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# GROWTH AND MORTALITY OF THE INDIAN SQUID (Loligo duvauceli) OFF COCHIN, INDIA

by

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**ABSTRACT**

The squid (Loligo duvauceli) is caught as by-catch in the shallow water shrimp fishery along the coast of Kerala (India). It accounts for the entire squid landings in the area. Length-frequency data, collected by sexes during 1981-84 were used in the studies. The length-weight relationship is:
males $W = 0.25429\ L^{2.143}$, females $W = 0.1893\ L^{2.298}$.
As the length-weight relationship indicated allometric growth, a modified growth formula based on weight and different from the classical VBGF was applied to estimate growth parameters, for males $L_\infty$ = 37.2 cm and K = 1.1 per year and for females $L_\infty$ = 23.8 cm and K = 1.7 per year. Natural mortality, M, was estimated at 2.2 per year based on data collected on a shoal of spawning males. The same M was assumed for females. As there is no directed fishing covering the stock, exploitation rates and stock estimates could not be obtained. The difference between Z and M probably reflects a change with length in the availability of squid to the shrimp fishery, since the values of Z found by the length converted catch curve method were very high (males 9.0 and females 10.6 per year).

## 1 INTRODUCTION

Cephalopods constitute an economically important by-catch in the shallow water shrimp fisheries of India. Shrimp trawlers account for 73% of the country's average production of cephalopods. The landings have shown a phenomenal increase during the last two decades from less than a thousand tonnes in the late sixties to nearly 43,000 t in 1986 (Table 1). This increase was partly due to effort increases in the shrimp fishery and partly to a change in discarding practices. Before 1973 the major part of cephalopods was thrown overboard to avoid the valuable shrimp catch from being contaminated with ink. However, as an export market for cephalopods developed during the seventies this practice ceased and in 1985 export earnings on cephalopods amounted to US $ 11.2 million (MPEDA, 1987).

On an average, 43% of the catch of cephalopods is constituted of squids and 57% of cuttlefishes. Octopus catches are negligible. Among the squids, the Indian squid (Loligo duvauceli), (Orbigny, 1848) is the dominant (97%) species.

Considering their importance as a foreign exchange earner to the country, studies on cephalopods were taken up by the Central Marine Fisheries Research Institute at different centres along the Indian coast in 1976. A comprehensive account on the taxonomy, distribution pattern, biology, fishery and stock estimates of the cephalopod resources from Indian wa-

ters has been given recently by Silas (1986), who has also estimated the potential harvest in the neretic sector to be 50,000 t. Earlier George et al. (1977) estimated the potential in the Indian EEZ at 180,000 t, while Chikuni (1983) estimated the potential stocks for the Eastern Arabian Sea at 100,000 to 150,000 t and for the entire Bay of Bengal at 50,000 to 100,000 t.

## 2 BIOLOGY

The biology of L. duvauceli has been studied by Silas et al. (1986) at different centres along the east and west coasts of India during 1976-80. This study revealed that there was no significant difference in the male-female composition and that they were more or less distributed in equal proportions. Fully mature and spawning specimens of both sexes were encountered in the catches almost throughout the year, thereby indicating continuous spawning, while no clear-cut spawning seasons were noticed. The size at first maturity varied from place to place. Juveniles of less than 4.0 cm were not observed in the landings. Largest sizes recorded for males were 18.4 and 28.5 cm respectively along the east and west coasts and the largest females measured 19.0 cm on both coasts.

The food of L. duvauceli consists chiefly of crustaceans such as shrimps, crabs, stomatopods and euphausids as well as fin fishes. Cannibalism is common (Kore and Joshi, 1975 and Oommen, 1977). Kore and Joshi (1975) also observed that there was a decreased feeding activity during the spawning period.

Very little is known about the aspects of biology which are essential for understanding the dynamics of squid populations. There is still uncertainty about the growth models fitting squids. Silas et al. (1986) estimated the growth parameter of L. duvauceli using the von Bertalanffy growth formula. Lange (1981) fitted exponential growth in weight in the case of L. pealei. Some others have assumed that the squids follow asymptotic growth (Lange and Sissenwine, 1983; Supongpan, 1988). Lange and Sissenwine (1983) were also of the opinion that some cohorts of L. pealei might follow linear growth in length depending upon food availability.

There is also considerable uncertainty about their natural mortality. It is generally assumed that post-spawning mortality in cephalopods is very high. Roper and Sweeney (1984) have reported that many species die after spawning, but the phenomenon is apparently not universal. Post-spawning mortality of squids of both sexes has been established in the case of the Japanese flying squid (Todarodes pacificus, Steenstrup) and the Opalescent inshore squid (Loligo opalescens, Berry), while there is strong evidence that some species may spawn more than once (Juanicó, 1983). There are few observations on spent squids and some authors report never having caught a spent animal. Juanicó (1983) gives three hypotheses viz.: 1) squids die after spawning; 2) they swim out of the fishing grounds after spawning; or 3) spent animals quickly recover from spawning and return to a maturing stage. At present nothing is known about the post-spawning mortality of L. duvauceli.

## 3 THE FISHERY AT COCHIN

Cochin is one of the important landing centres in Kerala State. A description of the trawl fishing grounds, crafts and gear is given by Suseelan and Rajan (this volume). On an average about 150 trawlers operate from Cochin at depths between 20 and 50 m. During the monsoon (June-August) they extend their operations to depths of 60 m. The codend meshsize of the trawlnet is 2.5 cm.

There is a lean period in the shrimp fishery between September and November, during which the trawlers serve as carrier boats for purse seiners.

Squids are only a by-catch for the shrimp trawlers as the whole effort is aimed at catching shrimps. The squid landings are composed of only one species, L. duvauceli. The figures on landings, effort and the catch rates for the period 1977-86 are given in Table 2. There have been great fluctuations in the landings during the period: as low as 17 t in 1980 to as much as 345 t in 1986. The catch rates ranged from less than one kg per trawler day to 7.3 kg/day. Squids are caught mostly at depths from 20 to 35 m and whenever trawlers operate beyond this range, which is common during the monsoon period, there is a decrease in the squid landings. Again the fishery suffers during the lean season for shrimp.

**Table 1 Estimated cephalopod production in India, 1967-1986 (tonnes)**

| Year | Production | Year | Production |
|---|---|---|---|
| 1967 | 521 | 1977 | 10005 |
| 1968 | 1636 | 1978 | 15931 |
| 1969 | 769 | 1979 | 15032 |
| 1970 | 1184 | 1980 | 11335 |
| 1971 | 1505 | 1981 | 9548 |
| 1972 | 1026 | 1982 | 15799 |
| 1973 | 1394 | 1983 | 18355 |
| 1974 | 3677 | 1984 | 20421 |
| 1975 | 7889 | 1985 | 31642 |
| 1976 | 10826 | 1986 | 42638 |

**Table 2 Production, effort expended and catch rates of squids at Cochin, 1977-1986**

| Year | Effort (trawler) days | Squid production (t) Males | Females | Total | C/E (kg) |
|---|---|---|---|---|---|
| 1977 | 48780 | | | 58 | 1.2 |
| 1978 | 25733 | | | 145 | 5.6 |
| 1979 | 43814 | | | 111 | 2.5 |
| 1980 | 47228 | | | 17 | 0.4 |
| 1981 | 44323 | 17.7 | 15.7 | 33.4 | 0.8 |
| 1982 | 50798 | 22.5 | 20.5 | 43.0 | 0.8 |
| 1983 | 43157 | 23.6 | 21.1 | 44.7 | 1.0 |
| 1984 | 39613 | 14.7 | 14.2 | 28.9 | 0.7 |
| 1985 | 27580 | | | 116 | 4.2 |
| 1986 | 47008 | | | 345 | 7.3 |

## 4 MATERIAL AND METHODS

Data on effort and landings were collected from the commercial trawlers at Cochin Fisheries Harbour for 18 days in a month and data on species composition, length and other biological aspects were collected for 4-6 days in a month. Length data were collected sex-wise. The data on observation days were first weighted to get the day's estimates and the days' estimates were pooled and weighted to obtain the month's estimates. The length mea-

**Table 3a** Length frequency data of L. duvauceli (Males), Cochin, 1981 *)

| Size **) (cm) | JAN | FEB | MAR | APR | MAY | JUN | JUL | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|
| 4- 5 | | | 716 | | | | | | |
| 5- 6 | | 4266 | 4723 | 371 | 28 | | | 272 | |
| 6- 7 | 658 | 13864 | 7337 | 2057 | 28 | | | 819 | 2009 |
| 7- 8 | 850 | 29624 | 17873 | 7896 | 1741 | | 87 | 272 | 8205 |
| 8- 9 | 1699 | 31788 | 12191 | 9099 | 1617 | 26 | 167 | 819 | 15412 |
| 9-10 | 2183 | 21481 | 15061 | 6544 | 6501 | 253 | 388 | 550 | 15752 |
| 10-11 | 5501 | 17784 | 13449 | 4555 | 5660 | 177 | 305 | 272 | 15566 |
| 11-12 | 4553 | 9254 | 4279 | 2413 | 2501 | 382 | 290 | 1092 | 19596 |
| 12-13 | 834 | 3831 | 13751 | 3074 | 279 | 350 | 185 | 550 | 11142 |
| 13-14 | 414 | 3308 | 2277 | 2247 | 1291 | 58 | 195 | 272 | 3919 |
| 14-15 | 153 | 1509 | 1668 | 644 | 1088 | | 65 | 272 | 3682 |
| 15-16 | 10 | 198 | 716 | 134 | 1090 | | 7 | 272 | 3057 |
| 16-17 | 73 | 1044 | 679 | 234 | 1068 | | | | 2138 |
| 17-18 | 156 | 1042 | 235 | 368 | 178 | | | | 721 |
| 18-19 | 970 | | 1355 | 281 | 178 | | | | 297 |
| 19-20 | 277 | | 3747 | 140 | | | | | 36 |
| 20-21 | 73 | | 5990 | | | | | | |
| 21-22 | 73 | | 3290 | | | | | | |
| 22-23 | | | 1636 | | | | | | |
| 23-24 | | | 564 | | | | | | |
| Total | 18477 | 138993 | 111537 | 40057 | 23248 | 1246 | 1689 | 5462 | 101532 |
| weight (kg) | 840 | 3673 | 5399 | 1403 | 1293 | 64 | 75 | 224 | 4691 |
| Sample no. | 750 | 789 | 726 | 836 | 556 | 165 | 264 | 300 | 695 |

**Table 3b** Length frequency data of L. duvauceli (Males), Cochin, 1982 *)

| JAN | FEB | MAR | APR | MAY | JUN | JUL | NOV | DEC |
|---|---|---|---|---|---|---|---|---|
| | 1636 | | 464 | | | | | |
| 807 | 2220 | 2419 | 2674 | 1235 | 5864 | 627 | | 698 |
| 2550 | 4577 | 13528 | 7082 | 1083 | 17592 | 1154 | 232 | 1033 |
| 3123 | 10605 | 57055 | 15479 | 5035 | 15637 | 627 | 3985 | 2275 |
| 3099 | 9430 | 65970 | 9219 | 7491 | 25410 | 5242 | 3373 | 1958 |
| 4170 | 3678 | 26894 | 9816 | 6595 | 23456 | 1118 | 3730 | 3876 |
| 3144 | 9135 | 18309 | 13485 | 9800 | 7818 | 1878 | 1701 | 6316 |
| 1794 | 8744 | 24062 | 8236 | 5343 | 7818 | 360 | 475 | 6963 |
| 615 | 3863 | 12294 | 7344 | 3183 | | 97 | 356 | 3036 |
| 213 | 2586 | 11889 | 1569 | 1539 | | | 443 | 1850 |
| 210 | 2586 | 9451 | 1088 | 926 | | | 304 | 1282 |
| 132 | 1135 | 5789 | | 269 | | | 180 | 953 |
| 132 | 1135 | 9159 | | | | | 41 | 1260 |
| | 1134 | 8745 | | | | | 678 | 953 |
| | | | | | | | | 545 |
| | | | | | | | | 329 |
| | | | | | | | | 136 |
| | | | | | | | | 136 |
| 19989 | 62464 | 265564 | 76456 | 42499 | 103595 | 11103 | 15498 | 33599 |
| 633 | 2286 | 10336 | 2566 | 1613 | 2541 | 280 | 568 | 1691 |
| 450 | 595 | 775 | 825 | 363 | 424 | 354 | 450 | 592 |

*) Raised to total catch

**) Mantle length

Table 3c Length frequency data of L. duvauceli (Males), Cochin, 1983 *)

| Size**) (cm) | JAN | FEB | MAR | APR | MAY | JUN | SEP |
|---|---|---|---|---|---|---|---|
| 4- 5 | | | 159 | | | | |
| 5- 6 | 618 | 1654 | 159 | 2121 | | 67 | |
| 6- 7 | 3642 | 9537 | 2269 | 9225 | 501 | 1347 | 407 |
| 7- 8 | 13889 | 16383 | 8169 | 15813 | 508 | 1075 | 609 |
| 8- 9 | 18554 | 11563 | 9619 | 30012 | 8713 | 1912 | 876 |
| 9-10 | 25479 | 12864 | 6762 | 19930 | 17633 | 2388 | 1449 |
| 10-11 | 14945 | 26310 | 9817 | 17019 | 23119 | 6421 | 1578 |
| 11-12 | 12918 | 6636 | 8137 | 9466 | 11803 | 4723 | 1567 |
| 12-13 | 9371 | 4659 | 5725 | 4874 | 5537 | 1325 | 1295 |
| 13-14 | 6008 | 3041 | 2924 | 4467 | 1724 | 583 | 472 |
| 14-15 | 3977 | 3041 | 3123 | 3344 | 1810 | 377 | 301 |
| 15-16 | 4938 | 362 | 2273 | 3735 | 3033 | 114 | 405 |
| 16-17 | 3841 | 465 | 1740 | 3086 | 1924 | 487 | 444 |
| 17-18 | 2988 | 465 | 1740 | 615 | 1044 | 201 | 449 |
| 18-19 | 2336 | 912 | 1494 | 358 | | | 674 |
| 19-20 | 1726 | 465 | 1442 | | | | 536 |
| 20-21 | 3481 | | 1275 | | | | 295 |
| 21-22 | 1137 | | 127 | | | | 59 |
| 22-23 | 1615 | | | | | | 93 |
| 23-24 | | | | | | | 59 |
| 24-25 | | | | | | | 295 |
| 25-26 | | | | | | | 59 |
| Total | 131463 | 98357 | 66954 | 124065 | 77349 | 21020 | 11922 |
| weight (kg) | 6733 | 3595 | 3393 | 4916 | 3312 | 818 | 792 |
| Sample no. | 552 | 414 | 546 | 508 | 636 | 489 | 505 |

3d Length frequency data of L. duvauceli (Males), Cochin, 1984 *)

| FEB | MAR | APR | MAY | JUN | JUL | DEC |
|---|---|---|---|---|---|---|
| | | | 165 | 265 | | |
| 404 | | 414 | 500 | 7641 | | |
| 1624 | | 7540 | 784 | 10780 | | 930 |
| 2404 | 602 | 12674 | 1168 | 18008 | 107 | 2094 |
| 2812 | 1811 | 16971 | 1960 | 21564 | 141 | 2907 |
| 3728 | 12690 | 19859 | 3360 | 19372 | 141 | 2234 |
| 2660 | 10277 | 15552 | 2228 | 35334 | 212 | 2496 |
| 1812 | 1811 | 25431 | 2056 | 13907 | 937 | 1337 |
| 1555 | 1215 | 9045 | 1281 | 8721 | 625 | 2281 |
| 404 | 602 | 5989 | 894 | 4901 | 625 | 1547 |
| 592 | 1215 | 5061 | 1079 | 3407 | 866 | 795 |
| 184 | 602 | 414 | 285 | 3275 | 1182 | 538 |
| | 1811 | 831 | 172 | 1497 | 625 | 851 |
| | | 417 | 450 | 1497 | 383 | 309 |
| | | 2409 | 281 | 1365 | 312 | 308 |
| | | 1582 | | 1910 | 312 | 126 |
| | | 1578 | | 1910 | 310 | 126 |
| | | | | | 34 | |
| | | | | | 34 | |
| 18179 | 32636 | 125767 | 16663 | 155354 | 6846 | 18879 |
| 740 | 1248 | 4884 | 662 | 5809 | 552 | 818 |
| 360 | 324 | 695 | 336 | 780 | 228 | 328 |

*) Raised to total catch

**) Mantle length

Table 4a Length frequency data of L. duvauceli (Females), Cochin, 1981 *)

| Size**) (cm) | JAN | FEB | MAR | APR | MAY | JUN | JUL | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|
| 4- 5 | | 222 | | | | | | | |
| 5- 6 | | 764 | 1093 | | | | | 275 | |
| 6- 7 | | 5827 | 4428 | 510 | | | | 275 | 2631 |
| 7- 8 | 137 | 15571 | 7934 | 2986 | 1078 | | | 275 | 8379 |
| 8- 9 | 510 | 13249 | 6387 | 3742 | 1483 | | 95 | 275 | 9526 |
| 9-10 | 385 | 14874 | 3033 | 4266 | 1732 | 26 | 204 | 548 | 7156 |
| 10-11 | 612 | 7090 | 9525 | 4347 | 4093 | 152 | 426 | 1645 | 9303 |
| 11-12 | 3892 | 11113 | 11857 | 4696 | 3692 | 204 | 135 | 275 | 10421 |
| 12-13 | 3300 | 6588 | 10185 | 5440 | 3199 | 429 | 247 | 275 | 13358 |
| 13-14 | 4733 | 5344 | 7023 | 3691 | 4697 | 330 | 446 | 548 | 14328 |
| 14-15 | 1832 | 1357 | 2969 | 1583 | 140 | 50 | 90 | 275 | 7622 |
| 15-16 | 564 | 454 | 2461 | 307 | | | 82 | | 5021 |
| 16-17 | 19 | | 235 | 305 | | | 82 | | 2222 |
| 17-18 | 10 | | | | | | | | 4357 |
| 18-19 | | | | | | | | | 1444 |
| Total | 15994 | 82453 | 67130 | 31873 | 20114 | 1191 | 1807 | 4666 | 95768 |
| Weight (kg) | 825 | 2760 | 3124 | 1649 | 1109 | 73 | 107 | 192 | 5883 |
| Sample no. | 655 | 576 | 432 | 604 | 464 | 155 | 288 | 255 | 595 |

4b Length frequency data of L. duvauceli (Females), Cochin, 1982 *)

| Size**) (cm) | JAN | FEB | MAR | APR | MAY | JUN | JUL | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|
| 4- 5 | | | | 687 | | | | | |
| 5- 6 | | | | 2063 | 417 | | 267 | | 192 |
| 6- 7 | 1488 | 1272 | 12115 | 5254 | 417 | 9770 | 800 | 281 | 1078 |
| 7- 8 | 2274 | 4125 | 33004 | 11676 | 9240 | 13678 | 1733 | 229 | 3409 |
| 8- 9 | 1458 | 4716 | 31064 | 8322 | 7510 | 19540 | 4600 | 1189 | 4538 |
| 9-10 | 1488 | 6649 | 25953 | 7738 | 7245 | 29310 | 2768 | 4984 | 6290 |
| 10-11 | 1137 | 4806 | 25896 | 8505 | 6448 | 5862 | 200 | 6021 | 5162 |
| 11-12 | 1974 | 7841 | 35263 | 6892 | 6570 | 1954 | 99 | 1629 | 5388 |
| 12-13 | 2184 | 4304 | 23572 | 7572 | 2839 | 1954 | | 1232 | 2995 |
| 13-14 | 846 | 13457 | 9884 | 4250 | 2152 | | | 675 | 1344 |
| 14-15 | 1041 | 2444 | 6269 | 1066 | 1896 | | | 362 | 539 |
| 15-16 | 402 | | 1892 | | 309 | | | 177 | |
| 16-17 | | | 1892 | | 152 | | | | |
| 17-18 | | | 1892 | | | | | | |
| 18-19 | | | 1892 | | | | | | |
| Total | 14292 | 49614 | 210588 | 64025 | 45195 | 82068 | 10467 | 16779 | 30935 |
| Weight (kg) | 642 | 2560 | 8971 | 2155 | 1761 | 1954 | 240 | 774 | 1435 |
| Sample no. | 345 | 430 | 615 | 684 | 426 | 336 | 348 | 552 | 555 |

*) Raised to total catch

**) Mantle length

Table 4c Length frequency data of L. duvauceli (Females). Cochin, 1983 *)

| Size**) (cm) | JAN | FEB | MAR | APR | MAY | JUN | SEP |
|---|---|---|---|---|---|---|---|
| 5- 6 | 408 | 1283 | 644 | 616 | | 354 | |
| 6- 7 | 2885 | 6153 | 4250 | 8644 | | 647 | 261 |
| 7- 8 | 9394 | 13482 | 8890 | 11698 | 386 | 1219 | 990 |
| 8- 9 | 11196 | 5943 | 9009 | 36025 | 7724 | 889 | 2275 |
| 9-10 | 14092 | 12503 | 9680 | 18287 | 13323 | 1238 | 2050 |
| 10-11 | 19497 | 14242 | 7702 | 21473 | 22470 | 3114 | 1077 |
| 11-12 | 24480 | 7656 | 7813 | 7712 | 32790 | 2043 | 1505 |
| 12-13 | 16465 | 5089 | 10403 | 7479 | 9605 | 4172 | 1198 |
| 13-14 | 14063 | 810 | 2777 | 2088 | 2968 | 1086 | 1038 |
| 14-15 | 5703 | 809 | 1871 | 2122 | 887 | 264 | 453 |
| 15-16 | 3345 | 362 | 640 | | 851 | 135 | 804 |
| 16-17 | 2211 | | | | 365 | | 152 |
| 17-18 | | | | | | | 191 |
| Total | 123739 | 68332 | 63679 | 116144 | 91369 | 15161 | 11994 |
| Weight (kg) | 6255 | 2768 | 2574 | 4085 | 4198 | 688 | 554 |
| Sample no. | 552 | 448 | 489 | 570 | 567 | 416 | 459 |

4d Length frequency data of L. duvauceli (Females). Cochin, 1984 *)

| Size**) (cm) | FEB | MAR | APR | MAY | JUN | JUL | DEC |
|---|---|---|---|---|---|---|---|
| 5- 6 | | | | 176 | 1778 | | |
| 6- 7 | 939 | | 646 | 507 | 5329 | | 468 |
| 7- 8 | 3559 | 607 | 11268 | 1643 | 12708 | | 1217 |
| 8- 9 | 1998 | 3024 | 23992 | 2038 | 11067 | | 2751 |
| 9-10 | 3501 | 6656 | 15379 | 2478 | 19367 | 976 | 2962 |
| 10-11 | 1622 | 15734 | 13130 | 2948 | 27681 | 1289 | 4309 |
| 11-12 | 2655 | 8471 | 15275 | 2313 | 23709 | 732 | 2106 |
| 12-13 | 1405 | 1816 | 15091 | 1355 | 16872 | 1080 | 1666 |
| 13-14 | | 607 | 6635 | 905 | 13336 | 698 | 1221 |
| 14-15 | | 1209 | 2412 | 729 | 6943 | 941 | 753 |
| 15-16 | | | 417 | | 1754 | 905 | 309 |
| 16-17 | | | 417 | | | 835 | |
| Total | 15679 | 38124 | 105162 | 15092 | 140544 | 7456 | 17762 |
| Weight (kg) | 625 | 1755 | 4188 | 603 | 5785 | 533 | 744 |
| Sample no. | 390 | 315 | 708 | 305 | 545 | 160 | 243 |

*) Raised to total catch

**) Mantle length

Table 5 Combined length frequency data of L. duvauceli (Males), Cochin, 1981-84 *)

| Size**) (cm) | JAN | FEB | MAR | APR | MAY | JUN | JUL | SEP | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4- 5 | | 16 | 6 | 5 | 3 | 1 | | | | | 31 |
| 5- 6 | 21 | 60 | 39 | 48 | 25 | 64 | 20 | | 15 | 12 | 304 |
| 6- 7 | 99 | 195 | 106 | 199 | 30 | 157 | 37 | 17 | 52 | 48 | 940 |
| 7- 8 | 163 | 386 | 356 | 467 | 180 | 179 | 37 | 26 | 131 | 133 | 2057 |
| 8- 9 | 217 | 375 | 368 | 506 | 287 | 260 | 198 | 37 | 143 | 191 | 2581 |
| 9-10 | 289 | 285 | 358 | 434 | 470 | 282 | 101 | 61 | 139 | 215 | 2634 |
| 10-11 | 357 | 352 | 323 | 396 | 361 | 382 | 115 | 67 | 64 | 261 | 2678 |
| 11-12 | 279 | 200 | 182 | 319 | 192 | 262 | 88 | 66 | 74 | 280 | 1943 |
| 12-13 | 87 | 109 | 184 | 213 | 74 | 121 | 53 | 55 | 41 | 169 | 1106 |
| 13-14 | 47 | 64 | 79 | 115 | 77 | 46 | 51 | 20 | 28 | 86 | 614 |
| 14-15 | 28 | 58 | 76 | 67 | 81 | 26 | 39 | 13 | 24 | 62 | 472 |
| 15-16 | 24 | 17 | 46 | 20 | 50 | 19 | 40 | 17 | 20 | 47 | 302 |
| 16-17 | 22 | 19 | 63 | 22 | 38 | 19 | 21 | 19 | 1 | 52 | 275 |
| 17-18 | 19 | 19 | 41 | 13 | 13 | 12 | 13 | 19 | 20 | 27 | 195 |
| 18-19 | 44 | 4 | 21 | 21 | 10 | 7 | 10 | 29 | | 17 | 167 |
| 19-20 | 18 | 2 | 36 | 12 | | 10 | 10 | 23 | | 8 | 119 |
| 20-21 | 18 | | 49 | 9 | | 10 | 10 | 12 | | 5 | 113 |
| 21-22 | 8 | | 22 | | | | 1 | 2 | | 2 | 36 |
| 22-23 | 7 | | 11 | | | | 1 | 4 | | | 23 |
| 23-24 | | | 4 | | | | | 2 | | | 6 |
| 24-25 | | | | | | | | 12 | | | 12 |
| 25-26 | | | | | | | | 2 | | | 2 |
| Total | 1752 | 2159 | 2371 | 2864 | 1891 | 1858 | 846 | 505 | 750 | 1615 | 16611 |

Table 6 Combined length frequency data of L. duvauceli (Females), Cochin, 1981-84 *)

| Size**) (cm) | JAN | FEB | MAR | APR | MAY | JUN | JUL | SEP | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4- 5 | | 2 | | 7 | | | | | | | 9 |
| 5- 6 | 2 | 14 | 12 | 25 | 7 | 17 | 9 | | 15 | 3 | 104 |
| 6- 7 | 49 | 115 | 97 | 113 | 14 | 78 | 27 | 10 | 24 | 42 | 569 |
| 7- 8 | 102 | 322 | 221 | 315 | 148 | 139 | 58 | 38 | 23 | 130 | 1493 |
| 8- 9 | 106 | 222 | 226 | 498 | 194 | 147 | 168 | 87 | 54 | 178 | 1881 |
| 9-10 | 115 | 331 | 225 | 357 | 241 | 232 | 145 | 78 | 194 | 198 | 2116 |
| 10-11 | 139 | 225 | 326 | 367 | 354 | 237 | 102 | 41 | 288 | 209 | 2289 |
| 11-12 | 316 | 262 | 309 | 307 | 398 | 183 | 41 | 58 | 69 | 190 | 2131 |
| 12-13 | 261 | 152 | 229 | 322 | 188 | 244 | 63 | 46 | 56 | 159 | 1719 |
| 13-14 | 277 | 159 | 100 | 170 | 165 | 124 | 86 | 40 | 52 | 130 | 1305 |
| 14-15 | 126 | 36 | 62 | 68 | 41 | 41 | 35 | 17 | 27 | 67 | 520 |
| 15-16 | 48 | 6 | 26 | 9 | 8 | 11 | 32 | 31 | 6 | 35 | 211 |
| 16-17 | 11 | | 7 | 9 | 4 | | 31 | 6 | | 14 | 81 |
| 17-18 | | | 6 | | | | | 7 | | 27 | 40 |
| 18-19 | | | 6 | | | | | | | 9 | 14 |
| Total | 1552 | 1845 | 1851 | 2566 | 1763 | 1452 | 796 | 459 | 807 | 1393 | 14483 |

*) Not raised to total catch

**) Mantle length

surement was taken along the dorsal midline from the posterior tip to the anterior tip of the mantle. Data collected during the 1981-84 period have been used for the present study. As the males and females appear to follow differential growth patterns they were treated separately.

Sex-wise monthly length frequency data (Tables 3 and 4) for 1981-84 were pooled (Tables 5 and 6) for further analyses. The Bhattacharya method (1967) was applied to distinguish different components from the length frequency data and the modes (mean values of the components) obtained were used for estimating growth parameters through modal progression and the Gulland & Holt plot (1959). Total mortality was estimated by the length converted catch curve method (Pauly, 1983). Computer programs developed by Sparre (1987) were used for data analysis.

## 5 RESULTS

### 5.1 Sex and maturity

Data collected for the present study agree with the findings of Silas et al. (1986 a) in Cochin waters. Males and females were found in equal proportion. Both males and females were found to mature from the size of 9.0 cm with the sizes at first maturity of the former being 12.6 cm and of the latter, 12.9 cm. Mature and spawning individuals of both sexes occurred in the catches throughout the year except during August and October. Juveniles of less than 4.0 cm were not caught by the trawlers.

Table 7 shows the average length composition of the males and females in the catch of 1981-84.

### 5.2 Length-weight relationship

Dorsal mantle length measured to the nearest 0.1 cm and weight in grams were used to arrive at the relationship of the form $W = a.L^b$. The results for males and females are summarised below.

| | n | length range | a | b | r |
|---|---|---|---|---|---|
| Males | 252 | 4.4 - 25.5 cm | 0.25429 | 2.143 | 0.992 |
| Females | 198 | 4.3 - 18.6 cm | 0.1893 | 2.298 | 0.987 |

Both males and females have exponents (b) significantly different from 3, indicating allometric growth.

### 5.3 Growth

Most of the growth studies on marine fish assume that the growth follows the von Bertalanffy's growth formula (VBGF) which has the basic form as

$$dW/dt = HS - kW$$

where dW/dt is the rate of change in weight, S and W are the surface area and the weight respectively and H and k are constants. This form is transformed into one in length by assuming S to be proportional to square of length and W to be proportional to the cube of length. This indicates that the growth form in length may only be suitable in the case of isometric growth or in cases where the exponent in the length-weight relationship is not very different from 3. When the exponent in the length-weight relationship is about 2 as in the case of squids, then the usual VBGF in length may not be valid as this gives rise to the assumption that the surface area (S) is directly proportional to the length, which is not a biologically tenable assumption. So a modified growth formula in length (dorsal mantle length) under the assumption that the growth in weight

**Table 7** **Average length frequency data *) of L. duvauceli (males and females), 1981-84**

| Size (cm) | Frequency Males | Females |
|---|---|---|
| 4- 6 | 10922 | 2810 |
| 6- 8 | 101568 | 67416 |
| 8-10 | 161942 | 120819 |
| 10-12 | 123984 | 127793 |
| 12-14 | 46704 | 76337 |
| 14-16 | 22328 | 18955 |
| 16-18 | 14395 | 3834 |
| 18-20 | 6676 | 834 |
| 20-22 | 5008 | |
| 22-24 | 1000 | |
| 24-26 | 89 | |
| Total | 494616 | 418799 |

*) Average over 4 years of raised frequencies from Tables 3 and 4

**Table 8** **Bhattacharya analysis of combined length frequency data *) of L. duvaucelii (Males), Cochin, 1981-84. Mean lengths of cohorts found **)**

| | | | | | |
|---|---|---|---|---|---|
| JAN | 8.219 | 10.932 a) | 14.426 c) | 18.501 d) | 21.600 |
| FEB | 9.348 | 15.419 | | | |
| MAR | 9.267 | 13.943 a) | 17.467 c) | 21.023 d) | |
| APR | 8.448 | 12.405 | 18.720 c) | | |
| MAY | 9.796 | 15.372 | | | |
| JUN | 9.724 | 15.822 b) | | | |
| JUL | 9.712 | 15.111 | 19.630 | | |
| SEP | 10.101 | 17.853 b) | 24.066 | | |
| NOV | 8.587 | 12.391 | | | |
| DEC | 10.403 | 16.704 | 20.927 | | |

*) See Table 5
**) The mean values used in fitting the growth curve are indicated by a), b), c) and d)

**Table 9** **Bhattacharya analysis of combined length frequency data *) of L. duvauceli (Females), Cochin, 1981-84 **)**

| | | | | |
|---|---|---|---|---|
| JAN | 7.832 b) | 11.835 a) | 14.676 | |
| FEB | 7.742 | 11.527 | | |
| MAR | 7.949 c) | 10.816 b) | 13.492 a) | |
| APR | 8.592 | 12.264 | | |
| MAY | 8.132 | 10.708 c) | 12.601 b) | |
| JUN | 7.975 d) | 10.648 | 13.056 | |
| JUL | 9.358 d) | 13.329 c) | 16.005 | |
| SEP | 9.016 | 12.141 | 15.737 c) | |
| NOV | 6.867 | 10.246 | 12.582 | |
| DEC | 8.203 | 10.753 | 13.338 | 16.611 |

*) See Table 6
**) The mean values used in fitting the growth curve are indicated by a), b), c) and d)

follows the VBGF has been derived starting from

$$\frac{dW}{dt} = HW^{2/3} - kW \qquad (1)$$

where H and k are constants.

Assuming W is proportional to $L^b$, where b is the exponent in the length-weight relationship, then the above equation can be transformed into one in length in the form given below, namely

$$\ln L/dt = (k/b) * (L_\infty^{b/3} * L^{-b/3} - 1) \qquad (2)$$

The above growth equation in length in fact reduces to a generalized VBGF in length, given by

$$Lt = L_\infty [1-\exp(-k/b * (t-to))]^{3/b} \qquad (3)$$

The above equation suggests a linear growth in the major part of the growth schedule. Here the estimation of $L_\infty$ and K are different from the corresponding ones in the classical VBGF and they are not comparable.

The estimates of $L_\infty$ and K (= k/b) in Eq. 2 were obtained using the Gulland and Holt plot through the modal progression of the mean lengths obtained from the Bhattacharya analysis. The mean lengths which we considered would fit the modified growth equation, keeping in mind the fast growing nature of the squid, are given in Tables 8 and 9.

The estimated values for males and females are presented below:

| | $L_\infty$ (cm) | K (per year) |
|---|---|---|
| Males | 37.9 | 1.1 |
| Females | 23.8 | 1.7 |

## 5.4 Estimates of mortality

Using the above growth parameters, the total instantaneous mortality rate (Z) was estimated using the length converted catch equation viz.,

$$\ln (N/dt) = a_o + a_1 * t$$

where N is the number of individuals in a length class,
dt is the time taken to grow from the lower limit ($L_1$) of the length class to the upper limit ($L_2$) and is given by,

$$dt = \frac{1}{k} \ln \left[ \frac{L_\infty^{b/3} - L_1^{b/3}}{L_\infty^{b/3} - L_2^{b/3}} \right]$$

t is the relative age corresponding to the mid length of the length class, $a_o$ is a constant, $a_1 = -Z$.

The length frequency data of catch in numbers were grouped in 2 cm intervals and Z was estimated, for males at 9.0 per year and for females at 10.6 per year.

Spent individuals of either sex have never been observed in the landings at Cochin. However, during September-October 1978 a shoal of spawning squids of this species was caught in cast nets and scoop nets in knee deep

waters along the Alleppey coast about 60 km south of Cochin. The fishery which lasted for two days yielded about 6.5 t of squids, 82% of them being spawning males. Males were in the size range of 14.0 to 33.0 cm and females 14.0 to 18.0 cm. It is of interest to note that male squids of the above size range never occurred in the trawl fishery at Cochin. The natural mortality rate for males was estimated by the catch curve method using the growth parameters already found:

$$Z = M = 2.2$$

Since data for females were not available it was assumed to be of the same magnitude as that of the males as they belonged to the same stock (Table 10).

**Table 10 Length frequency data of L. duvauceli (males) collected along Alleppey coast in scoop nets and cast nets in September/October 1978**

| Size *) | Frequency |
|---|---|
| 14-16 | 11627 |
| 16-18 | 6644 |
| 18-20 | 3876 |
| 20-22 | 4430 |
| 22-24 | 1661 |
| 24-26 | 2767 |
| 26-28 | 2214 |
| 28-30 | 2215 |
| 30-32 | 1661 |
| 32-34 | 1108 |
| Total | 38203 |

*) Mantle length in cm

## 6 DISCUSSION

The data collected on the squid landings at Cochin do not seem to represent the actual stock. The gear in which they are caught is directed towards shrimps and it sweeps an area up to about one metre from the bottom, while neretic squids are semipelagic. It is obvious that the gear is not efficient enough to catch the squids. The squids caught were in the size range of 4 to 25 cm for males and 4 to 18 cm for females during the last one decade or so. Squids outside this range were never caught by the gear. The landings during 1977-86 exibit a lot of fluctuations suggesting that the stock may not be an all time resident one.

The biology of the species is not fully understood. They seem to spawn almost throughout the year without any clear cut seasons. But nothing is known about the spawning behaviour, spawning grounds or juveniles. As indicated in the biology section post-spawning behaviour of this species is not known and it is essential that this aspect is studied to understand the dynamics of the population.

In short-lived species such as squids both growth and mortality are quite high (Caddy, 1983), but estimation of growth in squids is yet to be fully understood. We have deviated from the classical form of the VBGF as the exponents in the length-weight relationship were closer to 2. So we used

the modified growth equation in length assuming the growth in weight follows the VBGF. This needs further investigations and our present data base may not be suitable for the selection of an appropriate formula. Supongpan (1988), assessing the stocks of L. duvauceli in Thailand assumed that the growth in dorsal mantle length follows the VBGF, while she did not treat the sexes separately. The length-weight relationship given by her also indicates an exponent of 2. It is obvious that the application of the VBGF in the classical form is not tenable for the reasons we have already discussed. We have also estimated the growth parameters by applying the classical form of the VBGF and the values then become:

| | $L_\infty$ (cm) | K (per year) |
|---|---|---|
| Males : | 45.4 cm | 0.53 |
| Females: | 27.0 cm | 0.94 |

Unfortunately we are unable to compare our values with those of Supongpan's as her values are for the combined sexes. However, the K values in the present study and the one obtained by her confirm that the species is a fast growing one. The modified growth equation used in our study seems to be biologically reasonably sound.

Since the present method of exploitation is not efficient towards squids, the catch may not represent the actual stock. As such it is not possible to indicate the rate of exploitation with the available data. In this context, it may be pointed out that the difference between the total mortality (Z) and the natural mortality (M) for the males and females were 6.2 and 8.8 respectively. It is obvious that these values are not representing the fishing mortality as there is no directed fishing towards squids. Thus in this study we are neither making any estimates of the rate of exploitation nor of the stock size.

This paper should be treated only as a beginning in the way of understanding various problems in the population dynamics of the squids and formulating fishery management practices.

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