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FECUNDITY OF THREE SPECIES OF PENAEID SHRIMPS, *PENAEUS MONODON* (FABRICIUS, 1798), *PENAEUS INDICUS* (H. MILNE-EDWARDS, 1837) AND *PENAEUS JAPONICUS* (BATE, 1888) OF KARACHI COAST, PAKISTAN

Farzana Yousuf, Sergio Chazaro-Olvera and Noor-Ul-Ain
Department of Zoology, University of Karachi, Karachi-75270, Pakistan (FY, NA);
Laboratorio de Ecología de Crustáceos, Facultad de Estudios Superiores Iztacala,
Universidad Nacional Autónoma de México, Avenida de los Barrios Num. 1,
Los Reyes Iztacala, Tlanepantla, Estado de México, México,
Código Postal 54090, Apartado postal (SC)
E-mail : Farzanaseth@yahoo.com

ABSTRACT: In order to define the period of maturity of penaeid shrimps at least three indices (fecundity, size structure and density of mature females) are required. During the present study the relationships between fecundity and total length, carapace length, ovary length, body weight and ovary weight of three species of Penaeid shrimps, *Penaeus (Fenneropenaeus) indicus*, *Penaeus (Marsupenaeus) japonicus* and *Penaeus (Penaeus) monodon* were found out. Samples of shrimps were collected from fish market, identified to the species level, morphometric measurements of each individual were recorded and the fecundity of each developed shrimp was estimated.

The relationship between body weight and fecundity and between body length and fecundity were linear in all three species. The result indicated positive strong correlation between total length (size) and fecundity in all three species. Positive strong correlations were observed between carapace length and the fecundity, ovary length and fecundity, body weight and fecundity and ovary weight and fecundity in *P. indicus* and *P. monodon* while *Penaeus japonicus* showed moderate positive correlations between all mentioned morphometric parameters and fecundity.

There was a strong correlation between fecundity and body length in *Penaeus japonicus* (r =0.880), fecundity and ovary weight in *Penaeus indicus* (r = 0.943) and fecundity and carapace length in *Penaeus monodon* (r = 0.970). The estimated fecundity of *Penaeus indicus* varied between 989073.36 to 1380581.565 eggs for body length range 14.4 to 20.1 cm while that of *Penaeus japonicus* varied between 249602.2609 to 320026.71 eggs for length range 15.4 to 19.4 cm and fecundity of *Penaeus monodon*, with body length range 14.4 to 21.1 cm, varied between 221271.6 to 400296.288 eggs.

KEY WORDS: Fecundity, *Penaeus monodon, Penaeus japonicus* and *Penaeus indicus.*

INTRODUCTION

About twenty seven species of Penaeid shrimps belonging to seven genera have been reported from the coast of Pakistan (Gololobov and Grobov, 1969; Tirmizi and Bashir, 1973; Ahmed, 1985). The fisheries industry of Pakistan recognizes three categories of shrimps, popularly known as Jaira (largest, reaching 203 mm in length) Kalri and Kiddi (smallest, 76 to 102mm in length). They are designated as such on the basis of color, size and market value.

Fecundity has long been recognized as an ecologically important aspect of the population and life history studies of any species. Estimating fecundity in crustaceans, either in terms of egg number or egg mass volume, can become a very tedious and time consuming procedure, and any simplification of these processes would be advantageous in reproductive studies.

Fecundity is a phenotypic characteristic that is affected by numerous factors and intensities of specific features of different environments (Hines, 1991) and according to Nazari *et al*. (2003), its variation among species may enable species coexistence. The evaluation of fecundity becomes necessary because it is considered a measure of the reproductive fitness of crustaceans (Nazari *et al*., 2003) and is directly influenced by natural selection. Information on the fecundity**-** body size relationship of a species is important for understanding its population dynamics. Fecundity data can be combined with data on the size frequency distribution of the population, the size at onset of maturity, and the proportions mature over the size range to develop egg-per-recruit models and to estimate relative population fecundity. The results of such models can be used to assess effects of changes in the minimum legal size to capture and exploitation rate on the egg production of the population. Furthermore, fecundity, as well as breeding frequency, are characteristics that are directly related to the life strategy of a species (Oh and Hartnoll, 2004). Five stages of maturity of ovary have been observed. It is evident that a female is capable of producing several brood of eggs. **(**Subrahmanyam, 1965). According to Rao (1968) the number of eggs produced differs according to the size of the shrimp in linear logarithmic form. Fecundity was shown to be dependent on spawning technique, female size and whether the spawner was wild or domestic**. (**Emmerson, 1980). Fecundity was found to vary significantly with the size of the individual. **(**Penn, 1980). Positive correlation between the size of spawner and the fecundity and hatching percentage in *Penaeus monodon* were observed by Babu, M. *et al.* (2001)**.** A relationship between color of ovaries and histological stages of ovarian development was established. A female shrimp with a dark-green ovary is an indication of the ready**-** to-spawn condition. **(**Ayub and Ahmed, 1992). Fecundity increased with the size of shrimp (Teikwa, E. D. and Mgaya, Y. D. 2003).

The objectives of this study were to estimate fecundity of *Penaeus indicus, Penaeus monodon* and *Penaeus japonicus* of different body sizes and to find out the relationships of fecundity to total length, carapace length, ovary length, body weight and ovary weight. Since there is magian information available on the fecundity of penaeid shrimps of Pakistan, hence the present study would be a good edition on the topic.

MATERIALS AND METHODS

Specimens for the study were obtained once a month, (April to December, 2008). Most of the specimens were obtained from the Karachi fish harbour usually at the time of landing. Specimens brought to the laboratory in plastic bags which contained ice cubes.
In the laboratory, shrimps were sorted into species and identified according to Tirmizi and Bashir, (1973) and Bianchi (1985). Carapace length, total length were measured to

the nearest 1mm. Measurements were made with the help of cotton thread and an ordinary measuring rule. Carapace length was measured as the distance from the inside of the eye socket to the centre of the dorsal margin of the carapace, whereas total length was measured as the distance from the inside of the eye socket to the end of the telson. Excess moisture of freshly collected specimens was removed by blotting them with a paper towel and weight of each specimen was noted.

Ovary Examination:

After taking measurements of length and weight each specimen was dissected out dorsally to expose the reproductive system. Macroscopic (visual) observation of ovaries was carried out and on the basis of macroscopic observations shrimps were categorized into two as developed (maturity stages 3 and 4) and undeveloped (stages 1, 2 and 5). Ovary length was then measured with the help of a vernier caliper and weight of the ovary was recorded using an electrical balance.

Fecundity:

Females with developed ovaries were selected for fecundity estimation. Ovary was removed, weighed and then preserved by immersion in 10% (Vol/Vol) formalin. A piece of ovary from each developed female was cut and weighed as the sample, teased apart in water and the number of ripe eggs was estimated using a counting grid. The volumetric sub-sample method was used to estimate the number of ripe eggs in the ovary using the formula:

$$\mathbf{F = nV/v}$$

Where:

n = number of ripe eggs in the sub-sample;

V= volume to which the total number of eggs is made up;

v = volume of sub-sample.

(the formula the weight of piece of ovary used as the sample and weight of the whole ovary as fecundity is the number of ripe eggs in the ovary)

Correlation analysis was carried out to test whether there was a significant relationship between fecundity and carapace length, fecundity and total length, fecundity and ovary length, fecundity and ovary weight as well as between fecundity and body weight. These calculations were done with the help of ANOVA regression model.

RESULTS

Number of ovigerous females recorded for *P. indicus, P. japonicas,* and *P. monodon* during the experimental period was 64, 20, and 34 respectively. Higher proportion of ovigerous females of *P. japonicus* was found in December and that of *P. monodon* was found in May; the proportion of ovigerous females of *P. indicus* was high in August.

Table 1. Average No. of eggs recorded for the three species of *Penaeus* over the experimental period in the year 2008.

Month	Number of eggs		
	Penaeus japonicus	*Penaeus indicus*	*Penaeus monodon*
April	296871.7612	1117286.573	346672.1263
May	304485.8	1197939.722	239725.6987
June	NIL	1069270.791	248833.328
August	256314.5243	1106332.248	274100.3046
September	NIL	1138725.21	284709.3093
October	264669.156	1141749.626	316359.6553
December	292669.9397	1160247.25	319565.8192

Note maximum and minimum ranges of egg production through out the year:

Penaeus monodon
Maximum: April
Minimum: May

Penaeus indicus
Maximum: December
Minimum: June

Penaeus japonicus
Maximum: May
Minimum: August

Number of eggs per female (average):
Penaeus monodon 300374.7192
Penaeus indicus 1127730.306
Penaeus japonicus 279619.727

Table 2. Body length variation of ovigerous females of the three species of *Penaeus* over the experimental period in the year 2008.

Month	Mean body length(cm) (± SE)		
	Penaeus japonicus	*Penaeus monodon*	*Penaeus indicus*
April	18.6 ± 0.34	18.528±0.40	16.266±0.35
May	18.7± 0.48	15.1± 0.38	17.444±0.40
June	Nil	15.25±0.41	15.55±0.38
August	15.925± 0.42	16.214± 0.40	16.041±0.40
September	Nil	16.1±0.35	16.525±0.32
October	16.52± 0.38	17.066±0.39	16.6± 0.30
December	18.185±0.355	17.06±0.32	16.866±0.35

Large size of females of following species found in mentioned month:

Penaeus monodon 21.1 cm in April
Penaeus indicus 20.1 cm in May
Penaeus japonicus 19.4 cm in April and December.

Penaeus indicus

Collected specimens of *P. indicus* in developed maturity stage varied in total length from 14.4 to 20.1cm. Estimated mean fecundity for the species was 1112276.035± 0.4493. Results show a strong positive relationship between fecundity and total length (r= 0.9117). Strong positive correlations were observed between fecundity and carapace length (r = 0.936), fecundity and ovary length (r = 0.935) and fecundity and body weight (r = 0.935). Results of ANOVA regression model for relationship between ovary weight and fecundity shows that both values are highly dependent on each other with a high correlation coefficient (r = 0.942; P = 2.222457).

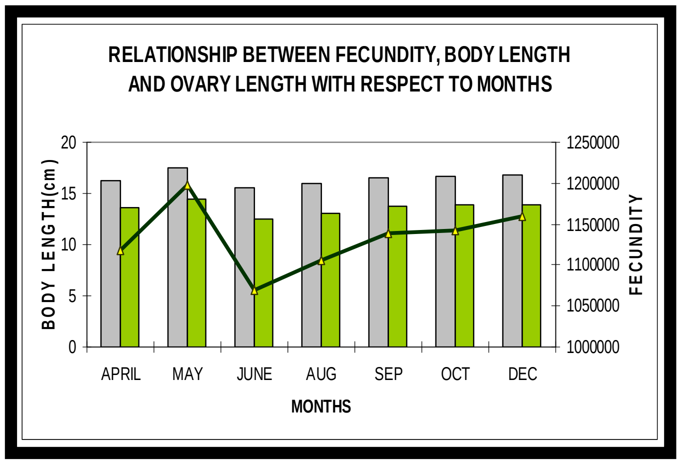

Fig. 1. Relationship between fecundity, body length and ovary length over the experimental period.

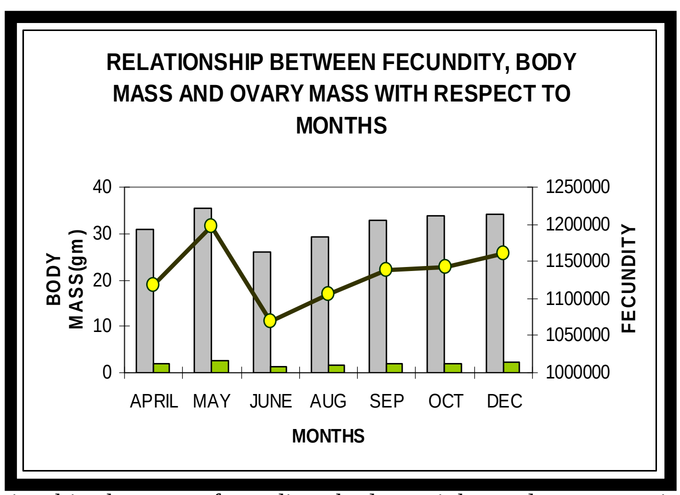

Fig. 2. Relationship between fecundity, body weight and ovary weight over the experimental period

Penaeus Japonicus:

P. japonicus in developed maturity stage varied in total length from 15.4 to 19.4 cm. Estimated mean fecundity for the species was 265218.525 ± 0.677068. Fecundity increased approximately as the cube of total length with a strong degree of association in *P. japonicas* (r = 0.880. Moderately positive correlations were found between carapace length and fecundity (r = 0.7706), ovary length and fecundity (r = 0.641), body weight and fecundity (r = 0.793). Relationship between ovary weight and fecundity also showed moderate correlation (r = 0. 742; P = 0.831639).

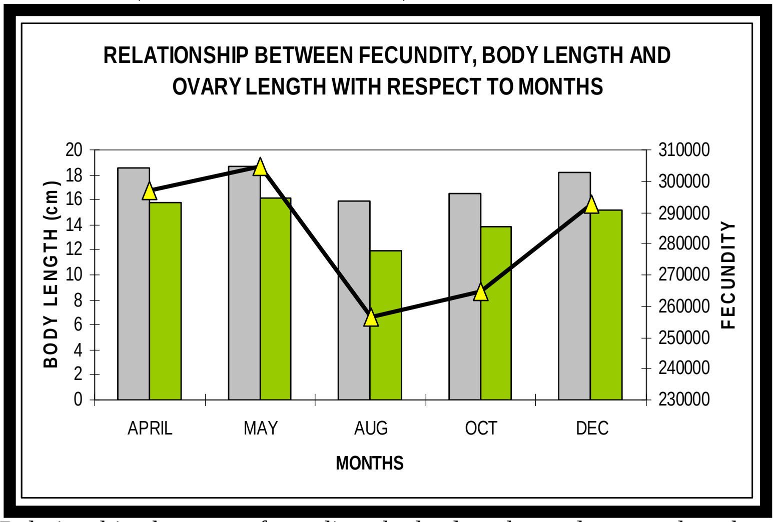

Fig. 3. Relationship between fecundity, body length, and ovary length over the experimental period.

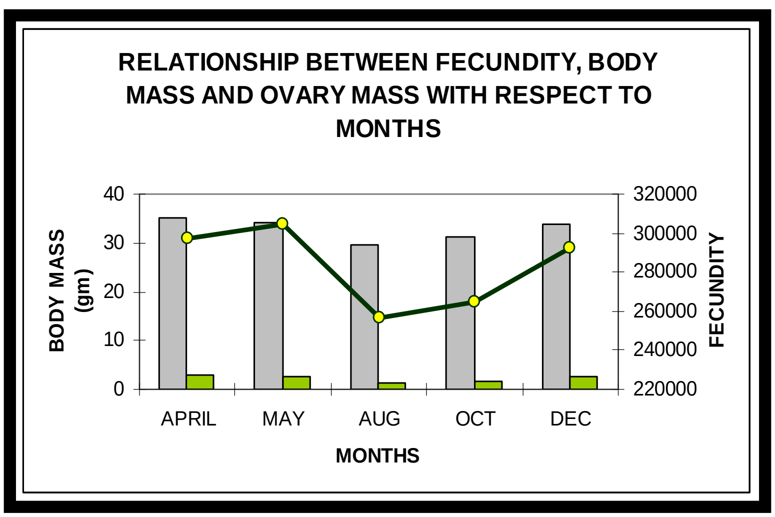

Fig. 4. Relationship between fecundity, body weight and ovary weight over the experimental period

Penaeus monodon:

Only 34 females of *P. monodon* were collected with total length ranging from 14.4 to 21.1 cm. Estimated mean fecundity for the species was 300374.7189 ± 0.55893.

Coefficient of correlation between total length and fecundity was r = 0.929, showing a strong positive correlation. There was a strong degree of positive association between carapace length and fecundity (r = 0.935). Fecundity increased almost in direct proportion to body weight; the relationship between body weight and fecundity was strong (r = 0.932). Results of ANOVA regression model for relationship between ovary weight and fecundity showed that both values were highly dependent on each other (r = 0.895; P=0.352134).

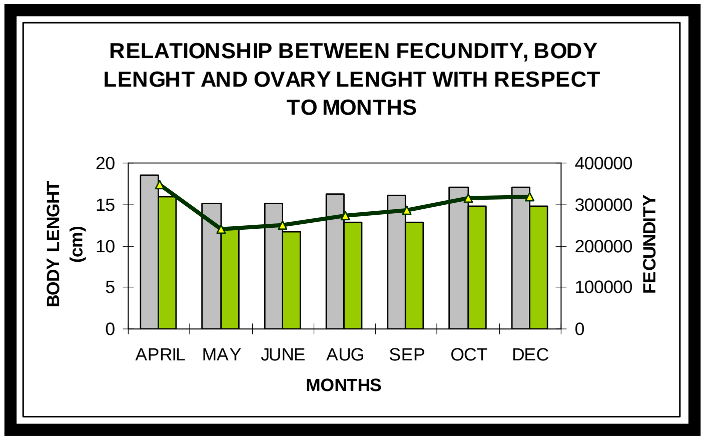

Fig. 5. Relationship between fecundity, body length and ovary length over the experimental period.

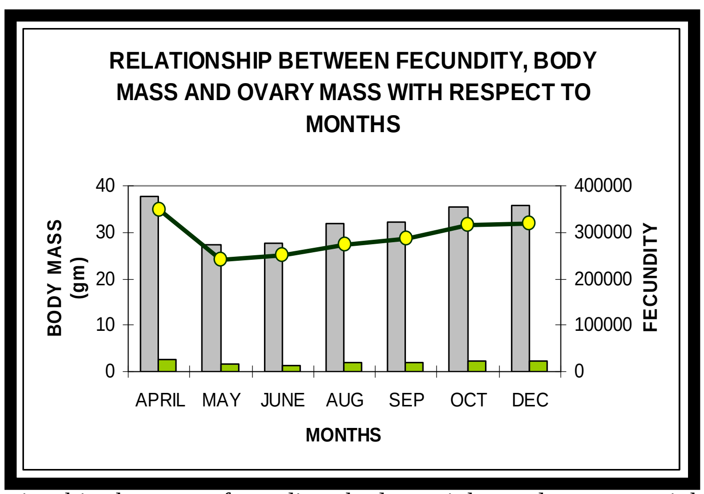

Fig. 6. Relationship between fecundity, body weight and ovary weight over the experimental period.

Table 3. Mean (± SE) total length, carapace length, ovary length, body weight and ovary weight of *Penaeus indicus. Penaeus japonicas, Penaeus monodon.*

	Total length (cm)	Carapace length (cm)	Ovary length (cm)	Body weight (gm)	Ovary weight (gm)	Fecundity
Mean±SE	16.3869375±0.42	6.0421875±0.23	13.46406±0.52	31.125±0.67	1.853656±0.213	1112276.035±4273.05
Mean±SE	17.405±0.310	6.48±0.12	14.344±0.432	32.45±0.682	2.1237±0.173	265218.525±5739.02
Mean±SE	16.81818±0.25	6.3575757±0.25	14.018118±0.378	33.666±0.585	2.12284±0.195	300374.7189±5983.06

Table 4. Coefficient of correlation (r) between fecundity and morphometric parameters of three species of *Penaeus.*

	Penaeus monodon	*Penaeus indicus*	*Penaeus japonicus*
Total length (cm)	0.929	0.911	O.880
Carapace length (cm)	0.970	0.939	0.770
Ovary length (cm)	0.935	0.935	0.641
Body weight (gm)	0.932	0.920	0.793
Ovary weight (gm)	0.894	0.943	0.7419

DISCUSSION

Many fecundity studies of fish, as well as of Penaeid shrimps, have been based on estimating number of ova. Fecundity is one of the most complex aspects of the biological cycle of any crustacean species and is basically determined by body size (Hines, 1982; Reid and Corey, 1991; Somers, 1991). Shrimps exhibit more than one spawning period in a year. Fecundity and size at sexual maturity of crustaceans is required for the determination of a minimum commercial exploitation size (Jewett *et al.*, 1985). After completion of the first spawning shrimps rest in a developing stage before going through the maturation cycle again (Jayawardane *et al.*, 2003). The positive relationship found here between the number of eggs and the size of females is consistent with observations made from other species of penaeid (Dall *et al.*, 1990). Moreover, the value of r2 demonstrated that carapace length (CL) is a good estimate of fecundity.

During the present study the relationships between fecundity and other morphometric parameters of *P. indicus*, *P. momodon*, and *P. japonicas* of Karachi coast, Pakistan, were found out. The increase of fecundity with body size seems to be a rule that is applicable to many crustaceans (Udo and Ekpe, 1991).

The relationship of fecundity to total body lengths of aquatic species is always exponential, giving a slope approximating a numerical factor of three or cube. Contrary opinions also are reported from results involving a few fish species, for example Babiker and Ibrahim (1979) reported a decline in the number of eggs with the increase in body length of specimens a rule which seems more applicable to crustacean than fish.

Motoh (1981) established a positive correlation between fecundity and female size in terms of carapace length and Villegas et al. (1986) demonstrated a positive correlation between fecundity and spawner weight. The present study also showed a positive relation between the weight of spawners and hatching percentage. But no relationship was observed between the size of spawner and start of hatching.

From Pakistan previous studies reported variable spawning activity of penaeid shrimps. Hassan (1983) studied the spawning season of *Penaeus* species was spring and late summer, with *Metapenaeus* spawning in the winter, spring and late summer and *Parapenaeopsis* spawning in the summer. Zupanovic (1971) studied the spawning seasons of *P. penicillatus* as October to May and *M. affinis* as October to April. Van Zalinge *et al.* (1987) studied spawning activity of *P. merguiensis* throughout the year with peak spawning activity in April to May and August while *M. affinis* spawned from May to October. Ayub and Ahmed (1992) observed the two peaks of spawning major and minor peaks found in *P. merguiensis* from January to April and October, *P. penicillatus* from November to April and July and *M. affinis* from February to March and October, respectively. During the post monsoon season percentage of actively spawning *P. indicus* was the highest (Aug. to Oct.) and the secondary peak was observed in pre monsoon season (Feb. to Mar.). *P. indicus* spawns most of the year with peaks around March-April and July-August in the Sri Lanka (Jayawardane *et al.,* 2003). From the coastal areas of India peaks in different months in different years, Devi (1987) in the Cochin backwaters spatial and temporal differences in the spawning periods of *P. indicus* have been reported varying from October to May with two peaks in November to December and February to April (George, 1962), December-January and May-June in the coastal waters off Cochin (George *et al.,* 1963), March-April in Madagascar waters (Crosnier, 1965), October-April in Cochin waters (Rao, 1968).

In *Penaeus indicus* fecundity is more closely related to ovary weight (r = 0.943) than body weight (r = 0.92). Ovary weight (r = 0.943) and ovary length (r = 0.93) are best indices related to fecundity in *Penaeus indicus.* However, it is easier to use body weight or total length to estimate fecundity, because these are simpler to measure than ovary weight. Though measuring length is much easier then measuring weight, weight of the animal is still a better fecundity indicator than length (r = 0.911 for the log-log relationship between fecundity and total length). All the parameters used in the study showed strong correlations with fecundity in *Penaeus indicus.*

In *Penaeus japonicus* total length (r = 0.880) showed strong correlation to fecundity than any other parameter while body weight, carapace length, ovary weight and ovary length showed moderate correlation to fecundity. Therefore, total length is the best parameter to predict fecundity of *Penaeus japonicus.*

In *Penaeus monodon* fecundity is more closely related to carapace length (r = 0.970) and total length (r = 0.9292) with a slight difference; fecundity could be predicted with total body length or carapace length. However, it is easier to measure carapace length than body length in order to predict fecundity. All the parameters tested during this study showed strong correlation with fecundity of *Penaeus monodon.*

From the three species, number of eggs per female (average) *Penaeus indicus* was 1127730.306 while in *Penaeus monodon* and in *Penaeus japonicus* it was 300374.7192 and 279619.727 respectively; the fecundity of former species is high. Results showed that in *Penaeus indicus* the best parameter to estimate the fecundity was body weight, in *Penaeus monodon* it was carapace length and in *Penaeus japonicus* it was total length.

Animals living under different conditions may differ in fecundity. Since fecundity is dependent to a great extent upon nutrition, the difference in fecundity of individuals of a given species from different geographical areas may reflect differences in food supply (Martosubroto, 1973). Fecundity in marine animals varies from individual to individual and shows a close relationship with the environmental variability. But in a particular ecosystem, the influence of environmental factors on the biological activity is a complex phenomenon. As such it is difficult to assess exactly the influence of a particular environmental factor on the fecundity of Penaeid shrimps. It is also generally believed that availability of a particular food item and temperature of environment control the fecundity of an animal. Water temperature is one of the environmental factors that strongly influenced reproduction of shrimps (Muncy, 1984; Primavera, 1985; Staples, 1991; Bray & Lawrence, 1992). In natural context, an increase of temperature from late winter to spring is believed as one of the cause that trigger spawning of shrimps (Dall *et .al*, 1990; Yano, 1993). Simultaneously increasing water temperature and day length promotes vitellogenesis in the *Penaeus japonicus* (Caubere *et al*, 1979).

Panikkar and Menon (1956) reported that the spawning in *Penaeus indicus* on the west coast has peak seasons from October to November and May to June, while Rao (1968) observed that this peak in Cochin waters was between October and April. But, Subrahmanyam (1963) reported the highest breeding activity in Madras waters in March and May to September. *P. semisulcatus* from Palk Bay and Gulf of Mannar also revealed similar peaks in June to September and January to February. The resemblance between the peak seasons at these two centres on the east coast of India is probably due to the profound influence of the North East Monsoon while the west coast is more affected by the South West Monsoon. The fecundity values of the present investigations are quite in conformity with those- recorded by Rao (1968). But, there was no correlation between the size of the prawn and fecundity. The sex ratio of *P. semisulcatus* is similar to those of P. *indicus* (Menon, 1957) in that the sexes were more or less equally distributed, although, distinct variation was observed by George and Rao (1967) in respect of *P. indicus, Metapenaeus dobsoni, M. afflnis* and *Parapenaeopsis stylijera* from the trawl catches off Cochin.Whereas the present study the peak spawning season for *Penaeus japonicas, Penaeusi ndicus and Penaeus monodon* from December to May.

The present study has revealed a strong relationship between fecundity and total length in all three species, as well as between fecundity and body weight in *Penaeus indicus* and in *Penaeus monodon* indicating a tendency for fecundity to increase with the body size of shrimp. There are differences in the pattern of allocation of food energy by the animal at different body sizes; usually, in large individuals when growth rates are low much of the available food energy is devoted to egg production compared to smaller individual in which a large fraction of the energy may be devoted to growth rather than for egg production.

Variations in reproductive quality of shrimp brood stock have been reported to be primarily genetic in nature (Coyama *et al.* 1991). But the present study shows that some factors like spawner size, amount of clumping of eggs, types of spawning and frequency of spawning also influence spawning success by changes in hatching rate and start of hatching.

For sustainable shrimp fisheries that may include reducing effort, setting bag limits, ban use of destructive gears, and illegal practices, reduce destruction of habitat through better legal frame work and implementation procedures and machinery.

The result of this study on *Penaeus indicus,P.monodon and P.japonicus* will provide valuable information to the fisheries biologists and fisheries management authorities on for proper management and conservation.

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