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MULTISPECIES STOCK ASSESSMENT WITH PARTICULAR REFERENCE TO MAJOR DEMERSAL FISH SPECIES IN THE TRAWLING GROUNDS OFF KAKINADA

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ABSTRACT

On the basis of data of four dominant demersal finfish species landed by trawlers at Kakinada, the method of multispecies stock assessment using the Beverton and Holt model is described and the problems involved are discussed. It is shown that with the present gear in use, the effort has to be reduced by about 6% to get MSY or with the present effort unchanged, the cod end mesh size has to be increased by 28% to get MSY. The latter option is considered to be the best because the present lengths at first capture are less than the lengths at first maturity, a situation that, if allowed to continue, can lead to recruitment overfishing.

INTRODUCTION

THE TROPICAL marine fisheries, particularly those exploiting demersal resources, take several species belonging to different genera and families having different maximum lengths, growth characteristics, mortality rates, *etc.* For various reasons— both biological and non-biological—the estimation of important parameters of individual species in these areas is still difficult, though methods to obtain reasonably accurate estimates have recently been developed (Pauly, 1980 a, 1980 b, 1980 c, 1982, 1983 ; Pauly and David 1981 ; Jones, 1981 ; Jones and van Zalinge, 1981 ; Srinath and Alagaraja, 1982 ; Alagaraja, 1984). The available methods for stock assessment of exploited fish populations fall under two main categories : the surplus production (Schaefer, 1954) and the analytic (Beverton and Holt, 1957) models. In the former, all the species together are treated as one species and the data required are only effort and catch for over a number of years. Though this model appears to be good for stock assessment of tropical multispecies fisheries, it has the significant draw back that it 'is ostensibly empirical with no theoretical basis.' (Larkin, 1982) and, 'real fish stocks do not fit the simple models '; besides, the curve of catch as a function of effort usually does not have such a sharply defined maximum as the parabola corresponding to the simplest assumption nor does the maximum always occur ' tidily at half the unexploited population ' (Gulland, 1983). Further, ' what we gain in simplicity with the surplus production models has the cost of a number of assumptions on the dynamics of fish stocks, which may be (and nearly always are) impossible to justify ' (Sparre, 1985). On the other hand, the analytic model, which takes into account the growth, mortality, *etc.* of a particular species stock, has a major advantage of the ' existence of an established body of theory and methods for dealing with single species ' (Larkin, 1982). However, since several species are exploited by several gears in the tropical seas like those of India, single species assessments do not generate meaningful

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management options. So far as the author is aware, there has not been any attempt to assess multispecies stocks using analytic models excepting Munro (1983) who considered the problem in general terms and Mennes (1985) who attempted stock assessment of sparid species off western Sahara region using his (Mennes, 1983) computer programmes. From India, there has been practically no attempt in this regard.

Among the demersal fin fishes landed by private trawlers at Kakinada, sciaenid, leiognathid and nemipterid fishes are most dominant and *Johnius carutta*, *Leiognathus bindus*, *Secutor insidiator* and *Nemipterus japonicus* are most dominant in these three groups. The present paper describes the method of assessing multispecies stocks, taking into account the above four species. Studies on the biology, mortality rates and yield per recruit of these four species were made earlier (Murty, 1983 a, b, 1984 a, b, MSS).

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MATERIAL AND METHODS

Catch and effort: Data were collected from the landings of private trawlers operating off Kakinada (Lat. 16°35′-17°25′ N; Long. 82°20′-83°10′ E). Boats of three different sizes operate in the region (CMFRI, 1981). Since the *Pomfret-Royya* category is the most dominant one, the effort (units as well as trawling hours) put in by this category was taken as standard effort and all the demersal groups landed were together considered as one group for standardising the effort. The data on effort and catch were collected for about 18 days each month and samples for biological study were collected at weekly intervals. The data of each observation day were given weightages to ultimately obtain monthly estimates.

Estimation of parameters: Parameters of growth in length were estimated earlier (Murty, MSS) using the data of 1980-'83 and the integrated method of Pauly (1980 a) in *N. japonicus*, *J. carutta* and *S. insidiator* whereas in *L. bindus* they were estimated using the data of 1979-'81 and following the modal progression method. For estimating all other parameters and yield, the data of 1980-'83 only were used.

The coefficient of total mortality (Z) was estimated following the length-converted catch curve method of Pauly (1982); the average of the four-year period was taken as the present value. The coefficient of natural mortality (M) was calculated using Pauly's formula (1980 b) taking the average water temperature as 27.2° C and K per year.

The length at first capture (L_c) was estimated following Pauly (1984) and the smallest length in the catch was taken as length at recruitment (Lr).

Yield-per-recruit: The yield in weight per recruit (Yw/R) was calculated using the well-known Beverton and Holt (1957) yield equation. In each species the value of W_∞ was calculated with the help of Length-weight relationship and the estimated value of L_∞.

Multispecies assessment: The values of the catchability coefficient (q=F/E) were calculated following Ricker (1975) and Pauly (1980 c), taking into account the present value of fishing mortality rate (F) of each species and the present average annual effort (E). The resultant values were used to derive values of F: taking a set of values of effort, values of F for each species corresponding to the same effort were calculated (F=Eq). The F values thus obtained were used to calculate Yw/R in each species; this enables plotting of yield per recruit against effort instead of against F.

For each species, the selection factors (SF) of the gear under operation were calculated as SF=present L_c/present cod end mesh size (Jones, 1976). The cod end meshes (stretched) were found to vary from 15 to 20 mm with the average at 15.6 mm, hence this was taken as the present cod end mesh size. A set of values of cod end mesh sizes (MS) were taken L_c values for each species corresponding to these mesh sizes were calculated as L_c=SF X MS. These L_c values were converted into t_c and the t_c values thus obtained were used to calculate Yw/R, thus providing to plot Yw/R against mesh size instead of against t_c.

In each species, the present values of F and Yw/R were taken and the present biomass per recruit (B/R) was calculated as Yw/R÷F. The average biomass (B) of each species in the fishing ground was calculated as Y/F where Y is the annual average catch of a particular species and F the present value of that species. From these values, the recruitment (R) was calculated as B÷B/R and the resultant value was taken as constant. In each species, the Yw/R values at different levels of effort or mesh size were multiplied by the R value of that species to enable to obtain yield. The yield values of all species corresponding to a particular effort level or cod end mesh size were pooled to get a yield curve common to all species as a function of effort or mesh size.

The values of effort or mesh size against which maximum yield is obtained were considered as those giving maximum sustainable yield (MSY).

OBSERVATIONS AND RESULTS

Catches: The demersal component in the catch during the period under study (1980-83) formed about 66% of the total trawl catch. Sciaenids, silverbellies and threadfinbreams together contributed about 2670 tonnes (annual average, Table 1) forming about 18.5% of total trawl catch and 28.1% of total demersal catch. An estimated annual average of 1,313 tonnes of the four species under consideration were landed, together forming about 50% of the above three groups. Except *S. insidiator*, the catches of which showed an increasing trend in successive years irrespective of fluctuations in effort (Table 1), there is nc clear trend in the landings of the other three species.

TABLE 1. *Particulars of catches (tonnes) of different groups and species and the effort during different years by private trawlers at Kakinada.*

	1980	1981	1982	1983	Average
Total trawl catch ..	9,911	9,275	16,554	21,857	14,399
Catch of demersal groups ..	7,155	6,928	9,854	14,053	9,498
Catch of sciaenids, silverbellies and threadfin breams	2,348	1,641	2,712	3,977	2,670
N. japonicus ..	261	201	632	365	365
J. carutta ..	410	132	60	167	192
L. bindus ..	269	246	428	612	389
S. insidiator ..	168	252	323	725	367
Standard effort					
No. of units ..	48,144	42,954	62,000	50,450	50,887
Trawling hours ..	3,22,655	3,84,436	4,59,599	3,28,461	3,73,788

Parameters of yield equation : The estimated values of different parameters are shown in Table 2. It is observed that in all four species, the lengths at first capture are smaller than those at first maturity.

Estimation of yield : The yield in weight as a function of effort (Fig. 1) shows that MSY is obtained at different effort levels in different species with the present gear in use ; in *S. insidiator*, however, there is no maximum in the yield. In *L. bindus* and *J. carutta*, the present effort is greater than the one that gives MSY whereas in *N. japonicus* it is slightly less. The pooled yield curve of all species, however, shows (Fig. 1) that there is scope to increase effort to get MSY, but to get the same, the effort should be 128% of the present and the yield will only be 100.6% of the present (Fig. 2). Further, this increase in yield is obviously only due to increase in yield of *S. insidiator*—a smaller species (Table 2) whereas there is bound to be a decline if the effort is increased in the yield of the other three species (Fig. 1), two of which attain greater lengths (Table 2).

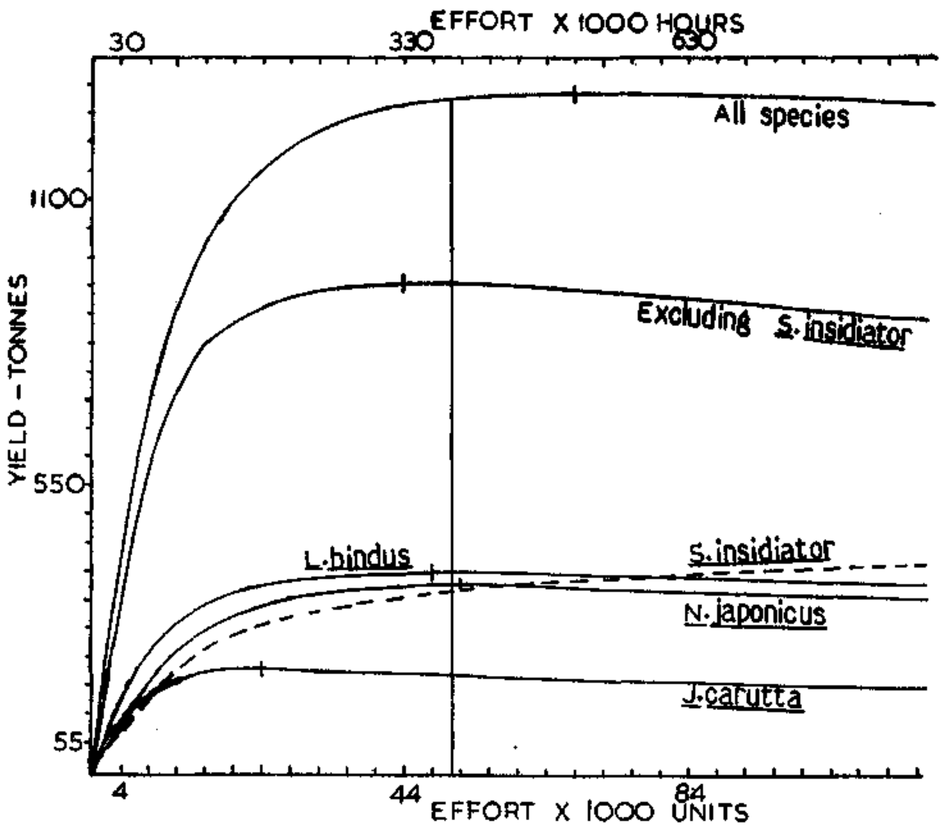

Fig. 1. Yield as a function of fishing effort with the present gear. The smaller vertical lines on each curve indicate the MSY and the bigger vertical line the present effort.

If *S. insidiator* is ignored, the MSY of the other three species together can be obtained at an effort level slightly less than (88% of the present) the present one (Fig 1 and 2). Since decrease in effort does not result in any harm to the resource of *S. insidiator*, decreasing the same slightly will ensure sustained returns of these commercially valuable species.

The yield as a function of cod end mesh size (Fig. 3) with the present rates of mortality (Table 3) operating, shows that for all species except *S. insidiator*, the present mesh size is much less than that which gives MSY. In all the four species together, the MSY is obtained at a mesh size slightly less than the present one, *i.e.* at about 96% of the present mesh size (Fig. 4)—this situation, again, is brought about by *S. insidiator*. If this species is ignored, the mesh size can be increased to about 135% of the present, to get over 110% of the present yield of the other three species (Fig. 4).

It was also observed (Murty, MSS) in the cases of *N. japonicus*, *J. carutta* and *L. bindus* that the effort giving maximum yield is greater if the age at first capture is increased. For the management of the resources of these species (ignoring *S. insidiator* for reasons explained above) thus, the following options are available.

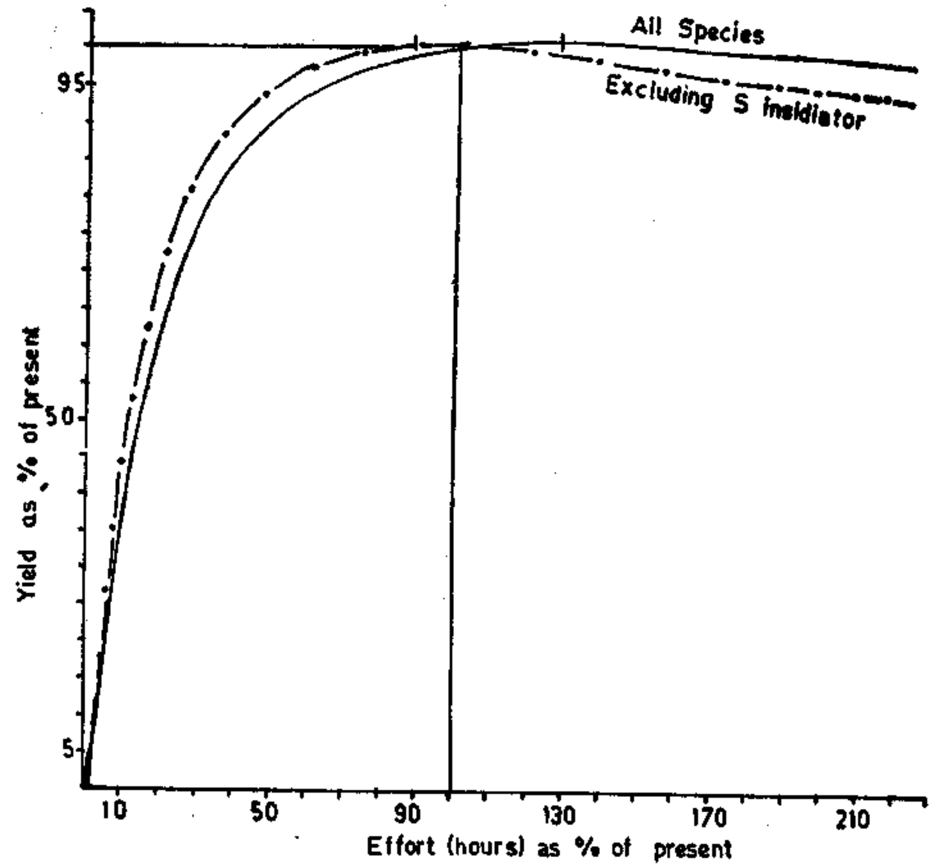

FIG. 2. Yield as percentage of present against effort-also as percentage of present. The smaller vertical lines indicate maximum values and the horizontal and vertical lines the present values.

(*i*) to decrease the present effort by about 6% and to retain the present cod end mesh size;

(ii) to increase the cod end mesh size about 20 mm and to retain the present effort, or

(iii) to increase both cod end mesh size and effort, Of these, the second one appears to be better because, while giving sustained yields, this measure will also ensure adequate recruitment.

Discussion

Among the available methods of estimating natural mortality rate of exploited populations because of lack of knowledge of effective effort in respect of a particular species and, because it is also known that any attempt to relate multispecies effort to Z of a particular species may, not only result in unrealistic estimates but in certain cases negative values also (Ricker, 1975; Pauly, 1982). Though the

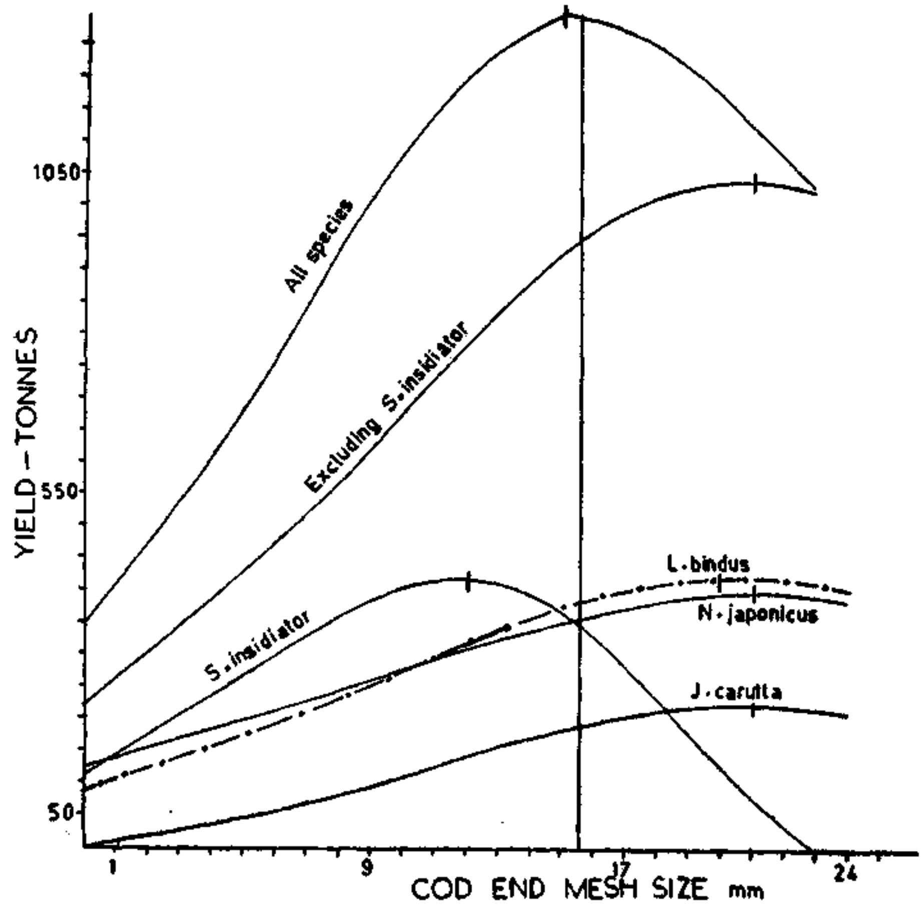

Fig. 3. Yield as a function of cod end mesh size with the present effort unchanged. The smaller vertical lines indicate MSY and bigger vertical line the present cod end mesh size.

the one in which the changes in total mortality are related to changes in fishing effort using the equation Z=M+qf (Beverton and Holt, 1957) gives an accurate estimate in addition to giving an estimate of catchability coefficient. This was not possible in the present work equation of Pauly (1980 b) helps in estimating a reasonably reliable value of M, the value of the other constant in the above equation — the q — has to be estimated through some other method. Pauly (1980 c) states that the method of obtaining this as a ratio of fishing mortality rate of a particular species and effort (even a multispecies one), 'can now be used as a routine method, since it is easier to estimate M than to estimate q'. Although it may appear that the q value thus obtained cannot be regarded as realistic for the same reason as pointed out above, it is believed that in multispecies assessments, this approach, which takes into account the catchabilities of all species, can be followed with reasonable justification because :

(*a*) 'each unit of fishing gear will generate a certain amount of mortality in each species in the fishery (defined as the 'catchability' q) (Munro, 1983).

(*b*) estimate of M and hence of F for each species can be obtained without taking the multispecies effort into account and

(*c*) values of *q* of different species can be derived using the same effort value.

It must be accepted, however, that this is all that can be done under the prevailing situation and there is need to develop methods to obtain more reliable estimates of M and q in tropical multispecies fisheries.

The reliability of the estimated values of Yw/R and recruitment in the present work (*vide supra*) can be questioned on two counts :

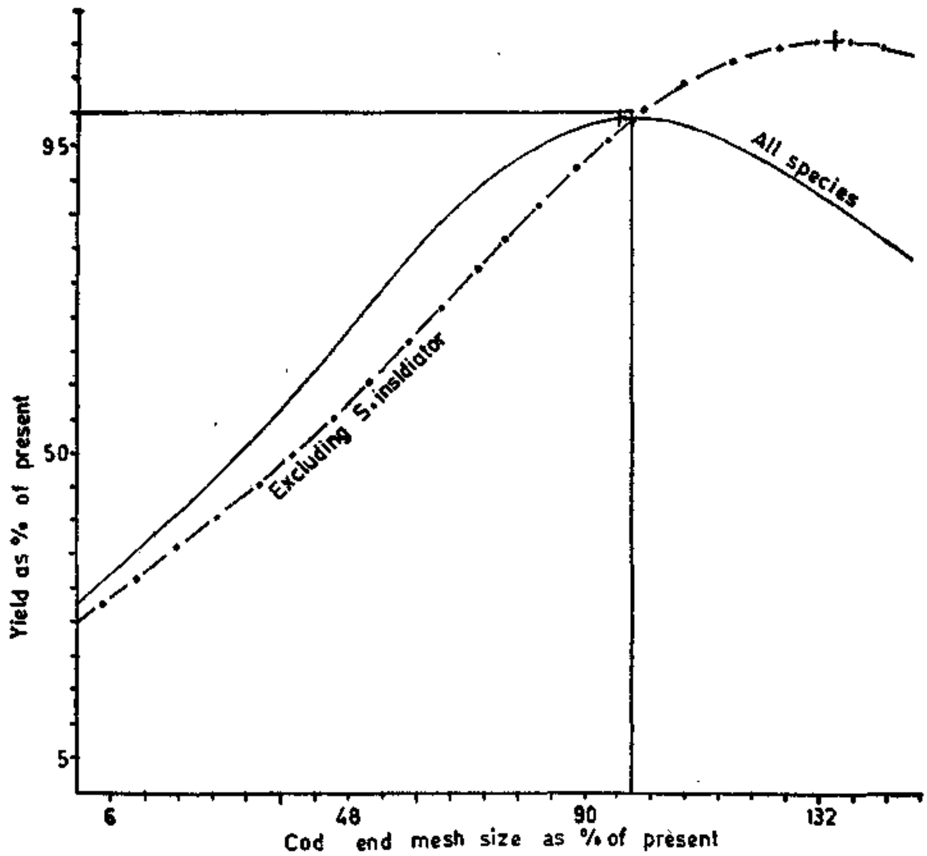

FIG. 4. Yield as percentage of present against cod and mesh size — also as percent of present. The horizontal and vertical lines indicate the present values.

The Yw/R was estimated following Beverton-Holt yield equation which assumes growth in weight with length to be isometric, whereas the situation in three of the four species considered, is not so (in *L. bindus*, however, the 'b' value in length-weight relationship is *not* significantly different from 3) and therefore the estimated values of Yw/R and hence R cannot be taken as exact.

In answer to this, it may be stated that while the value of W∞ taken is exact (*vide supra*), only for a part of the computation of Yw R, the exponent value of length-weight relationship (*b*) was, perforce, taken as 3. Even the method of Jones (1957) which is supposed to take into account the exact value of 'b' and hence give accurate values of Yw/R, does not do so because in the available tables of incomplete Beta function such as those of Wilimovsky and Wicklund (1963), the differences between successive entries are large and linear interpolation is not accurate (Clark, 1978) and hence, it is not possible to use the exact value of b. Therefore, it appears that the use of Beverton-Holt yield equation, under the assumption of isometric growth, is the only alternative (however disagreeable it may be) if one cannot calculate yield using a computer. Further since the important objective of the present study is to examine whether any regulatory measure in respect of effort or mesh size is necessary, it is believed that the method followed gives the desired results. It may be mentioned in this connection, that Clark (1978) has clearly shown that both the methods of calculating Yw R (original as well as the modified versions of Beverton-Holt model) will produce the same regulatory recommendation.

One of the prerequisites in estimation of Yw/R by Beverton-Holt method and R by the equation B÷B/R is the requirement of steady state condition which is difficult to verify and which is 'patently false' (Murphy, 1982). However, Murphy (1982) states that 'Nevertheless, even if recognised to be in error the methods to provide useful first estimates and insights into what is taking place'. Further, since the species considered here, like majority of tropical marine fishes, are short-lived and the fishable life-spans are still shorter (Table 2), it is believed that there is justification (Pauly, 1982) in making estimates as above.

According to Jones (1976), the selection factors for fish tend to range from about 2 to 6 and once the selection factor is determined for a given species and a particular cod end mesh size, it can be used to calculate L_c for a given mesh size or *vice versa*. From the Gulf of Thailand, the selection factor was estimated as 3.2 for both *N. japonicus* and *J. carutta* (Isarankura, 1966 ; Jones, 1976) with the help of a trawl net having a cod end mesh size of 40 mm. In the present work, since selection experiments were not conducted, the L_c values were estimated following Pauly (1984) and from these values (Table 2) and the cod end mesh size at Kakinada, the selection factors of the above two species were calculated as 7.7 and 8.3 respectively (3.7 in *L. bindus* and 5.1 in *S. insidiator*) which are not only beyond the range given by Jones (1976) but are also much greater than the values for these species estimated from Gulf of Thailand. If the selection factor of 3.2 is taken for *N. japonicus* and *J. carutta*, the L_c values are estimable at 50 mm from Kakinada whereas the data show that the lengths at recruitment (L_r) of these two species were 50 and 70 mm respectively and an L_c of 50 mm (50% retention length) cannot be regarded as realistic. Since the S.F. values of these two species from Kakinada are not comparable to those obtained from Gulf of Thailand, the validity of the estimated values of L_c in the present work may become questionable in view of the smaller cod end mesh size, though all possible care was taken to obtain adequate data and the most recent and acceptable method was followed to estimate L_c. It may be stated that the present situation has arisen probably because of prawn-biassed trawling which is restricted to areas 'supposed' to be rich in prawns and where smaller individuals of *N. japonicus* and *J. carutta* are probably not available to be retained in the gear.

The combined curve of yield of the four species against effort (Fig. 1) indicates that the effort can be increased substantially to get maximum yield without any fear of adversely affecting the stocks, though in respect of three species (*N. japonicus*, *J. carutta* and *L. bindus*) together (Fig. 1), the effort can only be slightly less than the present one to enable getting sustainable yield. This contradicting situation has come about because the yield of *S. insidiator* increases with increased effort without reaching a maximum (Fig. 1). The estimated values of L_c in all the four species are smaller than the lengths at first maturity (Table 2), which means that the fish are prevented from spawning at least once before they are caught in large numbers. In *S. insidiator*, the present cod end mesh size is much greater than the one that gives maximum yield (Fig. 3). In the light of what has been stated above, increased mesh size may not effect the stock of this species adversely though it may result in decrease in yield. Since the largest size of this species is itself small, decrease in mesh size may result in increased yield brought about by the yield of still smaller fish which are not of considerable value to the industry. In regard to the other three species, the present mesh size will not only result in decreased yield but is likely to result in recruitment over-fishing of these three species ; the latter is true in the case of *S. insidiator* also. There is therefore, need to increase the present mesh

TABLE 2. *Estimated values of different parameters in the four species.* (All lengths in mm, weight in g, ages in years, K-per year and mortality rates on annual basis)

Parameters	*N. japonicus*	*J. carutta*	*L. bindus*	*S. insidiator*
L_∞	.. 339.0	333.3	158.4	123.0
*W_∞	.. 389.7	529.0	54.7	28.0
K	.. 0.52	0.44	0.58	1.20
t_o	.. —0.16	—0.0002	—0.024	—0.01
Z	.. 2.7	5.1	4.4	7.2
M	.. 1.1	1.0	1.5	2.6
F	.. 1.6	4.1	2.9	4.6
L_r	.. 50	70	17	27
L_c	.. 120	130	57	80
L_m	.. 125	155	80	90
L_{max}	.. 305	255	142	117
t_r	.. 0.15	0.54	0.17	0.20
t_c	.. 0.68	1.12	0.75	0.87
t_m	.. 0.72	1.42	1.19	1.09
t_{max}	.. 4.26	3.29	3.89	2.51
$(t_{max}-t_c)$	.. 3.58	2.17	3.14	1.64

* Calculated from length-weight relationship and L_∞.

size to 20 mm (Fig. 3) to get sustained yield though it may result in some loss of *S. insidiator* for the fishery. In this connection, one can argue that increase in numerical strength of this species in the sea brought about by increase in mesh size can result in greater competition for food particularly in earlier stages (since most tropical fishes spawn almost round the year) and thus can cause depletion of the preferred species in the long run (Gulland, 1982). It is also possible that the increased numbers of *S. insidiator* thus available in the sea (at least some) may be consumed by predators inhabiting the same area. It may, however, be stated that management of multispecies resources requires a knowledge of possible interactions between species and attempts at understanding them are wanting in India. Though it is recognised that interspecies interactions do occur, it is not clear whether they exert such an influence on the stocks that ignoring them would lead to erroneous results (Larkin, 1982).

Though the present study did not take all the species in the fishery into account, it is believed that the results of the same can be taken to indicate how the other demersal species in the region *might* respond to exploitation because, since the four species considered have widely differing maximum lengths (Table 2) which are comparable to a majority of the other demersal species in the region, it is perhaps reasonable to assume (at least until information on all species becomes available) that the growth and mortality rates of the other species in the fishing ground are also comparable to those of the species considered.

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