

Discarded Biomass in the Moroccan Mediterranean Trawl Fisheries: Species Composition Dynamics and Spatio-Temporal Analysis

Sana El Arraf^{1,2*}, Mohammed Malouli Idrisi¹, Paolo Carpentieri³, Jilali Bensbai⁵, Anas Yassir⁵, Najib El Ouamari⁶, Mohammed Bakkali², Maryam El Bakali⁴

¹National Institute of Fisheries Research, Tangier, Morocco

²Faculty of Science and Technology of Tangier, Abdelmalek Essaâdi University, Morocco

³General Fisheries Commission for the Mediterranean, Food and Agriculture Organisation of the United Nations, Rome, Italy

⁴Polydisciplinary Faculty of Larache, Abdelmalek Essaâdi University, Morocco

⁵National Institute of Fisheries Research, Casablanca, Morocco

⁶National Institute of Fisheries Research, Nador, Morocco

*Corresponding Author: elarraf@inrh.ma, sana.elarraf@gmail.com

ARTICLE INFO

Article History:

Received: July 21, 2024

Accepted: Aug. 19, 2024

Online: Sep. 1st, 2024

Keywords:

Morocco,
Mediterranean Sea,
Trawl fishery,
Fishery discards,
Discard ratio

ABSTRACT

Fisheries discards in the Moroccan Mediterranean Sea present a significant challenge at the intersection of marine resource management and societal concerns. Bottom trawl fisheries, which involve dragging nets along the seabed, capture a wide array of marine species, many of which are subsequently discarded. This study offers the first comprehensive analysis of discard composition from Moroccan trawl fleets, drawing on data collected from 2019 to 2022 through an onboard sampling program. Among the 103 species from 59 families discarded, 16 were elasmobranchs and 88 were bony fishes. Discarded biomass showed significant variation based on season, fishing areas, and their interaction, with discard ratios ranging from 1.06% to 43.7%. Teleostei made up the predominant fraction of discarded biomass, followed by Elasmobranchii, Thaliacea, and Holocephali. The study found significant variations in mean biomass values across different ports and seasons, highlighting dynamic patterns in biomass distribution among marine classes. However, the number of species recorded in discards remained stable across ports and seasons, indicating consistent environmental conditions. The findings underscore the need for targeted fishery management measures to minimize the ecological impacts of discards, tailored to specific times and locations.

INTRODUCTION

The bottom trawl fisheries in the Mediterranean Sea caught a varied mix of fish and invertebrates, with a noteworthy amount of discards (Tiralongo *et al.*, 2021), constituting approximately 23% of the total catches. This poses a significant challenge in fisheries management (Guillen *et al.*, 2018). Discards represent a loss of natural resources and

negatively affect the sustainability of fisheries. Essential information on discards, such as species diversity and size, is crucial for better managing trawl fisheries (**Blanco *et al.*, 2023**).

The practice of discarding in fishing operations involves the disposal of unwanted sections of the catch back into the sea. This process includes discarding non-commercial and commercial species that do not meet minimum landing size requirements or have reduced economic value due to market conditions and quota limitations (**Catchpole *et al.*, 2005**). Discards are the part of the total catch brought on board but returned to the sea, dead or alive, for different reasons including economic, legal, or personal considerations. These discards, whether alive or dead organisms, represent a portion of the total catch that is returned to the marine environment, influenced by various factors such as economic considerations, regulatory compliance, and individual preferences. Typically, discarded species may lack commercial interest or comprise valuable species unsuitable for sale, such as undersized or damaged individuals. This practice is notably prevalent in trawl fisheries and significantly impacts ecosystem dynamics (**Sanchez, 2004; Bellido *et al.*, 2011**). Such a high percentage of species caught by trawlers compared to other types of fishing fleet has been previously described in the study area, particularly for vulnerable species (**El Arraf *et al.*, 2024**).

In addition to the decreasing trend in the total catch of trawls fisheries (ranging between 3178 and 10587t) operating in the Moroccan Mediterranean region (**INRH, 2019**), various factors affect the practice of discarding, with environmental, biological, and behavioral reasons playing a significant role in discarding practices as they influence catch composition. These factors include changes in species distribution over time and space, the presence of non-target species, fishers' abilities to reduce bycatch, the strength of different age classes, the demographics of exploited populations, and the interactions among other species in the catch (**Rochet & Trenkel, 2005**). Additionally, practical constraints such as limited onboard storage capacity can result in selective retention of commercially valuable species (**FAO, 2019**).

Fisheries discarding data play a crucial role in providing biological insights into regions not extensively covered by scientific surveys, offering valuable information on the health and structure of marine ecosystems (**Borges *et al.*, 2005**). Moreover, these data help identify the characteristics and behaviors of specific fishing fleets, including understanding the types of gear used, the species targeted, and the practices that lead to high levels of discarding. These valuable insights are crucial for formulating specific management approaches to minimizing discards and advancing sustainable fishing practices. The discarded data collection and analysis are vital for informing and improving fisheries management, ensuring the long-term sustainability of marine resources, and maintaining the health of our oceans (**Robert *et al.*, 2019; Suuronen & Gilman, 2020**).

The Moroccan Mediterranean region, situated within the FAO-GFCM GSA 3 sub-area, offers an ideal environment for examining discards owing to its ecological diversity and intricate oceanographic phenomena. Despite these favorable characteristics, this region lacks significant knowledge regarding discard dynamics. Our study aimed to fill this knowledge gap related to discards. Therefore, the goal of this study was to investigate, characterize, and analyze the spatiotemporal variations of discards generated by the bottom trawling and pelagic fishing activities along the Moroccan Mediterranean coast. In the context of this research, the term "discards" refers to the portion of the overall catch discarded into the sea by fishermen during the sorting and preparation stages before commercialization.

MATERIALS AND METHODS

1. Study area and data collection

The study area covers the Moroccan Mediterranean coast, extending around 512Km from Cap Spartel (5°50W) to Saidia (2°17W) (southwestern coast of the Mediterranean Sea; Geographical Subareas 3 of the FAO General Fishery Commission for the Mediterranean) (Fig. 1). The sampling was conducted on the bottom trawlers at three distinct fishing areas: M'diq, Al Hoceima, and Nador. From 2019 to 2022, monthly observations were systematically performed by onboard observers on commercial trawlers. Following the sampling scheme in the GFCM discards Monitoring Guideline (FAO, 2019), sixteen observers were selected for monitoring commercial fishing activities by collecting and recording at-sea data. The recording of various parameters data for selected fleet segments such the discards and landings composition (number and weight per specie) took place throughout each sampling fishing trips. This documentation occurred after the completion of fishing operations and catch sorting without interference with the crew during sampling. For each tow, specific information, such as the duration of the tow, the depth at which hauling occurred, and the geographic coordinates, were recorded. The total number of vessels per sampling port account for the 433 boats. The trawling boats working close to the coast carried out an average of 2 days per fishing trip. Bottom trawls represent 37% of the total fishing effort.

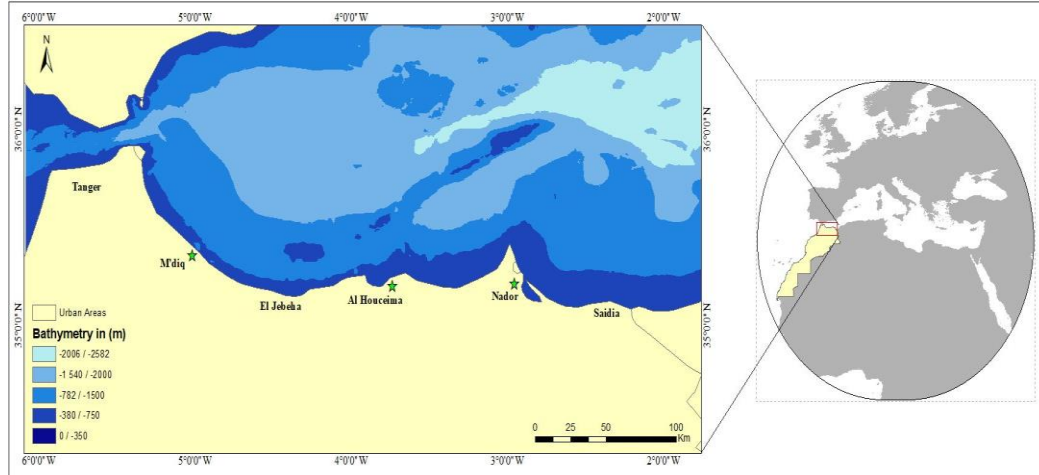


Fig. 1. Map of the study area in the map with the three investigated ports in green star

Based on the sampling designs used, the total number of observations and questionnaires carried out in each port are shown in Table (1). The observations were made on the 3 important ports: M'diq, Al Hoceima and Nador.

Table 1. Sampling effort deployed at the monitored ports during the study period

Area	Nb of Vessels	Nb of onboard fishing observations	Nb of questionnaires
M'diq	28	212	306
Al Hoceima	18	355	411
Nador	56	216	289
Total (GSA03)	162	783	1006

2. Data analysis

During fishing operations, discarded species were quantified and identified at the lowest possible taxonomic level by experienced scientific observers on board. This meticulous approach enables a detailed analysis of the composition of discarded species and their impact on the marine ecosystem. We categorized species according to their occurrence frequencies as follows: very frequent (VF) if present in over 70% of the samples, frequent (F) when ranging from 40 to 69.9%, little frequent (LF) between 20 and 39.9%, and occasional (O) if occurring in less than 19.9% of the samples (**Branco *et al.*, 2015**).

According to the GFCM protocol (**FAO, 2019**), the discard ratio (%) for each species during a fishing trip can be determined as the sum of the total landed quantity (kg and) of discarded fish divided by the total quantity caught (i.e. retained + discarded):

$$\text{Discards ratio (\%)} = \frac{\text{discards}}{\text{discards} + \text{landings}} \times 100$$

We utilized two-way factors ANOVA or Kruskal-Wallis test to analyze the total weight and discard ratio variation across fishing areas and seasons, along with Tukey post-hoc test on logarithm-transformed data or Dunn post-hoc test. Before these analyses, we verified the normality and homoscedasticity of the data using the Shapiro-Wilk and Bartlett tests, respectively. We classified the discarded species into distinct classes. Then, two-way crossed ANOVA was used to investigate the effect of fishing areas and season on biomass among these groups. Furthermore, an ANOVA test was applied to test variations in species numbers across seasons and fishing zones, with a significance level set at 5%. All statistical procedures were conducted using R 4.3.3.

The Bray-Curtis similarity index was calculated based on species occurrence between fishing operations. ANOSIM was used to examine variations in discard species composition among different fishing areas, with SIMPER employed to identify the key species driving these significant differences. The comparison of discarded species occurrence similarity among the three fishing areas was examined through SIMPER analyses, utilizing the PAST 4.13 software.

RESULTS

In the discarded faunistic groups, the ichthyofauna comprised four classes, namely Teleostei, Elasmobranchii, Thaliacea, and Holocephali, encompassing a total of 103 species from 59 families, including 16 elasmobranchs and 88 bony fishes. All species were occasionally observed during fishing operations, except for the bony fish *Trachurus trachurus*, which occurred with a little frequency (Lf) in the fisheries at Al Hoceima. The taxonomic classification of bony fish (the most representative) encompassed 88 species distributed among 72 genera and 50 families. The Sparidae family, with the highest number of recorded species (16) demonstrated notable species diversity but exhibited consistently low occurrence frequencies across all surveyed fishing areas (Table 1). Following the Sparidae, the families with the next highest species diversity included Macrouridae, Ophichthidae, Scorpaenidae, and Torpedinidae, each with four species recorded.

Table 2. List of discarded fish species, with their frequencies of occurrence in three distinct fishing areas, throughout the research period (2019-2022). VF: very frequent; F: frequent; LF: little frequent; O: occasional

Class	Family	Species	M'diq	Al Hoceima	Nador
Elasmobranchii	Dalatiidae	<i>Dalatias licha</i>	-	O	O
	Etmopteridae	<i>Etmopterus sp</i>	O	-	-
		<i>Etmopterus spinax</i>	O	-	-
	Oxynotidae	<i>Oxynotus centrina</i>	O	O	O
	Pentanchidae	<i>Galeus atlanticus</i>	O	-	-
		<i>Galeus melastomus</i>	O	-	-
	Rajidae	<i>Dipturus oxyrinchus</i>	O	-	O
		<i>Raja asterias</i>	-	O	O
		<i>Raja naevus</i>	-	-	O
	Scyliorhinidae	<i>Scyliorhinus canicula</i>	O	O	O
		<i>Scyliorhinus sp</i>	O	-	-
		<i>Scyliorhinus stellaris</i>	O	O	O
	Torpedinidae	<i>Tetronarce nobiliana</i>	-	O	-
		<i>Torpedo marmorata</i>	O	O	O
		<i>Torpedo nobiliana</i>	O	-	O
Torpedo	<i>Torpedo torpedo</i>	O	-	-	
Holocephali	Callorhynchidae	<i>Callorhynchus</i>	-	-	O
		<i>callorhynchus</i>			
	Chimaeridae	<i>Chimaera monstrosa</i>	O	-	O
Teleostei	Alosidae	<i>Alosa fallax</i>	-	O	O
		<i>Sardina pilchardus</i>	-	O	O
	Argentinidae	<i>Glossanodon</i>	-	-	O
		<i>leioglossus</i>			
	Belonidae	<i>Belone belone</i>	-	-	O
		<i>Blennius ocellaris</i>	-	O	O
	Blenniidae	<i>Parablennius</i>	-	-	O
		<i>sanguinolentus</i>			
	Callanthiidae	<i>Callanthias ruber</i>	-	-	O
	Caproidae	<i>Capros aper</i>	O	O	O
<i>Trachurus</i>		-	O	-	
Carangidae	<i>mediterraneus</i>				
	<i>Trachurus picturatus</i>	-	-	O	
	<i>Trachurus trachurus</i>	O	LF	O	

Discarded Biomass in the Moroccan Mediterranean Trawl Fisheries

	Carapidae	<i>Carapus acus</i>	-	0	0
	Centriscidae	<i>Macroramphosus scolopax</i>	0	0	0
	Cepolidae	<i>Cepola macrophthalma</i>	-	0	0
	Citharidae	<i>Citharus linguatula</i>	-	0	0
	Congridae	<i>Conger conger</i>	0	0	0
		<i>Gnathopis mystax</i>	-	0	0
	Cynoglossidae	<i>Cynoglossus canariensis</i>	0	-	-
		<i>Symphurus nigrescens</i>	0	0	0
	Dorosomatidae	<i>Sardinella aurita</i>	-	0	-
		<i>Sardinella maderensis</i>	-	-	0
	Engraulidae	<i>Engraulis encrasicolus</i>	-	0	0
	Epigonidae	<i>Epigonus constanciae</i>	-	-	0
		<i>Epigonus denticulatus</i>	-	-	0
	Gadidae	<i>Gadiculus argenteus</i>	0	-	0
	Gobiesocidae	<i>Diplecogaster ctenocrypta</i>	-	-	0
	Gobiidae	<i>Gobius niger</i>	-	0	0
		<i>Lesueurigobius friesii</i>	-	0	0
	Ipnopidae	<i>Bathypterois dubius</i>	-	-	0
	Lophiidae	<i>Lophius budegassa</i>	-	-	0
Teleostei		<i>Lophius piscatorius</i>	-	0	0
	Lotidae	<i>Gaidropsarus vulgaris</i>	-	-	0
		<i>Caelorinchus labiatus</i>	-	-	0
		<i>Coelorinchus caelorhincus</i>	0	0	0
	Macrouridae	<i>Nezumia sclerorhynchus</i>	0	-	0
		<i>Trachyrhynchus trachyrhynchus</i>	-	-	0
	Merlucciidae	<i>Merluccius merluccius</i>	-	0	-
	Molidae	<i>Mola mola</i>	0	-	0
		<i>Mola tecta</i>	-	-	0
	Moridae	<i>Lepidion lepidion</i>	-	-	0
	Mullidae	<i>Mullus barbatus</i>	0	0	0
		<i>Mullus surmuletus</i>	-	0	0
	Myctophidae	<i>Benthoosema glaciale</i>	-	-	0
	Myctophidae	<i>Lampanyctus crocodilus</i>	-	0	0
		<i>Notoscopelus elongatus</i>	-	-	0

	Nettastomatidae	<i>Nettastoma melanura</i>	-	O	-
		<i>Apterichtus anguiformis</i>	O	-	-
	Ophichthidae	<i>Echelus myrus</i>	-	O	O
		<i>Ophichthus rufus</i>	-	O	O
		<i>Ophisurus serpens</i>	-	-	O
	Ophidiidae	<i>Ophidion barbatum</i>	O	-	-
	Peristediidae	<i>Peristedion cataphractum</i>	O	-	O
	Phycidae	<i>Phycis blennoides</i>	-	O	O
	Scophthalmidae	<i>Lepidorhombus whiffiagonis</i>	-	-	O
		<i>Scorpaena elongata</i>	-	-	O
	Scorpaenidae	<i>Scorpaena notata</i>	O	-	-
		<i>Scorpaena scrofa</i>	-	O	O
		<i>Scorpeana elongata</i>	O	O	-
	Sebastidae	<i>Helicolenus dactylopterus</i>	O	-	-
	Serranidae	<i>Serranus hepatus</i>	-	O	O
		<i>Pegusa lascaris</i>	-	O	-
	Soleidae	<i>Solea solea</i>	-	O	O
		<i>Solea sp</i>	-	O	-
	Sparidae	<i>Boops boops</i>	-	O	O
		<i>Dentex dentex</i>	-	O	-
Teleostei		<i>Diplodus sargus</i>	-	O	-
		<i>Diplodus vulgaris</i>	-	O	-
		<i>Lithognathus mormyrus</i>	-	O	-
	Sparidae	<i>Pagellus acarne</i>	O	O	-
		<i>Pagellus bellottii</i>	-	O	-
		<i>Pagellus bogaraveo</i>	O	O	-
		<i>Pagellus erythrinus</i>	-	O	-
		<i>Pagrus pagrus</i>	-	O	-
	Sternoptychidae	<i>Maurolicus muelleri</i>	O	-	-
	Stomiidae	<i>Chauliodus sloani</i>	-	-	O
	Trachichthyidae	<i>Hoplostethus mediterraneus</i>	O	O	O
	Trachinidae	<i>Trachinus araneus</i>	-	O	O
		<i>Trachinus draco</i>	-	O	O
	Trichiuridae	<i>Lepidopus caudatus</i>	O	-	O

Discarded Biomass in the Moroccan Mediterranean Trawl Fisheries

	Triglidae	<i>Aspitrigla obscura</i>	-	-	O
		<i>Chelidonichthys cuculus</i>	-	O	-
	Uranoscopidae	<i>Uranoscopus scaber</i>	-	-	O
	Zeidae	<i>Zeus faber</i>	O	O	O
Thaliacea	Salpidae	<i>Salpa fusiformis</i>	-	-	O
		<i>Salpa maxima</i>	O	-	-

Discarded biomass showed significant variation impacted by season, fishing areas, and their interaction. Notably, there was a significant decrease observed in spring compared to the other seasons, as well as within the Al Hoceima fishing areas (Two-way ANOVA, season: $F=14.33$, $df=3$, $P<0.001$; fishing areas: $F=498.26$, $df=2$, $P<0.001$; interaction: $F=11.45$, $df=6$, $P<0.001$). Furthermore, significant variations were observed between M'diq-Al Hoceima ($P<0.001$) and Nador-M'diq ($P<0.001$, Fig. 2).

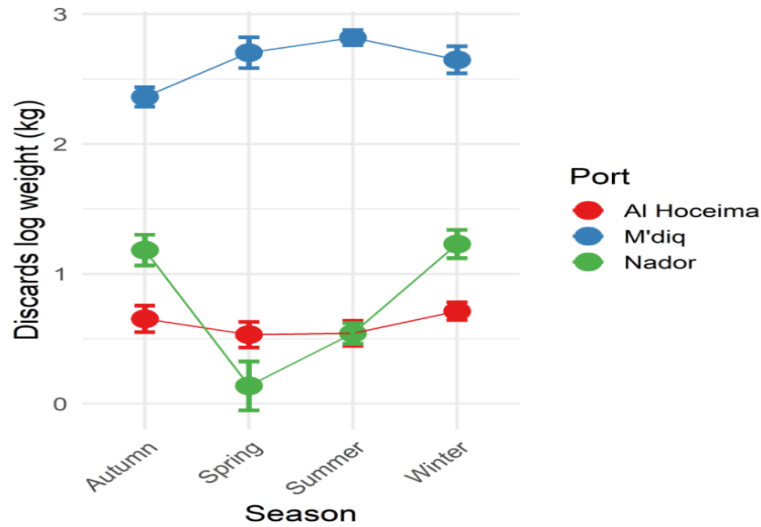


Fig. 2. Average value and standard error of discards (considered as log weight in kg) per season in the 3 areas of the study

Overall, the discard ratio ranged between 1.06 and 43.7%, with no significant seasonal variation in discard rates observed (ANOVA, $F = 0.242$, $df = 3$, $P = 0.865$), with winter having the highest value ($20.4 \pm 8.33\%$). However, there was a notable variation among areas (ANOVA, $F = 9.875$, $df = 3$, $P < 0.01$), with the M'diq region showing the

highest discard ratio at $30.2 \pm 5.51\%$. Pairwise comparisons using the Tukey test indicated a significant difference only between Al Hoceima and M'diq ($P = 0.004$) (Fig. 3). These findings underscore the significance of considering port-specific factors when evaluating discard rates in fisheries management and conservation contexts.

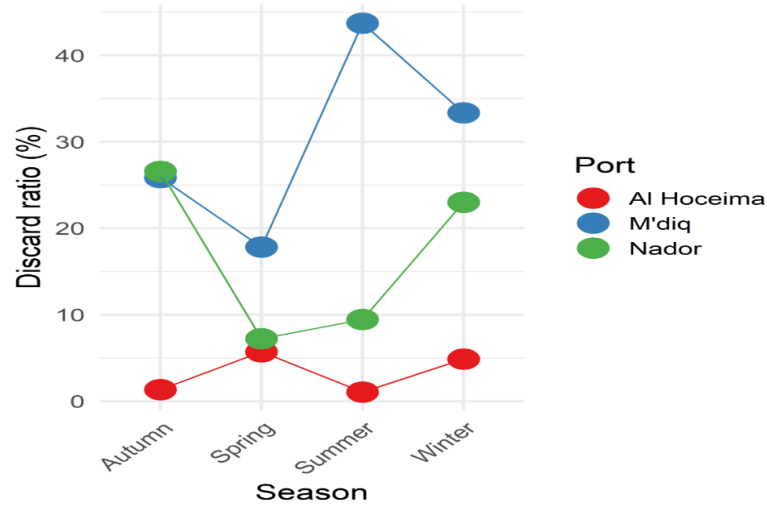


Fig. 3. Average value of discard ratio per season and area

Teleostei dominated the discarded biomass across seasons, accounting for 56% of the total, with significant seasonal fluctuations—peaking at 5kg in summer and dropping to 0.5kg in spring. Similarly, across different ports, Teleostei had the highest biomass, averaging 7.5kg at M'diq, while Thaliacea recorded the lowest biomass at 6.25kg, also at M'diq, highlighting significant area-specific and seasonal variations.

Discarded Biomass in the Moroccan Mediterranean Trawl Fisheries



Fig. 4. The discarded biomass (kg) of the different classes per season and fishing area

The discarded biomass of the different classes varied significantly across both seasons and areas, with noteworthy significance observed for Teleostei, Elasmobranchii, and Thaliacea (two-way ANOVA: $P < 0.001$; Table 3). In contrast, Holocephali showed significant variation only with respect to season (two-way ANOVA: $P < 0.05$; Table 3).

Table 3. Effects of season and fishing areas on discarded classes biomass: Two-way ANOVA findings

Variable	Class	Factor	df	Sum sq.	Mean sq.	F value	P	Sig.
Biomass	Teleostei	Season	3	84	27.9	12.66	3.46e-08	***
		Port	2	1593	79605	361.43	< 2e-16	***
		Season* Port	6	160	26.6	12.06	2.54e-13	***
		Residuals	1758	3874	2.2			
		Season	3	21.2	7.06	4.236	0.00556	**
		Port	2	531.5	265.74	159.481	< 2e-16	***
	Elasmobranchii	Season* Port	6	37.4	6.23	3.740	0.00113	**
		Residuals	752	1253	1.67			
		Season	3	8.93	2.977	2.846	0.04342	*
		Port	1	0.10	0.096	0.092	0.76252	

Thaliacea	Season*	2	15.73	7.865	7.518	0.00107	**
	Port						
	Residuals	73	76.37	1.046			
	Season	3	34.52	11.506	22.95	0.001092	**
	Port	1	18.48	18.485	36.87	0.000906	***
	Residuals	6	3.01	0.501			

Significance levels: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

The diversity of discarded species ranged from 15 to 43, with no significant differences among ports (ANOVA, $F = 1.762$, $df = 2$, $P = 0.226$) or seasons (ANOVA, $F = 0.22$, $df = 2$, $P = 0.88$) (Fig. 5).

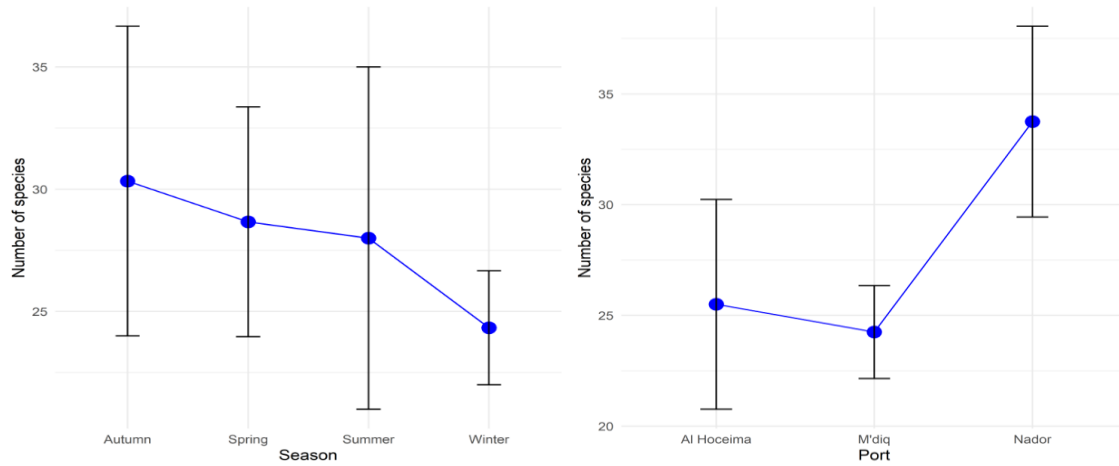


Fig. 5. Average value and standard error of total number of species per season and per fishing area

Although Nador had a higher average of discarded species (34) compared to M'diq (24) and Al Hoceima (26), these differences were not statistically significant, indicating similar biodiversity levels across ports. Seasonal variations in discarded species numbers were also minimal, with autumn (30), spring (29), summer (28), and winter (24) showing stable environmental conditions.

As revealed by the SIMPER analysis, the key species contributing significantly to the dissimilarities between fishing areas included *Coelorinchus caelorhincus* (9.40%), *Trachurus trachurus* (8.98%), *Conger conger* (8.79%), *Scyliorhinus canicula* (8.13%), *Hoplostethus mediterraneus* (5.87%), *Capros aper* (5.81%), *Torpedo marmorata* (5.43%) and *Etmopterus spinax* (5.36%) (Table 4), with an average dissimilarity of these fishing areas (91.6%). In the comparison between Al Hoceima and Nador, the primary species driving the distinctions were *T. Trachurus* (13.66%), *C. conger* (11%), *S.s canicula*

Discarded Biomass in the Moroccan Mediterranean Trawl Fisheries

(10.27%), *C. caelorhincus* (7.94%), *T. marmorata* (7.58%), and *C. aper* (7.29%). Regarding the differences between M'diq and Nador, the predominant species were *C. caelorhincus* (10.35%), *S. canicula* (9.32%), *C. conger* (9.037%), *E. spinax* (7.49%), *H. mediterraneus* (7.38%), and *C. aper* (6.96%). The SIMPER analysis also indicated the species that contributed the most to the distinction of the two fishing areas Al Hoceima and M'diq were *T. Trachurus* (12.44%), *C. caelorhincus* (9.74%), *E. spinax* (7.99%), *H. mediterraneus* (6.96%), *C. conger* (6.56%), *T. marmorata* (5.43%), and *C. aper* (7.29%). These findings emphasize the crucial species that play a principal role in the variation of discard composition across the three fishing areas.

Table 4. SIMPER analysis: findings on discard species occurrence across fishing areas

Species	Average dissimilarity	Contribution %	Cumulative %	Mean M'diq	Mean Al Hoceima	Mean Nador
<i>Coelorhincus caelorhincus</i>	8.61	9.40	9.40	0.96	0.06	0.51
<i>Trachurus trachurus</i>	8.23	8.98	18.39	0.02	0.72	0.14
<i>Conger conger</i>	8.05	8.79	27.17	0.42	0.31	0.66
<i>Scyliorhinus canicula</i>	7.45	8.13	35.30	0.45	0.10	0.71
<i>Hoplostethus mediterraneus</i>	5.38	5.87	41.18	0.80	0.01	0.20
<i>Capros aper</i>	5.32	5.81	46.99	0.28	0.08	0.49
<i>Torpedo marmorata</i>	4.97	5.43	52.41	0.09	0.35	0.27
<i>Etmopterus spinax</i>	4.91	5.36	57.78	0.84	0.00	0.00

Fig. (6) shows the average values of alpha diversity indices in the fishing areas of Nador, M'diq and Al Hoceima. Our findings reveal significant differences in alpha diversity indices among the areas of Nador, M'diq, and Al Hoceima. Nador exhibited higher average species richness (n=72) and Shannon diversity index (3.17), indicating a more diverse ecosystem. M'diq had the highest evenness index (0.505), suggesting a more balanced species distribution. These results highlight species richness, diversity, and evenness across the three fishing areas, with Nador notably standing out for

its richness and diversity. ANOSIM analysis revealed significant disparities in discard species composition across fishing areas, emphasizing substantial differences in pairwise comparisons involving all fishing areas ($P= 0.0003$).

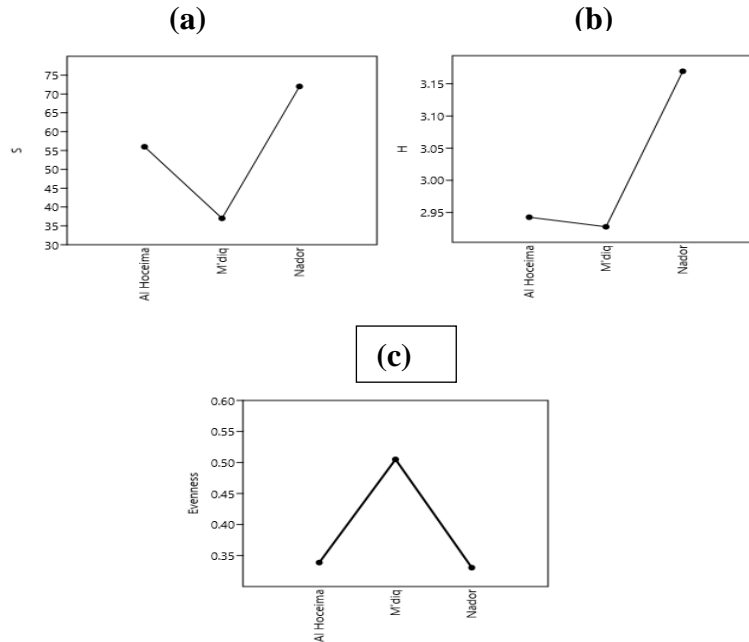


Fig. 6. Biodiversity metrics variation among the three fishing areas: (a) Species Richness, (b) Shannon Diversity and (c) Evenness

DISCUSSION

The present study analyzed the composition and quantity of discards from a multi-species trawl fishery in the Moroccan Mediterranean Sea, focusing on the fishing areas of M'diq, Al Hoceima and Nador over three years. The discarded fish fauna, including Teleostei, Elasmobranchii, Thaliacea, and Holocephali, confirmed significant biodiversity (**Briggs, 1960**). Bony fish (88 species) were more prevalent than elasmobranchs (16 species), consisting with global patterns. The Sparidae family (with 10 species) exhibited high species diversity despite low occurrence due to life history traits or incidental catches (**Tuapetel *et al.*, 2019**). This diversity highlights the broad impact of bottom trawl fisheries on marine ecosystems, capturing a wide range of species beyond the target catch.

Seasonal and spatial variations in discard biomass were significant, with a marked decline in spring, particularly in Al Hoceima area. These variations highlight the need to consider seasonal and geographical factors in fishery management to mitigate ecological impacts (**Casini *et al.*, 2009**; **Pennino *et al.*, 2014**; **Carbonell *et al.*, 2018**; **Shertzer *et al.*, 2019**). Considering these factors is crucial for effective management and minimizing

ecological effects (**Poisson *et al.*, 2014**). While this information can offer valuable insights into fish behavior and population patterns (**Gordoa *et al.*, 2006**), the complex interactions between season, fishing location, and discard biomass require further research (**Lewison *et al.*, 2009**). Furthermore, understanding these variations can aid in developing dynamic management approaches that adapt to changing environmental and fishing conditions.

The average discard ratio observed in this study was 16,67% lower than that reported for deep-sea trawl fisheries in the northwestern Mediterranean (**Sanchez, 2004**). Shallow-water trawl fisheries generally have higher discard ratios (**Sanchez, 2004; Tsagarakis *et al.*, 2024**), reflecting Mediterranean trends where discard rates vary widely across fisheries (**Fernandes *et al.*, 2015**). This high ratio is influenced by market forces and regulatory restrictions (**Fernandes *et al.*, 2015**) and is consistent with broader Mediterranean patterns where socio-cultural factors lead to higher discard rates (**Tsagarakis *et al.*, 2024**). Additionally, seasonal fluctuation was significant with discards peaking in autumn (89%), contrasting with higher discard ratios in spring reported in the Catalonia region of the northwestern Mediterranean Sea, particularly in shrimp fisheries (**Gorelli *et al.*, 2011**). Addressing discards in the Mediterranean trawl fisheries requires a comprehensive approach that considers these various factors (**Damalas *et al.*, 2018**). This includes regulatory measures, technological innovations in fishing gear, and better market incentives for utilizing previously discarded species.

Throughout the study, the species richness across fishing areas ranged from 37 to 72, with the Shannon diversity index (H) varying between 2.924 and 3.17 and the evenness index ranging from 0.33 to 0.50. Assessing the biodiversity within different fishing areas plays a crucial role in understanding ecological dynamics and developing effective management strategies (**Gatti *et al.*, 2020**). These indices highlight the ecological complexity and the need for specific management plans that address specific local conditions and more globally ecosystem considerations.

CONCLUSION

In conclusion, our research provides a comprehensive understanding of discard dynamics in Moroccan Mediterranean trawl fisheries, emphasizing the importance of considering seasonal and geographical variations for effective resource management. The dominance of the Teleostei class and the significant fluctuations in discard biomass across seasons and fishing areas highlight the need to incorporate these factors into management strategies (such as incorporating discard data into stock assessment processes). Additionally, the observed variations in discard composition among different areas reflect the complexity of marine ecosystems.

These findings underscore the need for tailored fisheries management approaches that consider seasonal and geographical variations to mitigate environmental impacts and

promote sustainability. By acknowledging the unique characteristics of each fishing ground and season, management strategies can be more effectively designed to address specific challenges and opportunities. These could include seasonal closures, zoning, gear modifications, or bycatch reduction devices to mitigate the capture of non-target species. Moreover, these insights provided by this study lay a solid groundwork for developing targeted policies and management strategies aimed at preserving marine biodiversity and supporting fishing communities reliant on these resources.

Effective management requires a holistic approach that considers ecological, economic, and social dimensions. This strategy will help ensure the long-term sustainability of marine ecosystems and the livelihoods of those who depend on them.

ACKNOWLEDGMENT

We are grateful to all observers for their diligent efforts to collect the data used in this report. Thanks also to all the officials of the Ministry of Agriculture, Marine Fisheries, Rural Development and Waters and Forests, the delegations of Marine fisheries for their crucial support to the project. The collaboration of all the stakeholders, fishermen and crews of the fishing vessels participating in the on-board observer programme is gratefully acknowledged. We thank the INRH staff of who responded to numerous assistance requests and were unfailingly helpful. A particular thanks to the General Fisheries Commission for the Mediterranean (GFCM) of the Food and Agriculture Organization of the United Nations (FAO) and we would like to thank the EU and the MAVA Foundation for fund raising this project.

The views expressed in this publication are those of the author(s) and do not necessarily reflect the views or policies of the Food and Agriculture Organization of the United Nations.

REFERENCES

- Bellido, J.M.; Santos, M.B.; Pennino, M.G.; Valeiras, X. and Pierce, G.J.** (2011). Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management? *Hydrobiologia.*, 670: 317–333.
- Blanco, M.; Nos, D.; Lombarte, A.; Recasens, L.; Company, J.B. and Galimany, E.** (2023). Characterization of discards along a wide bathymetric range from a trawl fishery in the NW Mediterranean. *Fish. Res.*, 258: 106552.
- Borges, L.; Zuur, A.F.; Rogan, E. and Officer, R.** (2005). Choosing the best sampling unit and auxiliary variable for discards estimations. *Fish. Res.*, 75: 29–39.

- Branco, J.O.; Freitas Júnior, F. and Christoffersen, M.L.** (2015). Bycatch fauna of seabob shrimp trawl fisheries from Santa Catarina State, southern Brazil. *Biota Neotrop.*, 15(2):1–4.
- Briggs, J.C.** (1960). Fishes of Worldwide (Circumtropical) Distribution. *Copeia.*, 1960 : 171–180.
- Carbonell, A.; García, T.; González, M.; Berastegui, D.Á.-; Mallol, S.; De La Serna, J.M.; Bultó, C.; Bellido, J.M.; Barcala, E. and Baro J.** (2018). Modelling trawling discards of the Alboran fisheries in the Mediterranean Sea. *Reg. Stud. Mar. Sci.*, 23: 73–86.
- Casini, M.; Hjelm, J.; Molinero, J.-C.; Lövgren, J.; Cardinale, M.; Bartolino, V.; Belgrano, A. and Kornilovs, G.** (2009). Trophic cascades promote threshold-like shifts in pelagic marine ecosystems. *Proc. Natl. Acad. Sci. U.S.A.* 106: 197–202.
- Catchpole, T.L.; Frid, C.L.J. and Gray, T.S.** (2005). Discards in North Sea fisheries: causes; consequences and solutions. *Mar. Policy.*, 29: 421–430.
- Damalas, D.; Ligas, A.; Tsagarakis, K.; Vassilopoulou, V.; Stergiou, K.I.; Kallianiotis, A.; Sbrana, M. and Maynou, F.** (2018). The “discard problem” in Mediterranean fisheries; in the face of the European Union landing obligation: the case of bottom trawl fishery and implications for management. *Medit. Mar. Sci.* 19: 459.
- El Arraf, S.; Malouli Idrissi, M.; Carpentieri, P.; El Bakali, M.; Nourredine, A. and Bakkali, M.** (2024). The bycatch estimate of threatened marine megavertebrates in Moroccan fleets operating in the Mediterranean Coast. *E3S Web Conf.*, 502, 01001.
- FAO.** (2019). Monitoring discards in Mediterranean and Black Sea fisheries: Methodology for data collection. *FAO Fish. Tech. Pap.*, No. 639. Rome.
- Fernandes, C.A.; Pérez, N.; Prista, N.; Santos, J. and Azevedo, M.** (2015). Discards composition from Iberian trawl fleets. *Mar. Policy.*, 53: 33–44.
- Gatti, C.R.; Amoroso, N. and Monaco, A.** (2020). Estimating and comparing biodiversity with a single universal metric. *Ecol. Modell.*, 424: 109020.
- Gordoa, A.; Lesch, H. and Rodergas, S.** (2006). Bycatch: complementary information for understanding fish behaviour. Namibian Cape hake (*M. capensis* and *M. paradoxus*) as a case study. *ICES J. Mar. Sci.*, 63: 1513–1519.
- Gorelli, G.; Blanco, M.; Sardà, F.; Carretón, M. and Company, J. B.** (2011). Spatio-temporal variability of discards in the fishery of the deep-sea red shrimp *Aristeus*

antennatus in the northwestern Mediterranean Sea: implications for management. *Sci. Mar.* 0.

Guillen, J.; Holmes, S.; Carvalho, N.; Casey, J.; Dörner, H.; Gibin, M.; Mannini, A.; Vasilakopoulos, P. and Zanzi, A. (2018). A Review of the European Union Landing Obligation Focusing on Its Implications for Fisheries and the Environment. *J. Environ. Sustain.*, 10: 900.

INRH. (2019). Rapport national sur la situation des stocks de petits pélagiques et leur exploitation au niveau de la zone marocaine a l'échéance 2019

Lewison, R.L.; Soykan, C. U. and Franklin, J. (2009). Mapping the bycatch seascape: multispecies and multi-scale spatial patterns of fisheries bycatch. *Ecol. Appl.*, 19: 920–930.

Pennino, G.M.; Muñoz, F.; Conesa, D.; López-Quílez, A. and Bellido, J.M. (2014). Bayesian spatio-temporal discard model in a demersal trawl fishery. *J. Sea Res.*, 90: 44–53.

Poisson, F.; Séret, B.; Vernet, A.L.; Goujon, M. and Dagorn, L. (2014). Collaborative research: Development of a manual on elasmobranch handling and release best practices in tropical tuna purse-seine fisheries. *Mar. Policy.*, 44: 312–320.

Robert, M.; Calderwood, J.; Radford, Z.; Catchpole, T.; Reid, D. G. and Pawlowski, L. (2019). Spatial distribution of discards in mixed fisheries: species trade-offs; potential spatial avoidance and national contrasts. *Rev Fish Biol Fisheries.*, 29: 917–934.

Rochet, M.J. and Trenkel, V.M. (2005). Factors for the variability of discards: assumptions and field evidence. *Can. J. Fish. Aquat. Sci.*, 62: 224–235.

Sanchez, P. (2004). Characterisation of the discards generated by bottom trawling in the northwestern Mediterranean. *Fish. Res.*, 67: 71–80.

Shertzer, K.W.; Williams, E.H.; Craig, J.K.; Fitzpatrick, E.E.; Klibansky, N. and Siegfried, K.I. (2019). Recreational sector is the dominant source of fishing mortality for oceanic fishes in the Southeast United States Atlantic Ocean. *Fish. Manage. Ecol.*, 26: 621–629.

Suuronen, P. and Gilman, E. (2020). Monitoring and managing fisheries discards: New technologies and approaches. *Mar. Policy.*, 116: 103554.

Tiralongo, F.; Mancini, E.; Ventura, D.; De Malerbe, S.; Paladini De Mendoza, F.; Sardone, M.; Arciprete, R.; Massi, D.; Marcelli, M.; Fiorentino, F. and Minervini, R. (2021). Commercial catches and discards composition in the central

Tyrrhenian Sea: a multispecies quantitative and qualitative analysis from shallow and deep bottom trawling. *Medit. Mar. Sci.*, 22: 521.

Tsagarakis, K.; Zupa, W.; Ligas, A.; Musumeci, C.; Tserpes, G. and Spedicato, M. T. (2024). Factors affecting the variability of discards in Mediterranean bottom trawl fisheries. *Fish. Res.*, 274: 106979.

Tuapetel, F.; Matruty, D.D. and Waileruny, W. (2019). Diversity of Demersal Fish Resources in Ambon Island Waters. *J Iktiologi Indones.*, 18: 223.