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TEN YEARS OF EXPERIMENTAL REARING OF PENAEID SHRIMP IN TAHITI AND NEW CALEDONIA (SOUTH PACIFIC)

AQUACOP (1)

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A B S T R A C T

Since 1973, the "Centre Océanologique du Pacifique" has been conducting in its Tahitian and New-Caledonian facilities, tropical penaeid shrimp rearings. Up to now, among the different species tested, Penaeus monodon, P. stylirostris, P. indicus and P. vannamei have been selected and currently cultured for several generations.

P. monodon is a fast growing species specially adapted to tropical semi-intensive culture conditions with a 2-3 Ton /ha/year production from post-larvae.

P. stylirostris is particularly suitable for cultures at lower temperatures (22-28°C). Yields are similar to the ones obtained with P. monodon.

P. indicus, a smaller species, is readily bred in captivity. In semi-intensive cultures, production is slightly inferior to the former. However, P. indicus tolerates high density culture conditions (> 100/m²), though at a lower growth rate. Yields : 15 Ton /ha/year.

P. vannamei excells in intensive systems. Productions obtained in small volumes (10 m³) average 40 Ton /ha/year but results in larger volumes (100 to 1 000 m³) are still lower.

INTRODUCTION

In May 1973, the first shrimp rearing trials started at the "Centre Océanologique du Pacifique" (C.O.P) a research aquacultural station from CNEXO in Tahiti, French Polynesia, within the following context : no indigenous species of penaeid shrimps available as ingredients for feed production ; few suitable sites for pond construction ; but very stable seawater temperatures (25 to 30°C) and salinities within the optimal range for penaeid culture and presence of large protected lagoons though with low natural productivity.

By the end of 1973, the "Centre National pour l'Exploitation des Océans" (C.N.E.X.O) and regional authorities take up and develop in New - Caledonia, the Saint-Vincent aquaculture station as an applied demonstration farm in a slightly different context : presence of local penaeid shrimps of commercial interest (Metapenaeus ensis, Penaeus merguiensis, P. monodon and P. semisulcatus); mangrove areas and salty swamps available for pond construction; existence of a fresh and hot season with marked temperature differences (20°C to 30°C for seawater).

The objectives of CNEXO were to develop tropical shrimp culture in the overseas french territories to supply local markets at first and then for exportation, but also transfer technologies to countries with tropical aquaculture potentials. Several penaeid shrimp species have been tested for different criteria as broodstock obtention easiness, hardiness of larvae during larval culture, adaptability to local culture conditions (salinity, temperature, ...), resistance to disease, growth performance in relation with alimentary requirements, capacity to endure high densities , tolerance to handling and commercial interest. (Aquacop, 1975 ; 1977a; 1977b, 1977c, 1977d, 1979a, 1979b, 1982a, 1982b).

Hundreds of growing experiments were done and resulted in the elimination or the selection of the different candidate species : *P. japonicus* and *P. aztecus* , in spite of good growths, were abandonned for being particularly susceptible to diseases mainly due to temperatures close to their upper limits, and for the high alimentary requirements of *P. japonicus*.

M. ensis and *P. merguiensis* were ruled out because of their slow growth rates and the small sizes reached at harvest.

Mortalities encountered in the first growing tests with *P. semisulcatus* made that this species was not further investigated.

Actually four species are still under experimentation : *P. monodon*, *P. indicus*, *P. stylirostris* and *P. vannamei*. *P. orientalis* have been recently imported, and other species are planned for preliminary tests.

This paper presents a summary synthesis of ten years of experimental results obtained in different rearing conditions, mainly with the four elected species.

MATERIALS AND METHODS

Growing facilities

Several kinds of ponds are used at COP (Fig 1): four 400 to 1200 m^2 hard bottom rectangular concrete ponds, 1.5 to 1.9 m deep ; three 755 to 1000 m^2 hard bottom circular concrete ponds, 0.9 to 2 m deep ; ten 100 m^2 hard bottom square concrete ponds, 1.2 m deep ; and twelve 250 to 2570 m^2 earth ponds, 1 to 2 m deep. All these ponds are provided with a continuous sea water flow and some with freshwater and aeration ; 15 and 100 m^3 floating cages are positioned in the adjacent lagoon.

The Saint-Vincent Station operates eleven earth ponds, 1 ha and 7.5 ha for the largests and 10.4 ha as a whole. These ponds are not supplied with aeration nor freshwater.

Culture schemes

Early post-larvae (PL 3 to PL 10) from the hatcheries can be stocked directly into the growing ponds or grown-out, for some weeks or months, at higher densities, in smaller nursery ponds before being transferred to rearing ponds.

The nursery phase can be conducted in two different systems : earth ponds without aeration ; initial density : 50-200/m^2; daily water exchange rate : 5-30 % duration 1-2 months; harvest weight : 1-2 g. Juveniles are then transferred to semi-intensive ponds.

or : Polyester tanks or concrete ponds with aeration; initial density : 1-10 PL's/liter; daily water exchange rate : 0-10 %; duration : 4-5 weeks ; harvest weight : 0.1 g. Juveniles are then used in intensive or semi-intensive cultures.

Nursery growings at intermediate densities between 100 and 500 PL's/m² have been realized in large aerated concrete ponds.

The growing phase has been experimented in both semi-intensive and intensive conditions : earth ponds without aeration; initial density : 5-30/m²; daily water renewals : from 5 to about 30 % by the time of harvest, duration : 4-8 months; harvest weight : 10 to 30 g

or : aerated concrete ponds initial density : 50-200/m²; daily water exchange rate : generally low from 5 to 20 %; air flow rate : 0.1 - 0.5 m³/hour/m³ of water; duration : 6-10 months; harvest size : 10-20 g.

Rearing medium

Two main types can be distinguished, each of them with a different sustained biomass ; in both types, salinity is the natural seawater salinity (35 ppm) :

Up to 200 g/m² and without aeration, the medium is characterized by a more or less dense phytoplankton bloom in relation with standing biomass and water exchange rates. Benthic macrophyte algae in filaments (enteromorphs) or layers (cyanophytes) may developp as long as the water stays clear. The growth of phytoplankton can be stimulated by standard commercial fertilizers and a supply of silica rich freshwater. A secchi disk disappearance depth of 60 to 90 cm is generally satisfactory.

In aerated ponds and with a biomass superior to 150-200 g/m² and up to 2 Kg/m², a complex medium containing bacterial flock, phyto and zooplankton, develops Such a medium is able to transform ammonia into nitrites then nitrates (nitrifying bacterial effect), prevent pH fall (phytoplankton effect) and supplement the shrimps diet, especially in nursery ponds (zooplankton effect).

Rearing management

In semi-intensive conditions, routine control of physico-chemical parameters is limited to water temperature, salinity and Secchi disk

RESULTS

The growth curves presented in this chapter were chosen neither from the best nor from the worst trials, but as the most representative of the results achieved on a routine basis. Temperatures mentioned in figures and text refer to morning measurements ; afternoon readings usually are 2°C higher.

Nursery results

When post-larvae are stocked directly in earth ponds without aeration, for semi-intensive grow-out (5 to 20 PL's/m²) at temperatures equal or superior to 24°C, survival rates are generally satisfactory (60 to 100 %) for all the species. P. monodon can though be subject occasionnaly to high mortalities just after stocking without clear reasons (algae toxicity)

At nursery densities of 50 to 200 PL's/m² survivals are usually inferior to 50 % for P. monodon and P. stylirostris when P. indicus and P. vannamei rates are still superior to 60 %.

At temperatures lower than 23°C, all the species suffer higher mortalities when no special acclimatization procedures are used.

As seen in figures 2 to 8, growth time from early post-larvae to a 1g mean weight is 1 to 4 months, depending on species, densities and, above all, temperatures. P. monodon and P. indicus start growing slower than P. vannamei and P. stylirostris. With all species, the growths are lower at increased densities and temperatures below 24-25°C.

When post-larvae of several species are stocked together, P. monodon growth and survival are clearly affected while the other dominant species are not (Fig 9).

When post-larvae are stocked directly in aerated concrete ponds without bacterial flock for intensive grow-out (50 to 500 PL's/m²), P. indicus survival rates range from 50 to 90 %, while P. monodon gives much more variable results (30 to 80 %). P. indicus generally reaches a 0.1 g mean weight in 40 to 50 days (Fig. 10) and P. monodon in 40 to 55 days (Fig. 11). Similar trials were not done with other species.

In 10 m³ nursery tanks with bacterial flock medium, at very high densities (1 to 6 PL's/liter), all species show good survival rates(from 70 to 90 %)and 0.1 g juveniles are obtained in 24 to 27 days. This technique is being transferred to 100 m³ concrete ponds : the results with P. indicus (Fig. 12) confirm the good growths achieved with bacterial flock, but survivals are lower until now (50 to 60 %).

Whatever nursery procedure is used, the main mortalities seem to occur within a few days after stocking.

Grow-out results

Survival rates are 60 % or higher when earth ponds are stocked directly with post-larvae and 70 % or more with juveniles. This is true for all species as far as the grow-out has been well conducted : adequate water renewal, right food quality and rations, temperatures within the optimal range (table 2).

Occasional diseases may affect the cultured shrimp and provoke mortalities . P. monodon suffers from the "blue disease" (soft blue shell syndrom) probably due to a nutritional deficiency that appears mainly above 20 g ; a vibriotic disease (soft redish shell syndrom) ; rolled up gills and carapace, often observed when pond bottoms are of poor quality. P. stylirostris, P. vannamei and P. merguiensis are affected by the "white pleura disease" (white spot shell disease), especially P. stylirostris when temperatures are 30°C or higher. No pathogenics have yet been observed on P. indicus.

Best growth curves obtained at low densities (Fig. 13) are not representative of the growths at commercial densities. Apart from the species, the main factors affecting growth in earth ponds are temperature density and feed quality.

P. monodon grows slowly up to 3-4 g and then at an accelerated rate (Fig. 14). When cultivated under good conditions and at densities of 5 to 15/m², it takes four months to pass from 1 to 20 g. At higher densities, shrimps reach a lower limit depending upon the density, the water renewal rates or the food quality. *P. monodon* can bear very high temperatures up to 35°C ; its growth decreases from 26 to 22°C and stops under 22°C (Fig. 15).

P. vannamei and *P. stylirostris* have a faster initial growth rate than *P. monodon* (Fig. 16.17); from 0.5-1g up to 15-20g growth curves are usually linear ; at densities of 5 to 15/m² and good temperature range, growth rates are about 3 to 5 g/month. These two species keep on growing at lower temperatures than *P. monodon* (*P. stylirostris* 20°C and *P. vannamei* 23°C).

P. indicus grows slower than the three former species and reaches a smaller size (Fig. 18). At low densities (1/m²) 15g males and 25g females are obtained in six months but, when density rises above 5/m², growth rates decrease and maximum mean weights range from 8 to 12g. This early weight limit is mainly due to males which stop growing around 7g. At temperatures of 20-22°C, *P. indicus* keeps growing, but at slower pace.

P. merguiensis is still more affected than *P. indicus* by the density factor. If 15-20g animals are common at very low densities, the maximum weight reached at densities higher than 5-10/m² is barely 3 to 4g, mainly because of stunt males again. Temperature tolerance is similar to *P. indicus*.

Average yields, at 5 to 30/m² densities, from post-larvae to 10g *P. indicus* and 20g *P. monodon*, *P. stylirostris* and *P. vannamei* are 2 to 4 Tons/ha/year.

P. vannamei proves remarkably adapted to intensive conditions and specially to bacterial flock mediums (Fig.19). Survival rates are high and growths similar to the ones obtained in earth ponds (3 to 5g/month). Up to 12-13 g mean weight, the effect of 50-200/m² densities on growth rates in little noticeable. In 3 to 12 m³ tanks, many experiments have given extrapolated yields of 40 Tons/ha/year in 15-20g animals. However, the few trials made in large ponds have not yet produced more than 20 Tons/ha/year.

P. indicus also stands high densities (healthy shrimps and good survival) but with a mean growth rate of only 1g/month (Fig. 20) ; food quality and density (100 to 400/m²) seem to exert little influence on growth. As in semi-intensive rearings, weight is limited to 8-10 g at a 100/m² density. The proposed scheme for intensive rearing of *P. indicus* implies 2 stages, each 5 months long : 500/m² from post-larvae to 4 g and 100/m² from 4 to 10 g. In these conditions, a yield of 15 tons/ha/year is obtained with a 3.5 total conversion ratio.

The *P. monodon* do not adapt so well to the typical bacterial flock mediums where they generally become weaker, with necrosis and a blue coloration, and have a slow growth rate. But a medium with a phytoplanktonic dominance achieved with less aeration and daily water renewals of 20 to 30 %, allows healthier animals, good survivals when juveniles are stocked and growths barely inferior to the ones obtained in semi-intensive conditions : 1 to 20 g in 5 months, resulting yields of 10 to 17 Tons/ha/year and a conversion ratio of 2.5 to 3.5 (Fig. 21).

With respect to *P. stylirostris* , the few intensive trials done were never decisive with neither culture mediums ; high temperature conditions (25 to 32°C) probably weakened the shrimps.

In floating cages experiments, with 30 to 140 individuals per m³, *P. monodon* showed slow growths and bad survivals (23 trials) ; *P. vannamei*, slow growths but good survivals (10 trials) and *P. stylirostris*, good growths but very low survivals (14 trials).

D I S C U S S I O N

When stocking post-larvae, the following points should be considered :

Unacclimatized PL's of P. indicus, P. monodon and P. stylirostris should not be stocked at temperatures lower than 23°C.

Post-larvae homogenous in size, age and species are to be stocked within a short space of time to avoid mortality by cannibalism.

Natural productivity intervenes as a feeding source, therefore affecting PL's survival as much as the pellets. This is particularly true for P. monodon. This explains why low density stockings generally bring good survival rates when lower survivals are observed at high densities, except in enriched medium.

P. monodon, P. vannamei and P. stylirostris are large species (adults average weight over 50g) that demonstrate a fast growth though initial rate is slow for P. monodon. P. indicus and P. merguiensis, in addition to their slowness to grow, don't reach large sizes. Size dispersion, at same size, is lower for P. vannamei and P. stylirostris than for a P. monodon.

In each ponds, the ways of improvement of the results with a given pellet are limited to increase in water exchange rate and use of mechanical aeration make up. With intensive systems, the efforts are concentrated on the optimization of aeration devices and ponds shape.

Betterment of the formula feed should be favoured both from a cost and qualitative point of view : improvement of the production process and quality of ingredients,use of least cost formulation.

Other species than the ones selected to date may demonstrate higher tolerance ranges to particular medium and rearing conditions.

During the past ten years, all density ranges were tested at the COP, from less than 1/m² (broodstock rearings) to hundreds/m². But the question stays of which density should be used in a given context ? Extensive and semi-intensive rearings seem to be the most reasonable option, for the moment, where large areas exist. The observed evolution of aquacultural practises goes from the extensive to the intensive ; in countries like Ecuador, shrimp farming relied until recently on extensive rearings but is now getting to semi-intensive practises. In other countries like Taiwan, where land is scarsier, semi-intensive methods are used in smaller ponds but farmers gradually introduce more intensive technics, increasing yields from 2-3 Tons/ha/year to 20 Tons/ha/year. The use of smaller ponds allows the practise of intermediate transfers to thin the population and optimize the pond utilization. Thus, the choice of density depends on local economical criteria and the state-of-the-art.

The necessity of nursery ponds is independant of the density used in the growing ponds ; it is often justified by a better occupation rate of the ponds compared to direct stocking. Other advantages of nursery rearings are the better survival rates achieved in growing ponds, specially when pond conditions are not optimal, the more precise estimation of the initial biomass to be grown and a better adaptation to climatic constraints.

The choice between intensive and semi-intensive nursery rearings is an apportunistic one that integrates different factors, economical but also biological. Intensive nursery rearings allow a better control of the culture medium,repetitively give good survivals for all tested species but necessitate more specialized labor and their short duration is not very interesting for growing pond occupation rate.

In comparison, the nursery in earth ponds is a simpler technic but results in less reliable survivals, for example with *P. monodon* and *P. stylirostris*. As animals harvested are of a bigger size, the turn-over of growing ponds is significantly improved.

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A. Michel : Former Tropical Aquaculture Program Coordinator.

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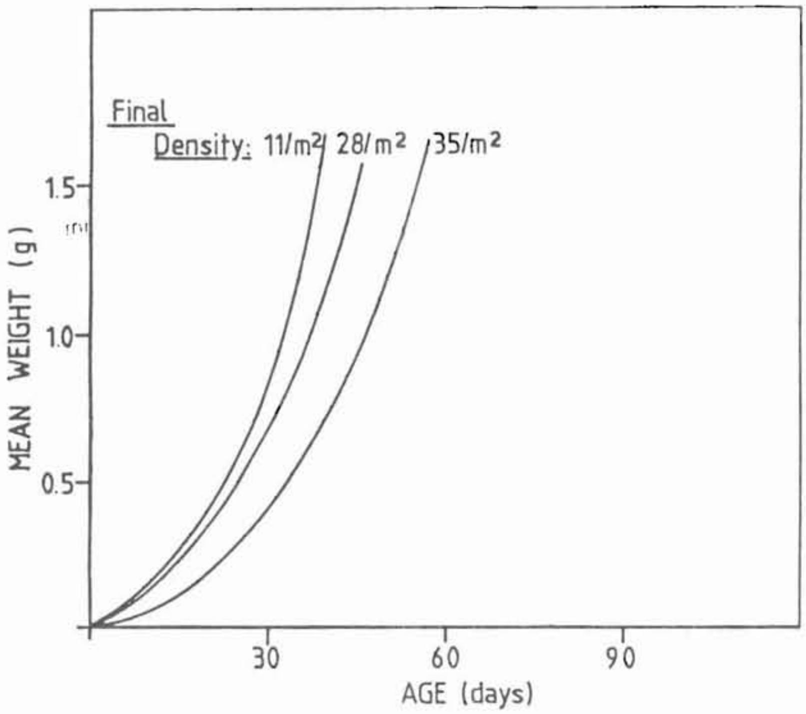


FIG. 2 : *P. stylirostris* : effect of density on initial growth in earth ponds (temperature range : 26-31°C : initial densities : 15,33 and 46/m² respectively).

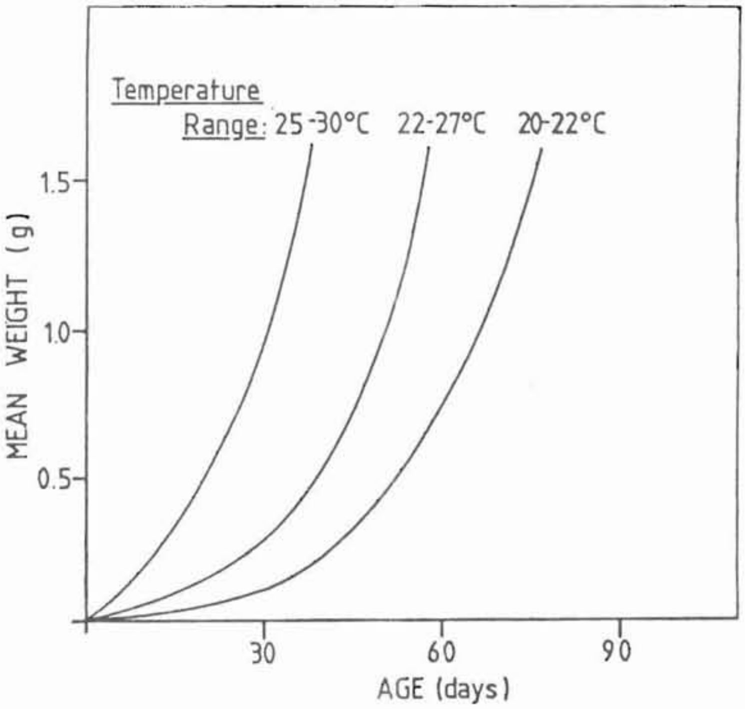


FIG. 3 : *P. stylirostris* : effect of water temperature on initial growth in earth ponds (final densities : 20-30/m²).

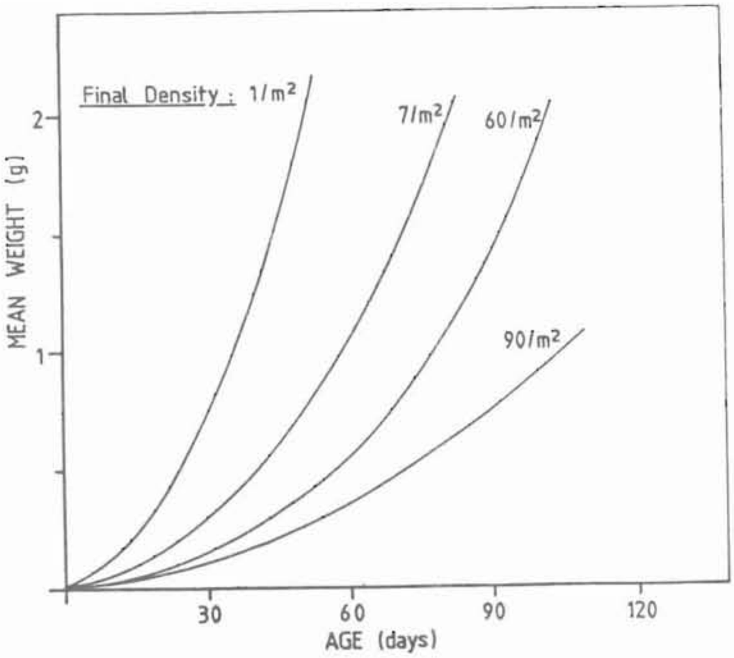


FIG. 4 : P. indicus : effect of density on initial growth in earth ponds (temperature range 25-30°C ; initial densities : 2, 12, 80 and 110/m² respectively).

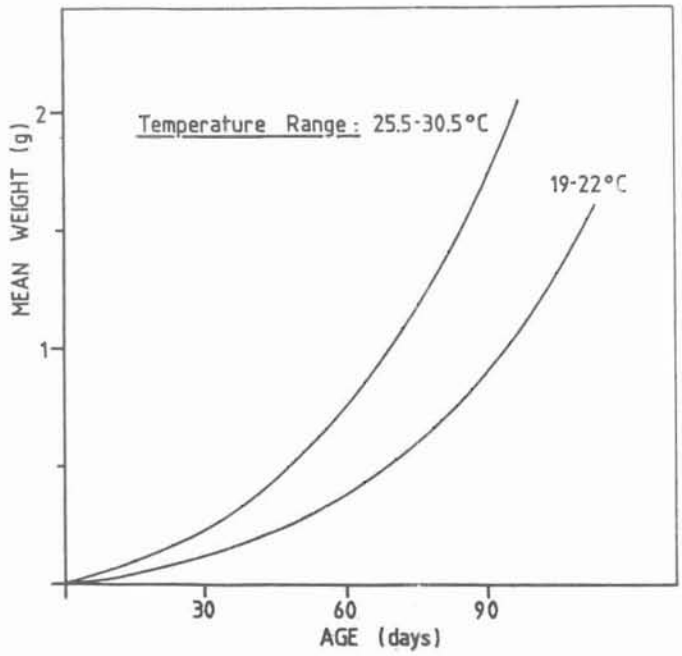


FIG. 5 : P. indicus : effect of water temperature on initial growth in earth ponds (final densities : 30/m²).

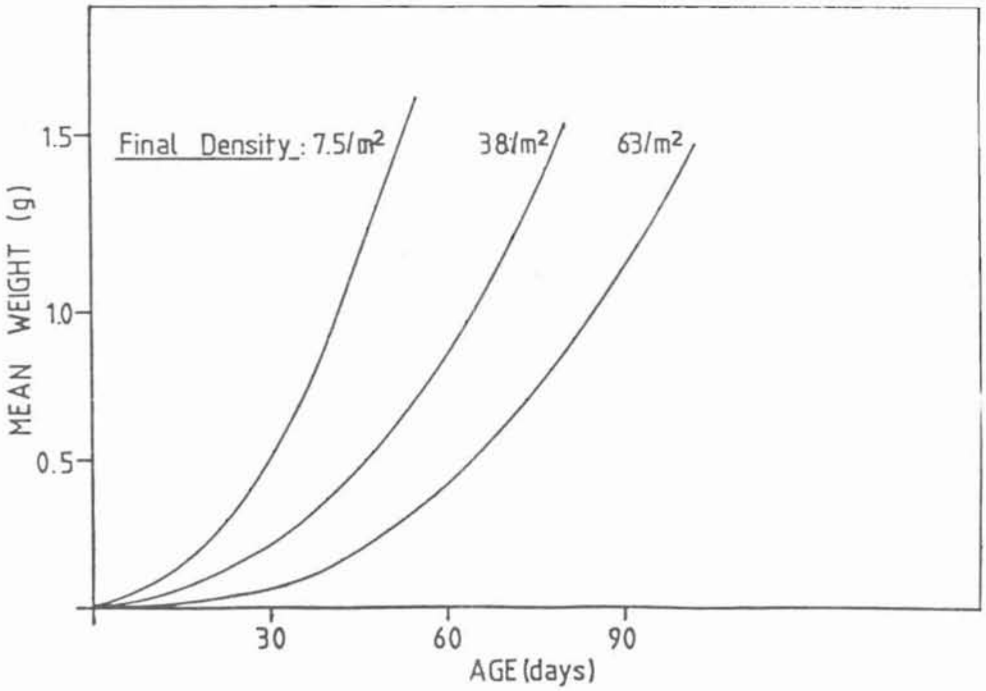


FIG. 6 : *P. monodon* : effect of density on initial growth in earth ponds (temperature range : 25-30°C; initial densities : 21, 89 and 156/m² respectively).

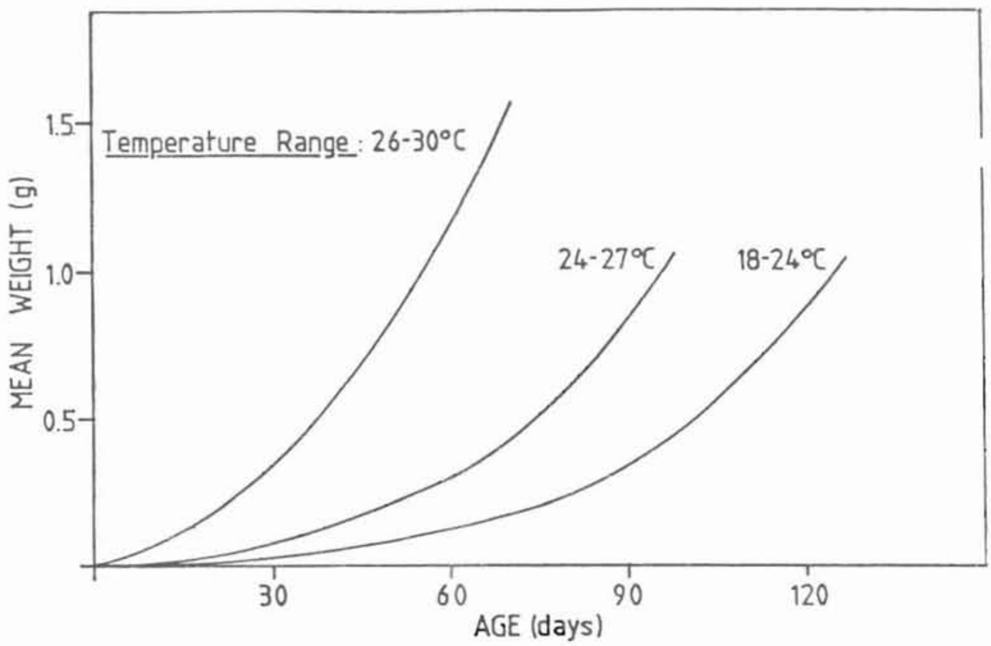


FIG. 7 : *P. monodon* : effect of water temperature on initial growth in earth ponds (final densities : 50- 60/m²).

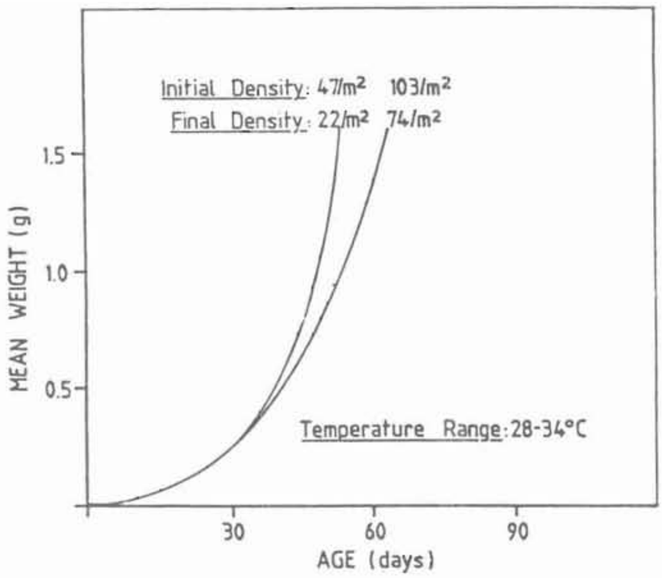


FIG. 8 : *P. vannamei* : initial growth curves in earth ponds,

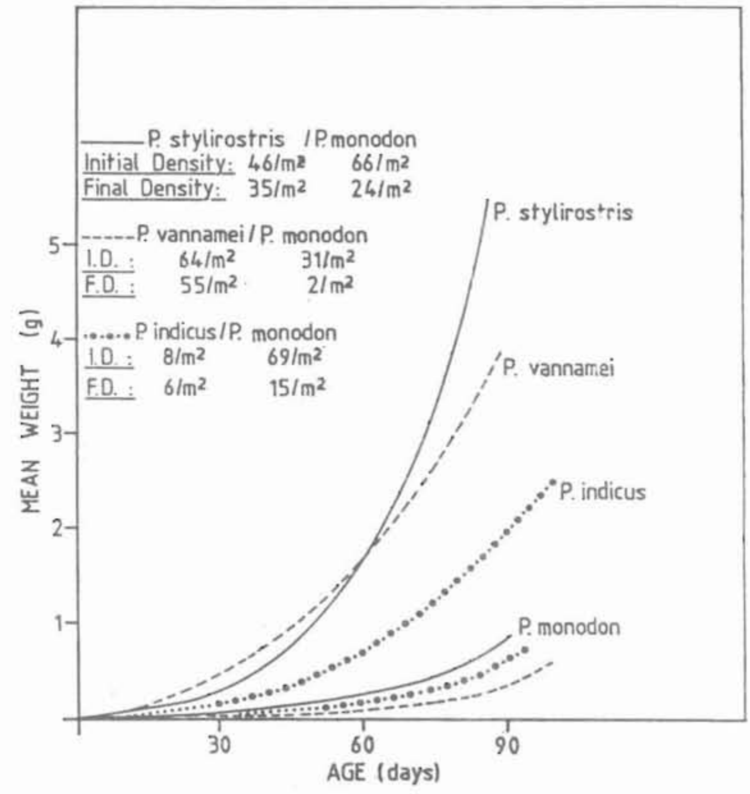


FIG. 9 : Dominance of *P. stylirostris*, *P. vannamei* and *P. indicus* over *P. monodon* juveniles in mixed cultures.

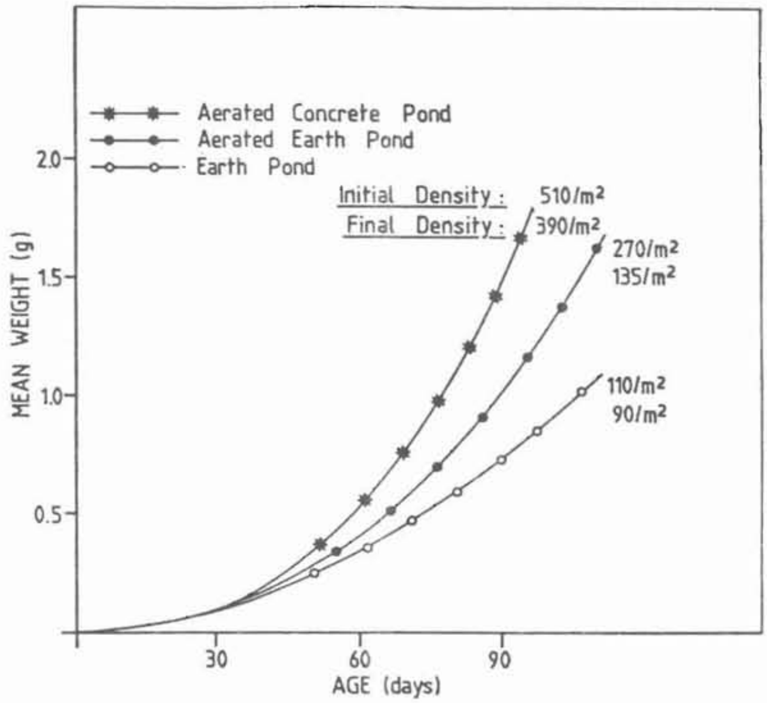


FIG. 10: *P. indicus* : effect of different culture systemes on initial growth.

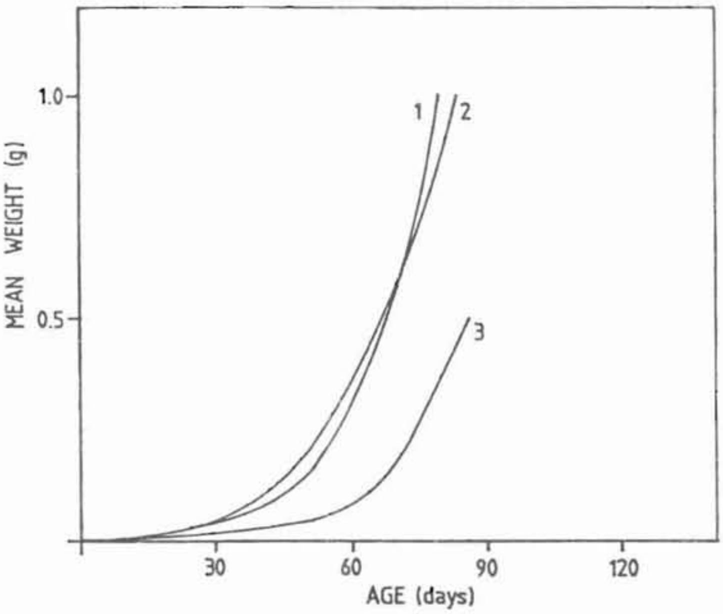


FIG.11 : *P. monodon* : initial growth curves at high densities (initial and final densities 1 : $162/m^2$ $96/m^2$ 2 : $147/m^2$ $136/m^2$ 3 : $338/m^2$ $230/m^2$).

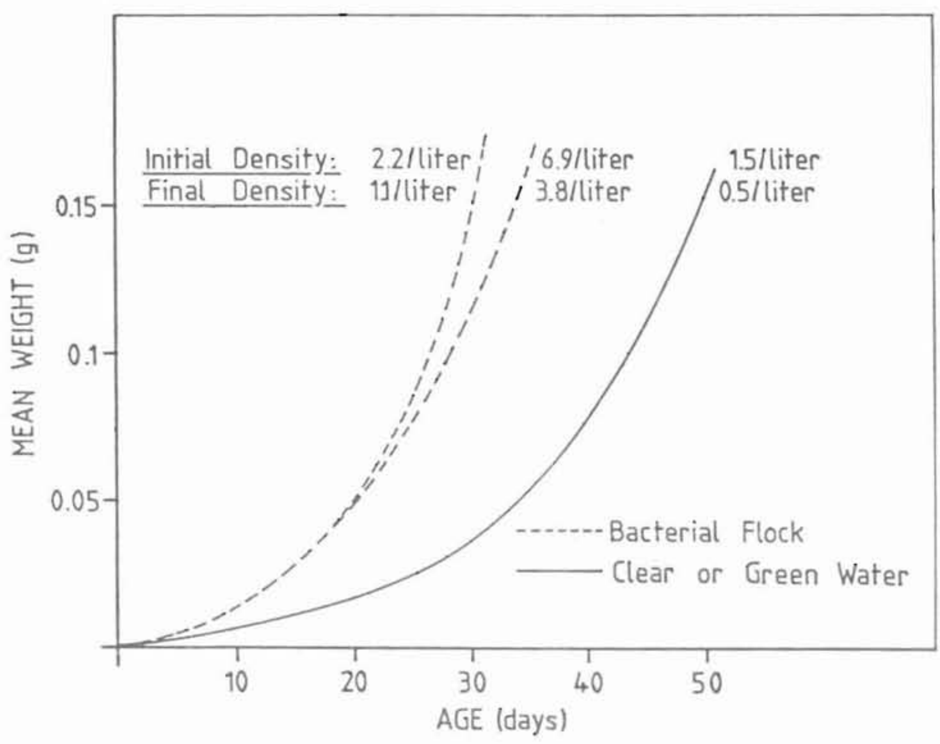


FIG.12 : P. indicus : initial growth curves at very high densities in two different mediums.

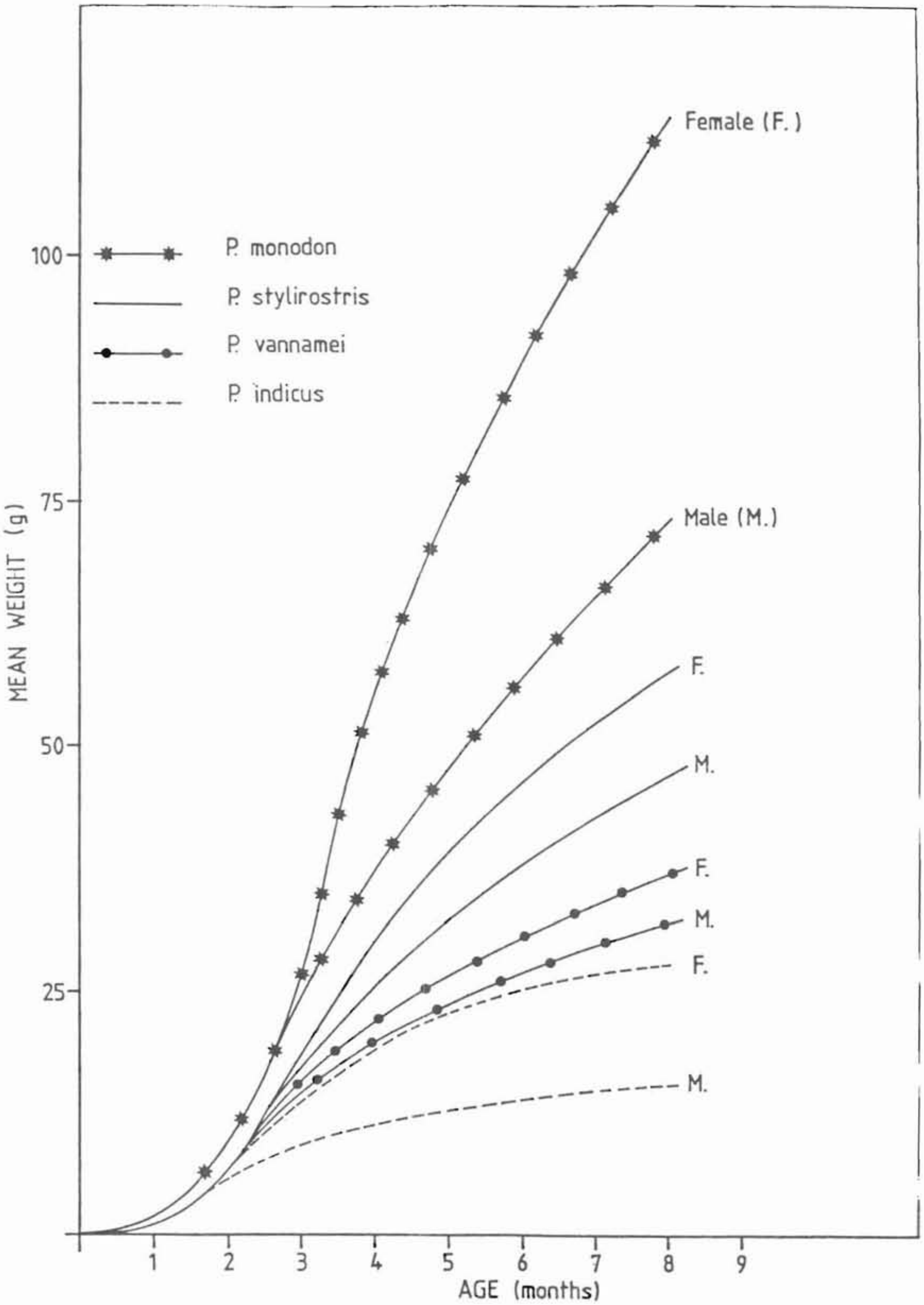


FIG.13 : Best growth curves of four species of penaeid reared at very low densities.

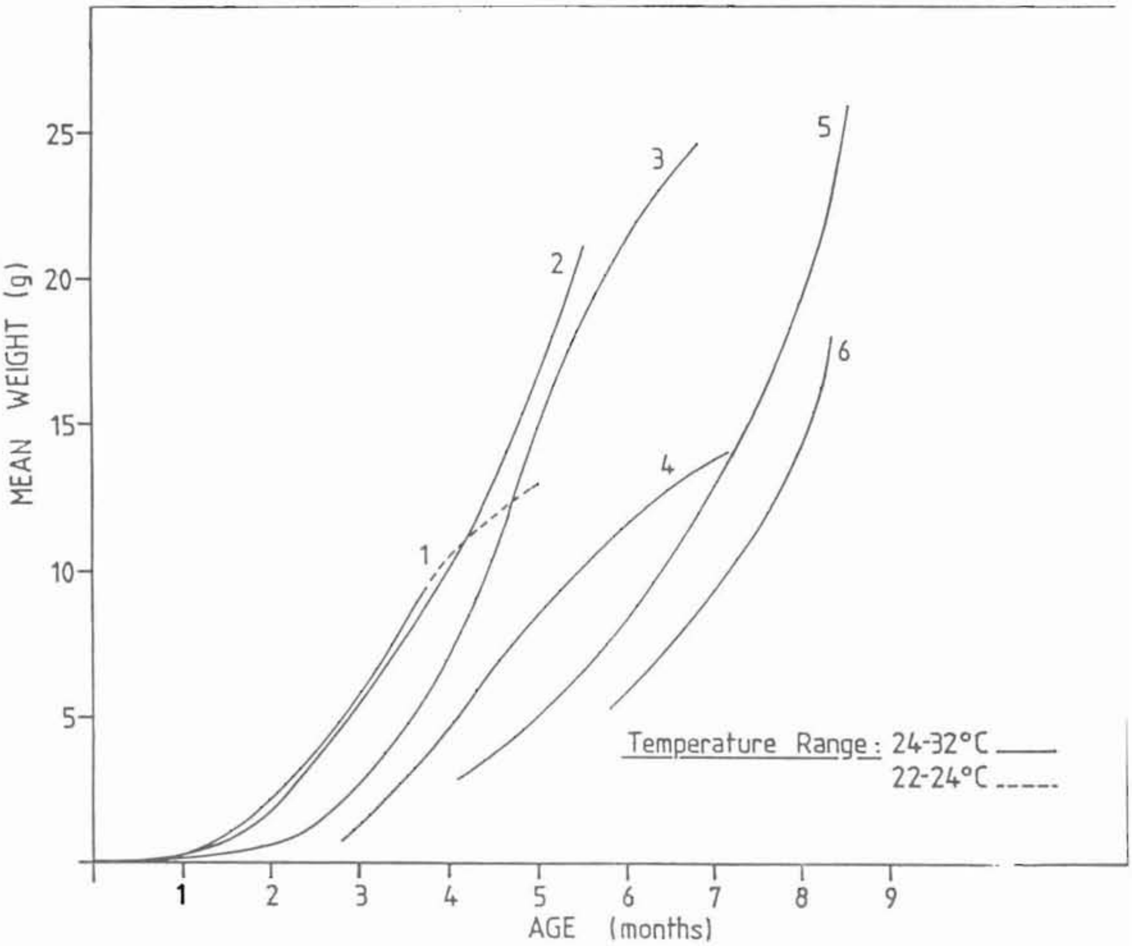


FIG.14 : *P. monodon* : growth curves in earth ponds.

Curve Number	Initial densities n° / m²	Final densities n° / m²	Yields T/ha/year	Conversion index
1	11	10	3.5	3.4
2	5.4	2.2	1.1	3.9
3	6	4	1.9	2.2
4	16	16	5.8	3.6
5	11	10	6.7	2.6
6	17	14	7.6	4.3

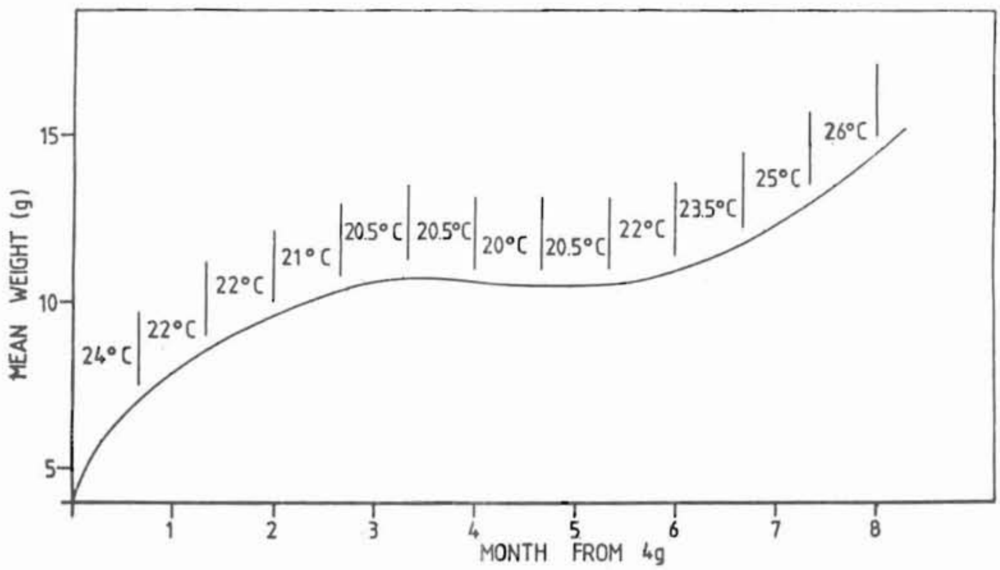


FIG.15 : *P. monodon* : effect of temperature on growth (initial densities : 18/m² ; Final densities : 12/m²).

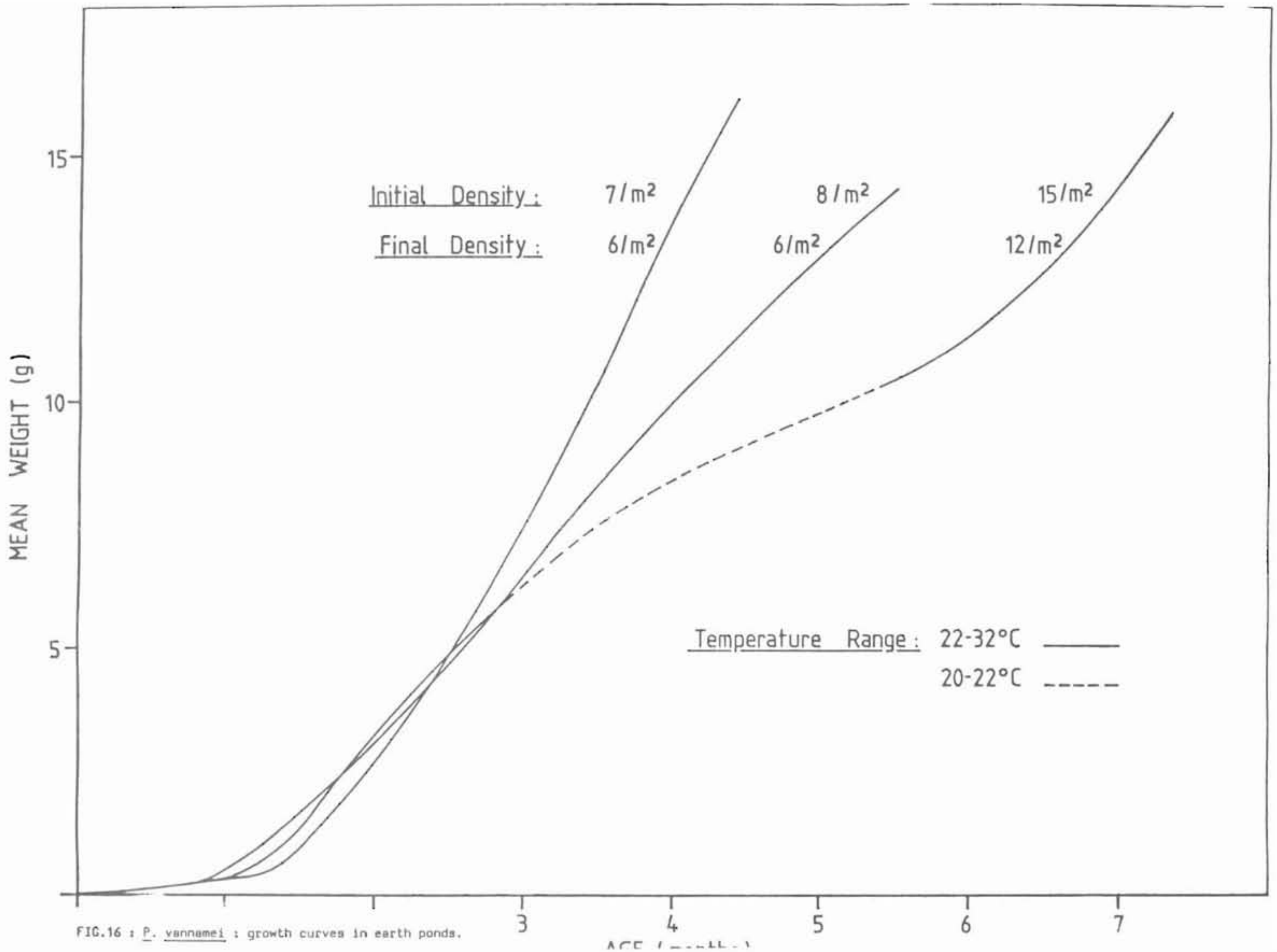


FIG.16 : P. vannamei : growth curves in earth ponds.

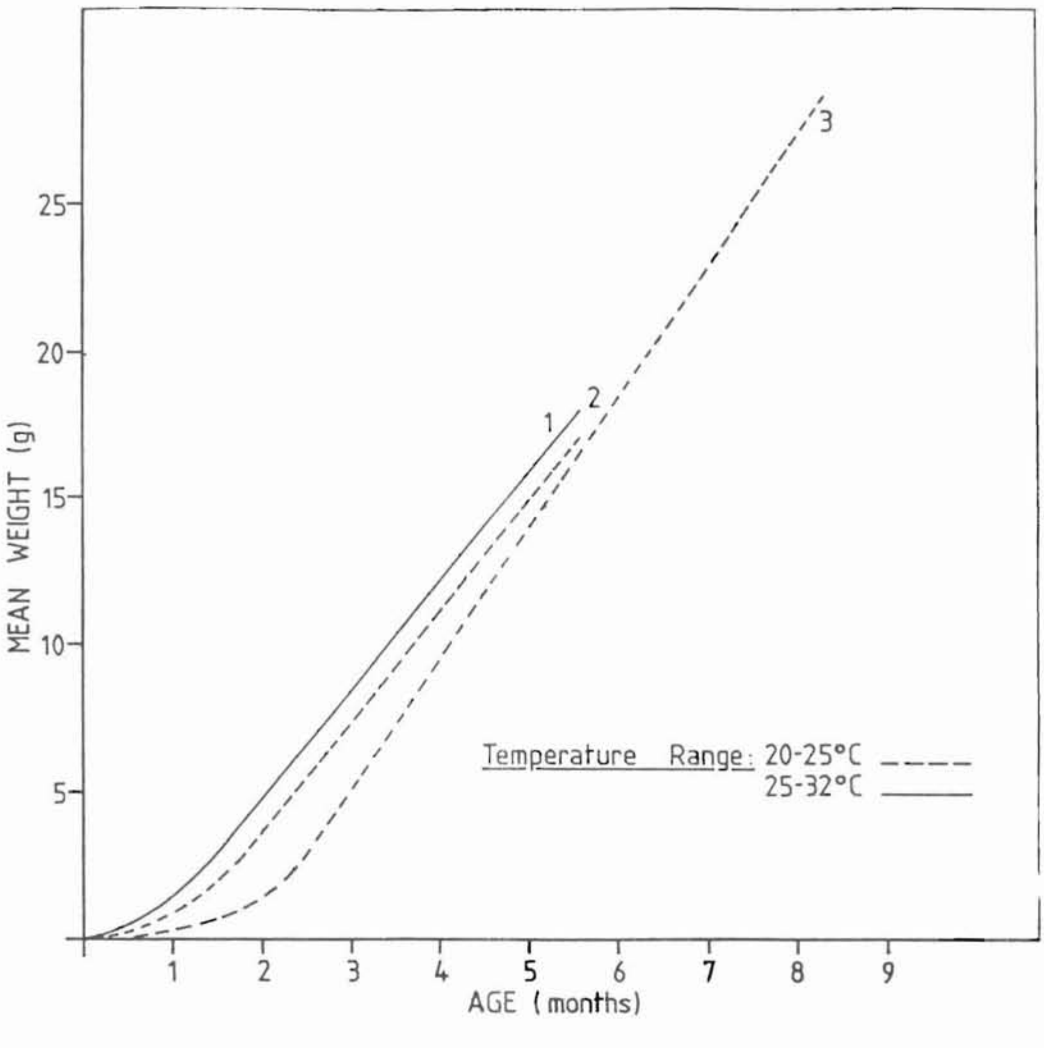
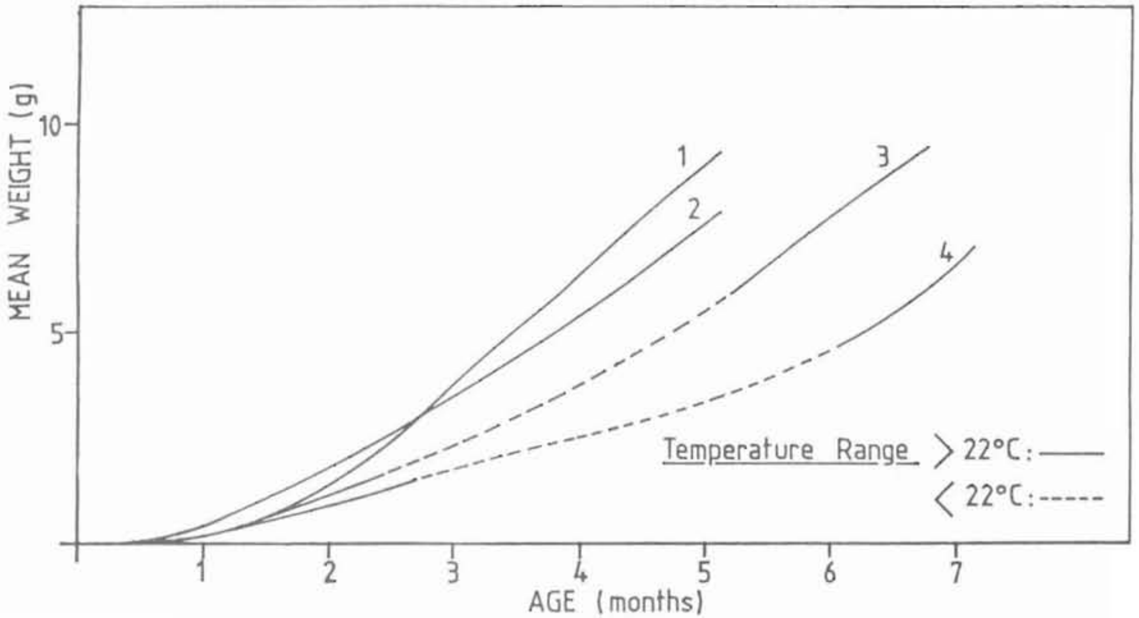


FIG.17 : P. stylirostris : growth curves in earth ponds.

FIG.18 : *P. indicus* : growth curves in earth ponds

Curve Number	Initial densities n° / m²	Final densities n° / m²	Yields T/ha/year	Conversion index
1	12.6	8.8	2.3	1.6
2	12	9	1.8	2
3	15.7	9.8	1.6	2
4	32	24	3.1	1.9



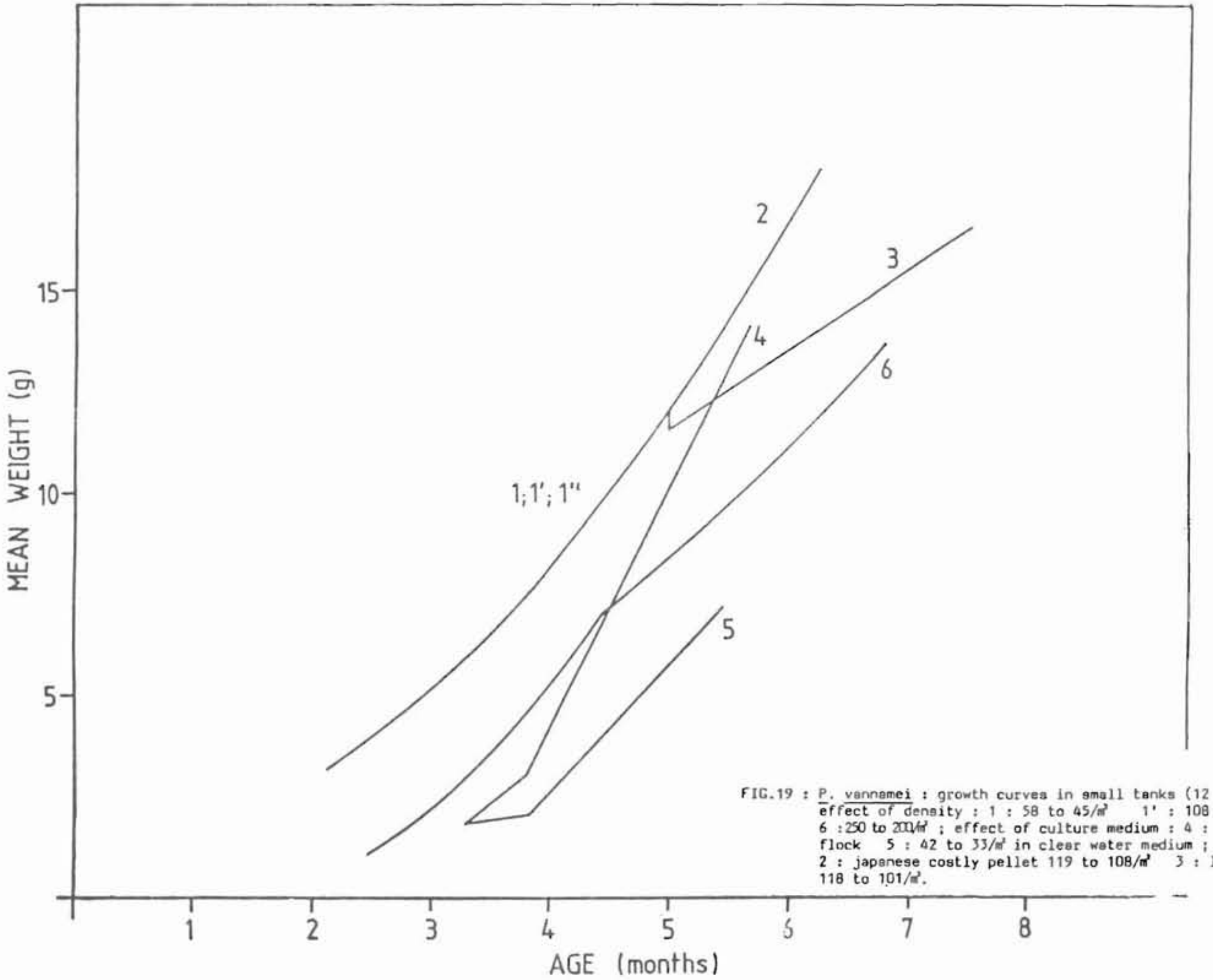
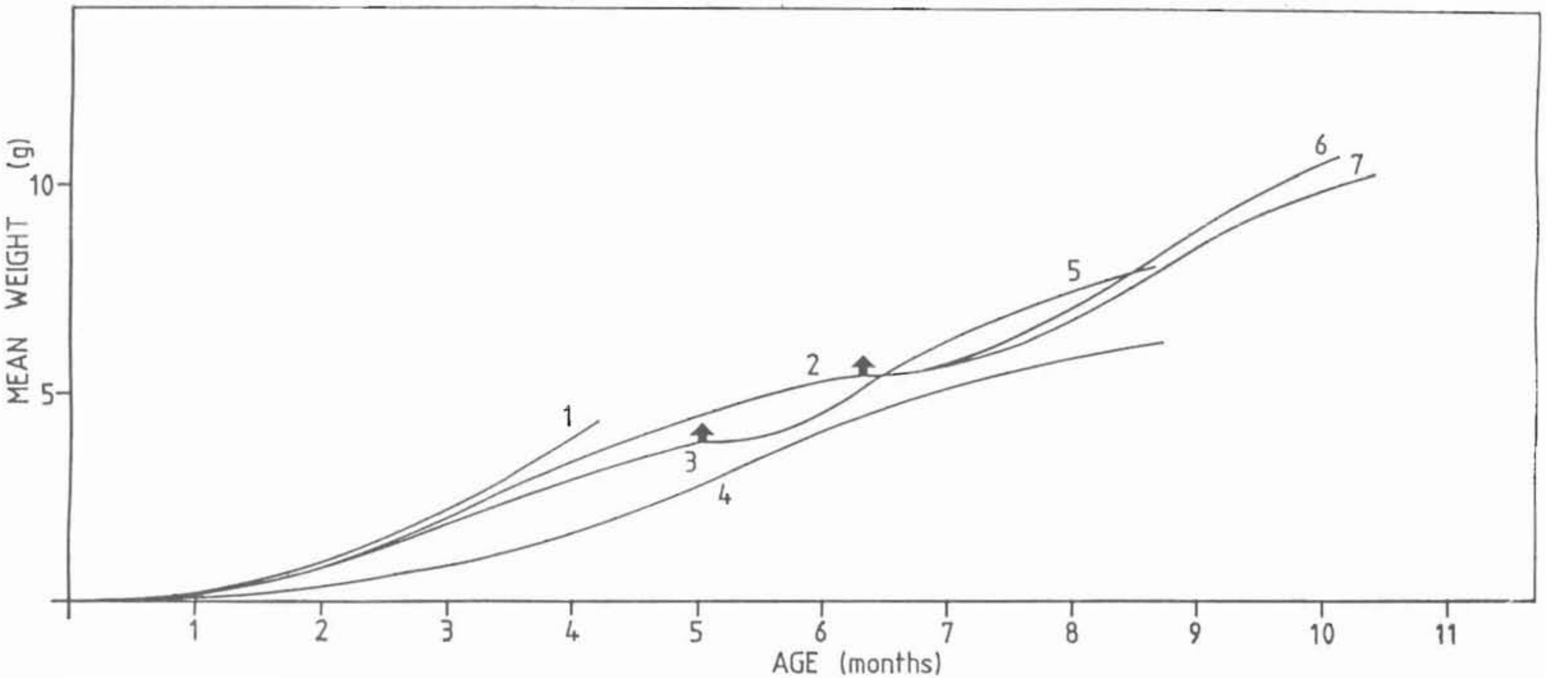


FIG.19 : *P. vannamei* : growth curves in small tanks (12 m^2) at high densities ; effect of density : 1 : 58 to 45/m^2 1' : 108 to 95/m^2 1'' : 167 to 102/m^2 6 : 250 to 200/m^2 ; effect of culture medium : 4 : 50 to 48/m^2 in bacterial flock 5 : 42 to 33/m^2 in clear water medium ; effect of food quality : 2 : japanese costly pellet 119 to 108/m^2 3 : local cheap pellet 118 to 101/m^2.

FIG.20 : P. indicus : growth curves in aerated ponds, with bacterial flock, at high densities.

Curve Number	Initial densities n° / m²	Final densities n° / m²	Yields T/ha/year	Conversion Index
1	204	137	17	2
2	336	193	20	3
3	515	384	36	2.5
4	171	123	15.5	3.5
5	134	123	15	5.5
6	108	101	15.5	4
7	103	89	10	5.5



Curve Number	Initial densities n° / m²	Final densities n° / m²	Yields T/ha/year	Conversion Index
1	126	44	17	3.5
2	125	71	16.6	2.8
3	71	37	6.1	5.4

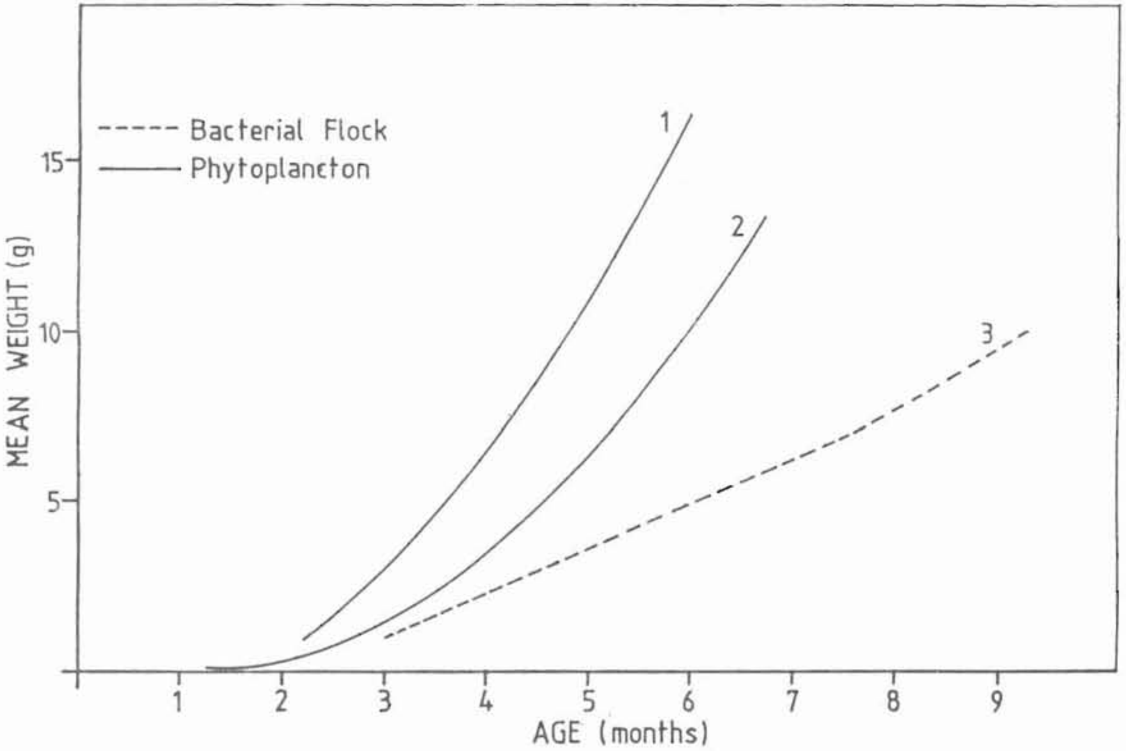


FIG.21 : P. monodon : growth curves at high densities in two different culture systems:(—— Ponds 1.8 deep, slightly aerated, epurated by phytoplankton mainly; (---- Ponds 0.9 deep, strongly aerated epurated by bacterial flock).

SPECIES	Densities No / m²	0.01	0.1	0.4	1.5	3	5	10	15	20
P. indicus	< 3	0					1 To 2			
	3 - 20	0				3	2.5	2.2	2	
	20 - 500	10	7	6	4.5	3.5	2.8	2.2	2	
	> 1/liter	20	10	7						
P. monodon	< 3	0					1 To 2			
	3 - 15	8	0		2		2.5	3		2.5
	15 - 40	8	5		4		3.5		2.8	2.5
	40 - 500	8	6	5	4	3.5	3			
	> 1 /liter	20	10	8						
P. stylirostris P. vannamei	< 3	0					1 To 2			
	3 - 15	8	0		3			2.5		2
	15 - 500	8	7	6	5	4	3.5		3	
	> 1 /liter	20	10	8						

TABLE 1 : Feeding tables in terms of species, densities and mean weight (per cent of biomass). Temperature range : 26 - 32 o C:

TABLE 2 : Good growth temperature ranges of different species of penaeid shrimp.

Species / Temperature	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34 °C
P. monodon							←	—	—	—	—	—	—	—	—	—	→
P. vannamei						←	—	—	—	—	—	—	—	—	—	→	
P. indicus					←	—	—	—	—	—	—	—	—	—	—	→	
P. merguiensis					←	—	—	—	—	—	—	—	—	—	—	→	
P. stylirostris			←	—	—	—	—	—	—	—	—	—	→				