Effects of Changes in Fishing Effort on Yield of Kuwait's Commercial Fish Stocks

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An assessment of Kuwait's commercial fish stocks: hamoor (*Epinephelus tauvina*), zobaidy (*Pampus argenteus*), nakroor (*Pomadasys argenteus*) and sheiry (*Lethrinus nebulosus*), was conducted using length-frequency data, mean growth and mortality estimates obtained during 1981~1988. The length-cohort analysis indicated that increases in fishing effort would not lead to long-term gains in yield of the stocks at the current estimate of natural mortality rate [M]. At high M which was assumed arbitrarily, some benefit in yield could be obtained, especially for hamoor and sheiry. At low M, the yield of all stocks decreased with increased fishing effort. Increases in fishing effort resulted in significant decline in spawning stock size for all the stocks. Yield-per-recruit analysis indicated that, under low M assumption, a higher yield can be obtained for zobaidy and nakroor by reducing fishing effort. At moderate M, decreases in fishing effort brought gains in yield per recruit of the stocks, but it was not substantial compared with the present level of M. At high M, most of the stocks reached the maximum yield-per-recruit. Overall, increased fishing effort either will not be associated with large long-term gains in yield or, in some stocks, might cause a decline from the present level.

Introduction

Commercial fishing has been conducted for valuable fish species since the early 1960s in Kuwait's waters using traditional fishing gears such as fish traps for hamoor (*Epinephelus tauvina*) and hamra (*Lutjanus coccineus*), and gillnets of various materials and mesh sizes for zobaidy (*Pampus argenteus*) and suboor (*Hilsa ilisha*). Biological investigations on the important fish species of Kuwait and data collection on catch and effort by different fisheries were initiated in 1980 to assess the stocks of fish and to formulate coastwide management strategies. The earlier assessments of the stocks, based on the 1981~1987 fishing season data, were carried out using production models (Samuel et al., 1987; Mathews et al., 1989) and the dynamic pool yield-per-recruit models (Baddar and Morgan, 1984; Morgan, 1985). Also a stock evaluation for the major species in the fish trap fishery was carried out by Lee and Al-Baz (1989) and Lee and Baddar (1989).

The general consensus of the earlier studies on Kuwait's commercial fish stocks was that, under present conditions and practices, most of the species were reached at a maximum sustainable yield level. A higher yield could be expected by simultaneously increasing the age at first capture and fishing mortality, but concern was expressed regarding the danger of spawning stock depletion (Lee and Al-Baz, 1989).

Length-composition analysis is a useful technique

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to assess the effects of changes in both fishing effort and mesh size on fish stocks that cannot be aged (Jones, 1984). Although the fish species, except zobaidy, in this study have been easily aged by annual marks in saggital otoliths (Williams, 1986), age-cohort analysis could not be applied because only short-time series of data on age composition were available. Length-cohort analysis, therefore, was used to predict long-term effects of changes in fishing effort on yield and relative spawning stock size. It also identifies the recommended exploitation level for the stocks by the application of the Thompson and Bell's (1934) yield-per-recruit model.

Methods and Data

Analytic Method

Length-cohort analysis is based on the method of Jones (1984). The basic equation is:

$$N_i = (N_{i+1}\ X_{Li} + C_{i,i+1})\ X_L \qquad (1)$$

where N_i and N_{i+1} represent numbers at sea with lengths L_i and L_{i+1} *cm*, respectively, and $C_{i,i+1}$ is the catch in number in the range between L_i and L_{i+1} *cm*, X_L is given by:

$$X_L = [(L_\infty - L_i)/(L_\infty - L_{i+1})]^{M/2k} \qquad (2)$$

where L_∞ and K are the asymptotic length and growth coefficient from the von Bertalanffy growth function, respectively, and M is the instantaneous rate of natural mortality.

Given X_L from Equation 2 and $C_{i,i+1}$ using Equation 1, numbers in year-class attaining each length group can be obtained, and it is possible to estimate fishing mortality rate for each length class based on the numbers. Fishing mortality rate estimated for each length class was then used to determine the long-term effects on yield according to the procedures described by Jones (1984). Relative spawning stock size per recruit was also estimated with 10,000 individuals, at mean size at first maturity in the same manner as in the length-cohort analysis. In analyzing effects of changes in fishing effort, the main assumption is that changes in fishing effort (percentage changes) will cause the same effect on fishing mortality rate at each length class. Percentage changes in fishing mortality give a range arbitrarily, from 40% decrease to 100% increase, based on the value which averaged each year's fishing mortality from 1981 through 1988.

Maximum yield-per-recruit curve was produced with 10,000 individuals for ages from age at first capture to age at which most fish leave the fishery using the method of Thompson and Bell (1934), assuming that mortality coefficients between ages remain constant. A weight-growth equation was used to estimate mean weight for each age:

$$W_t = W_\infty(1 - e^{-K(t-t_0)})^3 \qquad (3)$$

where W_t = mean weight (*g*) at age t; W_∞ = asymptotic weight, which is obtained from a length-weight conversion using the value of L_∞; t_0 = age at zero weight. The mean weight obtained for each age was used to convert the yield in number by age to the yield in weight.

Length-composition Data

The following fish stocks were selected from length-cohort analysis: hamoor (*Epinephelus tauvina*), zobaidy (*Pampus argenteus*), nakroor (*Pomadasys argenteus*) and sheiry (*Lethrinus nebulosus*). Other species were not included because length-frequency compositions and biological parameters were insufficient or not available to apply length-cohort analysis.

The length-frequency distributions of the four species have been obtained monthly since 1981 from fish measurements at Kuwait's fish markets. Fig. 1 shows the time series of data during 1981~1988 on the combined length composition for each species.

For length-cohort analysis, it is required that the input length composition should be representative of the fish population with constant recruitment. Jones (1984) suggested that a useful approximation to represent length compositions of fish populations could be obtained by using the average length composition over a period of as many years as possible. As approximations, therefore, the length compositions shown in Fig. 1 were used in the analysis, assuming that recruitments of the stocks were constant between years.

Growth Data

Length-at-age compositions were available for the stock of hamoor for 1981~1988 and sheiry for 1984~1985 (Fig. 2). The von Bertalanffy growth function of hamoor and sheiry was provided for each year by various authors (Baddar and Morgan, 1984; Baddar, 1987; Lee and Baddar, 1989). Even though the values of asymptotic length (L_{∞}) and growth coefficient (K) obtained from the best fit of the von Bertalanffy growth function are not necessarily required for length-composition analysis (Jones, 1984, 1990), growth parameters of hamoor and sheiry were selected from estimates using recent data on length-at-age compositions (Table 1). These were considered to be a representative of

Table 1. Growth parameters of the von Bertalanffy growth function and length (L)-weight (W) relationship of four fish species

Species	L_{∞} (*cm*)	K	t_0	$W=aL^b$ a	$W=aL^b$ b	W_{∞} (*g*)
Hamoor[1]	99.06	0.15	-0.34	0.014[2]	3.02[2]	15,640
Zobaidy	33.10[3]	0.50[3]	-	0.049[4]	3.04[4]	2,000
Nakroor[5]	94.00	0.18	-	0.015	2.97	10,960
Sheiry[6]	62.73	0.19	-0.36	0.017	3.00	4,450

— Not estimated
— Data sources:
[1] Lee and Baddar (1989);
[2] Samuel et al. (1987);
[3] Mean values from Morgan (1985) and Al-Baz and Bawazeer (in press);
[4] Morgan (1985);
[5] Bawazeer and Al-Baz (pers. comm.);
[6] Baddar (1987)

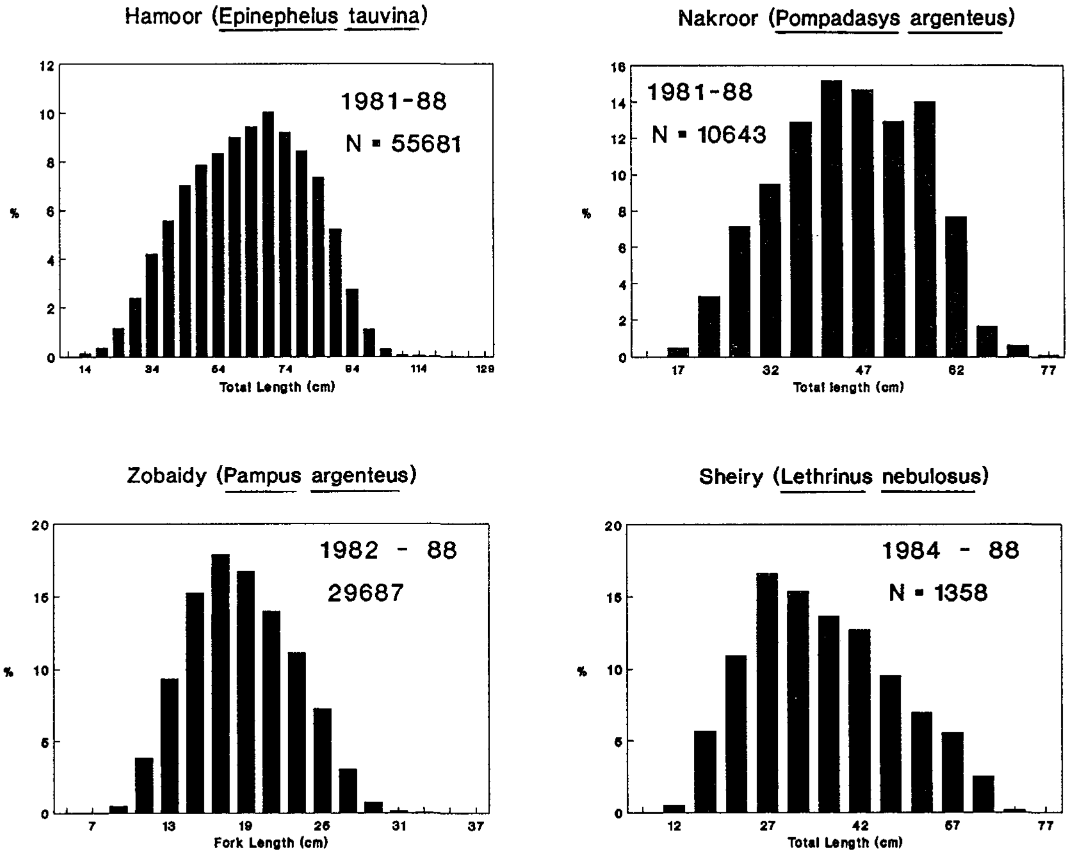

Fig. 1. Length compositions of four fish species combined for 1981~1988.

the population growth. In cases where age data were not available such as for zobaidy and nakroor (Table 1), values from the literatures were used to obtain appropriate growth estimates. These values also were regarded as average estimates. Length composition for length classes greater than L_∞ were not included in the length-cohort analysis because these length classes could not be fitted to Equation 2, but the proportion to the total was small or negligible (Fig. 1).

M/K and F/Z

The predicted natural mortality rate (M) from statistical methods and the growth coefficient (K) from the age and length data (Table 1) were used to obtain the ratio of M/K. The value of M for each fish species was estimated by applying the following equations:

$$ln\ [(M+3K)/M]/K=0.38\ t_{max} \quad (4)$$

(Alverson and Carney, 1975), and

$$\log_{10} M=-0.0066-0.279\ \log_{10} L_\infty+0.6543\ \log_{10} K+0.4634\ \log_{10} T \quad (5)$$

(Pauly, 1980)

where t_{max} = maximum age in the samples; T = mean water temperature. A value of 22.8℃, which was observed as an annual mean bottom temperature from Kuwait's waters in 1982, was used. Because the M values obtained for each fish species were from indirect methods, two different values of M were selected to determine if a different choice of M would affect the analysis of long-term effects of changes in fishing effort.

Total mortality rate (Z) was obtained from catch curves on both length- and age-frequency distributions (Figs. 1 and 2) for each species by regressing the natural logarithm of the number of fish (*ln* N) against the respective age. The length-frequency compositions were grouped into appropriate length intervals; then the mid length of each size group was converted to relative age using the values of L_∞ and K (Table 1), setting $t_o=0$, of the von Bertalanffy growth equation (Pauly, 1983). A linear regression was fitted to the frequencies of relative ages on the right hand side of the catch curve from the peak age in the age-frequency data. The slope of the regression was an estimate of Z. A simple method (Srinath, 1986) was also used to estimate Z, based upon the length-frequency data with size at first capture and growth parameters of the von Bertalanffy formula.

$$Z/K=-ln(1-q_{t,t+dt})/ln(L_\infty-l_t)/(L_\infty-l_{t,t+dt}) \quad (6)$$

where, $q_{t,t+dt}=C_{t,t+dt}/\sum_{\geq t} C_t$

$C_{t,t+dt}$ = numbers caught in the interval (t, t+dt); $\sum_{\geq t} C_t$ = cumulative catch from the largest length group to size at first capture (l_c); l_t and $l_{t,t+dt}$ = lengths at ages t and t+dt.

The estimated Z was assumed to be constant regardless of age groups, and fishing mortality rate (F) was obtained from F=Z−M. The Z and F values were used to estimate the ratio of F/Z requi-

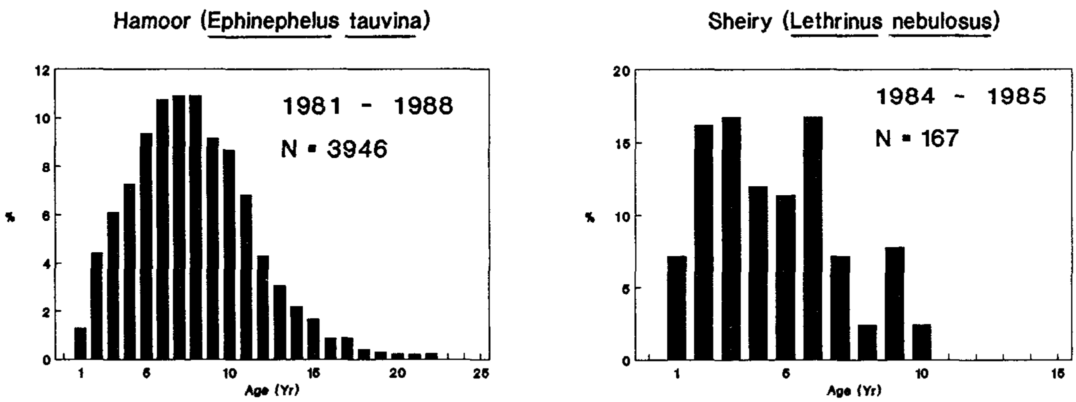

Fig. 2. Age compositions of hamoor (*Epinephelus tauvina*) combined for 1981~1988 and sheiry (*Lethrinus nebulosus*) for 1984~1985.

red for the largest length group.

Results

Changes in Yield and Spawning Stock Size

The analysis of the hamoor stock indicated that an increase in fishing effort would bring some advantage in yield at the most reasonable value of M (Fig. 3a). If the value of M was lower (M=0.10), then yield decreased upon increase in fishing effort. For high M (0.20), an increase in fishing effort would result in large increase in yield. When fishing effort was reduced from the current level, however, the yield decreased for all values of M. Relative spawning stock size with 10,000 individuals at age at first capture declined as fishing effort increased for all values of M (Fig. 3a).

For zobaidy and nakroor (Figs. 3b and 3c), there was a negligible increase in yield with increase in fishing effort up to a certain level for moderate values of M (0.75 and 0.40, respectively) and then a decrease with further increase in fishing effort. For low values of M (0.50 and 0.20), the yields declined at higher fishing effort. The yield of zobaidy remained at more or less the same levels when fishing effort was reduced approximately 20% and then decreased with further reduction in fishing effort when M is low (0.50). But, yield of nakroor increased with a decrease in fishing effort at low M (0.20). For high values of M (1.0 and 0.60), the magnitudes of gains in yield were increased with increased fishing effort, but not proportional to the increase in fishing effort. Relative spawning stock size of zobaidy and nakroor decreased as fishing effort increased for all values of M (Figs. 3b and

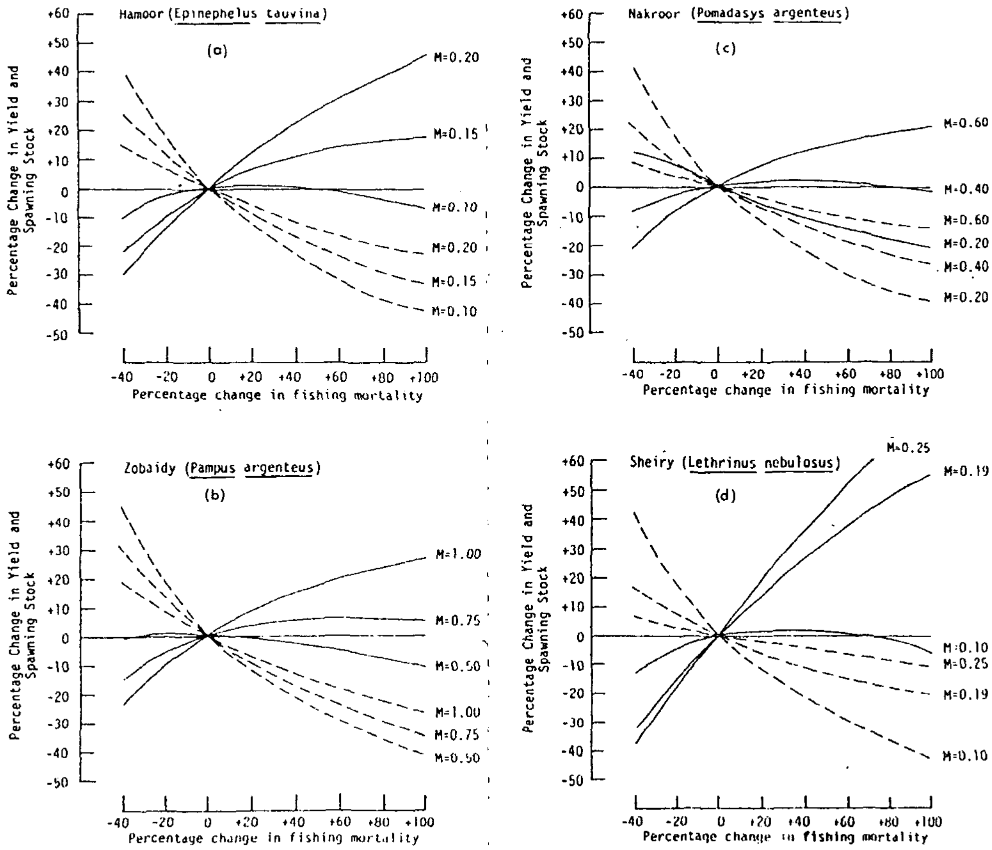

Fig. 3. Effect of fishing effort on yield and spawning stock at three different natural mortality rates (M). Solid lines represent changes in yield and broken lines represent changes in spawning stock.

3c).

For the stock of sheiry (Fig. 3d), increased yield could be expected at increased fishing effort when the values of M were 0.19 (moderate estimate) or 0.25 (a high value). When M was low (M=0.10), the yield appeared at more or less the same level with increased fishing effort. Relative spawning stock slowly decreased despite intensification of fishing effort for the moderate and high values of M (0.19 and 0.25), but it decreased rapidly with increased fishing effort for low M (0.10) (Fig. 3d).

Yield-per-Recruit Analysis

Yield-per-recruit analysis was done for the four stocks incorporating the mean total mortality coefficients (Z) and the three different values of M in Table 2. Under low M assumption, all the stocks appeared to be over-exploited, especially zobaidy and nakroor, while decreased fishing mortality would lead to substantial increase in yield per recruit of zobaidy and nakroor (Figs. 4b and 4c). For the moderate values of M derived from Equations 4 and 5, it is necessary to reduce fishing effort for all fish species to achieve maximum yield-per-recruit. For high M, the stocks studied appeared to be moderately exploited. It is suggested, in general, from yield-per-recruit analysis that under low M assumption, a higher yield can be obtained by reducing fishing. When M was moderate, decrease in fishing effort brought gains in yield-per-recruit of the stocks but it was not substantial compared with the presently estimated level of yield per recruit. For high M, most of stocks reached the maximum yield-per-recruit.

Discussion

An application of production models to commercial fish species of Kuwait is hampered because of

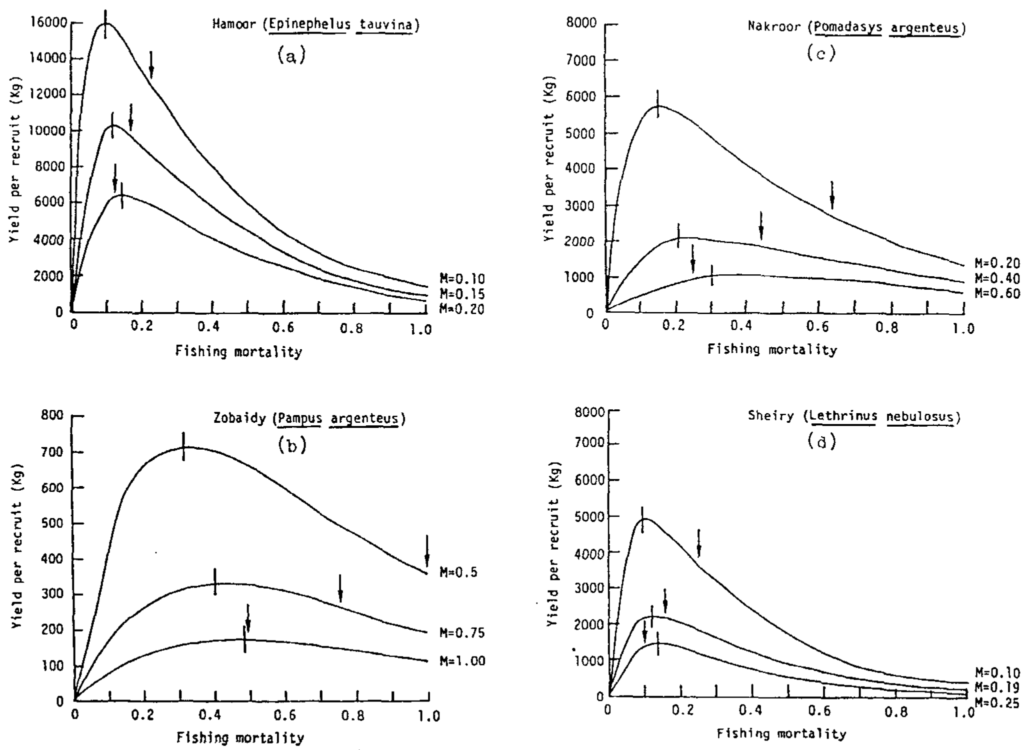

Fig. 4. Yield per recruit for the age at first capture of four fish stocks. Arrows indicate the levels of mean fishing mortality rate during 1981~1988 and bars represent the levels of the maximum yield-per-recruit in each value of natural mortality rate.

Table 2. Mortality rates, mean size at first maturity and age at first capture of four fish species

Species	Total mortality rate (Z)				Natural mortality rate (M)					Mean size at first maturity (cm)	Age at first capture (yr)
	Age composition	length-converted	Srinath method	Value used	Values estimated		Values used				
					Eq.(4)	Eq.(5)	Low	Moderate	High		
Hamoor	0.33	NA	NA	0.33	0.15[1]	0.34	0.10	0.15	0.20	61[1]	3.4[1]
Zobaidy	ND	1.51	1.50	1.50	0.55[2]	1.03[3]	0.50	0.75[4]	1.00	20[5]	1.0[2]
Nakroor	ND	0.87	0.81	0.84	ND	0.40	0.20	0.40	0.60	30[6]	2.1[6]
Sheiry	0.37	0.34	0.23*	0.35	0.19	0.45	0.10	0.19	0.25	36[7]	2.7[7]

* Not used in calculating average value of Z due to low value compared with other two.
[1] Lee and Baddar (1989); [2] Al-Baz and Bawazeer (in press); [3] Morgan (1985);
[4] Assumed; [5] Gopalan (1969); [6] Bawazeer and Al-Baz (pers. comm.); [7] Lee and Al-Baz (1989);
NA: Not applicable ND: No data available

the wide variations of relative stock abundance as well as the narrow range of fishing effort data (Samuel et al., 1987). As Gulland (1989) pointed out that changes in catch per unit of effort do not seem to reflect changes in stock abundance, yield-per-recruit dynamic pool model could be one of the most suitable method to establish management guidelines in Kuwait.

Yearly length-compositions for each species did not show much difference in its proportion by length-class to the total number of samples and also range of distribution during the study periods (Fig. 1). This seemed to imply that recruitments of the populations were constant between years. As for population parameters estimated and selected to apply length-cohort analysis, values of M for hamoor and sheiry estimated by Equation 5 were higher than the Z values. These values of M were not taken into account in analysing. Estimates of M for zobaidy obtained from Equations 4 and 5 were quite different. Therefore, moderate values of M were chosen for this species, which were 50% of the estimate of Z. In general, it is known very difficult to obtaine true M for any marine living resource. In cohort analyses, the effect of error in M on stock size estimates can build up to quite high levels (Sims, 1984). The choices of M will affect changes of a fish stock and stock-recruitment relationships when fishing intensity changes significantly or M fluctuates (Hilden, 1988). Two different values with the predicted M were used in this study.

At low and moderate M, yield-per-recruit analysis indicated that reducing fishing effort to an appropriate level would bring the maximum yield-per-recruit for all the stocks. At high M, the length-cohort analysis showed increased yield but the yield-per-recruit model did not indicate much, if any, increase in yield at increased fishing effort.

Zobaidy was assessed using a length-related method by Morgan (1985), who believed that this stock was not heavily exploited and that an increase in yield per recruit might be expected if fishing effort was increased. Another stock evaluation of zobaidy (Al-Baz and Bawazeer, in press) using the Beverton and Holt yield-per-recruit model suggested that the best management strategy was either to increase age at first capture or to decrease fishing mortality. It was clear from the results of both length-cohort and yield-per-recruit analyses in this study that increased fishing effort under low and moderate M would not bring further gains in yield for the zobaidy stock, but at high M, some increase in yield was expected.

The nakroor stock was evaluated for the first time in this study, based on preliminary growth and population parameters from the length-based method. More precise analyses of zobaidy and nakroor could be carried out when age compositions are available.

Stock assessments in this study were based only on the effects of changes in fishing effort. Effects of changes in mesh size were not considered due to lack of data on mesh selectivity (fish traps for hamoor, nakroor and sheiry, and gillnets for zobaidy). Assessments from length-cohort analysis and yield-per-recruit model appeared more or less not to be agreed each other (e.g., hamoor) or showed much different results (e.g., sheiry). Length-cohort analysis included data on length frequency of fish smaller than size at first capture in the length composition, but calculation of yield-per-recruit was made for ages from age at first capture to maximum age in age-frequency distribution. Therefore, the results obtained from length-cohort analysis might be affected from the small size frequency data less than size at first capture. The length-cohort analysis applied in this study is an approximation because of the absence of data on the effects of changes in mesh size on mesh selectivity. It seems reasonable to conclude, however, that increased fishing effort either will not be associated with large long-term gains in yield or, in some stocks, might cause a decline from present levels.

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