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Fish community in a surf zone of the northern Sicilian coast (Mediterranean Sea): diversity and functional guild composition

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Abstract

Fish assemblage in a surf zone of the southern Tyrrhenian Sea was investigated for the first time. Samples were collected during four surveys by a modified beach-seine, from June 2005 to May 2006. Overall, 42 species belonging to 19 families were recorded. Among them, *Sardina pilchardus* showed the highest abundance values, while Mugilids (*Oedalechilus labeo* and *Liza aurata*) were the most frequently caught species. The fish community was dominated by pelagic and gregarious species using this habitat as a foraging ground and recruitment area. Juveniles and early adults made up the largest proportion of the ichthyofauna. Fishes inhabiting the surf zone were mainly strictly benthic invertebrate feeders and invertivorous/piscivorous fish; strictly planktivorous were represented by few species but strongly dominant in terms of catch per unit effort; strictly piscivorous fish were poorly represented. Fish composition varied over the study period with the greatest abundance in May and December, and the highest richness and diversity in October.

Keywords: Sandy beach, ecological guilds, juvenile fish assemblage, southern Tyrrhenian Sea, Western Mediterranean.

Introduction

Surf zones, are important sites for the exchange of organic matter and nutrients between continent and sea (Yáñez-Arancibia, 1978; Brown & McLachlan, 1990) and support a wide range of fauna, mainly zooplankton and fishes (Maes *et al.,* 1998), that contribute to the energy transfer from this habitat to nearby areas (Modde & Ross, 1983; Du Preez *et al.,* 1990). According to the literature, surf zones fulfil many different vital functions for fishes, such as spawning and nursery grounds (Lasiak, 1981, 1983, 1984, 1986; Senta & Kinoshita, 1985), protection against predators and increased feeding opportunities (Layman, 2000; Selleslagh & Amara, 2007). For these reasons, the ichthyofaunal distribution and species composition in these areas are highly variable over spatial and temporal scales and are often the result of seasonal settling or periodic migration waves of young stages. Indeed, surf-zone fish communities are usually dominated by a small number of species, largely made up of juveniles that use shallow waters as nursery grounds and are most abundant during specific periods of the year (Lasiak, 1981, 1984; Ayvazian & Hindes, 1995; Gibson *et al.,* 1996). Surf zones are also populated by resident species, occurring throughout the year and represented by all life stages (Layman, 2000; Beyst *et al.,* 2001), as well as adult transient fishes, that are common in other marine habitats but move sporadically towards shallow waters to take advantage of temporally abundant or under-utilized food resources (Blaber & Blaber, 1980; Lasiak & MacLachlan, 1987; Esposito *et al.,* 2014). In order to better understand these complex temporal and spatial dynamics in estuarine and surf-zone fish assemblages, Elliott & Hemingway (2002) proposed a functional guild analysis based on the identification of fish groups exploiting the same class of environmental resources in a similar way (e.g., dietary preference, surf utilization, preferential habitat). This analysis simplifies complex ecosystems by reducing them to an ecologically meaningful level of complexity (Elliott & Dewailly, 1995; Garrison & Link, 2000) and, combined with traditional community descriptors (species composition, abundance and biomass), provides information on the functioning and on the internal and hierarchical structure of the fish communities.

In the present paper, classical community parameters were combined with ecological and dietary preference guilds as proposed by Layman (2000), Malavasi *et al.* (2004) and Suda *et al.* (2002) to describe the species composition and internal structure of the surf-zone fish assemblages off a sandy beach on the northern Sicilian coast (southern Tyrrhenian Sea). Moreover, considering that the few studies conducted on Mediterranean surf zones have focused only on the macro- and supra-benthic communities (León & Corrales, 1995; Munilla *et al.,* 1998; San Vicente & Munilla, 2000; Deidun & Schembri, 2006; Esposito *et al.,* 2011; Esposito, 2013) or on fish assemblages of Adriatic or north-eastern Mediterranean Sea (Lipej *et al.,* 2003; Giakoumi & Kokkoris, 2013) the specific objectives of this paper were: 1) to investigate, for the first time, the taxonomic composition of a fish assemblage in a surf zone of the Tyrrhenian Sea; 2) to assess the assemblage structure, with the aim of providing information on the functional aspects of this shallow water habitat for the ichthyofauna.

Materials and Methods

Study area

The study area is located on a surf-zone sandy bottom along the northern Sicilian coast, between Capo d'Orlando and Capo Calavà and is approximately 7 km long (Fig. 1). This bottom is characterized by gravel and very coarse sands near the coast, immediately followed by fine, well-sorted sands. It is subjected to the action of north-eastern currents and to a high sedimentation rate caused by irregular fluvial inputs; moreover, the presence of man-made structures (i.e. Capo d'Orlando harbour, breakwaters along the shore) causes variations in sedimentary structure and consequent accumulation of silt and clay in the surf zone (ICRAM, 2008; Esposito, 2013).

Sea-Surface Temperature

As in other temperate areas, temperature of the study area shows a classical seasonal pattern. Data recorded from 1999 to 2002 showed that temperatures were highest (24-28°C) during late June-August, declined in October-November (18-20°C) and reached low values (13-17°C) during December-early March, then increased to 18-20°C during early May-June (ICRAM, 2003).

Sampling methods

From June 2005 to May 2006, four fishing surveys were conducted during daylight, using a beach-seine (length: 40 m; height: 8 m) equipped with a 1 mm mesh size cod-end with the aim of collecting both adult and larval/juvenile fish. The mesh size used has been considered adequate to sampling larval stages, because in the study area this kind of net was used in the past to capture larvae of Engraulidae and Clupeidae by local fishermen for commercial purposes. The sampling periods were chosen on the basis of the different sea-surface temperature ranges recorded in the study area (late June, October, December, early May). Overall, 20 hauls were performed (5 per survey) in each of the two sampling stations. The net was set from a boat, describing a semi-circle which started from the shore, reached a maximum depth of 5 m

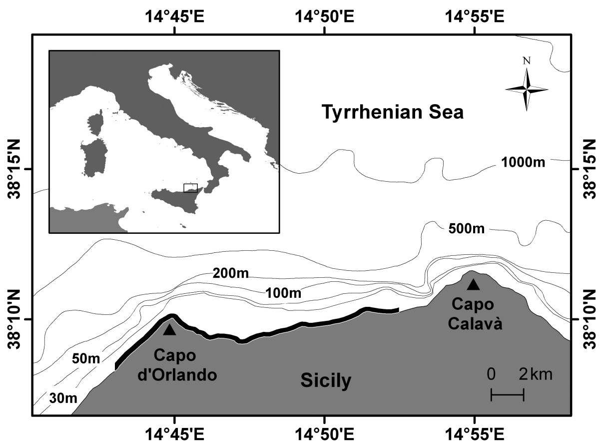

Fig. 1: Study area in the central Mediterranean Sea. The sampling stations were also showed (rectangles).

at a distance of 20-30 m from the coastline, and ended on the shore again. The net was hauled by 8 operators, four at each end of it. Both sides were pulled simultaneously from aloft and the net was closed off to trap the encircled fishes against the shore. During the fishing operations, the net extends vertically all over the water column and the footrope of the seine was in permanent contact with the bottom to prevent the fish from escaping from the enclosed area. Catches were analysed to determine species composition. Then, for each of the identified species, individuals were counted, measured to the nearest 1 mm total length (TL) and weighed to the nearest 0.001 g.

Abundance (N), biomass (W) and frequency of occurrence (F) percentages were assessed as follows:
%N = number of individuals of species *i*/total number of individuals * 100
%W = weight of species *i*/total weight of all species * 100
%F = number of hauls containing species *i*/total number of hauls * 100.

For each species, a sub-sample including fish of different sizes, was chosen and the stomach contents analysed (ICRAM, 2008), in order to categorize fish in terms of *dietary preference* depending on its ontogeny, following the classification proposed by Malavasi et al. (2004).

Fish community

The fish community was characterized by calculating the following diversity indexes for each sampling period:

- Specific Richness (S) expressed as the total number of species caught at each sampling.
- Shannon-Wiener Diversity Index (H›) (Shannon & Weaver, 1963) calculated as H′=*i*=1SP*i*∗lnP*i*
- Where P_i is the proportion of total sample represented by species *i*.
- Simpson's Index of dominance (D) calculated as D= p*i*2.

Also in this case, P_i is the proportion of total sample represented by species *i* (Clarke & Warwick, 2001).

The *dietary-preference* guilds, determined by the stomach content analysis of subsamples of each species and according to the available literature for Italian waters (e.g., Tortonese, 1970, 1975; Relini *et al.,* 1997), included the following groups: strictly planktivorous feeders (PS), strictly benthic invertebrate feeders (IS), strictly piscivorous feeders (FS), species feeding on invertebrates and fish (IF), detritivores (D) and herbivores (H). Fish species were also grouped, according to Suda et al. (2002), on the basis of their *developmental stage*: larvae (L), post-larvae (PL), juveniles (J), early adults (EA), adults (A), all life stages (LS), with larvae representing the developmental stage between hatching and the attainment of a full set of external meristic characters, and juveniles representing the developmental stage after larval stage and until first sexual maturity. The *surf utilization* guilds included the following categories: year-round residents (Y), seasonal nursery juveniles (J), transient adults common in other marine habitats (T) and the juvenile and adult transient group (J/T) (Layman, 2000), assigned on the basis of the fish assemblage composition in each sampling period. Finally, the *preferential habitat* guilds included the following groups: coastal area (C), estuary (E), offshore pelagic (P), rocky coast (RC), and sandy bottom (SB), assigned according to the available literature for Italian waters (e.g., Tortonese, 1970, 1975; Relini *et al.,* 1997).

Total and relative abundance for each species in each sampling period were calculated as standardized catch per unit effort (CPUE): total catches/number of hauls. CPUE, used as unit of relative abundance, and species number percentages for the ecological aspects *dietary preference* and *surf utilization* were calculated to identify the dominant functional groups in the fish assemblage by sampling period.

Juvenile fish assemblage

The use of the surf zone as a seasonal nursery by the fish community was investigated considering only larval and post-larval stages, juveniles and early adults, thus excluding adult fishes. A non-parametric multivariate analysis of variance (PERMANOVA) was applied on the abundance of each species, to estimate the potential differences in the juvenile fish assemblage by period. Data were transformed to square root and analysed on the basis of Gower distance using 4999 permutations. Pair-wise comparisons were computed when significant differences ($p<0.05$) among factor levels were detected; a multivariate multiple permutation test (SIMPER) was performed to determine the contribution of each species to average dissimilarity between groups, in terms of Bray-Curtis similarities. Finally, the pattern of correlation among fish species and sampling periods was investigated by the correspondence analysis. All these analyses were performed using the statistical software applications PRIMER6 & PERMANOVA+ (Clarke & Warwick, 2001; Anderson *et al.,* 2008) and the software package STATISTICA, version 10 (StatSoft, 2010).

Results

Fish community

Overall, 42 fish species belonging to 19 families were collected during the entire study period (Table 1). *Sardina pilchardus* recorded the highest value of abundance (N%=80.3) and biomass (W%=61.7), while mugilids (*Oedalechilus labeo* and *Liza aurata*) were the most frequent fishes in this environment (F%=79.5 and 61.5 respectively).

Diversity indexes calculated on the whole fish assemblage showed temporal variations (Fig. 2). In particular, species richness decreased from October to December (Fig. 2A); H' showed the highest value in October and was quite constant in the other sampling periods; D showed the lowest value in October and was rather constant in the other sampling periods (Fig. 2B).

As regards *preferential habitat*, the fish assemblage was mostly represented by species typical of sandy bottoms (n = 18), rocky bottoms (n = 9) and pelagic environment (n = 8), while, as to *developmental stage* guilds, juveniles dominated the fish assemblage.

Analysis of *surf utilization* highlighted that 11 species occurred in the study area throughout the year and, 4 of them spent their entire life cycle in the surf zone (Table 2), as shown by the catch of all their life stages (from larvae to adults). Moreover, seasonal nursery juveniles resulted the dominant group in terms of number of species (Fig. 3A), whereas the juvenile and adult transient group recorded the highest CPUE (Fig. 3B).

Within the *dietary-preference* guilds, strictly benthic invertebrate feeders had the highest number of species (Fig. 3C), while strictly planktivorous feeders highly dominated in terms of CPUE (Fig. 3D).

The analysis of temporal variations in fish assemblage within the category *surf utilization* revealed that the number of species representing the seasonal nursery juvenile group, was the highest in October (60% of the total species) and the lowest in late June (36% of the total species) (Fig. 4A); in contrast, the CPUE of group J recorded values <20% in October and early May and >80% in late June and December, thus seasonal nursery juvenile group represented almost the total fish community in these two sampling periods (Fig. 4B). Furthermore, the juvenile and adult transient group largely dominated the fish assemblage in early May (97% of total CPUE) and October (54% of the total CPUE). On the basis of *dietary-preference* guilds, strictly benthic invertebrate feeders were the dominant group over the whole sampling period, in terms of number of species (Fig. 4C), with increasing values from late June (36% of the total number of species) to early May (48% of the total number of species). In terms of CPUE, this group represented almost the whole fish community in late June

Table 1. Numerical abundance (N), biomass (W in grams) and frequency of occurrence (F) for fish species inhabiting the surf zone of the study area between June 2005 and May 2006.

Family	Species	Abundance		Biomass		Occurrence	
		N	% of total	W(g)	% of total	F	% of total
Ammodytidae	*Gymnammodytes cicerelus*	22	0.02	30.1	0.02	4	10.26
Atherinidae	*Atherina boyeri*	52	0.05	14.0	0.01	3	7.69
Belonidae	*Belone belone*	6	0.01	261.4	0.21	2	5.13
Bothiidae	*Arnoglossus laterna*	3	< 0.01	6.5	0.01	2	5.13
	Bothus podas	15	0.01	121.6	0.10	7	17.95
Callionymidae	*Callionymus pusillus*	5	< 0.01	8.2	0.01	3	7.69
Carangidae	*Caranx crysos*	68	0.07	612.0	0.50	5	12.82
	Lichia amia	1	< 0.01	36.9	0.03	1	2.56
	Seriola dumerili	1	< 0.01	105.9	0.09	1	2.56
	Trachinotus ovatus	125	0.12	295.8	0.24	9	23.08
	Trachurus mediterraneus	5	< 0.01	11.3	0.01	2	5.13
	Trachurus trachurus	6	0.01	31.9	0.03	2	5.13
Centracanthidae	*Spicara flexuosa*	437	0.43	966.7	0.79	3	7.69
Clupeidae	*Sardina pilchardus*	81007	80.29	75159.7	61.71	7	17.95
	Sardinella aurita	575	0.57	1035.3	0.85	2	5.13
Gobiidae	*Pomatoschistus marmoratus*	168	0.17	70.7	0.06	6	15.38
	Pomatoschistus minutus	1	< 0.01	0.7	< 0.01	1	2.56
Labridae	*Xyrichtys novacula*	9	0.01	234.0	0.19	5	12.82
Moronidae	*Dicentrarchus labrax*	14	0.01	1210.6	0.99	6	15.38
Mugilidae	*Liza aurata*	1610	1.60	12066.2	9.91	24	61.54
	Oedalechilus labeo	1301	1.29	20095.7	16.50	31	79.49
Mullidae	*Mullus barbatus barbatus*	111	0.11	1910.5	1.57	9	23.08
	Mullus surmuletus	20	0.02	345.9	0.28	7	17.95
Ophidiidae	*Ophidion barbatum*	1	< 0.01	43.1	0.04	1	2.56
Sparidae	*Boops boops*	78	0.08	251.9	0.21	2	5.13
	Dentex dentex	3	< 0.01	94.6	0.08	2	5.13
	Diplodus annularis	1	< 0.01	12.4	0.01	1	2.56
	Diplodus sargus sargus	4	< 0.01	77.3	0.06	3	7.69
	Diplodus vulgaris	99	0.10	117.5	0.10	7	17.95
	Lithognathus mormyrus	1728	1.71	853.8	0.70	14	35.90
	Oblada melanura	26	0.03	677.9	0.56	11	28.21
	Pagellus acarne	12662	12.55	2843.3	2.33	8	20.51
	Pagellus erythrinus	53	0.05	270.6	0.22	10	25.64
	Pagrus pagrus	3	< 0.01	3.3	< 0.01	1	2.56
	Sarpa salpa	617	0.61	1009.9	0.83	7	17.95
Sphyraenidae	*Sphyraena sphyraena*	1	< 0.01	283.4	0.23	1	2.56
	Sphyraena viridensis	34	0.03	211.6	0.17	2	5.13
Synodontidae	*Synodus saurus*	1	< 0.01	0.9	< 0.01	1	2.56
Trachinidae	*Echiichthys vipera*	4	< 0.01	34.5	0.03	3	7.69
	Trachinus draco	2	< 0.01	20.8	0.02	2	5.13
Triglidae	*Chelidonichthys lucerna*	10	0.01	352.0	0.29	6	15.38
	Eutrigla gurnardus	1	< 0.01	1.4	< 0.01	1	2.56

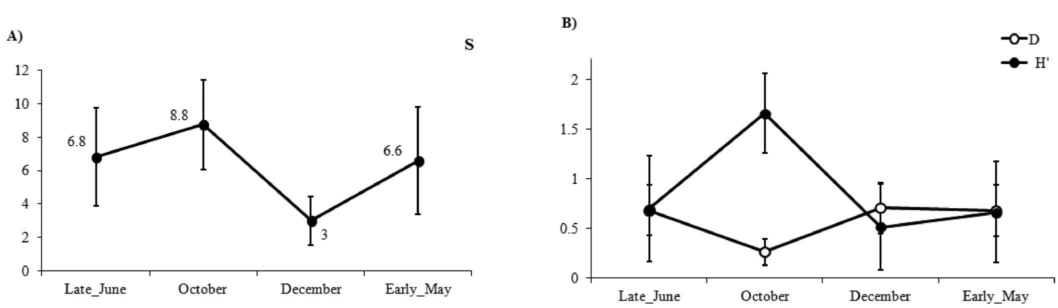

Fig. 2:Variations of the community indexes during the whole sampling period: A) Specific richness (S), whit average number of species for each season reported in the graph; B) Simpson's index of dominance (D) and Shannon-Wiener diversity index (H'). Standard deviation values are also reported.

Table 2. List of species caught in the surf zone of the northern Sicilian coast from June 2005 until May 2006. For each species mean TL and size range are reported. Each species is also classified according to the description proposed by Layman (2000) Suda et al. (2002) and Malavasi et al. (2004). Dietary preference (Malavasi *et al.,* 2004): PS=strictly planktivorous feeders, IS=strictly benthic invertebrate feeders, FS=strictly piscivorous feeders, IF=feeding on invertebrates and fish, D=detritivores and H=herbivores. Surf utilization (Layman, 2000): Y=year-round resident, J=seasonal nursery juvenile, T=adult transient common in other marine habitat and J/T= juvenile and adult transient. Developmental stage (Suda et al, 2002): L=larvae, PL=post-larvae, J= juvenile, EA=early adult, A=adult, LS=all life stages. Preferential habitat (Suda *et al.,* 2002): C=coastal area; E=estuary; P=offshore pelagic; RC=rocky coast; SB=sandy bottom.

Species	mean TL (cm)	size range (TL cm)	Dietary preference	Surf utilization	Developmental stage	Preferential habitat
Arnoglossus laterna	6.7 ± 0.5	6 - 7.1	IS	J	EA	SB
Atherina boyeri	3.1 ± 0.9	2.1 -7.5	PS	Y	LS	E-C
Belone belone	34.5 ± 7.0	21.2 - 42.3	IF	T	EA-A	P
Boops boops	6.9 ± 1.5	4.1 - 10	IF	J/T	PL-J-EA	P
Bothus podas	8.3 ± 2.2	4 - 13.6	IS	Y	EA-A	SB
Callionymus pusillus	11.0 ± 7.0	3.4 - 11.5	IS	Y	EA-A	SB
Caranx crysos	8.5 ± 1.5	5.5 - 12.3	FS	T	EA	RC
Chelidonichthys lucerna	11.0 ± 7.0	5.8 - 31.2	IS	J/T	J-EA-A	SB
Dentex dentex	13.1 ± 2.3	11 - 16.3	FS	J	J	RC
Dicentrarchus labrax	19.2 ± 2.6	13.7 - 24.5	IF	Y	EA-A	E
Diplodus annularis	-	9.1	IS	J/T	A	C
Diplodus sargus	8.9 ± 3.7	5.5 - 15	IS	J	EA	RC
Diplodus vulgaris	3.7 ± 1.4	2.6 - 9.4	IS	J	J-EA	RC
Echiichthys vipera	9.5 ± 0.5	8.7 - 10.1	IF	Y	A	SB
Eutrigla gurnardus	-	5.3	IS	J	J	SB
Gymnammodytes cicerelus	7.8 ± 1.3	4.4 - 12.3	PS	J/T	LS	SB
Lichia amia	-	16	FS	T	EA	E
Lithognathus mormyrus	3.2 ± 2.1	1.1 - 20.8	IS	J	LS	SB
Liza aurata	10.0 ± 6.2	4.5 - 39.4	IS/D	Y	J-EA-A	E
Mullus barbatus barbatus	8.8 ± 1.4	6 - 15	IS	J	J-EA	SB
Mullus surmuletus	9.5 ± 5.5	4.9 - 25.4	IS	J	J-EA	RC
Oblada melanura	11.9 ± 3.4	4.6 - 17.7	IF	J	J-EA	P
Oedalechilus labeo	10.3 ± 4.1	4 - 31.5	FS/D	Y	LS	C
Ophidion barbatum	-	22	IS	T	A	SB
Pagellus acarne	7.4 ± 0.9	4 - 9.6	IS	J	LS	SB
Pagellus erythrinus	6.6 ± 1.8	2.8 - 9.1	IS	J	J-EA	SB
Pagrus pagrus	4.1 ± 0.2	3.9 - 4.5	IS	J	J	SB - RC
Pomatoschistus marmoratus	3.6 ± 2.2	1.4 - 5.8	IS	Y	L-J-A	SB
Pomatoschistus minutus	-	4.6	IS	Y	J	SB
Sardina pilchardus	5.1 ± 0.6	2.2 - 9	PS	J/T	LS	P
Sardinella aurita	3.0 ± 1.2	1.8 - 4.1	PS	J/T	L-J	P
Sarpa salpa	3.9 ± 1.9	1.8 - 17.6	H	Y	LS	RC
Seriola dumerilii	-	20	FS	T	EA	RC
Sphyraena sphyraena	23.8 ± 18.8	5 - 42.5	FS	J/T	J-A	RC
Sphyraena viridensis	12.0 ± 1.5	10.3 - 15.1	FS	J	J	RC
Spicara flexuosa	5.8 ± 0.6	4.1 - 7.8	IF	J/T	J-EA-A	C
Synodus saurus	-	5.3	FS	T	EA	SB
Trachinotus ovatus	5.7 ± 2.1	3.7 - 17.5	IF	J	J-EA	P
Trachinus draco	10.7 ± 1.6	9.1 - 12.2	IF	Y	A	SB
Trachurus mediterraneus	6.3 ± 1.0	5.3 - 8	IF	J	J	P
Trachurus trachurus	8.7 ± 0.6	7.6 - 9.2	IF	J	J	P
Xyrichtys novacula	11.7 ± 3.0	8.5 - 15.9	IS	J	EA-A	SB

and December, with percentages above 87%. In early May, the fish assemblage was almost exclusively made up of strictly planktivorous feeders, whereas fishes feeding on invertebrates and fish formed 55% of total catches during October (Fig. 4D).

Juvenile fish assemblage

The analyses for the characterization of the fish community using the surf zone as a seasonal nursery were carried out on 96888 specimens belonging to 26 fish species (Table 3).

Results of PERMANOVA analysis, performed on

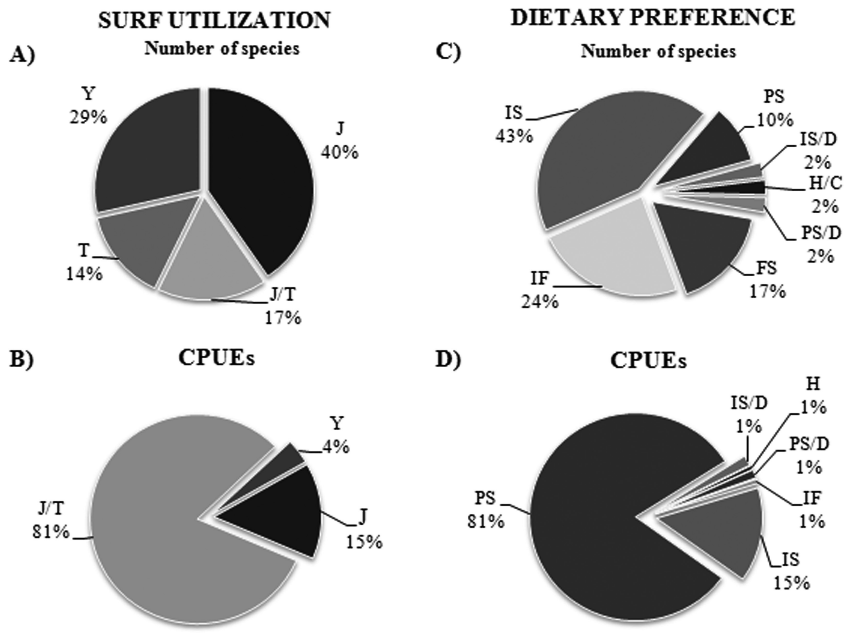

Fig. 3: Percent composition of the fish assemblage on the basis of surf-utilization guilds: Y=year-round resident, J=seasonal nursery juvenile, T=adult transient common in other marine habitat and J/T= juvenile and adult transient (Fig 3A: number of species; Fig 3B: Catches per Unit Effort - CPUEs) and dietary-preference guilds: PS=strictly planktivorous feeders, IS=strictly benthic invertebrate feeders, FS=strictly piscivorous feeders, IF=feeding on invertebrates and fish, D=detritivores and H=herbivores (Fig 3C: number of species; Fig 3D: CPUEs).

the abundance matrix, highlighted significant differences among sampling periods ($F_{1,35}$=3.88; p<0.001) and pairwise comparisons showed significant differences between all pairs of factor levels (p<0.05). SIMPER tests recorded the highest average dissimilarity between early May and late June groups (δ=95.91), mainly due to *S. pilchardus* (Av ab = 27.18) and *Lithognatus mormyrus* (Av ab = 9.66) which were more abundant during early May and late June, respectively. The average abundances of these species are also responsible for the dissimilarities found between early May-late June and October-December periods. *Mullus barbatus barbatus*, more abundant in October,

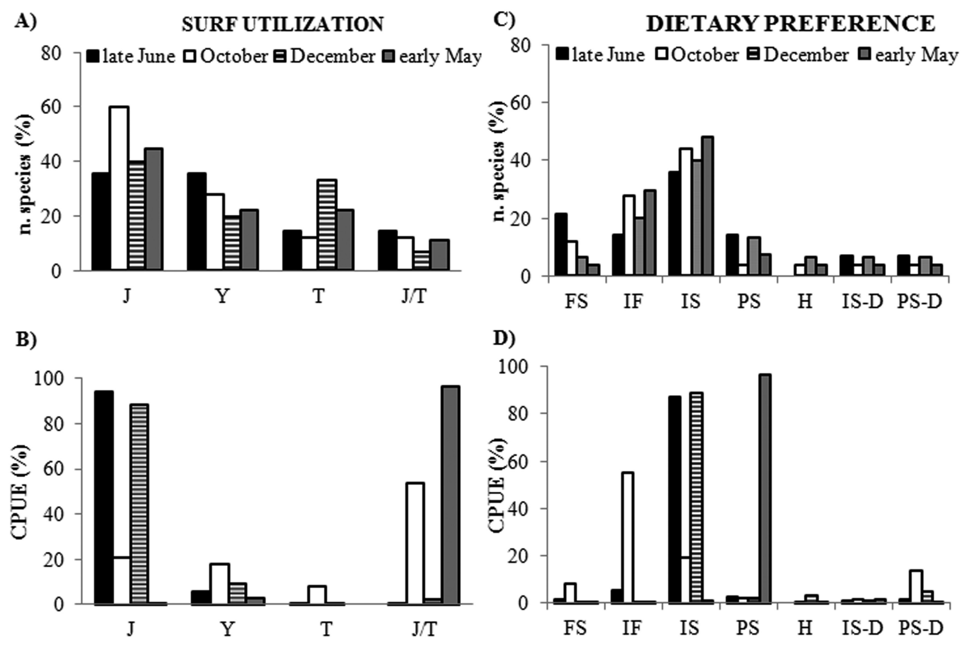

Fig. 4: Composition of the fish assemblages in the different sampling periods on the basis of surf-utilization guilds: Y=year-round resident, J=seasonal nursery juvenile, T=adult transient common in other marine habitat and J/T= juvenile and adult transient(Fig 4A: relative number of species; Fig 4B: % Catches per Unit Effort - CPUEs) and dietary-preference guilds: PS=strictly planktivorous feeders, IS=strictly benthic invertebrate feeders, FS=strictly piscivorous feeders, IF=feeding on invertebrates and fish, D=detritivores and H=herbivores (Fig 4C: relative number of species; Fig 4D: CPUEs).

Table 3. Number of individuals of species composing the seasonal nursery juvenile group caugth in each of the sampling period**.**

Species	Late June	October	December	Early May
Arnoglossus laterna	-	3	-	-
Atherina boyeri	50	-	-	-
Boops boops	-	41	-	22
Chelidonichthys lucernus	-	-	-	9
Dentex dentex	-	3	-	-
Diplodus sargus	2	1	-	1
Diplodus vulgaris	-	7	-	92
Eutrigla gurnardus	-	-	1	-
Lithognathus mormyrus	1708	14	3	4
Liza aurata	5	1	-	433
Mullus barbatus barbatus	-	81	29	1
Mullus surmuletus	14	-	6	-
Oblada melanura	6	8	2	10
Oedalechilus labeo	1	47	339	76
Pagellus acarne	-	-	12229	254
Pagellus erythrinus	13	37	-	3
Pagrus pagrus	-	-	-	3
Sardina pilchardus	-	-	-	80706
Sarpa salpa	-	-	144	155
Sphyraena sphyraena	-	1	-	-
Sphyraena viridensis	34	-	-	-
Spicara flexuosa	-	97	-	47
Trachinotus ovatus	108	14	1	2
Trachurus mediterraneus	-	5	-	-
Trachurus trachurus	-	-	-	6
Xyrichtys novacula	-	5	-	4

and *Pagellus acarne* and *O. labeo*, more abundant in December, accounted for most of the dissimilarity between these two months.

The results of PERMANOVA and SIMPER analyses agree with the ordination of fish species in the correspondence analysis biplot (Fig. 5). The first two axes of the graph explained 76.9% of the total variance. The first dimension highlighted a clear separation between late June and the other sampling periods, mainly related to the high abundance of *L. mormyrus* and *Trachinotus ovatus* and to *Atherina boyeri* and *Sphyraena viridensis* which were exclusively caught in this month (Table 3). The second dimension showed a clear separation between December (top left in the diagram) and early May-October months (bottom left). The fish community in December was dominated by *Pagellus acarne* and *O. labeo*, while in early May by *S. pilchardus* followed by *Liza aurata* and in October by *S. flexuosa* and *Mullus b. barbatus* (Table 3).

Discussion

There is strong evidence from several regions around the world that surf-zone fish assemblages are usually dominated by few species (McFarland, 1963; Modde & Ross, 1981), largely made up of juveniles (Lasiak, 1986; Reina-Hervas & Serrano, 1987; Gibson *et al.,* 1996; Clark, 1997; Layman, 2000). In agreement with the above findings, the surf-zone ichthyofauna of the study area is dominated by *S. pilchardus*, that makes up 80.3% of the

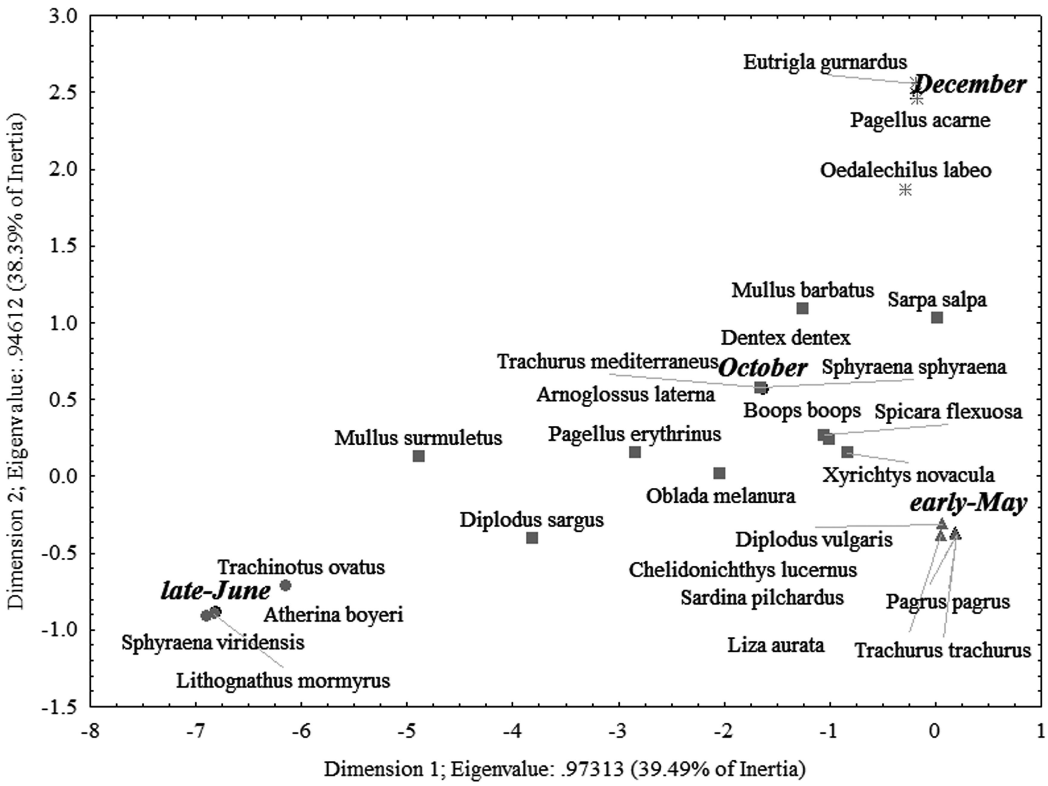

Fig. 5: Ordination diagrams for the first two canonical axes of the correspondence analysis performed on juvenile fish abundance data per sampling season.

total abundance. The fish assemblage is composed of a high percentage of juvenile stages, chiefly planktivorous, but there are also adult transients between the surf-zone and open-sea environments, that feed mainly on benthic invertebrates and other fishes and move inshore during specific periods (early May and December). Eleven species are found constantly throughout the year (year-round residents) and only four of them can be considered truly resident spending their entire life cycle in the surf zone, with the mugilid *O. labeo* being the most common. Unlike other members of Mugilidae family, which are typically euryhaline, this species is usually poorly tolerant to variations in salinity and shows affinity for more maritime conditions (Ben-Yami & Grofit, 1981; Mićković *et al.,* 2010). Mugilid and clupeid occurrence along beaches has been documented worldwide (McFarland, 1963; Modde & Ross, 1981; Clark *et al.,* 1996). Clupeids are usually found in great quantities in the surf zone during winter and autumn (McFarland, 1963; Lopes *et al.,* 1993) and play an important role in the coastal trophic web as prey for carangids, sparids, moronids and belonids (Reina-Hervás & Serrano, 1987; Dorman, 1988; Pipitone & Andaloro, 1995). In our study, *S. pilchardus* dominated in May as juveniles, while in December it occurred as adult transient, showing that this species may use the surf zone as both juvenile habitat and feeding place. Although dominated by few species, the surf zone exhibited a high degree of specific richness within the category of seasonal nursery juveniles (J), encompassing more than 60% of the total number of species, thus confirming the importance of this area as a juvenile habitat. Within Group J, a small fraction made up of sardines, picarels, bogues, barracudas and sand eels, reutilized the surf zone at adult stage (J/T) and made up 81% of total CPUE. Year-round resident (Y) and fishes found only as transient adults (T) included a relatively high number of species but they showed a CPUE of 4%. A similar fish assemblage composition in the surf zone has also been described by other Authors. Layman (2000) on the coast of Virginia (USA) and Beyst et al. (2001) on a sandy beach along the Belgian coast, report that the majority of the species inhabiting the surf zone are seasonal nursery juveniles and transient adults or “migrants”. By contrast, year-round resident fishes are less diversified, possibly because very few species are able to utilize turbulent shallow waters and to live in highly dynamic habitats such as the surf zone of oceanic environments. The high number of species found in our study area is possibly related to the low degree of both wave exposure and tide amplitude, both of which typify Mediterranean coastal zones.

As regards *dietary preference*, most fish species inhabiting the study area are strictly benthic invertebrate feeders (IS) and invertivorous/piscivorous fish (IF). The former are mainly juveniles, almost exclusively represented by the sparids *L. mormyrus* and *P. acarne* which, at this stage, chiefly rely on small or sedentary benthic organisms, such as amphipods, bivalve juveniles and polychaetes (Andaloro, 1983; Kallianiotis *et al.,* 2005; Fehri-Bedoui *et al.,* 2009), and are more abundant in June and December, respectively. The invertivorous/piscivorous fish include juveniles and adult transients (J/T); they are mainly represented by the species *Spicara flexuosa* that feeds principally on zooplankton (mainly copepods) but also on fishes (Mytilineou, 1987; Stergiou & Karpouzi, 2002) and that predominates in October. Few species are strictly planktivorous, but they strongly dominate in terms of CPUE, indicating that the pelagic habitat is heavily exploited in terms of food resources; they mostly occur during May and are mainly schools of juveniles of pelagic species, principally *S. pilchardus*, but also transient adults such as *Sardinella aurita*. Piscivorous fish are poorly represented in terms of CPUE (< 3%) although some of them, such as the lizardfish *Synodus saurus*, are very abundant in the adjacent infralittoral zone (Esposito *et al.,* 2009). The trophic composition of the surf-zone ichthyofauna described in our study area has also been reported in different oceanic regions (Springer & Woodburn, 1960; McFarland, 1963; Naughton & Saloman, 1978). There, planktivorous fishes are recorded as numerically important components of the surf-zone fish assemblages, in particular in spring-summer; they are usually followed by benthivorous fishes, while piscivorous predators usually occur in low numbers, as the turbidity of surf zones may impair their foraging efficiency (Lasiak, 1986). The cyclical variation in availability and abundance of primary food sources in the surf zone and the opportunistic exploitation of superabundant food resources by surf-zone teleosts could affect the assemblage structure in the different sampling periods. Populations of planktonic and suprabenthic prey organisms, such as copepods, mysids, decapod larvae and fish larvae, are highly dynamic in the surf zone and their great temporal availability occasionally lures adult fishes from deep to shallow waters (Lasiak, 1983; Modde & Ross, 1983; Lasiak & McLachlan, 1987; Esposito *et al.,* 2011; Esposito, 2013). In the coastal waters of the Tyrrhenian Sea, phytoplankton blooms support the increase in copepods in three periods of the year (i.e. March-April, July-August and October-November) (Ribera d’Alcalà *et al.,* 2004) while other important prey organisms, such as mysids and amphipods, proliferate from April to September (Sardà *et al.,* 1999; Chimenz Gusso *et al.,* 2001; Esposito *et al.,* 2014). Similar considerations have also been pointed out in the Straits of Sicily (central Mediterranean), where benthic fishes such as *Xyrichtys novacula* exploit pelagic organisms in distinct periods, corresponding to the increase in secondary production after phytoplanktonic blooms (Castriota *et al.,* 2010). The increase in benthivorous and planktivorous fishes recorded in our study area during early May and late June would therefore be justified by concomitant blooms of zooplankton and suprabenthic prey organisms. By contrast, piscivorous fishes dominate in October and early May, when specific richness or abundance of fish prey in the surf zone peak (see Fig. 2) and therefore predator-prey encounter rates are highest. In short, even in the Mediterranean Sea, the utilization of the surf zone habitat during different periods by different species or trophic groups and predation in high prey density can be considered as a viable strategy preventing competition for space and resources, and supporting optimization of energy gains, as observed in other extra-Mediterranean areas (Modde & Ross, 1983; Moreno & Castro, 1995).

Seasonal fluctuations in abundance and species richness are typical of many fish communities in shallow marine waters, reaching their highest values during spring and lowering in winter when fish migrate offshore in the search for better conditions. This seasonal migration is usually associated to the cyclical pattern of temperatures that significantly affects the species abundance and distribution (*e.g.* Lasiak, 1984; Ross *et al.,* 1987; Nash, 1988; Santos & Nash, 1995; Dulčić *et al.,* 2005) and to the influx of seasonal nursery juveniles of both resident and transient species, following their breeding season (Ross *et al.,* 1987; Gibson *et al.,* 1993; Barreiros *et al.,* 2004; Selleslagh & Amara, 2007). Although not directly demonstrated in this study, it seems likely that temperature either directly or indirectly (e.g. by influencing the timing of spawning), was the underlying factor influencing the cyclical dynamics of surf-zone assemblage. The major changes in the species composition were due to the high degree of dominance of few species that varied at each of the sampling period. The massive occurrence of *S. pilchardus* juveniles in early May, and the complete absence in the other sampling periods could be related to the after-spawning migration of larvae, post-larvae and juveniles from off-shore to shallow water, searching for better water temperatures and prey densities (Mužinić, 1973). The great abundance of *P. acarne*, in December could be imputable not only to the high after-spawning concentrations of post-larvae and juveniles in shallow waters but also to movement of the individuals during their growth in relation to their several feeding needs (Andaloro, 1983). The increase in the abundance of *L. mormyrus* juveniles from December to late June is probably related to the increase of water temperature that lures the juveniles of this species near the shoreline, until the reaching of sexual maturity, when they join adult schools in deeper and colder waters (Kallianotis *et al.,* 2005). Finally, the lack of a high degree of dominance of few species in October could be explained by the major occurrence of predators and by competition for trophic resources.

The high abundance of juveniles of commercial species, principally sparids, confirms the importance of the surf zone in the survival of stocks for fisheries; moreover, the horizontal transfer of fish from juvenile to adult habitats results in substantial movement of biomass, nutrients and energy from the surf zone to surrounding coastal and offshore habitats (Deegan, 1993).

In summary, the surf zone of the study area evidences some of the characteristics reported for the overall surf zone, i.e. serving as a significant refuge, juvenile habitat and feeding place for early but also for adult stages of several fish species, being relatively free of piscivorous and providing an abundant food supply for benthivorous and planktivorous fishes. The fish community is dominated by pelagic and gregarious species that use this area as foraging grounds and for recruitment, and is characterized by a typical pattern with the greatest abundance in early May and December and the highest richness and diversity in October, that appeared mainly related to different recruitment times, associated to variations in sea-surface temperatures, and consequent influx of seasonal nursery juveniles.

This study provides, for the first time, information on the composition and structure of the surf-zone icthyofauna in the Tyrrhenian Sea. Nevertheless, further research on the environmental characteristics and into the composition and temporal fluctuations of planktonic and benthic fauna living in this area, together with a study of the nocturnal fish assemblage, would help provide a better understanding of the mechanisms involved in the use of this zone and the dynamics of the associated fauna.

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