes-Côte d'Azur

General presentation

The Provence-Alpes-Côte d'Azur Region, with its 32,000 km^2 (7 % of the national coast line), groups together the six departments of the South East of France:

- Three inland departments (Alpes de Haute Provence, Hautes-Alpes and Vaucluse), each with abundant freshwater resources.
- Three coastal departments (Bouches-du-Rhône, covering 65 maritime communities and more than 80 % (2.3 million inhabitants in winter almost double in summer) of the total population of the region.

The region is provided with numerous natural features which not only represent and important source of tourist attraction ,but which are also often times very fragile. This for example is the case for the littoral fringe to a depth of approximately 30 m where prevails an important concentration of natural marine resources as sea beds of Posidonia for instance.

Schematically, the coastline depicts two different morphological areas, clearly visible from satellite photographs: along the East coast from the Italian border to the Gulf of Fos, there is, essentially a rocky, indented coast line (bays, creeks, rocky inlets) covering 656 km; in contrast, the West coast from the Gulf of Fos to the mouth of the "Petit Rhône" is characterized by a sandy coast formed by the alluvial deposits of the Rhône which extend for 107 km. The continental shelf is thus very narrow in the east, and gradually broader towards the west (Golfe du Lion).

<u>Political determination and plan of action</u>

Even though an official transfer of powers from the state to the Region took place on January 1st 1984, the Regional Council of Provence-Alpes-Côte d'Azur had already embarked on a plan to:

- aid to renew and modernize the inshore fishing fleet;
- aid the establishment development of marine culture firms;
- assume responsibility for maritime training (professional fishing, conchyliculture, aquaculture).

In 1980, the Regional Council established and unanimously agreed upon a development program of marine culture and management of Natural Resources, and upon a technical service for fishing and marine culture. Such transfer of power from the national administration to the local councils, merely reinforces the Regional Council's initiatives over the last four years. This has culminated in the recent creation of the Regional Maritime Office which supports the economy through development and employment programs for the coastal communities. Such a support structure has as its main objective an improved and more national form of coastal management. The regional budget set aside for marine culture and the management of halieutic resources in 1984, was 4.4 million francs.

<u>An important research potential and professional services</u>

The Provence-Alpes-Côte d'Azur Region has at its disposal, for cooperation, one of the largest chains of oceanographic research facilities in France, with more than 450 scientists grouped in the following centers:

- the Marine Station of Endoume
- the Science Faculty of St. Jèrome
- the Science Faculty of Luminy
- the Embiez Sea Observatory
- the Mediterranean Oceanographic Base (IFREMER)
- the Michel PACHA Institute at la Seyne sur Mer
- the Marine Station at Villefranche
- the Science Faculty of Nice

therefore, which the help of this important network, as well as with the assistance of other professional organizations and private firms, marine culture is rapidly growing, and can in fact, be considered as complementary to the traditional fisheries. If there exists a large diversity of aquaculture enterprises, there is likewise an extensive variety of culture methods and techniques employed.

Partly as a result of the expanding urbanization and extensive tourist industry along the coast which has as its affect to reduce potentially useful land for the development of an aquaculture industry, but also due to the scarcity of suitable lagoon sites, the main thrust of our efforts has been directed to that which could appropriately be termed as forms of "intensive growth" in the sea. For example, various types of floating cages suspended from rafts as well as submersible cages have been examined.

The two main species of fish on which much of our work has been conducted over the last few years are:

- sea bass, Dicentrarchus labrax
- sea bream, Sparus aurata

Both are hardly and commercially attractive species.

The Provence-Alpes-Côte d'Azur Region has a marine fish hatchery which uses heated water from a thermal power station and produces up to 500,000 fry annually. Its main objective is to supply bass and seabream for aquaculture operations in the region. Various other kinds of activities are also presently taking place in lagoon areas. These include intensive and semi-intensive breeding and rearing of seabass and seabream (of fisheries facilities), the release of Penaeus shrimp and assistance with the establishment.

A maritime cooperative consisting of 30 members and specialized in catching mussel spat has also been set up. It supplies the traditional Mediterranean conchyliogical areas with the young for purposes of fattening. The potential production of spat is 2,400 t. Due to the great potential of conchyliculture in certain sectors of the region, the Provence-Alpes-Côte d'Azur Regional Council is following a policy of developing shellfish breeding programs in deep sea beds. This is particularly applicable in the case of mussels. Other possibilities such as the catching and production of clams, as well as the production of oysters, are also being considered.

Halieutic resources management

Another aspect of marine culture is being developed in the region by enriching the halieutic resources through the development and management of protected marine zones. The emphasis is on submersible artificial structures and restocking programs.

There are currently five protected and ultimately stabilizing employment for the coastal population. It is likewise our intention to awaken public opinion with regard to the sea by providing information about education possibilities and in general promoting our marine heritage for what will hopefully become a more efficient management of our resources. The experience of the Provence-Alpes-Côte d'Azur Region in planning marine zones using artificial substrates, coupled to its desire to better administer such areas, has prompted it to establish an important project, i.e. the Regional Natural Marine Park.

By studying and monitoring this vast managed area, we hope to improve the marine environment and upgrade all the activities which can be said to be linked to the sea. Other projects are likewise being undertaken. These zones are considered to be protected marine areas where in agreement with the professional fishermen, all forms of fishing, anchorage and diving are forbidden. This is to ensure the regeneration of marine species and the proper administration of the aquatic environment.

Two types of complementary techniques are employed:

(1) Immersion of artificial reefs: In this case, we have on the basis of various experiments, submerged alveolar artificial reefs into the protected water. A method of evaluating the ichtyological fauna in situ has been developed by the Marine Station of Endoume, Marseille. This is being employed and allows us to follow the evolution of the colonization process and the attraction of fish to the reefs (zero point, regular scientific monitoring). In view of the particularly interesting results obtained, a project to exploit the reefs has already been planned and includes the submersion of bulky prefabricated structures in order to assess the return rate, restocking and monitored releasing operation have recently carried out in our Region.

(2) Restocking program: Restocking with sar, Diplodus sargus fry, and ten month-old lobsters in protected marine zones has been undertaken. Operations are being planned in the next years in terms of recapture rates such as monitored releasing of PL. 15 and PL. 30 of Penaeus shrimps in lagoon areas.

The experience that has the Provence-Alpes-Côte d'Azur Région in management of maritime sections and her will to develop halieutic resources, have induced her to work out the first project in France of Natural Regional Marine Park, which is a label of guarantee of protection and valorization of the marine environment.

The Regional Marine Office has consequently been created to implement all those plans and programs, concerted with the other Mediterranean Regions.

Recent Mariculture Activities in Japan

Yutaka UNO
(Tokyo University of Fisheries)

Recent commercial mariculture production in the shallow coastal waters in Japan has grown to nearly one million tons per year. The production by mariculture mainly consists of eight species of finfish, six of shellfish and three of algae. Finfish generally is cultivated by floating net cage and various types of enclosures, and shellfish and algae by hanging method like raft and long line types.

In commercial mariculture of specific species, the basic thing is to establish mass production techniques for seed animal of the species. For this purpose, the hatchery techniques are studied and continued to develop steadily for various species. In 1980, Japan Sea Farming Association and prefectural gvernments produced more than 18×10^8 larvae including both finfish and shellfish to stock the open sea. In the case of Kuruma shrimp, the techniques are stabilized with high level, and they produced ca. 600 million postlarvae but one half had to be released to the sea. The released larvae that survive and grow, have formed a new basis " Sea Ranching Fisheries ". The trial releases of larvae have proved that the sea ranching of shrimp could be successful.

To strengthen the foundation of sea ranching fisheries, much ecological knowledge is needed about the distribution, food habits, predation, etc of the species to be restocked. Recent releases in Hamana-ko, Shizuoka Pref., made by the research group of the Hamana-ko Substation, Shizuoka Pref. Fish. Res. Stn., have demonstrated the possibilities of sea ranching. In this report the brief research results of Hamana-ko and some problems of the application to the sea ranching method in unexpoited waters are discussed.

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Société franco-japonaise d'Océanographie

La Société franco-japonaise d'océanographie, déclarée à Paris le 20 février 1984, a pour but de faciliter les échanges entre la France et le Japon dans les différents domaines de l'océanographie au sens large : géomorphologie, océanographie physique, chimique, biologique, pêche et aquaculture marines et continentales. Consciente de la difficulté d'approche du Japon, due en grande partie à la barrière linguistique, la Société franco-japonaise d'océanographie s'efforce de faire connaître en France, l'océanographie japonaise, ses structures, ses organismes, ainsi que les personnes qui la constituent et qui y travaillent, chercheurs, techniciens, professionnels. La Société franco-japonaise est une association sans but lucratif régie par la loi du 1er juillet 1901.

MOYENS

Forte de l'expérience de ses membres qui ont séjourné au Japon et de l'aide directe de ceux qui s'y trouvent, la Société franco-japonaise d'océanographie française entretient de nombreux contacts au Japon, avec nos collègues japonais et avec le représentant permanent de notre Société au Japon. Des liens privilégiés mais non exclusifs unissent en outre la S.F.J.O. française et la S.F.J.O. japonaise.

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La Société franco-japonaise d'océanographie a pour mission :

—de proposer des contacts à ses membres,

* grâce à son fichier des laboratoires et des chercheurs japonais, réactualisé en permanence par ses membres qui résident au Japon ou qui en reviennent ;

—de fournir à ses membres :

* des renseignements pour préparer un séjour d'études ou de recherche de courte ou longue durée,

* une aide individualisée aux jeunes chercheurs océanologues boursiers,

* une aide pour la recherche ponctuelle d'information scientifique et technique ;

—d'envoyer à ses membres :

* des guides d'introduction à l'océanologie japonaise,

* des dictionnaires spécialisés à tarif préférentiel : dictionnaires trilingues (français-anglais-japonais) d'aquaculture, édités en coopération avec la Société franco-japonaise d'océanographie japonaise,

* des bulletins flash d'information sur les récentes activités et découvertes japonaises du domaine de l'océanographie,

* une bibliographie signalétique et analytique intégrée au Centre de documentation scientifique et technique du C.N.R.S.

Concerning the publication of this Symposium, all correspondence should be addressed to: Organizing Committee of the Second Japan-France Aquaculture Symposium, School of Fisheries Sciences, Kitasato University,Sanriku, Iwate, Japan.

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