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TECHNIQUES OF ARTIFICIAL REARING OF CRUSTACEANS

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CONTENTS

SUMMARY

The work so far performed on the artificial rearing of crustaceans in the littoral Mediterranean is reviewed, showing that rearing from egg is done on a laboratory level, while rearing on an industrial scale is practiced starting only from postlarval stages with specimens derived from Japan and Brittany.

There is a detailed description given of artificial rearing experiments with *Penaeus kerathurus*, from egg up to the adult phase at the Grao de Castellón Laboratory.

The development of *P. kerathurus* in laboratory coincides in every respect with the observations of other authors with *P. duorarum* in a natural environment.

The stomach contents of *P. kerathurus* from a natural population is examined and a description given of the feeding administered during its artificial rearing. Food transformation efficiency in *P. kerathurus* is similar to that of *P. japonicus* but inferior to that of other marine organisms.

INTRODUCTION

Apart from the work of Heldt (1938) in Tunisia, on the shrimp (*Penaeus kerathurus*) and other penaeid species, no experimental work had been conducted on the artificial rearing of shrimp along the Mediterranean coasts, either on a laboratory or an industrial scale. It is only in recent years that such studies have received encouragement, as shown by trials carried out in France, in 1969, by the "Compagnie générale transatlantique", on the acclimatization and growth of the Japanese shrimp *P. japonicus*, on the Island of Embiez; those of Cuzon (1970) at the Marine Station of Endoume, on the artificial rearing and feeding of the grey shrimp *Crangon crangon*, the shrimp *Palaemon serratus* and *Penaeus kerathurus*; those of Lumare, Gorzo and Blundo (1971) on the artificial rearing of *P. kerathurus*; and San Feliu (1969) on the same subject and species.

At present there is a great number of experiments, either projected or in execution, on these and other crustacean species, particularly in Egypt, France, Israel, Italy, Spain and Tunisia.

Generally speaking, the artificial culture of shrimp follows one of two patterns. One consists of catching young specimens from the sea, which are then placed in ponds for growth, and the other involves spawning and the rearing of larvae up to adult size in suitable facilities.

1. THE CULTURE OF JUVENILE SHRIMP CAUGHT IN THEIR NATURAL ENVIRONMENT

For several years some countries in Asia have been following the practice of taking immature shrimp from the sea and culturing them artificially in ponds where their development and growth continues. Some shrimp also enter the ponds as larvae or juveniles with pumped water or with the tides. This culture method avoids costly spawning and larval rearing work. Production will obviously depend, among other things, on the abundance of larvae and juveniles in the natural shrimp population, which will vary widely from year to year. Generally primary production in these ponds is high and moreover, competitors and predators have been expelled and kept out. Average shrimp production per year in such ponds according to Hempel (1970) is about 1 ton/ha.

To our knowledge there is not a single shrimp farm on the Mediterranean that employs the methods used in Asian countries. In France and Tunisia the first experiments with the growing penaeids on a broad scale are being carried out in large ponds, starting with juvenile stages that have been reared from egg in Japanese farms or in the F.A.E.M. farm in the Quiberon peninsula of France.

2. THE ARTIFICIAL REARING OF JUVENILE SHRIMP FROM EGG

Artificial rearing experiments are being performed on the Mediterranean coast with the shrimps Palaemon adspersus, P. serratus and Crangon crangon, but chiefly with penaeids and, in particular, Penaeus kerathurus.

The Grao de Castellón Laboratory of the Fisheries Research Institute has been studying for several years the biology and artificial rearing of P. kerathurus (San Feliu, 1964, 1965, 1966, 1966a, 1967, 1969, 1970, and San Feliu and Alcaraz, 1971).

Biological studies of the species have demonstrated an increase in the gonosomatic index (Figure 1) beginning in April-May, revealing the approach of the spawning season.

In operations of short duration, the shrimp are caught in May with trammel nets or trawl nets and the fertilized females, with full gonads, are separated and placed in plastic containers holding sea water, into which oxygen is blown intermittently. Once arrived at the installation, they are transferred to the spawning and larval-rearing tanks, in which the water temperature is raised to 26-28°C.

2.1 Spawning

Spawning occurs during the first or second night in the tank. If the female of P. kerathurus has not spawned by then, it is unlikely that she will do so afterward.

Normally, spawning takes place during early night hours, although it has also been observed at dawn. The female does not, as a rule, completely empty out her gonad in a single event. Although Heldt (1938) reported that a female P. kerathurus will eject between 1 000 000 and 1 300 000 eggs, we have never observed values of such an order in the tanks.

Physicochemical characteristics of the water at the time of spawning observed by the author were: salinity between 36 and 38 ppt, temperature between 26 and 28°C, pH between 7.8 and 8.3, low NO_2 values, and an oxygen content above 90 percent. Spawning has always been more copious in tanks containing near-shore water than in those with water from the high seas.

Females spawn while swimming as they swiftly flap their pleopods. The eggs remain suspended for one hour, agitated by the currents caused by the aeration of the tank. After one hour they descend to the bottom where their development continues. At our working temperatures, hatching comes about after 14-16 hours.

2.2 Larval development

After the eggs have hatched, the nauplii do not require much care, other than constant stirring to avoid crowding under the water's surface - due to marked phototropism - where they would become entangled with the setae of their appendices, drop to the bottom and perish.

As soon as the nauplii appear in the tanks, the water is fertilized with the Woods Hole Laboratory culture medium, based on the "f" medium of Guillard and Ryther (1962) and described in Table 1.

Once the water in the tanks has been enriched, seeding is done with cultures of the diatoms Skeletonema costatum and Thalassiosira sp. Artificial lighting is kept on 24 hours a day with Sylvania Grolux and Metal Mazda Fluor lamps.

When the nauplius larva reaches the protozoea stage, after approximately 2 days at 28°C, it has an abundant supply of S. costatum and Thalassiosira sp. cells on which to feed. It is not unusual, in these circumstances, for the diatom cultures to reach counts of 1 to 2 000 000 cells/cm^3. Obviously, the greater or lesser number of cells existing in the water at the end of two days depends, among other things, on the number of cells/ml contained in the seeding.

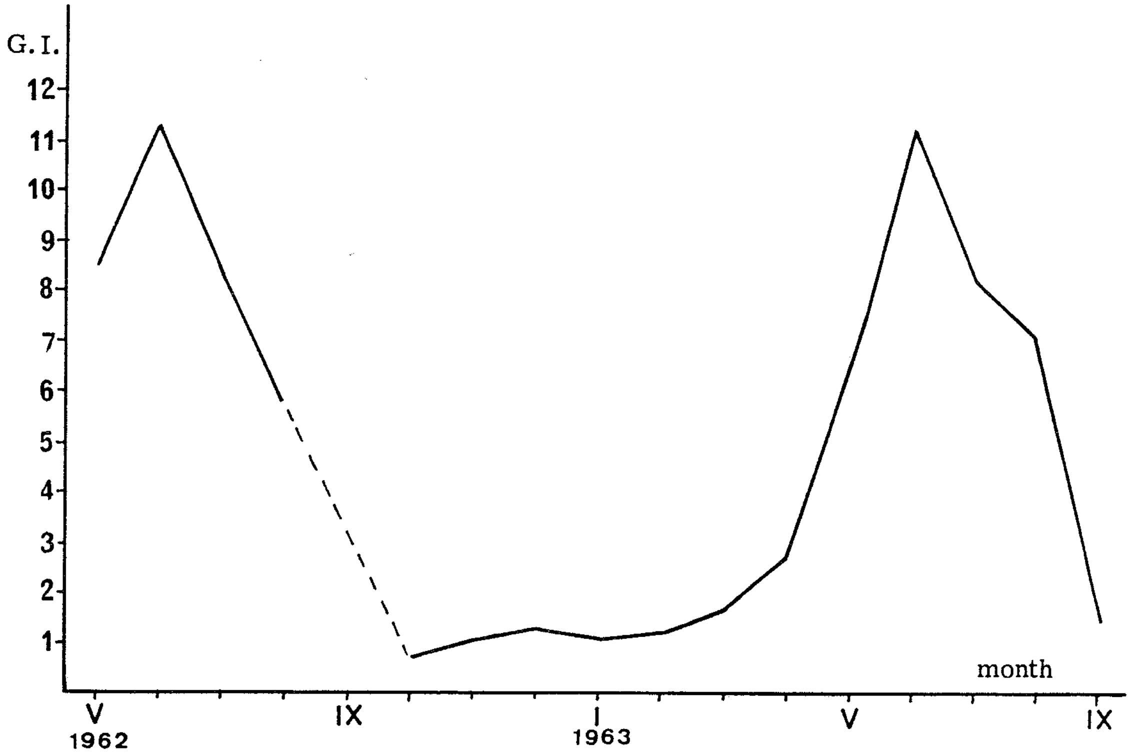


Figure 1 Evolution of the gonosomatic index (G.I.) of female *Penaeus kerathurus* from the natural population occurring south of the Ebro River estuary

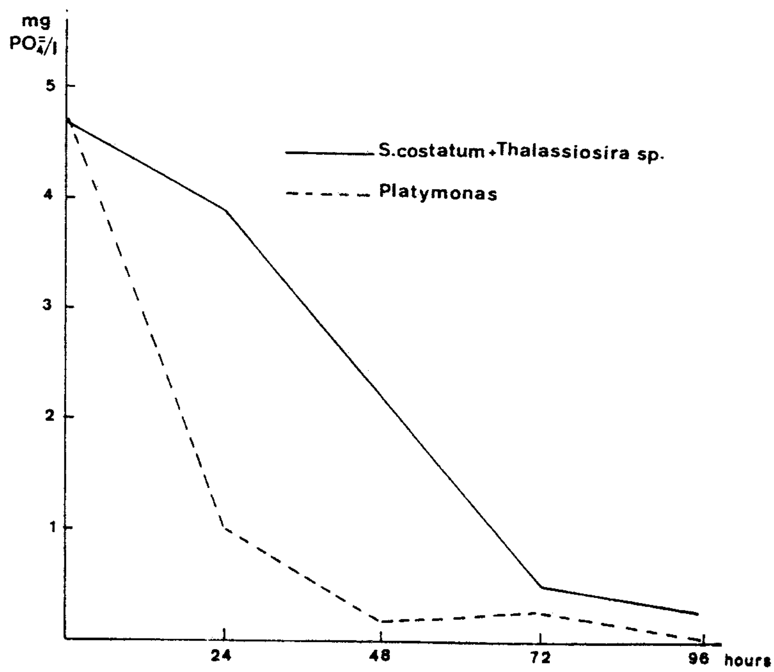


Figure 2 Phosphate consumption of two phytoplankton stocks as a function of time in hours

Table 1. COMPOSITION OF THE WOODS HOLE LABORATORY "f/2" MEDIUM

$NaNO_3$	75 mg
$NaH_2PO_4.H_2O$	5 mg
$Na_2\ SiO_3.9H_2O$	15-30 mg
Trace minerals:	
Na_2 EDTA	4.36 mg
$FeCl_3.6H_2O$	3.15 mg
$Cu\ SO_4.5H_2O$	0.01 mg
$Zn\ SO_4.7H_2O$	0.022 mg
$Co\ Cl_2.6H_2O$	0.01 mg
$Mn\ Cl_2.4H_2O$	0.18 mg
$Na\ Mo\ O_4.2H_2O$	0.006 mg
Vitamins:	
Thiamine.HCl	0.1 mg
Biotine	0.5 µg
B_{12}	0.5 µg
Sea water	up to 1 litre

In industrial establishments for the culture of penaeids, only phosphates and nitrates are employed to enrich tank water and the only source of phytoplankton is that contained as natural population in the sea water entering the tank. However, they always have at hand various strains of phytoplankton species to be utilized in the tanks should the natural species be considered inappropriate. A daily check must be made on the quantity of nutrients in the water and to keep up their level. Figure 2 shows the consumption of phosphates in two phytoplankton cultures: S. costatum and Thalassiosira sp. in one, and Platymonas sp. in the other. As shown in the illustration, phosphate consumption is very fast, and is practically exhausted on the fourth day.

In the experimental facilities, as the larva develops and passes through the protozoea stages, from 1 to 3 phytoplankton cultures are added to the rearing tanks since, as a rule, the number of larvae per litre is high and their consumption exceeds the rate of phytoplankton reproduction.

As phytoplankton cultures are added, tank water is exchanged, thereby reducing metabolite concentration. At the same time, this water exchange decreases the salinity, since the water introduced together with the cultures has a lower saline concentration than that existing in the tank at the time of spawning and nauplius development, thereby favouring the development of the protozoeae and of the S. costatum cultures. No larvae are lost in the process of water exchange as all rearing tanks have a double-bottom contrivance.

Once protozoeae reach stage 2-3 they feed not only on phytoplankton but also on minute organisms from the zooplankton, e.g. nauplius larvae of crustaceans and the developing eggs of Artemia salina.

Zooplankton is collected by the exploitation of the phototropism of some of its components. In the port of Castellón, near the rearing installations, an underwater light was fixed adjacent to the point where a pump draws the sea water that is propelled to the culture plant. At the entrance to the plant, the water is led through net-filters of different gauges, each of which screens the plankton organisms according to their size.

We have made experiments - not yet definitive - on feeding protozoeae with mixed feed prepared by the "Bioter" company for eels. When added to the water as a very fine powder, this nutrient remains in suspension due to the disturbance caused by the aerators. We have observed that, a few minutes after adding the nutrient, the larvae become much more active and that their excreta becomes longer and thicker, showing that they evidently feed on it.

With this regime and tank-water temperature kept at 29-30°C, protozoeae reach the mysis stage in 3 days. They can still feed on phytoplankton, but by now it is mixed with 1 day old Artemia salina nauplii. A daily check must be kept on the number of nauplii of this species per mysis of P. kerathurus for, if the number of the former is much higher than the number consumed by the latter, survivors reach such a size that they no longer serve as food for the mysis stages and tend to compete with it. Natural zooplankton, e.g. the mysis of copepod and cirriped larvae, is also added into the tank.

Table 2 gives the results of one experiment in a 1 200 litre tank. Tank water was analyzed in the early hours of the morning in order to insure adequate time for any necessary modifications. As Table 2 shows, water temperature is kept high, salinity decreases with time, pH values remain high on account of phytoplankton cultures, nutrients never reach a critical level because of daily additions, NO_2 values increase with time, and the number of phytoplankton cells rises as a result of culture growth and additions. Larval survival is high - 77 percent up to stage P 1.

As the larva's pelagic life ends, its benthic life begins; benthic organisms which entered the tank in the added zooplankton and propagated on the bottom of the tank are devoured in a few days. It then becomes necessary to feed the postlarvae on copepods and other zooplankton, crushed Balanus sp., and the finely ground meat of lamellibranch molluscs. This is the time to transfer the postlarvae to the large, open-air culture tanks.

Hudinaga and Kittaka (1966) hold the opinion that adequate feeds for protozoea stages of P. japonicus are planktonic diatoms, fresh and frozen oyster eggs and larvae, as well as rotifers, such as Branchionus plicatilis; benthonic diatoms, oyster eggs and larvae and rotifers, for the mysis stages; cirriped larvae and copepods, for the first postlarval stages; and benthic diatoms, crushed Balanus sp., the meat of lamellibranchs, etc. for later postlarval stages.

3. GROWTH

It is very difficult to determine the natural growth rate of shrimp and their age, inasmuch as they are devoid of the permanent skeleton or other reference points found in other marine animals.

Through various studies it is known that growth of crustaceans is not continuous and only occurs during a short period between moultings; that overall growth depends not only on the increase in size at each moult but also on the moulting frequency; that growth is rapid in the young phases; that some penaeids grow more quickly than others and that the growing process slackens as age increases, when the growth of the somatic mass is greater than that of the linear dimension.

Our facilities are not yet provided with open-air culture tanks, so that postlarvae must continue growing in the same tank in which they were spawned. We have seen in Table 2 that development from nauplius to first postlarva is fast, 11 days, and that the percentage of survival is high. But for want of large culture tanks, growth from this time on is slower and mortality higher than would be the case if postlarvae were bred under adequate conditions.

Table 2. PHYSICOCHEMICAL CHARACTERISTICS OF TANK WATER AND OTHER DATA OBTAINED FROM AN EXPERIMENT ON *Penaeus kerathurus* SPAWNING AND LARVAL REARING

Date	Temp. in °C	Salinity in °/oo	pH	mgPO4 per l	at.µg NO_2 per ml	No. cells per ml (x 1 000)	No. larvae (x 1 000)	Remarks
8-6-71	27.00	37.05	-	-	0.00	-	-	5 females immersed. Spawning occurs at 22 h
9-6-71	28.50	37.16	8.33	-	0.03	-	110	N 1 at 12 h. Enrichment. Phytoplankton culture seeded.
10-6-71	29.00	37.15	-	-	-	-	-	N 5 at 13 h
11-6-71	30.00	36.94	8.37	3.053	1.46	350	-	Z 1. Phytoplankton cultures introduced
12-6-71	29.00	36.45	8.44	2.651	0.71	400	-	Z 2. Zooplankton and phyto-plankton cultures introduced
13-6-71	29.00	36.25	-	-	-	480	-	Z 3. Zooplankton and phyto-plankton cultures introduced
14-6-71	29.00	35.68	-	-	-	515	-	M 1. Zooplankton, phytoplank-ton cultures and *Artemia* introduced
15-6-71	29.00	35.68	8.61	3.031	1.62	783	90	M 1-2. Same addition as on previous day
16-6-71	27.50	35.50	8.50	2.768	1.19	1 300	90	M 1-2-3. Same addition as on previous day
17-6-71	28.00	35.25	8.35	2.254	2.38	1 400	90	M 2-3. Same addition as on previous day
18-6-71	29.00	35.44	8.36	2.512	1.65	960	90	M 3 and P 1. Same addition as on previous day
19-6-71	29.90	35.25	8.12	2.918	2.08	620	85	P 1. Same addition as on pre-vious day

Figure 3 shows the percentages of size-frequencies in mm of a batch of Penaeus kerathurus spawned on 8 June 1971, measured on 23 October at the age of 4.5 months. The sex ratio in this lot was 54 percent females, 46 percent males.

The same illustration shows a broad size-scatter among males and females, although all individuals were of the same generation. Average size among males is 62 mm and slightly over, and 64 mm among females. The greater length of females is manifested when they are still quite small.

The batch of P. kerathurus in Figure 3 lived in water pumped in from a filtration well, which is consequently different in composition from sea water. In other experiments also made in small, covered tanks, but with water taken directly from the sea, growth coefficients were greater, which demonstrated the fact that, whenever circumstances allow, artificial rearing should be carried out in water brought in directly from the sea.

All experiments on the artificial rearing of P. kerathurus should commence at the beginning of the spawning period so as to have shrimp of marketable size by December. If rearing is commenced at the end of the spawning period - August/September - they will only attain commercial size toward the end of the ensuing spring or early summer, since growth in large, open-air tanks is slower during winter months.

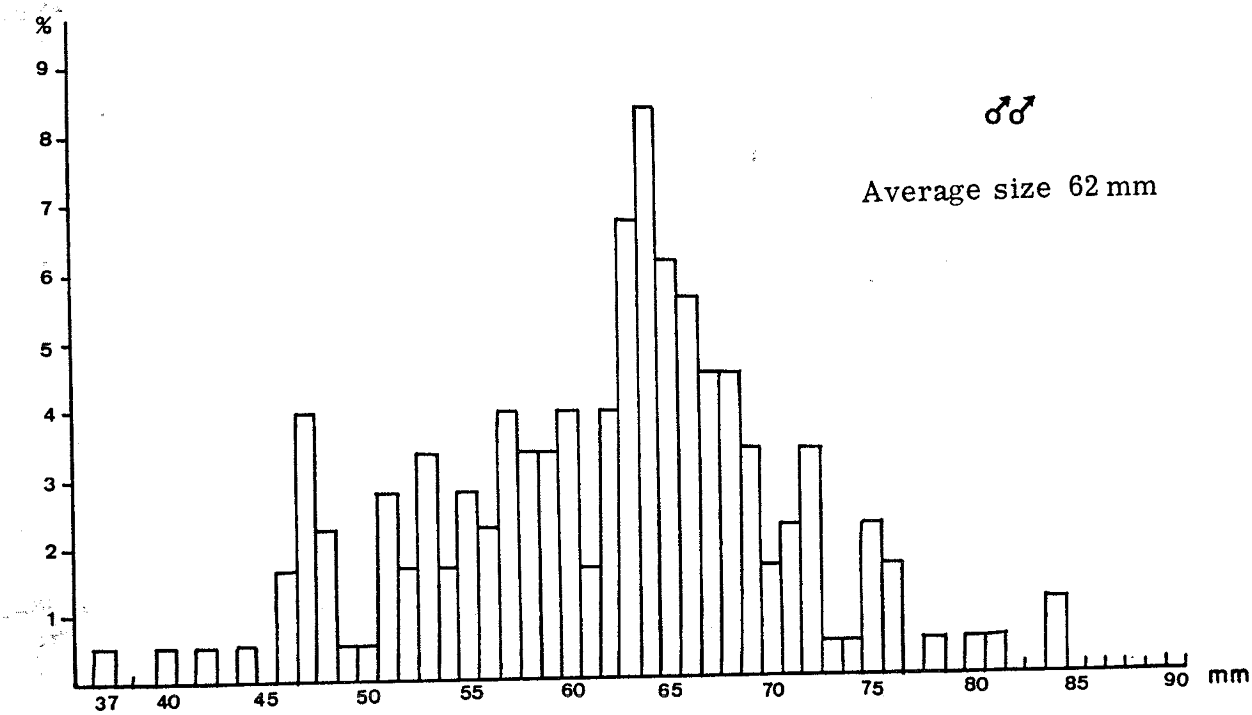
In another growth experiment (Table 3, Figure 4) two male shrimp were kept in a 60-litre tank from the end of November 1968 to the end of May 1969, in water taken directly from the sea. They had been reared in the facilities during the first ten days of August; after 3.5 months they averaged 64.93 mm in length.

It is very difficult and hazardous to measure the overall length of the exoskeleton shed by the shrimp at each moult. For this reason, growth data in Table 3 are based on the measurement taken of the cephalothorax which is shed in one single piece. By means of such measurement and applying the correlation (cephalothorax/overall length)/(overall length/weight) derived from specimens in a natural population some of the values given in Table 3 were arrived at.

Between November 1968 and May 1969 all specimens moulted 11 times, with periods between moults of 12 to 22 days; shorter periods correlate with smaller size. Average length during six months varied from 64.93 to 116.25 mm, with a growth of 51.22 millimetres. Growth between moults decreased inversely with size.

The results of this experiment show a growth of 19.16 mm/month from spawn to a length of 65 mm, and from this length up to 116 mm, 8.54 mm/month. We know of no published data on P. kerathurus growth at these lengths, except those by Cuzon (previously mentioned), which only cover a period of one month or those of San Feliu (1966) for greater lengths.

Eldred et al. (1961) reported that P. duorarum, at Beach Drive, grows about 20 mm/month between hatching and a length of 65 mm and, in Tampa Bay, 10 mm/month in lengths between 75 and 120 millimetres. These figures show that the growth of P. duorarum in natural environment is similar, if not identical, with that observed in the experiment with P. kerathurus in tanks.



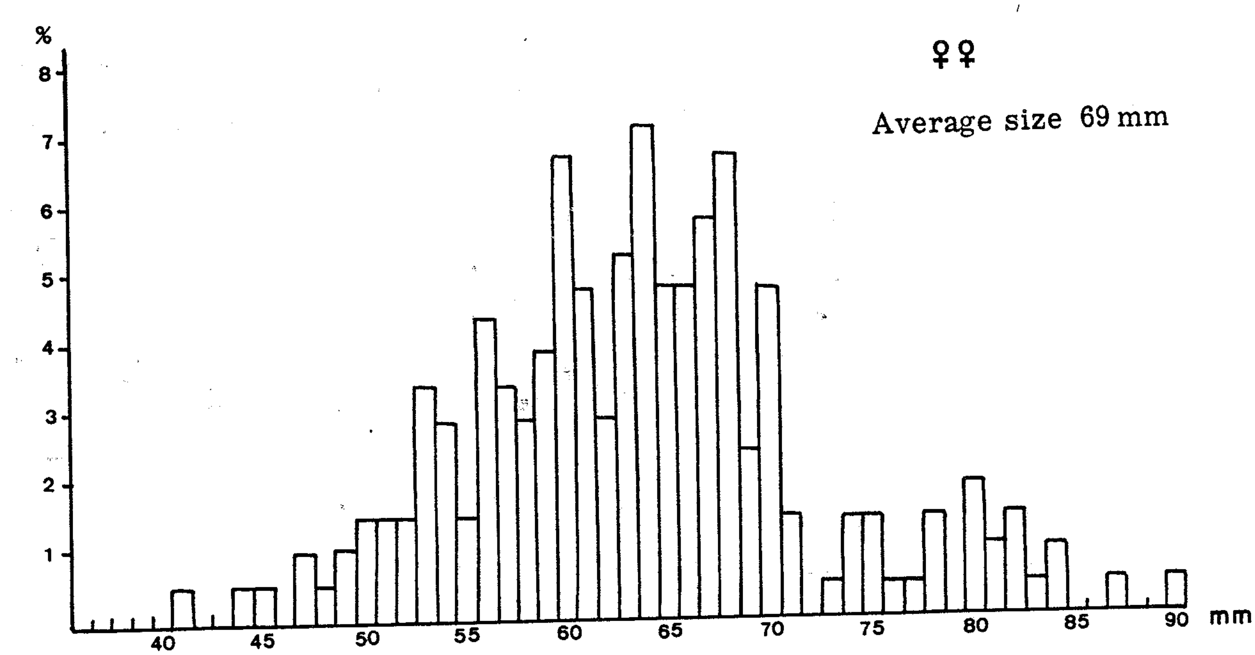


Figure 3 Percentages of length frequencies (in mm) of a group of 4.5 months-old *Penaeus kerathurus* reared artificially from eggs

Table 3. DATA ON GROWTH AND FOOD TRANSFORMATION EFFICIENCY IN LABORATORY-BRED SHRIMP

Moult Date	Length Cephaloth. (mm)	Length Overall (mm)	Weight (g)	Average weight increase per specimen (g)	Average feed consumption per specimen (g)	Efficiency between 2 moults (per cent)
21-11-68	15.00	62.86	1.3	-	-	-
25-11-68	16.30	67.00	2.0	-	-	-
5-12-68	16.65	69.00	2.3			
5-12-68	17.80	73.80	3.0	1.00	10.90	9.17
17-12-68	18.50	77.00	3.2			
20-12-68	19.60	85.00	4.0	0.95	23.15	4.10
1- 1-69	20.02	85.00	4.3			
3- 1-69	21.01	88.00	4.9	1.00	20.70	4.83
23- 1-69	21.65	91.00	5.5			
24- 1-69	22.50	94.50	6.0	1.15	16.50	6.97
14- 2-69	23.00	96.00	6.2			
16- 2-69	23.70	100.00	7.2	0.95	20.90	4.55
7- 3-69	23.75	100.00	7.2			
7- 3-69	24.35	103.00	7.8	0.80	37.70	2.12
26- 3-69	24.90	104.30	8.0			
29- 3-69	25.35	105.70	8.2	0.60	37.60	1.60
13- 4-69	25.90	107.50	8.7			
18- 4-69	26.40	111.50	10.0	1.25	27.00	4.63
3- 5-69	26.80	112.00	10.0			
5- 5-69	27.40	116.00	11.2	1.25	13.00	9.61
23- 5-69	27.30	115.00	11.0			
24- 5-69	27.80	117.50	11.5	0.65	25.50	2.55

4. FEEDS AND THEIR USE

As the feeding of shrimp larval stages has already been discussed, this section will only deal with the appropriate feeding of juveniles and adults. In order to ensure the success of a culture experiment on any species, it is important to know which is the best diet for it. It is a matter of general knowledge that one way of acquainting oneself with the foods preferred by a given species is the examination of stomach contents in the natural population and, on that basis, the necessary trials should then be made to endeavour to supply artificially reared animals the most suitable ingredients. In this context it is also useful to know the species' feeding habits.

The food ingested by P. kerathurus is finely ground before it reaches the pylorus and is practically unrecognizable once it is in the intestine; for this reason only the digestive content of the anterior and median parts of the stomach have been examined under microscope. The remains found have, naturally, invariably been the most resistant components of the food ingested: foot bristles and jaws of polychaetes, crustacean fragments, occasionally whole copepods, shell fragments from lamellibranchs and gastropods, mandibles and fragments of cephalopod tentacles, fish vertebrae and scales, spicules from echinoderms, foraminifera and hydrozoa. Data obtained from these studies must be handled with caution as the method tends to overestimate the alimentary importance of organisms having resistant parts, while underestimating easily digested foods which leave no identifiable trace.

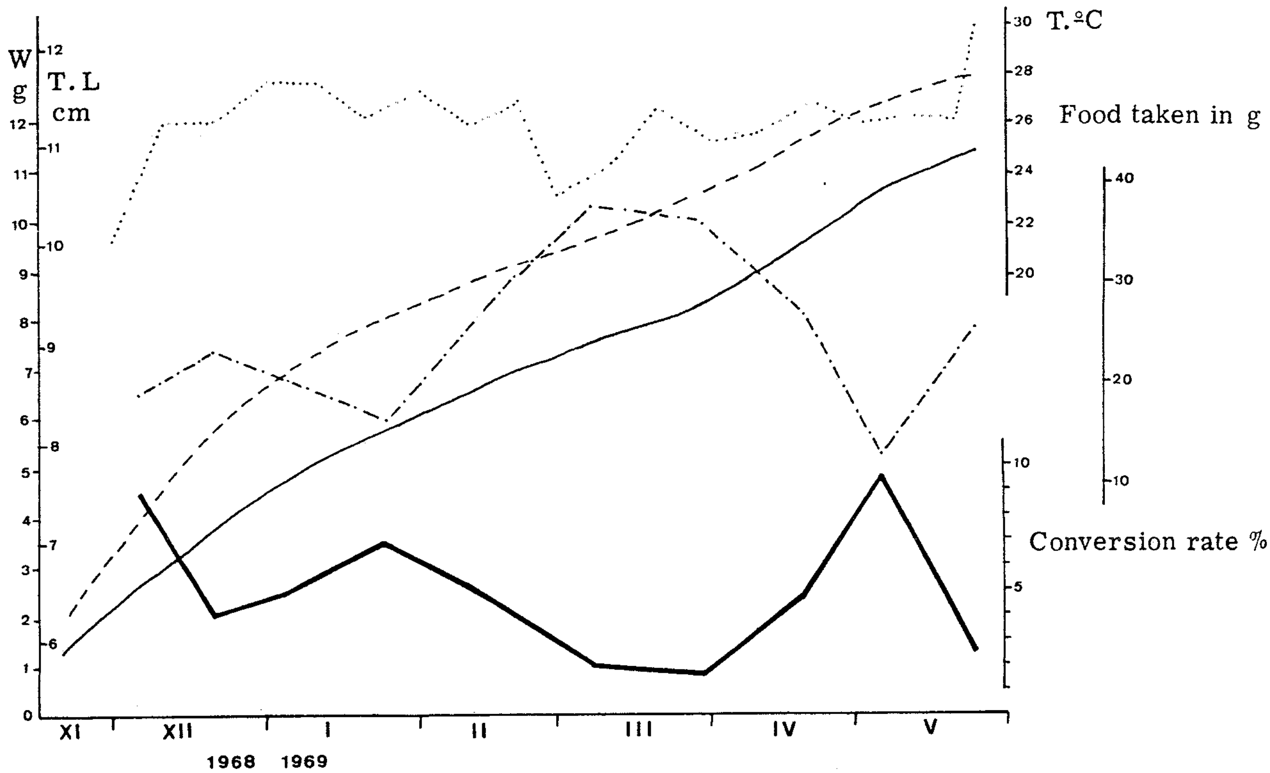


Figure 4 Growth in length (T.L) and weight (W) of two male shrimps reared from eggs; food taken and conversion rate. Length growth (——), weight growth (- - - -), food taken per animal, g (-.-.-.-.), conversion rate (▬▬), water temperature (.....)

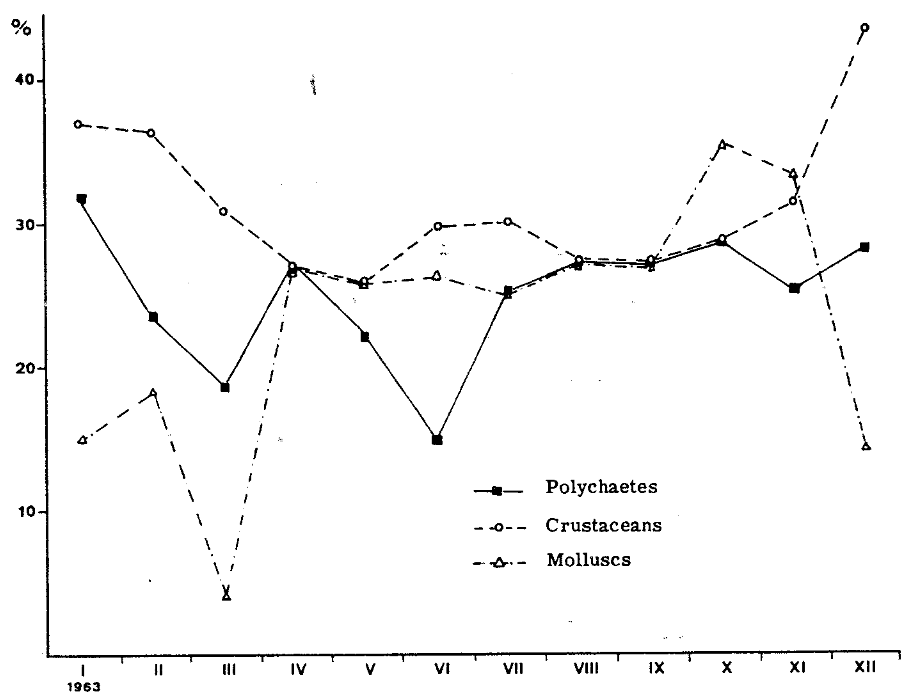


Figure 5 Monthly variation of the percentages of polychaetes, crustaceans and molluscs in the stomachs of Penaeus kerathurus from the natural population occurring south of the Ebro River estuary

No completely empty stomachs were found, in seeming contrast with the observations of Osisanya (1967), who in the analysis of the stomach content of P. duorarum off the Nigerian coast finds a considerable number of empty stomachs. In this connexion, it must be borne in mind that there is a relationship between the time of day when the catch is made and the feeding rhythm of the species. The individuals employed in our observations were caught during the night, and it is at that time that the shrimp feeds. In contrast with Osisanya (1967), no algal vestiges were found in the stomachs examined by us. The monthly variations in stomach content are set forth in Table 4, where it can be seen that crustaceans, molluscs and polychaetes are present throughout the year and are the staple food. The remaining groups are found only in small quantities, with the exception of fish, which are present in striking amounts.

Table 4. VARIATIONS IN THE COMPOSITION OF GASTRIC CONTENTS IN PERCENTAGE

Month	Poly-chaetes	Crus-taceans	Mulluscs	Cepha-lopods	Fish	Echino-derms	Forami-nifera	Hydro-zoa
January	31.5	36.8	10.5	-	21.2	-	-	-
February	23.0	36.3	18.1	-	13.6	9.0	-	-
March	19.2	30.8	3.8	7.7	34.6	4.0	3.4	-
April	27.7	27.7	27.7	-	16.9	-	-	-
May	22.0	26.0	26.0	-	26.0	-	-	-
June	14.6	29.3	26.7	2.5	19.5	2.5	5.0	-
July	25.0	30.0	25.0	-	-	20.0	-	-
August	27.7	27.7	27.7	-	-	16.9	-	-
September	27.3	27.3	27.3	-	13.6	-	-	4.5
October	28.6	28.6	35.7	7.1	-	-	-	-
November	25.4	31.3	33.3	-	10.0	-	-	-
December	28.5	43.0	14.2	-	14.2	-	-	-

Although the aggregate of cephalopods, echinoderms, foraminifera and hydrozoa amounts to only 6.79 percent of total food, they are not found at all in the stomach contents of animals under 100 mm length.

The amount of crustaceans in the stomach decreases with increase in size, while the reverse is true of molluscs. Polychaetes, crustaceans, molluscs and fish are found in the stomachs of shrimp captured at whatever depth, but the proportion of crustaceans in analysed stomachs decreases as depth of habitation increases.

Monthly variations of the three groups found throughout the year in stomachs examined by us are described in Figure 5. Generally speaking, variations are slight in terms of percentage, between April and November, and fluctuate much more widely between December and March, especially molluscs.

From the results of these stomach analyses it may be deduced that this species feeds close to the bottom since, together with the organic matter it takes in as nutrients which in the main consist of organisms of a benthic habit, there are found large quantities of sand and mud.

Daily observations of shrimp in acquaria have yielded information on feeding habits. During the daylight hours it remains buried and does not feed; in the evening, around 18 to 20 h it surfaces and begins to search for food. In a general way it may be said that not all individuals behave in the same way throughout the night as some of them, after feeding for a few hours bury themselves again in the bottom, and reappear in early dawn. During daylight hours they are not to be seen, save in exceptional cases. Yet young shrimp which have been kept in the dark in the daytime have shown a certain degree of activity and have even fed on supplied nutrients.

In the knowledge that natural populations feed basically on crustaceans, molluscs, polychaetes and fish, we have made tests in our laboratory with various diets, apart from mixed feeds. As polychaetes are hard to come by, a mixture of minced meat from lamellibranchs, such as the mussel Mytilus edulis, "chirla" Venus gallina, crabs Macropipus depurator, fish, e.g., anchovy Engraulis encrasicholus and scaldfish Arnoglossus laterna, to which corn flour is sometimes added.

With the purpose of gaining knowledge as to the utilization of this mixture by the shrimp, the feed added in the evening and what remains of it in the morning was weighed during 6 months in 1968/69. The difference between both weights gives us approximately the weight of the stuff consumed. The resulting figure is higher than the actual one, since part of the food disintegrates or dissolves in the water and has been accounted for as consumed.

Transformation efficiency was calculated by means of the formula:

$$E = \frac{Wi}{Fc} \times 100$$

where Wi is the average weight increase per individual between two moults and Fc stands for average weight of food consumed during that time. Values obtained are given in Table 3 and Figure 4, where it will be seen that they fluctuate between 1.60 and 9.61 percent, although, we repeat, these values must be lower than the actual, as part of the food disintegrates in the water. If we disregard the figures for mid-April and early May - respectively, 4.63 and 9.61 - which are not very realistic because a large amount of zooplankton added to the tanks was consumed by the shrimp, which barely touched the customary food, it will be observed that food-transformation efficiency tends to decrease as body length increases.

We have no comparative data on food-transformation efficiency for P. kerathurus from other authors, being acquainted only with those of Choe (1970) for P. japonicus. According to Choe, efficiency percentage in P. japonicus fluctuates between 2.8 and 7.8. It will be seen that these values are very similar to those obtained by us with P. kerathurus.

Transformation efficiency in P. kerathurus is low when compared with that of other marine animals; according to Hatanaka and Murakawa (1958), the value for Seriola quinqueradiata runs between 12.9 and 34.0 percent; and, according to Choe (1966), that of Sepia esculenta is 38.7 percent. It is, therefore, worthwhile to seek to find the food that will bring about the highest transformation efficiency in P. kerathurus.

5. YIELDS AND ECONOMICS OF ARTIFICIAL BREEDING OF CRUSTACEANS

The design of a crustacean culture establishment must provide for its operation practically on a year-round basis, inasmuch as any stoppage presupposes maintenance expenditures without profit. A good example is the F.A.E.M. farm in Brittany, which was wisely designed for the spawning and culture of P. kerathurus, P. japonicus, Palaemon serratus and Homarus vulgaris in such a way as to take advantage of the different spawning seasons of these species. The farm works with these and other marine species throughout the year, making efficient use of the same pumping, heating, aeration, food manufacture and other equipment and installations, without interruption.

Small-scale laboratory work is necessary to know the biology of different species. But, in order that artificial culture experiments may be economic, large rearing or culturing tanks are needed, or perhaps a complex facility is indispensable, according to the aims pursued. If a farm is to handle the rearing of crustaceans from spawn, a more complex installation is required than if it limits itself to culture young specimens up to the adult stage. In the first case, scientific personnel and equipment are indispensable, as well as spawning and rearing tanks, in addition to those for food cultures, water-heating equipment, etc. In the second case, only one technician and ancillary staff, plus large, open-air culture tanks will be required.

Earlier in this report it is stated that one female P. kerathurus will spawn between 1 000 000 and 1 300 000 eggs. Even though such high numbers per individual are not obtained in spawning tanks, values of that order could be attained by increasing the number of mature females in each tank. With the methods described by Japanese researchers for experiments on the spawning and rearing of P. japonicus larvae in tanks of 10 x 10 x 2 m, an average 500 000 juvenile shrimp per tank can be obtained. According to Fournier (in a personal communication), the Maguelonne, France establishment, with open-air ponds, has a survival rate of 50 percent. In the 6-7 months between May and December, shrimp in appropriate culturing conditions can reach average weights of 20 grammes. Thus production from one 10 x 10 x 2 m tank, cultured in open-air conditions may exceed 4 tons.

Due to the fact that our work up to now has been exclusively on a laboratory scale, we have no data of our own on industrial production costs. Acoording to Hempel's data (1970), cost of production up to the postlarval stage in Japanese P. japonicus culture plants comes to about U.S. $1.00/100 postlarvae. Production in outdoor experimental culture tanks reaches 10 tons/hectare.

The market price for P. kerathurus at the Central Fish Market of San Carlos de la Rápita, Tarragona, fluctuates during the year between 297 and 672 pesetas/kilogramme. The sales price to the consumer, however, is higher; on unusual occasions it has gone over 2 000 pesetas1/.

1/ U.S.$ 1.00 # 65 pesetas in January 1972

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