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MIXED FISHERIES ASSESSMENT WITH REFERENCE TO FIVE IMPORTANT DEMERSAL FISH SPECIES LANDED BY SHRIMP TRAWLERS AT KAKINADA

by

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ABSTRACT

Data collected on five species in the by-catch of shrimp trawlers at Kakinada (Andra Pradesh) during 1984-86 are used for a length based cohort analysis and Thompson and Bell assessments. An assessment of this mixed fishery is also carried out. The methods used are described in detail and problems involved in estimating the important parameters to assess mixed trawl fisheries are discussed. Growth parameters and mortality estimates for Nemipterus japonicus, N. mesoprion, Johnius carutta, Leiognathus bindus and Secutor insidiator were taken from published work on resources off Kakinada.

1 INTRODUCTION

In the trawl catches at Kakinada, some fishes of the families Nemipteridae, Sciaenidae and Leiognathidae are very important. They constituted over 20% of the total average annual trawl catch of 19,525 tonnes during 1984-86. Various aspects of the biology of the dominant species in these groups Nemipterus japonicus, N. mesoprion, Johnius carutta, Leiognathus bindus and Secutor insidiator, were studied earlier. The mortality rates and yield per recruit of four of the above species were estimated on the basis of data collected up to 1983 (Murty 1982; 1983; 1983a; 1984; 1984 a; 1986; 1986 a). However, studies pertaining to mixed fisheries assessments which help in regulating the fishing effort and mesh size of the nets effectively, are lacking. An attempt is made in this paper to assess the resources of the above five species together on the basis of data collected during 1984-1986. For the mixed fisheries assessment to be meaningful, it is necessary to take into account the majority of the species, particularly the more valuable species like shrimps. As the present study does not take into account the shrimps, it should be considered as a beginning for a more detailed study.

1.1 Description of the fishery

Small shrimp trawlers started operating off Kakinada in 1964. The industry has expanded substantially, particularly due to the lucrative export value of shrimps. During 1984-86, an average of about 120 boats was in operation. The length of the trawlers ranges from 9 to 11 m. The trawl gear is made of synthetic monofilament twine of 0.5-1.0 mm diameter, and it has a codend mesh size of about 1.6 cm. Fishing is conducted at depths ranging from 5 to 80 m but mainly in the 5-50 m depth range. Several species contribute to the fishery and data are regularly collected for 40 species or species groups. Shrimps, sciaenids, silverbellies, nemipterids, ribbon fish, scads, drift fish and lizard fish are the more abundant groups (Muthu et al., 1977 and CMFRI, 1981). From year to year there are varia-

Table 1 Some fish prices (in Rupees/kg) at Kakinada

Species	Price
N. japonicus	Rs. 3 upto 12 cm and Rs. 6 beyond
N. mesoprion	Rs. 3 all lengths
J. carutta	Rs. 3 all lengths
L. bindus	Re. 1 all lengths
S. insidiator	Re. 1 all lengths

Table 2 Estimated effort (trawling hours), total catch (t) and the catches of some particular groups and species during 1984-86 at Kakinada by the commercial trawlers

Years	Effort	Total catch	Catches by group			Catches by species				
			Nemip-terids	Sciae-nids	Silver-bellies	N.japo-nicus	N.meso-prion	J.carut-ta	L.bindus	S.insi-diator
1984	310367	17679	1060	1234	1725	398	583	129	1047	310
1985	330456	18451	548	1513	1677	186	319	105	870	367
1986	368532	22445	685	1472	1906	202	438	46	453	658
Average	336452	19525	764	1406	1769	262	447	93	790	445
% in average total catch			3.9	7.2	9.1	1.3	2.3	0.5	4.0	2.3
% in the catch of the group			-	-	-	34.3	58.5	6.6	44.7	25.2

tions in the abundance of the different groups, within the year, though, the maximum catch is obtained from December to March in most years. The boats land the entire catch without discarding, because also the trash fish has some value as poultry feed, manure etc. Some prices of fish at the landing centre are presented in Table 1.

The estimated total annual effort and the catch of the different groups considered in this paper are shown in Table 2.

1.2 Notes on biology

Estimated values of the von Bertalanffy growth parameters, length and age at first maturity, natural mortality (M) and L_{max} of the five species under study are given in Table 3.

Information on the biology of N. japonicus from different centres in India other than Kakinada is available in the works of Krishnamoorthi (1973, 1976), Dan (1980), Vivekanandan and James (1986), Vinci and Nair (1975) and Vinci (1983). It has been shown that this species is a fractional spawner. The spawning period off Kakinada is from August to April (Murty, 1984). Further north (Andhra Pradesh-Orissa) this species spawns during September-November and further south, off Madras during June-March. For N. mesoprion, the spawning period was determined as December-April. Also this species is a fractional spawner (Murty, 1982). For Johnius carutta, the information on biology is restricted to the accounts of Rao (1967) and Murty (1984 a, 1986). This species is also a fractional spawner with a spawning period from January to June. For Leiognathus bindus the available data show that the spawning season is during December-February off the southwest coast (Balan, 1967) whereas the study of material at Kakinada shows that this is a fractional spawner and that it spawns almost throughout the year (Murty, 1983). For Secutor insidiator Pillai (1972) showed that this is a fractional spawner with a protracted spawning period. Murty (MS) showed that this species spawns almost throughout the year.

1.3 Data base

During 1984-1986 data were collected on the landings of the small commercial trawlers operating off Kakinada (16°35'-17°25' N, 82°20'-83°10' E). Data on effort and the landings by family groups were collected on about 18 days in a month and samples for biological studies were obtained on 6-8 days in a month. Excepting silverbellies, length data were collected at the landing place for all species. The data on effort, catch, species composition and length composition collected on each observation day were weighted following Alagaraja (1984) to get monthly estimates. The monthly estimates were pooled to get annual estimates.

Parameters of growth estimated earlier using the integrated method of Pauly (1983) in N. japonicus, J. carutta and S. insidiator and following the modal progression method in L. bindus and N. mesoprion (Murty, 1982; 1986, 1986 a, 1987, MS) were used in the present study. The natural mortality range was estimated using Pauly's (1980) formula; for this purpose the average water temperature was taken as 27.2° C from the works of Ganapati and Murthy (1954) and La Fond (1958).

2 METHODS

Yield and biomass estimates were made using a micro computer with the help of the LFSA package, Sparre (1987). An assessment of the mixed fishery was made based on length frequencies, using the length-converted Thompson and Bell analysis developed by Sparre (1985). For easy reference the theory and method are described below.

Table 3 Estimated values of growth parameters (L_∞, K, t_o), natural mortality rate (M), lengths and ages of first maturity (Lm, tm) and maximum lengths (L_{max}) for five species based on research in India

Species	L_∞ (cm)	K (per year)	t_o (year)	M (per year)	L_m (cm)	t_m (years)	L_{max} (cm)	Region	Source	Method of estimation of growth parameters
Nemipterus japonicus	30.5	0.3141	-1.1079	0.5037	16.5	1.4	35.0	Andhra-Orissa coast	Krishnamoorthi (1973,1978)	Modal progression
- " -	29.0	0.6244	0.1439	-	-	-	30.5	Visakhapatnam	Rao and Rao (1986)	Scale studies *)
- " -	31.4	0.7514	-0.1731	1.1418	12.5	0.5	28.5	Kakinada	Murty (1983a, 1984	Modal progression
- " -	33.9	0.52	-0.16	1.1	12.5	0.72	30.5	Kakinada	Murty (1987)	Integrated method
- " -	30.5	1.004	0.2257	2.5254	14.5	0.87	30.1	Madras	Vivekanandan and James (1986)	Integrated method
N. mesoprion	21.9	0.83	-0.26	1.7	12.0	0.7	21.5	Kakinada	Murty (1982)	Modal progression
Johnius carutta	33.3	0.44	0	1.0	15.5	1.4	25.5	Kakinada	Murty (1984a, 1986	Integrated Method
Leiognathus bindus	15.8	0.58	-0.024	1.5	8.0	1.2	14.2	Kakinada	Murty (1983, 1986a)	Modal progression
	12.2	1.3	-	-	8.7	1.0	-	Calicut	Balan (1967)	
Secutor insidiator	12.3	1.2	-0.01	2.6	9.0	1.1	11.7	Kakinada	Murty (in press)	Integrated method

*) Rao and Rao (1986) estimated growth parameters through the Gompertz growth equation

2.1 Theory of length-based Thompson and Bell model

The Thompson and Bell model (1934) is an age-structured model for prediction of catch and stock size for a given fishing pattern (the array of fishing mortalities by age group). The model used here (Sparre, 1985) is the length-structured parallel of the Thompson and Bell model.

The starting point is Jones' length-converted cohort analysis:

$$X(L1,L2) = ((L_\infty - L1)/(L_\infty - L2))^{M/2K} \quad (1)$$
$$N(L1) = (N(L2)\ X(L1,L2) + C(L1,L2)\ X(L1,L2) \quad (2)$$
$$F/Z = C(L1,L2)/(N(L1) - N(L2)) \quad (3)$$
$$F = M\ (F/Z)/(1 - F/Z)$$

where L_∞ is the asymptotic length. K the curvature parameter and (L1,L2) the (lower limit, upper limit) of the length class considered, N is stock number, C is number caught, F is fishing mortality, M is natural mortality and Z is total mortality, (for further details see Jones (1984) or Sparre (1985).

The forward projection of the length based cohort analysis is named "length converted Thompson and Bell" analysis (Sparre, 1985) It takes the fishing mortalities by length group and the recruitment (number in smallest length group) as inputs and calculates the number caught and the stock numbers.

To turn Eqs. 1 to 3 into "forward projection", Eq. (3) is rewritten:

$$C(L1,L2) = (F/Z) * (N(L1) - N(L2)) \quad (4)$$

which inserted into Eq. (2) gives:

$$N(L1) = (N(L2)\ X(L1,L2) + (F/Z)\ (N(L1) - N(L2)))\ X(L1,L2)$$

Solving this equation with respect to N(L2) gives:

$$N(L2) = N(L1)*(1/X(L1,L2) - F/Z) / (X(L1,L2) - F/Z) \quad (5)$$

Eqs. (4) and (5) form the "forward version" of length converted cohort analysis.

In its simplest form, the length converted Thompson and Bell analysis uses the F-array estimated in cohort analysis as the reference F-array and assesses the effect of raising (reducing) all F's by a certain factor.

In the general case where all F-values are raised (or reduced) by the factor XX the general step becomes:

$$N(li+1) = N(li) * (1/X(Li,Li+1)-E(Li,Li+1))/(X(Li,Li+1)-E(Li,Li+1))$$

where

$$E(Li,Li+1) = XX * F(Li,Li+1)/Z(Li,Li+1)$$
$$Z(Li,Li+1) = XX * F(Li,Li+1) + M$$
$$C(Li,Li+1) = XX * F(Li,Li+1) * (N(Li)-N(Li+1))/Z(Li,Li+1)$$

The yield (catch in weight) in length group i is:

$$YIELD(Li,Li+1) = C(Li,Li+1) * W(Li,Li+1)$$

where W(Li,Li+1) is the mean weight of fish of lengths between Li and Li+1. It may be calculated from:

$$W(Li,Li+1) = a * (Li\hat{\ }b + Li+1\hat{\ }b)/2$$

where a and b are the parameters in the length-weight relationship.

The value of the yield is given by:

VALUE(Li,Li+1) = YIELD(Li,Li+1) * PRICE(Li,Li+1)

where

PRICE(Li,Li+1) is the kg price of fish between lengths Li and Li+1.

The mean number of survivors in length group i is:

NMEAN(Li,Li+1) = (N(Li) - N(Li+1))/Z(Li,Li+1)

and the corresponding mean biomass is

BIOM(Li,Li+1) = NMEAN(Li,Li+1) * W(Li,Li+1)

The prediction made by the length converted Thompson and Bell analysis is a prediction of the average long term catches, assuming recruitment to remain constant.

2.2 Assessment of mixed fisheries based on length frequencies

In the present case the kg prices differ between species and between size categories within some species. Therefore it is not correct to treat each species separately and subsequently sum the results in terms of yield. Before a summation makes sense the yields must be converted into units of value.

Moreover, even if yields are converted into values it is still not possible to sum the results of single species assessments. It will usually be so that the effort level which for one species gives the maximum sustainable economic yield (MSE), will not be at that level for the other species.

The approach suggested below combines all species in the estimation of MSE. The computational procedure of the assessment of a mixed fishery based on length frequency data works as follows:

a) Perform a single species length converted cohort analysis on each species separately. This gives estimates of the current fishing pattern for each species.

b) Perform separate length converted Thompson and Bell yield analysis on each species. Use the same F-factor for the fishing patterns of each species. Sum the values of the yields of all the species.

c) Use the sum of values to determine the optimum effort level.

The assumption behind this approach is that when the fishing mortality on one species is increased, that on the other species will automatically be increased also by the same relative amount. The above suggested computational procedure involves a large number of calculations and is greatly facilitated by the use of a computer. The LFSA-package (Sparre, 1987) with the program "MIXFISH" was used.

3 RESULTS

3.1 Length based cohort analysis

The raised annual length frequencies of the three years (1984-86) were pooled and the annual average frequencies were obtained as inputs for cohort analysis. The other input parameters are given in Table 4. The data of 1980-83 were earlier analysed for estimation of mortalities (Murty, 1986, 1986 a, 1987, MS) and F/Z values were found to range from 0.6 to 0.8. The terminal F/Z values for length cohort analysis were guessed (Table 4) on the basis of these values. The results of the cohort analysis on the five species are shown in Figures 1 to 5.

For N. japonicus (Fig. 1), F shows an increase to a maximum of 1.95 at 22.5 cm which is followed by a decline. The average F for fully recruited fishes (L>= 13.5) was 1.1.

For N. mesoprion (Fig. 2) F increased to 3.68 at 11.5 cm, then decreased to 1.1 at 14.5 cm and then increased again. The average F for fully recruited lengths (L>= 11.5) was 2.7.

For J. carutta (Fig. 3) F increased with increasing length to 17.5 cm and from there onwards was relatively stable. The average F for fully recruited fish (L>= 16.5) was 3.6.

For L. bindus (Fig. 4) F increased to a maximum of 4.5 at 8 cm and then showed a decline, after which they were more or less constant at around 3.5. The average F for fully recruited fish (L>= 6.75) was 3.4.

For S. insidiator (Fig. 5) F in different length groups showed an increase from a minimum of 0.1 to a maximum of 3.9, with increasing length. The average F for fully recruited fish (L>= 9.25) was 3.6.

Table 4 Input parameters for the length converted cohort analyses given in Figs. 1-5 *)

Parameters	N.japonicus	N.mesoprion	J.carutta	L.bindus	S. insidator
L_∞ (cm)	33.9 (30)	21.9 (18.5)	33.3 (24.5)	15.84 (13.0)	12.3 (11.0)
K per year	0.52 (0.71)	0.83 (1.20)	0.44 (0.85)	0.58 (1.00)	1.20 (1.79)
M per year	1.1 (1.4)	1.7 (2.27)	1.0 (1.68)	1.5 (2.22)	2.6 (3.41)
Terminal F/Z	0.50	0.68	0.78	0.68	0.6
q in $W = qL^b$ (g, cm)	0.0287	0.0168	0.0063	0.0153	0.0050
b in $W = qL^b$	2.702	2.877	3.233	2.962	3.437

*) Values for L_∞, K and M were taken from Table 3, while those in brackets are the parameters used for an alternative assessment presented in Fig. 7.

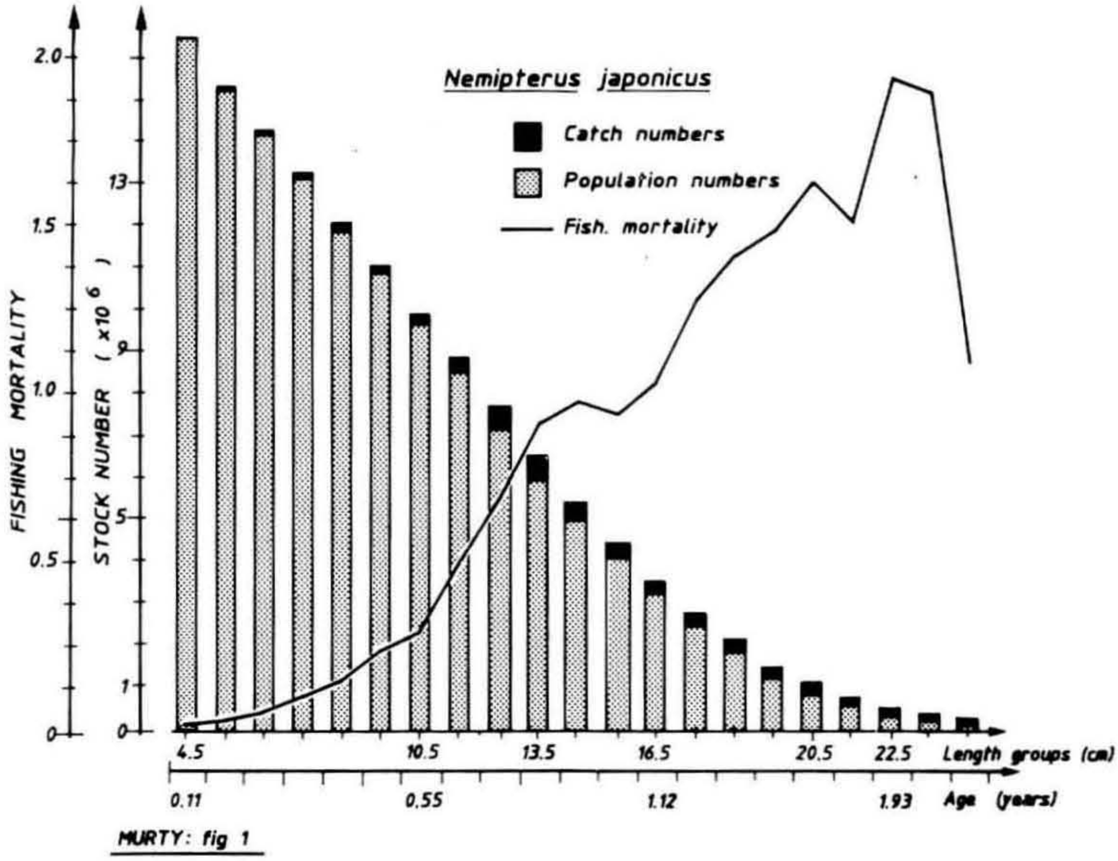


Fig. 1 Length cohort analysis of Nemipterus japonicus at Kakinada, 1984-1986. Mean F = 1.1

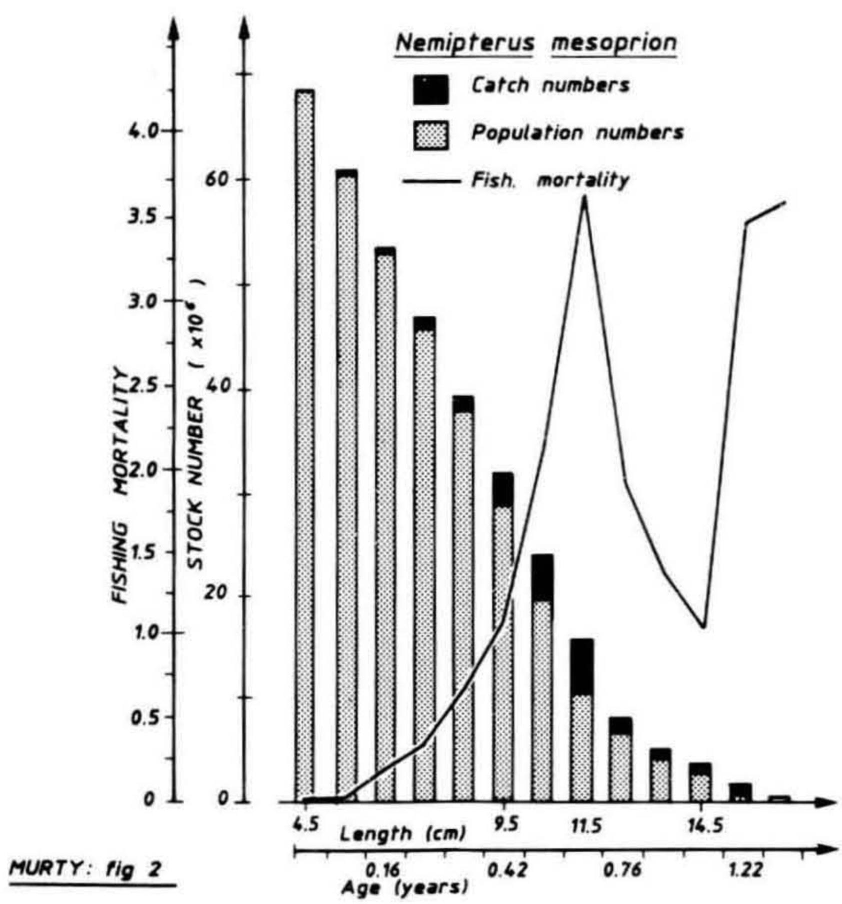


Fig. 2 Length cohort analysis of Nemipterus mesoprion at Kakinada, 1985-1986. Mean F = 2.7

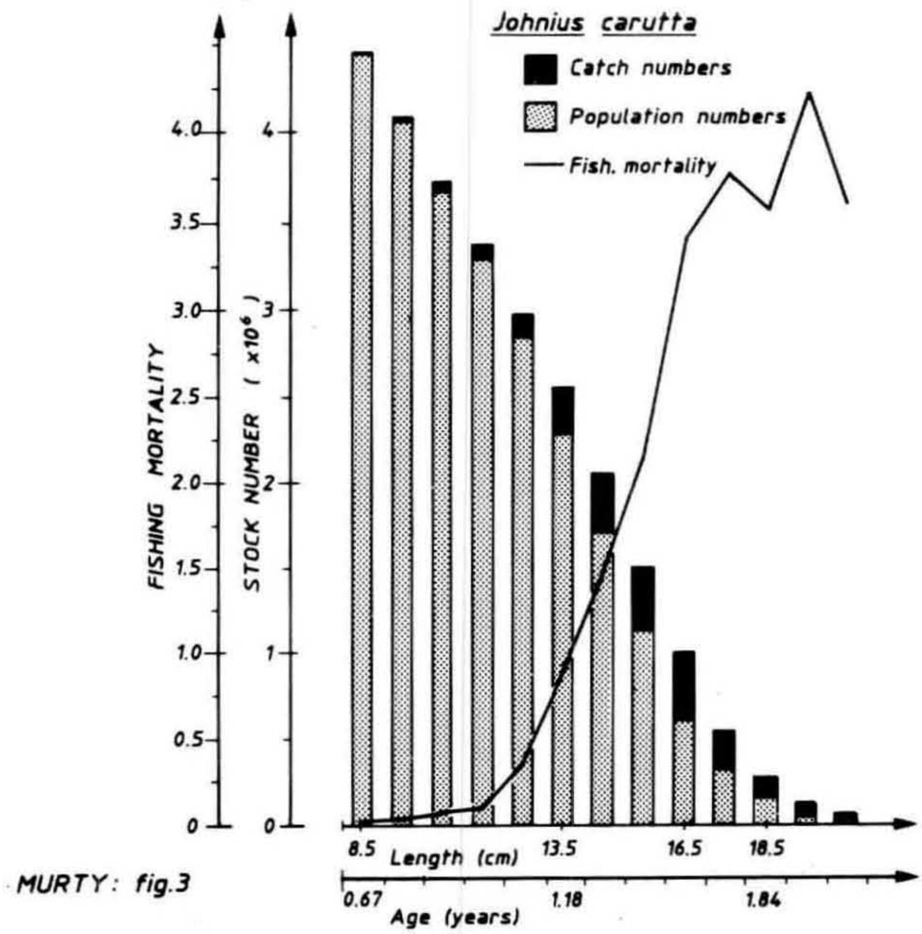


Fig. 3 Length cohort analysis of Johnius carutta at Kakinada, 1984-1986. Mean F = 3.6

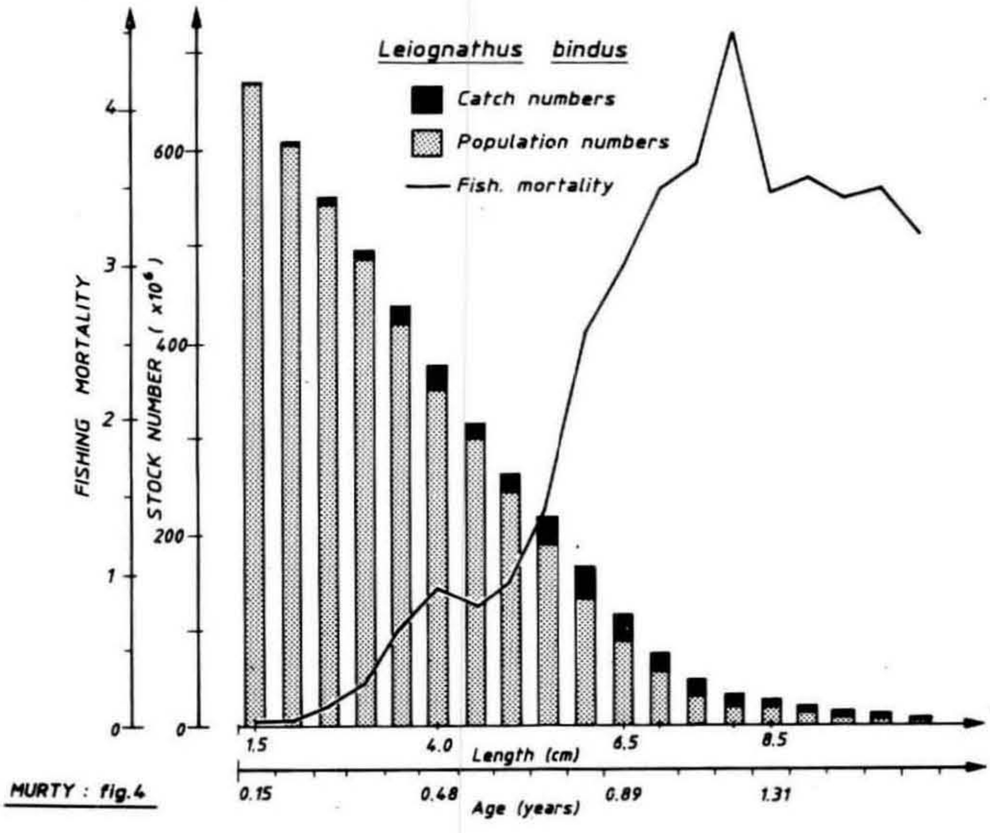


Fig. 4 Length cohort analysis of Leiognathus bindus at Kakinada, 1984-1986. Mean F = 3.4

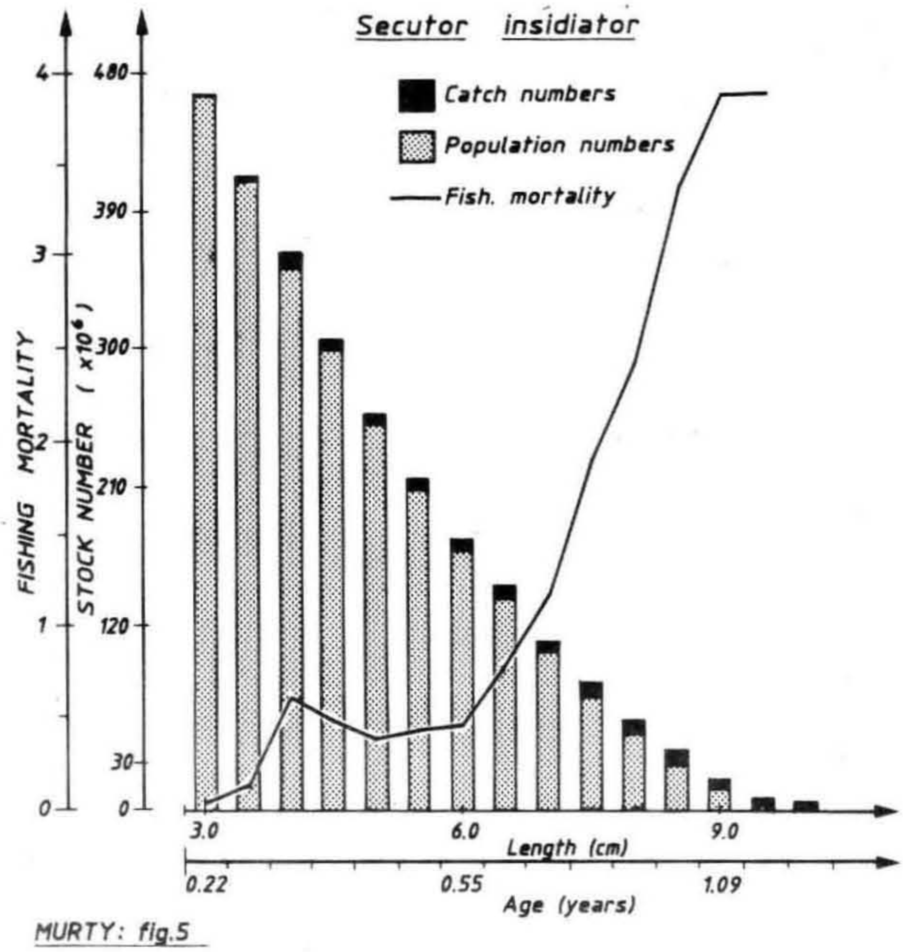


Fig. 5 Length cohort analysis of Secutor insidiator at Kakinada, 1984-1986. Mean F = 3.6

3.2 Length based Thompson and Bell analysis by species

To assess the conflicts between management strategies for individual stocks usually inherent in a mixed fishery, predictions were made for each stock separately. The conflicting results of this exercise can be summarized.

For N. japonicus, the maximum sustainable yield (MSY) of 254 t can be obtained by increasing the effort by 40% (Fig. 6). The maximum sustainable economic yield (MSE) can be obtained however, by increasing the effort by 20% only (Table 5). Furthermore, the 40% increase in effort will result in only 1% increase in yield which indicates that the catch per unit of effort will be reduced drastically.

For N. mesoprion (Table 6), the results indicate that the effort can be increased by 80% to get the MSY as well as the MSE (Fig. 6). Also in this case 80% effort increase will only result in a 1.8% increase in yield and will therefore not be remunerative.

For J. carutta (Table 7). the present effort is at optimum level (Fig. 6).

For L. bindus, the Thompson and Bell long term forecast (Table 8) shows that the present effort is 40% more than the one giving the MSY (Fig. 6) thus suggesting a need for a reduction in effort.

For S. insidiator, on the other hand, the analysis (Table 9) shows that the effort can be increased by 140% to get the MSY but the increase in yield will only be 6%.

3.3 Mixed fisheries assessment

The assessment of individual species has indicated that the present effort is optimal for one species only, it can be increased considerably in the case of three species and should be reduced for one species. The mixed fisheries assessment (Table 15) shows, on the other hand, that the MSE of all the five species together can be obtained by increasing the effort by about 19%. This suggestion should only be considered in the light of similar studies on shrimps and other valuable species.

It may be stated here that any gain or loss in yield should be considered together with a corresponding change in CPUE (which can be taken as roughly proportional to the biomass as calculated by the Thompson and Bell analysis).

Table 5 Thompson and Bell long term forecast of *N. japonicus* at Kakinada

XX factor	Yield (t)	Mean biomass (t)	Value (000 Rs)
0.0	0	725	0
0.2	126	539	751
0.4	191	423	1132
0.6	225	346	1325
0.8	243	293	1420
1.0	251	255	1460
1.2	254	226	1470 MSE
1.4	254 MSY	204	1463
1.6	253	186	1447
1.8	250	171	1425
2.0	248	159	1400
2.2	244	149	1374
2.4	241	140	1348
2.6	238	132	1322
2.8	235	125	1296
3.0	232	119	1271

Table 6 Thompson and Bell long term forecast of *N. mesoprion* at Kakinada

XX factor	Yield (t)	Mean biomass (t)	Value (000 Rs)
0.0	0	707	0
0.2	175	539	526
0.4	272	430	817
0.6	327	356	982
0.8	359	303	1077
1.0	377	264	1131
1.2	386	234	1160
1.4	391	212	1175
1.6	393	194	1181
1.8	393 MSY	179	1181 MSE
2.0	392	167	1178
2.2	390	158	1172
2.4	388	149	1165
2.6	386	142	1158
2.8	383	137	1150
3.0	380	131	1142

Table 7 Thompson and Bell long term forecast of *J. carutta* at Kakinada

XX factor	Yield (t)	Mean biomass (t)	Value (000 Rs)
0.0	0	231	0
0.2	56	148	168
0.4	78	107	234
0.6	86	85	260
0.8	89	71	268
1.0	90 MSY	62	270 MSY
1.2	89	56	268
1.4	88	52	265
1.6	87	49	262
1.8	86	46	259
2.0	85	44	256
2.2	84	42	253
2.4	83	41	250
2.6	82	39	247
2.8	81	38	245
3.0	81	37	243

Table 8 Thompson and Bell long term forecast of *L. bindus* at Kakinada

XX factor	Yield (t)	Mean biomass (t)	Value (000 Rs)
0.0	0	1854	0
0.2	587	1115	587
0.4	768	768	768
0.6	815 MSY	583	815 MSE
0.8	814	473	814
1.0	796	402	796
1.2	774	352	774
1.4	751	315	751
1.6	728	287	728
1.8	707	264	707
2.0	688	245	688
2.2	670	229	670
2.4	653	215	653
2.6	638	204	638
2.8	623	193	623
3.0	610	184	610

Table 9 Thompson and Bell long term forecast of S. insidiator at Kakinada

XX factor	Yield (t)	Mean biomass (t)	Value (000 Rs)
0.0	0	631	0
0.2	197	519	197
0.4	304	448	304
0.6	366	398	366
0.8	404	361	404
1.0	429	331	429
1.2	445	307	445
1.4	456	287	456
1.6	463	270	463
1.8	468	255	468
2.0	470	242	470
2.2	471	231	471
2.4	472 MSY	220	472 MSE
2.6	471	211	471
2.8	470	202	470
3.0	469	194	469

Table 10 Thompson and Bell long term forecast all species combined at Kakinada

XX factor	Yield (t)	Mean biomass (t)	Value (000 Rs)
0.0	0	4151	0
0.2	1143	2862	2231
0.4	1615	2179	3257
0.6	1821	1770	3750
0.8	1911	1503	3986
1.0	1945	1316	4089
1.2	1951	1178	4120 MSE
1.4	1942	1071	4113
1.6	1926	987	4083
1.8	1907	917	4042
2.0	1885	859	3993
2.2	1862	810	3942
2.4	1839	767	3890
2.6	1817	730	3838
2.8	1795	697	3786
3.0	1773	668	3736

4 DISCUSSION

An assessment of the mixed trawl fishery off Kakinada based on length frequencies has been attempted for the fish component of this fishery. Ideally shrimp, the most important component, should have been included. Data for this component, however, was not available to the author. The assessment presented here is thus not complete. The present paper should therefore be considered primarily as a presentation of a methodology for assessment of a mixed fishery rather than an actual assessment of the Kakinada demersal trawl fishery.

When making single species assessments for the components of a mixed fishery the management implications found for individual components may be conflicting. In the present study such conflicts were found, e.g. MSY for N. japonicus corresponded to a 40 percent increase in effort, whereas effort at MSY for L. bindus should be reduced by 40 percent (see Fig. 6).

The assumed simplest solution was chosen here, namely to convert the biomass of different species into a common unit. By doing so the gain from increasing effort for N. japonicus can be weighted against the loss for L. bindus.

Although an increase in yield and value is achieved with an increase in effort the implication need not to be that an effort increase is advisable. The yield and the value curves should always be considered in conjunction with the CPUE curve, since an increase in effort always results in a decrease of CPUE. The question to be addressed is whether the increase in yield is so big that it can justify the decrease in CPUE.

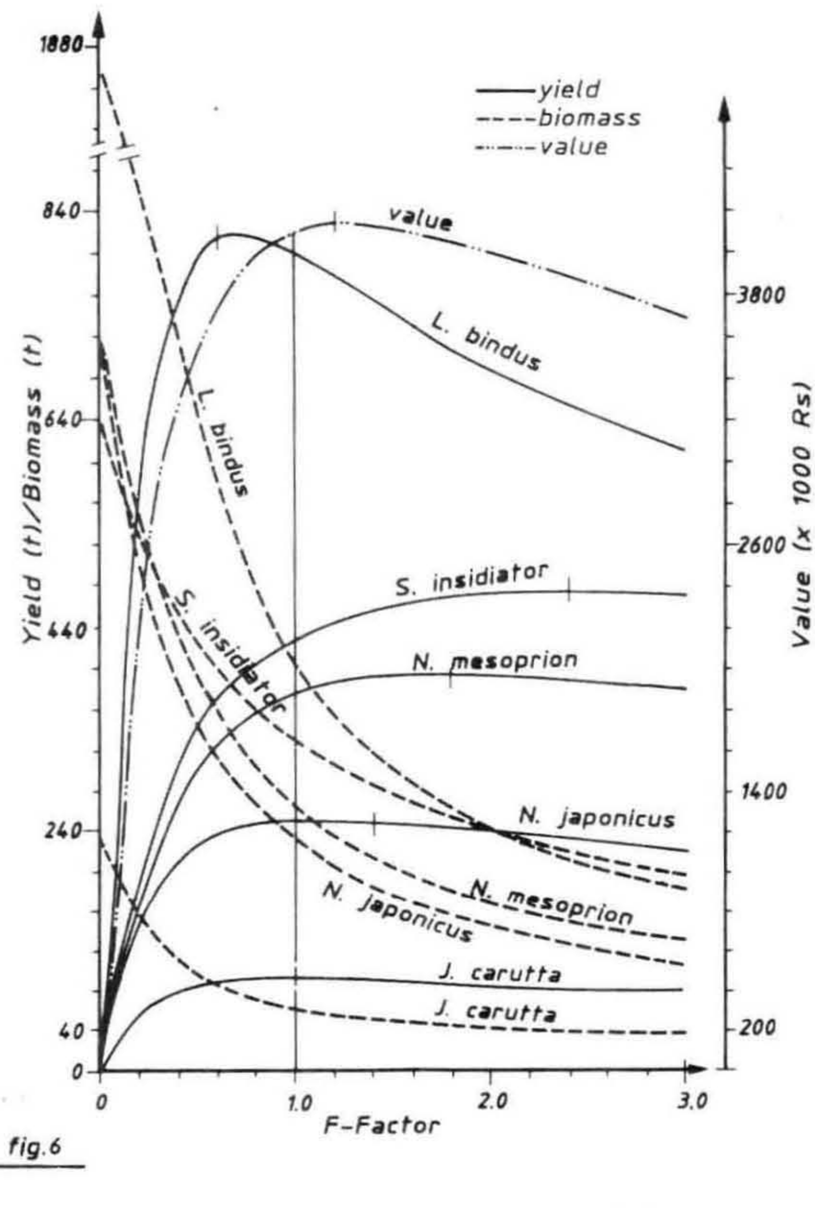


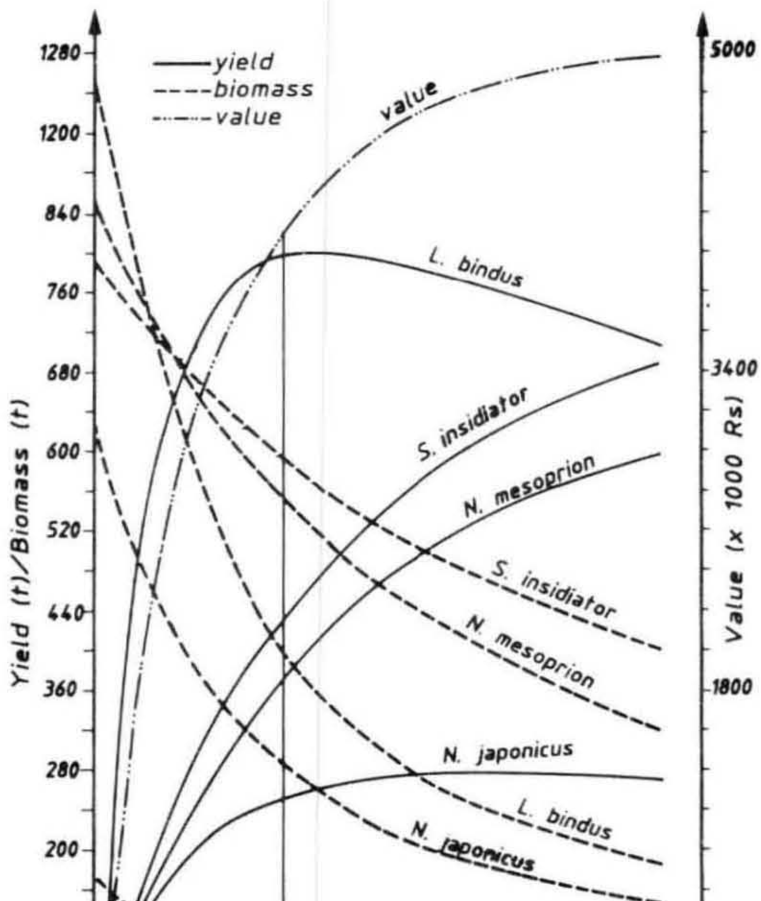
Fig. 6 Estimation of yield and biomass by length based Thompson and Bell method for different species and mixed fisheries assessment. (Small vertical lines on curves show the Fmsy and Fmse (value) levels, vertical line at X-Factor 1.0 shows the present effort level)

In the present analysis no explicit estimate of the CPUE was made. However, the estimated average stock biomass can be used as an index for CPUE. The above mentioned considerations apply in particular to many tropical fish species, for which the yield curves are flat-topped or in some cases have no maximum.

The present analysis is composed of a number elements all of which could form the basis for a lengthy discussion, however, only those aspects pertaining to the mixed fisheries will be considered in detail.

In particular the estimation of growth parameters and its implications for the cohort analysis presented here could be discussed in the light of the following aspects:

a) In addition to catch statistics, assessment of exploited fishery resources requires information on various aspects of biology and behaviour of the populations, in particular their distribution in space and time, spawning periods and recruitment.



MURTY: fig.7

Fig. 7 Estimation of yield and biomass by length based Thompson and Bell method for different species and mixed fisheries assessment, using arbitrarily selected lower values of L_∞ with compatable K values. (Small vertical lines show Fmsy levels, and the vertical line at X-Factor 1.0 the present effort level)

b) Information on the selectivity of the gear may be essential for a successful assessment.

The above mentioned features may have had an impact on the estimates of the growth parameters used in the present study (Table 4), which might represent overestimates of L_∞ and underestimates of K.

The fishing patterns estimated by cohort analysis (Tables 5-9 and Figures 1-5) show fishing mortalities increasing rapidly with the length of the fish. There is no straight forward explanation of this result. One explanation is that the L_∞'s are overestimated, as lower values of L_∞ would make the slopes of the F-curves less pronounced and make them resemble more the sigmoid selection ogive expected for trawls. An alternative explanation is that fishing mortality is mixed with the effect of migration out of the fishing grounds.

To assess the impact of changed growth parameters on the mixed fisheries assessment a set of alternative growth parameters were worked out. The L_∞'s were reduced arbitrarily and the K's subsequently modified accordingly. These parameters are presented as the figures in brackets in Table 4. Based on this alternative set of growth parameters, the entire assessment exercise was repeated and the result is summarized in Fig. 7.

It is believed that Fig. 6 represents the best possible assessment of the mixed fishery. Fig. 7 is given here primarily to illustrate the evaluation of the sensitivity of the results relative to the growth parameters and the natural mortality. It is noticed that the reduction of L_∞ and the related increase of K and M produce higher estimates of the MSY and MSE.

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