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Small-scale fishery catch composition in Rhodes (Eastern Mediterranean Sea)

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Abstract

Trammel net and boat-seine experimental fishing samplings were carried out seasonally, over a rocky-sandy and a *Posidonia oceanica* habitat respectively, in the coastal waters of Rhodes, south-eastern Aegean Sea, Greece, between 2019 and 2020. Fish catch composition, abundance and biomass were investigated as a contribution to the qualitative and quantitative monitoring of the fish assemblages in the artisanal fishery in this Greek marine region most affected by biological invasion. A total of 56 native and 11 alien fish species were captured. Five invasive species *Fistularia commersonii*, *Pterois miles*, *Siganus rivulatus*, *Siganus luridus* and *Lagocephalus sceleratus* were recorded using both fishing gear. In trammel nets, the alien to native fish species ratio was 1:2.87 with eight allochthonous species composing 43% of the total abundance and greatly exceeding native species biomass with the most dominant being *F. commersonii*, *P. miles*, *S. rivulatus* and *S. luridus.* Boat seine samples were dominated by *Spicara smaris* and *Boops boops,* which accounted for 84% and 56% of total abundance and biomass, respectively, while the alien to native fish species ratio was 1:5.1. The 10 Lessepsian fish, i.e., fish that have entered the Mediterranean Sea via the Suez Canal, identified on a *Posidonia* seabed represented a small proportion of the total abundance (3.4%), while their biomass reached 17% of the total catch, with a prevalence of *F. commersonii*. Among alien fish on *P. oceanica*, *S. rivulatus* exhibited the greatest abundance, followed by *F. commersonii*, *Parupeneus forsskali* and *S. luridus*, with small but not negligible densities of *Pteragogus trispilus* and *Torquigener flavimaculosus*. The abundance of *Pterois miles* over the rocky-sandy habitat was remarkable. Results indicate a transitional shift in fish catch composition with introduced species competing with natives for food and space (i.e. between introduced siganids and *Sparisoma cretense, Sarpa salpa*, between the recently introduced *P. forsskali* and mullids, and between introduced *P. miles* and scorpaenids), further influenced synergistically by environmental and anthropogenic factors. The Total-Standard length and Total weight-Total length relationships and their applications in fisheries data for the allochthonous fish are briefly discussed.

Keywords: Marine ichthyofauna; Lessepsian fish; length-length relationship; weight-length relationship; Rhodes Island; Aegean Sea.

Introduction

Mediterranean marine biodiversity is undergoing rapid alteration, driven by multiple stress factors, mostly due to anthropogenic activities (Bianchi *et al.*, 2012; Katsanevakis *et al.*, 2020). Among these factors, alien species (considered here as synonymous of non-indigenous, non-native, allochthonous, exotic, Lessepsian) are considered a major threat to the biodiversity of the basin, affecting community synthesis, habitats, ecosystem functioning and services (Katsanevakis *et al.*, 2014; Mannino *et al.*, 2017; Zenetos *et al.*, 2018; Giakoumi *et al.*, 2019).

The south Aegean, and in particular its eastern parts close to the Anatolian coastline, are characterized by an oligotrophic subtropical environment, heavily influenced by the Levantine water masses and the Asia Minor Current, which embraces the southern islands of the Dodecanese Archipelago. This environment is suitable for native thermophilic biota and for tropical or subtropical alien biota colonization (Papaconstantinou, 2014; Corsini-Foka *et al.*, 2015), sometimes in the form of invasions. The island of Rhodes (southeast Greece) is located along the natural pathway of the dispersion of aliens that follow the Levantine coastline after entering the Mediterranean via the Suez Canal (Lessepsian migrants) and constitutes the main pathway for further expansion into the Aegean waters. Furthermore, the study area is located along the route of intense maritime traffic (e.g. ELSTAT, 2020). The establishment and spreading of alien biota is further assisted by the ongoing warming of the sea (Raitsos *et al.*, 2010; Pancucci-Papadopoulou *et al.*, 2012; Bianchi *et al.*, 2014; Sisma-Ventura *et al.*, 2014).

Among the 46 alien bony fish species of Indo-Pacific/Red Sea origin recorded to date in Greek Aegean waters, 40 are Lessepsian migrants. Most were initially recorded in Rhodes and the adjacent region. Currently, 37 of these species inhabit the area, twelve times more than those known from the beginning of the 1940s (Zenetos *et al.*, 2018; Kampouris *et al.*, 2019; Kousteni *et al.*, 2019; Bariche *et al.*, 2020).

Most of the Lessepsian fish living in the Greek waters of the south-eastern Aegean Sea prey on fish and/or invertebrates; few species are planktivorous (e.g. *Etrumeus golanii*) and only two, the siganids *Siganus luridus* and *Siganus rivulatus*, are herbivorous. Most have planktonic propagules and reproduce during summer, some from spring to autumn (Golani *et al.*, 2006; Froese & Pauly, 2019). They live mainly at depths of up to 50 m, on various types of bottom: sandy, sandy-mud covered by well-developed vegetation, *Posidonia oceanica* meadows, sandy-rocky, rocky and also on artificial hard substrates.

Lessepsian fish establish rapidly in this area and integrate successfully along the food web. Most of these species appear almost regularly in fishery landings, in carying abundance depending on the species, habitat, season, method of collection and other factors, with fish assemblages in coastal fishery studies reflecting, to a certain degree, the upward trend of the alien to native ratio (Corsini-Foka *et al.*, 2017). Although common in fisheries landings, the majority of the aforementioned Lessepsian fish, are discarded for various reasons, namely, their small size, unpalatability, overall appearance, negligible catch numbers, risks for human health such as the tetraodontids, the large-sized and highly toxic invasive *Lagocephalus sceleratus* and the smaller ones *Lagocephalus suezensis* and *Torquigener flavimaculosus* (Kosker *et al.,* 2018; Katikou, 2019). Conversely, some alien fish species are of commercial value, at least in Rhodes and nearby islands, such as *S. luridus* and *S. rivulatus* and *Sphyraena chrysotaenia* or they are increasing in commercial value such as *Fistularia commersonii*, and the scorpaenid *Pterois miles*. Occasionally, *Sargocentron rubrum* is sold, whereas increasing commercial importance is observed for the mullids *Upeneus moluccensis* (Bleeker, 1855), *Upeneus pori* (Corsini-Foka *et al.*, 2017) and the recently introduced *Parupeneus forsskali*. Another widely distributed commercially valuable species is *Etrumeus golani*, which is caught generally by purse seine. No data is available for *Scomberomorus commersoni,* another commercially important species.

The area of Rhodes is usually the first region in Greece that is most affected by Lessepsian immigrant fish (Papaconstantinou, 1990; Corsini-Foka *et al.*, 2010; Corsini-Foka & Economidis, 2012; Papaconstantinou, 2014; Corsini-Foka *et al.*, 2017; Zenetos *et al.*, 2020). Monitoring qualitative and quantitative composition of small-scale fish catches in Rhodes is useful for the detection and quantification of eventual changes in fish assemblages and food webs. Furthermore, it could be used for predicting the undergoing trend of changes in the Aegean Sea and to contribute to the assessment of the quality of this bio-invaded marine area. Therefore, diversity, abundance, and biomass of both alien and native ichthyofauna data obtained from the small-scale coastal fisheries of Rhodes in 2019-2020 were investigated. The trammel net and boat-seine fishing gears used in the present work, along with the gillnet, are traditional fishing methods widely used in Greece (Adamidou, 2007). They constitute a source of subsistence for many fishing households, including those in the area of Rhodes that is heavily affected by marine biological invasions.

The Length-Length and Weight-Length relationships are important in fisheries science with many applications in biology, physiology, ecology and the evaluation of fisheries data (Karachle & Stergiou, 2008), but relevant information from the literature on Lessepsian fish in Greek waters is scarce. In biological studies, length-weight relationships allow the estimation of seasonal variations in catch growth, calculation of physiological indices (Richter *et al.*, 2000), and comparison of life cycle and morphology between different species or the same species in different habitats or regions (Goncalves *et al*., 1997).

Material and Methods

The investigation was carried out seasonally at two locations in the marine are of Rhodes, the Faliraki Gulf (Station F) and the Trianda Gulf (Station T), both well-known fishing grounds (Fig. 1). The seafloor of Faliraki Gulf is represented by rocks rich in vegetation interrupted by sandy bottom, whereas that of the Trianda Gulf is characterized by *P. oceanica* meadows, continuous or interrupted by sandy-mud bottom. The two experimental fishing methods used, trammel net and boat-seine, are described in Corsini-Foka *et al.* (2015).

Trammel nets of 2000 m in length were deployed from a 12 m professional trawling fishing vessel late in the afternoon and retrieved early in the morning. The mesh opening was 30 mm and depth ranged between 20 and 50 m. The boat-seine method (Danish method) was conducted with the same vessel during the day, and each sampling consisted of three successive hauls. The cod end mesh size ranged from 8 to 12 mm, and the length of nets was 500 m. Depth ranged between 8 and 25 m. Coordinates, dates, surface temperatures and salinities are summarized in Table 1.

All fish and invertebrate specimens collected on board during fishing operations were temporarily preserved in ice before being transported to the laboratory facilities for freezing.

At the laboratory, specimens were thawed and then identified to species level (Whitehead *et al.*, 1986; Fischer *et al.*, 1987; Golani *et al.*, 2002; Golani *et al.*, 2006; Louisy, 2015). The abundance and biomass of each species per sampling were recorded. For most specimens, total length (TL, cm), standard length (SL, cm; 0.1 mm accuracy) and total weight (TW, g; 0.1 g accuracy) of each individual were measured. The TL values of Lessepsian fish were tested for normality using the Shapiro-Wilk test (when $P < 0.05$, the hypothesis that data follow the normal distribution is rejected). SL-TL relationships were studied following the linear regression model verified by Pearson's correlation coefficient. In addition, the power model $W = a \cdot TL^b$, where *a* is a constant and *b* the allometry coefficient, was used to describe weight-length relationships. The analyses were carried out using the statistical software package IBM SPSS Statistics version 22.

Results

All samplings from both types of fishing gear produced 33,162 bony fish with a total of 364.18 kg biomass, belonging to 30 families. Of the 67 recorded species, 56 were native and 11 were alien (Table 2), with a total alien to native species ratio of 1:5.1. Seventeen native and seven alien species were common in both fishing gear methods. The few invertebrates captured were not taken into consideration, due to their negligible abundance and weight. These included the native cephalopods *Sepia officinalis* (3 ind., Station F, 540 g; 3 ind., Station T, 350 g) and *Eledone moschata* (1 ind.; Station T; 146 g) and the alien *Sepioteuthis lessoniana* (10 ind., Station T, 510 g), the stomatopod *Squilla mantis* (1 ind., Station F), the alien penaeid *Trachysalambria palaestinensis* (1 ind.; Station F) and few *Dardanus* sp. specimens.

Trammel net experimental fishing

At Station F (Fig. 1), where the trammel net experimental samplings took place, 31 bony fish species were identified, belonging to 19 families, of which 8 Lessepsian migrant species comprised 26% of the total abundance, namely *F. commersonii*, *L. sceleratus*, *P. forsskali*, *P. miles*, *S. luridus*, *S. rivulatus*, *S. rubrum*, *Stephanolepis diaspros*, with an alien to native species ratio of 0.35:1 (Fig. 2; Table 2). The richest families were Sparidae with 9 species and Scorpaenidae with 3 species. The total abundance obtained from the four trammel net experimental samplings was 306 fish, with an average per sampling of 77 ± 55 specimens (range 25-140 specimens), while total biomass was 44.18 kg, with an average per sampling of 11.05 ± 13.04 kg (range 2.94-30.47 kg). The biomass ranged from 2.11 kg to 15.24 kg per 1,000 m of net.

The abundance of alien fish was 132 individuals with a biomass of 28.8 kg with both greatly exceeding those of native species (Fig. 2).

The species *Boops boops*, *S. rubrum*, *Scorpaena porcus*, *Scorpaena scrofa*, *S. luridus* and *Sparisoma cretense*

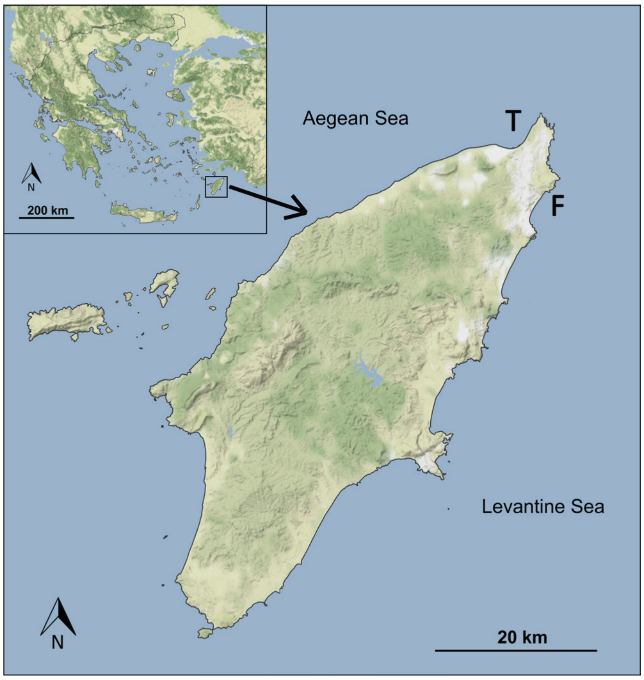

Fig. 1: Map of Rhodes, showing the sampling location of Faliraki (F) for trammel net and Trianda (T) for boat-seine experimental fishing.

Table 1. Coordinates, dates, surface temperatures and salinities of sampling stations (F: Faliraki; T: Trianda).

Station	Coordinates	Sampling Date	Fishing Gear	Surface Sea Temperature (°C)	Surface Salinity (‰)
F1	36.36736111°N,	15 May 2019	trammel nets	19.1	39.3
F2	28.24241667°E to	16 Sep.2019	trammel nets	26.4	39.6
F3	36.35588889°N,	26 Feb. 2020	trammel nets	18.5	39.2
F4	28.23086111°E	02 Jul. 2020	trammel nets	24.0	39.4
T1	36.42541667°N,	14 May 2019	boat-seine	18.9	39.3
T2	28.16463889°E to	10 Sep. 2019	boat-seine	25.8	39.6
T3	36.44669444°N,	25 Feb. 2020	boat-seine	18.2	39.2
T4	28.20641667°E	01 Jul. 2020	boat-seine	23.5	39.4

Table 2. Fish species, abundance and biomass, obtained through four trammel net (TN) samplings at Station Faliraki (F) and four boat-seine (BS) samplings (12 hauls) at Station Trianda (T) in Rhodes, between 2019-2020. Families are listed in alphabetical order. (A: Alien species; x: Presence in specific fishing gear; N: Number of specimens; W: Total weight, g; *: 3 hauls; F %: Frequency of occurrence in 12 boat-seine hauls).

Family	Species	Main gear	TN Sampling ID								Main gear	BS Sampling ID								
			F1		F2		F3		F4			T1*		T2*		T3*		T4*		
		TN	N	W	N	W	N	W	N	W	BS	N	W	N	W	N	W	N	W	F%
Atherinidae	*Atherina hepsetus*										x					10	26.5			16.7
Balistidae	*Balistes capriscus*										x							1	394.3	8.3
Bothidae	*Bothus podas*	x	1	17.8					59	1538.6	x	1	1.4	1	18.7	3	11.5	8	120.6	50.0
Carangidae	*Seriola dumerili*										x			4	1404.8					8.3
Carangidae	*Trachurus mediterraneus*										x	1	16.2							8.3
Carangidae	*Trachurus trachurus*										x							3	5.4	16.7
Centracanthidae	*Spicara maena*	x	1	100.5							x	1	55.41	99	3654.1	1	8.7	132	6319.8	66.7
Centracanthidae	*Spicara smaris*										x	101	1480.5	9242	14386.3	1220	11083.3	4413	11521.6	100.0
Clupeidae	*Sardina pilchardus*										x	3	5.1	40	341.7					16.7
Clupeidae	*Sardinella aurita*										x			430	2660.1	12	239.8			41.7
Fistulariidae	*Fistularia commersonii*[A]	x			33	9831.2					x			38	1344.0	28	4975.7	92	29504.2	58.3
Gobiidae	*Gobius geniporus*										x			1	25.8					16.7
Holocentridae	*Sargocentron rubrum*[A]	x	1	143.9	12	1481.5	3	309.9	1	171.9										
Labridae	*Coris julis*										x	3	17.5	16	174.4	22	106.1	11	88.3	91.7
Labridae	*Pteragogus trispilus*[A]										x	2	10.4	46	272.1	12	39.0	20	98.6	75.0
Labridae	*Symphodus doderleini*										x			5	50.1	1	9.6			25.0
Labridae	*Symphodus mediterraneus*										x	4	39.5	9	58.5			16	115.6	58.3
Labridae	*Symphodus ocellatus*										x	1	2.7							8.3
Labridae	*Symphodus roissali*										x	1	6.8							8.3
Labridae	*Symphodus rostratus*										x	3	13.9	12	92.5	8	41.1	8	40.5	91.7
Labridae	*Symphodus tinca*										x							1	84.7	8.3
Labridae	*Xyrichthys novacula*	x							1	32.9										
Monacanthidae	*Stephanolepis diaspros*[A]	x							1	36.4	x					2	8.9			16.7
Mullidae	*Mullus barbatus*										x	11	340.7	32	241.0	5	108.5	2	68.8	58.3
Mullidae	*Mullus surmuletus*	x			2	335	2	374.6			x	11	364.6	8	226.9	2	48.2	11	1253.9	75.0
Mullidae	*Parupeneus forsskali*[A]	x					1	133.8			x			97	859.1	1	2.5	32	2774.3	58.3
Phycidae	*Phycis phycis*	x			2	419.9														
Pomacentridae	*Chromis chromis*										x	1855	27454.6	44	152.6	7	37.1	3	36.7	58.3
Scaridae	*Sparisoma cretense*	x	2	376.1	16	2145.6	1	188.5	2	264.1	x	5	77.9	106	2435.8	4	18.5	90	5922.4	100.0
Sciaenidae	*Sciaena umbra*										x							1	125.5	8.3
Scombridae	*Scomber scombrus*										x							1	39.5	8.3
Scorpaenidae	*Pterois miles*[A]	x			28	7922.6	1	165.4	2	372.4	x	1	17.4			1	38.2	7	779.7	33.3
Scorpaenidae	*Scorpaena elongata*										x			1	7.1					8.3

Continued

Table 2 continued

Family	Species	Main gear		TN Sampling ID							Main gear	BS Sampling ID								
			F1		F2		F3		F4			T1*		T2*		T3*		T4*		
		TN	N	W	N	W	N	W	N	W	BS	N	W	N	W	N	W	N	W	F%
Scorpaenidae	*Scorpaena maderensis*										x							2	.	8.3
Scorpaenidae	*Scorpaena porcus*	x	2	308.2	5	433.7	1	119.4	2	105.7	x			1	47.5			3	239.5	16.7
Scorpaenidae	*Scorpaena scrofa*	x	3	214.8	2	245.5	5	631.4	2	215.1	x			5	119.8	5	112.3			25.0
Serranidae	*Epinephelus costae*										x			1	112.5					8.3
Serranidae	*Serranus cabrilla*	x					1	22.3	1	29.4	x	2	19.4	19	196.7	12	137.1	4	65.6	91.7
Serranidae	*Serranus scriba*										x	12	111.0	41	664.5	13	174.9	16	279.7	91.7
Siganidae	*Siganus luridus*[A]	x	1	112.3	18	2239.7	2	156.7	2	313.8	x	2	17.7	82	664.2	5	40.6	7	245.7	83.3
Siganidae	*Siganus rivulatus*[A]	x			9	1332.9	4	694	12	1156.5	x	3	517.2	430	998.2	34	99.2	43	2489.1	91.7
Soleidae	*Solea solea*	x							1	153.2										
Sparidae	*Boops boops*	x	1	376.1	1	106.7	1	201	2	272.8	x	2046	31508.7	6712	20450.4	712	10283.6	3299	79270.2	100.0
Sparidae	*Dentex dentex*										x			1	96.5			5	11.7	16.7
Sparidae	*Diplodus annularis*	x							1	73.5	x			11	101.11			1	31.1	33.3
Sparidae	*Diplodus puntazzo*										x	4	6.6					1	196.3	16.7
Sparidae	*Diplodus sargus*	x					1	738.2			x			2	123.1					8.3
Sparidae	*Diplodus vulgaris*	x			4	384					x	1	33.0	47	1110.9	1	23.6	67	2848.9	66.7
Sparidae	*Lithognathus mormyrus*	x							1	119.6										
Sparidae	*Oblada melanura*										x			16	2473.4			41	7184.8	41.7
Sparidae	*Pagellus acarne*	x	1	44.6							x			7	68.2	2	41.1	3	84.8	41.7
Sparidae	*Pagellus erythrinus*	x	19	289.4					2	400.7	x	12	378.4	16	172.4			60	1126.0	58.3
Sparidae	*Pagrus pagrus*	x	4	178.5	6	759.5	1	212			x	151	421.5	94	1612.9	2	52.3	157	3062.1	83.3
Sparidae	*Spondyliosoma cantharus*	x	3	623.7	1	610					x			33	312.2			3	212.1	41.7
Sphyraenidae	*Sphyraena chrysotaenia*[A]										x			2	6.1			50	3069.7	16.7
Sphyraenidae	*Sphyraena sphyraena*										x	2	435.6	1	291.8					25.0
Sphyraenidae	*Sphyraena viridensis*										x			4	1895.7			13	2995.1	33.3
Syngnathidae	*Syngnathus acus*										x					2	6.8			16.7
Syngnathidae	*Syngnathus typhle*										x			1	3.3	4	17.8			25.0
Synodontidae	*Synodus saurus*	x	4	150.4					2	243.8	x	2	72.2	1	7.1	14	975.6			41.7
Tetraodontidae	*Lagocephalus sceleratus*[A]	x			1	2222.2					x			7	3757.2					8.3
Tetraodontidae	*Torquigener flavimaculosus*[A]										x	2	31.8	4	38.1	57	767.5	8	128.5	58.3
Trachinidae	*Trachinus araneus*	x							1	389.2										
Trachinidae	*Trachinus draco*										x	1	11.0							8.3
Triglidae	*Chelidonichthys lastoviza*	x							1	152.8	x					1	76.2			8.3
Uranoscopidae	*Uranoscopus scaber*	x					1	265.2	2	521.7	x					3	165.5	1	18.7	25.0
Zeidae	*Zeus faber*										x	1	94.2			1	49.9			16.7
Total	67	31	43	2936.3	140	30470.0	25	4212.4	98	6563.9	61	4245	63562.7	17769	63729.2	2207	29826.9	8636	162875.9	

occurred in all samplings, followed by *Pagrus pagrus*, *P. miles* and *S. rivulatus* with a 75% frequency of occurrence (Table 2). In terms of abundance, the most representative families (%) were Bothidae (19.7%), Scorpaenidae (17.0%), Sparidae (16.1%), Siganidae (15.7%) and Fistulariidae (10.8%), whereas in terms of biomass the families Scorpaenidae, Fistulariidae, Siganidae and Sparidae predominated with 24.0%, 22.3%, 13.6% and 12.2% of the totl catch, respectively.

The fish species that constituted most of the relative abundance were the native *Bothus podas* and four alien species: *F. commersonii*, *P. miles*, *S. rivulatus* and *S. luridus*. In terms of relative biomass, the species that dominated were the alien *F. commersonii*, *P. miles*, *S. rivulatus*, *S. luridus* and the native *S. cretense* (Fig. 3). It is noteworthy that the abundance and biomass of the two alien herbivorous siganids was double compared to the native herbivorous *S. cretense*. Similarly, the abundance and particularly the biomass of *P. miles* markedly exceeded those of the two native scorpaenids *S. scrofa* and *S. porcus* (Fig. 3).

The number of Lessepsian fish species, present in all samplings, ranged from two to six species per haul, i.e., lower compared to the number of native species that ranged from nine to 15 species per haul (Table 2). However, the relative abundance and biomass of Lessepsian fish was high, particularly in samplings F2 and F3, carried out in September 2019 and February 2020, respectively. *Siganus luridus, S. rivulatus*, *F. commersonii, S. rubrum* and the recently introduced *P. miles* exhibited highly pronounced presence (Table 2) (Fig. 4). Almost 1/3 (31.25%) of the biomass obtained in the trammel net haul deployed after summer 2019 (F2) was characterised by alien fish (Table 2).

Boat-seine experimental fishing

The experimental samplings using the boat-seine method were carried out at Station T (Fig. 1). Overall, 61 fish species from 27 families were collected, including 10 Lessepsian migrants (16.4% of total species; Fig. 2), namely *F. commersonii*, *L. sceleratus*, *P. forsskali*, *P. miles*, *Pteragogus trispilus*, *S. diaspros*, *S. luridus*, *S. rivulatus*, *S. chrysotaenia*, *T. flavimaculosus*, with an overall 1:5.1 ratio of alien to native species (Table 2). Among the species observed in boat-seine nets, 17 native and 7 alien were also found in those captured by trammel nets (Table 2). The abundance of fish in all twelve boat-seine hauls was 32,856 individuals, with an average of 2,738 ± 3,474 individuals per haul (range 262-12,940 ind. per haul), while the total biomass was 320 kg, with an average of 26.7 ± 19.5 kg per haul (range 2.2-68.7 kg per haul) (Table 2). The richest families were Sparidae, with 11 species, Labridae with eight species and Scorpaenidae with five species, followed by Carangidae, Mullidae, Serranidae and Sphyraenidae, each with three species.

The abundance of alien fish species was 1,123 individuals, representing 3.4% of the total abundance, while their biomass reached 53.6 kg, representing the 17% of the total catch (Fig. 2).

Table 3. Length and weight (g) (W) measurements and relationships between total length (TL, cm) and standard length (SL, cm) and between weight and total length for 11 Lessepsian fish species (in alphabetical order) caught between 2019 and 2020 from Rhodes, SE Aegean Sea. N: sample size; SD: Standard deviation; s.e.$_{(b)}$: standard error of the slope *b*; R^2: coefficient of determination; *: TL measured without the tail filament.

Species	N	TL		SL		W		SL= *a* + *b* TL					W= *a* · TL^b				
		Mean ± SD	Min – Max	Mean ± SD	Min – Max	Mean ± SD	Min – Max	a	b	s.e.$_{(b)}$	R^2	P	a	b	s.e.$_{(b)}$	R^2	P
*Fistularia commersonii**	145	74.3 ± 12.5	35.3 – 104.5	71.3 ± 12.0	34.7 – 100.0	299.3 ± 154.8	22.1 – 884.4	0.2778	0.9565	0.007	0.992	0.000	0.0001	3.338	0.043	0.977	0.000
Lagocephalus sceleratus	8	35.9 ± 14.4	5.8 – 57.3	31.3 ± 12.9	4.8 – 50.9	747.4 ± 664.4	2.3 – 2222.2	-0.6083	0.8901	0.009	0.999	0.000	0.0118	2.995	0.033	0.999	0.000
Parupeneus forsskali	84	10.0 ± 3.5	4.4 – 22.5	8.0 ± 2.9	3.7 – 19.4	16.4 ± 21.7	0.7 – 133.8	-0.3400	0.8297	0.009	0.991	0.000	0.0050	3.339	0.030	0.993	0.000
Pteragagus trispilus	61	7.2 ± 1.4	3.8 – 9.9	5.3 ± 1.0	2.8 – 7.6	4.9 ± 2.6	0.7 – 12.2	0.3784	0.6892	0.020	0.953	0.000	0.0133	2.951	0.073	0.965	0.000
Pterois miles	39	24.6 ± 5.3	9.8 – 34.3	18.1 ± 4.3	6.7 – 25.8	237.9 ± 130.8	7.4 – 507.4	-1.4303	0.7971	0.011	0.993	0.000	0.0031	3.463	0.075	0.983	0.000
Sargocentron rubrum	16	17.6 ± 1.1	16.3 – 20.0	15.3 ± 0.8	14.2 – 17.1	122.7 ± 25.3	94.0 – 177.5	3.3947	0.6741	0.073	0.858	0.000	0.0515	2.705	0.366	0.796	0.000
Siganus luridus	63	12.5 ± 5.8	4.3 – 25.8	10.1 ± 4.7	3.4 – 20.7	54.0 ± 63.7	0.9 – 296.0	-0.1416	0.8167	0.005	0.997	0.000	0.0077	3.271	0.034	0.994	0.000
Siganus rivulatus	132	11.9 ± 7.6	3.5 – 27.8	9.6 ± 6.2	2.6 – 23.4	46.7 ± 66.7	0.3 – 285.3	-0.2067	0.8231	0.004	0.996	0.000	0.0080	3.125	0.032	0.987	0.000
Sphyraena chrysotaenia	7	17.5 ± 7.5	6.8 – 25.8	15.0 ± 5.9	6.6 – 21.5	40.3 ± 27.9	3.0 – 77.6	1.2882	0.7825	0.008	0.999	0.000	0.0255	2.490	0.038	0.999	0.000
Stephanolepis diaspros	3	8.50 ± 4.19	5.6 – 13.3	6.45 ± 3.39	4.0 – 10.3	15.1 ± 18.5	3.7 – 36.4										
Torquigener flavimaculosus	67	7.9 ± 2.9	3.8 – 13.2	6.1 ± 2.3	2.5 – 10.9	13.8 ± 13.7	0.7 – 51.4	-0.3606	0.8205	0.009	0.993	0.000	0.0157	3.097	0.042	0.988	0.000

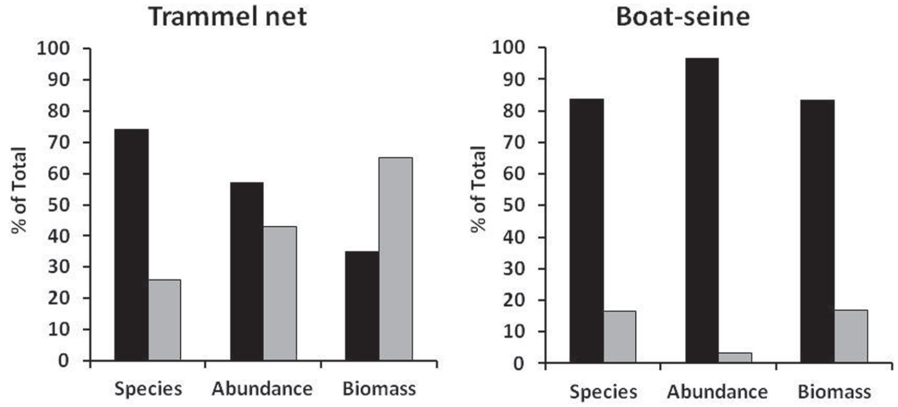

Fig. 2: Overview of results obtained from trammel net and boat-seine experimental fishing carried out in Rhodes, between 2019 and 2020 (Native species: black, Alien species: grey).

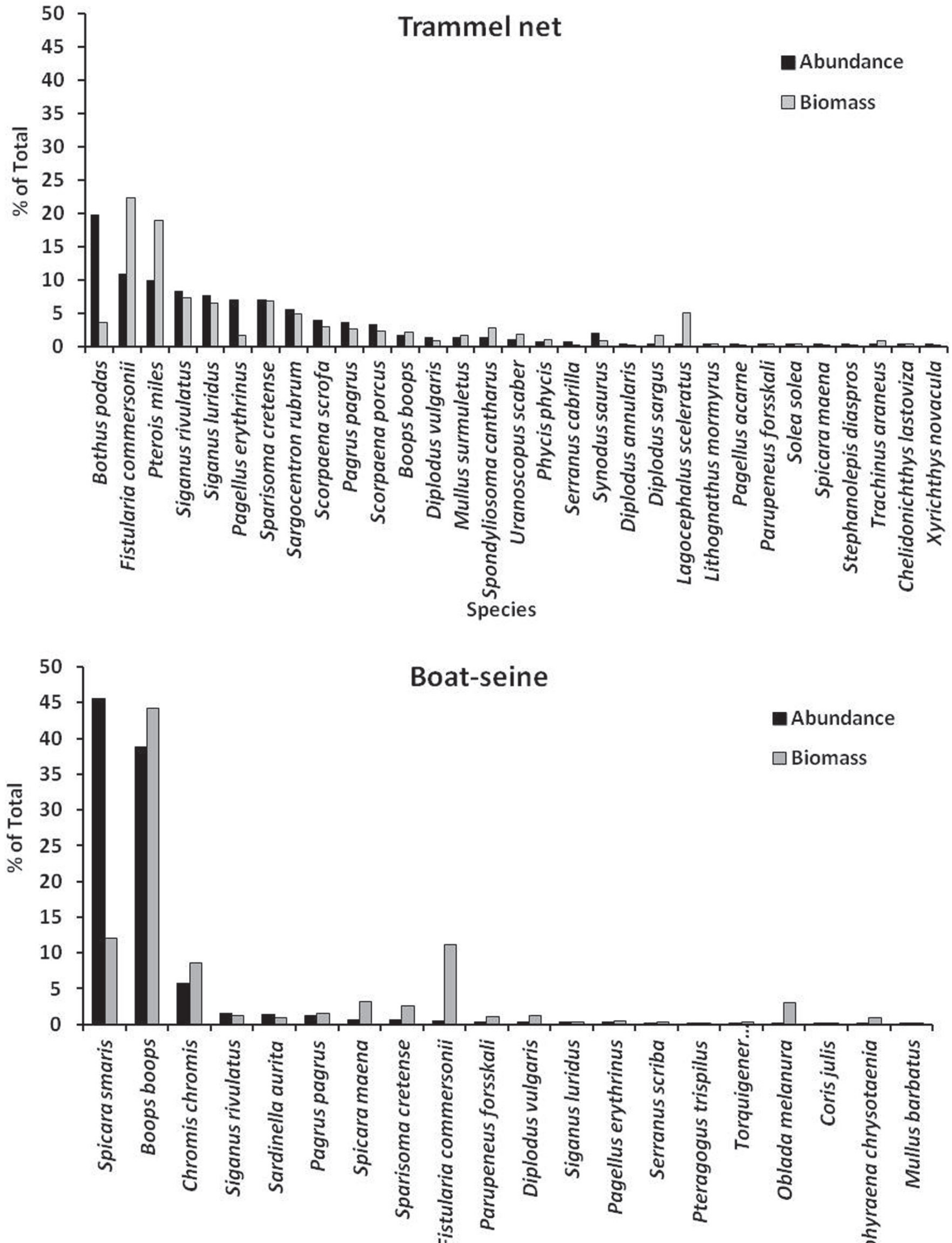

Fig. 3: Relative abundance and biomass of species caught in trammel net and boat seine samples in Rhodes, Greece (Eastern Mediterranean).

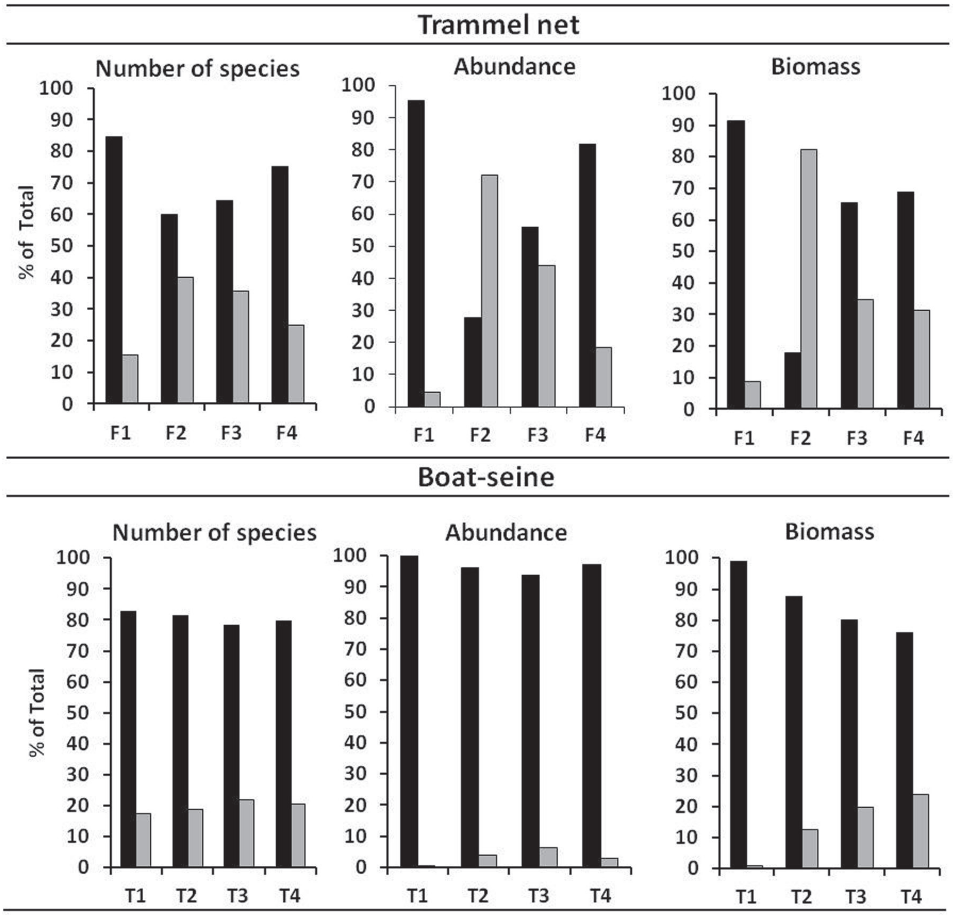

Fig. 4: Proportion of native and alien species, in number, abundance and biomass obtained during four samplings on rocky-sandy habitat with trammel net (1 haul per sampling) and on *Posidonia* beds with boat-seine (3 hauls per sampling) (Native species: black, Alien species: grey; number 1, 2, 3, 4 correspond respectively to May 2019, September 2019, February 2020, July 2020).

Boops boops, *S. cretense* and *Spicara smaris* occurred in all 12 hauls, while *Coris julis*, *Serranus cabrilla*, *Serranus scriba*, *S. rivulatus* and *Symphodus rostratus* exhibited 91.7% frequency of occurrence. High frequency of occurrence of *P. pagrus*, *S. luridus*, *P. trispilus* and *M. surmuletus* was also observed, ranging between 75% and 85%.

A notable fact was the predominance of *S. smaris* and *B. boops* that combined constituted 84% and 56% of total abundance and biomass respectively, followed by the alien *F. commersonii* and the native *Chromis chromis* comprising 11% and 9% of the total biomass, respectively (Fig. 3).

Considering each single boat-seine haul, alien fish species ranged from 0 (only in a single haul at T1) to seven, while the number of native species ranged from 13 to 27 per haul. Considering the four samplings as a whole (3 hauls for each sampling), in terms of fish diversity, native species ranged from 24 to 35, while the contribution of alien species was 5 to 8 species (Table 2), exhibiting the higher relative number at T3, during winter (22% of total species) (Fig. 4). The relative abundance of alien fish was lower when compared to native species, with a maximum of 6% of total specimens at T3, while their relative biomass steadily increased from a low 0.9% of total biomass observed at sampling T1 up to 24% at T4, in the early summer 2020 (Fig. 4). Considering only the alien fish, the highest abundance was observed for *S. rivulatus* at sampling T2 and the highest biomass for *F. commersonii* at T3 (Table 2). Among the alien species, the highest biomass or abundance was exhibited by the labrid *P. trispilus*, the tetraodontid *T. flavimaculosus* and the mullid *P. forsskali* (Table 2).

Length-length and weight-length relations

Overall, 625 specimens from 11 Lessepsian fish collected with the trammel net and boat-seine fishing techniques were examined. Unfortunately, most of *S. chrysotaenia* specimens were lost, due to technical problems. The number of individuals per species ranged from 3 (*S. diaspros*) to 145 (*F. commersonii*). The reticulated leatherjacket *S. diaspros* was excluded from the statistical analysis, due to their scarcity in the samples. In accordance with the Shapiro-Wilk test results, the TL values were approximately normally distributed only for *F. commersonii* (P= 0.064) and *P. trispilus* (P= 0.678). Means and ranges of measurements and the values of the parameters *a* and *b* of both the SL-TL and W-TL relations are shown in Table 3. For the ten species examined, the relationship between TL and SL revealed a significantly linear regression ($P < 0.001$) and the power curve was a good fit ($R^2 = 0.99$) for their weight vs TL values ($P < 0.001$) (Table 3). Six Lessepsian fish species showed positive allometric growth (*b* 3.097-3.463), while *L. sceleratus* exhibited isometric growth (*b*= 2.995), *P. trispilus* negative allometric growth (*b*= 2.951), while a negative allometric mode of growth was observed for *S. chrysotaenia* and *S. rubrum*.

Besides *S. rubrum*, juveniles of the remaining ten Lessepsian fish were collected (Table 3). Juveniles of *F. commersonii* were measured approximately and, due to their bad condition, were not included in Table 3. All small-sized Lessepsian fish specimens were collected over *P. oceanica* meadows using boat-seine. In particular, *F. commersonii* (<30 cm), *L. sceleratus* (4.8 cm), *P. forsskali* (3-5 cm), *S. luridus* (3-4 cm) and *S. chrysotaenia* (6-7 cm) were collected after the summer 2019 (sampling T2); *P. trispilus* (2-4 cm) and *S. rivulatus* (2-5 cm) after the summer and during winter (samplings T2 and T3), *S. diaspros* (4-5 cm) and *T. flavimaculosus* (2-4 cm) in the winter (sampling T3) and *P. miles* (6-7 cm) in the early summer of 2020 (sampling T4).

Discussion

Lessepsian fish were observed in all trammel net hauls and in almost all boat-seine hauls, thus indicating that they are widely dispersed in the studied habitats, rocky-sandy and *P. oceanica* meadows.

Many of the recorded Lessepsian fish present in the area are displayed in the historically important public Aquarium of the Hydrobiological Station of Rhodes since the 1980s, depending on the time of their entry and establishment in the south-eastern Aegean waters (Corsini-Foka *et al.*, 2014), including the recently introduced lionfish *P. miles*. This evidences that these species easily adapt to captivity conditions. Among the Lessepsian fish reported from Rhodes and the Greek seas, all the invasive species, i.e. *S. luridus*, *S. rivulatus*, *F. commersonii*, *L. sceleratus* and *P. miles* (Katsanevakis *et al.*, 2014), were detected with both fishing gears. Among these invasive fish, the highest frequency of occurrence was observed for the two siganids and the lionfish in trammel nets, whereas the siganids and the bluespotted cornetfish were the species with greater frequency in boat-seine nets.

The invasive highly toxic *L. sceleratus* was found here only after summer 2019: juveniles and adults in a single boat-seine haul and one adult in a trammel net. In contrast to older studies (Corsini-Foka *et al.*, 2010; Corsini-Foka M., 2010; Kalogirou *et al.*, 2010), *L. sceleratus* was observed in low abundance (Corsini-Foka *et al*., 2017). However, the high number of individuals and considerable biomass of this species are frequently observed using both static and dynamic gears (Authors, pers. comm.).

On the other hand, *P. miles* rapidly established a local population in the region, forcefully imposing its presence, mainly in the rocky sandy habitats of the island (Zannaki *et al.*, 2019), although known to dwell on *P. oceanica* meadows. The species is already well-established in the Levantine Sea, and in the south and central Aegean and Ionian Seas. From a biological viewpoint, in marine areas characterized by a subtropical environment such as Rhodes and the nearby islands, the increase of autumn-winter temperature of about 1˚C observed in surface waters since the 1990s, may be considered one of the most important factors contributing to the successful introduction and establishment of tropical species appearing during the last decades (Pancucci-Papadopoulou *et al.*, 2011; Pancucci-Papadopoulou *et al.*, 2012; Mavruk *et al.*, 2017). The winter isotherm of 15.3°C is considered a distribution limit for *Pterois volitans* across the invaded North Carolina (USA) continental shelf (Whitfield *et al.*, 2014) and this limit is exceeded in the study area all year-round (http://poseidon.hcmr.gr). Assuming that the mean winter sea surface temperature of 15.3°C is the main limiting factor for range expansion, the lionfish could extend its populations westward in the Mediterranean, with the exception of the the coolest northernmost regions (Dimitriadis *et al.*, 2020).

In terms of abundance and biomass, the four invasive species: *S. luridus*, *S. rivulatus*, *F. commersonii* and *P. miles* dominated the trammel net total catch, particularly in the hauls conducted after summer 2019. In other isolated occasions, before the lionfish arrived, the dominance of aliens as a whole has also been observed in the summer (Corsini-Foka *et al.*, 2010), while a lower relative abundance and biomass of aliens was observed in other cases, such as in Spring 2014 (Corsini-Foka *et al.*, 2015), as in this study. Remarkably, the lionfish has exceeded, both in abundance and biomass, its congeneric natives *S. scrofa* and *S. porcus*, two typical species dwelling on rocky grounds with feeding preferences similar to *P. miles* (Golani *et al.*, 2006). In its initial stage of invasion, lionfish probably shares habitats and food sources with native Scorpaenidae and the results obtained here could be interpreted as an indication of a possible competition for food and space of *P. miles* with the indigenous scorpaenids (Zannaki *et al.*, 2019) and in particular with the commercially important *S. scrofa*, similar in size to the lionfish. Nevertheless, recent data indicates that *P. miles* preys on Scorpenidae (Kondylatos unpub. data).

This study presents further information on the competition taking place among non-indigenous and native species. In 20 gill net hauls set during 2014-2015 along the eastern coast of Rhodes, the abundance and biomass of the native herbivorous *S. cretense* exceeded those of the two siganids combined (Corsini-Foka *et al.*, 2017) whereas in the current work, using four hauls of trammel net, the results were reversed, with the abundance and biomass of siganids being more than the double of those of the native *S. cretense*, as observed in the past, e.g, in Libyan waters (Shakman & Kinzelbach R., 2007; Shakman *et al.*, 2008). The two herbivorous siganids of tropical origin massively colonized the Levantine basin and reached the central Mediterranean Sea, probably aided by the paucity of native herbivorous competitors, *S. cretense* and *Sarpa salpa*, and presumably exploited unsaturated niches (Golani, 2010), leading to the alteration of community structure and the native food web of rocky infralittoral habitat and depriving the ecosystem of the valuable functions of algal forests (Bianchi *et al.*, 2014; Giakoumi, 2014; Katsanevakis *et al.*, 2014; Vergés *et al.*, 2014). Remarkably, the south Aegean areas where siganids are abundant, are also invaded by a wide variety of alien macrophytes (Tsiamis, 2012; Corsini-Foka *et al.*, 2015; ELNAIS, 2020); this complicates the issue and could lead to changes in the original-native structure of the bio-communities. As already mentioned, siganids are commercially important in the area under study, as in other invaded regions of the eastern Mediterranean (Turkey, Cyprus, Lebanon, Egypt, Libya, Israel) (Cerim *et al.*, 2020; Soykan *et al.*, 2020), contrarily to Crete where both siganids appeared later than in Rhodes, at the beginning of the year 2000, and, although common now (Skarvelis *et al.*, 2015), they are still discarded (Authors, pers. comm.). In the Cyclades as well, the common *S. luridus* is not appreciated (Giakoumi, 2014).

Therefore, the economic impact of siganids at local level in the south Dodecanese region may be considered positive (Katsanevakis *et al.*, 2014). However, from an ecological viewpoint, the absence of *S. salpa* during this study from both fishing gear is noteworthy. Its abundance was negligible in recent fishery surveys carried out around the island (Kalogirou *et al.*, 2010; Kalogirou *et al.*, 2012a; Kalogirou *et al.*, 2012b; Corsini-Foka *et al.*, 2017) and generally low in SCUBA diving surveys conducted in the south Aegean (Sini *et al.*, 2019). On the other hand, the species is fished in other fishing grounds of Rhodes and has often been observed by the authors at the local fish market but no official landing data for the catches of siganids and *S. cretense* are available at national or regional level. Available data on *S. salpa* landings at national level between 2004-2018, constitute 0.5-0.6% of the total national marine fish catches. However, no data is available at regional level (ELSTAT, 2020).

In the samplings performed with boat-seine on *Posidonia*, the native *S. smaris*, *B. boops* and *C. chromis* dominated in terms of abundance and biomass, as previously observed in the same fishing ground (Corsini-Foka *et al.*, 2010; Kalogirou *et al.*, 2010; Corsini-Foka & Kondylatos, 2015). The biomass of *F. commersonii* was also noticeable. It is interesting to note that the relative number of alien species (16.7%) and their biomass (17%) obtained in the present 12 boat-seine hauls were higher than those obtained in 20 hauls in 2008-2009 in Rhodes on various bottoms, 13.5% of the total number of species and 7.3% of total biomass (Corsini-Foka *et al.*, 2010), respectively, and also in the 60 hauls taken during the same period over various *P. oceanica* beds around the island, where the alien species represented 12.5% of the total fish species and 4% of total biomass (Kalogirou *et al.*, 2010). The relative abundance of aliens obtained here was comparable to the 4% reported by Kalogirou *et al.* (2010) and lower than that (7.8%) found in Corsini-Foka *et al.* (2010).

Among the aliens, the nocturnal *S. rubrum* appeared only in trammel nets, while *P. trispilus*, *S. chrysotaenia* and *T. flavimaculosus* were found only in boat-seine nets. Besides the recent invasive colonizer, the lionfish, remarkable was the abundance, especially on *Posidonia* beds, of another new entry, that of the Red Sea goatfish *P. forsskali*, a species that has colonized all the Levantine waters (Evagelopoulos, 2020) and has become important from an economic perspective (GFCM-UN Environment/MAP, 2018; van Rijn *et al.*, 2020). This mullid, firstly recorded in Rhodes in 2017 (Stamouli *et al.*, 2018), is already common at the local fish markets of the island, sometimes, but not always, confused with the native mullids and the alien *U. moluccensis* and *U. pori*, and its population is expanding quickly westward in the south Aegean (ELNAIS, 2020). It should be noted that in boat-seine hauls, the frequency of occurrence of this species is comparable to that of *Mullus barbatus* and *Mullus surmuletus* Linnaeus, 1758 considered together, and its total abundance and biomass was greater than those of the native mullids, a possible similarity with the situation described for Cyprus, where *P. forsskali* appeared for the first time in 2014 and its catches have exceeded those of the native and alien mullids in recent years, in the 0-50 m depth zone (Evagelopoulos, 2020).

Among the labrids, the density and biomass of the sideburn wrasse *P. trispilus* on *Posidonia* meadows were comparable to those of the Mediterranean rainbow wrasse *C. julis*, both species being more abundant than all the other labrids detected in this work, as previously observed (Kalogirou *et al.*, 2010). The presence of the tetraodontid *T. flavimaculosus* on *P. oceanica* beds, a species frequently captured in Rhodes in recent years (Corsini-Foka *et al.*, 2014) and also observed over *Halophila stipulacea* meadows, was notable. The yellow spotted puffer fish *T. flavimaculosus* has extended its distribution westward in the south Aegean up to the Ionian Sea (ELNAIS, 2020) and it has been reported as being one of the most invasive marine fish species in Greece (GFCM-UN Environment/MAP, 2018). Çek Yalnız *et al.* (2017) and Ulman *et al*. (2023) suggested that this species spawns from mid spring to late summer in the Turkish Eastern Mediterranean region of Iskenderun Bay and the finding during our study, of many juveniles during winter could corroborate a prolonged spawning period in our study area. Being highly toxic, due to its high content in tetrodotoxin (TTX), this pufferfish is dangerous for human consumption and should never be consumed (Kosker *et al.*, 2018; Katikou, 2019).

Juveniles and adults of Lessepsian fish on *P. oceanica* beds observed during this study indicate the important role of this habitat for native and alien fish, as assessed and widely discussed in Kalogirou *et al.* (2010).

Data on the linear regressions between SL and TL for Lessepsian fish are limited and the information provided here may be useful for future morphometric studies. The equation presented here for *P. miles* differs from that reported by Zannaki *et al.* (2019) in Rhodes and from those reported for the species in western Atlantic invaded regions (Perera-Chan & Aguilar-Perera, 2014). The equation obtained for *P. forsskali* could be comparable with the results obtained from Red Sea samples (Sabrah, 2015). The relationships described here for *L. sceleratus* appear to approach those reported from the Mediterranean and the Red Sea by Farrag *et al.* (2015) and Ulman (2021). The equations reported by Shakman *et al.* (2008) for siganids in the Mediterranean are comparable to our results. The relationship between total length and weight gives *b*-values greater than 3 for most of the Lessepsian fish investigated during our study, namely *F. commersonii*, *P. miles*, *P. forsskali*, *S. luridus*, *S. rivulatus*, *T. flavimaculosus*, reflecting a positive allometric mode of growth. Variations of the allometric coefficient may be observed within a species according to region, season, sex and gonad development, food availability, diet, sample size, length range and other factors (Edelist, 2014; Yapici *et al.*, 2015; Dimitriadis & Fournari-Konstantinou, 2018). As in previous studies carried out in Rhodes (Corsini-Foka *et al.*, 2010; Corsini-Foka, 2010), a positive allometric mode of growth for *F. commersonii* has been found in other invaded Mediterranean regions (Bariche & Kajajian, 2012; Castriota *et al.*, 2014; Edelist, 2014; Elbaraasi, 2014; Vitale *et al.*, 2016). The results for the two siganids may be compared with those reported in the literature (Taskavak & Bilecenoglu, 2001; Bariche, 2005; Shakman *et al.*, 2008; Ceyhan *et al.*, 2009; Erguden *et al.*, 2009; Corsini-Foka *et al.*, 2010; Başusta *et al.*, 2013; Beğburs & Kebapçioğlu, 2013; Erguden *et al.*, 2015; Soykan *et al.*, 2020). Furthermore, positive allometric growth was observed for *T. flavimaculosus* from Iskenderun Bay, Turkey (Erguden *et al.*, 2009; Erguden *et al.*, 2015). As regards the lionfish, a wide range of *b*-values from higher to lower than 3 have been obtained in various invaded regions of the western Atlantic (Barbour *et al.*, 2011; Perera-Chan L.C. & Aguilar-Perera A., 2014; Sabido-Itzá *et al.*, 2016; Villaseñor-Derbez & Fitzgerald, 2019). As reported here, positive allometric growth was found in the eastern Levantine waters (Dağhan & Demirhan, 2020; Savva *et al.*, 2020), while slightly negative allometric growth as been reported by Zannaki *et al.* (2019) in Rhodes. A *b*-value of 3.34 for *P. forsskali* was obtained from our data; in populations from the region of Hurghada, Red Sea, Egypt, the allometry coefficient ranged from 2.80 (Mehanna *et al.*, 2018) to 3.17 (Sabrah, 2015). A growth approaching the isometric one reported in our work for *L. sceleratus* has been observed in the same study area (Corsini-Foka *et al.*, 2010) and for combined sexes (Michailidis, 2010; Aydın, 2011), and for males (Başusta *et al.*, 2013) in populations of the eastern Levant and in its native range (Simon & Mazlan, 2008).

The slightly negative allometric growth observed here for *P. trispilus* was obtained by Edelist (2014) in the Mediterranean waters of Israel, while a negative allometric mode of growth for *S. rubrum* has been reported from the Mediterranean waters of Egypt (Farrag *et al.*, 2018). Considering the limited samples of *S. chrysotaenia* measured during our work, negative allometric growth was obtained in the same study area by Kalogirou *et al.* (2012a) and in the eastern Mediterranean coast of Turkey by Taskavak & Bilecenoglu (2001).

Although changes in the synthesis of fishery catches appear to be an ongoing process in the shallow waters of the study area, native demersal fish diversity encountered during the course of our study and in recent coastal fishery studies is comparable to those listed in the past and there is no evidence of disappearance of certain species from this heavily invaded area of the south-eastern Aegean Sea. Demersal species diversity along the depth gradient in Crete, the Cyclades and the Dodecanese islands remained stable over the period 2005-2014, suggesting that environmental or anthropogenic pressure has not dramatically affected community structure (Peristeraki *et al.*, 2017). Besides the predation on native fish, invertebrates and algae that sustain the alien fish populations, the results of our work could indicate potential competition, e.g., between siganids and the native herbivorous *S. cretense* and *S. salpa*, between *P. forsskali* and the native mullids and between *P. miles* and the native scorpaenids (Arndt *et al.*, 2018a; Arndt *et al.*, 2018b), but caution is necessary in drawing any conclusions for an environment under continuous change (Gilaad *et al.*, 2017). It should be underlined that a combination of pressures, such as overexploitation of biological resources, loss, or degradation of natural habitats, warming of the sea and alien integration in the food webs, could affect synergistically the composition and function of bio-communities. Since there is a dynamic interaction between the population of alien species and the component of the recipient ecosystem (Katsanevakis *et al.*, 2014), it is difficult to ascribe to one or another of the above factors, combined with natural ones, the reason for the low abundance or absence of certain native species observed during fishing operations at specific periods and areas (Arndt *et al.*, 2018a; Arndt *et al.*, 2018b). It is noteworthy that in Mediterranean regions more affected by the massive occurrence of bio-invaders, such the eastern Levant, alien fish gradually became an important and commercially valuable part of the catch during the period 1996-2013, with little effect on indigenous species, while the income of fishermen remained stable (van Rijn *et al.*, 2020).

To date, fishery data on landings of the invasive fish encountered in Greek waters are not provided separately by the Hellenic Statistical Authority, both as total annual catches throughout the Greek seas, and also as catches at regional level where they are common or abundant (ELSTAT, 2020).

Generally speaking, the biomass of alien fish species in the artisanal fishery of the south-eastern Greek Aegean waters is lower compared to that of the eastern Levant (Gücü *et al.*, 2010; Turan, 2010; Lefkaditou *et al.*, 2014; Corsini-Foka *et al.*, 2017; Mavruk *et al.*, 2017). Nevertheless, the occurrence, in certain hauls, of large numbers of alien fish that are discarded because of their lack of commercial value or are hazardous for human consumption, is undoubtedly a blow to the local fishery economy. Our suggestion is that the implementation of managerial strategies could contribute to the exploitation of these novel fishery resources. To give an example, despite the fact that *P. miles* is discarded mainly because its local consumption level is low, the species is increasingly being promoted by internationally recognized chefs and sold gutted in several regional fish markets at 10 EUR per kg. In conclusion, the survey of fish catches, using two common small-scale fishing gears in different habitats, allowed an assessment of the ichthyofaunal diversity in artisanal fishery along the coastal waters of the island of Rhodes, and further contributed to an early quantification of the eventual impact of alien fish on local fisheries.

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