Multi-species approach for stock management of kilka fish (genus: *Clupeonella*) in Iranian waters of the Caspian Sea

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Abstract

There have been recent changes in the Caspian Sea ecosystem, such as those due to changes in sea level or those caused by the invasive ctenophore, *Mnemiopsis leidyi*. It is believed that these changes had significant impacts on the absolute and relative abundance of the commercially important anchovy kilka (*Clupeonella engrauliformis*) and common kilka (*C. cultriventris caspia*) leading to decline in the former and increase in the latter species in the Iranian waters. Consequently, more rigorous management is required. The mixed-species yield-per-recruit was applied to the Iranian conical lift-net. This study showed that the pooled fishing mortality at $F_{40\%}$ was 0.70 yr^{-1} which is higher than fishing mortality of main species of anchovy kilka, but lower than the pooled fishing mortality at $F_{0.1}$ (0.75 yr^{-1}). The ABC under the best information available, at pooled species reference points for two species of anchovy and common kilkas, was estimated to be 8260mt. An analogous goal in a multispecies situation would be fishing at a fishing level, denoted F_{ws}, such that the fishing rate for the weakest stock (in this case; anchovy kilka) does not exceed its $F_{40\%}$ rate. Under this harvest strategy at $F_{40\%}$ for anchovy kilka, it is suggested that the ABC of pooled species of anchovy and common kilkas was estimated 7920mt to be selected in kilka fishery in Iranian waters.

Keywords: Multi-species fishery, Yield per recruit, Spawning biomass per recruit, Reference point, Acceptable biological catch

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Introduction

The most abundant fish of the Caspian Sea are three small clupeids known as "kilka": the common kilka (*Clupeonella cultriventris caspia* Bordin 1904), anchovy (*C. engrauliformis*, Svetovidov 1941), and big-eye kilka (*C. grimmi* Kessler 1877) (Svetovidov, 1963). Annual catches of kilka in the Caspian Sea reached historical high levels of about 423000mt in 1970 (Ivanov, 2000). Kilka fishing in Iran started with 6 ships in the port of Anzali in 1970. Until 1976, annual kilka catches were less than 4000mt (Razavi, 1993). Between 1989 and 1998, fishing activities and the number of fishing vessels increased steadily. Iran increased its quota of kilka to 95000mt in 1999. In next few years, however, the catch sharply decreased (19500mt in 2004).

During the past 30 years the environmental status of the Caspian Sea has changed significantly in response to impacts of various factors, such as fluctuations in sea level, pollution from different toxicants (Salmanov, 1999; Ivanov, 2000), and invasive species. The biological introduction of exotic organisms from ballast waters of vessels entering the Caspian has had serious ecological impacts (Ivanov *et al.*, 2001). In particular, the invasive jellyfish (Ctenophore, *Mnemiopsis leidyi*), that became apparent in November 1999 (Ivanov *et al.*, 2000) has subsequently affected all components of the ecosystem used by kilka (Kideys & Moghim, 2003).

It is a long time that fishery scientists have recognized that single-species harvest goals are generally unattainable in mixed-species fisheries where several species are harvested simultaneously with the same gear. Pioneering work on this problem of technological interactions was conducted by Beverton and Holt (1957), who used mixed-species yield-per-recruit analysis to derive an optimal level of fishing effort. Further developments have included multifishery mixed-species models (Murawski, 1984), incorporation of spawner-recruit relationships and predation mortality (Shepherd, 1988; Murawski *et al.*, 1991), and incorporation of fleet dynamics (Laurec *et al.*, 1991). To properly manage the stock and adjust for optimal catch and fishing effort of kilka, a mixed-species yield-per-recruit model is particularly appropriate. The objective of the present study is to develop mixed-species approach to assess kilka stocks. A yield-per-recruit analysis was applied to the Iranian conical lift-net. The overall fishing mortality values (F_x) for the multi-species analysis was estimated and compared to the spawning potential ratio ($F_{x\%}$) values estimated from spawning biomass-per-recruit model.

Materials and methods

Sampling areas for kilka were located in the fishing grounds in the Iranian provinces of Mazandaran and Guilan. The population biological parameters, biomass, and fishing mortality in which were estimated in previous studies (Fazli, 2007; Fazli *et al.*, 2007) were used as input parameters (Table 1).

Table1: Parameter estimates used in the yield-per-recruit and spawning biomass-per-recruit analysis for three species of kilka (Fazli, 2007)

Species	Input parameters							
	M	t_r	t_c	t_L	W_∞	K	t_0	$F_{current}$
Anchovy	0.473	0.18	2.49	8	20.6	0.238	-1.340	1.28
Common	0.506	0.12	2.80	7	15.9	0.259	-1.285	1.09
Weighted average								1.24

The kilkas examined in this study were caught at depths ranging from 40 to 100m by conical lift-nets equipped with underwater electric lights. The mesh size between two knots of the net is 7-8mm. The size and configuration of the conical lift-nets were nearly identically among all fishing vessels, so for the purposes of our analysis, it was assumed that all ships were equipped with the same basic net. Total catches of kilkas by each vessel during the night, recorded by fishermen in both of regions were collected by the Iranian Fisheries Organization (Mazandaran and Guilan branches) during the years of 1991-2004, used as input data for this paper. A density index (catch per unit of effort, CPUE), was calculated as the catch of each vessel per night or VN.

For single species, the following equation was used to determine the optimal fishing mortality and the optimal age at first capture (Beverton & Holt, 1957):

$$\frac{Y}{R} = Fe^{-M(t_c - t_r)]} W_\infty \sum_{n=0}^{3} \frac{U_n . e^{[-nK(t_c - t_0)]}}{F + M + nK} (1 - e^{[-(F+M+nK)(t_L - t_c)]})$$

where, asymptotic weight (W_∞), growth coefficient (K) and age at zero length (t_0) are parameters of von Bertalanffy growth function; R is the number of fish alive at time t_r, the age at recruitment, which was the youngest age in the catch; Y is the yield; M is the instantaneous coefficient of natural mortality (Fazli, 2007; Fazli *et al.*, 2007); t_L is regarded as the maximum age in the catch of 7 (Poorgholam *et al.*, 1996; Fazli and Besharat, 1997); and U_n is a summation parameter equal to +1, −3, +3, and −1 for n=0, 1, 2 and 3, respectively (Beverton & Holt, 1957).

An estimate of $F_{0.1}$, which represents the fishing mortality corresponding to 10% of the slope at the origin when no fishing occurs, was based on the following differentiated form of the Beverton & Holt (1957) yield per recruit equation:

$$\frac{d(Y/R)}{dF} = e^{-M(t_c - t_r)]} W_\infty \sum_{n=0}^{3} \{ \frac{(M+nK) U_n e^{[-nK(t_c - t_0)]}}{(F+M+nK)^2} + \frac{e^{[-(F+M+nK)(t_L - t_c)]}}{(F+M+nK)^2}$$
$$[(t_L - t_c)F^2 + (M+nK)(t_L - t_c)F - (M+nK)]\}$$

For multispecies of kilka, species composition of commercial catch (Fazli, 2007) during the years of 1995-2004, population ecological parameters and biomass of anchovy and common kilka in 2004 (Fazli 2007; Fazli *et al.*, 2007), used as input data for this analysis (Table 1). At present, the catch of bigeye kilka is negligible and data on biomass and fishing mortality are not available during 2002-2004 period. Therefore, we did not include this species in the multi-species complex.

The Beverton and Holt (1957) yield-per-recruit equation is:

$$\frac{Y}{R}=\sum_{i=1}^{s}\omega_i\alpha_i F e^{-M(t_c-t_r)]}W_\infty\sum_{n=0}^{3}\frac{U_n.e^{[-nK(t_c-t_0)]}}{\alpha_i F+M+nK}(1-e^{[-(\alpha_i F+M+nK)(t_L-t_c)]})$$

where, ω_i is the relative index of recruitment of species i (= species i catch rate/mean catch rate), α_i is the relative index of fishing efficiency ($=F_i/\overline{F}_\omega$), s is number of species. To estimate the relative index of recruitment (ω_i), catch rates of species i were divided by the mean catch rate of three kilka species (Table 2). To estimate the relative index of fishing efficiency (α_i), the fishing mortality of species i (F_i) divided by the pooled fishing mortality ($\overline{F}_\omega$). The pooled fishing mortality was calculated as shown in the following equation:

$$\overline{F}_\omega=\frac{\sum_{i=1}^{s}m_{xi}F_i}{\sum_{i=1}^{s}m_{xi}}$$

where, m_{xi} is catch rate of species i (Seo & Zhang, 2001).

An estimate of $F_{0.1}$, which represents the fishing mortality corresponding to 10% of the slope at the origin when no fishing occurs, was based on the following differentiated form of the Beverton & Holt (1957) yield per recruit equation:

$$\frac{d(Y/R)}{dF}=\sum_{i=1}^{s}\omega_i\alpha_i e^{-M(t_c-t_r)]}W_\infty\sum_{n=0}^{3}\{\frac{(M+nK)U_n e^{[-nK(t_c-t_0)]}}{(F+M+nK)^2}+\frac{e^{[-(F+M+nK)(t_L-t_c)]}}{(F+M+nK)^2}$$
$$[(t_L-t_c)F^2+(M+nK)(t_L-t_c)F-(M+nK)]\}$$

The spawning biomass-per-recruit equation was used to estimate the instantaneous coefficient of fishing mortality which would maintain the spawning biomass at a level equivalent to 40% (for common kilka) and x% ($F_{x\%}$; for multispecies) at a given age of recruitment in an un-fished population.

When F=0, the spawning biomass-per-recruit (SB/R) is:

$$\frac{SB}{R}\Big|_{F=0}=\sum_{t=t_r}^{t_\lambda}m_t e^{-M(t_c-t_r)}e^{-M(t-t_c)}W_\infty(1-e^{-K(t-t_0)})^3$$

where SB is spawning biomass and m_t is the age-specific proportion of mature females relative to all females in the cohort. In this study m_t is represented by a logistic equation fitted to maturity data collected from anchovy and common kilka caught in the southern Caspian Sea. The proportions of mature female of anchovy kilka were 0.04, 0.52, 0.80 and 1.00; common kilka were 0.01, 0.18, 0.68 and 1.00 for ages 1, 2, 3 and 4 year, respectively (Fazli, 2007).

When a certain specific value of F= F_1 the (SB/R) is:

$$\frac{SB}{R}\Big|_{F=F_1}=\sum_{t=t_r}^{t_\lambda}m_t e^{-M(t_c-t_r)}e^{-(M+F)(t-t_c)}W_\infty(1-e^{-K(t-t_0)})^3$$

Two harvest reference points were used to evaluate benefits from the multispecies complex, each pertaining to a specific management goal. Often, the harvest goal for multispecies complexes is focused on obtaining a target aggregate yield or revenue (Murawski, 1984; Piktch, 1987); this goal was represented here by the $F_{0.1}$ reference point. Alternatively, harvest reference points could be designed to minimize the likelihood of recruitment overfishing, as in the single-species $F_{40\%}$ policies (Clark, 1991). An analogous goal in a multi species situation would be fishing at a fishing level, denoted F_{ws}, such that the fishing rate for the weakest stock does not exceed its $F_{40\%}$ rate.

These harvest policies were used to obtain equilibrium yield under current conditions.

The estimation of acceptable biological catches (ABCs) of pelagic fish stocks in the Iranian fisheries management system must be taken into account the quantity and quality of data available and the exploitation history of the fishery. In this study it was adapted a five-tier-classification system (Table 3), which was modified from the six-tier system used under the US Fisheries Management Plan for the North Pacific ground fish fisheries (Anon, 1998). For tiers 1-3, once the reference fishing mortality (F_{ABC}) was determined, the following equation was used to determine ABC:

$$ABC = ABC_r + \sum_{i=r+1}^{t_L} \frac{B_i F_{ABC}}{M + F_{ABC}}(1 - e^{-(M+F_{ABC})})$$

where F_{ABC} is the instantaneous coefficient of fishing mortality for ABC determined by the available data and the stock status, r is a recruit age, and t_L is a maximum fishing age. ABC_r was calculated as following equation:

$$ABC_r = \frac{RF_{ABC}}{M + F_{ABC}}(1 - e^{-(M+F_{ABC})})$$

where R is the estimate of biomass at age 3, which was estimated from Fazli *et al.* (2007). ABCs for tiers 4 and 5 are based on maximum sustainable yield (MSY) and the arithmetic mean catch over an appropriate period (Y_{AM}), respectively (Table 3).

Results

The annual catches of anchovy kilka increased from 32800mt in 1995 to 67450mt in 1999, but dropped to about 510mt in 2004; the annual catches of bigeye kilka declined from about 5125mt in 1995 to 1845mt in 1998, and then dropped to less than 250mt during the years 2002-2004 (Table 2), and the annual catches of common kilka increased from 3075mt in 1995 to 13015mt in 1999, dropped to about 4780mt in 2001 and then increased to 13765mt in 2004. The fishing effort in Iranian coastal areas increased from 9314 VN (vessel × night) in the years 1995 to 28736 VN in the years 2001 and declined to 12992 VN in 2004. During the years 1995-1999 the CPUE of anchovy kilka ranged between 2.92-5.53mt per VN, then it declined sharply to less than 0.40mt per VN in 2004; bigeye kilka ranged between 0.39-0.60mt per VN, then it declined sharply to less than 0.1mt per VN in during the years 2001-2004, and common kilka ranged between 0.07-0.60mt per VN, declined to

0.17mt per VN in 2001, then it increased sharply to 1.06mt per VN in 2004 (Table 2).

The maximum yield-per-recruit of each of the two species of kilka and the pooled species is obtained at fishing mortality (F_{max}) more than 2yr^{-1} (Table 4). The maximum yield-per-recruit of anchovy and common kilka was 1.46g and 1.13g, respectively. The maximum-yield-per-recruit of the pooled species was estimated to be 2.56g (Table 4).

Table 2. Catch, biomass, effort, CPUE and species composition of the Iranian kilka fishery in weight during 1995-2004

Year	Species									Total catch		Effort
	Anchovy kilka			Bigeye kilka			Common kilka					
	Catch %	Biomass mt	CPUE mt/VN	Catch %	Biomass mt	CPUE mt/VN	Catch %	Biomass mt	CPUE mt/VN	%	mt	VN
1995	80.0	169554	3.52	12.5	36105	0.55	7.5	15742	0.33	100	41000	9314
1996	87.5	185249	3.30	10.7	47765	0.75	1.8	16053	0.07	100	57000	13838
1997	86.5	175810	3.35	11.1	52940	0.50	2.4	21560	0.09	100	60400	15344
1998	72.8	168347	2.92	21.7	52789	0.87	5.5	31168	0.22	100	85000	21190
1999	71.0	156763	3.12	15.3	34531	0.67	13.7	39092	0.60	100	95000	21623
2000	73.7	119387	2.26	12.6	17476	0.39	13.7	36779	0.42	100	78000	25407
2001	83.2	72308	1.31	6.2	5901	0.10	10.6	37870	0.17	100	45180	28736
2002	69.5	35793	0.75	0.1	-	0.00	30.4	40623	0.33	100	24975	23215
2003	50.5	17127	0.57	0.6	-	0.01	48.9	34712	0.55	100	14910	13405
2004	26.9	8325	0.40	1.2	-	0.02	71.9	27581	1.06	100	18918	12992
Mean	70.2			9.2			20.6			100		

Table 3: Methods constructed to determine the acceptable biological catch (ABC) for common kilka in the Iranian fisheries management system. (After Zhang and Lee, 2001)

Tier 1. Information available: Reliable estimates of B, B_{MSY}, F_{MSY} and $F_{40\%}$
1a) Stock status: $B/B_{MSY} > 1$
$F_{ABC}=F_{MSY}$
1b) Stock status: $\alpha < B/B_{MSY} \le 1$
$F_{ABC}=F_{MSY}\times(B/B_{MSY}-\alpha)/(1-\alpha)$
1c) Stock status: $B/B_{MSY} \le \alpha$: $F_{ABC}=0$
Tier 2. Information available: Reliable estimates of B, $B_{X\%}$ and $F_{X\%}$
2a) Stock status: $B/B_{40\%} > 1$
$F_{ABC}=F_{40\%}$
2b) Stock status: $\alpha < B/B_{40\%} \le 1$
$F_{ABC}=F_{40\%}\times(B/B_{40\%}-\alpha)/(1-\alpha)$
2c) Stock status: $B/B_{40\%} \le \alpha$: $F_{ABC}=0$
Tier 3. Information available: Reliable estimates of B and $F_{0.1}$
$F_{ABC}=F_{0.1}$
Tier 4. Information available: Times series catch and effort data
4a) Stock status: $CPUE/CPUE_{MSY} > 1$
ABC=MSY
4b) Stock status: $\alpha < CPUE/CPUE_{MSY} \le 1$
$ABC=MSY\times(CPUE/CPUE_{MSY}-\alpha)/(1-\alpha)$
4c) Stock status: $CPUE/CPUE_{MSY} \le \alpha$: ABC=0
Tier 5. Information available: Reliable catch history
$ABC=P\times Y_{AM}$ (arithmetic mean catch over an appropriate time period), $0.5 \le P \le 1.0$
i) Equation used to determine ABC in tiers 1-3:

$$ABC = ABC_r + \sum_{i=r+1}^{t_L} \frac{B_i F_{ABC}}{M + F_{ABC}} (1 - e^{-(M+F_{ABC})}) \qquad ABC_r = \frac{RF_{ABC}}{M + F_{ABC}} (1 - e^{-(M+F_{ABC})})$$

where B_i: biomass at age i, M: instantaneous coefficient of actual mortality, F_{ABC}: instantaneous coefficient of fishing mortality for ABC determined by the data available and the stock status, r: recruit age, t_L: maximum fishing age.
ii) For tiers 1, 2 and 4, α is set at a default value of 0.05.

Table 4: Yield and spawning biomass-per-recruit for each of two species and the pooled species of kilka in the Iranian waters under harvest strategies of F_{max} and $F_{0.1}$

Species	t_c	F_{max}	$F_{0.1}$	$F_{40\%}$	Y/R (g) at		SB/R (g)
					F_{max}	$F_{0.1}$	$F_{40\%}$
Anchovy	2.49	>2	0.69	0.67	1.46	1.23	2.35
Common	2.80	>2	0.94	0.80	1.13	0.94	1.34
Pooled	-	>2	0.75	0.70	2.56	2.18	4.21

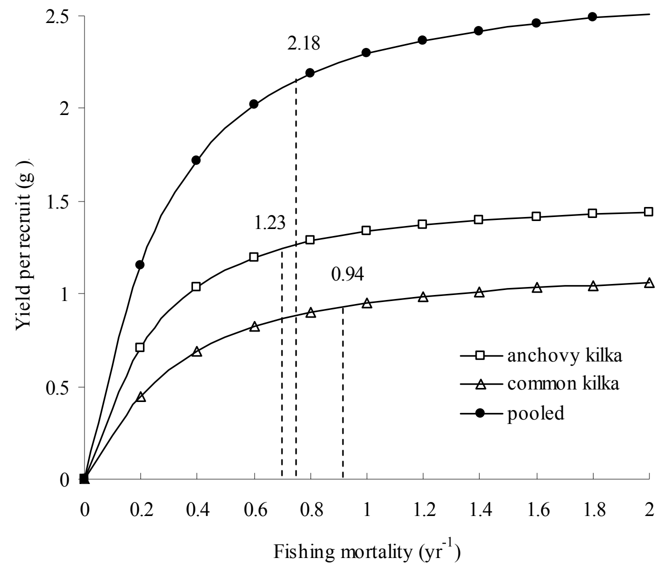

Figure 1: Multi-species yield-per-recruit curves showing $F_{0.1}$ points for each of the two species and the pooled species for Iranian kilka fishery

The biological reference point, $F_{0.1}$, of anchovy, common kilka and pooled species was estimated to be 0.69 yr^{-1}, 0.94 yr^{-1} and 0.75 yr^{-1}. The yield-per-recruit of anchovy and common kilka at $F_{0.1}$ was 1.23g, and 0.94g, respectively. The yield-per-recruit of pooled species at $F_{0.1}$ was estimated to be 2.18g (Table 4; Fig. 1).

The spawning potential ratio ($F_{x\%}$) at pooled F_x of anchovy and common kilka for $F_{0.1}$ was 38.1% and 41.6%, respectively (Table 5). The spawning potential ratio ($F_{x\%}$) at pooled F_x of three species for F_{max} was about 14.6% about and 7%, respectively (Table 5).

The biological reference point, $F_{40\%}$, for anchovy, common kilka and pooled species was estimated to be 0.67, 0.80 and 0.70 yr^{-1}. The spawning biomass-per-recruit of anchovy and common kilka at $F_{40\%}$ was 2.35 and 1.34 g, respectively. The spawning biomass-per-recruit of pooled species at $F_{40\%}$ was estimated to be 4.21 g (Table 4; Fig. 2).

Information considered for tier 1 includes the historic estimates of biomass, M, B_{MSY}, F_{MSY} and $B_{40\%}$ for anchovy and common kilka. The information of B_{MSY} and F_{MSY} were not available, because the fit of the biomass-based approach to the production model (Zhang, 1991), using biomass and fishing mortality, were not statistically significant, so these values could not be estimated.

Reliable current biomass, M, $B_{40\%}$ and $F_{40\%}$ of pooled species for two species of kilka were available to be used for tier 2 in this study. Biomass data estimated for anchovy and common kilka were available for age classes taken from fishery during 1995-2004.

Table 5: Fishing mortalities and spawning potential ratios for the different levels of the two species ok kilka in the Iranian fishery

Species	F_x		$F_{x\%}$ at pooled F_x	
	F_{max}	$F_{0.1}$	F_{max}	$F_{0.1}$
Anchovy	>2	0.69	14.6%	38.1%
Common	>2	0.94	7.0%	41.6%
Pooled	>2	0.75	-	-

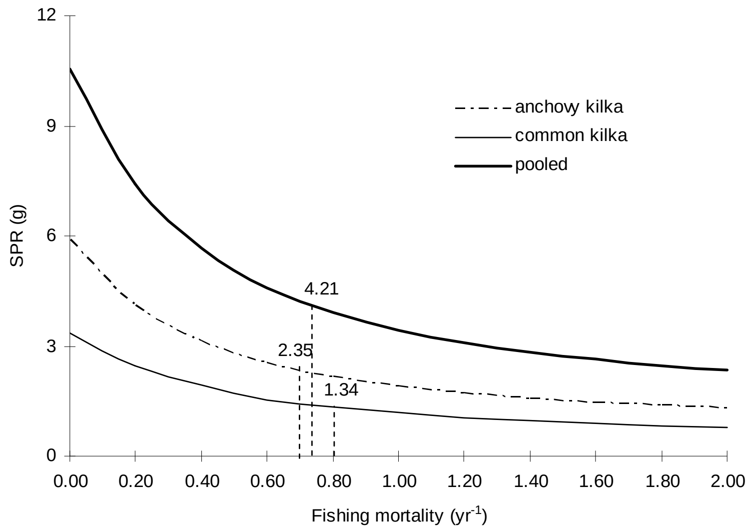

Figure 2: Multi-species spawning biomass-per-recruit (SPR) curves showing $F_{40\%}$ points for each of the two species and the pooled species for Iranian kilka fishery

The current estimated biomass of mixed-species of anchovy and common kilka at year 2004 was calculated to be 35906mt. The biological reference point for pooled species, $F_{40\%}$, was estimated to be 0.70yr^{-1}, and $B_{40\%}$ was estimated for current biomass as the 2004 was 49890mt. Since the ratio $B/B_{40\%}$ was 0.72, tier 2b was used to determine F_{ABC}, 0.49yr^{-1}. The biomass at recruited age (age 3) in 2004 was fixed at the recruitment (R) of 10420mt. Thus, ABC for pooled species with recruited age 3 was estimated to be 8260mt (Table 6).

To estimate ABC in tier 3, information of reliable of current biomass, M and $F_{0.1}$ is required. The F_{ABC} value of pooled species was derived from the estimated $F_{0.1}$, 0.75yr^{-1}. Thus, ABC for pooled species of anchovy and common kilka was estimated to be 11310mt (Table 6).

Information available in tier 4 is the time-series catch and effort data for anchovy and common kilka. The information of maximum sustainable yield (MSY) and f_{MSY} were not available, because a fit of the catch and effort data was not statistically significant, so those values could not be estimated.

The only information available in tier 5 is the annual catch. Selection of the most appropriate time periods to determine the arithmetic mean catch (Y_{AM}) is based on: i) a period that is, at least, longer than the time from the age at first capture to oldest age in catch, ii) a period of little variation in catch data, iii) a period of little variation in fishing effort data, and iv) a period of little variation in fisheries management, such as a quota. Because acceptable data were not available, the ABC in tier 5 could not be estimated.

The anchovy kilka single-species $F_{40\%}$ was lower than common kilka. Thus, anchovy kilka is the weakest stock in the complex, it would be the most susceptible to harvest its fishing rate exceed $F_{40\%}$ under the current conditions. Therefore, $F_{40\%}$ of anchovy kilka is used as F_{ws}. The biological reference point for F_{ws} was estimated to be 0.67yr^{-1}, and $B_{40\%}$ was estimated for current biomass as the 2004 was 50960mt. Since the ratio of $B/B_{40\%}$ was 0.71, tier 2b was used to determine F_{ABC}, 0.46yr^{-1}. Thus, ABC for pooled species (for anchovy and common kilka) was estimated to be 7920mt.

Table 6: ABC estimates for anchovy and common kilka by the Iranian TAC fisheries management system at kilka pooled species reference points

Stock status		ABC (mt)
Tier 1	B_{MSY}, F_{MSY} = not available	-
Tier 2	$B/B_{40\%}$= 35900/49890<1	8260
	Stock status: 2b	
	$F_{ABC}=F_{40\%}\times(B/B_{40\%}-\alpha)/(1-\alpha)= 0.49$	
Tier 3	$F_{ABC}=F_{0.1}$=0.75/yr	11310
tTier 4	$CPUE/CPUE_{MSY}$	-
Tier 5	Y_{AM}	-

Discussion

The yield-per-recruit curve and recent harvest levels for kilka provide direction for the conservation in their management. The management choices for mixed-species fishery systems fall along a continuum with maximization of aggregate yield at one extreme, and full protection with no harvesting at the other (Pikitch, 1995). The $F_{0.1}$ reference point follows previous modeling of harvesting species complexes, in which an aggregate output (yield, net revenue, or gross revenue) of the complex is maximized (Murawski, 1984; Pikitch, 1987). Except in unusually rare circumstances, this would result in a least one species in the complex being harvested at a rate greater than recommended under single-species management, therefore in some jurisdiction (*i.e.,* USA) this would posed a problem under the Magnuson-Stevens Fisheries Conversation Act to avoid overfishing (Spencer *et al*., 2002). The precautionary approach, as applied to Iranian kilka fishery, specifies a maximum harvest rate of $F_{40\%}$ as a target to be achieved.

Under these definitions, the pooled species fishing mortality at $F_{0.1}$ was estimated to be 0.75 yr^{-1} is higher than the fishing mortality at $F_{0.1}$ for anchovy kilka, whereas, the pooled fishing mortality would not achieve the target for common kilka (Table 4). The spawning potential ratio ($F_{x\%}$) at pooled F_x of two species of kilka for $F_{0.1}$ varied between 38.1-41.6% which is close to a target rate of $F_{40\%}$.

The current fishing mortality of anchovy, common kilka and weighted average fishing mortality of two species was 1.28yr^{-1}, 1.09yr^{-1} and 1.24yr^{-1}, respectively, which is higher than the pooled species fishing mortality at $F_{0.1}$ and $F_{40\%}$.

Anchovy kilka comprised about 80-90 percent of the total kilka catch in the Caspian Sea (Sedov & Rychagova, 1983; Fazli & Besharat, 1998). One of the imapcts of *Mnemiopsis* on the Caspian Sea ecosystem, was a significant decrease in the stocks of anchovy and bigeye kilka (Karpyuk *et al*., 2004; Fazli, 2007). Karpyuk *et al*. (2004) reported that, after the *Mnemiopsis* impaction on the Caspian Sea, only the stock of common kilka remained stable and according to Fazli *et al*., 2007, the biomass of common kilka increased by a factor of about 2. This study showed that the pooled fishing mortality at $F_{40\%}$ was 0.70yr^{-1} is close to fishing mortality of main species of anchovy kilka, and it is lower than the pooled fishing mortality at $F_{0.1}$ (0.75yr^{-1}). Therefore, when the stock of anchovy kilka recovered in foregone situation, the pooled fishing mortality at $F_{40\%}$ should be selected for application of a precautionary management approach of kilka stocks in Iranian waters of the Caspian Sea. At present, it is suggested that the fishing mortality at F_{ws} to be selected for application of a precautionary management approach of kilka stocks.

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