A Comparative study on the Ecosystem-based Fisheries Risk Analysis of Algerian Fisheries

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Abstract:

There is a growing need to evaluate how fishing activities is being affecting the ecosystem. The study seeks to frame the assessment of risk status of three main fisheries operating in the Algerian coastal ecosystem, which are trawl, purse seine, and small-scale fisheries. The ecosystem-based fisheries assessment has been suggested to conduct the present study. Tier 2 process analysis has been used since the qualitative data was not rich. Across the nested risk design, the trawl, purse seine, and small-scale fisheries risk indices were projected in the yellow zone. The highestfishery risk index(FRI)was observed in the trawl fishery (1.363), followed by the small-scale fishery (1.309), then the lowest value was found in the purse seine fisheries (1.114). The purse seine fishery risk index differed significantly from both of trawl and small-scale fisheries risk indices, whereas there was no significant difference between trawl fishery risk index and small-scale fishery risk index. A proper management measures were to improve the fisheries risk situations.

Key words: Ecosystem approach, EBFM, Risk assessment, Algerian fisheries.

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1. Introduction

The fishing activity in the Mediterranean Sea is characterized by the multi-specificity; moreover, the Mediterranean Sea is one of most important biodiversity hotspots of the world. Furthermore, human pressure is increasing on this environment, that's mean habitat and species destruction are increasing.

Algerian coastline is on the Mediterranean Sea, it has a long coastline (about 1300 km) and small continental shelf, the biodiversity is higher in the coastal areas and decreases with depth. The Algerian coastal zone encountered numerous problems such as urban, industrial and agricultural pollution, overexploitation of resources and coastal erosion.

To balance between ensuring sustainability, habitat and socio-economical requires became an issue for policy-makers. However, including all of previous dimensions allows interpreting the system's complexity and integrating them into fisheries assessment process.

In Algeria, the fishing activities are generally coastal, which target mainly the small pelagic. The landing composition of small pelagic represented about 78% (Maouel, 2003). A main issue for pelagic fisheries is their seasonal nature and their linkage to climatic conditions, which might create a high fluctuation in the market. The bottom trawling fleet targets the high value species such as red shrimp (Belhabib, 2007). The small-scale coastal fishing fleet represents nearly 61% of the total of the Algerian national fleet (Chakour & Guedri, 2014). The Algerian government grants in recent years the fishing sector, which might increase the pressure on fish stocks. The small-scale or artisanal fisheries do not have a single international accepted definition since their characteristics are different among the countries (Garcia-Florez et *al*., 2014). In Algeria the small-scale fishery differs from purse seine and trawl by the overall length of vessels (<12m) and the wide variety of fishing gears, basically passive fishing gears such as drift net, gillnet, trammel net, surface and bottom longline.

The traditional quantitative fish stock assessments are problematic whenever data are not enough or are inaccurate (Pazhayamadom et *al*.,2013);furthermore, Single-species stock assessment and sampling high-value can be an issue to cover all exploited species.

Three main fisheries are operating in Algerian coastal ecosystem, which are trawl, purse seine, and small-scale. Their average contributions in landing were estimated during the last ten years at 25.07%, 68.66%, and 6.18% respectively (MPPH,2016).

Within the ecosystem-based approach, there is an increasing requirement for measuring the impact of fishing on the ecosystem. The Algerian coastal ecosystem is under the pressure of fishing activities. Trawl, purse seine, and small-scale fisheries might share a limited fishing grounds delimited by the narrow continental shelf, and target in many cases the same species, which is one of the main shortcomings in Mediterranean fisheries assessment.

The ecosystem-based fisheries management (EBFM), or alternatively the ecosystem approach to fisheries (Garcia et *al.*, 2003; Pikitch et *al*., 2004) is a widely accepted concept. The approach is required since the concern is growing over how ecosystems are being affected by fishing. Furthermore, the approach is necessary to holistically assess and manage fisheries resources and

their associated habitats by considering ecological interactions of target species with predators, competitors, and prey species, interaction between fishes and their habitats, and the effects of fishing on these processes (Zhang et *al*., 2009).
In this perspective, the Tier 2 approach was suggested as an alternative analysis to assess the risk scores for indicators, objective, species, fisheries, and ecosystem. The aim of this study is: (i) to investigate the Algerian main fisheries risk, (ii) to compare the status of the main Algerian fisheries with target species overlaps concept, (iii) to suggest a proper management strategies and tactics to reduce high-risk indices and provide an effective policy.

2. Material and methods

2.1. Study area and data source

The study examined three fisheries (trawl, purse seine, small-scale fisheries) operate on the coastal ecosystem; the fishing effort is distributed among 14 coastal Wilayat's (Departments). The present study covered a variety of species, including 05 small pelagic, 04 demersal fish, 01 large pelagic and 02 cephalopods (Table1).

Table 1. Target assessed species by type of fishery in Algerian coastal ecosystem

Trawl	Purse seine	Small-scale
Sardine *Sardina pilchardus*	Sardine *Sardina pilchardus*	Surmulet*Mullus barbatus*
Mackerel *Trachurusspp*	Mackerel *Trachurusspp*	Axillary seabream *Pagellusacarne*
Bogue *Boopsboops*	Bogue *Boopsboops*	Blackspot seabream *Pagellusbogaraveo*
Surmulet*Mullus barbatus*	Anchovy *Engraulisencrasicolus*	Common Pandora *Pagelluserythrinus*
Axillary seabream *Pagellusacarne*	Round sardinella*Sardinellaaurita*	Cuttlefish *Sepia officinalis*
Blackspot seabream *Pagellusbogaraveo*		Common Octopus *Octopusvulgaris*
Common Pandora *Pagelluserythrinus*		Swordfish *Xiphias gladius*
Cuttlefish *Sepia officinalis*		
Common Octopus *Octopusvulgaris*		

The species were chosen depending on their availabilities in the coastal ecosystem, their representativeness in total production and the overlaps among the fishing gear (multi-gears concept).

2.2. Methodology

Six questionnaires were prepared to conduct the Tier 02 approach, three of them were addressed to fishermen and 03 were addressed to inspectors, each questionnaire deals with one of the fishery and the defined target species.

The current investigation examined 58 questionnaires collected from 09 ports which are located in 08 Wilayat's (Departments) 46 questionnaires were filled out by fisherman and 12 questionnaires were filled out by fisheries inspectors. Eight Wilayat's were surveyed. The basic issue was sampling size.

To assess the Algerian coastal fisheries and the status of management, a pragmatic ecosystem-based fisheries assessment developed by (Zhang et *al*., 2009) and, which integrates four management objectives: sustainability, biodiversity, habitat quality, and socio-economic. The approach has two tiers of assessment namely Tier 01 and Tier 02; the first one is used in the situations wherever the data are rich and available, while Tier 02 were used to assess the Algerian coastal fisheries system. Tier 02 is designed for a semi-quantitative or/and qualitative analysis of the data-poor situation. The present study carried out a Tier 02 process assessment for a total of 18 indicators developed by (Park et *al*., 2013). Specific to this study was including all indicators except 'Bycatch rate B-1' due to the particularity of Algerian fisheries which characterized by Multi-species (Table 2).

Table 2. Objectives, full indicators, selected indicators and factors weight to assess Algerian coastal ecosystem by Tier 02 approach

Full indicators			Indicators for Algerian costal ecosystem				
Objectives	**Attribute**	**Indicators**	**Indicators**	**surveyed population**	**Rationale**	**Alternative**	**Weight**
Sustainability	abundance	Catch or CPUE S-1	+	-Inspectors fisheries Survey -fishers survey			3
	Fishing intensity	Catch or fishing mortality (F) S-2	+	-fishers survey			2
	Optimum age (or size) at first capture	Age (or length) at first capture S-3	+	- Inspectors fisheries Survey			3
	Stock structure	Rate of mature fish S-4	+	-fishers survey			2
	Genetic structure	Ratio of (released stock abundance)/(wild stock abundance) in catch S-5	+				1
	Population resiliency	Reproduction habitat S-6	+	-fishers survey			1
	Community structure	Mean trophic level of catch (TLc) S-7	+	- Inspectors fisheries Survey			1
Biodiversity	Bycatch rate	Bycatch rate B-1	-		Fisheries in Algerian coast is multi-species	Focusing the minimal size of fish length and discards rate	

	Discards	Discards rate B-2	+	-fishers survey			3
	Discards	Discards rate B-2	+	-fishers survey			3
	Diversity	Diversity index (DI) B-3	+	- Inspectors fisheries Survey -fishers survey			1
Habitat quality	Habitat damage	Critical habitat damage rate H-1	+	- fishers survey			2
		Lost fishing gear H-2	+	- fishers survey			1
		Pollution of spawning and nursery areas H-3	+	- fishers survey			1

- +: indicator used for Algerian coastal ecosystem;
- -: indicator does not used for Algerian coastal ecosystem.

Target and limit corresponding to desirable and undesirable respectively, are reference points that were defined for each indicator to assess the status of objectives, species, and fisheries for each fishing segment.
The relative weights for each indicator were ranging from 01 to 03, and they are although in essence similar as in Zhang et *al*. (2009), except slight modifications for the sake of assessing the Algerian coastal ecosystem particularity situation.
A nested design was developed by Zhang et *al*. (2009, 2011) (Figure1), thus an bjective risk index (ORI), species risk index (SRI), and fishery risk index (FRI), ecosystem risk index (ERI) was estimated to assess the fishery and ecosystem status risk indices

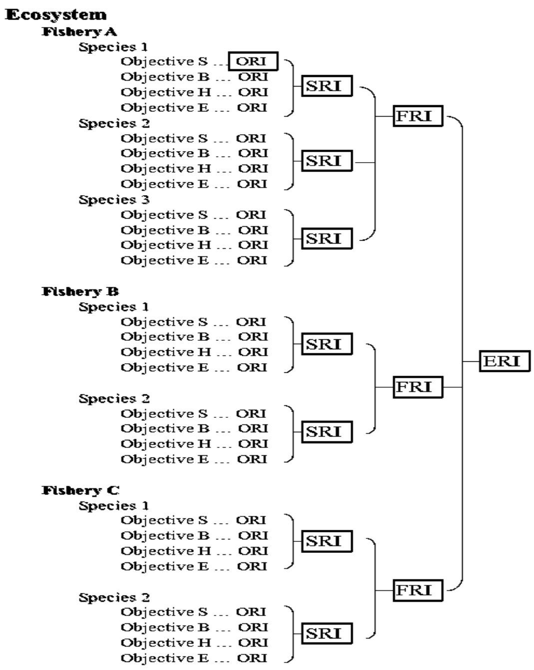

Figure 1. Nested structure of risk indices used in the ecosystem-based fisheries assessment approach. ORI: denotes objectives risk index, SRI: species risk index, FRI: fishery risk index, ERI: ecosystem risk index (Zhang et al., 2009).

The ORI is defined through the following formula:

$$\mathbf{ORI} = \frac{\sum_{i=0}^{n} \mathbf{RS}_i W_i}{\sum_{i=1}^{n} W_i}$$

Where $\mathbf{RS}_i$» is the risk score for indicator **i**, $\mathbf{W}_i$ is the weighting factor (1, 2 or 3) for indicator **i** and **n** is the number of indicators.

The species risk index is calculated for each species as mathematical weighted sum of the objectives risk indices

$SRIi = \lambda_S ORI_S + \lambda_B ORI_B + \lambda_H ORI_H + \lambda_E ORI_E$

Where: λ_S, λ_B, λ_H and λ_E : Weighting value for objectives, the condition is $\sum \lambda = 1.0$

$\mathbf{ORI_S}$: Sustainability risk index, $\mathbf{ORI_B}$: Biodiversity risk index, $\mathbf{ORI_H}$: Habitat risk index, $\mathbf{ORI_E}$: Socio-economic risk index.

The objectives factors were weighted equally, assuming that $\lambda S = \lambda B = \lambda H = \lambda E = 0.25$.

The SRIs were calculated for each questionnaire; the issue in this study is that the assessed species are targeted by different fisheries at the same time. To solve this issue, the fisheries markers (t), (p), and (s) were added to each species in order to indicate which fishery the species belong to. Where (t), (p), (s) were allocated to trawl, purse seine, and, small-scale fishery respectively, (i.e., *Sardina pilchardus* (p), *Sardina pilchardus* (t), *Xiphias gladius* (s)).

As mentioned earlier, the main objective of the present study is to investigate the main fisheries risk status in Algerian coastal ecosystem. The fishery risk index FRI is the weighted average risk index for exploited species in a fishery.

$$FRI = \frac{\sum BiSRIi}{\sum Bi}$$

Where $\mathbf{B}_i$ is the biomass or relative biomass such as catch per unit effort for species $\boldsymbol{i}$. Where this last one was used in the present study, as an alternative of biomass. Five years of catch per unit effort CPUE average were considered as an appropriate time period, furthermore, the CPUE were separated over fisheries.

One-way ANOVA procedure was performed to examine statistically the difference of risk indices means of the three fisheries. Fisheries risk indices of trawl, purse seine, and small-scale fishery wereFRIs tested group with unbalanced observations. Then post hoc analysis using Tukey-Kramer test to figure out which groups of FRIs are making the difference in means, Tukey-Kramer test is recommended in the unbalanced design situation.

The ecosystem risk index ERI is reported as the weighted average of the fishery risk indices in an ecosystem.

$$ERI = \frac{\sum CiFRIi}{\sum Ci}$$

Where Ci is the catch of i fishery.

Across the four management objectives namely sustainability, biodiversity, habitat quality, and socio-economic, these objectives are associated with their attributes including, abundance, fishing intensity, stock structure, genetic structure, population resiliency, community structure, discards, diversity, habitat damage, discarded wastes, economic considerations, and social considerations

The target reference point corresponds to a state of each indicator that considered desirable, while the limit reference point is defined as the limit beyond which the state of each indicator is considered undesirable. The risk score was evaluated for each indicator, producing possible risk value between 00 and 03. The risk assessment outcomes were separated into 03 risk zones; better than target corresponding to the risk value less than '1.0', between target and limit when the risk indices are located between '1.0' and '2.0', and beyond limit when the risk value exceed '2.0'.

3. Results and discussion

Objective risk indices (ORI's) assessment by Tier 02 approach for 09 assessed species caught by trawl:The calculated ORIs in trawl fishery showed that all nine species assessed, were ranged from 0.59 to 1.78 (Table 3). Only the ORI biodiversity was in the desirable zone at 0.59 (Fig.2). Although sustainability, habitat quality, and socio-economic benefits objectives risk indices fell in the yellow zone, where the highest value of ORI was estimated at 1.78 for habitat quality objective (Figure.2).

Trawl fishery had nine species namely ***sardine Sardina pilchardus, mackerel Trachurusspp, bogue Boops boops, surmuletMullus barbatus, axillary seabream Pagellus acarne, blackspot seabream Pagellus bogaraveo, common pandora Pagellus erythrinus, cuttlefish Sepia officinalis, and common octopus Octopus vulgaris.*** Sustainability risk indices were 1.40, 1.45, 1.46, 1.43, 1.44, 1.49, 1.44, 1.57 and 1.37 respectively.
The highest ORI of sustainability were estimated for the cephalopod ***cuttlefish***at 1.57, while the lowest were for cephalopod ***Common Octopus 1.37.***

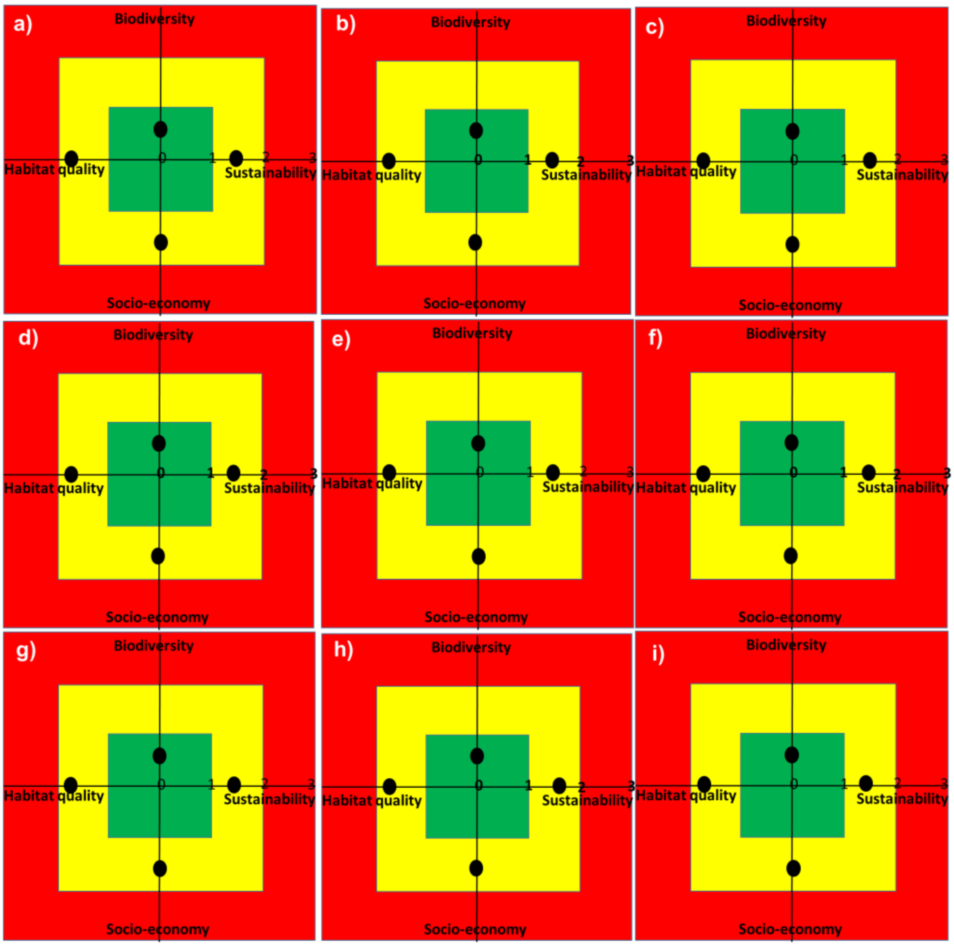

Figure 2. Relative positions of objective risk indices (ORI), for the nine species in the trawl fishery from the ecosystem-based Tier 2 fishery assessment approach. (a) Sardine *Sardina pilchardus*, (b) Mackerel *Trachurusspp*, (c) bogue *Boopsboops*, (d)Surmulet*Mullusbarbatus*, (e) Axillary seabream *Pagellusacarne*, (f) Blackspot seabream*Pagellusbogaraveo*, (g) Common Pandora *Pagelluserythrinus*, (h) Cuttlefish *Sepia officinalis*, and (i) Common Octopus. *Octopus vulgaris*.

Objective risk indices (ORI's) assessment by Tier 02 approach for 05 assessed species caught by purse seine: Sardine *Sardina pilchardus*, mackerel *Trachurusspp*, anchovy *Engraulisencrasicolus*, round sardinella*Sardinellaaurita*, and bogue *Boopsboops*, are 05 species assessed by Tier 02 approach in purse seine fishery. The objective risk indices (ORIs) for biodiversity and habitat quality were estimated at the green zone, 0.31 and 0.85 respectively (Figure 3). Although the ORI for sustainability and socio-economic were projected in the yellow zone for the fives assessed species in purse seine fishery with 1.61 for socio-economic benefits, and ORI sustainability varied from 1.66 to 1.70 depending on the assessed species (Figure 3).

Sardine, Anchovy, and Round sardinella had ORIs for sustainability 1.68, 1.66, and 1.67 respectively. Anchovy *s* and bogue had sustainability ORI estimated at 1.70.

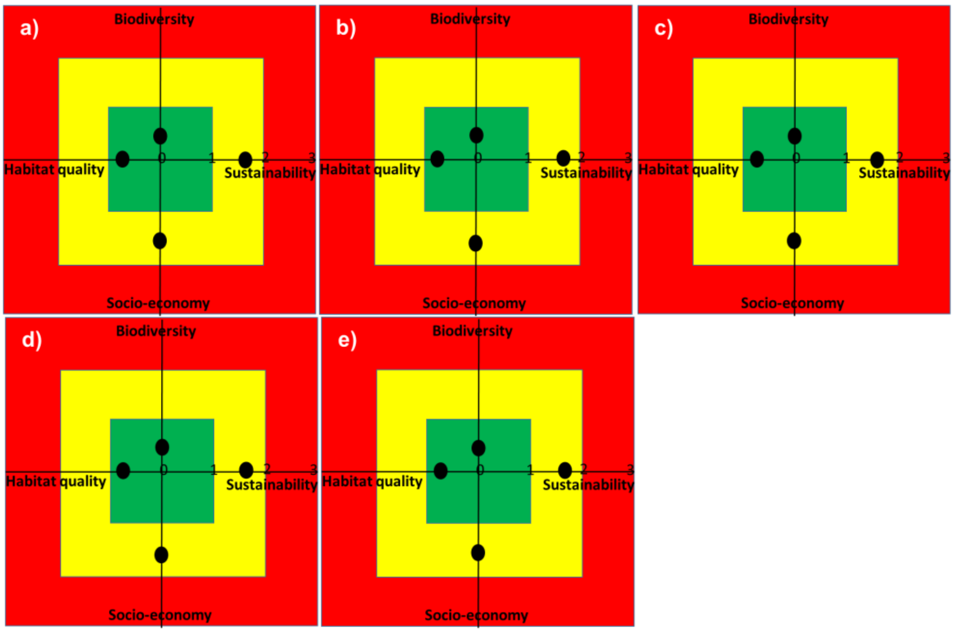

Figure 3. Relative position of objective risk indices (ORI) for the five species in the purse seine fishery from the ecosystem-based Tier 2 fishery assessment approach, (a) Sardine *Sardina pilchardus, (b) Mackerel Trachurusspp, (c) Anchovy Engraulisencrasicolus, (d) Round sardinellaSardinellaaurita, (e) Bogue Boopsboops.*

*Objective risk indices (ORI's) assessment by Tier 02 approach for seven assessed species caught by small scale-fisheries:*The small-scale fishery had 07 species, namely; surmulet*Mullusbarbatus*, axillary seabream *Pagellusacarne*, blackspot seabream *Pagellusbogaraveo*, common pandora *Pagelluserythrinus*, cuttlefish *Sepia officinalis*, common octopus *Octopusvulgaris* and, swordfish *Xiphias gladius* (Figure 4). surmulet had risk indices 1.59, 0.39, 1.52, and 1.77 for sustainability, biodiversity, habitat quality and socio-economy, respectively. Axillary seabream had risk scores of 1.63, 0.36, 1.53, 1.53, and 1.79 for sustainability, biodiversity, habitat quality, and socio-economy, respectively. Blackspot seabream had risk indices 1.67, 0.39, 1.52, and 1.77 for sustainability, biodiversity, habitat quality, and socio-economy, respectively. Common Pandora had risk scores of 1.56, 0.39, 1.52, and 1.77 for sustainability, biodiversity, habitat quality, and socio-economy, respectively. The two cephalopods; cuttlefish and common Octopus assessed in small-scale fishery had respectively 1.65, 1.50 for sustainability, 0.33, 0.38 for biodiversity, 1.58, 1.53 for habitat quality, and 1.80 for both of cephalopods in socio-economic benefits.

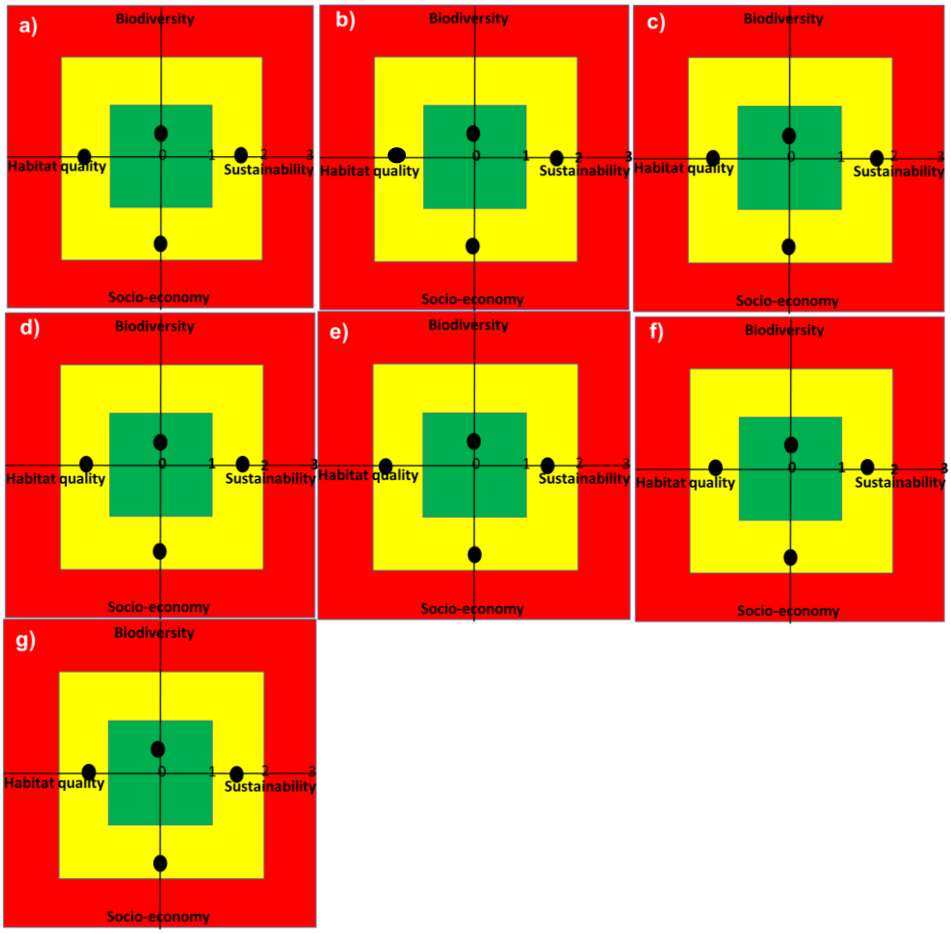

Figure 4. Relative positions of objective risk indices (ORI) for the seven species in the small-scale fishery from the ecosystem-based Tier 2 fishery assessment approach, *(a) SurmuletMullusbarbatus, (b) Axillary seabream Pagellusacarne, (c) Blackspot seabream Pagellusbogaraveo, (d) Common Pandora Pagelluserythrinus, (e) Cuttlefish Sepia officinalis, (f) Common Octopus Octopusvulgaris and, (g) Swordfish Xiphias gladius.4*

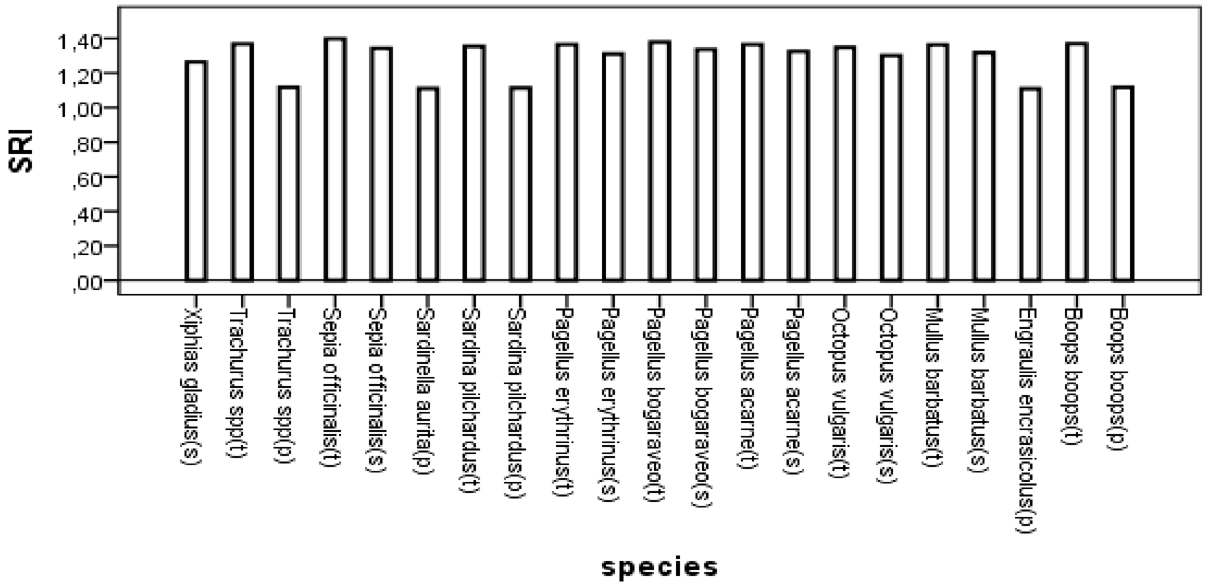

Figure 5. Mean SRIs by assessed species. (t): trawl fishery, (p): purse seine fishery, and (s): small-scale fishery

Evaluation of Algerian coastal fisheries and ecosystem indices based on estimated fisheries risk indices and ecosystem risk index: Estimation and comparison of fisheries risk indices FRIs, which are one of the most important indices in this research to interpret the fisheries risk conditions when many species are targeted by different fisheries.

Table 3. Fishery risk index (FRI), and ecosystem risk index (ERI) for the Algerian coastal ecosystemusing ecosystem-based assessment Tier02 approach

Fishery	FRI	ERI
Trawl	1.363	1.245
purse seine	1.114	
Small-scale	1.309	

From it can be seen that trawl, purse seine, and small-scale fisheries risk indices fell in the yellow zone. The lowest FRI value was observed in purse seine fishery at 1.114, while FRIs of small-scale and trawl fisheries were estimated at 1.309, 1.363 **respectively**

Box plots further illustrate the FRI's differences in (Figure.6). An analysis of variance was conducted and the difference of FRIs means was significant $P<0.05$. Post hoc analysis using Tukey-Kramer test, revealed that the mean FRI for purse seine

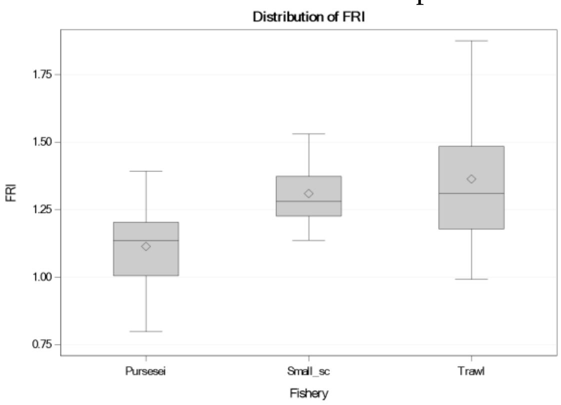

Figure 6. Box plot of FRI by trawl, purse seine, and small-scale fisheries.

was significantly different than the FRIs for small-scale and trawl fisheries $P<0.05$. However, the FRI of trawl fishery did not significantly differ from small-scale FRI mean.

Across the three assessed fisheries in the Algerian coastal ecosystem, the risk status of the assessed ecosystem was estimated at 1.245, which was projected in the yellow zone.

4. Conclusion

Evaluating fishing impact on ecosystem is critically necessary for implementing, correcting, and/or maintaining a proper management mechanism at the national, regional, and international level. There is a growing consensus about the need to assess and manage holistically fisheries resources. In the other hand, the measurability of indicators, the weakness of data, and the complexity of the system, became issues for scientists and decider makers.

Although trawl, purse seine, and small-scale fisheries are the main fishing pressure on the Algerian coastal ecosystem and target in different cases the same species.

The nested risk design was used to evaluate the risk conditions at different level; the first constituent are the indicators where the assessment was based on. Seven indicators related to sustainability were assessed for each fishery; the approach identifies the catch per unit effort (CPUE) as one of the most critical indicators of sustainability. The results showed that the risk score related to CPUE for all assessed species for the three assessed fisheries were beyond the limit. The others risk scores for indicators belonging sustainability were in the yellow zone for all species by fishery, except the indicator "rate of mature fish" for cuttlefish in small-scale fishery, where the risk exceeded the limit reference point. The biodiversity objective in this study lists two indicators namely 'discard rate' and 'diversity index', those indicators are based on the quantityof discarded fish and the change of dominant species. Four indicators were defined under the habitat quality objective. The socio-economic benefits included five indicators, most of their risk scores for all fisheries fell into yellow zone. The assessment of objective risk indices ORIs for nine exploited species by trawl showed that only the ORI biodiversity was in the desirable zone. Although sustainability, habitat quality, and socio-economic benefits objectives risk indices fell in the yellow zone, where the highest value of ORI was estimated at 1.78 for habitat quality objective, the evidence suggests that trawl-fishing gears have a high negative impact on the habitat. The ORI for sustainability and socio-economic were projected in the yellow zone for the fives assessed species in purse seine fishery, while ORIs for biodiversity and habitat quality were estimated at the green zone. It appears that the purse seine fishing gear has a low impact on habitat quality comparing to trawling. In small-scale fishery, only biodiversity fell into the green zone, while other objectives were in the yellow zone.

The present study suggests a useful alternative tool to evaluate the risk situation for the main fisheries operating on the Algerian continental shelf through EBFA Tier2 approach based on the overlaps target species among the fisheries. Trawl, purse seine, and small-scale fisheries risk indices were projected in the yellow zone. The importance of the fisheries risk indices in interpreting the fishing system status led to compare carefully the obtained indices among fisheries. The highest FRI were observed in trawl fishery (1.363), followed by the small-scale fishery (1.309), then the lowest value was found in the purse seine fisheries (1.114). The purse seine fishery risk index differed significantly from both of trawl and small-scale fisheries risk indices, whereas there was no significant difference between trawl and small-scale fisheries risk index.

The results could be a benchmarks for evaluating the fisheries risk situations and the management effectiveness. The future work should, therefore, shift to Tier1 approach analysis, either progressively by incorporating the available data for some selected indicators. In addition, the next assessment should be oriented to include other activities taking place in and around the ecosystem, particularly when the assessed ecosystem is defined as an inshore area.

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