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FISHING PATTERN AND INTERACTIONS OF FLEET COMPONENTS IN THE *ARGYROPS SPINIFER* (ACTINOPTERYGII: PERCIFORMES: SPARIDAE) FISHERIES OF THE ARABIAN SEA, OMAN

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Background. The influx of foreign fishing vessels in the Arabian Sea, during the mid 1990's, has sparked some conflicts between artisanal and industrial fleets and raised concerns related to the resource management implications of fish stocks in the region. To address the lack of management data on the basic biology and stock assessment for targeted species, the Ministry of Fisheries Wealth in Oman initiated this study with a view to contributing towards the development of a management plan for the sustainable exploitation of the living resources of the sea in this region.

Materials and methods. A database including biological parameters, length-frequency distributions and catches of king soldier bream, *Argyrops spinifer* (Forsskål, 1775), in Oman according to fleet (gear/technique) and region was compiled by monthly sampling in 2001 to 2002. In this study, length cohort and yield per recruit analyses were examined after simulating changes in fishing effort, in length at first capture and introducing a closed season for trawlers.

Results. The results showed that: (i) the status of the stock is healthy, the average fishing mortality rate is moderate (0.1) and acts in general on the adult fraction of the stock. The fishing pattern differs, however, among fleets with some fleet components fishing, in part, for immature king soldier bream. (ii) An increase in total fishing effort would not lead to any long-term substantial increase of the catch (according the uncertainty of M value); however, the spawning stock biomass would decrease significantly. This measure affects negatively fleets that target the larger specimens. (iii) A moderate (±20%) modification of minimum length limit in catches would not affect, substantially, the sustainable yield and the spawning stock biomass. (iv) Any regulation of trawler fishing by closed season (i.e. restricted trawler activities during some seasons) would not have a significant effect on the long-term yield.

Conclusion. The current pattern of exploitation and fishing effort acting on the *A. spinifer* stock are optimal and no changes to global fishing or length at first capture are recommended. Also, with the actual fishing effort of trawlers, no closed season is suggested. However, fleet components whose catches include some juvenile fraction should adopt more selective gear as used by the hand line fishery in the Al-Wusta region.

Keywords: *Argyrops spinifer*, stock assessment, fisheries management Arabian Sea, Oman

INTRODUCTION

The king soldier bream, *Argyrops spinifer* (Forsskål, 1775) is widespread in the Indo-West Pacific, where adults occur mostly between 30–100 m of depth, over a range of bottom types (Randall 1995). *A. spinifer* is a relatively large sparid; it is characterized by a long life span and low growth rate (Ben Meriem et al. 2004, Al-Mamry et al. 2009, Al-Mamry unpublished**). It attains a maximum size of 70 cm total length and age of approximately 25 years (Al-Mamry et al. 2009) and is probably protogynous, undergoing a sex reversal from female to male after a certain age (Grandcourt et al 2004, McIlwain et al. 2006, Al Mamry unpublished**). The species spawns each year between October and December and the size at first maturity is around 37 cm total length (Ben Meriem et al. 2004, Al-Mamry et al. 2009). Sea breams are economically

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** Al-Mamry J.M. 2006. Biology and fisheries management of king soldier bream, *Argyrops spinifer* and spangled emperor, *Lethrinus nebulosus* in the Arabian Sea, Oman. PhD Thesis. University of Wales, Bangor, UK.

important demersal species along the Arabian Sea coast of Oman. Between 1994 and 2003 the landings of all sea breams (including *A. spinifer*) fluctuated between 4000 and 9000 t per year (average of 5000 t per year) (Anonymous 2003). *A. spinifer* is one of the most important species in the demersal Omani fisheries and constitutes one of the most common sparids landed in Oman (around 800 t per year).

The fisheries of *A. spinifer* are located along the Arabian Sea coast of Oman (Sharqia, Al-Wusta and Dhofar regions; Fig. 1). It is exploited in inshore waters throughout its range; artisanal fisheries contribute around 3/4 of the total catch and with the rest of the catch landed by an industrial fishery (trawlers). Exploitation is based on six fleet components; fishing traps and hand lines are used by artisanal fleets in Dhofar and Sharqia regions, while in Al-Wusta region only hand lines are used. The industrial fleet uses exclusively bottom trawling gear. The latter fishery is limited to fishing grounds further than 10 nautical miles from the coast and/or a minimum depth of 50 m. Therefore, the exploitation pattern may differ among fleet components depending on fishing region, gears, and techniques used and could lead to some interactions in the fisheries for this species.

The influx of fishing vessels, especially foreign trawlers from Korea and Taiwan, during the mid 1990's, has generated some conflicts between artisanal and industrial fleets and raised concerns relating to resource management in the Arabian Sea. Confronting this problem, the Ministry of Fisheries Wealth in Oman decided in the late 1990's to limit the access of trawlers to the fishery and the number of trawlers operating in the Arabian Sea had been substantially reduced (from 60 to 5 trawlers) by the beginning of 2000. At the same time, the Ministry initiated a research project in order to carry out, for the first time, a stock assessment of the seven main species in the demersal fisheries in Oman with *A. spinifer* being one of those species.

The aim of this study is to provide the first detailed assessment of the fisheries for *A. spinifer* in the Arabian Sea by: (1) assessing the exploitation status of the species by the different fisheries in the region and (2) providing the necessary information required for stock assessment of the species and for management of its fisheries through the use of length cohort analysis (LCA) based on the demographic structure of the *A. spinifer* catch and biological parameters for the species.

MATERIALS AND METHODS

Definition of fleet components. Six fleet components are identified in the *A. spinifer* fishery in Oman: the first group was formed by small artisanal boats of around 5.5–7.5 m (18–24 feet) in length. This group is separated into five components: for the Sharqia and Dhofar regions (Fig. 1), the fleets were separated into 2 components, hand lines and fishing traps respectively, whilst only hand lines are used in the Al-Wusta region. The second is constituted by large industrial fishing boats (>40 m) that use demersal fishing gear (trawl). These different fleet components were abbreviated as follows:

- Industrial trawlers: TRAWL
- Artisanal boats in the Sharqia region using fishing traps: SHAFT.
- Artisanal boats in the Sharqia region using hand lines: SHAHL.
- Artisanal boats in the Dhofar region using fishing traps: DHOFT.
- Artisanal boats in the Dhofar region using hand lines: DHOHL.
- Artisanal boats in the Al-Wusta region using hand lines: WUSHL.

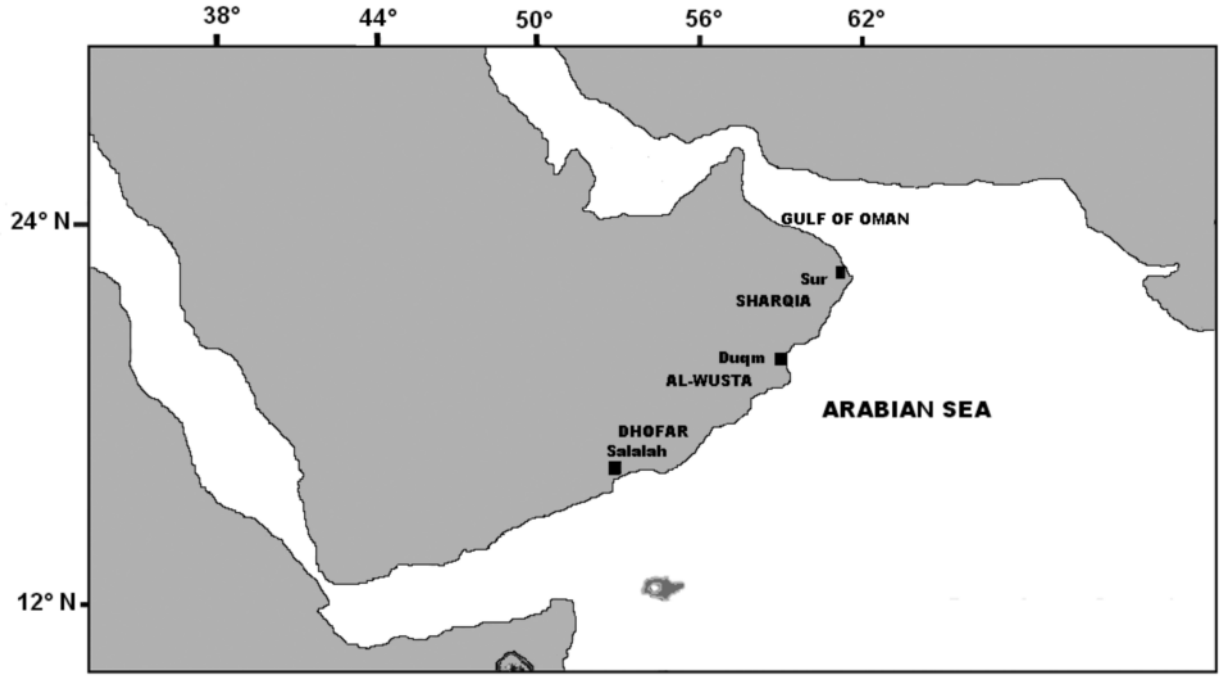

Fig. 1. Map of *Argyrops spinifer* fishing regions and sampling sites in Oman

The relative contributions to the total catch of these 6 fleet components are 27%, 23%, 16%, 13%, 11%, and 10%, respectively.

Catch data and length frequency distributions. It is important to stress that catch is synonymous to landing because there are no discards for this species. The catch per fishing gear data was obtained from the Omani Fisheries Statistics Department for the period of 2001–2002 (Ministry of Fisheries Wealth, Anonymous 2002, 2003). These data were collected for each type of fishing gear separately, and from all defined fishing boats operating in either the artisanal fishery or the industrial fishery in the Arabian Sea. For each of the traditional fishing gears (fleets), a number of boats (5–15 boats) were sampled every month by data collectors. For the industrial fleets, the catch was recorded on board. In each trawl boat, one or two observers monitored the trawling and recorded the catch (landing) and fishing effort.

The length frequencies of *A. spinifer* were obtained from 6 fleet components (Table 1) that contribute significantly to the exploitation of the species, based on length samples collected during the demersal fish project conducted by the Marine Sciences and Fisheries Center over a two year period between 2001 and 2002. Random samples were taken monthly for each fishing gear/technique utilized. The fish length sampling program covered the three regions which contribute to the traditional *A. spinifer* fishery: Sharqia, Al-Wusta, and Dhofar (Fig. 1); the total length measured to the nearest cm for around 200 randomly sampled fish per month, per site, for each gear identified above. To estimate the demographic structures of the whole catches, length frequency samples were extrapolated to the total landing per fleet and fishing region (Table 1). Also, length frequencies (pooled from monthly data) for each quarter of the year were prepared separately for trawlers in order to simulate the impact of a closed season on this fleet.

Biological parameters. Parameter estimates used in the length cohort analysis are taken from the biological studies on *A. spinifer* in Omani waters; including von-Bertalanffy growth curves (L_∞, K, and t_0), length-weight relations, length at sexual maturity (L_{50}), natural mortality (M), and selectivity factor (SF). The parameters estimates used in the present study are:

- L_∞ (asymptotic length) = 64 cm (Al-Mamry et al. 2009);
- K (growth coefficient) = 0.14 (Al-Mamry et al. 2009);
- SF: 3.5 (Anonymous unpublished*); This value is used for artisanal fishing gear in Al-Wusta and Dhofar;
- L_{50} = 37 cm (Ben Meriem et al. 2002a);
- Length-weight relation: $W = 7.03 \times 10^{-8} \times L^{2.61}$ (Ben Meriem et al. 2002b);
- M = 0.38 (this study).

Natural mortality. The value obtained in this study should be considered as a preliminary estimation. Natural mortality was obtained from the equation:
$\log(M) = -0.0066 - 0.279\log(L_\infty) + 0.6543\log(K) + 0.4634\log(T)$
(Pauly 1980) with T indicating the mean temperature of the water (25.56°C, Hydrographic Survey in Oman waters, unpublished data). The equation gives a value of 0.38 for M; this value was adopted in the present stock assessment. Also, a sensitivity analyses to this parameter was carried out, especially in case of overestimation of M, on LCA results. For this analysis a value of M = 0.2 is tested.

Length cohort analysis (LCA). Sparre and Venema (1992) and Jones (1981) provide a clear description of the LCA methods used in this study. This analysis supposes that the stock is in equilibrium state: i.e., with constant recruitment, F and M vectors. To attenuate the effect of the eventual variation of the exploitation pattern and/or the recruitment intensity, an average of the size distributions obtained over a period of two years (2001 and 2002) were therefore used.

Length cohort analysis was applied to estimate the fishing mortality and abundance vectors by length class. The length (L+), from which calculations of fishing mortalities are initiated, has been determined according to the recommendations of Pereiro and Pallares (1984) who recommended using a "group+" around 70% of L_∞ (in this study L+ is 45 cm). However, since in this study the numbers of fish larger than 70% of L_∞ have a significant importance in the catch length distributions, L+ was set to 54 cm in the present analysis. It is generally considered, that the value of F_t fixed for the group+ must be in continuity (i.e., a similar value) with the fishing mortalities of the previous size groups. The catches in number are estimated by fleet, and results are also presented for the global balance and by fleet component.

Exploitation pattern. For each fish length, the fishing mortality fraction of the fleet j could be estimated according to the contribution of this fleet to the total catch. Considering C_i and F_i be the total catch of *A. spinifer* and fishing mortality of the length class i, $C_{i,j}$ and $F_{i,j}$ are the contribution of the fleet j respectively. The estimation of the fishing mortality per fleet component is based on the following equations.

$$F_{i,j} / F_i = C_{i,j} / C_i$$

$$F_{\mathrm{i}} = \sum_{j=1}^{n} F_{\mathrm{i},j} \quad C_{\mathrm{i}} = \sum_{j=1}^{n} C_{\mathrm{i},j}$$

Where n is the number of fishing fleet components participating in the exploitation of the *A. spinifer* fishery in Omani waters.

Yield-per-recruit model. This analysis, using the Jones (1974) model of yield per recruit, investigated the impact of modifications of the fishing effort, minimum (first) catch size and fish closing season regulations for trawlers on the yield per recruit. It should be noted that, any modification of effort, first length in catches or period of closing season has both an immediate impact (immediately) and long-term effects (sustainable) which occur after the new equilibrium conditions of the stock have been established. For this analysis, the ANALEN (analyses data by size class) software program was used. This software was elaborated upon by Chevallier and Laurec (1990). The stock biomass is calculated from the length-weight relation and the abundance (N) per length class. The spawning stock biomass is derived by applying L_{50} to the number of survivors.

* Anonymous: Gears and techniques in Oman artisanal fishery

Table 1

Catch (number of individuals) of *Aryrops spinifer* per fishing fleet in the Arabian Sea n 2001–2002

Length class [cm]	Fishing fleet						
	DHOFT	DHOHL	TRAWL	WUSHL	SHAHL	SHAFT	Total
9	0	0	57	0	0	0	57
10	0	0	86	0	0	0	86
11	0	0	175	0	0	0	175
12	0	0	284	0	0	0	284
13	51	0	296	0	0	0	347
14	202	0	243	0	0	0	446
15	202	96	156	0	0	0	454
16	405	288	476	0	0	0	1169
17	455	669	1187	0	0	0	2311
18	607	772	1100	0	0	32	2511
19	455	2574	1587	0	0	97	4714
20	1730	3260	2109	0	0	289	7389
21	2201	2052	1557	0	171	217	6196
22	3765	1619	3138	0	513	362	9397
23	5480	1526	4234	0	1539	362	13141
24	5136	1329	3688	0	2936	426	13510
25	5991	1242	3049	45	4303	1306	15936
26	6823	2522	4745	112	9893	2459	26555
27	7904	4473	4717	195	11026	3936	32249
28	7136	7132	5779	409	10066	6736	37259
29	7927	11124	6324	552	7949	11702	45595
30	6762	13576	6940	729	6843	13226	48076
31	5355	15962	5055	867	6478	18675	52391
32	4686	12230	3776	1059	6302	21880	49934
33	3269	9226	6194	552	5884	14903	40028
34	2698	6659	6662	596	8278	9738	34631
35	2441	3323	8208	851	8836	8994	32654
36	2020	1960	11160	989	7592	9194	32915
37	2747	1321	7861	948	6720	7454	27050
38	2756	1346	7238	914	6875	8105	27234
39	2651	373	5258	1397	4927	8092	22697
40	3248	139	6766	1554	4650	7016	23373
41	4096	127	6819	1755	3917	4862	21575
42	2631	70	7746	1652	2874	4362	19336
43	23013	394	6452	1562	3057	2426	15903
44	2551	737	5284	1869	2333	3060	15835
45	2880	1729	4448	2181	2608	2144	15991
46	4849	1211	3633	1971	1856	1641	15161
47	2619	987	4247	2072	1569	1409	12903
48	2530	875	4184	2056	1231	1356	12232
49	1056	986	4129	2542	1066	1500	11279
50	638	521	3674	3091	743	1841	10508
51	582	824	4300	2861	883	1360	10810
52	422	1013	3948	2989	575	2165	11112
53	261	663	3423	3011	571	1475	9404
54	330	488	3480	2456	346	2046	9150
55	255	399	3317	1858	319	1396	7544

Abbreviations: TRAWL = Industrial trawlers; SHAFT = artisanal boats in the Sharqia region using fishing traps; SHAHL = artisanal boats in the Sharqia region using hand lines; DHOFT = artisanal boats in the Dhofar region using fishing traps; DHOHL = artisanal boats in the Dhofar region using hand lines; WUSHL = artisanal boats in the Al-Wusta region using hand lines.

Simulations. Changes in following parameters were considered in the simulations:

Modification of the fishing effort: simulation variation in total effort in the same proportion for the different fleet components (métiers); the actual minimum length limit in catches (current size at first capture) is not modified (set constant at 9 cm).

Modification of current size at first capture: the simulations suppose that the different fleets keep their actual level of fishing effort, while their exploitation pattern is changed by setting the fishing mortality to zero for length classes lower than the simulated length.

Fishing closed season regulation: This regulation limits, solely, the access period for trawlers to the fisheries accompanied by increasing their fishing effort. These simulations have been tested because the fishery administration in Oman plans to develop the activities of trawlers (actually only 4–5 trawlers). Keeping their quotas (catch) unchanged, four management scenarios have been tested for trawler period activities; these scenarios suppose a closed season for the trawlers between 3 and 6 months deferring in time. So, quarterly length frequencies have been prepared for these simulations. During closed season periods, catches of trawlers are supposed equal to zero and the corresponding length frequency is removed from the input data base.

RESULTS

Fishing mortality *F*. Different terminal fishing mortalities (F_t) have been tested to estimate total fishing mortality (F) of Omani *A. spinifer*. The most probable value of F_t was considered equal to 0.35; this value is close to those of fishing mortalities of the previous lengths (Fig. 2). The fishing mortality averaged across all size classes is 0.1, but F differs significantly in relation to size. F was low (<0.10) for fish sizes lower than the size at which sexual maturity is attained (27 cm). Above this size, F increased around 0.16 for size range 30–48 cm and reached quickly its maximum value of 0.35 for the largest size categories (at fish sizes ≥ 50 cm). The low fishing mortality on immature fish (< 27cm) should be noted; then the exploitation pattern of *A. spinifer* is oriented to the mature fraction of the stock.

To estimate the sensitivity of fishing mortalities to the M value used in this analysis, a value of M = 0.2 was tested. The results (Fig. 2) obtained showed a high sensitivity to this parameter. The mean value of F was nearly doubled in the intermediate sizes but the F profile kept the same shape (oriented to adult fraction of the population).

The fishing mortality per fleet component is shown in Fig. 3. The trawl fleet contributed largely to the total fishing mortality of the stock. The hand lines of Al-Wusta region and trawlers targeted largely adult specimens with high fishing mortalities in the length range around 50 cm. In contrast, the fishing traps fleet of Sharqia and Dhofar hand lines targeted primarily the younger fraction of the stock with high fishing mortalities in the length range between 27 and 32 cm. The fishing traps fleet of Dhofar and hand lines of Sharqia catch a mix of adult and young animals.

Recruitment and stock biomass. Recruitment was estimated as the number of fish in the smallest class size, in this case 9 cm, i.e., 10.5×10^9 individuals (Fig. 2). This figure also shows the number of survivors per length class. The proportion of survivors larger than 37 cm (L_{50}) is around 20% of the recruits. The sensitivity of the survivors number to the M value used should be noted (Fig. 2).

Yield per recruit and exploitation pattern.

(1) Effort regulation. Any increase of the actual fishing effort (effort multiplication = 1) would, in the long-term, lead to an increase of the long-term production (Fig. 4), when the minimum length limit is not modified. An increase of 50% of the actual fishing effort would lead to a gain of 24% in long-term yield. A reduction of the effort would, in the long-term, lead to a loss of the production, e.g., an effort reduction of 50% would result in a decrease of 37% in long-term yield.

With M = 0.2, the increase of fishing effort would not improve the long-term catches. In fact, an increase of fishing effort by 50% would not lead to any significant increase of the actual catches, but the level of the spawning stock biomass (SSB) would decrease from 54% to around 44% of the virgin SSB value. Therefore, no increase of actual fishing effort should be considered. In any case, any reduction of fishing effort would lead to an increase in spawning stock biomass (SSB) (Fig. 4).

An increase in total effort would lead to significant long-term gains for all fleet components (Fig. 5) except

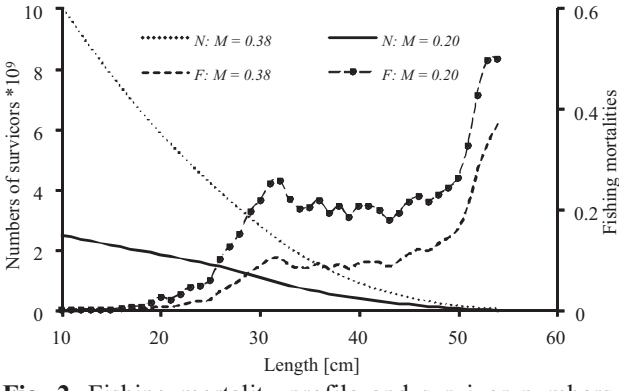

Fig. 2. Fishing mortality profile and survivor numbers, according to the value of M, of *Argyrops spinifer* in Arabian Sea, Oman

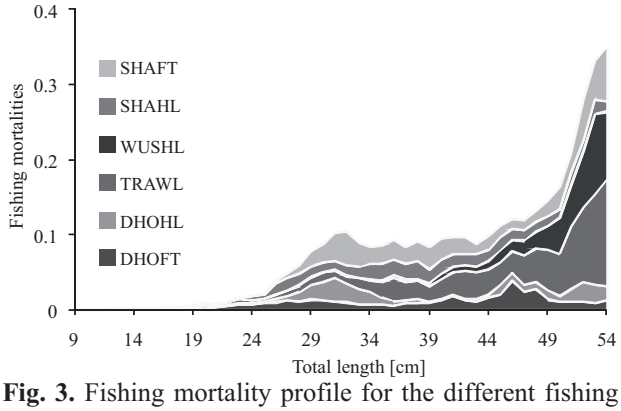

Fig. 3. Fishing mortality profile for the different fishing fleets of *Argyrops spinifer* in Arabian Sea, Oman

for the hand line fleet of Al-Wusta (WUSHL). The gains are highest for fleet components that capture the smaller specimens, i.e., the fleet components of Sharqia and Dhofar regions (SHAHL, SHAFT, DHOFT and DHOHL). For example, an increase of 50 percentage points in effort would result in an increase in long-term yield of 32, 32, 29, 27, and 18 percentage points, for the DHOHL, SHAHL, DHOFT, SHAFT and TRAWL fleets, respectively. For an important increase of effort (double effort) WUSHL would lose around 2 percentage points.

With $M = 0.2$, an increase in total effort would only lead to long-term gains for fleet components that capture the smaller specimens, i.e., fleet components in the Sharqia and Dhofar regions while fleets that targeted adults (Al-Wusta and trawlers) would lose out. For an increase of 50 percentage points in effort, the gains are around 16, 11, 9, and 7 percentage points for DHOHL, SHAHL, DHOFT, and SHAFT respectively; however, the losses in catch are 27 and 8 percentage points for WUSHL and TRAWL, respectively.

Therefore, if fishing pressure is set to increase substantially, it will be affecting negatively the fleets targeting the adult fraction of the stock and then will affect negatively the pattern of exploitation in the fishery. Then, the increase of effort should be particularly precautionary and exclusively for fleets targeting the adult fraction. In addition, this management measure should be accompanied by a monitoring system of the resources status and an economical study should be carried out in advance of any changes to provide evidence of the sustainability of any economic profitability derived from such an increase in effort.

(2) Size at first capture regulations (Minimum length limit). Keeping the actual fishing effort unchanged, a moderate change (increase/decrease by 20 percentage points) in the length at first capture would not affect substantially the long-term yield (Fig. 6). If the minimum length limit is substantially increased (50 percentage points), the long-term catch will decrease by 13 percentage points. However, the long-term gain in spawning stock biomass of such a measure would be very significant; gains would exceed 15 percentage points.

A moderate change (i.e., an increase/decrease of 20 percentage points) in minimum length limit would not lead to any major modifications of the long-term catches For all fleet components excepting SHAHL that lose around 13 percentage points. An important increase (50 percentage points) of this length would lead, in the long-term, to substantial losses for the hand lines fleets of Sharqia and Dhofar (Fig. 7) while trawlers and fishing traps of Sharqia would gain around 4–5 percentage points from such a measure.

A simulation was, also, performed with a value of $M = 0.2$ and the results obtained lead to similar conclusions as using $M = 0.38$. So, this regulation is not actually recommended as a management option for the *A. spinifer* fisheries.

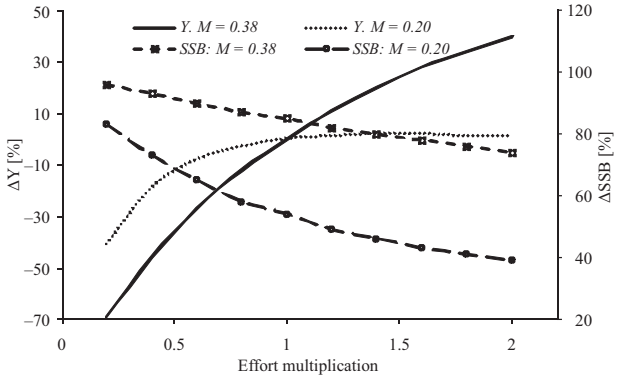

Fig. 4. Relative variations in long-term yield and SSB versus fishing effort, using two values of M, for *Argyrops spinifer* in Arabian Sea, Oman

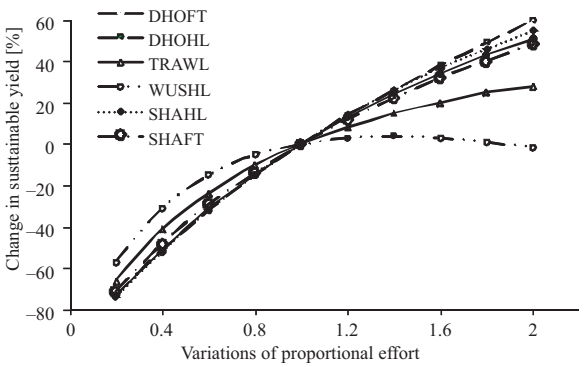

Fig. 5. Relative change in sustainable yield versus fishing effort per fishing fleet of *Argyrops spinifer* in Arabian Sea, Oman

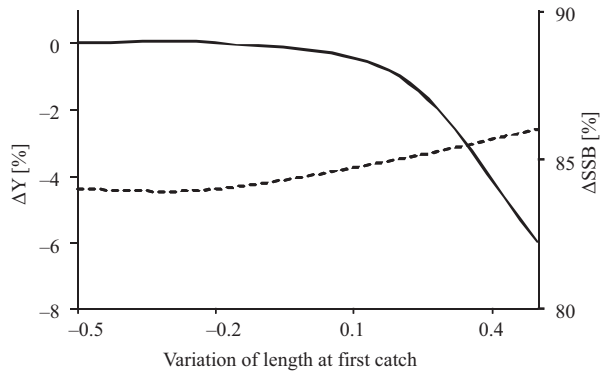

Fig. 6. Changes (%) in long-term yield and SSB (%) versus minimum length limit of *Argyrops spinifer* in Arabian Sea, Oman; ΔY(%) is the percentage change in yield. ΔSSB (%) is the percentage change in spawning stock biomass

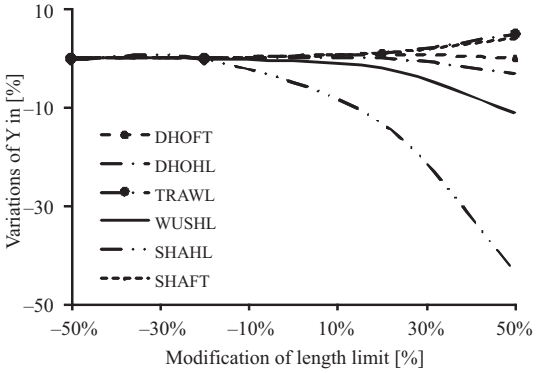

Fig. 7. Relative change in sustainable yield per fishing fleet versus minimum length limit of *Argyrops spinifer* in Arabian Sea, Oman

(3) Closed seasons regulations and increasing the fishing effort of trawlers. The managers of the fishery sector in Oman require analyses of the following periods: July–December; October–December; April–June; and April–September.

As a result of the low level of fishing effort for the trawlers, a closed season does not seem to have any significant impact on the total long-term catches. However, if effort is considerably increased, a closed season during April–September would lead to a slightly (marginal) gain in the total long-term catches (Fig. 8). Also, this regulation would, in the long term, lead to the highest gain for the artisanal fleets (Fig. 9) while it affects, in the long term, negatively the catch of trawlers. In contrast, the trawler fleet gains substantially if a closed season is regulated between July–December (Fig. 10).

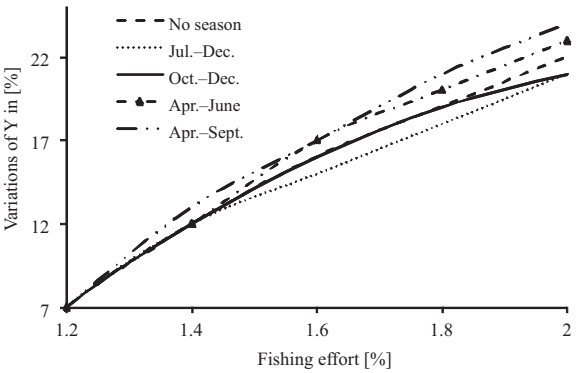

Fig. 8. Impact of a closed season regulation for trawlers on the total long-term catch of *Argyrops spinifer* in Arabian Sea, Oman; ΔY(%) is the percentage change in yield

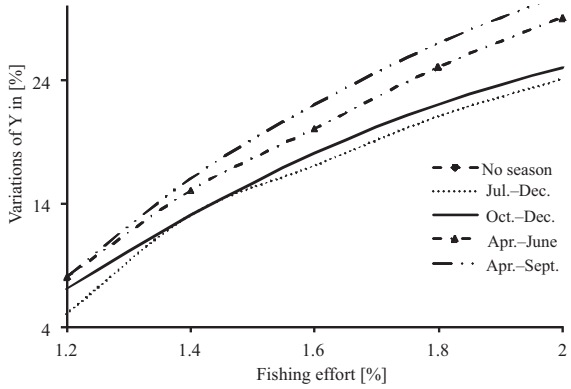

Fig. 9. Impact of a closed season regulation for trawlers on the artisanal long-term catch of *Argyrops spinifer* in Arabian Sea, Oman; ΔY(%) is the percentage change in yield

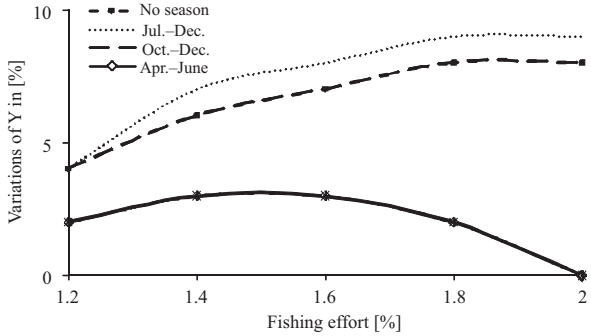

Fig. 10. Impact of a closed season regulation for trawlers on their long term catch of *Argyrops spinifer* in Arabian Sea, Oman; ΔY(%) is the percentage change in yield

DISCUSSION AND CONCLUSION

The level of fishing mortality rate for the *A. spinifer* stock is, in general, relatively low; the mean value is around 0.1, and it acts largely on the mature fraction of the stock. The different fleet components investigated contributed at different levels to this fishing mortality. The hand lines fleet of Al-Wusta region and trawlers targeted mainly the larger specimens; the fishing traps fleet of Sharqia and Dhofar hand lines targeted primarily the younger fraction of the stock while the fishing traps of Dhofar and hand lines of Sharqia fleets catch a mix of adult and young animals. The exploitation pattern seems appropriate according to the biological characteristics of the species and it should be preserved by keeping the current selectivity of the fishing gears used in the fishery.

The long-term yield according the fishing effort is very sensitive to the value of natural mortality value used in the analysis. An increase in fishing effort by 50 percentage points would lead, in the long term, to a yield gain of around 15 percentage points if the adopted M value is 0.38. However, for $M = 0.2$, the stock appears to be near to full exploitation status. In the two simulations with different M values, the spawning stock biomass would decrease substantially if the effort is increased considerably. This measure affects negatively the fleet components targeting the adult fraction of the population. So, any increase of the effort should not be recommended.

A moderate increase in the size at first capture does not seem to lead to any significant impact in the long-term yield of *A. spinifer*. Nevertheless, if this length is, substantially, increased a loss in the long term yield would result.

The fishing closed season regulation for trawlers would not affect in the long-term the yield of the stock, but if their effort is considerably increased the appropriate closed season would be from April to September.

The results obtained in this study lead to the same conclusions obtained by Grandcourt et al. (2004) who estimated the exploitation rate ($0.407 \cdot \text{year}^{-1}$) for *A. spinifer* in the southern Arabian Gulf to that at the estimated safe harvest level ($0.401 \cdot \text{year}^{-1}$). Also, Edwards et al. (1985) indicated moderate total mortalities Z (from 0.31 to 0.61) for 11 species of fish (including *A. spinifer*) from the Gulf of Aden.

As opposed to the healthy status of *A. spinifer* stock in Arabian Sea (Oman), many fish stocks in this region, are under greater fishing mortalities and suffer from growth overfishing. In fact, Grandcourt et al. (2004) indicated for *A. spinifer* in the southern Arabian Gulf that the high juvenile retention rate (66.9%) and the discrepancies between the mean size at first capture and that which would maximize yield per recruit, suggest that the existing mesh size regulations in the trap need to be reviewed. Devaraj

and Vivekanandan (1999) indicated inappropriate exploitation patterns for most of the exploited stocks in Indian fisheries; they have shown fishing mortality coefficients higher than those for natural mortality. Recently, Biju Kumar and Deepthi (2006) pointed out that the impact of trawling leads to a considerable by catch and that this is major concern affecting the sustainability of marine fisheries. Mohamed and Zacharia (2007) indicated that the key resources from the Arabian Sea of Karnataka (India) showed rapid decline in yields within 5 years due to a consistent increase of fishing effort between 20% and 100%.

Unfortunately, no study on the dynamic stock of *A. spinifer* fisheries in the Arabian Sea (Oman) has been previously carried out to which our results can be compared and discussed. These results constitute the first investigation of the exploitation pattern and potential management options of the Omani *A.spinifer* fisheries that have been conducted at a relatively early stage of its fishing development (history). More investigations should be carried out in order to monitor the evolution of the fishery and to identify eventual stock units and operational management units. It is not excluded that the *A. spinifer* populations in the Arabian Sea could constitute two distinguished management units (stocks); one in the east (Sharqia and Al Wusta regions) and the second in the south (Dhofar region). In this case, data collected should be analyzed separately.

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