The Rich Get Stronger: The Purse Seine Fishery of the Turkish Straits System

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Abstract: Purse seiners generally try to maximize their revenues by targeting multiple species, starting with the most valuable ones available. The technology and capacity of purse seiners can be exceptionally high for the stocks found in the Marmara Sea, Turkey's only inland sea, due to its small size and nearly totally enclosed nature. Due to their large capabilities, they are responsible for the majority of catches and hence declines from this sea and thus should be held responsible for the poor state of marine stocks in the region. This study examines the catch compositions, expenses, and revenue sharing of purse seiners by using one representative vessel class for each of the four vessel length categories in the Marmara Sea. Surveys were also conducted with purse seine fishers to assess their perceptions related to fisheries management strategies along with their ideas for transitioning towards sustainable fisheries. As purse seiners are prominent stakeholders in the Marmara Sea fisheries, they should be incorporated into management guidance for effectiveness, along with other stakeholders. This study provides novel socio-economic data along with their perspectives, which may assist in improving policy decisions and capabilities. Our results demonstrate that purse seiners do not consider that their actions are a contributing factor to the current state of the fisheries, they trust in their amassed historical local knowledge, and seem to want to rebuild the resources, however only with minimal rules imposed on their sector.

Keywords: purse seine; fisher perception; management; legislation; Istanbul Strait; Marmara

1. Introduction

The Sea of Marmara, with a surface area of 11,500 km^2 and a total volume of 3378 km^3, is a semi-enclosed, small inland sea that connects to neighboring seas via two narrow straits: the Istanbul Strait (average 35 m depth, 31 km length, 1.6 km width) and Çanakkale (average 55 m depth, 62 km length, 4 km width) [1] and these three water bodies combined form the Turkish Strait System and General Fisheries Commission for the Mediterranean (GFCM) sub-area GSA28. Hence, when the Marmara Sea is mentioned, it includes its tributaries of the Istanbul and Çanakkale Straits. Both the Turkish Statistical Institute and GFCM data, also include the catches of the two straits when reporting catches from the Marmara Sea. When specifically discussing the sea without the two straits, we refer to the Sea of Marmara in this paper. Fishing practices contribute financially, culturally, and socially to almost all coastal communities surrounding the Marmara Sea, Turkey's only inshore sea [2]. The fisheries of the Marmara Sea are primarily dominated by purse seiners, which account for 90% of all fish catches from this sea [2], along with coastal fisheries targeting benthic/demersal species to a much lesser extent. The purse seine fisheries target pelagic fishes, systematically based on their seasonal migration patterns and periods. The migrating pelagics include Atlantic bonito (*Sarda sarda*), bluefish (*Pomatomus saltatrix*), Atlantic mackerel (*Scomber scombrus*), Atlantic horse mackerel (*Trachurus trachurus*), Mediterranean horse mackerel (*Trachurus mediterraneus*), sardine (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*). These pelagic stocks generally migrate from the Aegean

Sea, through the Sea of Marmara, the Istanbul Strait, to the Black Sea, and return the same way back to the Aegean Sea. These pelagics represent most of the shared stocks in the Aegean and Black Seas. Bluefish is currently the most important commercial pelagic species in this sea [3] due to its higher market price and systematic stock declines. The marine fisheries in the Marmara Sea are open-access commons, which expanded eight-fold in the last 50 years, peaking in 1999, then busting in 2009, and declining ever since to this day [4]. Fishery management problems are often iniquitous resulting from conflicts and complexities. Conflict can be defined as disagreements between different user groups regarding the control, access, and use of resources [5]. Along with the decrease in fish stocks, small and large-scale fishing sectors regularly conflict with each other in this region, especially due to the purse seiners' amplified capabilities to catch most of the migrating stocks. This highlights the importance of gaining further insight into the economics, perceptions, and management dynamics of the purse seine fishery examined in this study.
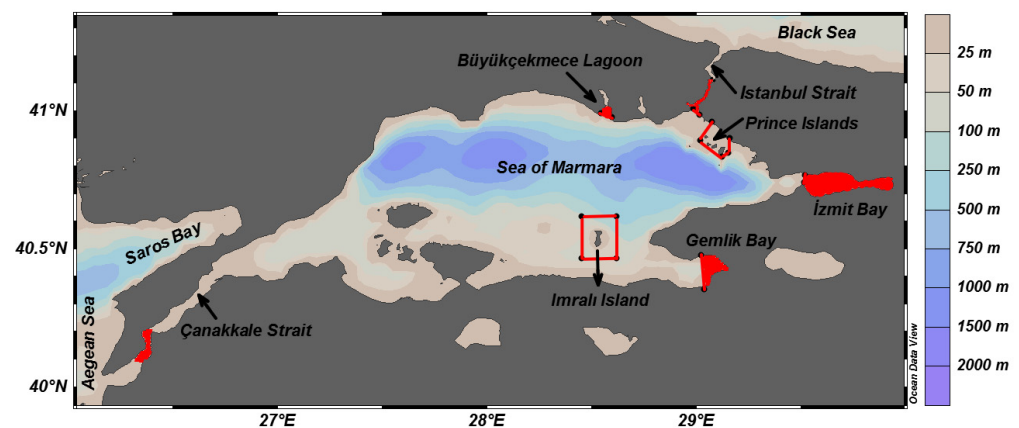
1.1. Purse Seine fisheries in the Marmara Sea

As of 2021, there were 203 purse seiners registered to ports in the Marmara Sea, with vessel lengths ranging from 15 to 62 m [4]. The total capacity of the Marmara Sea purse seine fleet is just over 14,000 GT and 65,000 kW [6] (Table S1). Most of these are concentrated in the eastern part of the sea, along with the migrating fish they target. This fleet is the fourth strongest purse seine fleet in the Mediterranean after the Turkish Black Sea fleet, the Algerian fleet, and the Greek fleet (Table S1). Much accumulated knowledge traditionally used and passed on by fishers sequentially got replaced by the modernization of their tools such as fish finders, along with specific information on the algorithms of currents, depths, locations of obstacles and wrecks, fish sizes, and fish school shapes and their movements. The commercial fisheries are seasonally closed from 15 April to 1 September each year in the Marmara Sea to benefit the spawning and reproductive periods of some important commercial stocks. Fishers know the seasonal availability of target species based on their experience (Table 1). A few areas, however, remain permanently closed to fishing (Figure 1). Purse seine vessels represent the highest share of "macro-enterprises", defined as commercial operations employing between 10 to 30 workers. Both tactical and strategic decisions are typically made by the owner/operator. Unlike some other fishing sectors, purse seine vessels do not cater to tourists in the closed season.

Table 1. Temporal seasonal target stock agenda of purse seiners in the Marmara Sea (structured within the knowledge of experienced purse seine fishers), with shaded grey areas indicating target seasons.

	January	February	March	April	May	June	July	August	September	October	November	December
Atlantic horse mackerel	▓	▓	▓	▓					▓	▓	▓	▓
Mediterranean horse mackerel	▓	▓	▓	▓					▓	▓	▓	▓
Atlantic bonito	▓	▓	▓						▓	▓	▓	▓
Bluefish	▓	▓	▓								▓	▓
European anchovy	▓										▓	▓

The national fishery management system applies a variety of management measures such as gear restrictions, seasonal and area closures, size limits, depth limits, and some gear specifications. The fisheries are under an open-access regime, with no catch limits [7]. As so, many conflicts arise between various fishing sectors, i.e., large-scale and small-scale fishers, and between commercial fishers and recreational fishers, mostly over sharing the same area, or same target species, aside from European anchovy and sprat that are exclusively caught by large-scale vessels. Many large-scale fishers also consider dolphins as competitors for fish [8,9] (Figure 2). These competition types affect everyone's catch efficiencies [10].

Figure 1. Permanently closed areas (in red) for purse seine fishing in Marmara Sea [7].
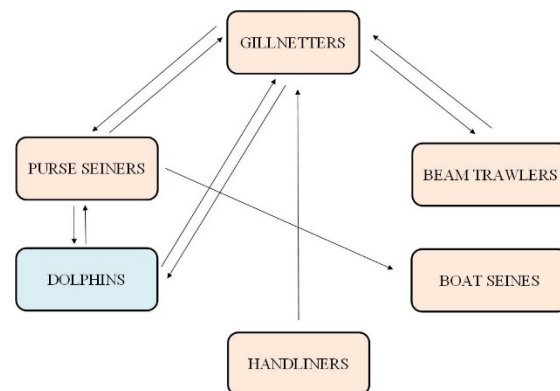
Figure 2. Conflicts between resource users in the Sea of Marmara [8,9]. The direction of the arrows displays the source of conflict.

1.2. Pressing Issues in the Marmara Sea

The coastal regions of the Marmara Sea have experienced notable anthropogenically created coastline alterations over the last few decades owing to a rapid increase in industrialization and urbanization [11]. The region also suffers from the dangers of heavy ship traffic, as well as domestic, agricultural, and industrial wastes [12], inorganic substances transported by rivers, and oil/waste pollution from occasional shipwrecks [13]. From a resource management perspective, Zengin [14] and Turan [15] stated that overfishing activities in the Marmara Sea have existed since 1988. A total catch limit to attain sustainable fisheries was advised to cap catches at 45,000 t in the Marmara Sea, with a maximum of 2247 operating fishing vessels [16]. However, when the statistical data are examined, the total catch amount was 50% higher in the early 2000s than the catch amount required to produce sustainable fisheries determined by Zengin and Mutlu [16], indicating excessive overfishing. Additionally, Alkan [17], Karakulak et al. [18], and Öztürk and Uzer [19] have expressed that illegal fishing is one of the main threats facing the environment and marine life in the Marmara Sea.

In terms of fisheries management, the public perception is that fishers seldom follow regulations, but rather direct the fishery by their own accords. Another threat facing this sea is that jellyfish have been gradually increasing in abundances [20], which consume zooplankton and hence, also contribute to the depletion of marine resources. Some fishers tried to battle the jellyfish/ctenophore infestations by developing jellyfish excluder devices by altering some purse seine nets [21]. According to Öztürk [22], non-indigenous species are increasingly found in the Sea of Marmara, but their overall impacts are not yet known. A new ecological crisis is from the mucilage (sea snot) formation that formed over large parts of the Marmara Sea in 2021 which blanketed and killed a lot of benthic

life [23], affecting all regional stakeholders in ecosystem integrity degradation, catch losses, reduced incomes [24], and higher fish prices [25]. Due to global warming, the average seawater temperature has also been increasing. Therefore, as an ecosystem, there are many concurrent stressors currently being inflicted, which combined have also contributed to decreasing catches in addition to pressure from overfishing [26].

1.3. Three Ongoing Debates

Many issues have been raised this century regarding the fisheries [27,28], and its management in the Marmara Sea as well as Turkey [29–31]. The stakeholders and public suggest that three main issues have not yet been adequately addressed by management but are of high importance to the Marmara Sea stakeholders as they are key regional challenges: (1) purse seine fishing in the Istanbul Strait; (2) the fishing depth limit for purse seiners; and (3) the minimum landing size of bluefish (*Pomatomus saltatrix*).

National awareness of fisheries sustainability is improving each year. This can be demonstrated from Table S2, which summarizes the various petitions addressing these issues on the famous online petition site- www.change.org (accessed on 14 September 2021), which are constantly on agendas of stakeholders and the public. Purse seine fishing in the Istanbul Strait is a highly controversial issue, mostly raised by small-scale fishery organizations, non-governmental organizations and citizens. Since Istanbul Strait is a narrow waterway, [1] many suggest that purse seiners equipped with their highly technologically advanced equipment leave very little escape potential for fish [32]. Many fishing vessels in the Istanbul Strait exert an intense amount of effort, and can also conflict with other ships in transit, especially in Beykoz Bay (Figure 3). In order to protect the inshore coastal zone, fishing < 24 m from the shore is closed to purse seiners. However, purse seine fishers claim that migratory species use the coastal area for migration and demand that this closed area to them be reduced to <18 m or even shallower [33]. The third issue is that bluefish minimum landing sizes are inadequate to preserve the spawning capable portion of stocks, which have long received attention from the public due to ongoing stock depletions.
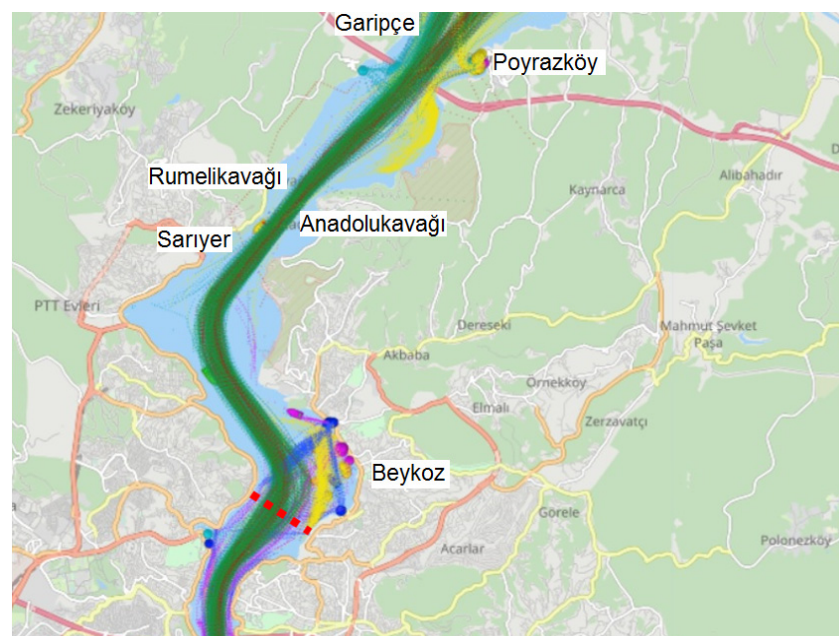
Figure 3. AIS tracks between 21 October 2021 and 26 October 2021 of different vessels in the portion of Istanbul Strait where purse seine fishing allowed (the dashed red line indicates that purse seine fishing is allowed in the north of this line). Green, red, yellow, blue, and purple tracks indicate cargo ships, tankers, fishing vessels, passenger ships, and other vessel types, respectively (Source https://www.myshiptracking.com/, accessed on 27 October 2021).

The most affected sectors by the changes in the Marmara Sea ecosystem are the fisheries sectors [2] since they are fully dependent on it. They are also directly responsible for both the deterioration of biodiversity and the decline in fish stocks [34]. Healthy marine biological resources are intricately tied to human health, but although renewable, their extraction needs to be controlled in order to be sustainable [35]. Open-access fisheries and increasing population abundances put far too much pressure on the resources, resulting in inequities. Understanding fisher behaviors is especially important in the context of changing seas to help fishers adapt to shifting management approaches towards sustainable or ecosystem-based fisheries [36–38]. Governance is a challenge due to the open-access regime and multi-species approach used by most industrial fisheries. Additionally, there is a strong illegality component that plagues this industry and undoubtedly uncoils the effectiveness of some governance measures. Thus, both the industrial sectors (political) strength and suggested certain manipulative behavior types tend to circumvent certain governance measures are part of the problem but can also be used as part of the solution to improve the state of this sea if they are respected as stakeholders and incorporated into management decisions.

The Marmara Sea was chosen as the study site due to its small, enclosed area, its high incidence of fishing activity and directed capacity, and its cumulative environmental concerns that are underrepresented in current research (see Pressing Issues in Marmara Sea). Other similar directed research in this sea has been on the economics of the purse seine fisheries in Turkey [39,40], and the variables behind its regime shifts [41]. This is the first study to investigate the perceptions of purse seine fishers towards the fisheries and fisheries management tactics, and also investigates the economics of this fishery. Understanding the drivers and socioeconomics of this fishery is of high importance in developing effective management strategies as it is human behavior that is managed, and not the resources [42]. Transitioning towards sustainable fisheries is only possible under proper governance, and fisher's compliance towards them [43,44]. All fisher stakeholders, along with their perceptions should be integrated into designing more effective fisheries policies [36,45], which is a clear challenge as most stakeholders have conflicting views.

Noting the poor understanding of purse seine fleet dynamics, and their massive portion of catch contributions, it is imperative to understand their perceptions of the state of fisheries and socio-economic indicators to help shape the future management of resources. Specifically, for the first time, this study combines a few approaches to represent an unbiased snapshot of this fleet, to explain its spatial fishing effort, its socio-economic state, and its perception of management measures, along with some key issues that require resolution for the purse seine fishers in the Marmara Sea. Additionally, historical changes to the policy are reviewed to clarify the fundamental purposes behind policy developments.

2. Material and Methods

2.1. Purse Seine Vessel Classification

This part of the study consisted of three phases: first, purse seiners were classified into four categories based on their total vessel lengths (LOA). Then, one purse seine owner from each length category was surveyed in face-to-face interviews to learn the basic characteristics of the main vessel categories. The details of their vessels, fishing gear, and fishing gear companies were also investigated to better understand total costs incurred by fishers.

2.2. Fishing Fleet Cost-Benefit Analysis

The annual catch tonnage per vessel was obtained from fisher interviews conducted in 2021. Then, these values were verified by the intermediary marketing firms the vessels use to sell their fish, along with the amount of revenue the vessels earned by species. In addition, the same vessel owners were directly interviewed about their vessel expenditures (e.g., fuel, salaries, equipment).

2.3. Fisher Questionnaires

To understand purse seine fisher viewpoints, we conducted in-depth interviews with 25 "key-informant" purse seine fishers via face-to-face interviews between April and June 2021. The overall purpose was to obtain owner-operators feedback on current and possible proposed regulations pertaining to the purse seine fishery in the Marmara Sea. Each fisher was informed of the goals of the study. The fishers selected for the survey all consisted of currently active experienced purse seine owners/managers. All fishers represented one of the four categories of purse seine fishing in the region and belonged to local fishing cooperatives. Fishers agreed to participate in the study and provided consent to use their responses. Names however were not collected to retain some anonymity due to the controversiality of the subject matter. The questionnaire contained ten semi-structured questions and took approximately 15–20 min to complete. The questionnaire content was shaped based on current problems and issues facing the region in and in close proximity to the Marmara Sea. Questions were closed-ended and were grouped in thematic sections including questions on the existing measures and possible changes to regulations. Questions between Q1 and Q6 were dichotomous (Yes/No). All questions were asked in the same order to all respondents, starting with the easier questions. Each question required a reply for a completed survey.

2.4. Fishing Effort

Although the Turkish Ministry of Agriculture uses a fishing vessel tracking system, these data are not made available to external parties. Alternatively, the Global Fishing Watch (GFW) database, which provides publicly available fishing effort datasets was used to evaluate the effort the purse seine fleet exerts in the Sea of Marmara and Istanbul Strait over one season. Global Fishing Watch's map displays fishing vessel type, activity, and tools to help monitor global fishing patterns [46] based on vessel tracking data. The Mediterranean and Black Sea workspace of Global Fishing Watch is a map-based visualization showing fishing effort data using data layers such as no fishing areas. Vessel tracking and satellite imagery datasets differ in how, when, where, and which vessels can be presumed to be fishing. For vessel tracking datasets—AIS and VMS—Global Fishing Watch uses a machine learning approach similar to our vessel classification model to identify where and when a vessel is fishing based on its movement patterns [46]. After harvesting and preprocessing each dataset, GFW applies a variety of algorithms and machine learning models to monitor the activity of fishing vessels at sea. To identify fishing vessels, GFW combines the comprehensive vessel registry database with the predictions from a machine learning model to classify vessels into one of 40 vessel categories, for example purse seiner, trawler, and long-liner. Using these analytics, the amount of fishing effort in the Sea of Marmara and Istanbul Strait was calculated between 2013 and 2021.

2.5. Historical Policy Changes

All national management regulations were investigated to determine the sequential development of the purse seine fishery regulations specifically pertaining to the depth limits, limit of overall drop and length of purse seine nets and purse seining activities in the Istanbul Strait, a subject that has been under constant debate for years.

2.6. Limitations

Common limitations of the approaches used here need to be considered. An initial mistrust of reporting true catch amounts and disclosing financial details were occasionally sensed. Contacting operators/owners during their fishery closed season was highly challenging, and during the open season was also challenging as vessels spend little time in ports. In addition, many owners/operators approached for interviews did not consent to taking part in this study. The number of desired surveys therefore could not be reached. Instead, only a total of 25 surveys with purse seine owners/operators were conducted.

2.7. Statistical Analyses

A Kruskal–Wallis test was used to compare catch amounts since the groups did not have normally distributed data (*p*-value < 0.05). To compare catch compositions, all species landed by sampled vessels were structured in a matrix using the Primer 6 statistical package program [47], with length category being the fixed variables (columns), and species the random variables (rows). Visualization of patterns was performed through cluster ordination based on BrayCurtis similarity. Then, by the same matrix, SIMPER (contribution of each species percentage to the dissimilarity between each group) and Similarity Profile (SIMPROF) were used to test for dissimilarities between length categories [47]. The statistical difference between the rates of fishing effort in the Sea of Marmara and the Istanbul Strait was determined by the χ^2 (chi-square) test [48]. For dichotomous questions in the fisher questionnaire, one proportional z test was applied to determine if the proportions of categories significantly differ from 50%.

3. Results

3.1. Vessel and Equipment Costs

It is well known that the technological components purchased for added to purse seine vessels can cost as much or even greater than the vessel itself (Table S3). The main engine, generators, and fishing nets are the most expensive investments on purse seine vessels, and purse seiners have more than one main engine regardless of their overall length and gross tonnage. Even the smallest vessel queried had vessel and gear costs > USD 375,000. The fact that vessels use different types of sonar for different distances shows how fundamental the use of fish finder devices is for this sector. The four length categories and their vessel characteristics of the purse seine fishing fleet are provided in Table 2, based on our purse seine fisher survey results.

**Table 2.** Four categories of purse seine vessels and their characteristics.

Vessel Code	LOA Category	Overall Length (m)	Beam Length (m)	Gross Tonnage (GT)	Horse Power (HP)	Number of Crew	Construction Year
A	>50 m	51.5	15.3	680	3200	27	2004
B	>40 m	42.0	11	415	2450	26	1989
C	>30 m	35.7	9	247	1980	30	1993
D	>20 m	28.0	8	111	935	30	1989

3.2. Catch Composition

The seasonal directed nature of purse seiners directly depends on the specific fish stocks they are targeting. Based on their local ecological and fish migration knowledge, fishers act strategically and diversify their operations as much as possible by focusing on multi-species in this small sea. Fishers tend to principally target Atlantic bonito and bluefish due to their higher values. However, it is important to note other species are commonly caught as by-catch such as turbot, which was recently placed under a catch quota system by the GFCM in the Black Sea. Landings were dominated by small pelagics, mostly sardine and European anchovy, followed by Atlantic bonito and bluefish. Demersal species represent a much smaller proportion of total landings but fetch higher market prices. Overall, 16 fish species were listed as target species and by-catch species (Table 3), highlighting the multi-specificity of the fishing activities in the region. The Kruskal–Wallis H test indicated an insignificant difference in catch amounts by vessels ($\chi^2(3) = 2.72$, $p = 0.437$). However, catch compositions were divided into two significant groups by the hierarchical cluster analysis using the SIMPROF test (Figure 4). Vessel A and B did not show significant differences ($\pi = 0$, $p = 1$). According to the SIMPER results, dissimilarities were higher than 10% in all cases, with the highest dissimilarities (28.85%) between vessels C and D, which were mainly represented by European anchovy (31.82%), sardine (11.28%), and Pontic shad (9.77%).

Table 3. Average annual catch totals by species per vessel length category for 2020 (in cases-c).

Fish Species Caught by Purse Seiners	Target or By-Catch	>50 m	>40 m	>30 m	>20 m
Atlantic bonito	Target	5975 c	8431 c	8301 c	6383 c
Large-sized Atlantic bonito	Target	5875 c	1648 c	38 c	184 c
Bluefish	Target	4603 c	764 c	2709 c	3390 c
European anchovy	Target	7956 c	6191 c	5393 c	-
Horse mackerel(s)	Target	7379 c	2445 c	1207 c	4769 c
Turbot	By-catch	-	-	1 c	3 c
Blotched picarel	By-catch	-	-	8 c	-
Brown meagre	By-catch	-	-	2 c	-
Mugilidae	By-catch	12 c	5 c	32 c	29 c
Striped red mullet	By-catch	-	2 c	13 c	30 c
Scorpionfish	By-catch	-	-	1 c	1 c
European seabass	By-catch	8 c	4 c	7 c	3 c
Tub gurnard	By-catch	-	-	1 c	-
Garfish	By-catch	-	1 c	2 c	-
Sardine	By-catch	-	-	20 c	-
Pontic shad	By-catch	-	6 c	-	13 c
Big-scale sand smelt	By-catch	-	1 c	-	-
Total		**31.808 cases**	**19.498 cases**	**17.735 cases**	**14.805 cases**
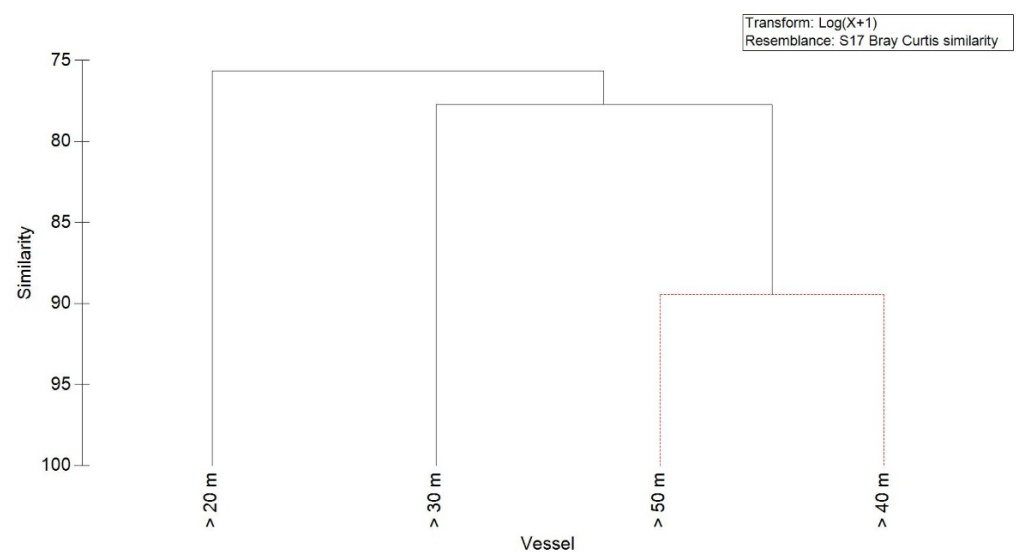
Figure 4. Hierarchical cluster dendrogram based on Bray-Curtis similarity: red dotted lines represent insignificant differences between vessel classifications by SIMPROF test.

Labor and other costs were not homogeneous (Table 4). Total sales did not correlate with the total vessel length and the gross tonnage of vessels. Among the expenses, the largest portion went to labor costs, which ranged from 57.2–84.6%, while fuel costs ranged from 17–32%. The remaining revenue allotted to the owner/captain was still a very high amount.

3.3. Interview Results

All interviews were completed in full, with clear answers, and free of errors. All fishers (100%) were males ranging from 18 to 75 years with a mean age of 50. Fishing experience ranged from three to 60 years with a mean of 32 years. Fishing was the sole source of household income for 100% of fishers, and they all fished on a full-time basis and only worked primarily on purse seine vessels. All respondents were the owner-operators of the purse seine vessel. All respondents targeted more than one species primarily. For

the highest education level attended, about 50% had high school degrees, 34% graduated primary school, and 16% held a university degree.

Table 4. Net revenue calculated per vessel owner based on sales and associated costs for 2020 (in USD). Note: 1 United States Dollar = 7.02 TL in 2020.

	>50 m	>40 m	>30 m	>20 m
Total fish sales	1,531,435.90	316,881.05	386,572.79	464,747.01
Ice	-	-	-	114.67
Box	46,296.30	8511.68	10,023.08	9611.40
Victuals	42,735.04	12,236.47	10,937.32	10,434.47
Diesel fuel	22,934.47	66,955.41	74,462.25	45,158.55
Oil	14,245.01	1866.10	2022.79	1830.77
Staff labor costs	569,800.57	117,216.95	144,563.66	199,418.66
Total expenses	696,011.40	206,786.61	242,009.10	266,568.52
Total revenue	835,424.50	110,094.44	144,563.70	198,178.49

Generally, purse seine owners responded negatively to survey question numbers #1, #2, #4, and #6 and positively to #3 and #5 (Figure 5). Unanimously, all interviewees did not perceive the current regulations to be efficient in controlling the fishery resources (Q1). The interviewees all agreed that their traditional purse seine fishing grounds (Sariyer and Beykoz) in the Istanbul Strait should remain open to purse seines, and thus none of them would support a fishing ban in the Istanbul Strait (Q2). All respondents felt that dolphins pose a problem to their industry using words such as "problematic", "conflictive", and "difficult" relating to dolphin interactions (Q3). The majority of fishers (85%) would not support the placement of fishery observers on their vessels (Q4). Most respondents perceived that European anchovy caught in early 2021 were under the legal landing length (Q5), yet very few believed (15%) that a one-month European anchovy fishing ban would be beneficial for European anchovy stocks (Q6). For all dichotomous questions, the proportion was different from 50% ($p < 0.05$). No fishers were in favor of increasing the minimum depth limit to 30 m (Q7), but instead, the majority were in favor of reducing the depth limit to 18 m. No fishers were in favor of increasing the minimum landing size for bluefish (Q8), but some were in favor of further decreasing the size limit. No fishers attributed the mucilage event to be caused by overfishing (Q9). The majority of fishers considered climate change to be the primary cause of increasing jellyfish abundance (Q10, 47%), followed by pollution (33%).

3.4. Fishing Effort

In the GFW system, after identifying fishing vessels and detecting fishing positions in the AIS data, the apparent fishing effort can be calculated for any area by summarizing the "fishing hours" for all fishing vessels in that area.

The fishing effort in the Istanbul Strait varied between 24% and 44.5% compared to the Sea of Marmara effort from 2013–2021 (Table 5). This clearly demonstrates the importance of the Istanbul Strait for the purse seine fleet where they can easily target the migrating pelagic fish schools (mainly bluefish and Atlantic bonito) on their migrations to and from the Sea of Marmara. For six out of the eight fishing seasons examined here, percentages of fishing effort were statistically different in the Sea of Marmara and Istanbul Strait ($p < 0.05$).

3.5. Historical Policy Changes

In the fisheries management legislations of Turkey, a depth ban for purse seine fishing was first adopted in the 1986–1987 fishing season with a maximum depth limit of 5 m for all Turkish territorial waters. This regulation has changed several times over years. In the following regulation (1987–1988), purse seine fishing was firstly regulated in some areas north of the Istanbul Strait (for the Black Sea). For the first time in the 1992–1993 season, a special depth ban was introduced for the Marmara Sea at 8 m. In the following years,

a different depth limit was applied for the Marmara Sea in general until 2008. Purse seine fishing has been conducted in the Istanbul Strait, however, prior to this regulation.
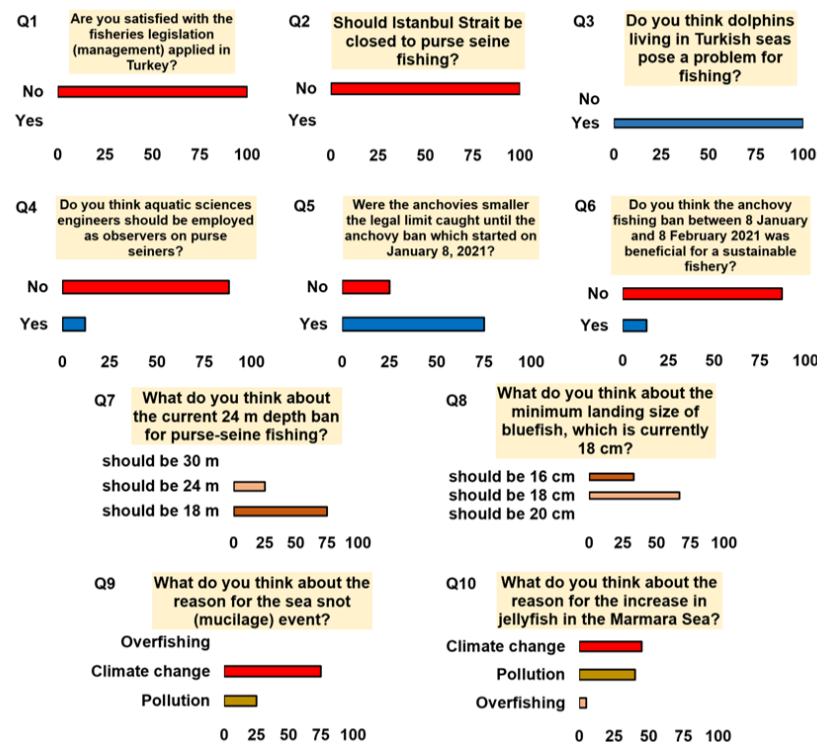

Figure 5. General results of the ten survey questions with % of respondents on X-axis.

Table 5. Fishing effort in total hours for the Sea of Marmara and the Istanbul Strait. * Indicates statistically different efforts in the Sea of Marmara and Istanbul Strait (# number of vessels).

Industrial Fishing Seasonal Dates	# Purse Seiners	Fishing Effort Sea of Marmara	Fishing Effort Ist. Strait	Total Effort	% Effort Sea of Marmara	% Effort Ist. Strait
1 September 2013–15 April 2014	155	22,778	7196	29,973	75.99 *	24.01
1 September 2014–15 April 2015	151	21,970	15,706	37,676	58.32 *	41.68
1 September 2015–15 April 2016	155	17,051	13,669	30,720	55.51	44.49
1 September 2016–15 April 2017	136	18,215	9446	27,661	65.86 *	34.14
1 September 2017–15 April 2018	114	13,219	11,401	24,620	53.70	46.30
1 September 2018–15 April 2019	112	13,121	7762	20,883	62.84 *	37.16
1 September 2019–15 April 2020	103	8772	6567	15,339	57.19 *	42.81
1 September 2020–15 April 2021	124	11,137	7708	18,845	59.10 *	40.90

Over the following years, the depth limit was gradually increased and regionalized and is currently set at 24 m, excluding the Black Sea which is set as 18 m from 1 September to 15 December. Details of the changes to these regulations are provided in Table S4.

Since 1988, a 145 m maximum length limit was introduced as the in-depth length of purse seine nets for all Turkish territorial waters. This ban was later reduced to 110 m in 1994–1996 for all Turkish territorial waters but was increased to 164 m in 2000 for the Marmara Sea only. Since 2006, it has been applied as 164 m for all territorial waters.

In addition, the maximum length of purse seine nets was set at 730 m only for the 1988–1989 fishing season, but no information could be found as to why this decision was taken. Regulations applied to purse seiners have not yet prescribed specific mesh sizes.

4. Discussion

The Turkish purse seine vessels in the Marmara Sea ranged from 28 to 51.5 m in overall length with horsepower ranging from 935 to 3200. Interestingly, despite massive differences in lengths and power, all vessels had similar numbers of crew onboard ranging from 26–30 members. According to the GFCM database, Greek purse seiners are on average much smaller, from 15.2 and 36.3 m in vessel lengths, and according to the Greek national data, the average purse seiner employs more crew than Turkey, with an average of 38 fishers on board [49]. The 20 m> and 30 m > length classes did not have significant differences in catch amounts, but the largest vessels did significantly catch more fish. The >50 m length class had over four times the total revenues of the >20 m length class and 7.7 times the revenues of the >40 m length class showing that the largest purse seiners are highly successful at catching huge amounts of fish and generating large profits. Çeliker [50] reported that the lengths of the purse-seine fishing vessels in the Black Sea Region vary between 12–62 m and Mutlu [51] reported that the catch per unit effort in the Black Sea is the highest for the small and medium-sized (20–39 m) purse seiners compared to the larger purse seine vessels, which differs from our results in the Marmara Sea. The costs of technological auxiliary gear were approximately four times the price of the vessels, which shows why the buyback schemes did not work, as these programs only supplemented the costs of the boat but not the gear. Fishing effort was shown to be extremely high for the small portion of the Istanbul Strait that is open to purse seining compared to the comparatively larger Marmara Sea.

4.1. Purse Seining in Istanbul Strait

From the number of signatories from petitions for change and activism, it can be understood that purse seine fishing is a highly debated issue by several tiers of social strata (small-scale fishers, environmental activists, non-governmental organizations, and civil citizens). Amongst the campaigns related to fish and fisheries, the number of signatories for purse seine-related partitions is higher, excluding mucilage. Due to the narrowness of the Istanbul Strait, migratory stocks become very dense in certain transit pathways, where the majority can easily be caught due to the high precision of fish finders. From the incredible sophistication of today's fish finders used in Turkey, which are not permitted in many first-world countries due to their high precision, fishers can tell the species of fish and even exactly how many cases they can catch if they take the whole school, leaving no room for traditional fisher's luck. Because of this, many common people are highly concerned that medium pelagic migratory fish have little chance to survive their transit, inhibiting their chance to contribute to future stocks, and contributing to unsustainable fisheries [52,53]. However, fishers argue that the fish do have plenty of opportunities to escape through the deeper channels in the strait. To understand what proportion of migratory fish can make a safe passage would have to be either monitored via acoustic tags or tag and recapture studies annually. Objections to purse seine fisheries in the Istanbul Strait are not new, as the first objections were vocalized as early as the 1930s [54,55]; the fishers' society replied that purse seiners opportune cheaper fish prices. So even early on, the economics of the fisheries took precedence over environmental concerns. Additionally, one Icelandic fishing expert Ragnar Gudmundsson, who provided technical assistance to Turkish purse seiners in 1956, advised that purse seine nets should primarily be used in deeper waters. He explained that they can also be used in shallow waters, but burying the lead line in the soft bottom makes it difficult to suppress the net which can cause benthic damage. In this respect, he advised against using purse seine nets net in shallow waters such as the Istanbul Strait, but supported their use in the Sea of Marmara [56]. Generally, as catch amounts increase, their prices decrease, except for rarer or declining species, which often sell for higher prices.

A positive relationship between Black Sea fishers and cetaceans is challenging, whereas conflicts between fishers and cetaceans are more common (ACCOBAMS-MOP3/2007/Res.3.11). The Istanbul Strait serves as a highly important biological corridor between the Aegean and Black Seas [1] and is also considered as a Cetacean Critical Habitat (ACCOBAMS-MOP3, 2007). Purse seine fishers generally regard dolphins as a threat or competitor to fisheries, based on a perceived increase in dolphin abundances and fisher–dolphin interactions with depredation and some associated damages to fishing nets. From a management perspective, Tonay et al. [57] suggested that purse seine fishing should be prohibited in the Istanbul Strait. This was based on the concern that fishing activities can affect the diel movement patterns of marine mammals such as *Delphinus delphis* and restrict access to their feeding areas, especially during the seasonal pelagic fish autumn return migrations [1,58].

Due to national regulations designed for safe vessel passages [59], a common routing system and traffic separation scheme was established in Istanbul Strait, which also impacts different fishing sectors. According to coastal safety personnel and Vessel Traffic Services (VTS) personnel, the regions where fishing vessels pose the highest danger to transit vessels are as follows, listed in decreasing order of importance: Üsküdar-Beşiktaş, Haydarpaşa Port-Sarayburnu and Yeniköy-Beykoz [60]. From the data obtained from the Ministry of Transport, Maritime Affairs and Communications, 57 out of a total of 891 (6.4%) marine accidents that occurred in the Istanbul Region between 2006 and 2015 were caused by fishing vessels [59]. According to the accident risk analysis created for maritime transport in the Istanbul Strait, the risk of collision in areas open to purse seine fishing was indeed much higher than in closed areas to purse seine fishing [61]. Such safety matters should also be taken into consideration when designing appropriate management measures in the Strait.

4.2. Purse Seine Depth Limit

Nationally, fish stocks have been drastically declining in all Turkish seas since the mid-1990s [62]. In the Marmara Sea, the exploitation of marine living resources is heavily reliant on market prices and fish migrations. WWF, a prominent environmental NGO actively expresses the purse seine depth ban should be amended to a minimum depth of 50 m to synchronize the limit with European Union (EU) Standards [63]. Since the early 2000s, Turkey has been making some progress towards aligning its fisheries measures with those of the EU, as is a required step for Turkish accession into the EU, but there is still plenty of room for progress, especially for improving its sanctions on illegal, unreported and unregulated fishing (IUU), as stated in the latest EU report update [64].

From a fisher's perspective, Murat Kul (purse seine owner/operator and Fishing Activities Professional Committee Chair in Chamber of Shipping) explained that if the minimum depth limit is increased from even 24 to 30 m, the purse seine fishers will go bankrupt [33]. Turkish formal regulations notoriously suffer from a high level of non-compliance or illegal fishing. The control level is inadequate in preventing illegal fishing. One study that evaluated fishing violations between 2012 and 2014, showed that half the violations in Istanbul occurred in the Istanbul Strait [65]. Purse seiners caused a high level of non-compliance as the Istanbul Strait and its surroundings (26.1%) were the most affected regions for non-compliance, where disobeying the 24 m depth limits for purse seine fishing was encountered in 13% of cases [65,66]. One of the main reasons behind implementing the minimum 24 m operational depth ban was to separate the fishing grounds between small-scale fishers and large-scale fishers who both generally rely on the same resources. Small-scale fishers suffer from damage to their fishing gear along with the declining state of the benthic habitats [67]. Waters deeper than 30 m provide spawning grounds for many fish species and spawning grounds need to be preserved to ensure the sustainability of the resources. The current 24 m minimum depth limitation is a drastic increase from the initial 5 m depth limit but in theory should exclude purse seiners from operating in the strait, while creating fishing grounds for the small-scale sector. According to Yildiz and

Karakulak [2], coastal fishers are adversely affected by catch losses and reduced fishing area due to this 24 m limit.

Another controversial topic regarding the minimum 24 m depth limitation is the overall depth of purse seine nets used. In Turkey, the maximum allowable drop for purse seine nets is 90 fathoms (164 m), excluding tuna nets [7]. However, this law for fishing gear control is insufficient, as deeper nets are used. For vessels using purse seine nets, it is obligatory to obtain a "Fishing Net Measurement Certificate" from the Ministry, which measures the depth of their nets and is valid for one fishing season [7]. However, this measurement is made only once at the beginning of the season and nets are often elongated after this. Lead lines of purse seine nets can sweep the sea bottom like a trawler, especially in shallow waters [2], damaging benthic structure, function, and connectivity. The species composition of this study also shows that purse seine nets sweep the ground. Since purse seine nets target pelagic species living in the water column, demersal species should not be found in their catch compositions. To improve the efficacy of purse seine regulations, the following EU regulations implemented for the entire Mediterranean should be adopted under the current EU management structure; "*Deployment not allowed at depths less than 70% of the overall drop of the purse seine itself*" [68].

4.3. Bluefish Minimum Landing Size

Since bluefish is the most culturally iconic species of Istanbul, the fishing pressure on the stock and implementation of improved larger minimum landing size has been a constant debate amongst citizens, environmental NGOs, and management for the last 20 years [69]. Minimum landing sizes are meant to guarantee that the stock can reproduce at least once before they are caught, thus are generally assigned based on a females minimum length of maturity. For bluefish, the minimum length of maturity was 29.4* cm TL in the Marmara Sea ([3]-*converted from FL using equation in [70]). However, under the current fishery regulations, the minimum landing size for bluefish is set at just 18 cm [7], which is obviously not based on science, and should be increased for improved stock sustainability [70]. Bluefish are primarily exploited by purse seines in the Marmara Sea and the majority of their catches are based on juvenile fish ranging from 11 to 23 cm FL [71]. No purse seiners interviewed here supported an increased bluefish minimum landing size, while some even supported a reduction of the current size regulation. From their perspective, there is no way to amend purse seine gear to release undersized fish, so undersized catches are difficult to avoid, but if minimum mesh sizes were regulated, this could be easily circumvented. Purse seiners can be generally understood to be driven only by generating higher catches and fear that increased MLS will reduce their catches over the short term. Long-term outlooks of sustaining stocks are not on their radars.

4.4. Socio-Economic Drivers of the Purse Seine Sector

The production and maintenance of a purse seine vessel, especially with the addition of their high-cost technological equipment, is very expensive compared to other sectors. These results suggest that purse seine fishers in the Marmara Sea will face difficulties adapting to more restrictive implementations which have been publicly articulated. Our study shows that despite having a good understanding of ecological changes to the ecosystem over the last 20 years, they do not perceive themselves or their sector to be attributable to stock declines. They will generally not be in favor of any measures that impair their ability to fish, but would support more relaxed measures, as they are driven solely by profit.

Turkish purse seine vessels are perhaps one of the most advanced fishing fleets globally in terms of state-of-the-art technology. Historically, those with the first purse seine vessels invested their profits in acquiring more vessels with the latest technological advancements. Thus, most purse seine owners have become strong and powerful over time, especially when government aid was abundant. As their vessel size increased, their purchasing costs increased along with their profits, which reduced the need for more manpower [72]. Fishers in the purse seine fleet aim to pay off their loans in a reduced time by trying to fish smarter

where possible. The national fishing vessel buyback programs, which were conducted four times since 2013, with the aim of reducing the overall effort to alleviate pressure on the resources were not effective at reducing overall effort as approximately 95% of the retired vessels were in fact small-scale vessels [73]. Industrial fishing vessel owners were not in favor of the measure as their technological investments were not included in the buy-back scheme, which often rivals the vessel price itself, and the fishers already make more revenue than the buy-back support offered [74]. So, in summary, there are stronger vessels chasing around a smaller share of fish, and the most advanced portion of the fleets have the best chance of finding and catching the highest shares.

Purse seine revenues only come from fish sales. As to how the revenue is divided, first, the operator's input costs are deducted from total revenues, then the remainder is divided in half, one half is kept for the owner for 'gear investments', while the other half is shared by the owner and crew. If fish are not caught, then the owner covers the loss. Industrial purse seine owners are not subject to the declining catches and revenues commonly suffered by the small-scale sector [75] due to their very high catch capacities. Their disposition resulting from the combination of catch capacities, catch efficiencies, and fish migrations make them currently the most profitable fishing sector. To compare with the historical revenue sharing system from Ottoman times, vessel owners would receive two shares of revenue to one share that the crew would share [76], but now the owners receive a slightly higher proportion of the total share due to their very high investment costs.

How the fishers perceived the state of the resources demonstrates that they have a limited scientific understanding of the impacts of fishing on fish stocks, and do not understand the consequences of an open-access system. Their attitudes towards sustainable fishing are overshadowed by their general goal of catching as many fish as they can. Educating them on the current state of the fisheries and longer-term sustainability options and goals may improve their understanding of the logistics of the wild capture fisheries industry. Their perceptions are also dependent on their interpretations of management practices [77]. If fishers have positive attitudes that the management aim is to contribute to the sustainability and longevity of the sector, they may be more in favor of regulatory control [78]. Whereas now they generally perceive regulations as one sector benefitting in lieu of another. As one small-scale fisher pointed out, the fate of the fisheries depends on the goodwill of the fishers themselves [79].

5. Conclusions

It has been stated that a new management approach is needed in the Marmara Sea, while the stocks in the region are sensitive due to a myriad of problems, most of which are related to the declining overall health of the ecosystem, listed in the Pressing Issues in the Marmara Sea section. After the last mucilage crisis in 2021, to address the bad state of the stock, the government adopted a course of action ("Marmara Sea Action Plan") [80], including an ecosystem approach to fisheries. The viewpoints stressed in this study may help to better structure an equitable management framework that benefits all fishers over the long-term, but of course, improved control is needed to improve the fisheries, which must come a cost to some.

Currently, there is a paradox between the economic, environmental, and cultural aspects of purse seine fishing in the Istanbul Strait. The way to help bridge this paradox would be to restructure the local management system into a co-management system that includes all stakeholders. The fishing authority should develop new communication channels and implement a share-based or allocation arrangement for catches, remembering that the Istanbul Strait is a narrow waterway and navigational hazard. A commercial fishing ban in the Istanbul Strait has been vocalized by many stakeholders (e.g., small-scale fishery sector, non-governmental organizations, activists, and some scientists), but is opposed by all purse seiners. It is clear that the minimum landing size of the bluefish should be increased from 18 cm to 30 cm, to at least the length of the first maturity, based on science. In addition, fishers need to learn that dolphins are an integral part of the ecosystem

and in fact make it healthier, rather than viewed as an enemy. It should be highlighted that a disparity exists between governance, fishery science professionals, and the purse seine fishing industry, which gains generous profits at the expense of sustainable fishing. The resources belong to everyone but are being overharvested predominantly by one sector only in the Marmara Sea. However, to reduce the overall effort to appease more stakeholders, more formal limitations on effort (weekend closures and catch quotas) could be introduced. In the future, better data on the spatial and temporal patterns in fishing efforts will be needed for robust management and adopting a zoning strategy by introducing limits to vessel numbers and limiting total catch.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes7060301/s1, Table S1: Specifics of the Mediterranean Sea purse seine fleets including number of vessels, engine power, and gross tonnage by country and region (for Turkey; Source: GFCM, 2022); Table S2: Change.org petitions showing the topics raised pertaining to fishing in the region with number of signatures and commencement year; Table S3: Total itemized costs pertaining to the purse seine vessels and their technological investments. Prices in US Dollar; Table S4: National regulations changes for the depth limit, overall drop and length of purse seine nets, and status of Istanbul Strait for purse seiners from 1986 to present.

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