

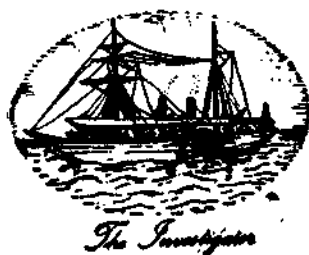
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INDUCED MATURATION OF PENAEID PRAWNS—A REVIEW

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ABSTRACT

For hatchery production of penaeid prawn seed a steady supply of spawners is essential for effective planning of the operations. The uncertainty of procuring spawners from the wild has stimulated world wide interest in the efforts to induce penaeid prawns to mature under controlled conditions. The methods employed, research results achieved and the constraints encountered are reviewed critically in this paper.

INTRODUCTION

With the rapid expansion of penaeid prawn culture in many countries of the world, the need for producing large quantities of quality prawn seed under controlled conditions is keenly felt and hatchery systems are being developed. The biggest constraint in the hatchery production of prawn seed is the non-availability of adequate number of spawners of the desired species as and when required. Apart from Japan where there is a well organised trade in the capture and transport of live adult *Penaeus japonicus* from the sea, the securing of ripe spawners for the hatcheries is an uncertain and costly operation. Hence the highest priority in penaeid prawn culture research is given to work on the reproduction of the prawns in captivity (Conte, 1978). Efforts have been made in the past 10 years to induce the penaeid prawns, which normally mature and spawn only in the sea, to attain maturity under captive conditions. These research efforts are reviewed in this paper.

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manuscript and offering valuable suggestions for improvement.

MATURATION IN CAPTIVITY WITHOUT EYESTALK ABLATION

Although *Metapenaeus bennette* is known to breed in land locked coastal lakes (Morris and Bennett, 1952), the only report of natural reproduction of a penaeid prawn in a man-made earthen pond is that of Lichatowich *et al.* (1978) who obtained 50,000 postlarvae of *P. merguensis* from a 0.2 ha pond filled with seawater filtered through a nitex mesh and stocked with adult prawns of this species. Silas *et al.* (MS) who collected mature females of *M. dobsoni* from the brackishwater culture ponds of the Prawn Culture Laboratory, Narakkal, Cochin, during the summer months when the salinity was 28-29 ppt, have made them spawn successfully in the laboratory and have reared the larvae using the pond water itself, thus proving that *M. dobsoni* can complete its life-cycle in the culture ponds during the high salinity months. However, no larvae have been collected from the pond itself so far.

A few instances of natural maturation and spawning of unablated, captive *P. monodon* in seawater ponds and tanks have been reported

by Chen (1976) and Liao (1977) from Taiwan, by Primavera *et al.* (1978) from the Philippines, by AQUACOP (1979) from Tahiti. In Japan *P. latisulcatus* has spawned viable eggs in captivity without eye ablation (Shokita, 1970). Ryther (1979) observed that in China *P. orientalis* routinely matures in captivity. Primavera (1978 b) mentioned that at the SEAFDEC laboratories *P. merguensis*, *P. indicus* and *Metapenaeus* spp. have attained natural maturity and spawned in 4 tonnes ferroceement tanks with running seawater facility. Patlan (1977, 1978 a, b, c) reported that at the Galveston Laboratories in the U.S.A. success has been achieved in making unablated *P. setiferus* attain maturity in circular tanks and raceways where the environmental parameters were rigidly controlled. Although many spawnings were obtained the eggs were not fertilized as the females were not impregnated. Private prawn farmers in Central and South America are said to have succeeded in maturing *P. vannamei* and *P. stylirostris* in seawater ponds (Anon, 1977). The details of environmental conditions under which these results were obtained are not available.

However, some well documented reports of natural maturation and spawning of unablated penaeids in land-based maturation tanks are available. Laubier and Laubier (1979) and Caubere *et al.* (1979) from France have made *P. japonicus* mature and spawn in large circular tanks with flowthrough seawater system, by step-wise increase of temperature and photoperiod. In Mexico, Moore *et al.* (1974) have obtained maturation and spawning of *P. californianus* in raceways covered with inflated polyethylene bubble canopy. AQUACOP (1975, 1977 b, 1979) in Tahiti have succeeded in making *P. merguensis*, *P. japonicus*, *P. stylirostris*, *P. vannamei* and *M. ensis* attain full maturity and spawn in circular fibreglass tanks with running seawater facility. At Conway in the U.K. Beard *et al.* (1977) have reared many generations of *P. merguensis*

in captivity in rectangular concrete tanks with subgravel filters. More details about these successful experiments are summarised in Table 1 and discussed in section 4 below.

INDUCED MATURATION THROUGH EYESTALK ABLATION

In many groups of decapod crustaceans the removal of eyestalks that contain the X-organ-sinus gland complex which produces and stores gonad inhibiting hormones has become a well recognised technique for inducing gonadal maturation (Adiyodi and Adiyodi, 1970). The application of this method in penaeid prawns was first started by Idyll (1971) and Caillouet (1973) in the U.S.A. on *Penaeus duorarum*. Bilateral eyestalk removal was also tried by Arnstein and Beard (1975) in the U. K. on *P. monodon* and *P. orientalis*, by AQUACOP (1975) in Tahiti on *P. aztecus*, by Santiago (1977) in Philippines on *P. monodon* and by Muthu and Laxminarayana (1980) on *P. indicus* and *P. monodon*. The results were identical in all these experiments: the initial mortality was very high but in the prawns that survived, full development of the gonads was observed within 5-14 days of eyestalk removal; however, spawning did not take place and the ovaries regressed gradually and the prawns died within a month; loss of balance and spiral swimming behaviour were also observed. The present authors also found that the colour of the ovary of bilaterally ablated females was pale and never attained the dark olive green colour seen in wild spawners. The only report of successful spawning of bilaterally ablated penaeid prawns is that of Alikunhi *et al.* (1976) from Indonesia who stated that *P. merguensis* and *P. monodon* spawned after bilateral eyestalk removal, the eggs of the former species even developing into normal postlarvae while the eggs of the latter were unfertilized.

Duronslet *et al.* (1975) using electron microscope to study the sequence of development of the oocytes in the ovary of bilaterally eyeablated and normal females of *P. aztecus* and *P. setiferus*, found that the process is identical in the experimental and normal individuals; but the ablated females after reaching full ovarian growth never spawned and the gonads regressed. Their most interesting observation, however, was that, although the oocytes from ablated animals demonstrated normal growth, they did not undergo meiosis. Unfortunately this important point has not been elaborated by them.

The high mortality and inability of the females to spawn after bilateral removal of eyestalks, prompted the research workers to abandon this method. After Arnstein and Beard (1975) found that full development of ovaries and good survival could be achieved in *P. orientalis*, *P. occidentalis* and *P. monodon* by the removal of only one eyestalk, unilateral eyestalk ablation was used successfully in many countries to induce maturation and spawning of captive penaeids (AQUACOP, 1977 a, 1979; Wear and Santiago, 1976; Santiago, 1977; Primavera, 1978, a, b; Primavera *et al.*, 1978; Primavera and Yap, 1979; Rodriguez, 1979; Halder, 1978, 1980; Muthu and Laxminarayana, 1979, 1980; Lumare, 1979). The results of these investigations are summarised in Table 2 and discussed in the following sections.

Methods of eyestalk removal: The simplest way is to cut the eyestalk near its base with a pair of sharp scissors (Arnstein and Beard, 1975; Lumare, 1979). However, this leads to profuse bleeding and in delicate species, such as *P. indicus* results in high mortality. Caillouet (1973) used a pair of scissors and immediately cauterised the wound with a pencil type soldering iron to avoid loss of blood. Muthu and Laxminarayana (1979, 1980) used a medical electrocautery apparatus to remove the eyestalk. In this method, while cutting the

eyestalk the wound is simultaneously sealed, resulting in cent percent survival. To simplify the ablation procedure, Primavera (1978 a) incised the eyeball with a sharp blade, allowed the fluid to ooze out and then squeezed the contents of the eyeball outwards between the thumb and forefinger and crushed the eyestalk 2-3 times to destroy the tissue. For rapid ablation of large numbers of *P. monodon* for stocking in marine pens, Rodriguez (1979) simply squeezed out the contents of the eyeball and crushed the eyestalk by pressing between the fingers. This method is suitable only for hardy species like *P. monodon*. The present authors encountered heavy mortality in *P. indicus* ablated by this method.

Latency period: The time taken by the females to attain full maturity after eyestalk ablation varies considerably (Table 2.) Maturation appears to be faster (5-10 days) in white prawns such as *P. merguensis*, *P. indicus*, *P. vannamei* and *P. stylirostris*, than in *P. monodon* and *P. aztecus* (average 3 weeks). It also appears to depend upon the season. Lumare (1979) found that ablated *P. kerathurus* kept at a constant temperature of 25°C took 43-69 days to attain maturity during November-December; 30 days in March and only 10 days in May-June *i.e.*, they appear to mature faster as their natural breeding season is approached. Size also appears to have a bearing on the time taken to attain maturity; the larger ones which are perhaps physiologically ready for maturation respond to the eyestalk ablation treatment faster than the smaller ones.

Rematuration: Ablated female prawns repeatedly remature and spawn viable eggs. Tagging of ablated female *P. monodon* at the SEAFDEC, Philippines showed that of a given number of females that spawned once, 14% spawned a second time, 3% a third time and 0.8% a fourth time (Primavera, 1978 b). A subsequent spawning may take place as quickly as 3-5 days after the preceding one (Primavera and

Borlongon, 1978 ; Primavera *et al.*, 1979). In Tahiti, AQUACOP (1979) reported that six *P. monodon* gave 18 spawnings in three months ; one of them spawned 3 times within 2 weeks without moulting. Lumare (1979) observed that *P. kerathurus* spawned upto 8 times after eyestalk ablation at intervals of less than 10 days ; no reduction in the number of eggs was noticed with repeated spawning. The present authors found that one ablated *P. indicus* spawned 5 times at intervals of 13, 12, 11, 18 and 26 days, although viable nauplii were obtained only on one occasion.

Impregnation : It is well-known that in penaeid prawns mating and spawning are independent processes. Under natural conditions mating in the case of penaeids with closed thelycum takes place between a hard (intermoult) male and a soft (freshly moulted) female which stores the spermatophore received from the male in its thelycum. Spawning takes place in the absence of the male, the female herself releasing the sperms from the thelycum at the time of oviposition. So, for obtaining fertilized eggs the female should be impregnated. But in captivity an unimpregnated female can be induced to mature and spawn after eyestalk ablation, but the eggs won't be fertilized. To avoid this, ablation of eyestalk should be done on impregnated females only. Hence making the prawns mate successfully in captivity is as important as inducing the females to develop the ovary. In actual practice it is easier to achieve the latter than the former (Arnstein and Beard, 1975; Patlan, 1977, 1978 a, b, c). It is especially difficult in the penaeids such as *P. setiferus*, *P. vannamei* and *P. stylirostris*. AQUACOP (1979) found that the percentage of impregnated females could be increased by keeping the males and females in separate tanks and introducing only the ripe females into the male tank. Separation seems to increase the attraction between the sexes. Perhaps even in the penaeids with closed thelycum the impregnation rate could be improved,

by keeping the males and females in separate tanks and introducing the female which is about to moult, into the male tank.

FACTORS THAT AFFECT THE MATURATION PROCESS

The physiological and environmental factors that influence maturation in penaeid prawns are discussed here.

Eyestalk principle : The fact that bilateral eyestalk ablation usually does not lead to spawning and our observation that the ovary of the bilaterally ablated female is pale in colour suggest that the eye is in some way necessary for normal ovarian growth and for triggering the spawning reflex. Maturation of ovaries is said to be stimulated by the gonad stimulating hormones secreted by the brain and the thoracic ganglia and inhibited by the Gonad Inhibiting Hormone (GIH) of the eyestalk (Adiyodi and Adiyodi, 1970). But the very fact that, in nature, the prawn is able to mature and spawn with both eyes intact suggests that the antagonism of the eyestalk principle may be reduced by a decline in the titre of the GIH as the prawn grows and moves into an environment suitable for spawning and the final spawning act may, in fact, be triggered by a stimulus, either visual or hormonal, originating in the eyestalk. In unilateral eyestalk ablation the titre of the GIH is artificially lowered and this appears to stimulate vitellogenesis.

Age : Successful maturation and spawning of *P. monodon* was obtained by ablating females that were 15 months old (Santiago, 1977), 8 month old (AQUACOP, 1977) and 5 months old (Primavera, 1978 a). However, the quality of the eggs produced by the 5 month old pond-reared females is considered to be inferior to the eggs produced by 1-2 year old wild females (Primavera, per. comm.) Females of the same size differ widely in age, depending upon the conditions under which they have

grown (Primavera, 1978 b). She feels that given the same body size (minimum of 90 gm) wild females are older and therefore more responsive to induced maturation than pond reared females at normal harvest age of 4-5 months. However, the age at which the females mature in captivity varies with the species. AQUACOP (1975) found that *P. merguensis* spawned after 4-5 months, *Metapenaeus ensis* after 8 months and *P. japonicus* and *P. aztecus* after one year. Beard *et al.* (1977) reported that the age of female *P. merguensis* at first maturation was 6-7 months.

Food: Caillouet (1973) fed unablated *P. duorarum* with diets to which additives such as beta carotene, phosphatidylcholine, cholesterol, DL alpha tocopherol, calciferol and 17 beta estradiol were added; but the prawns did not attain maturity.

In most of the successful experiments (Table 1, 2) the captive broodstock has been fed *ad libitum* on fresh mussel, oyster or clam flesh. However, Primavera *et al.* (1979) reported that better results were obtained when the prawns were fed mussel flesh in the morning and pelletised feed in the evening. AQUACOP (1979) observed that among the different compounded pellets tested, the best ones were high protein diets (60%) containing squid meal. They also reported that if the females are isolated and allowed to complete the ovarian development in separate tanks where a supplement of fresh Trocha flesh is given, the quality of the eggs spawned is much better. Molluscan flesh in some way seems to be good for gonad development. The present authors have observed that the visceral masses of the clams used for feeding the brood stock, generally contain developing gonads which probably provide the right type of fatty acids and lipoproteins essential for vitellogenesis in the maturing prawns.

Stress: Any sort of physiological stress, due to overcrowding, frequent handling or

poor water quality, delays the maturation process or causes regression of developed ovaries. *P. monodon* is especially sensitive in this respect (AQUACOP, 1979). To reduce handling stress while checking the prawns for determining the stage of maturation, the prawns are examined at night using an underwater flashlight tied to a pole and held close to the prawn so that the light strikes perpendicular to the upper part of the body when the dark green, mature ovaries show up very well (Primavera, 1978 b; AQUACOP, 1979).

From Table 1 and 2 the stocking density in the maturation tanks is found to vary from 3-7 animals per m². The lower density is preferred for the larger species such as *P. monodon*. The highest density used was 20/m² in the case of the small sized *P. merguensis* in Tahiti. AQUACOP (1979) report that in their broodstock tanks maturations are rare and spawning does not occur if the biomass of prawns in the tanks exceeds 300 gm/m².

Poor water quality in ill maintained pools is a major source of stress to the prawns. If the uneaten food, moults, and faecal matter in the pools are not removed daily, the water quality deteriorates rapidly as decay of these substances, apart from releasing toxic substances, increases the biological oxygen demand of the water. Under such circumstances the intake of food by the prawns declines markedly (personal observations). Another source of stress is the accumulation of the toxic ammonia excreted by the prawns themselves. Ammonia toxicity in penaeid prawns has been studied by Wickins (1976 a) who states that the maximum acceptable level of ammonia concentration is 0.1 mg NH₃-N/ litre. This value may apply to normal maintenance and growth of prawns in culture systems but a still lower ammonia level may be required by the prawns for successful maturation. All the recirculating systems and flowthrough facilities referred to in Tables 1 and 2 are mainly designed to prevent

TABLE 1. Summary of results of experiments on maturation of penaeid prawns in captivity without eyestalk ablation

Authors	Type and size of the container	Water management	Stocking density Nos/m ²	Sex ratio M:F	Temp. (°C)	Salinity (‰)	pH	Light	Feed	Species	Time taken to reach maturity
AQUACOP (1975, 1977 b, 1979)	4m dia. Fibreglass tanks with 1 m water depth. Water fed through perforated concentric PVC tubes embedded in gravel bottom and covered with coral sand; water drained through central stand pipe.	Flow-through water exchange rate 2-3 times/day	20 for <i>P. merguinesis</i> and <i>M. ensis</i> 6.6 for <i>P. vannamnei</i> and <i>P. stylirostris</i>	1:3 or 1:1	25.5 to 29.0	34.5	8.2	Natural daylight. Tanks covered with synthetic material to allow only 10 to 40% of incident light.	Pelletised feed supplemented with squid flesh	<i>P. merguinesis</i> <i>P. japonicus</i> <i>P. stylirostris</i> <i>P. vannamnei</i> <i>M. ensis</i>	3-4 weeks
Beard et al. (1977)	Concrete tank 2.9 x 1.65 x 0.3 m inside a heated hut with clear PVC roof. Half the bottom area covered with a sub-gravel filter with air-lift recirculation	50% of water renewed each week	5	1:1 or 1:2	25 to 31	30-36	7.5 to 8.5	1000 to 3,000 lumens per m ²	Fresh mussel and frozen shrimp	<i>P. merguinesis</i>	Repeated spawning every 2.6 months
Caubere et al. (1979)	5 m dia. concrete tank with 1.2 m water depth. Provided with air-lift recirculation and double bottom	Flowthrough at 200 litres per hour	4	1:3	Step-wise increase from 15 to 24 over a 3 month period	30.5 to 36.0	7.5 to 8.5	4,000 lux step-wise increase from 8 to 16 hrs/day over a 3 month period	Fresh oysters and mussels	<i>P. japonicus</i>	3 months
Laubier and Laubier (1979)	2.9 m concrete tank; 1 m water depth; with double bottom and air-lift recirculation	Flowthrough at 450 litres per hr. exchange rate 150% per day	7.5	1:1	Increased from 15°C on 21st Apr. to 24 on 21st June	sea-water	8.1 to 8.3	2,000-6,000 lux., photo-period increased from 12½ to 14½ hrs/day over a period of 11 weeks	Fresh mussel	<i>P. japonicus</i>	3 months
Moore et al. (1974)	23 x 3 x 0.6 m raceway under inflated polyethylene bubble canopy	Flowthrough exchange rate 700% per day	6.4	1:1.6	22-28	sea-water	8.0 to 8.3	20% of natural light	Flaked food	<i>P. californianus</i>	4 months

TABLE 2. Summary of results of experiments on captive broodstock after unilateral eyestalk ablation

Authors	Type and size of containers	Water management	Stocking density Nos/m ²	Sex ratio M : F	Temp. (°C)	Salinity (‰)	pH	Light	Feed	Species	Time taken to reach maturity after eyestalk ablation (days)
AQUACOP (1977 a, 1979)	Same as AQUACOP (1975) vide Table 1	Flowthrough water exchange 2-3 times/day	3.3	1 : 1	25.5 to 29.0	34.5	8.2	Natural day light 10-40% of incident light	pelletised feed	<i>P. monodon</i>	21-28
Arnstein and Beard (1975)	Rectangular fibreglass tanks, 86 × 76 × 25 cm ; with subgravel filter and air-lift recirculation at 8-9 litres/minute	50% of water replaced every week	6	1 : 1	20+2	28-30		Subdued artificial light ; photoperiod 8 hrs/day	Fresh mussel and frozen Crangon	<i>P. orientalis</i>	12-14
Halder (1978, 1980)	Nylon net cages kept in a 200 m ² brackishwater ponds 2 m deep	Flushed by tides	..	1.6 : 1	Increased from 22.4 to 26.4	Increased from 15 to 25		Natural daylight	Prawns and trash fish	<i>P. monodon</i>	40
Lumare (1979)	2 × 2 × 1 m cement tank, with subsand filter, kept in a green house, recirculation at 6 times water vol. in 24 hrs.	1/3rd of water replaced everyday	10 to 15	1 : 1.1 to 1 : 5.9	25	36	7.8 average	Natural daylight and photoperiod	fresh mussel	<i>P. kerathurus</i>	43-69 in Nov-Dec./ 30 in Mar., 10 in May-June.

Muthu and Laxminarayana (1979, 1980)	3.6 m dia. plastic lined pools with subgravel filter and air-lift recirculation	Water changed when the clarity declines	5	1 : 1	24.5 to 30.2	27.0 to 36.0	average 7.9	Natural daylight inside a tile covered shed without side walls	fresh and frozen clam meat	<i>P. indicus</i> <i>P. monodon</i> <i>M. dobsoni</i> <i>Parapenaeopsis stylifera</i>	10-16
Primavera (1978 b)	4 m. dia. ferrocement tank 1-1.5 m water depth (Tolosa, 1978)	Flowthrough water exchange rate 2-4 times/day	4-7	1 : 1 or 1 : 2	tanks covered with black cloth so that light intensity is reduced by 40% to 60%	Mussel flesh in the morning and pellets in the evening	<i>P. monodon</i>	7 days to 2-3 months av. 21
Primavera (1978 a)	Concrete tanks 4.85 × 4.85 × 1 m under transparent plastic roof. Aeration by air stones	Water changed only once a week	4	1 : 1	23.8 to 26.2	30-34	7.8 to 8.1	Natural light filtering through plastic roofing	Fresh mussel flesh	5 months old pond reared <i>P. monodon</i>	21
Primavera et al. (1978)	Concrete tanks 7.25 × 7.25 × 1 m under transparent plastic roof	Flowthrough tank emptied and water completely changed every 5-6 days	7	1 : 1	23.5 to 26.8	30-34	7.8 to 8.0	-do-	-do-	<i>P. monodon</i>	11-25
Wear and Santiago (1976), Santiago (1977), Rodriguez (1979)	250 m ² marine pens in a sheltered tidal cove in 4-6 m depth	flushed by the tides	1,2 to 1.6	1 : 1 or 1 : 2	27.1 to 30.7	31.5 to 34.6	—	Natural daylight	-do-	<i>P. monodon</i>	7-60

the accumulation of ammonia and to maintain the quality of the seawater in the pools. The recirculating systems employ some form of biological filter which aerobically oxidizes ammonia to harmless nitrates through the action of the nitrifying bacteria growing on the surface of the filter material (Spotte, 1970). Vigorous aeration is used to maintain the oxygen concentration in the pools at near saturation levels and to operate the air lifts in the recirculation systems.

Salinity: The fact that penaeid prawns which live as juveniles in brackishwaters migrate to the sea for spawning purposes, suggests that salinity is one of the important factors that affect the maturation process. This is supported by the observation of Silas *et al.* (MS) that *M. dobsoni* attains full maturity in the brackishwater ponds when the salinity increases to 28-29 ppt. Even *P. indicus* in stage III of maturity have been collected by George (1974) from the brackishwater ponds during the high salinity months. From Tables 1 and 2 it is seen that the penaeids have attained full maturity and spawned in salinities ranging from 27-36 ppt. The only exception was reported by Halder (1978, 1980) who stated that ablated *P. monodon* attained maturity and spawned viable eggs in a brackishwater environment when the salinity was 25 ppt.

pH: Best results were obtained when oceanic water at a steady pH of 8.2 was continuously made to flow through the maturation pools (AQUACOP, 1975, 1977 a 1979). In recirculation systems pH declines rapidly due to the physiological activity of the organisms present in the pool and may become a limiting factor when it reaches 7.3 (Wickins, 1976 a). Reduction in pH and depletion of inorganic carbon in the water, which is said to affect the calcification of the cuticle and the normal moulting process, are direct consequences of bacterial nitrification of ammonia to nitrates in a biological filter (Wickins, 1976 b).

So a completely closed system of recirculation is not feasible; at least part of the water has to be replaced by fresh seawater periodically or required amounts of sodium carbonate or bicarbonate should be added regularly to maintain the quality of the water.

Temperature: Laubier and Laubier (1979) kept *P. japonicus* in three different tanks in which the temperature was increased from 15 to 20°C, 15 to 24°C and 15 to 26°C respectively over a period of 11 weeks and found that the largest number of spawnings occurred in the tank having a temperature of 24°C. Caubere *et al.* (1979) showed that if the temperature is increased from 15 to 24°C over a period of 3 months, maturation was accelerated and spawnings took place after 3 months, whereas in a tank where the temperature was allowed to increase naturally from 15 to 24°C over a 6 month period the maturation process was delayed and spawning occurred only after 6 months. It is significant that these two experiments were performed in sub-tropical region. In the tropics temperature does not appear to be a limiting factor and penaeids had attained maturity in temperatures ranging from 22°C to 31°C (Table 1 and 2).

Light: The influence of photoperiod on maturation of unabladed *P. japonicus* has been studied by Laubier and Laubier (1979) and Caubere *et al.* (1979) and in unilaterally abladed *P. kerathurus* by Lumare (1979). Laubier and Laubier (1979) found that more spawnings occurred in a tank where the light period was increased from 12½ hours/day to 14½ hrs/day over a period of 11 weeks. Caubere *et al.* (1979) observed that best maturation and spawning occurred when the light period was increased from 8 hrs/day to 16 hrs/day over a 3 months period. However, in these two experiments the temperature was also gradually increased over the same period from 15°C to 24°C. So it cannot be assessed whether the accelerated development of gonads

was due to increase in photoperiod or due to increase in temperature. However, Lupare's (1979) experiment in which the temperature was kept constant at 25°C and the photoperiod varied, suggests that increase in photoperiod from 13 hrs/day in March to 16 hrs/day in May-June might have accelerated the maturation process. Even here the evidence is not conclusive since the difference in the seasons might have influenced the results, as May-June was their natural spawning season. This doubt is further strengthened by the fact that during Nov.-Dec. maturation was faster at 9 hrs of light/day than at 12 hrs of light/day. So the effect of photoperiod on maturation is not fully understood.

On the other hand there seems to be sufficient evidence to conclude that a reduction in the intensity of the light to about 10% of natural day light has a beneficial effect on the maturation process (Table 1, 2).

Caillouet (1973) studied the effect of coloured light on maturation in unablated *P. duorum* and got negative results with blue, green and white light. Alava (1979) experimented with blue, red and natural light on unablated *P. monodon* and found that they did not attain full maturity in any light; however, under blue and natural light prawns with stage III ovaries were obtained while those exposed to red light reached only stage II.

Pressure : Only Caubere *et al.* (1979) have tried to study the effect of pressure on spawning. Mature females subjected to a pressure of 2.5 kg/cm² for 12 hrs spawned. But mature females spawned even without subjecting them to increased pressure. Pressure does not appear to have any effect on the maturation process either, since Beard *et al.* (1977) have obtained full maturation of gonad in unablated *P. merguensis* grown in a tank with only 0.3 m depth of seawater.

Size of the maturation pool : The present authors found that ablated *P. indicus* and *P. monodon* did not attain maturity when kept in 1.8 m dia pools whereas they matured well in 3.6 m dia pools. Primavera (1979) opined that the mating behaviour of *P. monodon* calls for a large pool with sufficient area for swimming about freely, if impregnation is to take place normally. Arnstein and Beard (1975) also found that although *P. orientalis* attained maturity in 0.6 m² fibreglass tanks, they were not impregnated. Good results have been attained in maturation tanks which exceeded 4 m² in area (Table 1, 2). The large marine pens used in Philippines for maturation of ablated *P. monodon* are no doubt very good. But the difficulty of getting a suitable sheltered site for constructing the pens near a hatchery and the short life of the bamboo pens and the consequent high cost of frequent renewals and the difficulties involved in sampling the prawns from the pens, are some of the disadvantages that make this system less popular. On the other hand the land based maturation facilities referred to in Tables 1 and 2 can form part of the hatchery, making use of its aeration and seawater pumping facilities.

CONCLUSION

It is now evident that many penaeids can be made to mature and spawn in captivity without eyestalk ablation in raceways and concrete tanks with running seawater facility or in open recirculating seawater systems. It is essential that the water quality be maintained as close to that of good open seawater as possible. Some of the species which do not easily attain maturity in captivity can be induced to mature by unilateral eyestalk ablation. Some basic information on the factors that affect the maturation of the ovary are available. However, more research is needed to understand (i) the hormonal control of maturation in penaeid prawns, (ii) the effect of dietary factors on maturation.

(iii) the factors that promote mating in captivity and (iv) the effect of photoperiod on reproduction. Technological improvements to reduce the cost of construction of the maturation pools, seawater supply systems and water purification systems are also urgently needed.

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