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Adaptabilité et repeuplement de jeunes homards expérimentations de transplantation au Japon

Adaptability and propagation of lobster seedlings transplant experiments in Japan

Yves HENOCQUE
MAISON FRANCO-JAPONAISE SURUGADAI KANDA 2-3, CHIYODA-KU, TOKYO
ET ECOLE PRATIQUE DES HAUTES ETUDES, CENTRE D'OCEANOLOGIE DE MARSEILLE
RUE BATTERIE DES LIONS, 13007 MARSEILLE

The clawed lobster (Homarus sp.) appears to be a good potential species for aquaculture since it fits to a certain number of essential criteria to economical development, that is an important demand, high price, reproduction in captivity, simple larval development, good conversion rate and resistance to diseases.

Since the end of the last century, both European (Homarus gammarus)and American (Homarus americanus) species have been studied on aquaculture purpose.

Today, the trend is to develop intensive battery systems to rear lobsters to marketable size, although projects to augment natural stocks by release of hatchery-reared post-larvae or juveniles still continue. These projects are located in USA (one hatchery in Massachusetts), France (three hatcheries on the Atlantic coast) and Great-Britain (one hatchery in Wales).

In USA, about 500,000 stage IV post-larvae (about 1.5cm total length) a year are released into the natural environment, usually at night and from the surface. No tagging is possible since the animals are too small and no monitoring is achieved. Thus, although since more than 30 years, millions of post-larvae have been put into the sea, there is no report about any positive impact from these releases on natural populations.

In France, post-larvae and juvenile lobsters have been released since ten years at the rate of about 250,000 stage IV post-larvae a year supplemented by 15,000 one year old lobsters (about 6cm of total length) each year since 1978. The animals are released in different areas, usually in sanctuary areas. Till now, in spite of fishing catches surveys, no positive impact on commercial landings was observed.

In Great-Britain, the first juvenile lobsters (two month old: about 3cm total length) experimental release was implemented two years ago (1981) and repeated in 1982 and 1983. All the releases were achieved in the same area, in a bay of the Yorkshire coast. The animals were monitored daily by dives during one week after release.

Besides these projects, a new lobster transplantation experiment, leaded by Pr. KITTAKA from Kitasato University, has been implemented since 1981 in the South-West of Japan, around one of the Koshiki Islands group.

In 1981, about one thousand post-larvae (stage IV) were released in a natural pond without monitoring. In 1982 and 1983, post-larvae (stages IV and V) and juvenile lobsters were released on a sandy bottom using cages and artificial habitats; daily monitoring was achieved on a period of 10 days or more following release. Since this pilot study is carried out in a totally new environment with no natural lobster populations, it allows an easier monitoring and estimation of the survival rate which can contribute scientifically and technically to the improvement of lobster restocking in other countries.

Rearing methods previous to release

It is well-known that hatchery-reared fry are subject to high mortalities when released directly, even in a suitable site, for they are ill-adapted to the natural environment. To palliate this problem, the fry are first reared in nurseries or controled natural areas till they have the same characteristics (sear for food, escape from predators, sheltering etc.) as natural juvenile individuals. This is also considered as a first natural selection of weakened or diseased individuals which often can survive seemingly without any problem under artificial rearing.

In the case of lobster, yet there is no achievement of such an intermediate rearing in the three countries dealin with restocking. Furthermore, juvenile rearing is achieved individually in totally artificial conditions, while in Japan, communal rearing in a semi-natural environment is applied right from the first post-larvae (stage IV). Regarding the condition of the juvenile lobsters and their survival rate potential at release, it is important to compare both rearing methods and try to clarify the differences between wild and artificial seedlings.

. Individual rearing: In individual rearing, water temperature, salinity, dissolv oxygen, pH and other physical and chemical conditions are held relatively constant at appropriate levels, adequate food is provided and predators are excluded. Therefore, beyond genetical heredity, juvenile lobsters never experienced environmental fluctuations and do not know how to search for food nor escape from predators. Furthermore, in these conditions, biological and physiological conditions may be different from wild animals although a great deal of research is still to be done in this field.

Already, under eye observation, current individual rearing methods induce two different traits to juvenile lobsters: carapace colour which is usually much more pale and a non-differentiation of the two chelipeds.

The pigmentation of the carapace depends on the source of food, that is the presence of dietary carotenoids which, in nature, are always fully provided by the multiple sources of food. In individual rearing, a unique source of food (usually, bri shrimps, alived or frozen) is used for maintenance convenience.

In nature, lobster two chelipeds are differenciated in a thinner claw (the cutter) and a bigger one (the crusher). This external dimorphism of the paired chelipeds into a cutter and crusher claw is detectable as early as the 7th stage (2 month old) and is quite distinct by the 12-13th stage (about 1 year old). In the individual rearing system, individual plastic trays have no specific substrate but plastic and most of the animals, evem at 1 year old, develop two cutter claws. If a removable substrate (oyster shells, gravels, sand) and living food are provided, the claws will differentiate normally. Although the specific role of each of the different environmental factors is not yet clear, it has been already demonstrated that use and disuse have an influence on closer muscle development in the lobster. As a matter of fact, the individual rearing results "suggest that differential use of the claws might determine claw type and muscle fiber properties" (OGONOWSKI et al, 1980, The J. of Exp. Zool., 213:359-367).

It has been suggested that the shorter, stout crusher claw, would be only capable of closing slowly while the longer, narrow cutter claw, would be capable of closing very rapidly. It might be an additional reason to its reduced weight why lobsters usually seize living preys with their cutter claw.

It seems plausible, although no study has been carried out yet, that, at least these two traits somehow influence predators behaviour (bright colour) and lobster behaviour itself (chelipeds) when released into the natural environment.

. Communal rearing: To the contrary, by achieving communal rearing in large scale tanks, as it is the case in Japan, it appears that juvenile lobster traits and behaviour are very similar to wild juvenile lobsters, although these latters are rarely seen either in the case of the American species (Homarus americanus) or, all the more, in the case of the European species (Homarus gammarus).

As a matter of fact, these large scale outdoor tanks (surface: 59m2) allow a semi-natural environment to develop following the seasons variations. Natural or artificial food is distributed but the lobsters can also feed on Amphipods, Molluscs, worms etc. living on or within the substrate (oyster shells) of the tank. With a density of 20-30 individuals/m2, agonistic encounters are not scarce and induce a cautious behaviour to lobsters.

Thus, communal rearing appear to be the adequate intermediate rearing previous to release.

Optimal size at release

Regarding lobster, research is just beginning in this field but yet some considerations can be made.

New lobster post-larvae (stage IV) are still pelagic; they will definitely settle down only at the next stage, about 6 or 10 days later (about 2cm total length). From that moment, they adopt a burrowing behaviour under stones, on a cobble/boulder substrate. Experiments in the laboratory showed that Homarus americanus and Homarus gammarus juveniles elected the same type of substrate (roughly, stones on sand) and adopted the same burrowing behaviour. Experiments in Japan and Great-Britain, both achieved in the natural environment, are in agreement with these former experiments, but it does not mean they include other behaviour characteristics like activity and movements which may be different as we will discuss it further.

It is not known yet how far the environment conditions required could change during the first two or three years of the life of the lobster.

In these conditions, the current size of juvenil lobsters released is variable as we saw before. The current main criteria in choosing the size at release are the practical possibility of tagging the lobsters and the cost of maintenance in the culture system. The size will then decides on the release technics to be used.

Release conditions

The survival rate of released juvenile lobsters depends not only on their adaptibility to the natural environment but also on their release conditions.

In Japan, a pilot study has been carried out in 1982 and 1983 on three different sizes (different ages) of juvenil lobsters: three weeks old individuals (1.5-2cm total length) released in cages settled on the bottom and one year old (1982) and two years old (1983) individuals released on small artificial reefs (unit size: 0.4x0.2x0.1m). In 1982, all the released individuals were of the American species. In 1983, the two years old individual included both species, American and European.

The two sets of release (1982-1983) have been achieved in the same area but in the slightly different location (Figure 1). This area is located in a small bay of Kamikoshiki island, the most Northern one of the group, in a water depth of 3-5m with a sandy substrate, close (50-100m) to a coastal boulder/coral substrate. The currents are weak and, in July, period of release, the water temperature is around 23°C.

Daily monitoring was achieved after release, on a period of 11 days in 1982 and 9 days in 1983.

. Three weeks old lobsters: In July 1982 and July 198 three weeks old lobsters were released in net cages partly hidden into the sandy substrate. The density was about 17ind./m2 in 1982 and 10 ind./m2 in 1983. Oyster shells were provided as small shelters.

After 9 or 11 days following release, the avera survival rate was between 12 and 20%, although daily observation does not give always the accurate number of individuals actually present in the cage. The numerous and unchecked interstices may hi lobsters from the observer. A maximum of 33% has been observed for one cage in 1983.

In 1982 as in 1983, early 4th stage lobsters showed a typical pelagic behaviour, swimming upwards the roof of the cage and, thus, showing their unsuitability to release.

Usually, the degree of movement of 4th and 5th stage lobsters between oyster shells is important, partly due to oyster shells poor stability on the bottom and stresses induced by the observer at checking their presence.

Burrows under oyster shells have a very simple shape with one opening and a small chamber behind, very similar to the one observed in the laboratory.

In spite of the poor survival rates achieved, technological improvements might allow keeping a signifivant number of early juvenile lobsters (from three weeks old) in captivity, in the wild, without any supply of food. In the future, this method may prove to be convenient as intermediate rearing before free release, using small lobsters and thus, eliminating the expense of maintening them longer in a culture system. However, in regard of restocking and since the animals are too small, no mechanical tagging is possible in that case.

. One and two years old lobsters:

In 1982, 97 one year old lobsters (about 5cm total length) of the American species were released under 97 blocks (0.4×0.2×0.1m) arranged in two lines, at a 2m distance of each other.

In 1983, 50 two years old lobsters of the two species (H.americanus: 27 ind.; H.gammarus: 23 ind.) were released under larger artificial shelters made of 4 block-units. Although they have the same age, the average size was rather different for the two species: about 6cm long for H.gammarus individuals and 8cm long for H.americanus individuals. Thus, the two years old individuals of the European species in 1983 were only slightly bigger than the one year old individuals of the American species in 1982.

As a matter of fact, at the end of the two experiments, in 1982 and 1983, the occupation rates under the artificial habitats are the highest for this latter size of lobster (5 to 6cm total length): 16% after 11 days for the American species and 30% after 9 days for the European species. As soon as the sixth day after release, the two years old American lobsters were not observed any more under the artificial habitats and in their surroundings. More experiments are needed to know how far these results have to be related to the size of the lobster, a distinct behaviour for each species or both.

However, yet a very interesting trend can be pointed out concerning the behaviour of each species: the American juvenile lobster appears to be much more active and, thus, mobile, than the European lobster at the same size and, all the more, if the American species individuals are bigger. This may have consequences on use conditions of artificial habitats leading to rather different results depending on the species. This difference in behaviour has been already suggested by comparing these two species survival rates in communal rearing.

The complexity or the number of shelter openings observed under each habitat is related to the length of stay of the lobster inhabiting it. Under the artificial habitats used in the experiments, shelters with one or two openings are the majority (85%), although shelters with 3 or 4 openings are also encountered.

These shelter openings and their appearance are a good mean of monitoring the presence or absence of lobsters under their shelter without removing it, at least on a soft bottom (mud, sand or gravels).

The predators are related to the site chosen although artificial shelters will attract species from adjacent areas which, eventually, have to be considered in the project.

So, because of a slight difference in location, the fauna composition was significantly different in 1982 and 1983. The distance from the rocky/coral substrate appear to be the main factor involved in: in 1982, the nearest from the rocky substrate, Gobiidae (Amblyeleotris japonica, Acentrogobius ornatus), Pomacentridae (Pomacentrus coelestis) and the whiptail (Pentapodus nagasakiensis)were numerous and very active in undermining the artificial habitats leading to the destruction of lobster shelters and, eventually, to its predation. At first, this suggests that the number of lobsters decreased because of dispersion rather than mortality.

In 1983, where the artificial shelters were farther from the rocky substrate, no such an undermining was observed because of the absence of the species named before. Fishes species encoutered were generally rather solitary, never in school, and non-residents except for a few individuals. However, one of the most serious threat for lobsters was represented by the cuttlefish, Sepia sp., and the octopus, Octopus sp., which readily occupied the new shelters. Since the blocks used for the experiments were honeycombed it is not sure that these two species would be attracted the same in the case of "filled" habitats.

In all the cases, it remains very difficult to observe juvenile lobsters outside of their shelter, at night. Such a monitoring would be greatly improved by using automatic cameras and video systems.

Obviously, on a sandy substrate, there is a lack of algal cover which makes the young lobsters more vulnerable to predations. In these conditions, it would be better to proceed to artificial algal implantation knowing that, anyway, the presence of artificial shelters will lead to algal development and, thus, invertebrate development in less than one year. In 1983, the artificial shelters set in 1982 were already covered with brown algae, including a rich fauna of small attached organisms and species like sea-urchins, Gastropods etc.

Thus, at least on a short term, the use of artificial shelters on a sandy substrate may be essential for monitoring survey since dispersion or mortality fluctuate in time (on a daily basis) and in space.

Due to lack of such monitoring for released Penaeus japonicus in Japan, no consensus on release effect has been reached yet. All the more, in countries where the presence of natural populations makes difficult the distinction between natural and artificial recruits, such monitoring, coupled with tagging studies and classical population dynamics assessments, will give important data related to seedling quality and site suitability and, thus, assuming that the initial mortality rate is the highest, will lead to a good understanding of the future of the released juvenile lobsters.

Combined with the use of sanctuary areas, as they exist in France, deployment of artificial shelters and introduction of young lobsters contribute to the fourth phase of restocking allowing the development of lobster sea-ranching.

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Technologie japonaise des récifs artificiels de pêche

On the Japanese artificial fishing reef technology

Satoru TODA et Makoto NAKAMURA
NATIONAL RESEARCH INSTITUTE OF FISHERIES ENGINEERING,
HASAKI, KASHIMA, IBARAKI KEN, JAPAN

An artificial fishing reef is the facilities aimed to provide and cultivate the biological resorces , and to increase a steady productivity in coastal areas . At the present time , they are an important technology used in fishing ground construction . In the future the artificial fishing reefs will be the means to develop new phase which include the management and enhancement of the fish stock. In this report we will introduce the present state of the art of Japanese artificial fishing reef technology and discuss the future probrem .

There are several theories to explain why fish swarm around a reef . We think that the basic reason is " fish's instinct ". An example of this behavior is the thigmotaxis-induced stationary position held by fish . In order to arouse such instinctive behavior , the stimulation is necessary . After considering the behavioral patterns of fish to the reef , we show one of the classification of fish species , and introduce some hydrodynamical phenomina as an example of stimulation that cause instinctive behavior to the reef .

In the planning of a deployment of artificial fishing reef , we should consider about characteristic responses of given species ,oceanographical conditions , optimization of reef size and geometry. We show the size categories of artificial fishing reef now being practiced in Japan , and some examples of site selection strategy.

Finally , we show annual fish catches per unit volume of artificial fishing reefs as an index of reef productivity . According to the surveys , artificial fishing reefs are considered to give justifiable benefit to cost ratio over 30 years of the planned durability of the reef structure.

1. Introduction

Japan is a country with few natural resources. So we have come a long way to enhance marine catches in our waters, begining with crude, stone-filled wooden cribs in 18th century to the modernistic concrete and steel modules of today. (Fig 1)

Recent proliferation of the 200-mile exclusive zone gave Japan an impetus to accelerate her program to develop maximum resources in her own waters. And to accomplish this objective, our strategy is two-fold. One is to seek immediate goals, the other, future goals. The important immediate goal is, of course, to help fishermen to catch more fish with less costs. For this purpose, we depend heavily on artifical fishing reefs. The Japanese Government has a well-funded program to subsidize artificial reef construction. The government also provides technical guidance and demonstrations.

One of the important future goals is to utilize the entire continental shelf for cost-effective fisheries production. We have already begun a pilot program toward achieving this ambitious goal, which we call "Marine Ranching". In this future goal also, the artificial fishing reef technology is an essential component.

The recent government spending on the Artificial Reef Program in Japan is shown in Fig 2. The subsidy rate for Reef Construction is as high as between 50 and 70 percent, depending upon the types and dimensions of the reef.

Although the history of artificial reef is very old in Japan, advancement of this technology has become particularly vigorous since the government began a major subsidy program in 1976. In the first four years of this program, the government spending expanded rapidly to about 15 billion yens a year. During the recent three years, the budget for the artificial reef program has remained essentially level, at about 15 billion yens a year.

The amount of artificial reefs installed in recent years, expressed in terms of bulk volume is shown in Fig 3. Bulk volume is the volume of the space which surrounds the reef structure including its interior voids. According to this figure, annually, about 1.5 million cubic meters of artificial reefs are being installed in Japan.

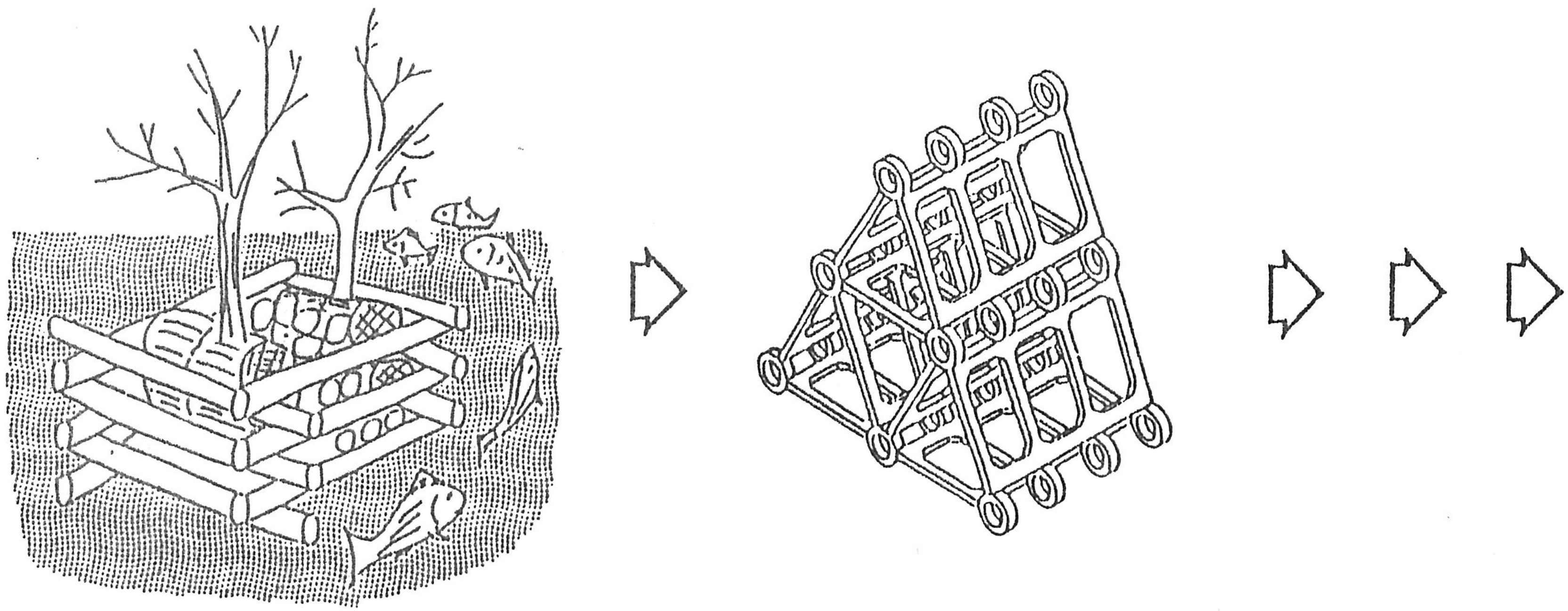

Fig.1 Evolution of artificial fishing reef in Japan

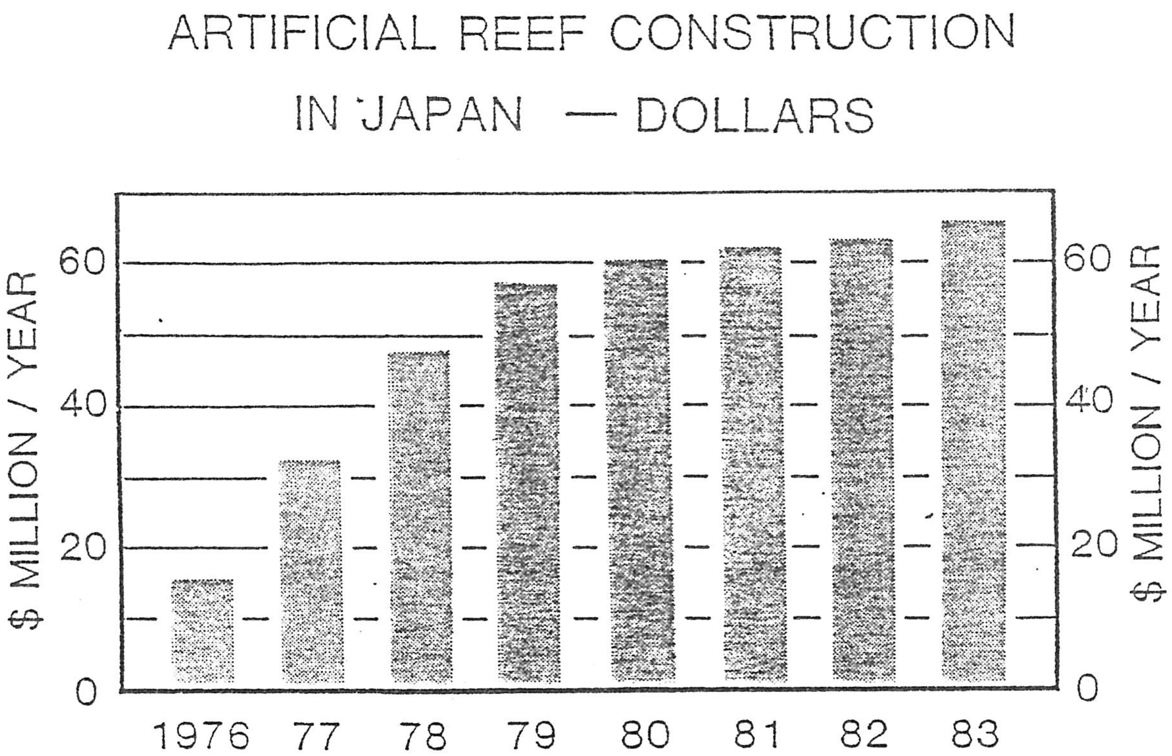

Fig.2 Artificial reef construction in Japan - dollars

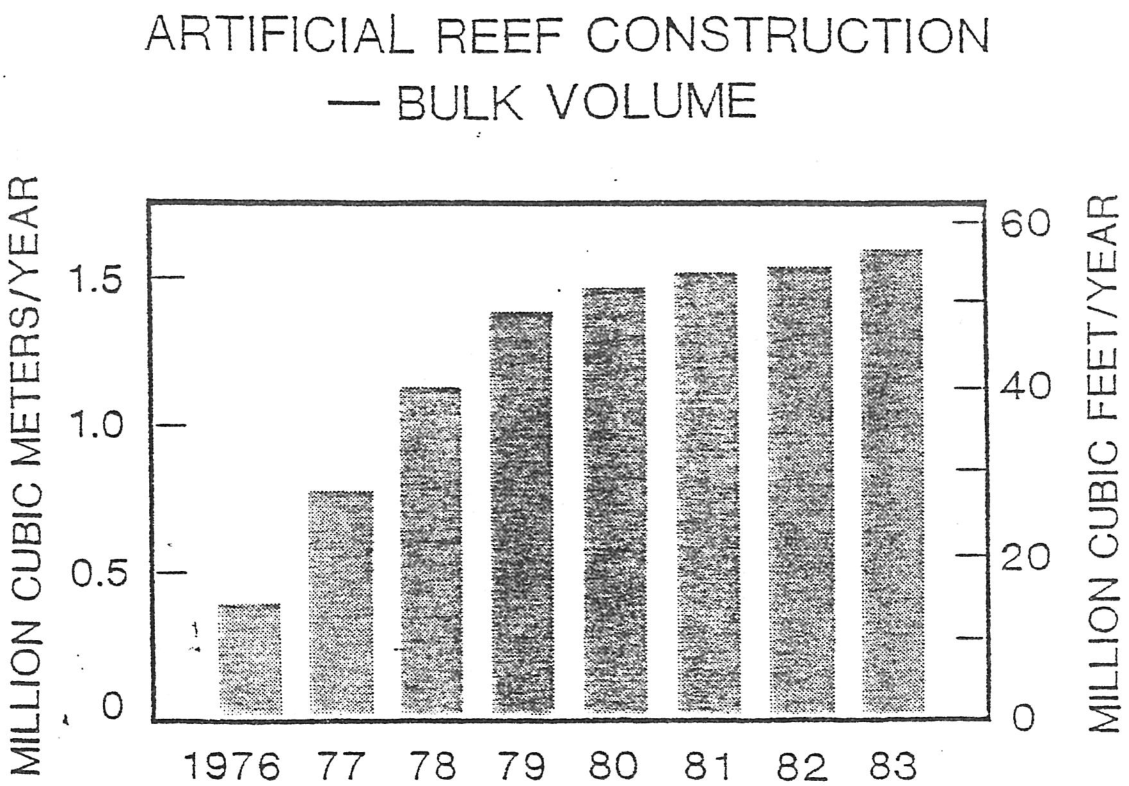

Fig.3 Artificial reef construction - bulk volume

2. Behaviorial patterns of fish and environment

In designing an artificial reef, we can take advantage of certain behaviorial patterns of fish species. Around Japan, about 150 species have been recognized as exhibiting typical behaviors in response to a reef.

One of the classification of fish species based on their characteristic responses to a reef is as follows (Fig 4).

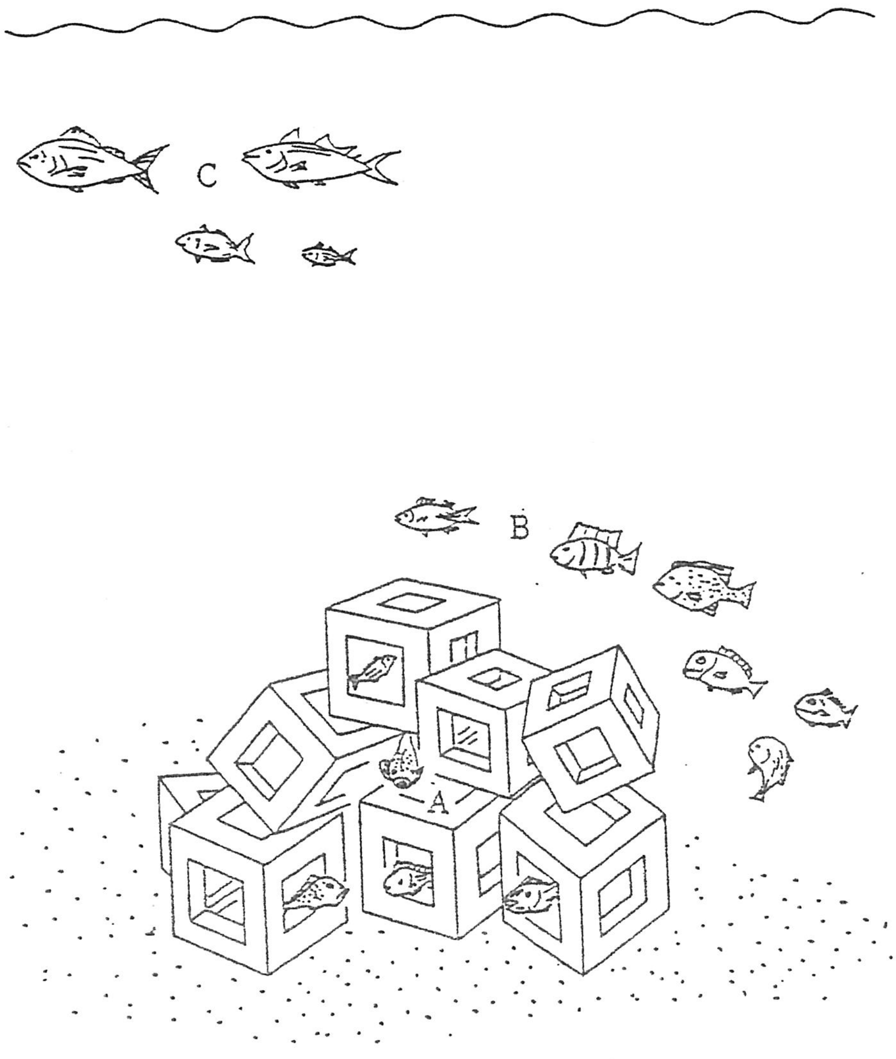

Fig.4 The classification of fish species

Type " A " fish prefer physical contact with the reef, and they like to occupy holes and narrow openings. They are dominantly bottom fish, such as rockcod and rockfish.

Type " B " fish are linked with the reef through vision and sound. This type of fish likes to swim "AROUND" the reef while remaining near the bottom.

Type " C " fish like to hover " ABOVE " the reef while remaining in the middle and upper parts of the water column.

For instance, the fish vision has a field of view of up to 160 degrees. However, the fish is short-sighted and can rarely resolve objects more than 1 meter apart. for this reason, an opening in the reef should be no more than 2 meters in diameter, otherwise the fish can not perceive it.

For another example, during the night, when the vision is not working, pressure variation in the water due to vortex shedding off the reef takes over as a liaison between the fish and the reef. This is particularly true for type " B " fish. We can disign a reef to maximize such a liaison using a well-established hydrodynamic guideline. We also can design a reef to provide a safe shelter for the fish in the lee of the reef structure when the current speed becomes too strong for them to remain in the open water.

(lee wave)

Another important medium which induces typical fish response is the " LEE WAVE ". The Lee Wave is a stationary disturbance behind an obstacle in a continuously stratified water column(Fig.5). The fishes have been known to sense the Lee Wave and take up characteristic positions relative to the reef. Therefore, in this case, the Lee Wave is a liaison between the fish and the reef.

Optimum conditions necessary to generate a Lee Wave are well known. For example, when the densimetric froude number is about 0.09 , the Lee Wave is best developed if the height of the reef is about 10 percent of the water depth. Because a Froude number of this magnitude is quite common in nature, a reef height corresponding to 10 percent of the water depth is a good practical guideline.

(wake or current shadow)

When the current speed increases, a densimetric Froude number exceeds a certain critical limit, and the Lee Wave vanishes. It now gives way to plain wake, as shown in Fig 6.

The length of the wake is up to 15 times the height of the reef when the reef is impermeable. Because the reef is permeable, the length of the wake is shorter, and may be only as much as about 4 times the height. The knowledge of the size of the wake can be used in designing the separation between adjacent reefs.

3. Size of reef

Artificial reefs come in different sizes depending upon the purposes. For example, the basic element is a reef block, which may be a piece of quarry rock or any single articulated module.

Next in the hierarchy is the unit reef. This is the minimum-size reef system which is capable of sustaining a stable fisheries production by itself. The reef unit may consist of a single pile of reef blocks or more than one such pile placed so they interact with each other.

Next in the hierarchy of reef size is the reef group. The reef group consists of more than one reef unit whereby the reef units are placed within each other's range of influence.

Finally, the reef zone is a designation given to a number of reef groups which are located in the same general region but functioning independently from each other.

An example of a "Unit Reef", when aiming at the type " A " bottom fish is shown in Fig 7. We recommend that the bulk volume of

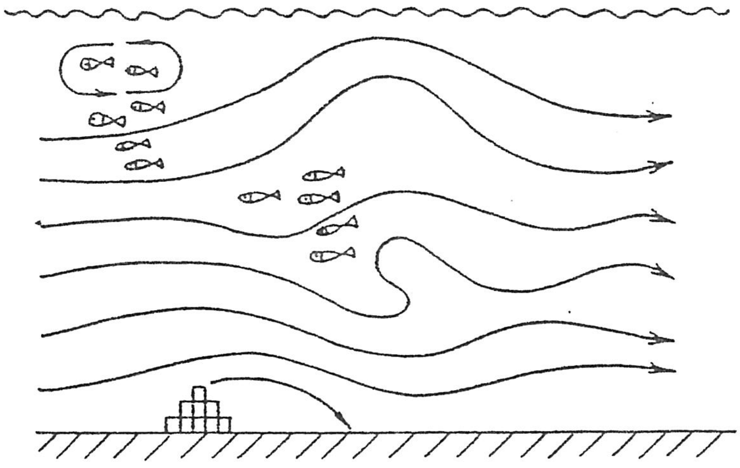

Fig.5 Fish location vs. lee wave

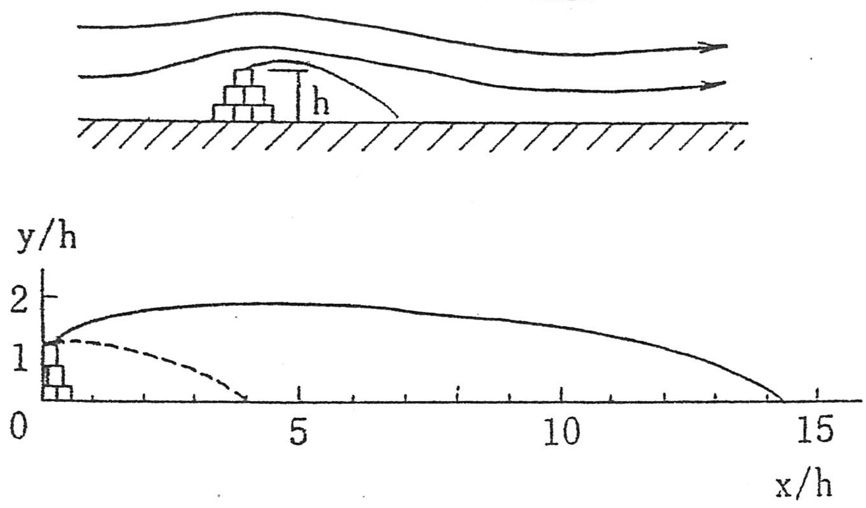

Fig. 6 Wake behind a reef ($Fr > 1/\pi$)

the unit reef should be at least 400 cubic meters
Also, its overall area must be no more than 20 times the sum of the individual floor spaces occupied by the reef piles.

When aiming at the type " B " fish - the fish which swims around the reef while remaining near the bottom - the horizontal spread is an important factor for the unit reef. In this case, we recommend that the reef piles should taper smoothly to the sea floor between adjacent unit piles.

An example of a reef group is shown in Fig 8. A reef group is formed by assembling reef units close enough to each other, so that the fish can readily commute from one reef unit to another, usually, the distances between adjacent reef units in a reef group should be no more than 1000 meters. The optimum distances we recommend are about 200 meters for bottom fish and about 300 meters for surface fish.

Also, in order to attract the Migratory Fish Schools, the reef group is placed where it will intercept the known fish path.

4. Deployment Strategy

One of the most important criteria in the site selection is to investigate the existing fish life and the performance of exisiting reefs in the vicinity - whether natural or artificial, a new reef which is being installed should be complementary and/or remedial to the existing conditions, if this objective cannot be met, one must look for a new location for the site.

A list of various factors which would affect the decision of site selection is shown in Table 1. In general, topographic discontinuities are conducive to the desirable oceanographic and hydrodynamic requirements listed in this table. In Japan, the majority of reef sites are located at the upper part and along the perimeter of submarine topographies which would emerge as a new island, a new peninsula, a new headland, or a new bay if the sea

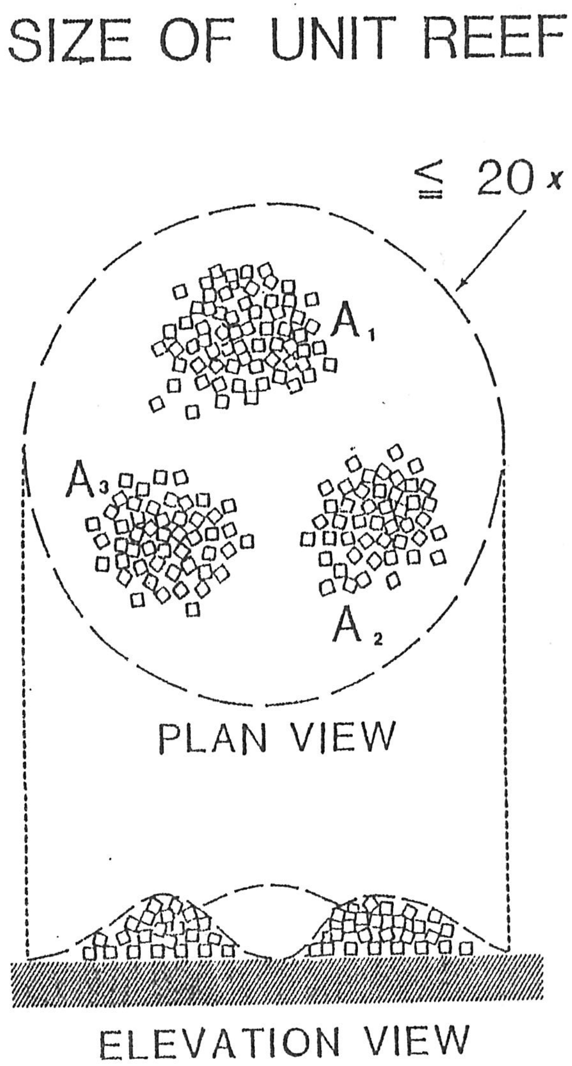

Fig.7 Size of unit reef

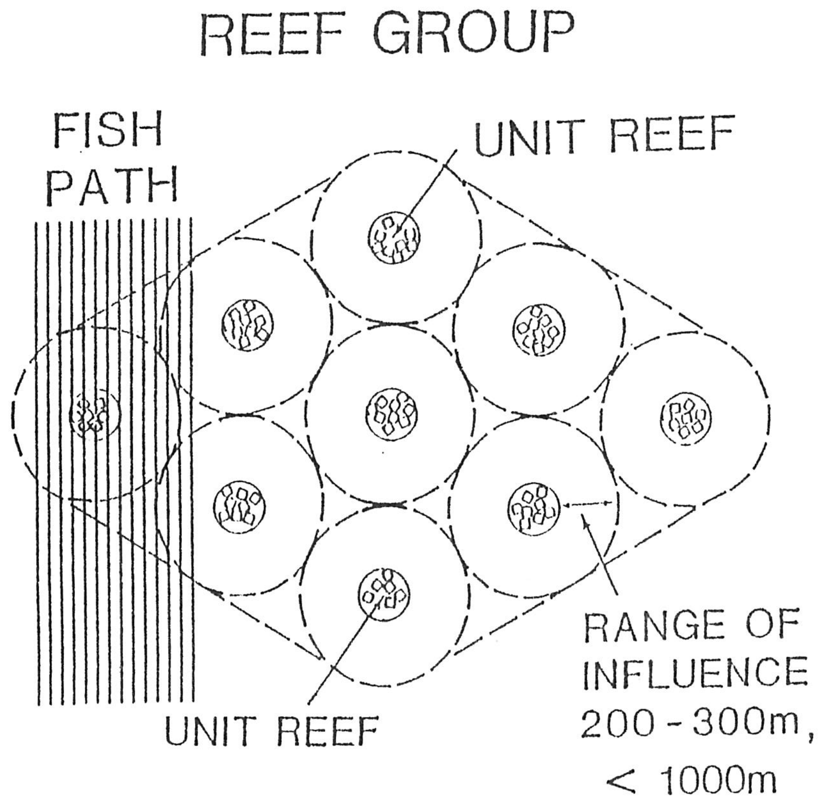

Fig.8 Reef group

level were to drop 50 meters, the next most popular reef sites are a flat sea floor in water depths of between 30 and 70 meters:

Table 1 Site selection

TOPOGRAPHY	discontinuities peninsula headland canyon ridge island substrata diversity existing reefs
OCEANOGRAPHY	upwelling downwelling gyre drift internal wave
HYDRODYNAMICS	turbulence ascent of nutrient salts seston entrainment eddy - shedding

Site selection strategy may also be dictated by the life cycle habit of the fish. For example, many of the type " A " fish live near the surface as juvenile fish, usually following the drifting algae, upon reaching adulthood, these fish settle down to the sea floor to inhabit holes and narrow openings of the reef. In Oita prefecture, Japan, successful artificial reefs were constructed on a sandy sea floor by intercepting the migration route of type " A " infant fish using the drifting algae as an indicator.

In this case, the productivity was found to be proportional to the volume of the reef.

For type " B " fish, the strategy is to localize the entire life cycle needs from womb to tomb, as shown in Fig 9.

This example is a small island group located in the sea of Japan. The bay surrounded by the three islands has characteristic pathways of internal waves because of its unique bottom topography and the locaion of the entrance to the bay where the internal waves arrive.

Investigations showed that schools of sea bream formed a migratory course coinciding with the propagation of the internal waves in the bay, as shown in this figure. Based on this finding, the strategy adopted was to place the induction reef at the entrance to the bay in order to attract the adult fish into the bay, and to place the spawning reef at the location where internal waves will converge after refraction. By confining the entire life cycle of the fish within the bay, chances of their survival were considerably improved.

The flounder reef shown in Fig 10 is designed to promote intentional scour holes due to the wave action during the winter storm season. These scour holes will trap detritus during April through August, helping to improve the chances of survival for the flounder juveniles.This reef module has been placed in Tottori prefecture in Japan. Again the reefs were placed in such a way as to intercept longshore migration of the fish, while also intercepting on and off shore movement of detritus.

5.Verification of reef productivity

The most pressing need , undoubtediy, is quantification of the effects of fishing reef, in terms of the verification in productivity by species and fish size as a function of the characteristics of the fishing reef, locality, and oceanographic and other environmental conditions. And finally, the quantification of economical effects of

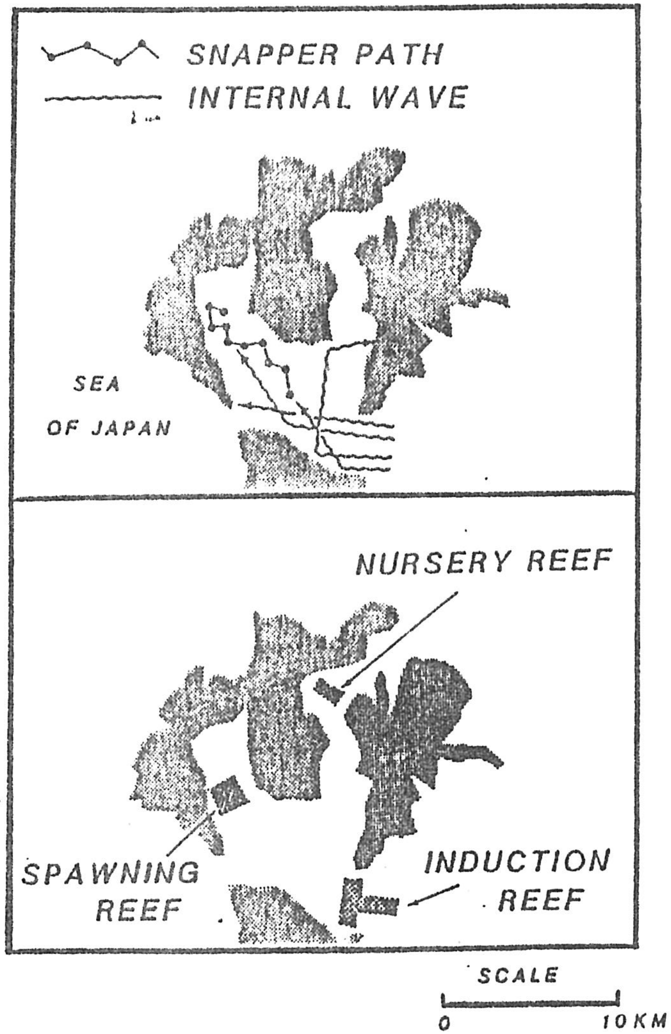

Fig.9 An example of site selection

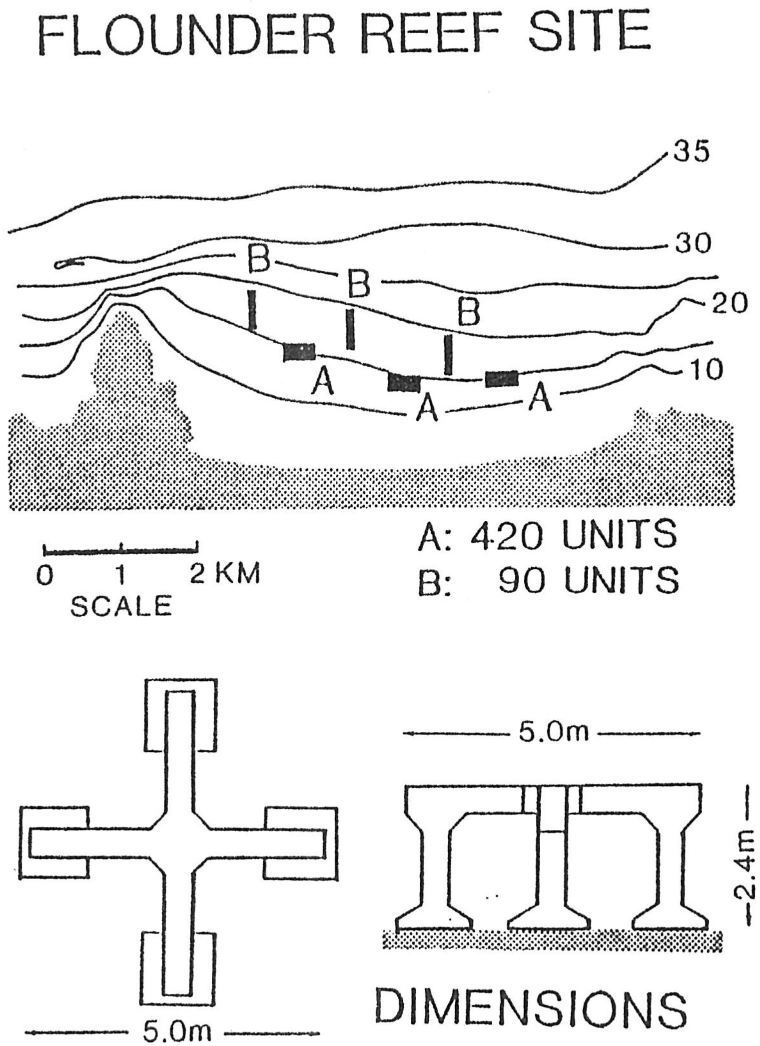

Fig.10 Flounder reef site

fishing reef is needed. That is, not only direct results such as increases in fisheries production but also the indirect such as increase in operative days (safety operation), a reduction in travel time to and from fishing ground, and saving in production costs, should be quantified systematically.

Now in Japan, though many efforts are being made to investigate such objectives, the results are not yet being conclusive. So in this chapter, we show some examples of the results of the survey.

INOUE conducted an interview to fishermen groups of the northern coast of Kyushu Island to certain the effects of artificial fishing reefs. Table 2 summarize the results. Of the total 28 responses to the interview 27 reported the artificial fishing reef improved fish catches.

Table 2 Survey result showing the effectiveness of artificial fishing reefs in northern coast of Kyushu Island , Japan

	NUMBER	PERCENT
TOTAL SAMPLES SURVEYED	28	100
REPORTS ON FAVORABLE RESULTS	27	96

Survey result showing the effectiveness of artificial fishing reefs in northern coast of Kyushu Island , Japan.

Fisheries Agency is now investigating the productivity of government -subsidized artificial reefs. The heart of this program is the creation of "Fishing Reef Ledger", a balance sheet between the investment and the return on increased fish catches. In 1983, Fisheries Agency planned to support about 30 reef monitoring projects around the country. Each project was equipped with 10 survey vessels. According to this survey the average productivity index in Japan ranged between 2 to 12 kilograms per cubic meter of reef volume, depending upon the types and dimensions of the reef.

At this rate of productivity, artificial reefs are considered to have justifial benefit to cost ratio over 30 years of the projected life of reef structure.

6.Future problem

In the long term, a maximum yield of marine productivity cannot be sustained without successful conservation measures. Artificial fishing reefs are an important means of accomplishing this objective and even enhancing the fish stock. Regulations alone cannot successfully prevent overharvesting. Artificial reefs are particularly effective in discouraging the overharvesting by bottom trawlers. Artificial reefs greatly increase the chance of survival for the artificially released juvenile by providing a shelter and nursery.

Artificial reefs have a long history. However we have begun very recently to develop scientific analysis for reef placement, and many problems are still unsolved. For example, population dynamics associated with a reef involving intra-species, inter-species and oceanographic inter-actions is unresolved. And, as mentioned before, the verification of the artificial fishing reef remain empirical. The necessity is to make more efforts to solve these problems and to improve techniques by mobilizing technologists and advancing research in every field.

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ELEMENTS DE PROSPECTIVE CONCERNANT LES DOMAINES DE COOPERATION POTENTIELLE DANS LE DOMAINE DE L'AQUACULTURE ENTRE LA FRANCE ET LE JAPON

Au cours des réunions préparatoires, des conversations en cours de colloque, des réunions finales et de la table ronde, un certain nombre de thèmes de coopérations potentielles ont été dégagés. Ils ont été réunis ci-dessous afin de faire le point du contexte actuel favorable à des échanges scientifiques et techniques dans le domaine de l'aquaculture entre la France et le Japon. Ils constituent ainsi la trame de travaux futurs sur lesquels s'appuient les coopérations entre les deux pays.

Ces différents domaines sont la gestion des entreprises aquacoles, les récifs artificiels, la conchyliculture en eau profonde , la culture des algues, la reproduction et l'élevage larvaire des poissons et des crustacés marins.

ENTREPRISES AQUACOLES

CONTEXTE ACTUEL

AU JAPON

La stratégie actuelle de développement économique de l'aquaculture se base entre autres sur l'évolution des techniques de communication (réseaux informatisés), l'automatisation des systèmes d'élevage et le développement des biotechniques pour la fabrication d'aliments composés.

Pourtant, l'aquaculture, à l'instar de la pêche,reste une activité très artisanale mis-à-part quelques grosses sociétés telles que MBC ou Mitsui pour la crevette japonaise mais qui investissent surtout dans les pays en voie de développement.

Sur les 360.000 pêcheurs côtiers, 103.500 personnes environ pratiquent l'aquaculture (92.700 en tant qu'exploitants et 10.800 à titre d'employés). La majorité d'entre eux cultivent encore l'algue rouge (nori) quoique la tendance soit à l'augmentation des élevages de poissons, surtout la daurade. Ces pêcheurs se regroupent souvent en coopératives (coopératives de pêches spécifiques) pour conduire leurs activités économiques telles que l'achat d'aliments et la commercialisation de leurs produits. En moyenne, les revenus par exploitation sont plus élevés pour l'aquaculture que pour la pêche côtière.

EN FRANCE

L'aquaculture emploie 25.000 personnes, surtout dans les secteurs traditionnels, produit environ 195.000 tonnes correspondant à un chiffre d'affaires de 1,2 milliard de francs pour les activités de production et de 8,2 millions pour les activités d'ingénierie. Les activités traditionnelles que sont la conchyliculture et la pisciculture représentent plus de 95% de la production aquacole.

Les exploitations sont artisanales ou de taille moyenne. Récemment, certaines sociétés se sont intéressées à l'élevage de nouvelles espèces pour l'aquaculture telles que le bar, le turbot ou la sole.

COOPERATIONS POTENTIELLES

Elles peuvent porter sur les points suivants :

Collaboration en matière d'information et d'économie des cultures marines pouvant porter sur les points suivants :
- système de formation et d'information des utilisateurs de l'aquaculture (recherche ⟷ administration et profession),
- facteurs de production et organisation des circuits,
- techniques d'aménagement et interrelations pêche/cultures marines.

RECIFS ARTIFICIELS

CONTEXTE ACTUEL

AU JAPON

En 1974, le Gouvernement promulgait une loi pour la mise en valeur et le développement des fonds de pêche côtiers et, en 1976, démarrait un programme de sept ans, d'un budget annuel d'environ 16 milliards de yens, soit 544 millions de francs, (cours au 1er décembre 1983 , 100 ¥ens : 3,40 F).

Ce programme comprend deux axes : la construction de récifs artificiels à poisson de grande taille, disposés isolément ou en réseau et l'aménagement des conditions du fond pour des espèces de haute valeur commerciale telle que l'ormeau, la langouste, l'oursin ou l'holothurie et les algues.
Cette dernière action concerne le maintien ou l'expansion des aires de ponte et des nurseries, l'introduction de portoirs spécialisés contenant des spores ou des oeufs, la construction de digues déviant les courants, la construction d'habitats artificiels...etc. Ainsi, dans le cadre de la mise en valeur des zones de pêches côtières, les récifs et les habitats artificiels ne sont qu'une des techniques employées afin de protéger, de concentrer et d'accroître la productivité naturelle. Ils sont aussi utilisés dans le cadre des repeuplements comme support de colonisation du milieu par les recrues artificielles.

EN FRANCE

A ce jour, quatre opérations de récifs artificiels ont été réalisées :

- en 1986, à Palavas les Flots, avec l'immersion de carcasses de voitures sur dix hectares par des fonds d'une vingtaine de mètres,
- en 1970, à Concarneau avec l'immersion de 99 cubes de béton de 1 m3,
- en 1972, à Arcachon, avec des carcasses de véhicules immergés par 15 mètres de fond,
- en 1980, à Port-la-Nouvelle, 3.000 m^3 d'assemblages de pneumatiques, de bases et des cubes de béton ont été immergés par 35-40 mètres de fond pour un coût de 645.000 F.
- Enfin, une amorce de création de récif artificiel au large de Saint-Cyprien a été effectuée à l'aide d'épaves de navires : cette opération en Méditerranée va être prolongée par un programme d'implantation de récifs dès 1984 pour un coût de 4 millions de francs.

Par ailleurs, les habitats artificiels ont fait l'objet d'expériences dans le cadre des repeuplements de certaines espèces comme l'ormeau en Bretagne-Nord, le pétoncle noir en rade de Brest (support de fixation) et le homard sur la côte ouest du Cotentin, sur des zones de cantonnement.

COOPERATIONS POTENTIELLES :

Elles peuvent porter sur les points suivants :

Technologie et méthodologie

- architecture récifale en fonction du milieu et des critères d'exploitation.
- récifs d'alevinage et de protection des juvéniles dans les cantonnements.
- suivi des récifs : techniques et analyses des données.

Eco-éthologie

- succession des peuplements sur les surfaces disponibles ; rôle de la nature des substrats et de leurs orientations.
- rôle sur les peuplements benthiques des substrats meubles voisins.
- effets des récifs sur la qualité des eaux, le maintien de la matière organique et le recyclage des éléments minéraux.
- comportement des poissons ou d'autres animaux vis-à-vis des récifs.

CONCHYLICULTURE EN EAU PROFONDE

CONTEXTE ACTUEL

AU JAPON

La production conchylicole concerne principalement l'huître (*Crassostrea gigas*). la coquille Saint-Jacques (*Patinopecten yessoensis*) et l'ormeau (60% de la production : *Haliotis discus hannai*).

En 1982, 145825 tonnes de coquilles Saint-Jacques étaient débarquées dont environ 50.000 tonnes étaient obtenues à partir de nouvelles techniques d'élevage (semis sur fonds vierges, paniers suspendus). La production d'huîtres est de 260.000 tonnes (35.000 tonnes de chair) et celle de l'ormeau 5.000 tonnes, les stocks de cette dernière espèce étant soutenus par l'immersion annuelle de quelque 12 millions de juvéniles.

L'huître est le plus souvent produite en cultures suspendues, principalement dans les Préfectures de Hiroshima (73% du total) et de Miyagi (13% du total). La coquille Saint-Jacques est produite soit en cultures de fond, soit en cultures suspendues dans la partie nord du Japon (Iwate, Aomori, Hokkaido).

Ces dernières années, la demande croissante d'espace pour l'extension des élevages a conduit au développement des filières en eau profonde.

EN FRANCE

La production est d'environ 105.000 tonnes pour les huîtres (*Ostrea edulis* et *Crassostrea gigas*), 50.000 tonnes pour les moules (*Mytilus edulis*, et *Mytilus galloprovincialis*) ; la culture de la palourde (*Ruditapes philippinarium*) est encore naissante.

A partir de 1984, un programme pilote de cinq ans a été établi pour le développement des cultures de coquilles Saint-Jacques en Bretagne nord, en rade de Brest. De nombreux essais de conchyliculture en mer sont actuellement faits sur les côtes de la Manche, de l'Atlantique et en Méditerranée où les captages d'huître plate et le grossissement de moules ont déjà fait leurs preuves. L'élevage de l'huître plate, le captage de moules, le captage et l'élevage de pectinidés en mer sont encore du domaine de l'expérimentation biologique.

OBJET : Collaboration et échanges scientifiques et techniques pouvant porter sur les points suivants :

Biologie
- évolution des biomasses et potentialités biotiques du milieu,
- influence du milieu sur les cultures marines.

Technologie
- théories du dimensionnement des filières,
- effets et limites d'une structure réseau,
- filières immergées et filières de fond.

ALGUES

CONTEXTE ACTUEL

AU JAPON

EN 1980, la production d'algues était de 512.670 tonnes, c'est à dire plus de la moitié de la production aquacole totale.

Trois espèces d'algues sont cultivées intensivement : *Porphyra tenera* ("nori"), *Undaria pinnatifida* ("wakame") et *Laminaria japonica* ("kombu"). La production de *Undaria* est réalisée à 75% dans les préfectures d'IWATE et MIYAGI, et celle de *Laminaria* à 90% dans le Hokkaïdo.

Les problèmes qui se posent pour les cultures intensives sont les suivants : - amélioration des techniques pour la prévention des maladies (*Porphyra* et *Undaria*) ; - fertilisation efficace des champs de culture (*Undaria* et *Laminaria*) ; - adaptation des semences (*Undaria* et *Laminaria*) ; - diversification des produits (*Porphyra* et *Laminaria*) ; - sélection génétique des meilleures variétés ou familles (*Porphyra* et *Laminaria*).

Les cultures extensives sont aussi utilisées dans le cadre de la préservation des champs naturels, de l'amélioration des habitats et des alevinages. Ces cultures nécessitent d'une part le contrôle des conditions de l'environnement telles que les courants, l'action des vagues, l'intensité lumineuse et les qualités chimiques de l'eau et, d'autre part, la mise au point de techniques d'intervention sur les mécanismes de succession de la flore et de la faune sur les fonds de pêche.

EN FRANCE

Seules sont utilisées les algues de ramassage. En 1982, la production a été de 41.300 tonnes.

On en extrait des alginates, des carraghenanes, des additifs (gélifiants, émulsifiants, stabilisants). Ils sont utilisés dans l'industrie alimentaire, en pharmacie, cosmétologie, dentisterie, dans l'industrie de l'emballage, voire pour la fabrication d'engrais. Des recherches sont envisagées pour développer les cultures de certaines espèces et diversifier les produits commercialisés.

COOPERATIONS POTENTIELLES

Elles peuvent porter sur les points suivants :

- Exploitation de nouvelles espèces,
- Technologie des cultures,
- Eaux rouges et relations avec la conchyliculture et l'aquaculture,
- Etude des cycles biologiques et de la reproduction,
- Transformations industrielles.

REPRODUCTION ET ELEVAGE LARVAIRE DES POISSONS

CONTEXTE ACTUEL

AU JAPON

L'aquaculture des poissons représentait en 1980, 243.429 tonnes soit 22% de la production aquacole totale avec un fort taux d'accroissement annuel (23,2% pour la daurade, 10,7% pour la sériole, 8,9% pour l'anguille).

En 1979, l'Agence des Pêches a lancé un programme de développement des techniques d'accroissement de la productivité des zones de pêche dans lequel la production larvaire tient une place importante.

Actuellement, le saumon (Oncorhynchus masou), la sériole (Seriola quinqueradiata), l'anguille (Anguilla japonica, Anguilla anguilla), la carpe (Carassius carassius), la truite (Salmo gairdneri) et la daurade (Chrysophrys major) sont les principales espèces élevées en écloserie.

EN FRANCE

EN 1981, la production de truites arc-en ciel était de 24.000 tonnes en eau douce et de 270 tonnes en eau de mer, le saumon coho, 60 tonnes et le bar, environ 15 tonnes ; la production de turbot devrait atteindre ce stade très prochainement.

Depuis une dizaine d'années, des recherches pour la mise au point des techniques permettant de maitriser la reproduction et l'élevage larvaire du bar (Dicentrarchus labrax), de la sole (Solea vulgaris), du turbot (Scophthalmus maximus) et de la daurade (Sparus aurata) sont menées en laboratoire et en écloserie. La truite (Salmo gairdnerii) et le saumon (Oncorhynchus sp.) font aussi l'objet de recherches intensives, notamment de physiologie de la reproduction.

COOPERATIONS POTENTIELLES

Elles peuvent porter sur les points suivants :

- Recherches pluridisciplinaire pour la mise au point de la reproduction et de l'élevage larvaire de genres communs à la France et au Japon,
- Etudes des mécanismes endocrinologiques et physiologiques contrôlant la reproduction, l'ovogenèse et la ponte,
- Physiologie nutritionnelle respiratoire,
- Biologie larvaire,
- Génétique,
- Recherches de nouvelles proies naturelles et utilisation de micro-capsules,
- Besoins nutritionnels en fonction des facteurs du milieu et éthologie,
- Problèmes posés au cours des changements de régimes alimentaires et du sevrage

REPRODUCTION ET ELEVAGE LARVAIRE DES CRUSTACES

CONTEXTE ACTUEL

AU JAPON

L'aquaculture des crustacés, dont les premiers succès ont été obtenus au Japon, est basée principalement sur l'élevage de la crevette Penaeus japonicus ou Kuruma-ebi, qui est extrêmement appréciée sur le marché intérieur et qui atteint vivante, un prix très élevé de l'ordre de 250 F le Kilo aux consommateurs.

De grandes campagnes de repeuplement existent depuis plusieurs années et sont mises en place en différents points des zones côtières japonaises. Les travaux portent sur l'amélioration des formules alimentaires et sur l'amélioration de la productivité dans les écloseries.

EN FRANCE

Plusieurs espèces de Penéides sont élevées, en Polynésie en particulier, au Centre Océanologique du Pacifique à Tahiti. Plusieurs zones d'essais existent en Méditerranée et dans certains départements et territoires d'Outre-Mer. Les travaux portent sur Penaeus stylirostris, Penaeus vannamei, Penaeus indicus, Penaeus monodon.

Des élevages industriels de Macrobrachium rosenbergi existent à Tahiti et commencent à être mis au point en Guyane, à la Réunion, et dans les Antilles.

Des travaux visant à mieux contrôler la ponte chez les géniteurs, à mieux comprendre la physiologie de l'ovaire au cours de l'ovogenèse, à mieux connaître les besoins nutritionnels, larvaires, à mieux comprendre les mécanismes qui permettent une utilisation optimale, à connaître les propriétés des activités enzymatiques digestives, ainsi que la régulation de leur synthèse, sont en cours de développement.

COOPERATIONS POTENTIELLES

Elles visent à améliorer nos connaissances sur les facteurs optimaux de la nutrition pour chaque espèce ainsi que les effets des facteurs du milieu comme la salinité, la température et l'éclairement, sur la physiologie des différents stades larvaires ainsi que chez les juvéniles et chez les adultes. Un accent particulier sera mis sur la nutrition des géniteurs. La régulation des différentes fonctions physiologiques par des mécanismes endocrines fera l'objet de recherches particulières.

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