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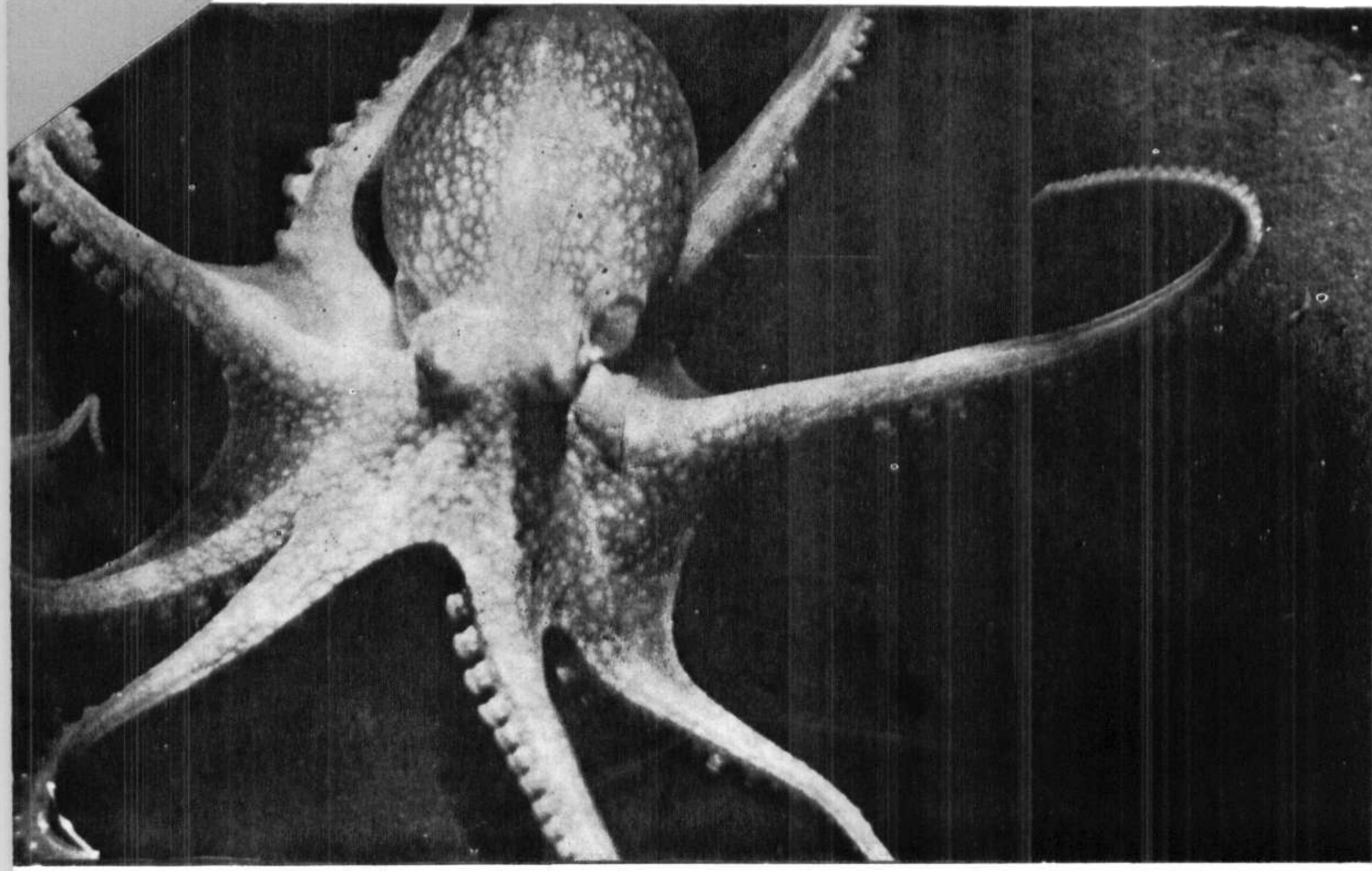

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STOCK ASSESSMENT : SQUIDS AND CUTTLEFISHES AT SELECTED CENTRES

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Abstract

Stock assessment studies have been made on the squid *Loligo duvaucelii* of Madras and Cochin areas, the cuttlefish *Sepia aculeata* of Madas area and *Sepia pharaonis* of Vizhinjam area. The exploitation rate, total mortality, instantaneous mortality, average annual stock and standing stock have been estimated and discussed. The study shows that in Vizhinjam area there is scope for increasing production in the existing fishing grounds.

Introduction

Cephalopods comprising squids and cuttlefishes are one of the important marine fishery resources in India especially since they are processed and exported to various countries. However, so far no detailed studies have been attempted on the stocks of this resource which is distributed in various parts of the Indian coasts. Stock assessment and management of cephalopod resources of Japan Sea and different areas of Atlantic, Pacific and Indian Oceans have been investigated or reviewed by Okutani (1977), Sanders (1981), Lange and Sissenwine (1983), Osako and Murata (1983), Sato and Hatanaka (1983), Chikuni (1983) and Caddy (1983). Studies on the stocks of cephalopods have been carried out at three selected centres viz., Madras, Cochin and Vizhinjam (Trivandrum) in the present work and the results obtained are presented here.

Data Base

Squids and cuttlefishes are obtained as by-catch mostly in shrimp trawl nets, shore seines and boat seines. Only along the southwest coast of India between Kanyakumari and Vizhinjam there is an organised fishery for cuttlefishes exploited with hooks and lines. In this work, the cuttlefish *Sepia pharaonis* fishery at Vizhinjam conducted with hooks and lines during 1978-'80 and trawl catches of *Loligo duvaucelii* at Madras and Cochin and the cuttlefish *Sepia aculeata* catches at Madras during 1979-'80 have been studied. The fishery is limited to the 50 m depth line in the traditional trawling grounds as it is the case in most of the marine fisheries of the country.

The data base consists of sexwise weighted length frequency composition on observed days from which the monthly estimates are arrived at. The average length frequency data which has been used in the stock assessment was obtained by considering the average contribution of each length class during the study period.

Estimation of Growth Parameters

It is assumed that growth in dorsal mantle length of the species considered follows von Bertalanffy's (1938) equation, its functional form being

$$L_t = L_\infty (1-e^{-K(t-t_0)}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where L_t = length at age t

L_∞ = asymptotic length that is attained if the fish is assumed to grow to an infinite age.

K = a growth parameter, which determines how rapidly the fish approaches the limiting length L.

t_0 = intercept on the age of axis corresponding to zero length.

The growth parameters L_∞ and K were estimated by applying the straight line method proposed by Alagaraja (1984) which is similar to ELEFAN proposed by Pauly and David (1981). The estimated parametric values for different species at different centres are given below :

			$L\infty$(mm)	K (annual)
Cochin	*Loligo duvaucelii*	Male	327	0.61
		Female	205	1.19
Madras	*Loligo duvaucelii*	Male	200	0.945
		Female	200	0.945
Madras	*Sepia aculeata*	Male	205	1.1318
		Female	205	1.1318
Vizhinjam	*Sepia pharaonis*	Male	365	0.7128
		Female	342	0.8634

STOCK ESTIMATION

Cohort Analysis

In studies on fish stock assessment, a basic assumption is that, within any one age group, the decline in number with age follows an exponential curve. In cohort analysis this curve is replaced with a 'step function' with two assumptions viz., (1) the entire catch of that age group is fished at exactly the middle of the age interval, and that (2) only natural declines take place continuously in an exponential form.

The adjustments that have to be made to the procedures based on age data to make them applicable to the length data (Jones, 1981) are adopted here.

In cohort analysis, by examining the numbers of the species caught at successive intervals during their lives, it is possible to understand what is happening to the stock, if the data considered represents average conditions. Further the length of the species could be used to define boundaries between successive intervals. Each length interval denotes a successive interval in the life of the typical year class, though the duration of the interval will vary.

It is assumed that the input length composition in length cohort analysis, is representative of a steady state situation and that the numbers caught represent annual catches per length group. But this is not likely to be in practice. However, a useful approximation can be obtained by determining the average length composition over a period of as many years as possible.

FORMULATION (Jones, 1981)

The basic equation

$$N_t = N_{t+\Delta t}\, e^{M \Delta t} + C_t\, e^{M \Delta t/2} \quad \ldots\ldots (2)$$

Where N_t = number in sea at age t

C_t = catch during age interval

t = time required to grow from the beginning to end of a length interval

The time required to grow from the beginning (L_1) to the upper limit of a length interval (L_2) had been calculated with von Bertalanffy's growth equation rearranged as

$$\Delta t = t_2 - t_1 = (1/K) \ln [(L\infty - L_1)/L\infty - L_2)] \quad \ldots (3)$$

This equation is a function of $L\infty$ and K but independent of t. This expression for Δt had been used in conjunction with equation (2) to arrive at the following one for analysing the length composition :

$$N_1 = (N_2 X_L + C_{1,2}) X_L \quad \ldots\ldots\ldots\ldots (4)$$

Where $C_{1,2}$ represent the number caught during a year with lengths between L_1 and L_2, and

$$X_L = [(L\infty = L_1)/(L\infty - L_2)]^{M/2K} \quad \ldots\ldots (5)$$

N_1 and N_2 represent numbers in the sea with length L_1 and L_2 respectively.

This equation is a function of $L\infty$, M and K ; more particularly since the M and K appear as the ratio M/K, the equation is a function of the two variables $L\infty$ and M/K.

The procedure involves first the estimation of a value for the number of the particular species reaching the length corresponding to the beginning of the largest length group. Successive application of the equation (4) leads to the estimates of numbers reaching a particular length for successively smaller animals.

If the oldest age group comprises all individuals older than a certain age, an input value of F/Z is required. The effect on the estimates among the younger ages, of adopting different values for F/Z will depend on whether the stock is heavily exploited or not. When the stock is heavily exploited, the choice of terminal F/Z value is not likely to effect the calculations critically.

Estimates of exploitation rate designated by the ratio F/Z has been determined directly for each length interval using the relationship

F/Z = number caught/number dying.

Calculation of instantaneous fishing mortality rate integrated over a particular time interval is attained from the relationship

$$F \Delta t = (F/Z)(Z \Delta t) \quad \ldots\ldots\ldots\ldots (6)$$

TABLE 1. *Cohort analysis of the numbers landed in different length groups of males of* Loligo duvaucelii *at Madras during* 1979-'80.

L ∞ = 200 (mm) K = 0.9450 (annual) M/K = 1.5

Length* Class (mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average numbers in the sea
40 —	2130	716547	0.0999	0.0313	0.0031	1.4632	46571
50 —	18400	648402	0.1338	0.2265	0.0303	1.8327	44317
60 —	30711	567183	0.1701	0.3461	0.0589	2.1679	40925
70 —	63100	478461	0.2709	0.5557	0.1506	3.1903	35594
80 —	78408	364906	0.3911	0.6639	0.2596	4.2174	28004
90 —	77578	246802	0.5549	0.7381	0.4096	5.4125	19419
100 —	54542	141698	0.6969	0.7670	0.5345	6.0833	11690
110 —	29651	70586	0.7908	0.7687	0.6078	6.1271	6296
120 —	7142	32011	0.4835	0.5820	0.2814	3.3910	3619
130 —	4990	19739	0.5650	0.5857	0.3309	3.4212	2490
140 —	8665	11219	2.4320	0.8458	2.0569	9.1909	1113
150 —	690	986		0.7000			

0 Lower limit

TABLE 2. *Cohort analysis of the numbers landed in different length groups of females of* Loligo duvaucelii *at Madras during* 1979-80.

L ∞ = 200 (mm) K = 0.9450 (annual) M/K = 1.5

Length* Class(mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average numbers in the sea
40 —	3074	642560	0.1018	0.0494	0.0050	1.4912	41724
50 —	12892	580343	0.1272	0.1860	0.0237	1.7415	39793
60 —	24111	511045	0.1623	0.3149	0.0511	2.0690	37010
70 —	24285	434472	0.1813	0.3372	0.0611	2.1386	33679
80 —	47211	362448	0.2802	0.5330	0.1494	3.0353	29182
90 —	76521	273871	0.4998	0.7130	0.3550	4.8935	22014
100 —	43864	166145	0.4945	0.6767	0.3346	4.3847	14783
110 —	44259	101326	0.8251	0.7775	0.6415	6.3701	8936
120 —	27193	44399	1.3303	0.8326	1.1076	8.4674	3857
130 —	7564	11739	1.5162	0.8256	1.2518	8.1293	1127
140 —	1804	2577	—	0.7000	—	—	—

* Lower limit.

TABLE 3. *Cohort analysis of the numbers landed in different length groups of males of* Sepia aculeate *at Madras during* 1979-'80.

L∞ = 205 (mm) K = 1.1318 (annual) M/K = 1.5

Length * Class (mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average number in the sea
30 —	1039	341596	0.0914	0.0348	0.0032	1.7589	16971
40 —	2194	311745	0.1012	0.0731	0.0074	1.8317	16379
50 —	7408	281744	0.1281	0.2187	0.0280	2.1730	15586
60 —	9852	247877	0.1500	0.2853	0.0428	2.3754	14538
70 —	18036	213344	0.2093	0.4477	0.0937	3.0739	13105
80 —	20888	173059	0.2626	0.5226	0.1372	3.5563	11239
90 —	18973	133091	0.3021	0.5468	0.1652	3.7460	9263
100 —	17540	98393	0.3635	0.5849	0.2126	4.0899	7332
110 —	17028	68405	0.4823	0.6505	0.3138	4.8576	5389
120 —	14293	42229	0.6526	0.7061	0.4608	5.7774	3503
130 —	8120	21988	0.7442	0.7036	0.5236	5.7270	2015
140 —	4209	10447	0.8606	0.6981	0.6008	5.6241	1072
150 —	1563	4418	0.8308	0.6270	0.5209	4.5511	548
160 —	875	1925	1.1729	0.6583	0.7721	4.9679	268
170 —	417	596	—	0.7000	—	—	—

* Lower limit.

TABLE 4. *Cohort analysis of the numbers landed in different length groups of females of* Sepia aculeata *at Madras during 1979-'80.*

L∞ = 205(mm) K = 1.1318 (annual) M/K = 1.5

Length * Class (mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average numbers in the sea
30 —	650	367136	0.0901	0.0205	0.0019	1.7333	18252
40 —	1020	335499	0.0970	0.0329	0.0032	1.7554	17663
50 —	4943	304493	0.1173	0.1467	0.0172	1.9896	16932
60 —	10909	270805	0.1506	0.2881	0.0434	2.3847	15878
70 —	11843	232939	0.1708	0.3238	0.0553	2.5106	14568
80 —	26020	196364	0.2771	0.5475	0.1517	3.7515	12669
90 —	22848	148835	0.3160	0.5666	0·1790	3.9170	10295
100 —	19779	108509	0.3689	0.5909	0.2180	4.1495	8067
110 —	13818	75034	0.3902	0.5700	0.2224	3.9481	6141
120 —	12853	50792	0.5134	0.6302	0.3235	4.5907	4443
130 —	9543	30397	0.6447	0.6607	0.4260	5.0035	2887
140 —	3842	15953	0.5694	0.5548	0.3159	3.8130	1816
150 —	4189	9027	1.0762	0.7040	0.7577	5.7359	1037
160 —	2154	3077	—	0.7000	—	—	—

*Lower limit

TABLE 5. *Cohort analysis of the numbers landed in different length groups of males of* Loligo duvaucelii *at Cochin during* 1979-'80

L∞ = 327 (mm) K = 0.61 (annual) M/K = 1.5

Length* Class (mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average numbers in the sea
40 —	3050	1156498	0.1111	0.0251	0.0028	0.9385	129613
60 —	90818	1034851	0.2144	0.4547	0.0975	1.6779	119037
80 —	213836	835115	0.4452	0.7126	0.3173	3.1841	94237
100 —	296725	535052	1.0405	0.8575	0.8922	6.4223	53878
120 —	80506	189028	0.7679	0.7946	0.6101	4.4539	22749
140 —	35266	87707	0.7954	0.7652	0.5704	3.8376	11824
160 —	7730	41622	0.4220	0.5416	0.2274	1.9960	7151
180 —	17381	27349	1.4545	0.8292	1.2060	5.3557	3914
200 —	4435	6386	1.8163	0.8293	1.5063	5.3615	997
220 —	727	1039	—	0.7000	—	—	—

* Lower limit.

TABLE 6. *Cohort analysis of the numbers landed in different length groups of females of* Loligo duvaucelii *at Cochin during* 1979-'80

L∞ = 205 (mm) K = 1.19 (annual) M/K = 1.5

Length* Class (mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average numbers in the sea
50 —	1987	1655192	0.1013	0.0125	0.0013	1.8075	88219
60 —	7949	1495734	0.1128	0.0498	0.0056	1.8786	84939
70 —	37764	1336168	0.1458	0.2083	0.0304	2.2545	80426
80 —	83850	1154843	0.2055	0.3908	0.0803	2.9303	73215
90 —	75464	940305	0.2263	0.3963	0.0897	2.9567	64406
100 —	134419	749876	0.3648	0.5864	0.2139	4.3157	53116
110 —	146576	520645	0.5322	0.6822	0.3630	5.6172	38248
120 —	113274	305796	0.7101	0.7286	0.5174	6.5769	23639
130 —	59697	150327	0.7982	0.7222	0.5765	6.4252	12865
140 —	46054	67665	1.7266	0.8279	1.4294	10.3706	5364
150 —	2561	12037	0.5851	0.4803	0.2811	3.4348	1552
160 —	2650	6705	1.0256	0.6162	0.6320	4.6510	925
170 —	1683	2404	—	0.7000	—	—	—

* Lower limit.

TABLE 7. *Cohort analysis of the numbers landed in different length groups of males of* Sepia pharaonis *at Vizhinjam during* 1978-'80

L∞ = 365 (mm) K = 0.7128 (annual) M/K = 1.5

Length* Class (mm)	Numbers landed	Numbers in the sea	Zdt	F/Z	Fdt	Z	Average numbers in the sea
100 —	305	175161	0.1196	0.0155	0.0018	1.0860	18175
120 —	405	155423	0.1305	0.0213	0.0028	1.0925	17408
140 —	911	136405	0.1468	0.0489	0.0072	1.1242	16569
160 —	5786	117779	0.2085	0.2610	0.0544	1.4469	15320
180 —	8245	95613	0.2703	0.3641	0.0984	1.6814	13468
200 —	12680	72968	0.4063	0.5204	0.2115	2.2294	10929
220 —	11254	48603	0.5221	0.5693	0.2972	2.4823	7969
240 —	5486	28834	0.5060	0.4792	0.2424	2.0529	5577
260 —	3953	17385	0.6268	0.4883	0.3060	2.0893	3875
280 —	5369	9289	1.6294	0.7190	1.1715	3.8045	1963
300 —	1288	1821	3.2385	0.7362	2.3840	4.0525	432
320 —	50	—	—	0.7000	—	—	—

* Lower limit.

TABLE 8. *Cohort analysis of the numbers landed in different length groups of females of* Sepia pharaonis *at Vizhinjam during* 1978-'80

L∞ = 342 (mm) K = 0.8634 (annual) M/K = 1.5

Length0 class (mm)	Numbers landed	Numbers in the sea	Zdt.	F/Z	Fdt.	Z	Average numbers in the sea
100 —	11	263659	0.1294	0.0003	0.0004	1.2955	24708
120 —	107	231648	0.1421	0.0035	0.0006	1.2996	23612
140 —	2328	200961	0.1690	0.0745	0.0126	1.3944	22330
160 —	6938	169714	0.2203	0.2068	0.0455	1.6328	20548
180 —	17379	136164	0.3495	0.4327	0.1512	2.2829	17593
200 —	22252	96000	0.5285	0.5647	0.2984	2.9750	13246
220 —	14228	56593	0.6076	0.5521	0.3355	2.8917	8912
240 —	,10511	30823	0.8410	0.5996	0.5043	3.2347	5419
260 —	3982	13294	0.8805	0.5117	0.4505	2.6520	2934
280 —	3572	5511	2.6089	0,6996	1.8252	4.3114	1184
300 —	284	406	—	0.7000	—	—	—

* Lower limit.

Actual time intervals Δt for each length interval have to be taken into account in estimating the annual mortality rates Z and F. This requires additional input information. Besides knowing M/K, it is also necessary to know either one of them. Assuming that the value of M is known, then the total instantaneous mortality rate is

$$Z = M / (1-F/Z) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The basic input data in the present study are (1) M/K taken as 1.5 on the assumption that 99% of the individuals die when they attain 95% of $L\infty$ and (2) terminal F/Z taken as 0.7 besides the $L\infty$ and K and average annual length composition of the study period.

Results and Discussion

The sexwise exploitation rate, total numbers and average numbers in the sea, total mortality and instantaneous mortality rate for *Loligo duvaucelii* and *Sepia aculeata* along Madras coast, *Loligo duvaucelii* along Cochin coast and *Sepia pharaonis* at Vizhinjam are given in Table 1-8, and the stock estimates (in tonnes) in the three areas in Table 9.

Table 9. *Stock Estimates at Selected Centres (in tonnes)*

	Average landings	Average annual stock	Standing stock
***Loligo duvaucelii* (Cochin)**			
Male	32	70	11
Female	35	180	14
Total	67	250	25
***Loligo duvaucelii* (Madras)**			
Male	15	51	5
Female	18	53	5
Total	33	104	10
***Sepia aculeata* (Madras)**			
Male	15	75	6
Female	17	93	8
Total	32	168	14
***Sepia pharaonis* (Vizhinjam)**			
Male	45	295	51
Female	61	341	53
Total	106	636	104

The results show that the average annual stock of *L. duvaucelii* of Cochin area is 250 t which is nearly 2½ times that of Madras area. Correspondingly the standing stock in Cochin area (25 t) is also higher than in Madras area (10 t). In both areas the average annual stock as well as the average landings of females are greater than males. The standing stock of the two sexes are of equal abundance in Madras area while in Cochin area the standing stock of males is lesser than that of females.

In the case of *Sepia aculeata* of Madras coast the average annual stock amounts to 168 t of which females account for 55%. The standing stock of this species (14 t) is slightly more than that of *Loligo duvaucelii* of Madras coast (10 t) and females are dominant in the stock.

The average annual stock of *Sepia pharaonis* in Vizhinjam area where it supports a good fishery, is high, 636 t and females form 54% of the population. The standing stock of the species is 104 t comprising of males and females more or less in the same proportion.

The exploitation of the three species studied is greater in the case of females than males in all the three centres.

The effect of change in fishing mortality from the present rate on the yield was analysed for all the three species (Fig. 1). It could be observed that in the case of *Sepia pharaonis* of both sexes the yield will increase with increase in further fishing mortality. In the case of females of *Sepia aculeata* of Madras area and females of *Loligo duvacuelii* of Cochin area by increasing the effort by another 20% only a marginal increase in the yield can be realised.

Since squids and cuttlefishes form only a small percentage of the total trawl catches any further increase or decrease in fishing effort has to be considered keeping in view the multispecies nature of the gear which is directed mainly at shrimps.

Based on the stocks estimated at Madras, Cochin and Vizhinjam, assuming that the density of stocks and rate of exploitation of the three species studied are uniform all along the coasts, the all India average annual stock and standing stocks of the three species which accounted for major portion of the country's landings, have been worked out from the average all India landings of cephalopods for the period 1978-'80 and the estimates are as follows:

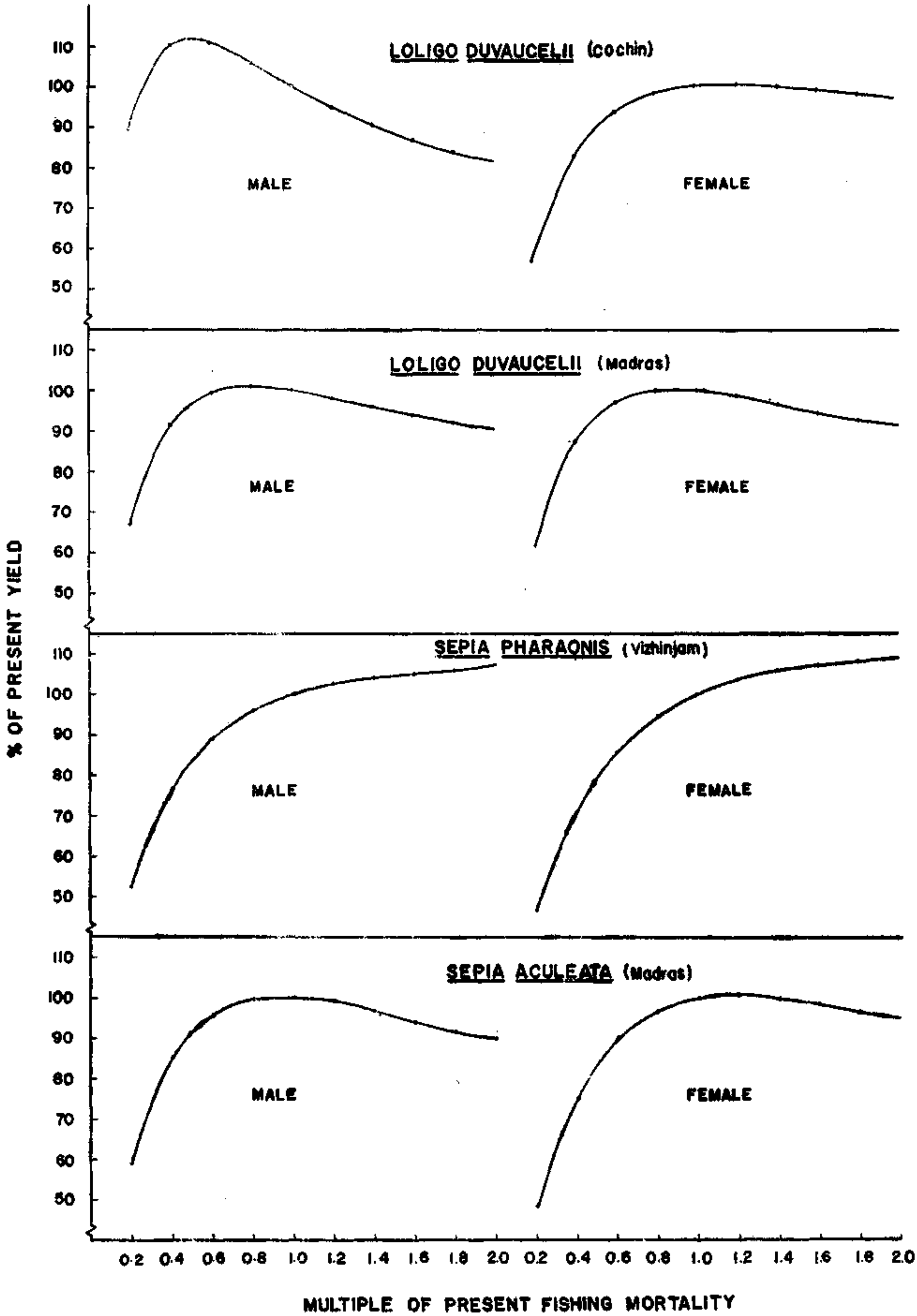

FIG. 1. The effect of change in fishing mortality on yield of males and females of *Sepia aculeata* (Madras), *Sepia pharaonis* (Vizhinjam) and *Loligo duvaucelii* (Madras and Cochin).

	Average landings	Average annual stock	Standing stock
Loligo duvaucelii	5142 t	18203 t	1800 t
Sepia aculeata	4483 t	23536 t	1961 t
Sepia pharaonis	2397 t	15245 t	2352 t
Total	12022 t	56984 t	5513 t

The reasons for the lesser estimated annual stocks of males than females in the case of all the three species studied are not clear. It may be due to factors like differential bathymetric distribution of the sexes or migration of males. This aspect has to be studied.

There are good possibilities for increasing production of the cuttlefish *Sepia pharaonis* in Vizhinjam area by stepping up the effort. At present indigenous hooks are only used in fishing cuttlefish in the area. Employing modern methods of fishing as with special types of jigs may improve yield from the fishery.

The stock estimates for the three centres studied represent the figures for the existing fishing grounds within the 50 m depth zone which are being traditionally exploited at present. For increasing the production substantially, fishing range has to be extended to neighbouring grounds within the 50 m depth zone and also beyond the 50 m contour in the continental shelf and upper continental slope.

This is the first study on stock assessment of squids and cuttlefishes in selected grounds in the Indian seas. The study brings out the urgent need for assesing the standing stock of squids and cuttlefishes specieswise in all other major fishing grounds and taking up exploratory surveys for neritic and oceanic squids.

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