Indian Journal of Geo Marine Sciences
Vol. 47 (11), November 2018, pp. 2267-2277

Fishery, population dynamics and stock status of Jinga shrimp, *Metapenaeus affinis* (Milne-Edwards, 1837) from Gujarat waters of India

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Received 20 February 2017; revised 20 September 2017

The life history parameters and stock status of Jinga shrimp, *Metapenaeus affinis* was assessed by collecting length frequency, catch and effort data for the species during January 2012 to December 2015 from the commercial trawlers operating from Veraval fish landing centres in Gujarat. Growth parameters *i.e.*, L_∞, K and t_0 were estimated as 185.5 mm, 1.9 yr^{-1} and -0.001 yr, respectively for male and 204.75 mm, 1.7 yr^{-1} and -0.001 yr, respectively for the female *Metapenaeus affinis*. The growth performance of female was found to be higher than male shrimp. Mortality parameters *i.e.,* Z, M and F estimated were 8.37 yr^{-1}, 2.926 yr^{-1}, 5.45 yr^{-1} for male and 6.76 yr^{-1}, 2.61 $yr^{-1}$and 4.15 yr^{-1} for females, respectively. Current exploitation ratio (E_{cur}) for the male was found to be higher than that of the female shrimp. Length at capture (LC_{50}) for shrimp was higher than the length at maturity (LM_{50}). Relative yield per recruit (Y/R') model projected the E_{max} of 0.75 for the species, which implies that the current exploitation (E_{cur}) could be increased to maximize the yield. Thompson and Bell bio-economic model indicates that an increase of current fishing level by 5.2 and 3.8 times could maximize the yield (MSY) for male and female shrimp respectively. However, this increase could decimate the virgin spawning stock biomass (SSB_0) to 12 and 15% that could be dangerous for stock regeneration. Considering the high resilient nature of the species, the current fishing pressure could be increased by 1.8 times while maintaining the biomass at a comparatively safer level of 25%.

[**Keywords**: Precautionary approach, spawning stock biomass, stock assessment, fisheries management]

Introduction

Metapenaeus affinis (H. Milne Edwards, 1837), commonly known as Jinga shrimp, belongs to the family Penaeidae and is widely distributed across the Indo-pacific region[1]. The shrimp is primarily a brackish water dwelling benthic species but is also found up to a depth of 92 m and prefers wide range of substrata ranging from muddy to sandy bottom[1,2,3]. The species is globally considered as one of the important edible marine shrimp resources with very high commercial value[4]. Despite its small contribution, the shrimp is considered as the most important *Metapenaeus* species in Gujarat after *Metapenaeus monoceros* and also constitute a commercially important shrimp fishery along the south-east and west coast of India[5].

Considering its fisheries significance, several attempts have been made outside India to generate information on the stock status of the shrimp from Thailand waters[6] and Kuwait waters[7], morphometric relationships from Zhujiang estaury, China[8], growth parameters from Pakistan waters[9] and Turkey waters[10], maturation and spawning characteristics from Pakistan waters[11] and population dynamics from south Vietnam waters[12] and Iran waters[13].

There are also few studies from India where attempts have been made to understand the larval development[14,15,16], maturation and reproduction[17,18,19], age and growth[20,21], bionomics, fishery, population dynamics and stock status of the species from the west coast of India[17,19,22,23]. It is quite surprising to note that, despite its commercial importance, there is actually a scarcity of studies where attempts should have been made to update information about the life history parameters, reproductive biology, trophodynamics, population dynamics and stock status of the species, especially under the present scenarios when the fisheries have undergone so much of change.

Considering the research attempts those have been made in recent years outside India, the earlier studies conducted in India appears to be preliminary as well as obsolete and therefore, attempts should be made to update the information on *M. affinis* at the regional level. It is also important to mention that no attempts have been made till date to study the biology and fishery of the species from the Gujarat waters of India. Present study is to generate information on the life-history parameters, population dynamics and stock status of *M. affinis* so that some management plans can be proposed for the sustainable exploitation of the resource.

Materials and Methods

Data on catch, effort and size composition were collected at fortnight interval for a period of 4 years from January 2012 to December 2015 from the commercial trawlers operating from Veraval fish landing centres in Gujarat (Figure1). Individual total body length (TL) between anterior tip of the rostrum to the posterior tip of telson was measured to the nearest mm using a standard measuring scale and the individual body weight was recorded to the nearest mg using an electronic weighing machine (Scale-Tec™, India). Fortnightly collected length frequency data were raised by the raising factor derived by dividing the sample weight with the actual *M. affinis* catch of the observation day at the fish landing centre obtained from the fisheries resource assessment division (FRAD) of Central marine fisheries research institute (CMFRI), India. The Von Bertalanffy's growth parameters *viz*. asymptotic length (L_∞) and growth co-efficient (K) were estimated using monthly raised data in the ELEFAN 1 module of FiSAT II[24]. Age at zero length (t_0) was back calculated using equation derived from von Bertalanffy growth equation *i.e.*, t_0=1/K $\log_e$ [1-($L_{t=0}/L_\infty$)], where $L_{t=0}$ is length at birth. For the calculation of t_o, 0.25 mm was used as length at birth ($L_{t=0}$) which is the usual size of the nauplius-1[16,25]. Growth performance index (φ) was calculated from formula suggested by Pauly and Munro[26], *i.e.*, $\varphi=\log_{10} K + 2\log_{10} L_\infty$. Longevity was estimated from the equation suggested by Pauly[27], *i.e.*, t_{max}= 3/K+ t_0. The TL-weight relationship of *M. affinis* was established following the formula suggested by Le Cren[28], *i.e.*, $W=aL^b$. Analysis of covariance (ANCOVA) test was performed to check the similarity of regression line between male and female.

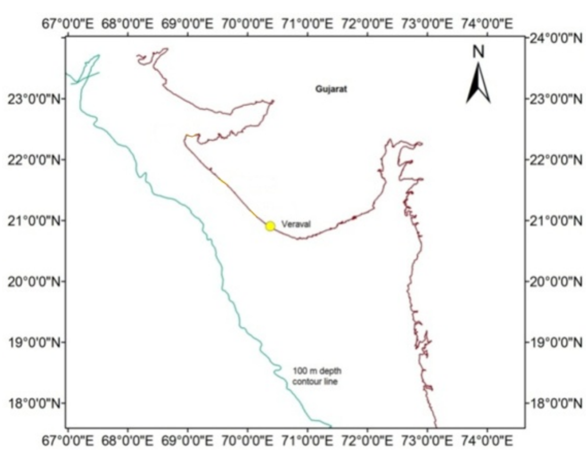

Fig. 1 — Map showing fishing area and sampling locations for the present study around Gujarat, India

The instantaneous total mortality rate (Z) was estimated by FiSAT II package using the length converted catch curve method[29]. The natural mortality rate (M) was estimated by Alagaraja method[30], i.e., M=-Ln (0.01)/t_{max}, where M is the natural mortality and t_{max} is the longevity of the species. Fishing mortality rate (F) was obtained as F= Z-M. Current exploitation ratio (E_{cur}) was calculated by following the equation suggested by Ricker[31], *i.e.*, E= F/Z. Length structured virtual population analysis (VPA) of FiSAT II was used to obtain fishing mortalities at each length class. Midpoint of the smallest length group in the catch during the four year period was taken as length at recruitment (Lr). Length at capture *i.e.*, length at which 50% of the shrimps in the population becomes vulnerable to the gear (LC_{50}) was estimated by probability of capture routine in the FiSAT-II package. The probability of capture was approximated by backward extrapolation of the regression line of descending limb of length converted catch curve. Probability of capture of sequential length classes were regressed using a logit curve for the estimation of LC_{50}. For determining length at maturity *i.e.*, length at which 50% of the shrimps in the population matures (LM_{50}), females of *M. affinis* (TL=88.5-198 mm, n=2824) collected during the study period were used for the analysis. Maturity stages of the females were determined by the size and appearance of the ovary and were classified into 5 stages following the method described by King[32] as follows:

Stage I: undeveloped-ovaries small and translucent; Stage II: developing-ovaries larger, opaque, and yellowish, with scattered melanophores over the surface; Stage III: nearly ripe-ovaries larger and yellow to greenish; Stage IV: ripe-ovaries green, filling virtually the whole space among other organs and Stage V: spent-spawned ovaries flabby and mud colored. Spent and the proportion of female shrimps those have completed stage-3 in sequential length classes (10 mm) were used for the logistic regression analysis as described by Ashton[33], *i.e.*, $P(TL) = e^{a+b(TL)} / 1+ e^{a+b(TL)}$ where P is the predicted mature proportion at length TL, a and b are the estimated coefficients of the logistic equation and TL the total length of the shrimp. LM_{50} was estimated as the negative ratio of the coefficients (-a/b). The SOLVER routine in Microsoft™ Excel was used to obtain maximum likelihood estimates of the parameters.

The relative yield per recruit (Y'/R) and relative Biomass per recruit (B'/R) at different fishing levels were estimated by FiSAT II package using Beverton & Holt relative yield per recruit analysis method[34]. The yield (Y), total biomass (B) and spawning stock biomass (SSB) at different fishing levels were predicted using length based Thompson and Bell bio-economic (TBEM) model[35].

Results and Discussion

The annual catch and effort data for *M. affinis* along Gujarat coast during 2012-2015 is shown in the Table-1. During the study period an average quantity of about 2628 tonnes of *M. affinis* was harvested per annum with an average catch rate (CPUE) of 0.21 and 0.18 Kg per hr using trawlers and dol netters as the major fishing gears. Analysis of 4 years catch data revealed that the contribution of the species to the total fishery is very less (0.37%). In Gujarat, the commercial fishery usually targets ribbon fishes, threadfin breams, squids and shrimps. However, contrary to other maritime states, a huge portion of the shrimp landing is mainly contributed by non-penaeid shrimps such as *Acetes* spp., *Exhippolysmata ensirostris* and *Nematopalaemon tenuipes* which together constitute nearly about 76.5% of the total shrimp landings of the state[5]. Among the penaeid shrimps, the catch is dominated by *Parapenaeopsis* spp. (40.63%), *Solenocera* spp. (30.10%) and *Metapenaeus* spp. (22.55%) followed by meager landings from *Metapenaeopsis* spp. (3.50%) and *Penaeus* spp. (3.22%)[5]. Despite its meager contribution to the total fishery, *M. affinis* is however, considered as an important *Metapenaeus* sp. that contributes about 7.5% of the annual average penaeid shrimp landings of the state (Table-1). The species is mainly exploited by multiday trawlers (68%), followed by dol netters (15%) and singleday mechanized trawlers (3%) (Figure 2). Miscellaneous gears like motorized and mechanized gill netters, bag netters etc. with sporadic landings together contribute nearly 14% of the *M. affinis* catch of the state. During the study period, higher landings for the species were recorded in the last quarter of the year (*i.e*., October to December) (Figure 3).

The samples obtained from the stock showed a normal distribution (Figure 4). A total of 4,972 shrimps were collected for the study of which male constituted 43.20% (n=2148) and female constituted 56.80% (n=2824) with an overall sex ratio (Male: Female) of 1.3. In the stock, the male shrimps size varied from 82.0 to 176.0 mm (TL) whereas, the female size was in the range of 88.5 to 198.0 mm (TL). The annual length frequency distribution revealed that the abundant size group in the population is mainly consisted of shrimps with a size range of 130 to 140 mm (Mode= 135 mm TL) with a mean of 136.7 ± 16.7 (SD).

Length restructured frequency distribution and growth performance of sex-segregated data is given in the Figure 5. Growth estimated by Von Bertalanffy growth equation revealed that the male shrimp grows to 113.86 mm (TL) in 6 months, 157.79 mm (TL) in 1

Table 1 — Catch and effort of *Metapenaeus affinis* landed along Gujarat coast during 2012 to 2015

Years	2012	2013	2014	2015	Average
Total fish landings (t)	690396	705945	712794	721549	707671
Total crustacean landings (t)	136849	151046	158286	150664	149211
Total penaeids and non-penaeids shrimp landings (t)	116687	135276	145384	138361	133927
Total penaeid shrimp landings (t)	33066	36461	38540	32453	35130
M. affinis dol netter catch (t)	621	464	498	307	472
M. affinis trawler catch (t)	1457	2033	1998	1943	1858
M. affinis catch by other gears (t)		416	541	236	398
M. affinis total catch (t)	2078	2912	3036	2487	2628
Dol netter effort (Actual fishing hours)	2394808	2035216	2316811	3930714	2669387
Trawler effort (Actual fishing hours)	7557969		9825813	9533324	9040391
CPUE of dol netter (kg h^{-1})	0.26	0.23	0.21	0.08	0.18
CPUE of trawler (kg h^{-1})	0.19	0.22	0.20	0.20	0.21
% to total fish landings	0.30	0.41	0.43	0.34	0.37
% to total crustacean landings	1.52	1.93	1.92	1.65	1.76
% to total shrimp landings	1.78	2.15	2.09	1.80	1.96
% to total penaeid shrimp landings	6.29	7.99	7.88	7.66	7.48

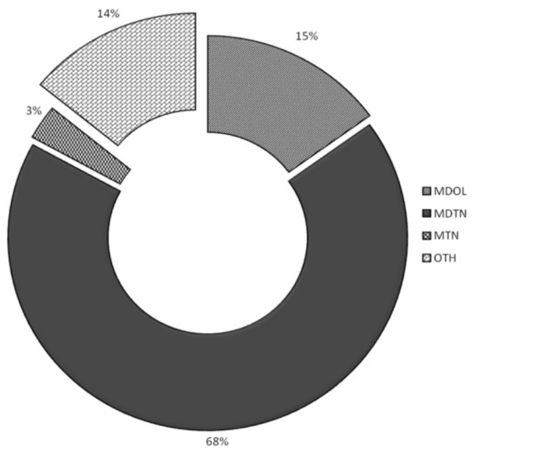

Fig. 2 — Gear-wise (MDOL: Mechanized dol netters; MDTN: Mechanized Multiday trawlers; MTN: Mechanized singleday trawlers and OTH: Other gears) contribution of *Metapenaeus affinis* landed along Gujarat coast during 2012 to 2015.

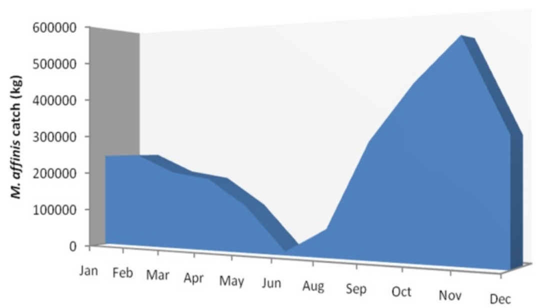

Fig. 3 — Monthly average catch trend of *Metapenaeus affinis* landed along Gujarat coast during 2012 to 2015.

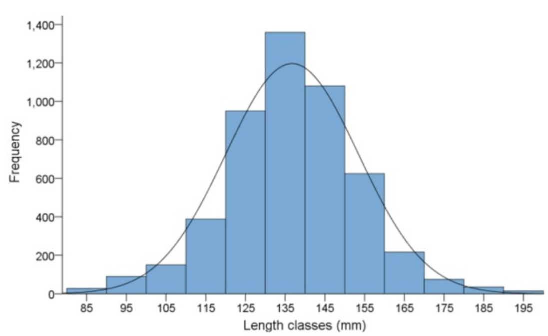

Fig. 4 — Stock structure of *Metapenaeus affinis* in Gujarat waters during 2012 and 2015

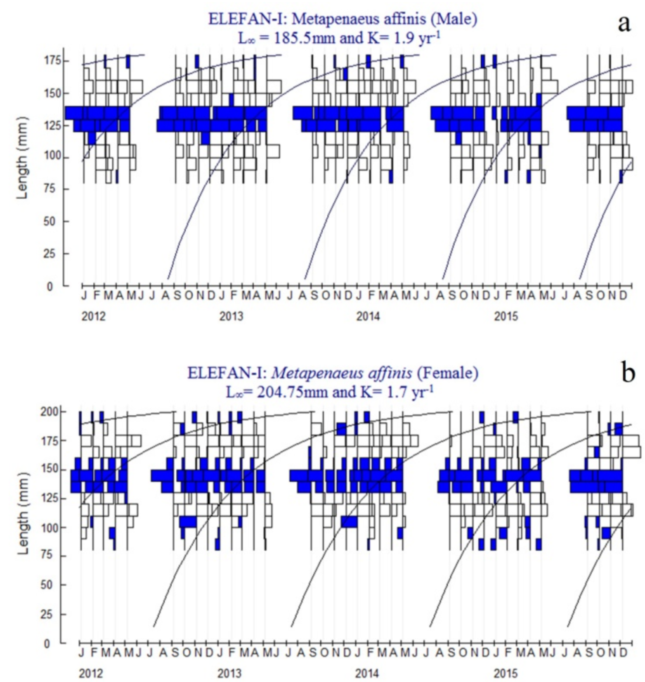

Fig. 5 — Restructured growth curve of *Metapenaeus affinis* (a. male and b. female) from Gujarat waters

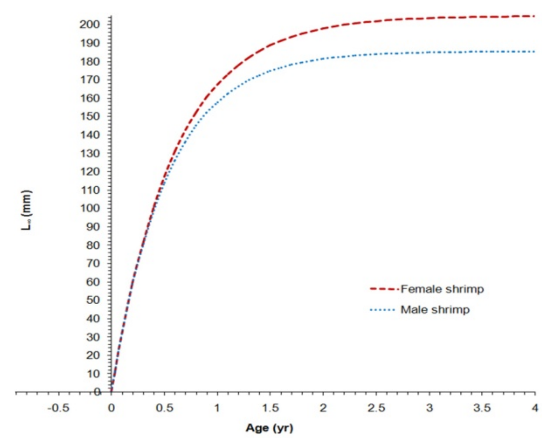

Fig. 6 — Growth estimates of *Metapenaeus affinis* by Von Bertalanffy's growth equation from Gujarat waters

year and 174.78 mm (TL) in 1.5 year, whereas female shrimp grows to 117.34 mm (TL) in 6 months, 167.39 mm (TL) in 1 year and 188.78 mm (TL) in 1.5 year (Figure 6). The growth parameter and performance for different groups (male and female) are given in Table-2 and Figure 6, respectively. Growth coefficient (K) of male was comparatively higher than the female shrimp, whereas, the L_∞ and φ of female were higher than that of the male shrimps. This indicates that females grow larger than male shrimps (Figure 6) which is found to be in agreement with the findings of Franco[36].

The L_∞ and K obtained in the present study can be compared with the earlier reports which are given in the table 3. The L_∞ values obtained in the present study were found to be comparatively larger than the earlier reports except for the report by Paralkar from Mumbai waters[22]. Similarly, the K values obtained in the present study were also found to be comparatively

Table 2 — Stock parameters of *Metapenaeus affinis* from Gujarat waters during 2012 and 2015

Sex	Von Bertalanffy's growth parameters			Longevity	Growth	Mortality rates			Exploitation rate
	L_∞ (mm)	K (yr^{-1})	t_0 (yr)	t_{max} (yr)	performance index (φ)	M (yr^{-1})	Z (yr^{-1})	F (yr^{-1})	E_{cur}
Male	185.5	1.9	-0.001	1.58	2.82	2.92	5.45	8.37	0.65
Female	204.75	1.7	-0.001	1.76	2.85	2.61	4.15	6.76	0.61

L_∞: asymptotic length; K: growth co-efficient; t_0: Age at zero length; φ: growth performance index; M: Natural mortality rate; F: Fishing mortality rate; Z: Total mortality rate and E: Exploitation ratio; mm: millimetre and yr: Year

Table 3 — A summary of the earlier reports on growth parameters of *Metapenaeus affinis* from Gujarat waters

Sex	Von Bertalanffy's growth parameters				Location	Ref
	L_∞ (mm)	K (yr^{-1})	t_0 (yr)	Φ		
Male	185.5	1.9	-0.001	2.82	Gujarat	Present study
Female	204.75	1.7	-0.001	2.85	Gujarat	Present study
Male	174.3	0.84	1.7	1.33	Mangalore waters	19
Female	188.0	0.72	0.17	1.33	Mangalore waters	19
Male	156.0	1.73	1.7	0.99	Goa waters	20
Female	202.0	0.89	0.17	1.12	Goa waters	20
Male	193.0	0.6		2.35	Mumbai waters	22
Female	235.0	0.56		2.49	Mumbai waters	22
Male	188.8	1.47		2.72	Maharashtra waters	23
Female	155.0	1.5		2.56	Maharashtra waters	23
Male	160.0	2.0	0.009	2.71	Mumbai waters	21
Female	198.0	2.5	0.013	2.99	Mumbai waters	21
Male	150.0	0.85		2.28	Gulf of Thailand	6
Female	174.0	0.84		2.40	Gulf of Thailand	6
Male	162.0	1.09		1.19	Kuwait waters	7
Female	182.0	1.22		1.45	Kuwait waters	7
unsexed	119.0	1.55		2.34	Pakistan waters	9
unsexed	190.00	1.00		2.56	Viet Nam waters	12
Male	35.00	1.2	0.76		Iran waters	13
Female	47.00	1.1	0.69		Iran waters	13
Male	35.42	1.33	-0.05		Turkey waters	10
Female	49.75	0.68	-0.99		Turkey waters	10

higher than the earlier reports except for the report by Leena and Deshmukh from the same Mumbai waters[21]. Growth parameters may vary for different stocks of the same species depending on the geographic locations[37]. Moreover, the estimation of L_∞ is greatly influenced by L_{max} *i.e.*, the maximum length of the species in the sample[38] and therefore, varies with location depending on the fishing pressure. The gestation period or hatching times (t_o) derived in the present study were found to be more realistic compared to most of the earlier studies. The t_o obtained in the present study using 0.25 mm as the body length of nauplius-1 and the estimated growth parameters was about 0.001 yr^{-1} (about 9 hr) which is in agreement with earlier reports where the hatching time for the species has been mentioned as 8 to 10 hrs after fertilization[16]. Longevity (t_{max}) of the shrimp, in the present study, was found to be less than 2 yr. This is found to be shorter compared to the earlier studies, where t_{max} has been reported to be 2 yrs[39] or even 3 yrs[17]. The t_{max} of a species implies that 99% of the animals in stock (in the unexploited state) die when they reach L_{max} which is approximately 95% of L_∞[30] and therefore, should be shorter for a fast growing species. Growth performance index (φ) obtained in the present study for both the sexes (table 2) are found to be in the reasonable range ($2<\varphi<3$) within the same family[26].

The relationships between total body length (TL) and body weight for different groups (male and female) are given in Figure 7 and mentioned below as equations.

Male: $W= 0.009\ (TL)^{2.86}$ (r^2=0.86, n=2148)

Female: $W= 0.004\ (TL)^{3.13}$ (r^2=0.93, n=2824)

Where, W is weight in g and TL is total body length in cm. The slope of the female was found to be significantly higher ($p \leq 0.01$) than that of the male shrimps. On the contrary, the intercept of the male was found to be significantly higher than that of female shrimp. It was found out that in the present stock, the males are initially heavier than the female shrimps of similar sizes. But later, as the shrimps mature, females become heavier than the male shrimps of similar sizes. This is found to be in agreement with the observations of Chu, who reported similar relationship in the length weight relationship of *M. affinis* from the Zhujiang estuary of China[8]. The higher body weight of mature female shrimps compared to the immature females as well as the male shrimps could be due to the higher energy requirement for the reproduction which warrant a noticeable change in feeding behaviour and accumulation of the energy reserves for the metabolism during maturation[8].

The mortality rates for different groups (male, female and pooled data) are given in table 2. Natural mortality rate (M), fishing mortality rate (F), total mortality rate (Z) and current exploitation rate (E_{cur}) were found to be higher in the case of males compared to the female shrimps (Figure 8).

Virtual population analysis showed that F increased with the increase in the size of shrimps and attained a maximum value of 5.60 yr^{-1} at TL range of 130 to 140 mm for male and 4.62 yr^{-1} at TL range of 150-160 mm for female shrimps, respectively (Figure 9). At LM_{50}, the F on the stock of shrimp was lower than M, but it exceeded when the shrimps grew larger.

Estimation of natural mortality rate (M) is important to understand rate of stock decay. Widely used Pauly's empirical formula[40] though provides a reasonable estimate of 'M' for slow growing,

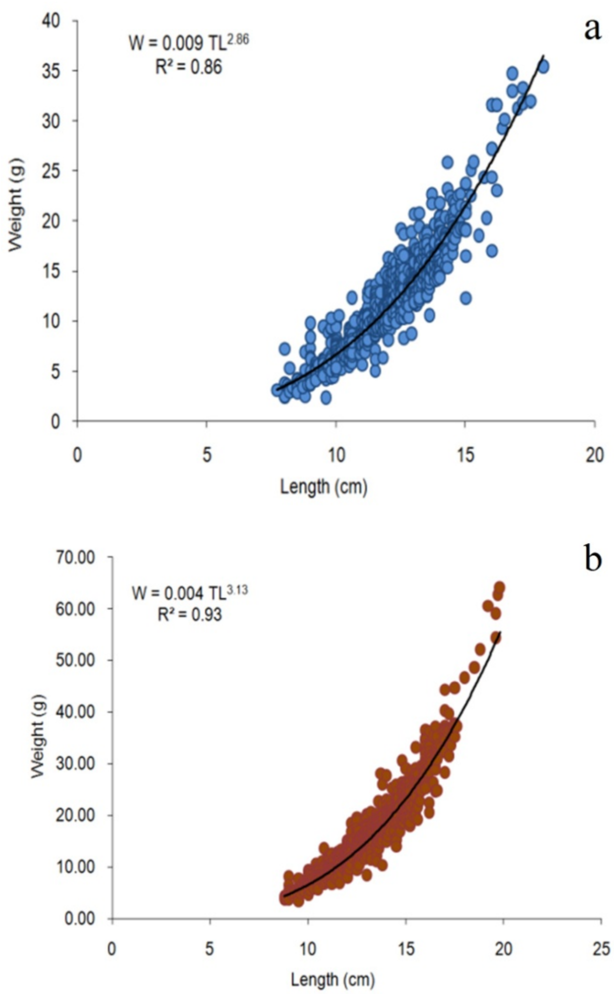

Fig. 7 — Total length and weight relationship of *Metapenaeus affinis* (a. male and b. female) from Gujarat waters

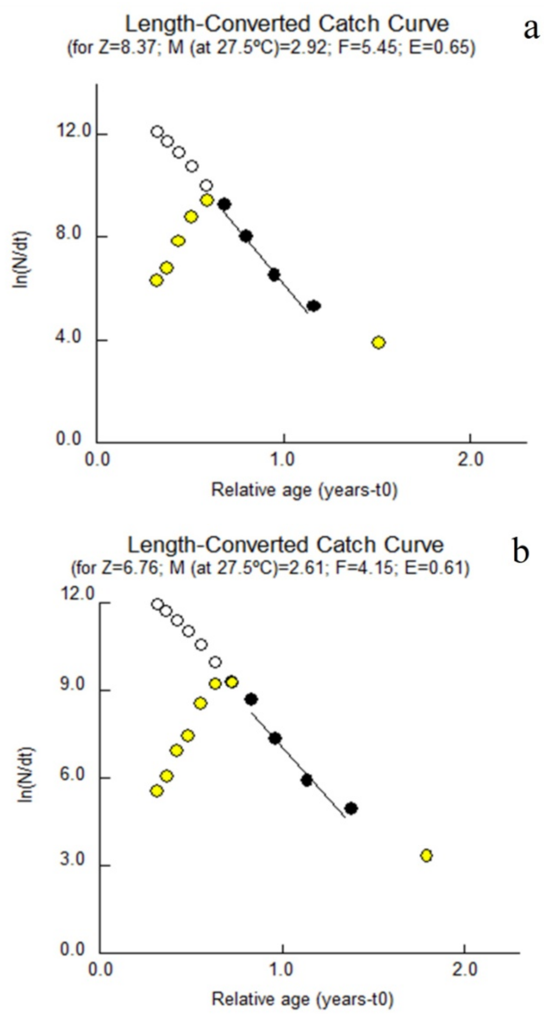

Fig. 8 — Estimation of mortality and exploitation parameters of *Metapenaeus affinis* (a. male and b. female) from Length converted catch curve method

temperate finfishes it could be erroneous for the fast growing, tropical species[41].

Therefore, Alagaraja method[30] was used for the estimation of natural mortality which assumes that 99% of the animals in stock in the unexploited state die by the time they reach t_{max}. High growth rate and short lifespan clearly indicates that the species is a typical r-selected species which suffers tremendous mortality due to natural causes which is capable of decimating the stocks of male and female shrimps by nearly 94.6% and 92.6%, respectively just within one year. Therefore, the stock of the species could be subjected to higher exploitation to improve the yield which otherwise would be simply wasted due to higher mortality from natural causes. However, optimum care should be taken not to decrease the spawning stock biomass to a critical level which could result unsustainable recruitment overfishing. In the present stock the F was found to be lower than M till the shrimp attained LM_{50} which is a good indicator of the fishery.

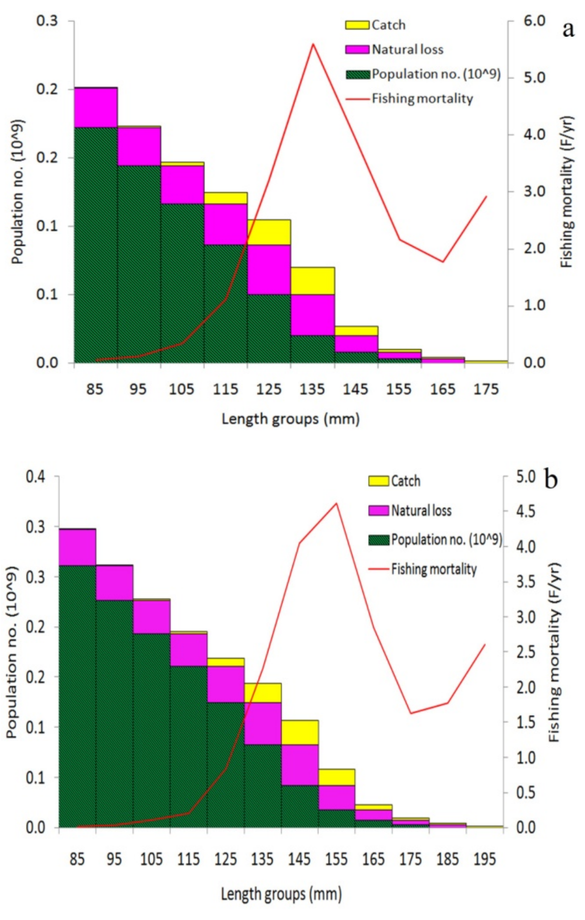

Fig. 9 — Length structured VPA for *Metapenaeus affinis* (a. male and b. female) from Gujarat waters

The length at recruitment (Lr) for *M. affinis* was found to be 82 mm (TL). Logistic regression of the probability of capture for sequential length classes obtained from length converted catch curve analysis using trawl type selection revealed that 50% of the shrimps in stock become vulnerable to gear (LC_{50}%) at the TL of 123.75 mm for males and 135.55 mm for female shrimps (Figure 10). Mature females were recorded throughout the entire fishing period.

Maturity study revealed that, 50% of the shrimps in stock become mature (LM_{50}) at TL of 120.67 mm (Figure 11). The LM_{50} observed in the present study was found to be in agreement with the earlier report by Subrahmanyan who reported 120 mm as the length at first maturity for the species from the Malabar coast of India[17]. However, the present LM_{50} was higher compared to the earlier reports such as 94 from the

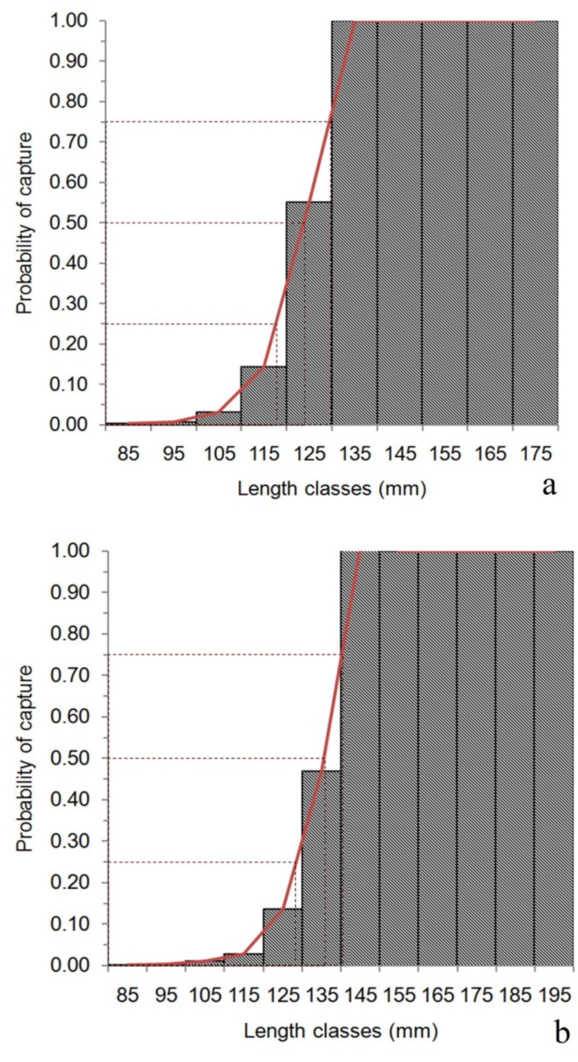

Fig. 10 — Length at capture (L_{50}) of *Metapenaeus affinis* (a. male and b. female) from Gujarat waters

south west coast of India[18], 116 from Mangalore coast of India[19] and 113 mm from the Pakistan waters[11].

Age at maturity estimated using derived growth parameters revealed that 50% shrimps in the stock matures at the age of about 6 month after birth (TM_{50}). The present estimate of TM_{50} appears to be quite earlier compared to the previous reports where TM_{50} has been estimated to be about 1 year from Mangalore waters[19] and even more than 1 year from Malabar waters[17]. It is interesting to observe that, despite a lesser LM_{50} compared to the present study, the TM_{50} estimated by these earlier studies were found to be too late possibly due to the under estimation of growth parameters. However, the present estimate of TM_{50} is found to be more realistic and close to the established penaeid shrimps growth model that predicts an age of about 4 to 5 months for the maturity after which the adult shrimps show very slow increase in size and attain asymptotic length in 6 to 8 months after birth[36,42]. The LM_{50} obtained in the present study was also found to be less than the LC_{50} which indicates that the half of the shrimps in the stock gets the opportunity to breed and regenerate the stock prior to entering the peak phase of exploitation.

The relative Y/R and B/R analysis of *M. affinis* were estimated using selection ogive procedure of FiSAT II (Figure 12). LC_{50}/L_{∞} and M/K ratio of 0.667 and 1.537 for male and 0.662 and 1.535 for female shrimps were used as the input parameter for the analysis. Analysis indicated that, the exploitation rate which maximizes yield per recruit (E_{max}) is 0.75 for both the male as well as female stocks. Since shrimp is a short living, fast growing, high fecund r-selected species, maximum yield is achieved at higher rates of exploitation compared to the long living, slow growing, low fecund k-selected species[43,44]. Though r-selected species can sustain higher fishing mortalities, precautionary approach should be taken while arriving at the management reference point mainly because of following two limitations of the relative Y/R analysis i.e. (1) the analysis tends to overestimate the E_{max} unrealistically high in the case small tropical species with high natural mortality[45,46] and (2) it does not give any consideration for the spawning stock biomass (SSB) which is essential for the regeneration of the stock[47].

Due to the principle of uncertainty in the stock assessment, it is advisable to use precautionary management reference points such as spawning stock biomass (SSB) to prevent recruitment overfishing[48]. A theoretical value of 20-30 % of virgin spawning stock biomass (SSB_0) is considered safe for the regeneration of stock[49]. Thompson and Bell bio-economic analysis was conducted to simulate the impact of increase in effort (F) on total biomass (B), spawning stock biomass (SSB) and economy (Figure 13). Analysis showed that the SSB_0 for both

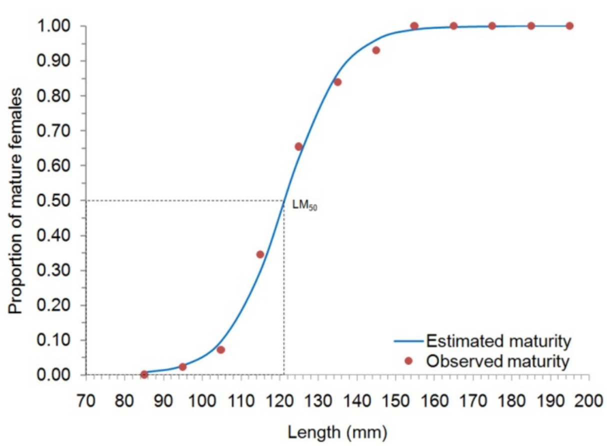

Fig. 11 — Size at maturity (LM_{50}) of *Metapenaeus affinis* (female) from Gujarat waters

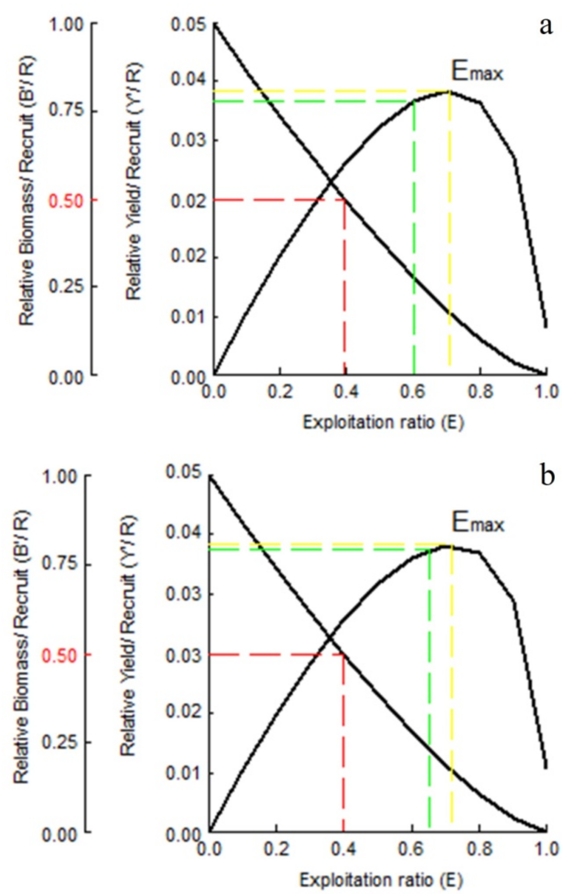

Fig. 12 — Relative yield per recruit analysis of *Metapenaeus affinis* (a. male and b. female) from Gujarat waters

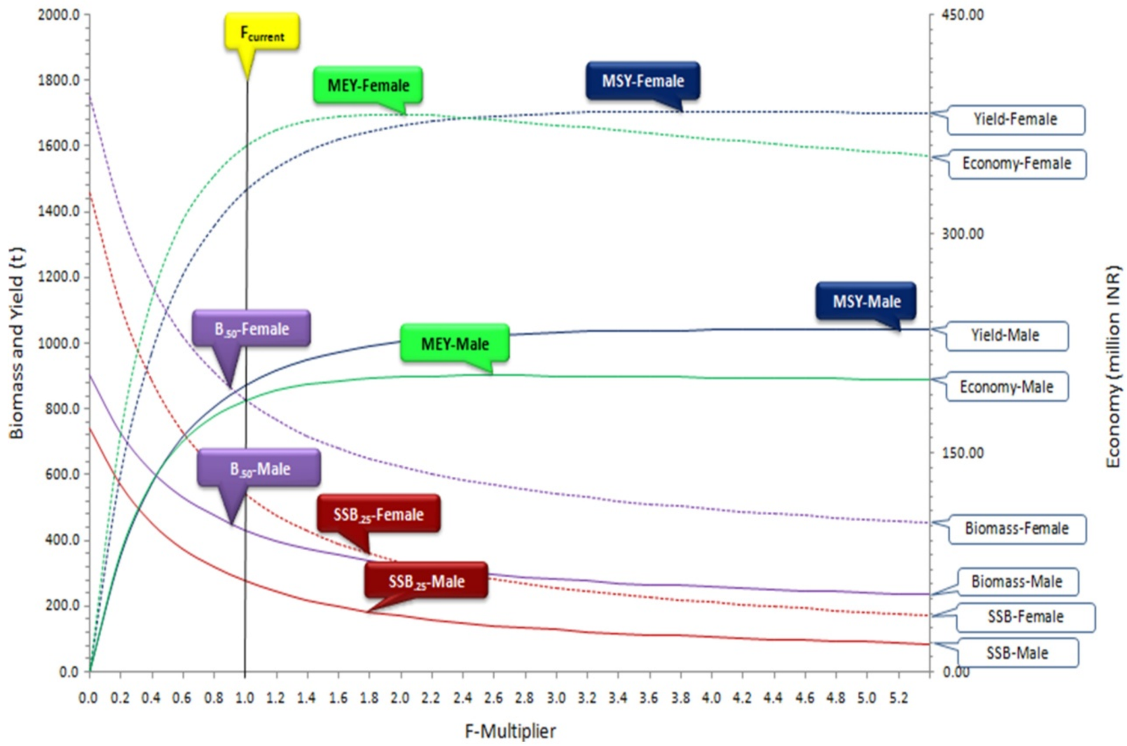

Fig. 13 — Length based Thompson and Bell analysis of *Metapenaeus affinis* from Gujarat waters

the sexes is getting depleted to about 37% by the present fishing pressure which could be considered safer for a high fecund species like the shrimp. The analysis revealed that the current fishing pressure needs to be increased by 5.2 and 3.8 times for the male and female shrimps, respectively to maximize the sustainable yield (MSY) which would deplete the SSB_0 of male and female shrimps to 12 and 15% respectively that could be risky for the regeneration of stock.

Similarly, in order to maximum economic return in a sustainable manner (MEY), the current fishing pressure needs to be increased by 2.6 and 2.0 times for the male and female shrimps, respectively that would also consequently deplete the SSB_0 to 19 and 23%, but could be considered safer compared to the SSB that would have been resulted from the increase in fishing pressure for MSY (Figure 13). However, it would be impracticable to increase the fishing pressure separately for male and female shrimps as they inhabit the same fishing area and are exploited by similar gear. Therefore, it is necessary to arrive at a suitable management reference point that is mutually beneficial and appropriate for both the sexes. Considering the high resilient nature of the species, the current fishing pressure could be increased by 1.8 times on both the sexes while maintaining the biomass at a comparatively safer level of 25%. This exploitation level would decrease the overall yield marginally by 52 t from male stock and 60 t from female stock as well as economic yield by 1.8 million INR from male stock and 0.1 million INR from female stock that otherwise could have been gained by running the fishery at MSY and MEY, respectively. Despite this marginal decrease, the adequate SSB level of 25% ($SSB_{0.25}$) would probably help in regeneration of the stocks for a sustainable shrimp fishery. However, due to the multi-species and multi-gear nature of the tropical fishery[50], the stock status of the other species should be carefully considered while arriving at the appropriate management reference point as it could potentially influence the fishing pressure on the other species.

Conclusion

Present fishery, though showed a high overall exploitation ratio, appears to be sustainable as 50% of the shrimps are getting the opportunity to reproduce before reaching peak phase of exploitation. At present fishing level, the SSB was found to be at a much safer level of 37% which also indicates a scope for the expansion of the fishery. Since the increase in fishing level in order to achieve MSY and MEY could drastically reduce the SSB_0, the exclusive fishing pressure for the prawn species could be increased by 180% following a precautionary approach which would maintain the SSB at a safer 25% level that will ensure sustainability of the resource.

Acknowledgement

The authors would like to express sincere gratitude to Dr. A. Gopalakrishnan, Director, ICAR-CMFRI, Cochin for providing facilities and encouragement to carry out the above research work.

References

1 Holthuis L B, Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries, FAO Species Catalogue, Vol. 1, (FAO press, Rome, Italy) 1980, pp. 20.

2 Carpenter K E, Krupp F, Jones D A & Zajonz U, The living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates, FAO species identification guide for fishery purposes, (FAO press, Rome, Italy) 1997, p. 293.

3 Ruppert E E, Fox R S & Barnes R D, Invertebrate Zoology. A functional evolutionary approach, 7th Ed., (Brooks/Cole, Thomson Learning learning Inc.) 2004, p. 990.

4 Sumaila, U.R., Marsden, A.D., Watson, R. & Pauly, D., A global ex-vessel fish price database: construction and applications. *J. Bioecon.*, 9 (2007) 39-51.

5 CMFRI. Annual report 2015-16, (Central Marine fisheries Research institute, Kochi) 2016, p. 294.

6 Vibhasiri A, An assessment of Jinga shrimp, *Metapenaeus affinis* (Penaeidae) in Ban Don Bay, Gulf of Thailand, in: *Contributions to tropical fisheries biology*, FAO Fisheries Report, edited by S. Venema, J. Möller-Christensen & D. Pauly, (FAO Press, Italy, Rome) 1988, pp. 101-116.

7 Mathews, C.P., The biology, assessment and management of the *Metapenaeus affinis* (H. Milne Edwards, Penaeidae) stock in Kuwait. *Kuwait Bull. Mar. Sci.*, 10(1989) 3-36.

8 Chu, K.H., Chen, Q.C., Huang, L.M & Wong, C.K., Morphometric analysis of commercially important penaeid shrimps from the Zhujiang estuary, *China. Fish. Res.*, 23(1995) 83-93.

9 Ahmed, M. & Abbas, G., Growth parameters of the finfish and shellfish juveniles in the tidal waters of Bhanbhore, Korangi Creek and Miani Hor Lagoon. *Pakistan J. Zool.*, 32(2000) 21-26.

10 Kapiris, K. Metin, G. & Aydinage, I., Age and growth of the Jinga shrimp, *Metapenaeus affinis* (H. Milne Edwards, 1837) in the bay of Izmir, Turkey. *Rapp. Comm. int. Mer Médit.*, 40(2013) 451.

11 Ayub, Z. & Ahmed, M., Maturation and spawning of four commercially important penaeid shrimps of Pakistan. *Indian J. Mar. Sci.*, 31(2002) 119-224.

12 Dinh, T.D., Moreau, J., Van, M.V., Phuong, N.T. & Toan, V.T., Population dynamics of shrimps in littoral marine waters of the Mekong Delta, South of Viet Nam. *Pakistan J. Biol. Sci.*, 13(2010) 683-690.

13 Gerami, M.H., Paighambari, S.Y., Ghorbani, R. & Momeni, M., Population Structure, Growth and Mortality Rates of Jinga Shrimp, *Metapenaeus affinis* in Fishing Grounds of Hormozgan Province, Iran. *Caspian J. Appl. Sci. Res.*, 1(2012) 29-35.

14 Mohamed, K.H., Rao, P.V & George, M.J., Post-larvae of penaeid prawns of southwest coast of India with a key to their identification. *FAO Fisheries Report*, 57(1968) 487-503.

15 Rao, P.V., Studies on the larval development of the commercially important penaeid prawns of India. *J. Mar. Biol. Ass. India*, 15(1974) 95-124.

16 Thomas, M.M., Kathirvel, M & Pillai, N.N., Spawning and rearing of the penaeid prawn, *Metapenaeus affinis* (H. Milne Edwards) in the laboratory. *Indian J. Fish*., 21(1974) 543-556.

17 Subrahmanyam, C.B., Notes on the bionomics of the penaeid prawn *Metapenaeus affinis* (Milne edwards) of the Malabar coast. *Indian J. Fish.*, 10A(1963) 11-22.

18 Rao P V, Maturation and spawning of the penaeid prawns of the southwest coast of India. FAO Fisheries Report 2, (FAO Press, Italy, Rome) 1968, pp. 285-302.

19 Ramamurthy, S., Kurup, N.S. & Annigeri, G.G., Studies on the fishery of the penaeid prawn *Metapenaeus affinis* (Milne Edwards) along the Mangalore coast. *Indian J. Fish*., 22 (1975) 243-254.

20 Achuthankutty, C.T. & Parulekar, A.H., Growth of penaeid prawns in Goa waters. *Indian J. Mar. Sci.*, 15 (1986) 117-120.

21 Leena, K. & Deshmukh, V.D., Age and growth of Jhinga prawn *Metapenaeus affinis* Milne Edwards (Decapoda, Penaeidae) in Mumbai waters. *Indian J. Fish*., 56(2005) 1-5.

22 Paralkar S H, *Population dynamics of penaeid prawns of the genera Metapenaeus and Parapenaeopsis exploited in the trawl fishery along the coast of Maharashtra*. Ph.D. Thesis (University of Bombay, CIFE, Mumbai) 1990, pp. 297.

23 Chakraborty, S.K., Desmukh, V.D., Zaffarkhan, M., Vidyasagar K. & Raje S.G., Estimates of growth, mortality, recruitment pattern and MSY of important resources from the Maharashtra coast. *J. Indian Fish. Assoc.* (*Proc. Nat. Symp. Aquacrops*) 24(1994)1-39.

24 Gayanillo, Jr.F.C., Sparre, P. & Pauly, D., FAO-ICLARM Stock Assessment Tools II (FiSAT II). User's guide. FAO Computerized information Series (Fisheries), No.8, Revised Ver., (FAO Press, Rome, Italy) 2005, pp.126.

25 Treece, D.G. & Yates, M.E., Laboratory manual for the culture of Penaeid shrimp larvae, (Marine Advisory Service, Sea Grant College Program, Texas, USA) 1988, p. 95.

26 Pauly, D. & Munro, J.L. Once more, on the composition of growth in fish and invertebrates. ICLARM *Fishbyte,* 2 (1984) 21.

27 Pauly D, Some simple methods for the assessment of tropical fish stocks, FAO Fisheries Technical Paper No. 243, (FAO Press, Rome, Italy) 1983, pp. 52.

28 Le Cren, E.D., The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *J. Anim. Ecol.*, 20 (1951) 201-219.

29 Pauly, D., Length converted catch curves. A powerful tool for fisheries research in tropics (Part-I). ICLARM *Fishbyte*, 1(1983) 9-13.

30 Alagaraja, K., Simple methods for estimation of parameters for assessing exploited fish stocks, *Indian J. Fish.*, 31(1984) 177-208.

31 Ricker, W.E., Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can.*, 191 (1975) 1-382.

32 King M, Fisheries Biology, Assessment and Management, (Oxford University Press, Oxford, UK.) 1995, p. 342.

33 Ashton W D, The logit transformation with special reference to its uses in bioassay. (Haffner Publishing Co., Inc. New York, USA) 1972, pp. 88.

34 Beverton R J H & Holt S J, Manuals of methods for fish stock assessment: Part II Tables of yield function, FAO Fisheries Biology Technical Paper 38 (4), Ver. 1, (FAO Press, Rome, Italy) 1966, pp. 67.

35 Thompson W F & Bell F H, Biological statistics of the Pacific halibut fishery. Effect of changes in intensity upon total yield and yield per unit of gear. Report of the International Fisheries (Pacific halibut) Commission, No. 8, (IFC, Seattle, USA) 1934, pp. 49.

36 Franco, A.R., Ferreira, J.G. & Nobre, A.M., Development of a growth model for penaeid shrimp. *Aquaculture*, 259(2006) 268-277.

37 Sparre P & Venema S C, Introduction to tropical fish stock assessment, (FAO Press, Rome, Italy) 1992, pp. 376.

38 Froese, R.C. & Binohlan, C., Empirical relationship to estimate asymptotic length at first maturity and length at maximum yield per recruit in fishes with a simple method to evaluate length frequency data. *J. Fish Biol*., 56(2000) 758-773.

39 George, M.J., Raman K. &. Nair, P.K., Observations on the offshore prawn fishery of Cochin. *Indian J. Fish*., 10A(1963) 460-499.

40 Pauly, D., On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Conserv. CIEM*, 39(1980)175-192.

41 Vivekanandan E, Estimation of mortality rate. In: Stock assessment of tropical marine fishes, (Indian Council of Agricultural Research, New Delhi) 2005, pp. 52.

42 Bala B K, Arshad F M & Noh K M, System Dynamics: Modelling and Simulation, (Springer texts in business and economics, Singapore) 2017, pp.100.

43 Clarke M, A life history approach to the assessment of deepwater fisheries in the Northeast Atlantic. Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries, Part 1: Conference reports, FAO Fisheries Proceedings, (Food and Agriculture Organization of the United Nations, Queenstown, New Zealand) 2005, pp.196-210.

44 Silvestre, G.T. & Garces, L.R., Population parameters and exploitation rate of demersal fishes in Brunei Darussalam (1989-1990). *Fish. Res.*, 69 (2004) 73-90.

45 Gulland J A, Fish stock assessment. A manual of basic methods. FAO Wiley Series on Food and Agriculture, Vol. 1, (Wiley Interscience, Chichester, U.K.) 1983, pp. 223.

46 Pauly, D., Fish population dynamics in tropical waters: a manual for use with programmable calculators. *ICLARM Studies and Reviews* 8(1984) 1-325.

47 Clark, W.G., Groundfish exploitation rates based on life history parameters. *Can. J. Fish. Aqua. Sci*., 48(1991) 734-750.

48 Rosenberg A A & Repestro V R, Precautionary management reference points and management strategies, Precautionary approach to fisheries-Part 2, FAO Fisheries Technical Paper 350 (2), (FAO Press, Rome, Italy) 1996, pp.129-140.

49 Mace P M & Sissenwine M P, How much spawning per recruit is enough? in: *Risk Evaluation and Biological Reference Points for Fisheries Management*, edited by Smith, S. J., Hunt, J.J. & Revered, D. (Canadian Special Publication of Fisheries and Aquatic Sciences, National Research Council of Canada) 1993, pp. 101-118.

50 Pauly D, Theory and management of tropical multi-species stocks. A review with emphasis on the south-east Asian demersal fisheries. ICLARM Studies and Reviews 1, (ICLARM, Penang, Malaysia) 1979, pp. 35.