THE BIODIVERSITY AND SEASONAL VARIATION OF PELAGIC FISH CAUGHT BY PURSE SEINES IN TRIPOLI, NORTHERN LEBANESE COAST

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ABSTRACT

Jemaa, Sh., Lteif, M., Khalaf, G. & Fakhri, M. (2021). The Biodiversity and Seasonal Variation of Pelagic Fish Caught by Purse Seines in Tripoli, Northern Lebanese Coast. *Lebanese Science Journal,* 22(1), 82-97.

This study highlights for the first time the biodiversity of fish assemblages in purse seine fisheries in the Tripoli region, north of Lebanon. A total of 925 specimens from 17 species of 11 families were identified and studied from the monthly samples collected between April and November 2017. The catch was dominated by 3 families (Clupeidae, Engraulidae and Dussumieriidae) in varying abundances. Seasonal variation of abundance was detected with Sardina pilchardus (32%) in Spring, Engraulis encrasicolus (56%) in Summer and Sardinella maderensis (58%) in Fall. Weight length relationships ($W=aL^b$) were estimated for the most abundant species, and they show a positive allometry for Engraulis encrasicolus (b=3.276), as well as, Herklotsichthys punctatus (b=3.477), and a negative allometry for Sardinella aurita (b=2.886). Seasonal diversity was evaluated and the highest diversity was observed during the spring season following Shannon Index (H'=1.44), Pielou evenness (J'=0.74) and Simpson Index (1-D=0.74). The Shannon Index differed from one season to another reaching the highest value in Spring. Despite the progress in studying diversity and abundance, variation in pelagic fish catches is evident in Lebanese sea water, where a management plan for purse seine fisheries should be applied under the framework of ecosystem approach to fisheries.

Keywords: Purse seine fisheries, Small pelagic fish, North Lebanon.

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INTRODUCTION

The Mediterranean Sea is a diverse region with a unique climate, geography, and history making it one of the richest basins for both animal and plant diversity (Cuttelod et al., 2008). This diversity is characterized by fish richness increasing from east to west (Quignard & Tomasini, 2000) due to the low primary production in the Levantine basin (Por, 1978). In addition, the Aswan Dam construction in 1964 eliminated important sources of nutrients by decreasing the amount of freshwater reaching the Mediterranean (Aleem, 1969; Halim, 1976). The Eastern Mediterranean region was also affected by the opening of the Suez Canal in 1869 allowing the introduction of invasive species (Por, 1978). With this invasion, only reef-associated or demersal species have been described (Bariche et al., 2003; Bariche et al., 2004) whereas pelagic species are still not adequately studied. Small pelagic fish are the key to the trophic chain where their presence maintains ecosystem balance (Smith et al., 2011). Across the GFCM areas, catches are dominated by small pelagic fish representing nearly 49 percent of the catches (versus 51 percent reported in 2016). Among these fish, sardines and anchovies were targeted since the 50's by industrial fishing; thus, they have both commercial and biomass importance (Pinnegar et al., 2003; FAO, 2005; FAO, 2018). In Lebanon, small pelagic fish constitute a large part of people's diet and have shown increasing prices. Small pelagic fisheries are developing even though there are stock fluctuations due to environmental factors. The fisheries sector in Lebanon mostly consists of artisanal fleets, using a wide range of fishing gear, and lacks basic data related to stock assessment. The main fishing grounds targeted by the Lebanese vessels are located on the continental shelf area and according to the Ministry of Agriculture in Lebanon, the fleet effort is within the 6 nautical miles with the highest concentration within the 3 nautical miles.

Pelagic fish populations in Lebanon are targeted by purse seines also known as "schincholas", therefore, they constitute the largest percentage of the catches (Sacchi and Dimech, 2011) and are targeted at 0 age class (Mercedes & Safina, 1995). The majority of purse seine vessels (45%) are located in the North governorate of Lebanon. Lebanese fisheries legislation had set some laws concerning gear and mesh size, and the practice of surrounding gear for small pelagic fish (Sacchi and Dimech, 2011), but these laws are not applicable in most fishing harbors. The Lebanese purse seiner fleet is relatively small in terms of number of vessels, only 87 vessels (FAO, 2018). The fleet has high production in terms of total landings, and highest in terms of catch per day or efficiency. When compared to the other fleets, it shows the highest value of landings per vessel. The total amount of revenues generated by this fleet is $5.8 million, representing about 11% of the national value production (Pinello and Dimech, 2016). According to the latest statistics done FAO (2018), 78% of fish stocks for which validated

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assessments are available are overexploited. This overfishing can alter ecosystems, hence, disturbing the role of the prey, predator, or competitor of an ecosystem with a severe decline leading to both functional and ecological extinction (Mercedes & Safina, 1995).

Lack of data for fishing sector management in Lebanon is one of the reasons that led to the reduction of fish stocks over the years. Biological data for some indicator species should be collected along with socio-economic information to improve the exploitation of fisheries resources and realize the stock status (Pinello & Dimech, 2013). Moreover, purse seiners are rarely studied and managed, they require further investigation. However, since 2015 Lebanon has started to collect socioeconomic and landing data for management purposes.

The aim of this study is to assess the diversity of pelagic fish collected using purse seines and the abundance of each species individually. Furthermore, biological data was gathered in order to ensure a good management to a sector lacking proper organization.

MATERIAL AND METHODS

Sampling area and morphometric measurements

The study was implemented from April to November 2017 in Tripoli, north Lebanon (Figure 1). Surface temperature data was taken from the monthly measurements (monitoring system) of the National Center for Marine Sciences – Lebanese National Council of Scientific Research (NCMS – CNRS-L). Monthly fishing trips on board of commercial fishing vessels were executed and random samples were taken before separating the fish. Species were identified according to their morphologic characteristics using the identification guides: Fishes of the Eastern Mediterranean (Golani et al., 2006) and Field Identification guide to the living marine resources of the Eastern and Southern Mediterranean (Bariche, 2012). Total length (LT) was measured to the nearest millimeter; from the tip of the snout to the tip of the caudal fin. The total weight (WT) was measured by an electrical balance to the nearest 0.1 gram (g). The sex was identified macroscopically (male, female or undetermined) and the gonad weight (WG) was measured using an electronic balance to the nearest 0.01 gram (g). Sexual maturity was determined macroscopically while observing the male and female gonads using the MEDITS – International bottom trawl survey in the Mediterranean – Version 6 instruction manual (MEDITS, 2012).

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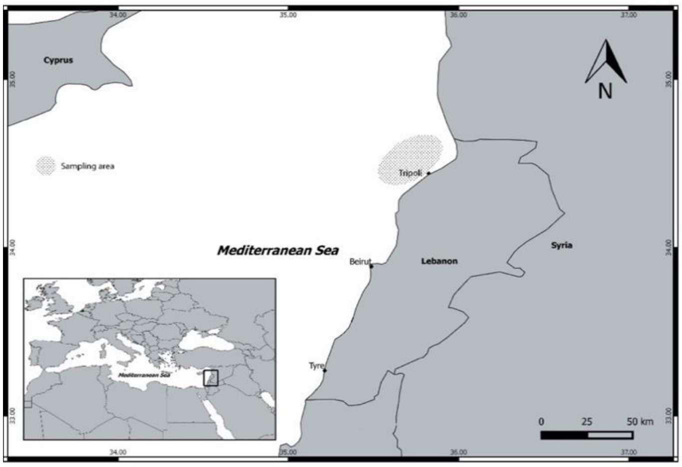

Figure 1: Map of the Lebanese coast and the sampling area.

Biodiversity indices

Biodiversity (monthly and seasonal) was evaluated for the collected data by calculating the diversity indices according to (Magurran, 2004). The Shannon Index (H'), Shannon evenness (Pielou's evenness: J'), Simpson Index (1-**D**), and taxonomic distinctness and diversity (**Δ+**) were computed using the vegan' package on the statistical software R project (R Development Core Team, 2014). The Shannon Index is used to measure the abundance and evenness of the species sampled from a large community (Pielou, 1975). The taxonomic distance was calculated using *taxa2dist* function where species were classified along their class, then the diversity was calculated using the function *taxondive*.

Statistical analyses

The normality of the data was tested using a Shapiro-Wilk normality test from the *shapiro.test* function on R. A One-Way ANOVA was done to observe if there are significant differences in the region's surface temperature according to the seasons of the catches. This test was done using the *aov* function in R. A CCA was performed on the matrix of number of species caught according to season. The data were log transformed before the analyses into log(x+1) in order to homogenize the variances and normalize the distributions. The CCA analysis was performed using the *cca* function of the 'vegan' package on R program (R Development Core Team, 2014).

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RESULTS

Surface temperature

The average surface temperature was calculated according to season in the sampling area and is represented by the boxplot in Figure 2. The temperature fluctuates seasonally, showing the highest value in summer, followed by fall and spring. The One-Way ANOVA shows significant differences in temperature distributions according to the seasons presented (ANOVA, F = 6.39, *p*=0.042 < 0.05).

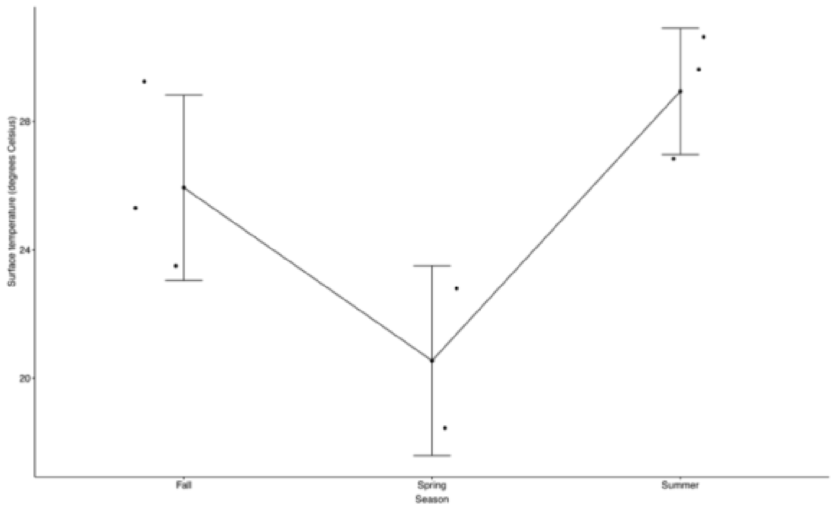

Figure 2. The mean and standard deviation of the surface temperature according to season in 2017. The central part of the bar represents the mean and the upper and lower horizontal bars represent the standard deviation.

Species identification

In this study, 925 individuals were analyzed and a total of 11 families consisting of 17 species were identified (Table 1). Among these species, 9 were invasive and 8 species were native. The most caught species by purse seine was *Engraulis encrasicolus* with 333 individuals and *Sardinella aurita* with 219 individuals. *Herklotsichthys punctatus, Sardinella maderensis, Sardina pilchardus and Etrumeus teres* were also caught with 120, 104, 82, 32 individuals, respectively. The rest of the species occurred with a number of specimens less than 11.

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Weight-Length relationship

The weight (WT) – length (LT) relationship was estimated for the most abundant three species (*E. encrasicolus, S. aurita* and *H. punctatus*) in the catch using a nonlinear power regression analysis. The calculated parameters of WT – LT relationship for sexes combined revealed a scaling coefficient less than three (b=2.88) for *S. aurita* with a determination coefficient equal to 0.98 (Figure 3). This shows negative allometry where the length of the fish grows at a faster rate than its weight. *E. encrasicolus* and *H. punctatus* demonstrate a positive allometric growth as the 'b' parameter is greater than 3, meaning that the fish grows in weight faster than in length.

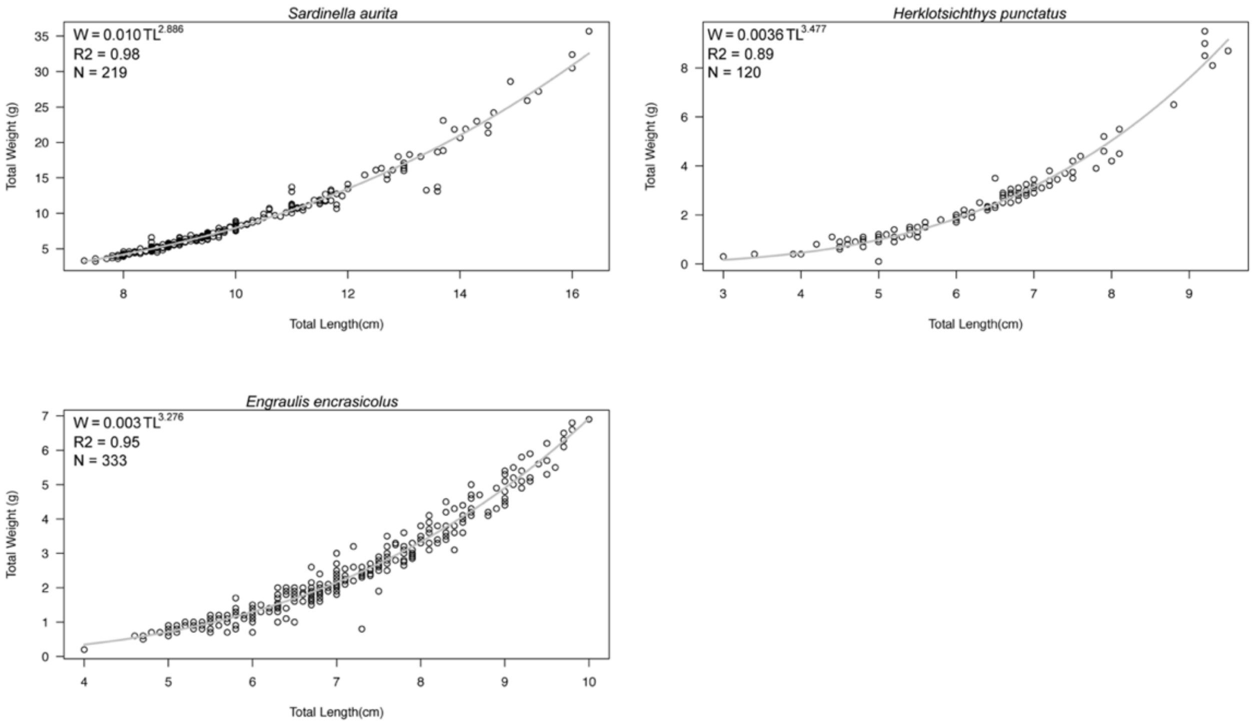

Figure 3. The weight – length relationships of *Engraulis encrasicolus, Sardinella aurita* and *Herklotsichthys punctatus.*

Species temporal abundance

The abundance of each species was calculated according to month and seasons, the pie charts in Figure 4 represent the species relative abundance per month. Individuals with a number less than 10 specimens in the samples are represented as

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'Other'. *Sardina pilchardus* and *E encrasicolus* are dominant in April with 42.78% and 36.36%, respectively. *S. aurita* shows to be the most abundant species in June constituting 95.92% of the catch. *E. encrasicolus* constitutes approximately half of the catch in July (50.93%) and August (49.49%) and represents 84.05% from the catch in September. In October, *S. aurita* dominated the catch with 83.33% and *H. punctatus* represented only 13.88%. *Sardinella maderensis* (87.28%) was dominant in November. The percentage of other species varies between 0.934% and 6.77 in throughout the months presented.

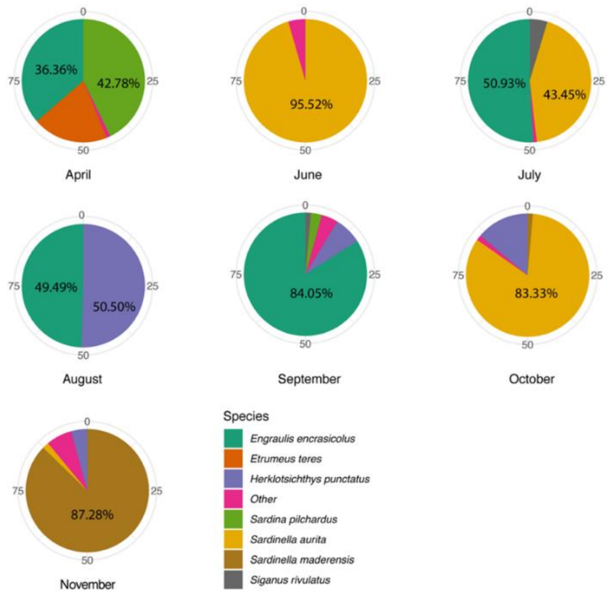

Figure 4. Species relative abundance according to different months: April, June, July, August, September, October and November.

In spring, *E. encrasicolus* and *S. aurita* had almost similar abundances with 26.77 % and 25.19% respectively. *Sardina pilchardus* was dominant in spring with and abundance of 31.49%.

Species abundances differed greatly between summer and fall. In summer, anchovies constituted most of the catch with an abundance of around 54.86%, whereas in fall its abundance decreased and it was not part of the catch. Moreover, the abundance of *Sardinella aurita* was contradicted with that of anchovies for it represented 19.25% in summer and 41.89% in fall. *Sardinella maderensis* had constituted 41.89% of the catch in fall yet no specimens were caught during summer throughout our sampling. Other species constituted 1.96%, 1.44%, and 6.08% of the catch in spring, summer and fall, respectively (Figure 5).

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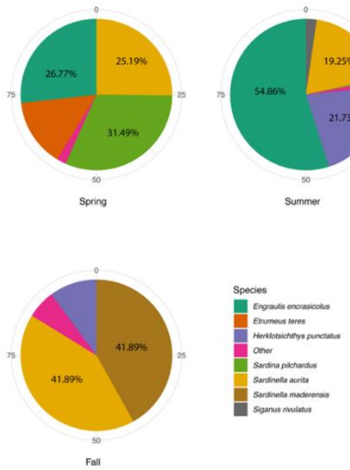

Figure 5. The relative abundances of pelagic species caught in spring, summer and fall.

A CCA was performed to better picture the relationship of the species observed according to the season following abundance (expressed in number) for the collected data. The ordination diagram with small pelagic species and environmental variables are presented in Figure 6. According to the CCA, small pelagic species showed clear opposition along the two components according to season.

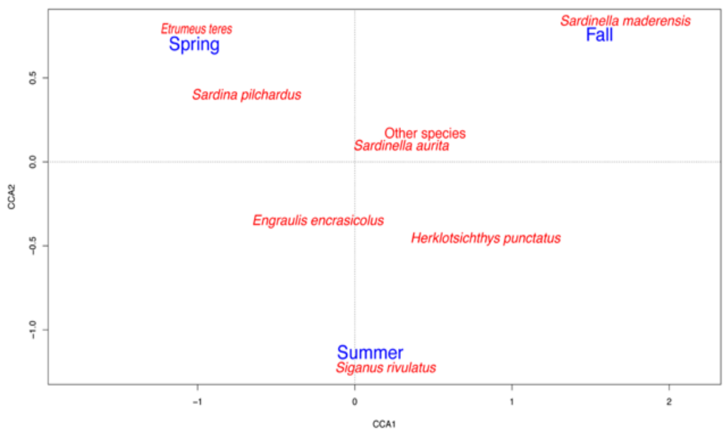

Figure 6. Canonical Correspondence Analysis (CCA) ordination diagram of small pelagic species according to season following the log transformed number per season.

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CCA of the seasonal data

The abundance of *Sardinella maderensis*, *Etrumeus teres*, and *Siganus rivulatus* showed a close relationship with fall, spring and summer, respectively. The abundance of *S. aurita* did not demonstrate any bias according to season. In addition, the abundances of *Sardina pilchardus* and *Herklotsichthys punctatus* showed clear opposition along the first and second component.

Biodiversity indices

Seasonal diversity was assessed for the 17 species documented throughout this study. The highest diversity and even distribution of species abundances were observed during the spring season according to H', J' and 1-D. However, fall showed to have the highest phylogenic diversity, followed by spring, with the least phylogenic diversity in summer. The Shannon Index differed from one season to another reaching the highest value in Spring (1.44) (Table 2).

Table 2. The diversity indices used to assess seasonal diversity (S is the number of species in each sample; H': Shannon Index; J': Pielou's evenness; 1-D: Simpson's Index; Δ+: Taxonomic distinctness).

Diversity Indices	Spring	Summer	Fall
S	7	9	7
H'	1.44	1.14	1.1
J'	0.74	0.52	0.56
1-D	0.74	0.61	0.58
Δ+	85.98	85.82	89.68

DISCUSSION

We analyzed data collected from commercial purse seine vessels in the north Lebanon, Eastern Mediterranean, to describe the diversity of the catch and highlight the abundance of small pelagic species mostly caught by this method.

Purse seining is the most efficient method for catching aggregated pelagic species in Lebanese waters. In this study, 11 families were recorded as caught in purse seine vessels, with landing sizes ranging between 3 and 17 cm. Some of the species caught were demersal or reef associated, such as, *Lithognathus mormyrus*, *Siganus*

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rivulatus and *Pomadasys incisus*. The presence of these species at very small length classes (Table 1) show the destructive role of purse seines for several fish stocks in the Lebanese waters. From each trip, only six species constituted the vast majority of landings (>90%), indicating the consistency of the catches and the high selectivity of the gear. This number is very low compared to other Mediterranean fisheries that are multi-species in nature (Lleonart & Maynou, 2003). The low selectivity of the purse seine fishery was also proved by the low discard rates observed in this study and in Bariche et al. (2007). Catches are mainly delivered for human consumption and were sold in auctions and fish markets (no fish industries in Lebanon) and often to a highly quality-conscious market in which prices are strongly influenced by fish size and quality. Therefore, the purse seine fishing activities are driven by the market, and in some cases, the catch was discarded as observed in the Norwegian purse seine fishery (Tenningen, 2014). In addition, the presence of the pufferfish *Lagocephalus sceleratus* was noted for the first time in purse seine assemblages in the Lebanese water. This species contains a high concentration of tetrodotoxin (TTX) that leads to cardiac and smooth muscle inhibition (Nader et al., 2012). As Lebanese people like to eat small fried fish, they can be subject to the effects of TTX, because sometimes, people do not separate fish and they eat them as assemblages of small fish.

The growth of the three most abundant species, *Engraulis encrasicolus* (n=333), *Sardinella aurita* (n=219) and *Herklotsichthys punctatus* (n=120), was evaluated using the length-weight relationship (LWR). The parameters of this relationship help to assess the status of the fish caught in purse seines in Lebanon, thus, evaluating the fishing effects of this method. The LWR for *S. aurita* from Tripoli (northern Lebanese waters) showed negative allometry (b=2.861). Jemaa et al. (2016) reported the length-weight relationship for sardinella along the Lebanese coast and it showed positive allometry (males: b=3.128 females: b=3.282) for both sexes when caught by purse seine and gillnet operations. These variations in growth may be due to the difference in gear type used during the fishing operation. The LWRs for *E. encrasicolus* and *H. punctatus* were evaluated for the first time in this study area and showed positive allometry. These LWRs were estimated from purse seine catches in north Lebanon that are targeting small fish of age 0. In fact, many LWR estimates for juveniles differ from those evaluated for adults in the same species (Peyton et al., 2016). It was predicted by Froese (2006) that juveniles had ontogenetic development phase changes and can influence LWR estimation. Therefore, it is recommended to estimate LWRs for juveniles and adults separately. This is the case for this study; purse seiners are targeting juvenile and immature fish, such as, *S. aurita*, that have not reached L50 according to Jemaa et al. (2016). Finally, LWRs can also be affected by stomach fullness, gonad maturity and sex (Tesch, 1971; Wootton, 1998).

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Table 1. Species list of fish recorded during sampling from Tripoli region showing their type, their Arabic and English name.

Family	Species	Type	English name	Min - max (LC)	N of fish	Arabic name
Carangidae	*Trachurus picturatus*	Native, Mesopelagic	Blue jack mackerel	8	1	عصَيْفر
Clupeidae	*Sardina pilchardus*	Native, Pelagic	European pilchard	6 - 10	82	سردين
	Sardinella aurita	Native, Pelagic	Round sardinella	7 - 16	219	سردين مبروم
	Sardinella maderensis	Native, Pelagic	Maderian sardinella	9 - 17	104	لاطشو
	Herklotsichthys punctatus	Invasive, Pelagic	Spotted herring	3 - 9	120	سردين صفرا
Dussumieriidae	*Etrumeus teres*	Invasive, Pelagic	Red-eye round herring	6 - 9	37	رينغا
Engraulidae	*Engraulis encrasicolus*	Native, Mesopelagic	European anchovy	4 - 10	333	ام حنك / ام مونة
Scombridae	*Euthynnus Alletteratus*	Native, Reef-Associated	Little tunny	3 - 9	2	بلاميدا
	Scomber japonicus	Native, Pelagic	Chub mackerel	9 - 10	2	سكمبري
Siganidae	*Siganus rivulatus*	Invasive, Reef-Associated	Rivulated rabbitfish	2 - 7	11	مواصطة/عقّيص/ بو شوكة
Sparidae	*Lithognathus mormyrus*	Native, Reef-Associated	Striped sea bream	6 - 8	3	مرمور
Sphyraenidae	*Sphyraena chrysotaenia*	Invasive, Bentho-Pelagic	Obtuse barracuda	9 - 12	4	ملّيفا
	Sphyraena viridensis	Invasive	Striped barracuda	11	1	ملّيفا
Tetraodontidae	*Lagocephalus sceleratus*	Invasive, Bentho-Pelagic	Pufferfish	5	1	نفّيْخة
	Torquigener flavimaculosus	Invasive, Bentho-Pelagic	Yellows potted puffer	7	1	نفّيْخة
Exocoetidae	*Parexicoetus mento*	Invasive	African sailfin flying fish	11	1	سمك طيار
Haemulidae	*Pomadasys incisus*	Invasive	Bastard grunt	9 - 10	3	قصطارة/قريق

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Lebanon is characterized by a typical Mediterranean climate with two very opposing seasons (summer and winter) and two intermediate seasons (spring and autumn). According to Abboud Abi Saab et al. (2013), the mean monthly variation of sea surface temperature between 2000 and 2012 ranged from a minimum of 17.82°C in March to a maximum of 29.71° C in August. The average sea surface data in 2017 coincides with what was mentioned previously showing a decreasing trend from summer to spring.

The seasonal variation in temperature had an effect on the seasonal variation of the purse seine catches. Temperature impacts metabolism and growth in poikilotherms (Clarke & Johnston, 1999) and acts in shaping the ecophysiology and life history strategy of fish (Pörtner & Peck, 2010). The ability of a species, a population or an individual to persist over a range of temperatures is limited by the thermal adaptation capacity of biochemical, cellular and organismal processes which limits the geographic distribution of stocks and influences inter-annual variability in survival (Jordaan & Kling, 2003).

The three diversity indices used also show a decreasing seasonal trend. The indices calculated seem be more or less sensitive to the abundance of species. Temperature of the water and its concentration of dissolved oxygen can affect the vertical migration (Dagorn, 1994), since purse seiners operate at the surface at night. Nevertheless, it is difficult to identify the factor that is really responsible for this trend. Many authors have shown that several environmental variables are related to this variation, such as water temperature, salinity, or type of sediment (Demestre et al., 2000). The trend can be also attributed to the change in fishing effort that changes according to season, and the depth at which fishing operations were performed. The variation of temperature among seasons can affect the migration of small pelagic fish (Amesbury & Babin, 1990). For example, seawater temperature can cause the fluctuation in distribution and abundance of *S. pilchardus* (Coombs et al., 2006; Planque et al., 2007; Bellido et al., 2008; Alheit et al., 2012; Santos et al., 2013; Montero-Serra et al., 2015), which showed to be more abundant in spring as shown in this study. Higher temperatures in fall and summer might be affecting the biology of this species because warming might have a negative effect on the early stages of *S. pilchardus*, namely on their survival, metabolism, feeding behavior and stress response (Lopes et al., 2016). In addition, round sardinella tolerates a wider sea surface temperature than anchovies, the fact which makes it more flexible in choosing a suitable habitat (Diankha et al., 2015). This is supported by the CCA results that have shown that round sardinella does not show any seasonal bias and can appear in the catches at variable.

While environmental features play an important part in the movement of fish, they are not the only ones. Predator-prey relationships can affect the behavior and the distribution of small fish (Soria, 1994). Moreover, oceanographic factors, especially those related to high marine productivity can influence diversity levels, as the high diversity observed during the spring can be related to the definite prey availability during that season due to the phytoplankton bloom (Lakkis and Novel-Lakkis, 1981). In addition, the Shannon Index gave a higher diversity in spring despite a lower number of species (7 species compared to 9 in summer) due to the fact that Shannon takes into consideration the evenness of species abundances, which was better confirmed with Pielou’s evenness that gave a higher value in spring. Finally, the higher taxonomic diversity shown in fall, indicated the higher diversity in the taxa to which the species belong. Interannual differences in size composition of the stock would result in different reproductive strategies and recruitment pattern in a given year (Zwolinski et al., 2001). The purse seine catches in this study are dominated by juveniles and show seasonal variability in abundance and diversity. This can somewhat reflect the status of these stocks in the study area and provide a basic idea regarding the composition of the stock. According to the Ministry of Agriculture (MoA), the fishing grounds in Lebanon serve as juvenile fish habitats and nurseries, and the majority of landed fish comprises of juvenile small pelagic fish. Therefore, future research questions will aim to address fishery management of this ecosystem in Lebanon, especially in the northern studied area, where most fishing operations take place (Majdalani, 2005). This study highlights the destructive role of purse seines in Lebanon. The variation of abundances and biodiversity observed in this study show that the purse seine fishery is not stable and should be taken in to consideration in all management approaches. The majority of the catches being juveniles can have a devastating effect on the ecosystem. The results of this study have provided new information and contributed better to an ecosystem-based management for purse seine fisheries in north of Lebanon.

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