www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 12: 239-246 (2012) DOI: 10.4194/1303-2712-v12_2_07

Fishery Characteristics and Population Dynamics of Indian White Shrimp, *Fenneropenaeus indicus* from Arabian Sea, Sultanate of Oman

Sahar Fahmy Mehanna[1,*], Juma Al-Mamary[1], Lubna Al-Kharusi[1]

[1] Marine Sciences and Fisheries Centre Muscat, Oman.

* Corresponding Author: Tel.: +968.247 36449; Fax: +968.247 36449;
E-mail: Sahar_mehanna@yahoo.com

Received 28 December 2011
Accepted 4 February 2012

Abstract

Monthly carapace length frequency data of Indian white shrimp *Fenneropenaeus indicus* were collected from commercial cast net catch from the Omani waters of the Arabian Sea at Al-Mahout fishing area. Sampling covered the first three months of the shrimp fishing season from September to November during two years 2010 and 2011, where more than 95% of shrimp catch was landed. FiSAT software program was used to analyze its length frequency distribution. The size structure of *F. indicus* is characterized by sexual dimorphism, where females are significantly larger than males. Allover sex ratio was slightly in favor of females with an overall sex ratio 1:1.1 in 2010 and 1:1.28 in 2011. Growth parameters (K and L_∞) were estimated based on age-length data obtained from Bhattacharya method (1967). Also, the instantaneous rate of total mortality (*Z*), natural mortality (M) and fishing mortality (F) were estimated and accordingly the exploitation ratio was determined as F/Z. Per-recruit analysis showed an overfishing situation for *F. indicus* in Oman and the present level of exploitation rate should be reduced by about 12% to achieve the maximum yield per recruit and by about 50% to maintain a sufficient spawning biomass. To overcome any bias in our estimations, we suggest a gradual decrease in fishing effort starting by 10% and make year-to-year analysis to adjust computations of fishing mortality and age at first capture.

Keywords: Indian white shrimp; *Fenneropenaeus indicus;* Arabian Sea; population dynamics; management.

Introduction

Crustaceans, such as penaeid shrimp, crabs and clawed and spiny lobsters have become very important of world annual fishery production due to high demand for them in world markets. Shrimps are regarded as the most consumed fishery products in most developed countries. The demand and high foreign exchange earnings have driven exploitation of most shrimp stocks to unhealthy levels. The world's production of shrimp is about 6 million ton of which approximately 3.4 million ton is contributed by capture fisheries and 2.4 tons by aquaculture (FAO, 2000). Among the shrimp, the contribution of *Fenneropenaeus indicus* to global fisheries was around 2.4% (FAO, 2008). The species *F. indicus* is one of the major commercial penaeid species of the world. It is found in the Indo-West Pacific from East and Southeast Africa, through Malaysia and Indonesia to South China and Northern Australia. It is a marine shrimp (with estuarine juveniles) which likes mud or sandy mud at depths of 2 to 90 m.

The penaeid shrimp fishery is one of the most important fishery resources in Oman. The penaeid shrimp catch is composed of a number of species of which the Indian white shrimp *Fenneropenaeus indicus* is the most abundant one along with *P. semisulcatus*. Shrimps are greatly contributed to the Oman economy where 854 tons were landed in 2010 from which 790 tons were exported forming more than 2 million Omani Rial (OR = 2.6 USD).

Although the penaeid shrimp fishery has a great economical importance in Oman, very few studies of these species are available (Siddeek *et al.*, 1989, 2001). On the other hand, a number of studies concerning biology and fishery of penaeid shrimps were undertaken in different water bodies around the world (Chavez, 1973; White, 1975; Garcia and Le Reste, 1981; Jayakody and Costa, 1988; Dall *et al.*, 1990; Xucai and Mohammed, 1996; Mehanna, 1993, 2000, 2003; Jayawardane *et al.*, 2002; Cha *et al.*, 2004; Lopez-Martinez *et al.*, 2005; Mehanna and Khalifa, 2007; Mehanna and El-Gammal, 2008). The present work was to evaluate the shrimp fishery at Al-Mahout fishing area, as well as determination of population parameters required for its sustainable management in the Omani waters of Arabian Sea.

Material and Methods

Fishing Area

Al-Wusta Province is the first in shrimp production in Oman where about 96% of shrimp catch of Oman comes from it. There are a number of landing sites along Al-Wusta Province from which Al-Mahout is the most productive one. Al-Mahout (Figure 1), one of the main landing sites along the Arabian Sea coast of Oman.

Sampling

Length frequency data of *F. indicus* were collected from the commercial catch of the cast net fishery in Mahout area (Al-Khalouf landing site). Sampling procedure covered three months from September to November during two fishing seasons 2010 and 2011. It is worth mentioning that the shrimp fishery in Oman is seasonal starting at September and extending to the end of April. Nearly the whole shrimp catch was landed during the first three months with a very little proportion landed during December (Fishery statistics book, 2010). After sex-wise sorting out, the carapace length (straight length from posterior margin of the orbit to the median dorsal posterior edge of the carapace) to the nearest mm was measured by caliper for 1200 *F. indicus* in 2010 and 800 ones in 2011 and then the monthly carapace length frequencies for the two years were grouped into 2 mm classes for modal progression analysis (MPA).

Methods

For each sex the length frequency was resolved into normally distributed cohort components using Bhattacharya (1967) method and the results were used as input to Ford (1933) – Walford (1946) plot to estimate the asymptotic carapace length (CL_∞, in mm) and the rate at which the asymptotic length is attained (K, in y^{-1}). The growth parameters were also estimated using the ELEFAN I program. Initial values for L_∞ were obtained using the Powell-Wetherall method (Powell, 1979; Wetherall *et al.*, 1987). Total mortality (Z) was estimated using the cumulated catch curve (Jones and van Zalinge, 1981) this method is based on the existence of a linear relationship (over at least the central part of its range) between the natural logarithms of the cumulated frequency and the natural logarithms of (L_∞ - L). This relationship is expressed as: $\ln(CN) = a + (Z/K) \ln (L_\infty - L)$, Where ln(CN) is the natural logarithm of cumulated frequency, Z is the total mortality coefficient and K is the growth coefficient. Natural mortality (M) was calculated using the Pauly's (1980) formula using SST (annual mean sea surface temperature) equal 26°C (McIlwain *et al*., 2006). The fishing mortality (F) was computed as F = Z – M and the exploitation rate was computed from the rate F/Z (Gulland, 1971). The length at first capture (L_c) was estimated by the analysis of catch curve using the method of Pauly (1984).

Growth performance index (ǿ) for *F. indicus* was computed based on the length data using the following equation (Pauly and Munro 1984): $ǿ = \log K + 2 \log L_\infty$

The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated by using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986). The relative yield per recruit (Y'/R) model was used because it can provide the kind of information needed for management (Sparre and Venema, 1998). The following reference points were used to determine the status of *F. indicus*

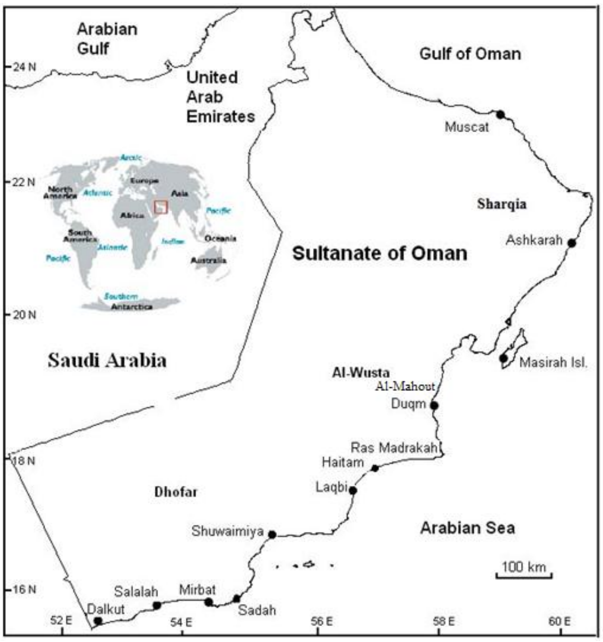

Figure 1. Main landing sites along the Omani coast of Arabian Sea.

stock in the Arabian sea: $E_{0.1}$ (the exploitation level at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase computed at a very low value of E), $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50%) and E_{max} (the exploitation level that produces the maximum yield per recruit).

Results and Discussion

Length Frequency Distribution

The carapace length frequency distribution for September, October and November combined of *F. indicus* during 2010 and 2011 is shown in Figure 2. In both 2010 and 2011, the largest percentage of males *F. indicus* (86%) is within the length classes of 27–37 mm CL and that of females is within the range 28-42 mm CL in 2010 (80%) and within the range 29-45 mm CL in 2011 (71%). The observed maximum length was 53 mm CL for males and 64 mm CL for females, while the observed minimum one was 18 mm CL for males and 22 mm CL for females. The size structure of *F. indicus* population in the Arabian Sea showed sexual dimorphism, where females are significantly larger than males.

Sex Ratio

The sex composition of *F. indicus* in commercial catches from Arabian sea varied significantly from month to month and from year to year. In 2010, male:female ratio was 1:1.06 in September, 1:0.74 in October and 1:1.49 in November, while in 2011, it was 1:1.09 in September, 1:1.75 in October and 1:2.54 in November. The overall sex ratio in the samples was 1:1.1 in 2010 and 1:1.28 in 2011 males to females which indicates the predominance of females in the commercial shrimp catch.

Population Parameters

Longevity and Growth in Length

The results obtained indicated that the maximum life span of males is 12 months while that of females is 18 months. Both males and females attain their highest rate of increase in length during the first three months of life after which a gradual decrease in growth increment was noticed with further increase in age. It was also apparent that females have a slightly higher growth rate than males (Figure 3). The results dealing with the life span of *F. indicus* show agreement with the fact that penaeid shrimp are characterized by a short life span in the order of two years (Garcia and Le Reste, 1981). The results also agree with the findings of Thomas (1975); Garcia and Van Zalinge (1982); Tom *et al.* (1984); Dredge (1990); Somers and Kirkwood (1991); Mehanna (1993, 2000 and 2003); Mehanna and Khalifa (2007); Mehanna and El-Gammal (2008).

Growth Parameters

The mean lengths for cohorts estimated by the Bhattacharya method for males and females were

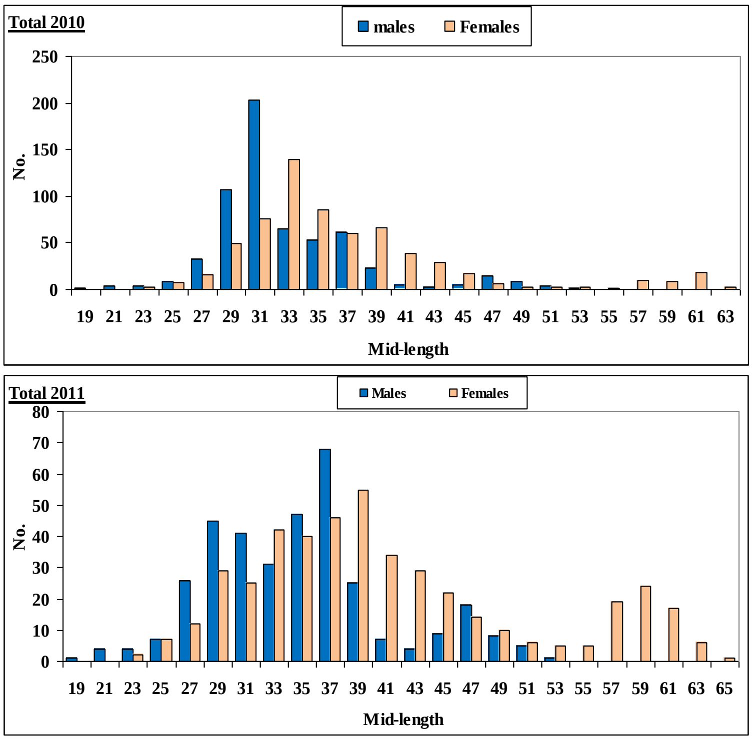

Figure 2. Carapace length frequency distribution for the three months combined for *F. indicus* in the Arabian Sea, Oman during 2010 and 2011.

fitted into Ford-Walford plot to estimate the growth parameters. The obtained values of K were 2.11 and 1.69 y^{-1} for males and females respectively, while CL_∞ = 57.11 and 68.56 mm carapace length for males and females respectively. Table 1 shows the growth parameters estimates obtained from ELEFAN I program and Wetherall method. The value of K for males is higher than that for females indicating the faster decrease in growth rates of males than females. The rapid growth of this species implied by high K -values agrees with the fact that the short-lived animals like shrimp reach their asymptotic length in a year or two and are characterized by a high K-value (Beverton and Holt, 1957 and Garcia and Le Reste, 1981). Also, the values obtained were consistent with those reported in other studies for related species (Table 2) and are within the reported range for other penaeids (D'Incao and Fonseca, 2000).

Growth Performance Index (ǿ)

The estimated values for the growth performance index (ǿ) of *F. indicus* during the present investigation were 3.84 for males and 3.9 for females

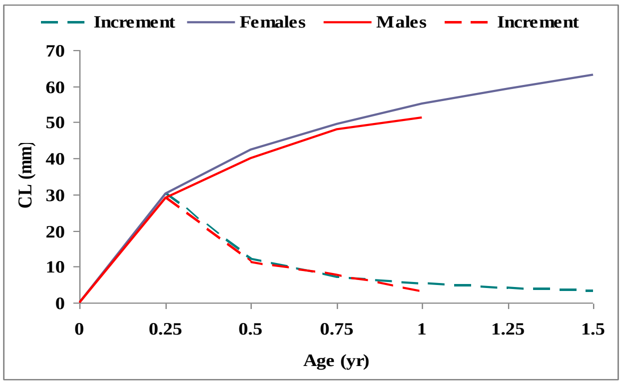

Figure 3. Length by age and growth increment of *F. indicus* in the Arabian Sea, Oman

Table 1. Growth parameters of *F. indicus* from the Arabian Sea of Oman obtained from different methods

Method	Males		Females		Sexes combined	
	K	CL_∞	K	CL_∞	K	CL_∞
Bhattacharya and Ford- Walford	2.11	57.11	1.69	68.56	1.73	68.33
ELEFAN I program	2.21	57.80	1.78	68.10	1.80	67.91
Wetherall and Bertalanffy plot	2.29	56.21	1.83	67.98	1.85	67.93

Table 2. Summary of the growth parameters (L∞ and K), natural mortality (M) and longevity available for some penaeid shrimp in different localities

Species	CL∞		K		M		Life span (month)	Locality	Author
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀			
Penaeus indicus			1.20	1.00	2.20	1.94	12	Manila Bay	Agasenand DelMundo, 1988
Penaeus indicus		56**		1.8		3.04	24	Srilanka	Jayakody and Costa, 1988
Penaeus stylifera			1.19	1.05	2.60	2.30		India	Suseelan and Rajan, 1988
Penaeus merguiensis			1.31	1.05	3.7	3.1		Indonesia	Sumiono, 1988
Penaeus longistylus			2.05	1.12		3.72	12	Australia	Dredge, 1990
Penaeus semisulcatus	38.1	62.2	1.3	3.2			18 - 24	Australia	Somers and Kirkwood, 1991
Penaeus japonicus			1.82	1.65	2.73	2.44	15 - 18	Red Sea, Egyp	Mehanna, 199
Penaeus indicus	200*	230*	2.0	2.0	2.0	2.0	12	India	Rao *et al.*, 1993
Penaeus semisulcatus			1.77	1.56	2.52	2.40	15 - 18	Red Sea, Egypt	Mehanna, 2000
Penaeus indicus	192*	199*	1.51	1.87	1.73	1.73		Srilanka	Jayawardane *et al.*, 2002
Penaeus latisulcatus			1.91	1.70	2.74	2.45	12 – 15	Red Sea, Egypt	Mehanna, 2003
Metapenaeus joyneri	29	34.7	1.02	1.22					Cha *et al.*, 2004
Litopenaeus stylirostris			2.28	1.92			15 - 20	California Gulf	Lopez-Martinez *et al.*, 2005
P. semisulcatus	38	50.4	1.6	2.2	2.11	2.41	15 - 20	Iran	Niamaimandi *et al.*, 2007
Metapenaeus stebbingi			2.63	2.16	3.73	3.16	9 - 12	Lake Timsah, Egypt	Mehanna andEl-Gammal, 2007
Penaeus indicus	57.1	68.6	2.11	1.69	2.35	1.93	12 - 18	Oman	Present study

* Total length ** sex not given

which were higher than those reported in the literature (2-3.1: Devi, 1986; Agasen and Del Mundo, 1988; Rao *et al*., 1993; Jayawardane *et al*., 2002). It is obvious that females have a slightly higher growth rate than males of this species and this species has a higher growth rate in Omani waters than other places.

Mortality and Exploitation Rate

The results (Figure 4) indicated that the total mortality coefficient differs between the two sexes (Z = 6.81 yr^{-1} for males and 5.38 yr^{-1} for females). Sparre (1990) pointed out that for small short-lived species which exposed to strong fluctuations in growth due to changing environmental conditions, the length based methods show an over estimation for Z. With the shortage of data available and the difficulties facing the direct methods of mortality estimation, these methods are widely used (eg. Jones and van Zalinge, 1981; Devi, 1986; Jayakody and Costa, 1988; Agasen and del Mundo, 1988; Sumiono, 1988; Dredge, 1990; Villarta *et al*., 2006; Nwosu, 2009). Also, these high values of Z are acceptable, because most of penaeid fisheries around the world have high fishing mortalities and thus show high Z values (Garcia and Le Reste, 1981; Garcia, 1984, 1985). According to the previous Z-estimations for penaeid shrimp, the present Z-values appear to lie in an acceptable range. The values of M obtained were 2.35 and 1.93 yr^{-1} for males and females respectively. Beverton and Holt (1959) found that the fast growing species have high K- values with high natural mortalities (Table 2). The values of fishing mortality rate F were 4.46 yr^{-1} for males and 3.45 yr^{-1} for females while the exploitation rate was estimated as 0.65 for males and 0.64 for females. Gulland (1971) suggested that the optimum exploitation rate for any exploited stock is about 0.5 at F_{opt} = M. More recent, Pauly (1987) proposed a lower optimum F that equal to 0.4 M. In the present study, F was higher than the values of F_{opt} given by Gulland and Pauly indicating a high level of exploitation of the *F. indicus* stock in the Oman coast of Arabian Sea.

Length at First Capture

The lengths at first capture (the length at which 50% of the fish are vulnerable to capture) were estimated as $L_{50\%}$ = 22 and 23.4 mm CL for males and females, respectively (Figure 5).

Per-Recruit Analysis and Reference Points

The use of yield-per-recruit models may be particularly restrictive for fast growing tropical species with high rates of natural mortality because

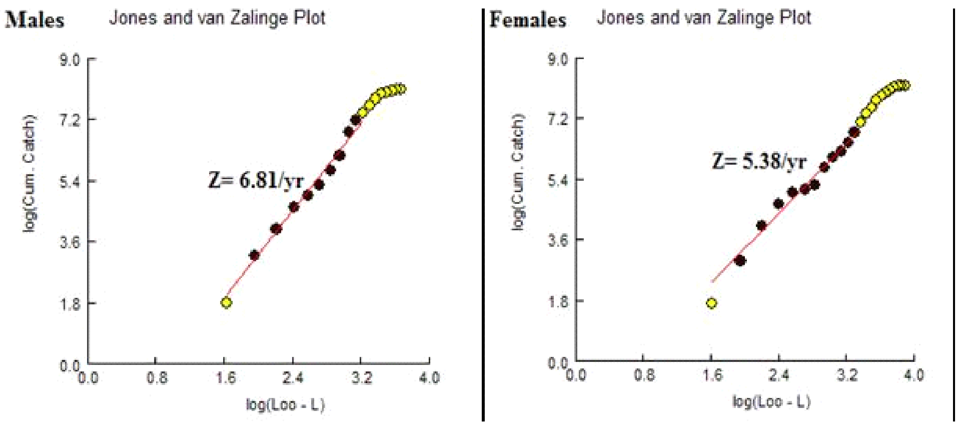

Figure 4. Length converted catch curve of *F. indicus* in the Arabian Sea, Oman.

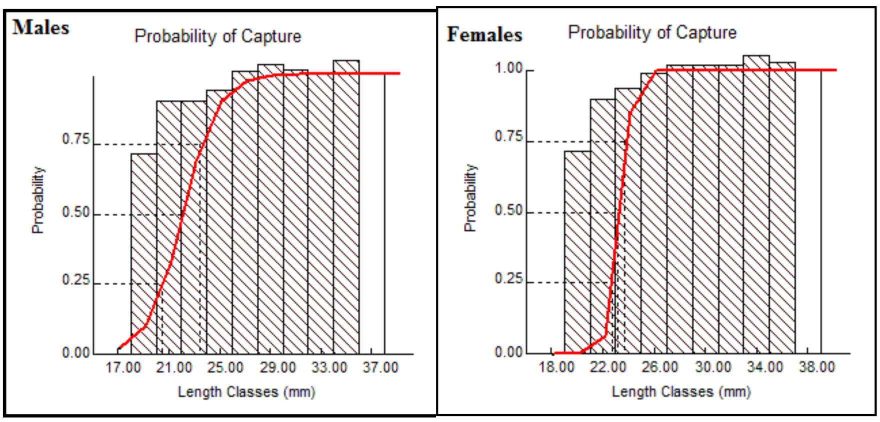

Figure 5. Probability of capture of *F. indicus* in the Arabian Sea, Oman.

the curves may not reach a maximum within a reasonable range of fishing mortality values (Gayanilo and Pauly 1997).

The plot of relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for males and females *F. indicus* (Figure 6) showed that the maximum (Y'/R) was obtained at nearly the same value of E (E_{MSY} = 0.57 for males and 0.54 for females). Both of $E_{0.1}$ and $E_{0.5}$ were estimated and the obtained values were 0.45 and 0.33 for males and 0.46 and 0.32 for females, respectively. The estimates of both values were lower than the current E which is also higher than that gives the maximum Y/R. For resource management purposes, it is suggested that the exploitation rate should be reduced to the conservative ones ($E_{0.1}$ or $E_{0.5}$). Accordingly, the fishing mortality should be reduced by about 30-52% of its current value.

Stock Status and Recommendations

The present study indicated that the Indian white shrimp exploited by the cast nets in the Oman coast of the Arabian Sea is overexploited, as the cast nets exploit under sized shrimps of *F. indicus* in varying proportions. This situation may also due to the illegal fishing practices and illegal fishing in the closure season, or also in the nursery areas.

The current measurements; closed season for four months each year and prohibition of trawls have been insufficient to conserve the shrimp fishery in Oman. Therefore, complementary measures are required such as reduce the fishing effort, this could be applied gradually starting by 10% decreasing reaching to 40% of its current value, protect the spawning and nursery grounds through the implementation of marine protected areas MPA to reduce the natural mortality, improve the national statistics on catch and fishing effort and increase the scientific efforts to make year-to-year analysis to adjust computations of fishing mortality and age at first capture based on the gradual decreasing scenario of fishing effort. Also, it is advisable to introduce an appropriate mesh regulation for cast nets with a view of increasing the mean size of the shrimps exploited, which would also be favorable from an economic point of view.

References

Agasen, E.V. and Del Mundo, C.M. 1988. Growth, mortality and exploitation rates of *Penaeus indicus* in Manila Bay, Philippines and south east India. In: S. Venema, J.M. Christensen and D. Pauly (Eds.), Contributions to Tropical Fisheries Biology. FAO Fish. Rep., 389: 89-100.

Bertalanffy, L. von 1938. A quantitative theory of organic growth (Inquiries on growth laws. 2). Hum. Biol., 10: 181-213.

Beverton, R.J.H. and Holt, S.J. 1957. On the dynamics of exploited fish populations. Fisheries Investigation Series II, 19: 1-533.

Beverton, R.J.H. and Holt, S.J. 1959. A review of the life spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. Ciba Foundation Colloqia on Ageing, 5: 142-180.

Beverton, R.J.H. and Holt, S.J. 1966. Manual of methods for fish stock assessment. Tables of yield functions. FAO Fisheries Technical Paper/ FAO Document Rome, 38(1): 1-67.

Bhattacharya, C.G. 1967. A simple method of resolution of a distribution into Gaussian components. Biometrics, 23: 115-135. doi: 10.2307/2528285

Cha, H.K., Choi, J.H. and Oh, C.W. 2004. Reproduction biology and growth of the shiba shrimp, *Metapenaeus joyneri* (Decapoda: Penaeidae) on the western coast of Korea. Journal of Crustacean Biology 24(1): 93-100. doi: 10.1651/C-2399

Chavez, E.A. 1973. A study on the growth rate of brown shrimp *Penaeus aztecus* (Ives., 1891) from the coasts of Veracruz and Tampaulipas. Mexico Gulf Res. Rep., 4(2): 278-299.

Dall, W., Hill, B.J., Rothlisberg, P.C. and Staples, D.J. 1990. The biology of the penaeidae. In: J.H.S. Blaxter and A.J. Southward (Eds.), Advances in Marine Biology, 27 Academic Press, London.

Devi, S. 1986. Growth and population dynamics of the Indian white prawn *Penaeus indicus* M Edwards from Kakinada. Proc. Indian Acad. Sci., 95(5): 629-639.

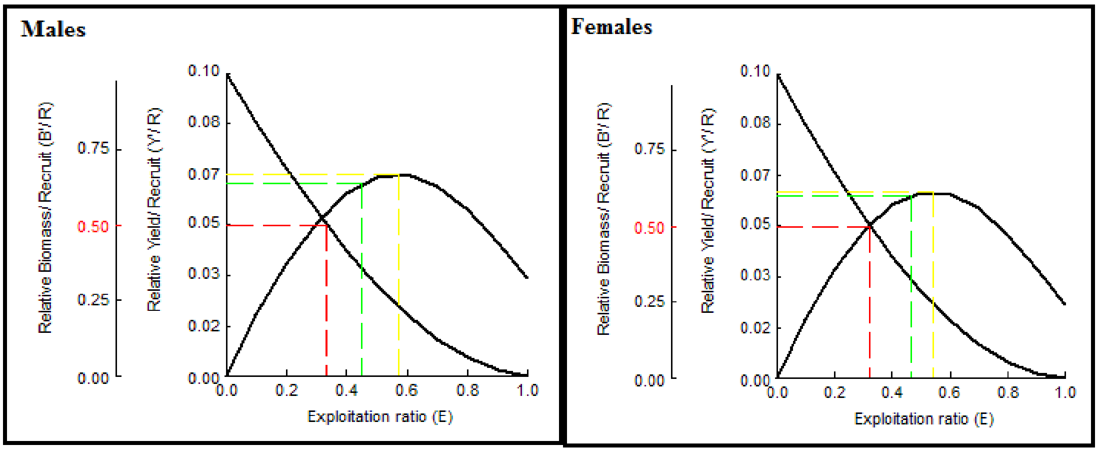

Figure 6. Per-recruit analysis of *F. indicus* in the Arabian Sea, Oman

doi: 10.1007/BF03179428

D'Incao, F. and Fonseca, D.B. 2000. Performance of the von Bertalanffy growth curve in penaeid shrimp: a critical approach. In: J.C. von Kaupel Klein and F.R. Schram (Eds.), the Biodiversity Crisis Crustacean, Bakena ed Rotterdam, 848 pp.

Dredge, M.C.L. 1990. Movement, growth and natural mortality rate of the red spot king prawn, *Penaeus longistylus* Kubo, from the Great Barrier Reef Lagoon. Aust. J. Mar. Freshw. Res., 41: 399-410. doi: 10.1071/MF9900399

FAO 2000. Fisheries Department, Fisheries Information, Data and Statistics Unit. FAO, Rome.

FAO 2008. Fisheries and Aquaculture Department, FAO Fisheries Statistics. FAO, Rome.

Fishery Statistics Book 2010. Year Book Issued by Department of Fisheries Statistics. Agricultural and Fisheries Wealth Ministry, Sultanate of Oman.

Ford, E. 1933. An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. J. Mar. Biol. Assoc. U.K., 19: 305-384.

Garcia, S.M. 1984. A note on environmental aspects of penaeid shrimp biology and dynamics. In: J.A. Gulland and B.J. Rothschild (Eds.), Penaeid shrimp-Their Biology and Dynamics. Fishing News Books Ltd, Farnham, UK: 268-271.

Garcia, S.M. 1985. Reproduction, stock assessment models and population parameters in exploited penaeid shrimp populations. In: P.C. Rothlisberg, B.J. Hill and D.J. Staples (Eds.), Second Australian National Prawn Seminar: 139-158.

Garcia, S.M. and Le Reste, L. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. FAO Fisheries Technical Paper No. 203: 1-215.

Garcia, S.M. and van Zalinge, N.P. 1982. Simple fishing in Kuwait: methodology for a joint analysis of the artisanal and industrial fisheries. In: Report on the workshop on assessment of the shrimp stocks of the west coast of the Gulf between Iran and the Arabian Peninsula. Fisheries development in the Gulf, FAO, Rome: 119-142.

Gayanilo, F.C. Jr. and Pauly, D. 1997. FAO–ICLARM stock assessment tools. Reference Manual. FAO, Rome. 262 pp.

Gulland, J.A. 1971. The fish resources of the Ocean. West Byfleet, Surrey, Fishing News (Books), Ltd., for FAO: 1-255.

Jayakody, D.S. and Costa, H.H. 1988. Population dynamics of Indian shrimp (*Penaeus indicus*, Milne Edwards) on the West Coast of Srilanka. Asian Fisheries Science, 1: 135-146.

Jayawardane, P.A., McLusky, D.S. and Tytler, P. 2002. Estimation of population parameters and stock assessment of *Penaeus indicus* (H. Milne Edwards) in the western coastal waters of Sri Lanka. Asian Fisheries Science, 15: 155-166.

Jones, R. and van Zalinge, N.P. 1981. Estimates of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bull. Mar. Sci., 2: 273-288.

Lopez-Martinez, J., Rabago-Quiroz, C., Nevarez-Martinez, M.O., Garcia-Juarez, A.R., Rivera-Parra, G. and Chavez-Villalba, J. 2005. Growth, reproduction and size at first maturity of blue shrimp, *Litopenaeus stylirostris* (Stimpson, 1874) along the east coast of the Gulf of California, Mexico. Fish. Res., 71: 93-102. doi: 10.1016/j.fishres.2004.06.004

McIlwain, J.L., Hermosa, G.V., Claereboudt, Jr., M.R., Al-Oufi, H.S. and Al-Awi, M. 2006. Patterns of spawning and reproduction of six exploited teleost species from the Arabian Sea, Sultanate of Oman. Journal of Applied Ichthyology, 22: 167-176. doi: 10.1111/j.1439-0426.2006.00723.x

Mehanna, S.F. 1993. Rational exploitation of *Peneaus japonicus* in the Gulf of Suez. MSc thesis, Egyp: Zagazig University, 236 pp.

Mehanna, S.F. 2000. Population dynamics of *Penaeus semisulcatus* in the Gulf of Suez, Egypt. Asian J. Fish., 13: 127-137.

Mehanna, S.F. 2003. Stock assessment and management of *Penaeus latisulcatus* in the Gulf of Suez, Egypt. Bull. Nat. Inst. Oceanogr. Fish., ARE, 29: 31-49.

Mehanna, S.F. and El-Gammal, F.I. 2008. Population dynamics and management of white shrimp *Metapenaeus stebbingi* (Penaeidae) at Lake Timsah, Suez Canal, Egypt. Asian fisheries science, 21: 305-317.

Mehanna, S.F. and Khalifa, U.A. 2007. Small shrimp fisheries management at Southeastern Mediterranean (Port Said region), Egypt. Egypt. J. Aquat. Biol. and Fish., 11(3): 927–942.

Niamaimandi, N., Bin Arshad, A., Daud, S.K., Saed, R.C. and Kiabi, B. 2007. Population dynamic of green tiger prawn, *Penaeus semisulcatus* (De Haan) in Bushehr coastal waters, Persian Gulf. Fisheries Research, 86: 105–112. doi: 10.1016/j.fishres.2007.05.007

Nwosu, F.M. 2009. Population dynamics of the exploited penaeid shrimp, *Penaeus* (*Farfantepenaeus notialis*) in the Cross River Estuary, Nigeria. Journal of Fisheries International, 4(4): 62-67. doi: 10.3923/jfish.2009.62.67

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. CIEM, 39(3): 175-192.

Pauly, D. 1984. Length-converted catch curves. A powerful tool for fisheries research in the tropics. ICLARM Fishbyte, 2(1): 17-19.

Pauly, D. and Munro, J.L. 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2(1): 21.

Pauly, D. and Soriano, M.L. 1986. Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In: J.L. Maclean, L.B. Dizon and L.V. Hosillo (Eds.), The First Asian Fisheries Forum, 491-496.

Powell, D.G. 1979. Estimation of mortality and growth parameters from length frequency of a catch. Rapports et Procès-verbaux des Réunions, Conseil International pour l'Exploration de la Mer, 175: 167-169.

Rao, G.S., Subramaniam, V.T., Rajamani, M., Manickam, P.E.S. and Maheswarudu, G. 1993. Stock assessment of *Penaeus* spp. off the east coast of India. Indian Journal of Fisheries, 40(1,2): 1-19.

Siddeek, M.S., El-Musa, M. and Abdul-Ghaffar, A.R. 1989. Final report of the shrimp fisheries management project, Phase V, Kuwait. Kuwait Inst. Sci. Res., KISR 3158: 104 pp.

Siddeek, M.S., Hermosa, G., Al-Amri, M.N. and Al-Aisery, A. 2001. Stock assessment of shrimp in the Gulf of Masirah, Sultanate of Oman. In: S. Goddard, H. Al-Oufi, J. McIlwain and M. Claereboudt (Eds.), Proc. 1st International Conference on Fisheries, Aquaculture and Environment in the NW Indian Ocean, Sultan

Qaboos University, Muscat, Sultanate of Oman: 107-118.

Somers, I.F. and Kirkwood, G.P. 1991. Population ecology of the grooved tiger prawn *Penaeus semisulcatus* in the north-western Gulf of Carpentaria, Australia: growth, movement, age structure and infestation by the bopyrid parasite *Epipenaeon igens*. Aust. J. Mar. Freshw. Res., 42: 349-367.

Sparre, P. 1990. Can we use traditional length-based fish stock assessment when growth is seasonal? ICLARM Fishbyte, 8(3): 29-32.

Sparre, P. and Venema, S.C. 1998. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper 306. Rome, 407 p.

Sumiono, B. 1988. Estimation of growth and mortality in banana prawn (*Penaeus merguiensis*) from the south coast of Java, Indonesia. In: S. Venema; J. Moller-Christensen and D. Pauly (Eds.), Contributions to Tropical Fisheries Biology. FAO Fish. Rep., 389: 69-88.

Suseelan, C. and Rajan, K.N. 1988. Stock assessment of the kiddi shrimp *Parapenaeopsis stylifera* off Cochin, India. In: S. Venema and N.P. Van Zalinge (Eds.), Contributions to tropical fish stock assessment in India. Gcp/Int/392/Den/1: 15-30.

Thomas, M.M. 1975. Age and growth, length-weight relationship and relative condition factor of *Penaeus semisulcatus* de Haan. Indian J. Fish., 22:133-142.

Tom, M., Shlagman, A. and Lewinsohn, C. 1984. The benthic phase of the life cycle of *Penaeus semisulcatus* de Haan (Crustacea, Decapoda) along the south eastern coast of the Mediterranean. Mar. Ecol., 5: 229-231.
doi: 10.1111/j.1439-0485.1984.tb00123.x

Villarta, K.A., Annabelle del Norte-Campos, G.C. and Campos, W.L. 2006. Some aspects of the population biology of the green tiger prawn *Penaeus semisulcatus* De Haan, 1844) from Pilar and Capiz Bays, Northern Panay, West Central Philippines. Science Diliman, 18(1): 1-10.

Walford, L.A. 1946. A new graphic method of describing the growth of animals. Biol. Bull. Mar. Biol. Lab., Woods Hole, 90(2): 141-147. doi: 10.2307/1538217

Wetherall, J.A., Polovina, J. and Ralston, S. 1987. Estimating growth and mortality in steady-state fish stock from length-frequency data. In: D. Pauly and G.R. Morgan (Eds.), Length-based Methods in Fishery Research: 53-74.

White, T.F. 1975. Population dynamics of the tiger prawn, *Penaeus esculentus*. PhD thesis, Australia: University of Western Australia.

Xucai, X. and Mohammed, H.M.A. 1996. An alternative approach to estimating growth parameters from length-frequency data, with application to green tiger prawns. Fishery Bulletin, 94: 145-155.