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Assessment of Fish Stocks Exploited by Fish Traps in the Arabian Gulf Area

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Abstract

The yield isopleth diagrams of six commercially important fish species of the Arabian Gulf fish trap fishery showed that the stocks of hamoor *(Epinephelus tauvina)*, hamrah *(Lutjanus coccineus)*, sheim *(Acanthopagrus latus)*, sheiry *(Lethrinus nebulosus)* and fersh *(Plectorhynchus pictus)* are exploited at an appropriate age at first capture and fishing effort, while newaiby *(Otolithes argenteus)* should be fished at a reduced effort level. However, the mean sizes at first maturity of all the fish species were greater than the present sizes at first capture. The multispecies analysis for this fishery suggested that the maximum yield per recruit will be obtained by an increase in fish trap mesh size (presently 4.0 cm in bar size) to about 6.0-7.0 cm. Alternatively, the present yield per recruit can be maintained by reducing fishing effort by 20%, keeping the present mesh size.

Introduction

A fish trap (locally known as *gargoor*) fishery, well-suited for various bottom fish living in coral areas, is operated from traditional wooden-hulled boats (called dhows) powered with a diesel engine ranging from 150 to 450 hp in the Arabian Gulf. Annual landings from the fishery in Kuwait varied from 1,700 t to 4,500 t during 1980-1986, and provided an average of 50% of Kuwait's total fin fish landings (Lee, in press).

Stock assessment of commercially important fish species from the fishery has been carried out on a species by species basis (Baddar and Morgan 1984; Samuel and Morgan 1984; Mathews and Samuel 1985; Morgan 1985; Baddar 1987; Samuel et al. 1987; Baddar, in press). Biological studies have also been made on most exploited fish stocks in Kuwait (Hussain and Abdullah 1977; Abu Hakima et al. 1982), regardless of the gear used.

Single-species stock analyses do not consider the effects of the different levels of exploitation upon each fish species exploited at a given level of effort by the fishery. Although a preliminary multispecies assessment of the stock assemblage comprising the *gargoor* fishery in Kuwait was carried out by Morgan (1984), a comprehensive multispecies analysis for this fishery has not yet been carried out.

The objective of this study is to assess the major fish stocks of the fish trap fishery in Kuwait and to identify the most appropriate management strategy for the fishery through a multispecies yield-per-recruit analysis.

Materials and Methods

The following six fish stocks were chosen for single-species and multispecies stock assessments of the fish trap fishery: hamoor *(Epinephelus tauvina),* hamrah *(Lutjanus coccineus),* newaiby *(Otolithes argenteus),* sheim *(Acanthopagrus latus),* sheiry *(Lethrinus nebulosus)* and fersh *(Plectorhynchus pictus).* Other fish species were not included because of insufficient information and were minor components of landings.

Length composition

Fish have been measured as total length to the nearest cm under at Kuwait fish markets since 1980. Representative samples of 500-1,000 fish for hamoor and hamrah, and samples of 100-200 fish for the other four fish species, were collected on a monthly basis. The length-frequency distribution combined for 1980-1986 was used to estimate size at recruitment and size at first capture for each fish species.

Growth parameters and length-weight relationship

Growth analysis of individual fish species related to this study was performed by various authors (Baddar and Morgan 1984; Samuel and Morgan 1984; Mathews and Samuel 1985; Morgan 1985; Baddar 1987; Samuel and Mathews 1987; Baddar, in press). These publications were consulted for selection of the most appropriate estimates of growth parameters and length-weight relationships as well as maximum age (t_{max}) observed in samples. The parameters selected were assumed to be representative of each population growth patterns without variation between sexes, areas and years during the study period (Table 1).

Table 1. Growth parameters of six commercially important fish species.

Species	L_∞ (cm)	K	t_0	$W = aL^b$		W_∞ (g)	Data source
				a	b		
Hammur *Epinephelus tauvina*	99.1	0.15	-0.34	0.014*	3.0*	15,640	Lee and Baddar (unpublished) *Samuel et al. (1987)
Hamrah *Lutjanus coccineus*	68.9	0.36	-0.76	0.019	2.9	3,960	Mathews and Samuel (1985)
Newaiby *Otolithes argenteus*	69.6	0.50	-0.53	0.011	3.0	3,470	Mathews and Samuel (1985)
Sheim *Acanthopagrus latus*	43.0	0.20	-0.12	0.029**	2.8**	870	Morgan (1985) **Samuel and Mathews (1987)
Sheiry *Lethrinus nebulosus*	62.7	0.19	-0.36	0.017	3.0	4,450	Baddar (1987)
Fersh *Plectorhynchus pictus*	74.5	0.21	-0.68	0.014	3.0	5,160	Baddar (in press)

Selection curve and mean selection length

Gear selectivity studies on the fish traps have not been carried out in the Arabian Gulf. Hence, an alternative method was used to estimate both size at recruitment (L_r) and size at first capture (L_c).

The smallest length class from the length-frequency distribution for each fish species was assumed to be an estimate of L_r and was converted to the corresponding age in conjunction with the growth equation. For estimating L_c, the length-frequency distribution was grouped into appropriate length intervals; the mid-length of each size group was converted to the relative age using the growth equation. A linear regression was fitted to the right hand limb of the catch curve; $l_n(N/\Delta t)$ was plotted against relative age and this regression was projected straight backward. The selection patterns (Pauly et al. 1984) were obtained from the ratio between the antilogarithms of the observed and expected values of $l_n(N/\Delta t)$. The mean selection size was then extracted from the 50% point of the selection curve.

Size at maturity

Approximately 30-50 fish of each species were sampled monthly for 1982-1987 along with information such as the fishing area and fishing gear used, and were measured for total length (cm), sex and gonadal phase (Laevastu 1965). Each maturity stage of the fish sampled was observed in different length groups with equal class interval. In estimating the mean size at first maturity for each fish species, fish identified from stage I (virgin) to IV (developed) were regarded as immature and fish above stage V (gravid) as mature. The Spearman-Karber formula (Udupe 1986) was used to estimate size at first maturity based on the sexual maturity of females during the spawning season.

Mortality

The instantaneous rates of total mortality (Z) and natural mortality (M) for each fish species were derived from the publications mentioned in the section on growth parameters. Where no information was available for M of the fish stocks, an indirect method was used for predicting this value.

$$t_{max} \times 0.38 = (1/K) \cdot \ln((M + 3K)/M) \qquad \ldots 1)$$

(Alverson and Carney 1975)

where t_{max} is maximum age in samples and K is the von Bertalanffy growth parameter.

The instantaneous fishing mortality rate (F) was obtained by F = Z - M. Total annual mortality rate (A) was calculated from the expression A = 1 - S, where annual survival rate (S) was estimated by the exponential function, S = exp (-Z).

Single-species yield-per-recruit analysis

The Beverton and Holt yield equation (1957) was applied to data on age at recruitment (t_r), age at first capture (t_c), M, F and asymptotic weight (W_∞) of fish obtained as described above. The yield-per-recruit patterns at different values of F and t_c were analyzed to obtain the highest yield. The relative spawning stock-per-recruit was estimated by the method of Thompson and Bell (1934), based on size at first maturity, to determine the effects of changes in fishing effort on spawning stock.

Multispecies yield-per-recruit analysis

A multispecies Beverton and Holt model developed by Mennes (1984) was used to assess the fish trap fishery based on the single-species population parameters for the six fish species studied. The combined yield per recruit (Y/R_{Tot}) for the multispecies stocks can be obtained from the following equation, assuming no upper limit to life span and $t_o = 0$:

$$Y/R_{Tot} = \sum_{i} \left(W_{f,i} F_{h,i} W_{\infty,i} \exp\left[-M_i(\hat{t}_{c,i} - t_{r,i})\right] \left\{ \sum_{n=0}^{3} \frac{U_n \exp(-n K_i \hat{t}_{c,i})}{F_i + M_i + n K_i} \right\} \right) \quad \text{... 2)}$$

where $W_{f,i}$ is the weighting factor of fish species i (as a relative index of recruitment), $F_{h,i}$ is the hypothetical fishing mortality of fish species i, $W_{\infty,i}$ is the asymptotic weight of fish species i in growth curve, $\hat{t}_{c,i}$ is the hypothetical relative age at first capture of fish species i, $t_{r,i}$ is the relative age at first recruitment of fish species i, K_i is the growth coefficient of fish species i, and U_n takes the values of +1, -3, +3 and -1 for n equal to 0, 1, 2 and 3, respectively.

$F_{h,i}$ was defined as corresponding to a certain level of relative fishing effort (E_r), assuming that a linear relation exists between fishing effort and fishing mortality. The value of 100, as the actual relative fishing effort, was assigned to the fishing effort for 1985-1986 because most information on population parameters for this study was derived during this period. Thus:

$$F_{h,i} = F_i \cdot E_r/100 \quad \text{... 3)}$$

Under condition that selection factors are constant for all fish species in question, the hypothetical length of fish species i ($L_{h,i}$) at which 50% of fish are retained was defined as:

$$L_{h,i} = L_{c,i} \times M_s/40 \quad \text{... 4)}$$

where $L_{c,i}$ is the size at first capture (cm) of fish species i, M_s is the hypothetical mesh size and 40 is the actual mesh size in mm (bar size) of the trap used in the fish trap fishery.

From the value of $L_{h,i}$, $\hat{t}_{c,i}$ was calculated, putting $t_{o,i} = 0$ by:

$$\hat{t}_{c,i} = -K_i^{-1} \cdot \ln (1 - L_{n,i} \cdot L_{\infty,i}^{-1}) + t_{o,i} \qquad \ldots 5)$$

where if $L_{h,i} > L_{\infty,i}$, then $L_{h,i}$ was assumed to equal $L_{\infty,i}$.

In applying various levels of recruitment for each fish species to one overall yield isopleth diagram for all species combined, a relative index of recruitment (R_h) was included in the model. This index was regarded as a weighting factor (W_f) while summing the yield per recruit for all the fish species. This value was calculated by multiplying the average number of fish caught per unit of effort by the instantaneous rate of total mortality for each fish species:

$$R_{h,i} = Z_i \cdot (CPUE)_i \qquad \ldots 6)$$

where $R_{h,i}$ is the relative index of recruitment of fish species i, Z_i is the total mortality rate of fish species i, and $(CPUE)_i$ is the catch per unit of effort of fish species i. The CPUE was calculated using the 1985-1986 catch and effort data.

Results

Selection curve and mean selection length

A linear regression of right hand limb of the length-converted catch curve for each fish species of hamrah, newaiby, sheim, sheiry and fersh was constructed by plotting the value of $l_n(N/\Delta t)$ against the relative age converted from the midlength of each size class (Fig. 1a). The selection curve constructed and the mean selection size (50% point of the selection pattern) are shown in Fig. 1b. The mean selection size was converted to the corresponding age using the growth equations in Table 1, setting t_o = zero. Size at recruitment (as the smallest length class in Fig. 1a) and mean selection size for the six fish species are summarized in Table 2. The mean selection size was regarded as the size at first capture for each fish species.

Mean size at first maturity

Fig. 2 shows the ratios of mature and immature female fish in different length classes for hamrah, newaiby, sheim and fersh. Using these data, the mean size at first maturity (l_m) was estimated with 95% confidence limit for each fish species (Table 2). The minimum size at first maturity for sheiry was used because the data were insufficient to provide an estimate of mean size at maturity. The mean size at first maturity for all the fish species was greater than the size at first capture, whereas the estimates of newaiby showed an identical value.

Table 2. Estimates of sizes at recruitment and first capture and mean size at first maturity of six fish species.

Species	Size at recruitment Length (L_r, cm)	Size at recruitment Age (t_r, year)	Size at first capture Length (L_c, cm)	Size at first capture Age (t_c, year)	Mean size at first maturity Length (l_m, cm)	Mean size at first maturity Age (year)	Mean size at first maturity 95% confidence limit of l_m (cm)
Hamoor[1] *Epinephelus tauvina*	11	0.8	39.8	3.4	61.1	5.0-6.0	57.4-65.0
Hamrah *Lutjanus coccineus*	11	0.5	23.9	1.2	47.3	2.5-3.0	44.8-50.0
Newaiby *Otolithes argenteus*	7	0.2	22.4	0.8	22.1	0.7-0.8	20.0-24.3
Sheim *Acanthopagrus latus*	10	1.8	14.9	2.1	23.7	3.5-4.0	22.8-24.6
Sheiry *Lethrinus nebulosus*	16	1.5	25.3	2.7	35.0[2]	4.0-4.5	-
Fersh *Plectorhynchus pictus*	11	0.7	29.1	2.3	53.6	5.0-7.0	49.5-58.1

[1] Lee and Baddar (unpublished).
[2] Minimum size at first maturity.

Mortality analysis (Z, M and F)

Table 3 shows the values of Z, M and F for the six fish species together with the total annual mortality rates. The stocks of hamoor, hamrah, sheiry and fersh showed values of total annual mortality rate less than 50%. For the stocks of sheim and newaiby, the values were higher at 62% and 80%, respectively.

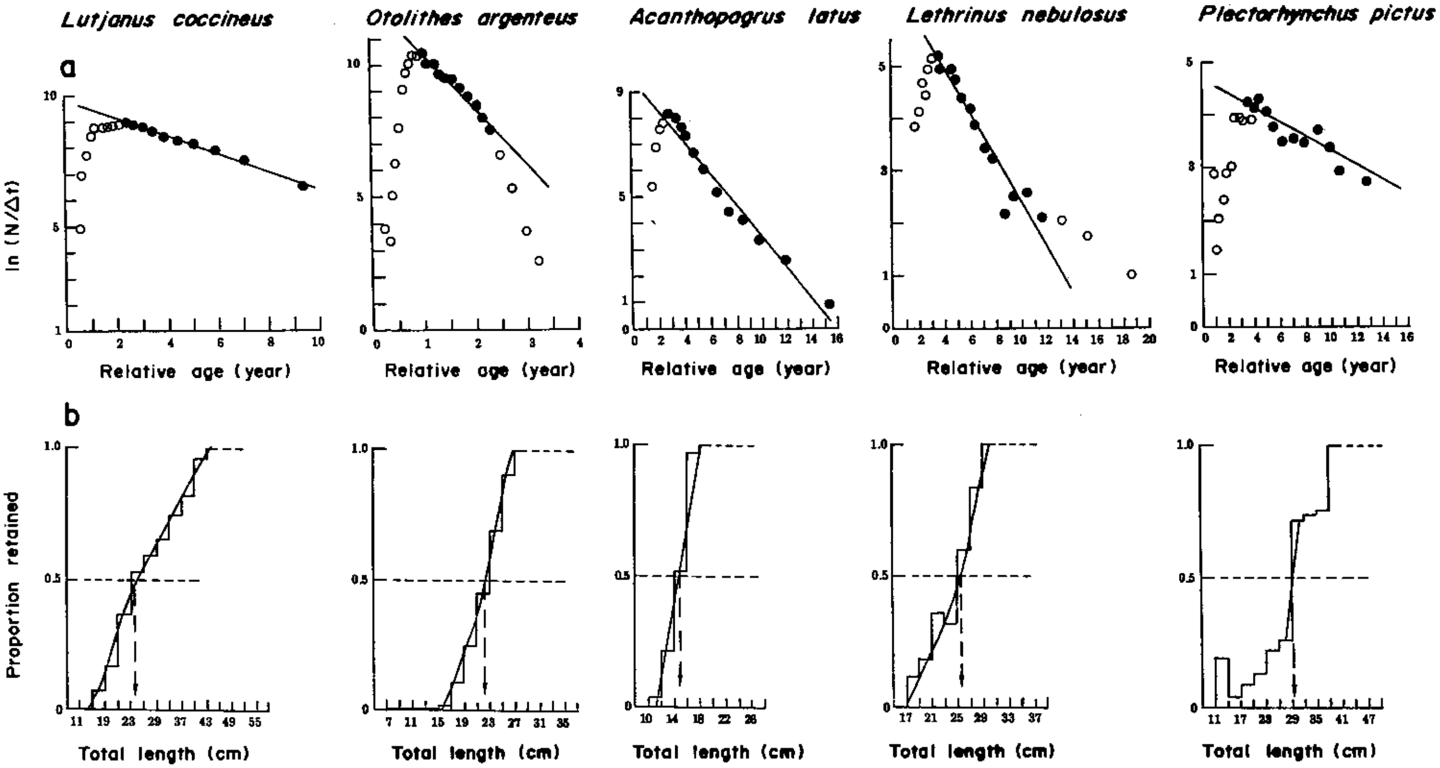

Fig. 1. Construction of selection patterns from length-converted catch curve for estimating mean selection size for each fish species. Fig. 1a: straight descending right hand limb of the catch curve. Fig. 1b: selection curve fitted to proportions between the observed value and the expected value obtained from the linear regression.

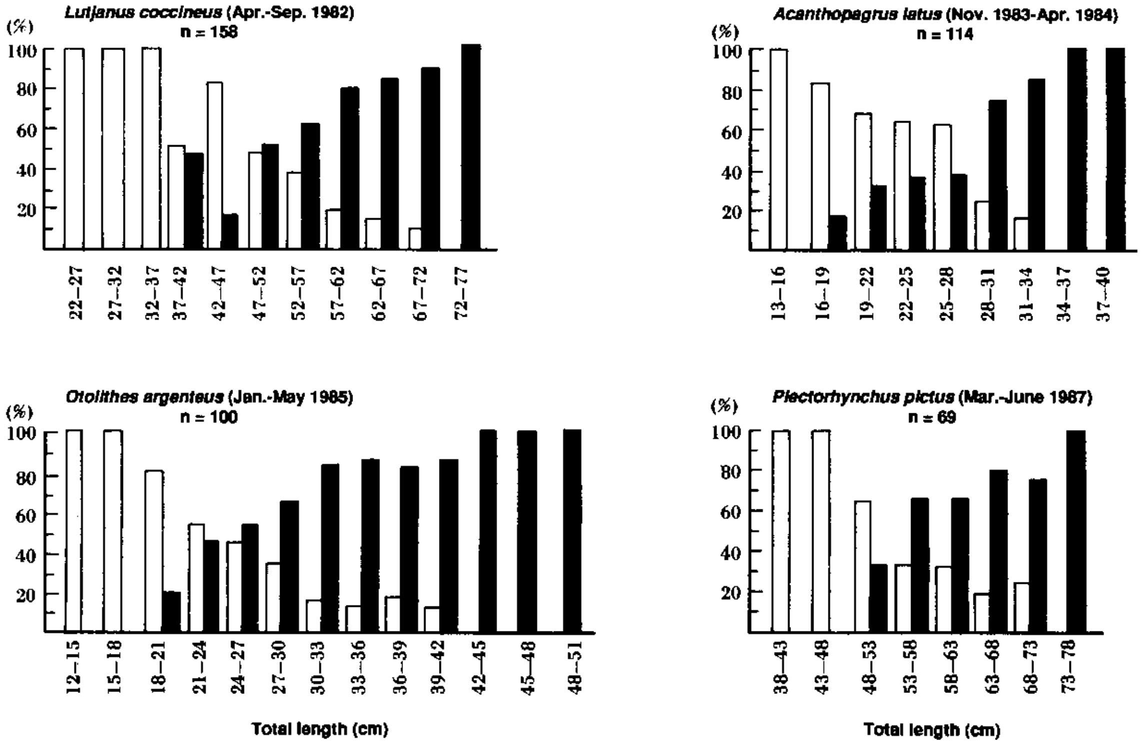

Fig. 2. Proportion of mature female fish (shaded area) and immature female fish (open area) in total number of female samples for each fish species.

The natural mortality rates for the stocks of hamrah and sheiry were estimated according to equation (1) using the value of K in Table 1, with t_{max} = 45 and 20 (which were obtained in samples) for hamrah and sheiry, respectively (Table 3). The estimate of hamrah (M = 0.002) was very low compared to the value of Z of this fish species. Accordingly, a value of M = 0.09 (50% of Z) was assumed arbitrarily, taking account of the exploitation ratio (F/Z) of the hamoor stock, because the fish trap fishery mainly targets these two fish stocks distributed in the coral areas.

Table 3. Mortality rates and weighting factor of six fish stocks.

Species	Total mortality rate (Z)	Annual mortality rate (A, %)	Natural mortality rate (M)	Fishing mortality rate (F)	Weighting factor (Wf)	Data source
Hamoor *Epinephelus tauvina*	0.34*	28.8	0.15*	0.19	216	*Lee and Baddar (unpublished)
Hamrah *Lutjanus coccineus*	0.18	16.5	0.09**	0.09	170	Mathews and Samuel (1985) **Assumed to be 50% of Z
Newaiby *Otolithes argenteus*	1.60	79.8	0.53	1.07	370	Mathews and Samuel (1985)
Sheim *Acanthopagrus latus*	0.97	62.1	0.53	0.44	456	Morgan (1985)
Sheiry *Lethrinus nebulosus*	0.37	30.9	0.20***	0.17	50	Baddar (1987) ***Estimate in this study
Ferah *Plectorhynchus pictus*	0.20	18.1	0.10	0.10	47	Baddar (in press)

Single-species yield-per-recruit analysis

The population parameters (K, t_r, t_c, W_∞ and M) listed in Tables 1, 2 and 3 were used for applying the Beverton and Holt yield-per-recruit model. The instantaneous rates of natural mortality and fishing mortality were assumed to be constant for ages greater than age at recruitment. The mean selection age was regarded as age at first capture. The relative spawning stock per recruit for each fish species was estimated with an initial population of 1,000 individuals over all the ages from the age at first maturity to the age at which most fish leave the fishery.

Fig. 3 shows changes in the yield per recruit in weight at various levels of fishing mortality and the present age at first capture, as well

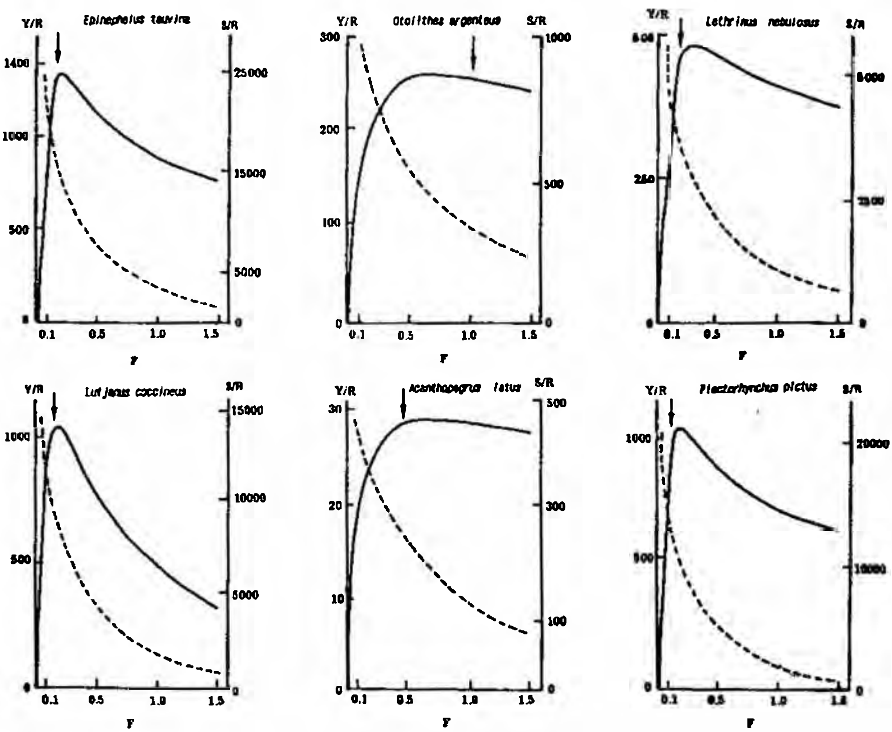

Fig. 3. Yield per recruit (solid line) and the relative size of spawning stock per recruit (broken line) in weight for each fish species. Arrow indicates the present level of fishing mortality rate (the diagram of *Epinephelus tauvina* from Lee and Baddar, unpublished).

as patterns of decrease of the relative spawning stock per recruit with fishing intensity. The optimum yield per recruit was attained at the present fishing mortality level for the stocks of hamoor, hamrah, sheim, sheiry and fersh. The maximum point on the curve of newaiby lies well to the left of the current level of fishing mortality. This might not reflect the real status exploited only by the fish trap fishery because newaiby is one of highly segmented fish resources in Kuwait, being taken by trawl, gillnet and hadrah (a kind of setnet) as well as the fish trap fishery. It is clear, however, that a bigger yield can be expected by decreasing fishing effort from all sectors of fishery for this fish stock. Similar situation arises from the sheim stock which is exploited by other fishing gear such as hadrah and gillnet, but the status of exploitation appeared to be an appropriate level. When fishing intensifies the spawning stocks of all the studied fish species decrease at a much faster rate than their yields. This implies that any increase in fishing effort would be likely to cause a spawning stock depletion.

The yield isopleth diagram for each fish species was constructed as a function of t_c and F (Fig. 4). The broken lines in each diagram represent the ranges which are able to produce optimum yield per recruit. The current level of exploitation for hamoor, hamrah, sheim, sheiry and fersh stocks is in the line of the optimum yield, which is exploited at a suitable age at entry to the fishery at the current level of fishing mortality. It is obvious, however, that the newaiby stock is overfished at the current fishing effort and the present size at entry to the fishery.

In all the fish stocks, it appears that there is a wide range of combinations of t_c and F which would attain a higher yield. Nevertheless, no increase in fishing effort would lead to a significant increase in the yield at the present size of t_c for any stocks. When both t_c and F increase simultaneously, higher yields would result but it would lead to a decrease in spawning stock per recruit. The ages at first capture of all fish species studied at the present level of F were smaller than the ages at first maturity (Table 2).

A useful management policy would be to take fish older and larger than the current t_c, holding F at its current level of each species.

Multispecies yield-per-recruit analysis

Results of the multispecies analysis of the fish trap fishery based on the data used for single-species assessments (Tables 1, 2, 3) are shown in Fig. 5. The broken line indicates the level which is able to generate maximum yield from this fishery at different fishing effort levels. The current position (effort = 100 and mesh size = 40 mm) lies below the broken line. Therefore, the yield can be increased by increasing mesh size to about 60-70 mm at the current fishing level. Alternatively, the present yield per recruit may be maintained while fishing effort is reduced by about 20% and mesh size is kept unchanged. This strategy would keep the yield per recruit constant but would reduce cost of fishing.

Fig. 6 illustrates changes in percentage species composition of the yield per recruit obtained from various levels of relative fishing effort when size at first maturity for each fish species was assumed to be equal to size at first capture. As fishing effort increases, the proportion of hamoor is nearly constant, but hamrah and fersh show a decreasing trend. The proportions of sheiry, sheim and newaiby show an increasing trend. Newaiby and sheim provide only a low

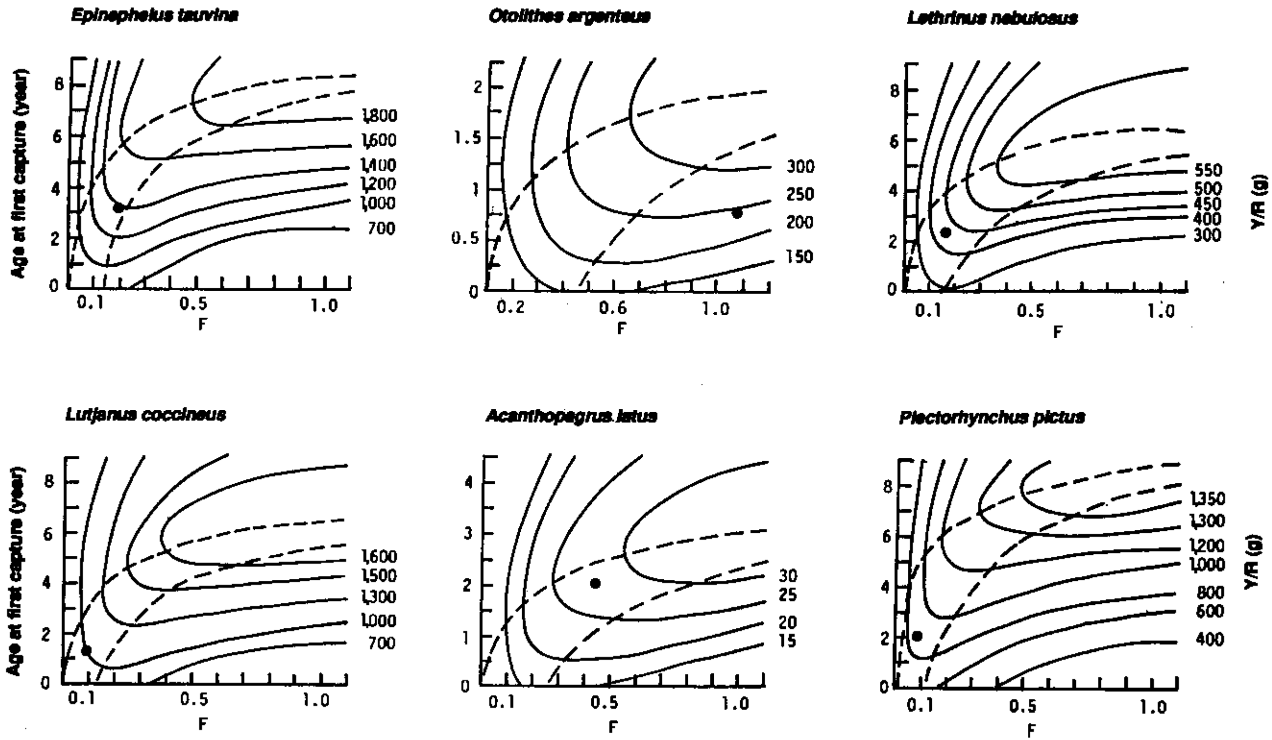

Fig. 4. Yield isopleth diagram in terms of size at first capture and fishing mortality for six fish species. Closed circle denotes the present position of exploitation and dotted lines represent the range which can obtain the optimal yield (the diagram of *Epinephelus tauvina* from Lee and Baddar, unpublished).

proportion of the total compared to the other three fish species. Overall, there is little variation in the species mix.

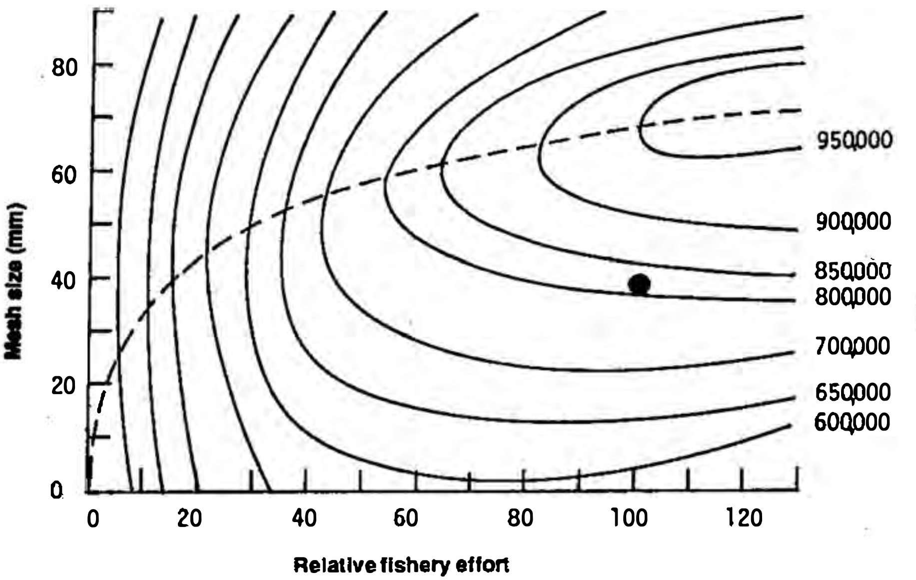

Fig. 5. Yield isopleth diagram for multispecies stock assessment of the fish trap fishery. (Actual fishery effort = 100 and actual mesh size = 40 mm). Dotted line shows the level which is able to produce a higher yield from this fishery.

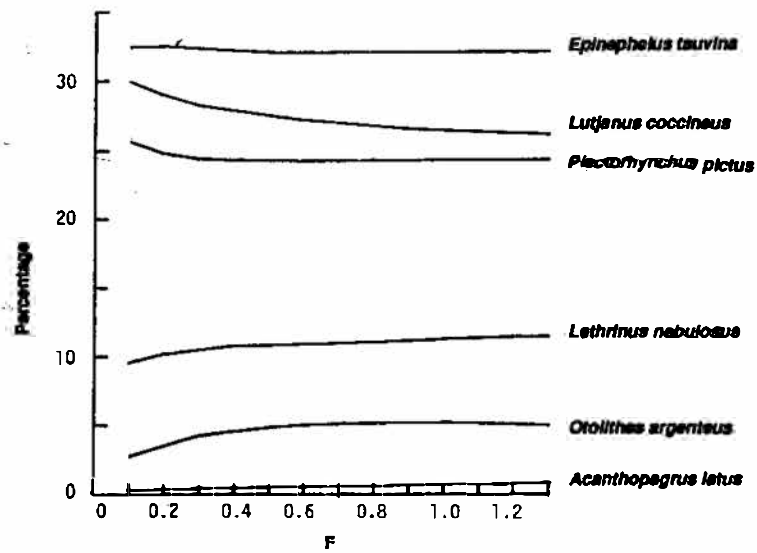

Fig. 6. Changes in percentage species composition of yield per recruit for six fish species at increasing levels of F.

Discussion

Earlier yield-per-recruit analyses indicated that the hamoor stock should be managed with a combination of high fishing effort and large size at first capture (Baddar and Morgan 1984) and that this stock appears to be exploited at a right level (Mathews and Samuel 1985). Although a higher yield can be expected by increasing both age at first capture and fishing mortality from the present level in this study, this strategy will cause a significant reduction of spawning stock (Fig. 3).

Previous assessment of the hamrah stock (Mathews and Samuel 1985) suggested that increases in size at entry to the fishery with increases in fishing effort are likely to cause some improvement in the yield. On the other hand, an increase in fishing effort with constant size at entry would cause a modest increase in the yield. This study suggests that it is advisable to increase size at first capture at the current fishing mortality, taking into account the danger of spawning stock depletion.

Samuel and Morgan (1984) suggested that the overall optimum for the newaiby stock would be achieved with increases in both size at first capture and fishing effort. Mathews and Samuel (1985), using more recent data, showed that this stock was very close to optimal exploitation and that increases in fishing effort and small changes in size at entry were unlikely to increase the yield. The present assessment modifies earlier results and shows that this fish stock is already heavily exploited. Thus, either fishing effort should be reduced or size at first capture should be increased. This strategy should be imposed not ony to the fish trap but also to the other fishery, since about two-thirds of the newaiby catch has come from the trawl and gillnet fishery. For more accurate stock assessment of this fish species, interaction study between different fishery sectors is required.

Morgan (1985) indicated that the sheim fishery is producing the maximum yield per recruit at the current size at first capture and fishing mortality, and any changes in the existing situation will most likely result in a reduction in yield per recruit. The result obtained in this study showed that both simultaneous increases in the size at first capture and the fishing effort would give some benefit in the yield per recruit. Sheim is not the main targeted fish stocks in the fish trap fishery, less than 50% of total production of sheim. Hence, stock assessment of sheim should be linked with the other fishery for this fish species. For the stocks of sheiry and fersh, there will be much increase in the yield per recruit as fishing effort intensifies with increase in the size at first capture, but any increase in fishing effort is expected to result in decline in the spawning stock.

It should be pointed out, in general, that the earlier studies on the yield-per-recruit analysis for the above-mentioned fish stocks did not include any estimate of spawning biomass.

According to Morgan (1984) who carried out a preliminary multi-species analysis, the fish trap fishery in Kuwait waters appeared to be only moderately exploited and substantial increases in the yield could be achieved by increasing fishing effort. He reported that when fishing effort increases, hamrah becomes more important and hamoor less important in the catch. This was not in agreement with the current study which showed that optimal strategies were either to increase size at first capture or to reduce fishing efort, while maintaining the present size at first capture (Fig. 5). The proportion of hamoor was constant and high, regardless of different levels of effort, while hamrah showed a decreasing proportion with increasing fishing effort (Fig. 6). This difference in findings might be due to the use of different growth parameters and mortality estimates, especially for hamoor and hamrah.

The multispecies analysis of the fish trap fishery excluded nakroor *(Pomadasys argenteus),* one of the commercially important fish stocks, because essential information on age was unavailable. Nevertheless, the six fish stocks included constitute 71% to 85% of the total annual landings from the fishery in Kuwait for the period 1980-1986. Accordingly, the results obtained from this analysis provide a useful multispecies stock assessment of the fish trap fishery.

The fin fish and shrimp fisheries in Kuwait have been affected by the Gulf conflict. With the outbreak of the conflict, the fishing grounds have become gradually limited to the areas near Kuwait waters. Even within Kuwait waters, the available fishing areas have been reduced in recent years. It was estimated, as a result of this influence, that there was about 10-20% reduction in total fish catch (Mathews, in press). Significant quantities of hamoor and hamrah, which are main target species of the fish trap fishery, were taken from the fishing grounds outside Kuwait waters in 1980 whereas from 1981 onwards, the entire catch was being taken from the areas within Kuwait waters (Samuel et al. 1987). In spite of the above aspects, it was considered that any serious effects on the stock assessments of the fish trap fishery in this study would not be involved, because they are migratory fish species even though very little information is available.

The present study has inevitably involved numerous assumptions due to lack of information on each fish stock. The relationship between Z and fishing effort could not be applied in estimating the value of M for the stocks of hamrah and sheiry, because there was no time series of Z and reliable data on fishing effort were unavailable. An attempt was made to obtain the value of M for both fish species using the expression of Pauly (1980), and the value estimated was 0.61 and 0.42 for hamrah and sheiry respectively, which showed $Z < M$. Problems, in fact, were not met in estimating growth parameters and total mortality from age data and length-based method in Kuwait. A need is evident for better estimates of natural mortality. Other assumptions are that the length and age samples are representative of each population.

An indirect method was used to estimate size at first capture (Fig. 1). It is clear that this estimate totally depends on the slope of the right hand limb; the steeper the slope of the right hand limb, the larger the values of size at first capture. Valid estimates of this size can only come from mesh selectivity study.

Management strategy and suggestions were made for commercially important fish species and for the fish trap fishery. These are based only on information from the Kuwait fraction of research work. The results obtained here can be applied on a Gulf-wide basis, because research data have come from suitable areas throughout the Gulf, except for the eastern part.

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