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Stock assessment of the spiny lobster *Panulirus polyphagus* (Herbst) off north-west coast of India

P V KAGWADE[1]

Central Marine Fisheries Research Institute, Cochin, Kerala 602 014

ABSTRACT

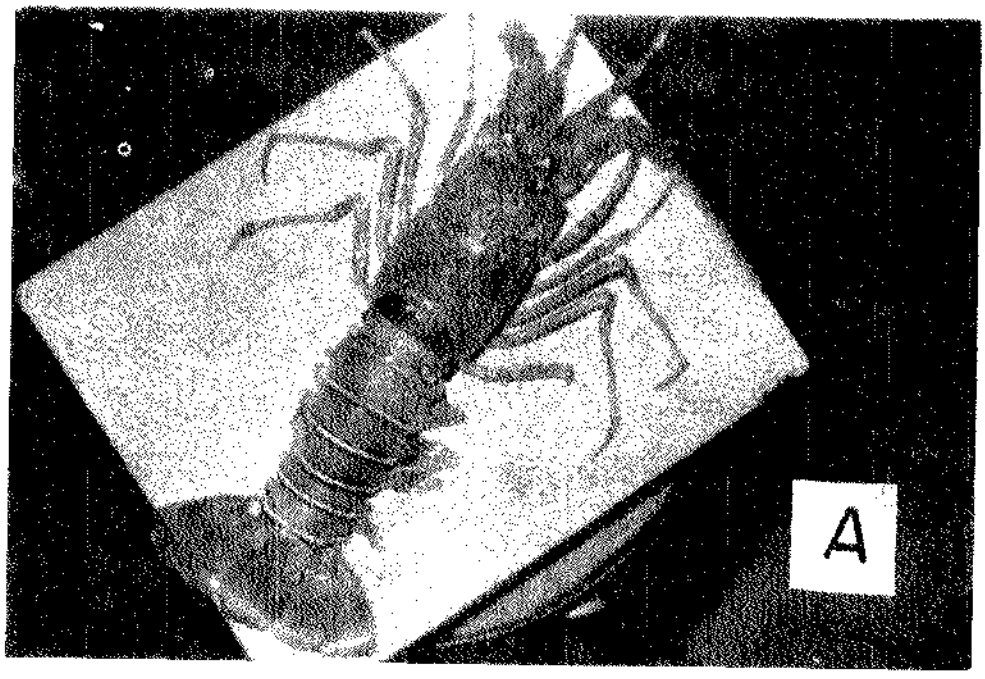
The fishery of *Panulirus polyphagus* has demonstrated successive periodic decline and revival. It has been able to survive for over 1 1/2 decades in spite of heavy exploitation. The present yields are 503.5 tonnes for males and 825.4 tonnes for females, while the MSY are 520.365 tonnes for the former and 837.8249 tonnes for the latter. The fishing effort would have to be reduced by 40% to reach the MSY level. Exploitation rate is 0.5096 for males and 0.4925 for females. Protecting the spawners either by banning their capture or by throwing them back into the sea during September, their peak spawning month, has been suggested as a small conservation measure.

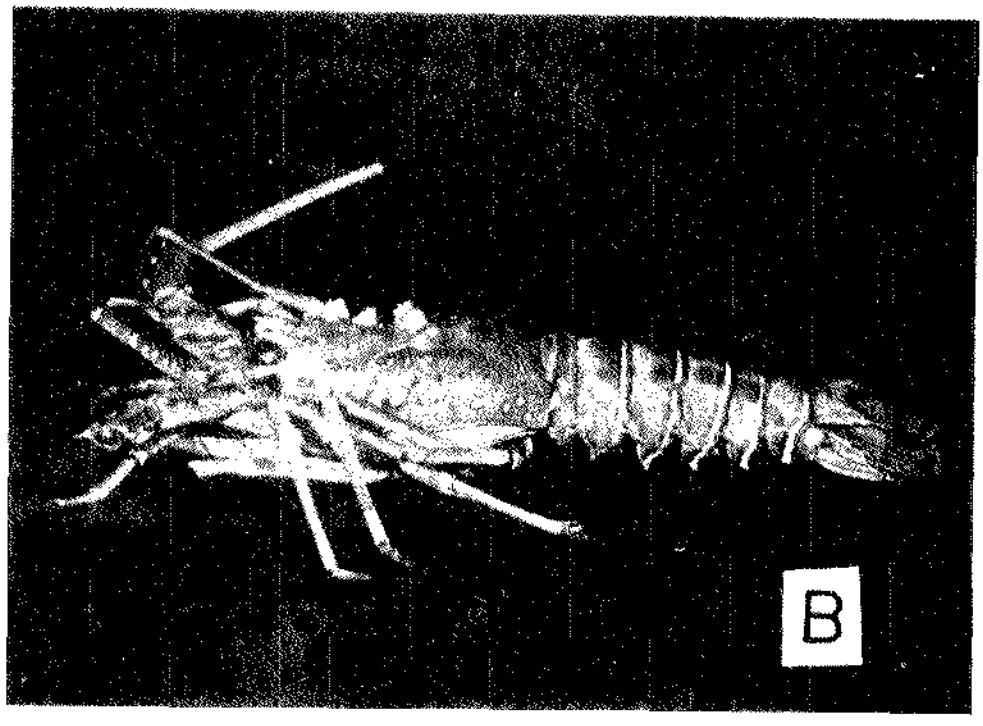
Miyomoto and Shariff (1961) conducted preliminary surveys to know the magnitude of lobster resources to take advantage of the lucrative world-wide market for the lobster tails. Chacko and George (1958) and Balasubramanyan *et al.*(1960) showed substantial potentialities for lobsters in the south-west coast of India. Though records of lobsters in the fisheries of Bombay (Rai 1993) and India (Chopra 1939) were available much before this, there was no attempt to increase their catch or to find out their availability in any other part of the country, because of the limited domestic demand. The entry of Indian lobster into the foreign market in late fifties led to intensive investigation for the lobster resources all over the country. New areas of good fishery potentials for lobsters were found along the coasts south of Trivandrum and north of Kozhikode in Kerala (George 1967) and Mandapam in Tamil Nadu (Nair *et al.* 1973). The strong urge to develop commercial fishery for lobsters in the second half of seventies brought to limelight some exploitable rich regions for this valuable commodity and thus enhanced its foreign trade. Export of frozen lobster/lobster tails from India increased from 560 tonnes (Rs 406 million in 1979-80 to 1 663 tonnes (Rs 2.36 million in 1988-89 (Mohamed and Madhavan 1989) thus signifying the importance of its fishery.

Two types of lobsters have been inhabiting the coastal waters of India. Of the 6 species of spiny lobsters, also known as rock lobsters and all belonging to the genus *Panulirus,* available in our waters 4 and one single species of sand lobster of the genus *Thenus* have been of commercial importance. These species are *P. polyphagus, P. homarus, P. ornatus, P. versicolar* and *T. orientalis.* The distribution and commercial abundance of each of these species are specific (Kagwade *et al.* 1991).

P. polyphagus is the most abundant species, contributing to nearly 3/4 of the lobster catch of this entire country. Its fishery has flourished well in Maharashtra and Gujarat in the north-west. The fisheries of the other 3 species of *Panulirus* are of very

Present address : [1]Principal Scientist, Bombay Research Centre of CMFRI, 148 Army and Navy Building, Bombay 400 023.





Penaeus polyphagus (Herbst). A. Dorsal view B. lateral view

small magnitude and restricted to small areas of Tamil Nadu and Kerala. *T. orientalis* has been landed in good quantities by the trawlers in the north-west coast and in Madras.

The status of the lobster fishery in this country depended on the prospects of the fishery of *P. polyphagus* because of its unique position in relation to its abundance. Much of the biological information is available on this species. Hence, the same has been chosen for the stock assessment studies.

DATA BASE

Primary data for all biological studies were collected from the major landing centres of Sassoon Dock and New Ferry Wharf in Bombay from 1984 to 1988. Data on fishery were drawn from the readily available published works and from the Fishery Resources Assessment Division of the Central Marine Fisheries Research Institute.

METHODS

Weekly random samples (each of at least 100 specimens) of *P. polyphagus* were drawn at the landing centres Sassoon Dock and New Ferry Wharf. This number could not be adhered to during the lean season. Sex-wise total lengths to the nearest million were measured from the transverse ridge between supraorbital horns to the tip of telson. The usual techniques were followed for various biological aspects of the study.

For the stock assessment study during 1984-88 the total number of *P. polyphagus* landed each year was estimated separately for males and females by the length groups. The number of lobsters so obtained were used as input for the Jones (1984) length cohort analysis. From this instantaneous fishing mortality (F) and instantaneous total mortality (Z) were estimated. The standing stock and biomass of this species were assessed by using length converted Thompson and Bell analysis (1934) using LFSA programme (Sparre 1987).

Jone's method (1979) for different combinations of L and M/K as inputs in cohort and Thomspon and Bell analysis were followed.

Fishery

Catch data for 1978-88 from the Central Marine Fisheries Research Institute were used for discussing the fishery. The annual fluctuations in the catch was a common phenomenon. The catches were lowest (679) in 1980, and highest in 1985 with the annual average catch of 2 016 t (Table 1). Percentage composition of *P. polyphagus* in Gujarat, Maharashtra, Kerala and Tamil Nadu are also given in Table 1. Kagwade *et al.* (1991) observed that Gujarat, Maharashtra and Kerala, each had only one major centre at Veraval, Bombay and Calicut respectively. Tamil Nadu had 3 centres one each at Kanyakumari, Tuticorin and Madras. Since the number of years of observations varied from centre to centre, the annual average catches were taken into consideration for this purpose. During the long period of 11 years, data were available for 3 years at Calicut, 5 years at Kanyakumari, 9 years at Veraval and 11 years for the rest. The maximum annual average catch for *P. polyphagus* was in Maharashtra (233 tonnes; 71.11%), followed by Gujarat (63 tonnes; 21.12%), Kerala (2 tonnes; 0.67%) and Tamil Nadu (0.3 tonne; 0.1%).

The landings of *P. polyphagus* in Bombay and Veraval representing Maharashtra and Gujarat, respectively, showed annual fluctuations (Table 2). Successive periodic decline and revival have

Table 1. All-India lobster landings and state-wise annual average lobster catch and percentage catch distribution of *P. polyphagus* during 1978-88

Year	All-India lobster catch (tonnes)	States	Period of observation	Annual average catch of lobsters (tonnes)	*P. polyphagus*	
					Catch (tonnes)	%
1978	1 307	Gujarat	1980-88	147	63.0	21.12
1929	1 135					
1980	679					
1981	1 481	Maharashtra	1978-88	429	233.0	71.11
1982	1 764					
1983	1 300	Kerala	1982-83 1983-84	8	2.0	0.67
1984	3 222		1985-86			
1985	4 082					
1986	3 057	Tamil Nadu	1978-88	47.3	0.3	0.1
1987	2 562					
1988	1 587					

Table 2. Quarter-wise distribution of annual average catch (kg), catch rate (kg, U) and percentage catch of *P. polyphagus* at Bombay during 1978-88

Annual average catch	Quarter				
	I	II	III	IV	Total
Kg	76 051	44 710	31 922	80 721	233 404
Kg/U	6.43	4.56	3.62	5.91	
%	32.6	19.1	13.7	34.6	

been noticed in its fishery. Similar trend of decline and revival was noticed in the All-India lobster catch also (Table 1).

P. polyphagus, though available all round the year, displayed seasonal abundance in its fishery. Its quarterly distribution based on the annual average catch during 1978-88 is given in Table 3. In Bombay the catch was maximum in the fourth quarter, followed by the first quarter. The catch rate in the first quarter was higher than 5.91 in the fourth quarter. The fishery of this species appeared to be the best during October-March. Similar observation was made by Kagwade *et al.* (1991) for *P. polyphagus*.

Table 3. Annual landings of *P. polyphagus* in tonnes in Bombay and Veraval during 1980-88

Year	Bombay	Veraval	Total
1980	189	66	255
1981	176	31	207
1982	176	30	206
1983	84	34	118
1984	309	107	416
1985	384	96	480
1986	450	61	511
1987	230	104	334
1988	147	35	182

This species was landed mainly by otter and shrimp trawls. These were of 16-23 mt with the head rope of varying length. Mesh size at the cod-end was 2.5 mm.

Biology

George (1967) reported the annual growth rate for *P. homarus* by length frequency method, and Mohammed and George (1971) estimated the length at age of the same species by tagging experiments. Growth under captivity was noted by Thomas (1972) in *P. homarus*, Kathirvel (1973) in *P. polyphagus* and Nair *et al.* (1981) in *P. homarus*, *P. ornatus* and *P. peniciliatus*. All these growth rates reported for lobsters were of preliminary nature limited to short time intervals and between certain lengths. There had been no intensive study to follow it up from the juvenile to adult stage. Eyestalk ablation studies by Radhakrishnan and Vijayakumaran (1982) showed acceleration of moulting frequency in *P. homarus*.

Using the 7-year length frequency data from 1976 to 1982, Kagwade (1987a) estimated the age of *P. polyphagus*. Juveniles of both the sizes showed identical growth rates and measured 85 mm in the first year, 145 mm in the second year and 205 mm in the third year. The growth rates differed in the 2 sexes thereafter. Males demonstrated faster growth rates and were 265, 315 and 355 mm by the end of years 4, 5 and 6 respectively. Females due to their slower rates of growth measured 255, 290, 320, 345 and 365 mm by the end of successive years from 4 to 7. Growth in the juvenile phase presented arithmatic type with the constant annual growth increment of 60 mm in both the sexes. Adults followed retrogressive geometric growth wherein the annual growth increment decreased year after year.

Growth parameters derived for adults by von Bertalanffy's growth formula were:

Males: L_∞ = 537 mm
K = 0.2
t_o = 0.6037 and
Females: L_∞ = 443 mm
K = 0.2231
t_o = 0.1985

Morphological relationships and conversion factors in *P.polyphagus* (Kagwade 1987b) showed that each of the relationships of carapace length with total length and of abdominal weight with the total weight was linear while the relationships between total length and total weight, total length and abdominal weight, and carapace length and abdominal weight were exponential. Formulae for the 2 most important relationships commonly in use in the fishery biological studies for this species were

1. CL = 6.4550 + 0.4074 TL for males
   and
   CL = 5.7934 + 0.3945 TL for famales
2. TW = 0.00007447 $TL^{2.8022}$ for males
   and
   TW = 0.0001950 $TL^{2.6163}$ for females

Kagwade (1988a) mentioned that based on the gonadal maturity the size at maturity at 50% level for this species was at 175 mm for females but, the physical maturity was at 265 mm for males and 205 mm for females.

Impregnated and ovigerous females were encountered in the catches all round the year. Spawning was repetitive and several broods entered the fishery in a year. Major spawning was in January and September. The minor one was in April, May and August. The spawning being throughout the year, occasional spawning was noticed in April, May and August. Predomination of one sex over the other was very marginal being 1.3:1 whenever

males dominated, and 1:1.7 whenever females dominated. Extreme sex ratios resulting in sexual segregation have never been reported.

More than one linear relationship between fecundity and the length of *P. polyphagus* (Kagwade 1988b) showed a progressive increase in the number of batches of eggs and also in the number of eggs in each of the batches with the increase in the size of the lobster. The number of batches of eggs ranged from 2 to 5. The absolute number of eggs in all the batches together was 143 000 in a lobster of 180 mm size and 7 423 000 in a larger one (353 mm).

The instantaneous mortality rates, viz. total (Z), natural (M) and fishing (F) for *P. polyphagus* for 1978-85 were given by Kagwade (1988, MS). The values estimated were:

Z = 1.76
M = 0.33
F = 0.35 for males, and
Z = 1.15
M = 0.35
F = 0.80 for females

Stock assessment

The unconventional growth pattern prevalent among crustaceans was more pronounced in lobsters. For this reason, often lobsters could not be aged. In a situation like this Jones (1979) applied a method for the stock assessment of Nephros wherein the values of the growth parameter L and of the ratio M/K between the instantaneous natural mortality (M) and the growth coefficient (K) were made use of.

The estimated age and length for *P. polyphagus* were available only for 6 years in males and 7 years in females at the end of which they measured 355 and 365 mm respectively (Kagwade 1987a). However, on record, the largest male measured 450 mm (George 1973) and the largest female 395 mm (Kagwade 1987a). Spiny lobsters beyond 6-7 years of age were not known and hence, the method followed by Jones (1979) was utilized to assess the stock of this species.

$L\infty$ was 537 mm for the males and 443 mm for the females of *P. polyphagus* (Kagwade 1987a). Jones (1979) conducted preliminary analysis with different combinations of values of $L\infty$ and the ratio M/K was worked out (Jones 1979). The range between 400 and 450 mm was considered to represent the range of $L\infty$ for both the sexes. Making use of the age at length estimates (Kagwade 1987a), values of K and M for different values of $L\infty$ were arrived at by back calculation.

Different values of M/K were tried to determine the rate of exploitation. Critical values for this ratio were between 1 and 1.5. Various combinations of the values of $L\infty$ between 400 and 450 mm and of M/K between 1 and 1.5 were used to assess the stock of *P. polyphagus*.

Input parameters used for Cohort analysis are given in Table 4. Sex-wise Cohort analysis using the values of 1 and 1.5 for the M/K ratio for each of the two values of 400 and 450 mm for $L\infty$ gave the exploitation rate (F/Z), instantaneous mortality rates of (F) and (Z), biomass and yield for the species (Table 5).

The current state of yield and biomass was assessed by the Thompson and Bell (1934) model. The yields were 503.6 tonnes for males and 825.4 tonnes for females. For the combination of $L\infty$ of 400 mm and M/K of 1, MSY obtained was 519.9140 tonnes, for males and 839.2977 tonnes for females (Table 6). To reach the MSY level in this case the fishing effort would have to be reduced by 40%. Considering the same

Table 4. Input parameters for cohort analysis of *P. polyphagus*

Sex	L	K	M	M/K	Terminal F/Z
Males	400	0.383	0.383	1	0.530
	400	0.383	0.574	1.5	0.530
	450	0.270	0.270	1	0.683
	450	0.270	0.405	1.5	0.683
Female	400	0.309	0.309	1	0.600
	400	0.309	0.464	1.5	0.600
	450	0.21	0.21	1	0.811
	450	0.21	0.315	1.5	0.811

Table 5. Mean values of exploitation rate, mortality rate, biomass and yield of *P. polyphagus* obtained by length cohort analysis using different combinations of L∞ and M/K

L∞ (mm)	M/K	Sex	Exploitation rate F/Z	Fishing mortality F	Total mortality Z	Biomass (tonnes)	Yield (tonnes)
400	1	Male	0.6556	0.7309	1.1149	658.0764	504.1513
400	1.5	Male	0.5254	0.6355	1.2095	794.8983	504.1513
400	1	Female	0.6692	0.6245	0.9323	1490.3193	826.1097
400	1.5	Female	0.5470	0.5601	1.0240	1817.6907	826.1097
450	1	Male	0.7678	0.8930	1.1630	660.3887	504.1513
450	1.5	Male	0.5096	0.8369	1.2419	752.5179	504.1513
450	1	Female	0.5659	0.7662	0.9762	1543.3811	826.1097
450	1.5	Female	0.4925	0.7355	1.0505	1775.4309	826.1097

Table 6. Thompson and Bell long-term forecast of yield and biomass in tonnes for male and female *P. polyphagus* when L∞ = 400 mm and M/K = 1

	Male		Female	
Effort	Yield	Mean biomass	Yield	Mean biomass
0.0000	0.00	3761.12	0.00	7049.24
0.2000	394.99	1954.78	657.15	3663.02
0.4000	499.31	1253.30	807.64	2407.07
0.6000	519.69	933.33	838.02	1972.54
0.8000	515.16	762.17	836.30	1679.13
1.0000	503.60	656.92	825.40	1488.16
1.2000	490.60	584.84	812.01	1351.22
1.4000	477.92	531.55	798.30	1246.70
1.6000	466.05	489.98	784.98	1163.47
1.8000	455.08	456.32	772.30	1095.12
2.0000	444.96	428.30	760.31	1037.65

Male: MSY 519.914; X 0.6375; Biomass MSY 896.055.
Females: MSY 839.2976; X 0.6625; Biomass MSY 1830.064.

L∞ of 400 mm but taking M/K as 1.5, the MSY noted was 504.7006 tonnes for males and 836.9321 tonnes for females (Table 7). The fishing effort in this case, however, would have to be increased by 20-40% to reach the level of MSY.

Table 7. Thompson and Bell long-term forecast of yield and biomass in tonnes for male and female *P. polyphagus* when L∞ = 400 mm and M/K = 1.5

	Male		Female	
Effort	Yield	Mean biomass	Yield	Mean biomass
0.0000	0.00	2586.27	0.00	5083.21
0.2000	302.12	1713.16	509.42	3414.79
0.4000	424.24	1280.21	695.12	1661.90
0.6000	475.19	1040.16	772.63	2252.13
0.8000	496.10	892.62	808.23	1994.51
1.0000	503.60	793.44	825.40	1814.91
1.2000	504.80	721.73	833.40	1680.46
1.4000	502.95	666.88	836.67	1574.73
1.6000	499.56	623.12	837.02	1488.60
1.8000	495.41	587.07	835.64	1116.57
2.0000	490.90	556.64	833.17	1335.08

Male : MSY, 504.7006; X, 1.2125; Biomass MSY = 711. 1263.
Female: MSY 836.9321; X 1.6125; Biomass MSY = 1475.101

The MSY for the combination of L of 450 mm and M/K of 1 worked out to 573.0253 tonnes for males and 914.2406 tonnes for females (Table 8). To reach the MSY level, the fishing effort in this situation would have to be cut down by 60% from the current effort. For the combination of L∞ of 450 mm and M/K of 1.5, the MSY obtained was 520.3650 tonnes for males and 837.8249 tonnes for females (Table 9). Here also, as observed earlier, the fishing effort would have to be reduced by 40% so as to reach the MSY level.

DISCUSSION

The combination of L∞ as 400 mm and of M/K as 1.5 alone suggested for an increase in the fishing effort by 20-40% to reach the MSY level. In all the other three

Table 8. Thompson and Bell long-term forecast of yield and biomass in tonnes for male and female *P. polyphagus* when L∞ = 450 mm and M/K = 1

	Male		Female	
Effort	Yield	Mean biomass	Yield	Mean biomass
0.0000	0.00	5662.90	0.00	10711.99
0.2000	520.17	2210.71	864.68	4038.80
0.4000	573.81	1279.65	916.32	2598.31
0.6000	555.13	933.27	888.63	2041.03
0.8000	528.19	762.56	855.30	1738.40
1.0000	503.60	659.20	825.40	1541.01
1.2000	482.46	587.90	799.41	1398.93
1.4000	464.29	534.66	776.72	1290.08
1.6000	448.49	492.83	756.68	1203.25
1.8000	434.58	458.79	738.79	1131.85
2.0000	422.17	430.38	722.64	1071.73

Male : MSY, 573.0253; X, 0.4125; Biomass MSY = 1195. 927.
Female: MSY 914.2406; X 1.4125; Biomass MSY = 2467.699

Table 9. Thompson and Bell long-term forecast of yield and biomass in tonnes for male and female *P. polyphagus* when L∞ = 450 mm and M/K = 1.5

	Male		Female	
Effort	Yield	Mean biomass	Yield	Mean biomass
0.0000	0.00	3682.59	0.00	7243.18
0.2000	424.40	1881.74	710.15	3709.14
0.4000	509.22	1272.52	819.82	2700.31
0.6000	520.65	1000.12	837.59	2235.91
0.8000	514.60	848.92	834.40	1960.58
1.0000	503.24	751.11	825.40	1772.68
1.2000	492.38	681.11	814.74	1633.39
1.4000	481.62	627.62	803.81	1524.55
1.6000	471.55	584.88	793.11	1436.32
1.8000	462.21	549.64	782.82	1362.82
2.0000	453.54	519.89	773.02	1300.26

Male: MSY 520.365; X 0.6125; Biomass MSY = 967.7751
Female: MSY 837.8249; X, 6375; Biomass MSY = 2178.388

combinations, the fishing effort had to be reduced. Between the lengths 400 and 450 mm, it would be justified to consider the latter for L∞ value because when the largest lobster on record was 450 mm, it would be unrealistic to consider the former for it. Instantaneous natural mortality (Kagwade 1988 MS) was 0.33 for males and 0.35 for females. The growth coefficient (K) was 0.2 for males and 0.2231 for females. The ratio of M/K for these sets was 1.6 for both the sexes. Hence, between the values of 1 and 1.5 for M/K, the latter appeared to be appropriate since it is close to 1.6. In view of all these, the combination of L∞ as 450 mm and M/K as 1.5 was considered as the best suited. For this combination (Table 5) the status of the fishery was:

	Males	Females
Exploitation rate	0.5096	0.4925
Fishing mortality	0.8369	0.7355
Total mortality	1.2419	1.0505
Biomass	752.5179 (tonnes)	1775.4309 (tonnes)

In the context of the current decline in the fishery of *P. polyphagus* the use of critical values for L∞ and M/K established that there should be no further increase in the fishing effort (F). However, it would not be practical to take up any control measure in fishing for this species because it formed a by-catch of extremely small proportion in the trawler landings which comprised a variety of other fishes.

Natural mortality for lobsters in the adult phase is minimum as they have limited enemies. Though teleosts, sharks, rays, skates and octopuses are their natural enemies, the stomach analysis of many of the fishes from Bombay waters had not reported lobster from their stomach. The reason is their gregarious movements and sheltering habit in rocky areas and crevices. Over and above all these, the hard shells of large lobsters might also be not suited to be preyed upon. This showed that fishing had been the main factor for affecting its fishery.

Mesh regulation is practised for controlling a fishery. However, because of the highly irregular shape of the lobster with long walking legs and antennules, the mesh regulation of the trawl net would be

meaningless for *P. polyphagus*. Even with large mesh size the lobster could get entagled and caught in the net.

While introducing management measures, care should also be taken to include biological considerations. The present requirement for export by the traders has been the minimum tail weight of 30 g when the lobster would be about 150 mm in total length (Kagwade 1987b). At this length, the animals would be juveniles. Therefore, the minimal legal weight for export of lobsters should be fixed at about 80 g for the tails when most of them measured about 200 mm in total length, a size when they would be mature.

Fecundity rate is very high in this species, crossing over 4 million in larger specimens. It is in direct relation with the length. Mated or impregnated and ovigerous females formed a good percentage in the catches. It would be difficult to ban the capture of these breeding stocks because they occur in all length groups throughout the year. In the trawler catches percentage of ovigerous females declined from as high as 40.7% in 1978 (Kagwade 1988a) to 24.06% in 1988 due to heavy exploitation. During the major spawning in September and January, the percentage of spawners remained high even after 1988 and often crossed 50%. The fishery of *P. polyphagus* with the exception of some years, picked up in the third week of September. In view of heavy landing of spawners right from the beginning of lobster fishery soon after the lean period for it in monsoon, it was felt that a short ban on capture of lobsters or at least compelling to throw the ovigerous females back into the sea till the end of September might act as a small conservation measure and help in the protection of good number of spawners for the replenishment of the stock.

The fishery of the sand lobster (*T. orientalis*) in Bombay waters was short lived lasting not more than 5 to 6 years, probably because of the low fecundity and high exploitation. Unlike this, the fishery of *P. polyphagus* with its periodic decline has been able to service for over 1 1/2 decades in spite of heavy exploitation. This has been attributed to its high fecundity and breeding throughout the year. However, this gifted aspect of its reproductive biology should not be taken advantage of to harm its fishery by over-exploitation. If the present trend of fishing continued, sooner or later, it might reach the same fate as of *T. orientalis*.

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REFERENCES

Balaubramanyan R, Satyanarayana R V V and Sadanandan K A. 1960. A preliminary account of the experimental rock lobster fishing conducted along south-west coast of India with bottom set gill nets. *Indian Journal of Fisheries* 7(2) : 407-22.

Chacko P I and George S. 1958. An appraisal of the sea fisheries resources of the Kanyakumari District. Madras Fisheries Marketing Report No.III.

Chopra B. 1939. Some food prawns and crabs of India and their fisheries. *Journal of the Bombay Natural History Society* 61(1): 203-207.

Goerge M J. 1967. Observation on the biology and fishery of the spiny lobster *Panulirus homarus* (Linn). *Proceeding of the Symposium on Crustacea, Marine Bilogical Association of India.* 4: 1308-16.

Goerge M J. 1973. The lobster fishery resources of India. *Proceedings of the Symposium on Living Resources of Seas Around India.* Spl. publication, Central Marine Fisheries Research Institue, Cochin, pp. 570-80.

Jones R. 1979. An analysis of a Nephros stock using length composition data. Rapp. P.V.Reun. Cons. int. Explor. Meri. 175: 259-69.

Jones R. 1984. Assessing the effects of changes in

exploitation pattern using length composition data (with notes on VPA and cohort analysis). *FAO Fisheries Technology Papers* (256): 118.

Kagwade P V. 1987a. Morphological relationships and conversion factors in spiny lobster *Panulirus polyphagus* (Herbest) from the north-west coast of India. *Indian Journal of Fisheries* 34(3): 348-52.

Kagwade P V. 1987b. Age and growth of spiny lobster *Panulirus polyphagus* (Herbst) of Bombay waters. *Indian Journal of Fisheries* 34 (4): 389-98.

Kagwade P V. 1988a. Reproduction in the spiny lobsters *Panulirus polyphagus* (Herbst). *Journal of Marine Biology Association of India* 30 (1,2): 37-46.

Kagwade P V. 1988b. Fecundity in the spiny lobster *Panulirus polyphagus* (Herbst). *Journal of Marine Biology Association of India* 30 (1,2): 114-120.

Kagwade P V. 1988MS. Estimates of the stocks of the spiny lobster *Panulirus polyphagus* (Herbst) in the trawling ground off Bombay.

Kagwade P V, Manickaraja M, Deshmukh V D, Rajanmani M, Radhakrishnan E V, Suresh V, Kathirvel M and Rao G S. 1991. Magnitude of lobster resource of India. *Journal of Marine Biology Association of India* 33 (1,2): 150-58.

Kathirvel M. 1973. The growth and regeneration of an aquarium held spiny lobster, *Panulirus polyphagus* (Herbst). *Indian Journal of Fisheries* 20 (1): 219-21.

Miyamoto H and Shariff A T. 1961. Lobster fishery off the south-west coast of India. Anchor hook and trap fisheries. *Indian Journal of Fisheries* 8 (1): 252-68.

Mohammed K H and George M J. 1971. Results of the tagging experiments on the Indian spiny lobster *Panulirus homarus* (Linn.) - Movement and growth. *Indian Journal of Fisheries* 15: 15-26.

Mohammed K K and Madhavan K K. 1989. Marine products export review 1988-89. *The Marine Products Export Development Authority, Ministry of Commerce, Government of India* pp 1-20.

Nair R V, Soundarajan R and Nandakumar G. 1981. Observations on growth and moulting of spiny lobsters *Panulirus homarus* (Linnaeus), *P. ornatus* (Fabircius) and *P. penicillatus* (Oliver) in captivity. *Indian Journal of Fisheries* 28: 25-35.

Rai H S. 1933. Shell fisheries of Bombay Presidency Part II. *Journal of Natural History Society* 36(4): 884-97.

Radhakrishanan E V and Vijayakumaran M. 1982. Unprecedented growth induced in spiny lobsters. *Marine Fisheries Information Service, T and E ser.* 43: 6-8.

Sparre P. 1987. Computer programmes for fish stock assessment. Length based fish stock assessment for Apple II computers. *FAO Fisheries Technological Paper* (10) Suppl. 2: 218.

Thomas M M. 1972. Growth of the spiny lobster, *Panulirus homarus* (Linnaeus) in captivity. *Indian Journal of Fisheries* 19: 125-29.

Thompson W F and Bell F H. 1934. Biological statistics of the Pacific halibut fishery 2. Effect of changes in intensity upon total yield and yield per unit of gear. *Report of the International (Pacific Halibut) Committee* 8: 1-49.