Quantifying the dolphins-fishery competition in the Gulf of Taranto (Northern Ionian Sea, Central Mediterranean Sea)

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***Abstract* - The dolphins-fishery competition in the Gulf of Taranto (Northern Ionian Sea, Central Mediterranean Sea) was investigated during the period 2009-2016. In particular, the biomass removal by the striped and common bottlenose dolphin and the local fishery was estimated by means the food consumption rates of dolphins and landing data of the main fishing gears operating in the area. In addition, an indication on the overlap, in terms of diet/landing composition, occurring between both dolphin species and fishery was discussed.**

I. INTRODUCTION

The competitive interactions between cetaceans and fishery represents a common trait of several harvested marine ecosystems [1]. Although these interactions could cause negative impacts to the fishery due to dolphins' depredation of the fishing gears turning in economic losses [2], the dolphins-fishery conflicts are often dealt with reductive approach overestimating the harmful interactions [3,4]. Moreover, the increase of competition seems to occur in ecosystems overexploited where the fishing activities result unsustainable [5,6], with the risk of a depletion of the cetaceans' food resources [7]. Therefore, potential negative impacts due to the overfishing could affect the cetaceans' populations and the marine ecosystems functioning. Thus, any management actions needed to ensure a sustainable exploitation of the fishing resources requires the adoption of a holistic approach able to integrate ecological and fishing information.

Several studies have demonstrated a scarce competition between dolphin species and fishermen in the Mediterranean areas, especially when the analysis was based on the quantitative comparison between cetaceans food consumptions and fishery catches, as well as the overlapping between dolphins' preys and the landing composition [8,9].

In the marine food web of the Gulf of Taranto, odontocetes species, especially the striped dolphin (*Stenella coeruleoalba*) and the common bottlenose dolphin (*Tursiops truncatus*) have proved to be key species in the trophic controls [10]. However, their interactions with fishing gears and the competition for the harvested resources are scarcely known. Thus, the study aims to provide a preliminary assessment on the dolphins-fishery competition comparing the food consumption rates of the striped and common bottlenose dolphin inhabiting the area with the biomass removal performed by the local fishery. In addition, an indication on the overlap, in terms of diet/ landing composition, occurring between both dolphin species and fishery was discussed.

II. MATERIALS AND METHDOS

A. Study area

The Gulf of Taranto is extended approximately for 14.000 km² from Santa Maria di Leuca to Punta Alice and it is characterized by the system of submarine canyons of Taranto Valley reaching depth of more than 2200 m (Fig. 1) [11]. The basin hosts several habitats identified along the sea floor, such as seagrasses meadows, the Amendolara seamount (Cape Spulico) and the deep-water coral province of Santa Maria di Leuca [12,13]. Moreover, it has been widely recognized as critical area for the day-to-day life of the striped and common bottlenose dolphins [14,15,16,17,18,19], as well as for other cetacean species [20,21,22,23].

The fishing activities occur from coastal waters to about

800 m deep waters and it is characterized by the bottom otter trawls that mainly exploit the shelf break and slope and the small scale fishery operating on the coastal grounds [24]. Thus, the interactions between dolphins and the fishery was assessed for a study area of 7745 km^2 from S. Maria di Leuca to Punta Alice in a range of 10-800 m of depth (Fig. 1).

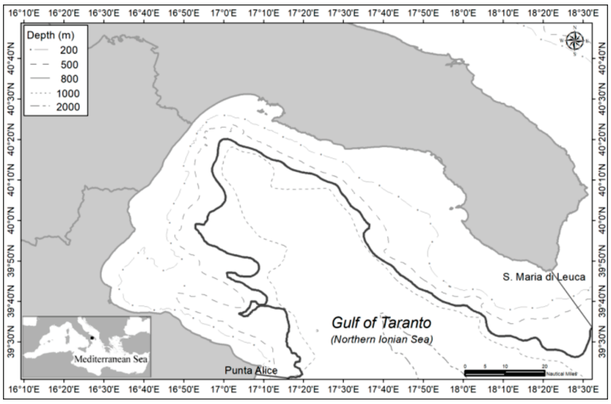

Fig. 1. Map of the Gulf of Taranto in the Northern Ionian Sea (Central Mediterranean Sea). The study area is included in the bold line.

B. Dolphins' food consumption rate

The average value of the daily food consumption, referred to a medium sized dolphin, has been calculated separately for the striped and common bottlenose dolphin, in order to quantify their consumption of annual biomass in the study area. Four different equations have been used for estimating the daily food consumption [8]:

$$IB = 0.123\ M^{0.8} \quad (1)\ [25]$$

$$IB = 0.482\ M^{0.524} \quad (2)\ [26,27]$$

$$IB = 0.035\ M \quad (3)\ [28]$$

$$IB = 0.1\ M^{0.8} \quad (4)\ [5]$$

where IB is the ingested biomass (kg/day) and M is the body mass of dolphin in kg. The results of these estimates were averaged each other, and the confidence interval (CI) was expressed as two times the standard deviation [8]. Then, IB value, for each dolphin species, has been multiplied for the abundance value estimated in the study area (7745 km^2) (see paragraph C) obtaining the total food consumption (Q expressed as tons).

The value of adult body mass (M) for *T. truncatus* was computed using the following equations:

$$M = 17.261e^{0.0156(L-140)} \quad (5)\ [29]$$

while, those for *S. coeruleoalba* was computed according the formula:

$$M = 1.38*10^{-4} * L^{2.5177} \quad (6)\ [30]$$

in both equations, L is the body length expressed in cm.

Body lengths (L) data of several individuals of both dolphin species, coming from the Gulf of Taranto or nearby zones, were gathered from stranding records, ecological studies and the Italian Stranding Network database [31,32,33,34] (Table 1). A total of 74 and 29 measures of body length have been collected for striped dolphins and common bottlenose dolphins, respectively. Body lengths below the value of mean body length minus the standard deviation (i.e. striped dolphins below 119 cm and bottlenose dolphins below 157 cm) were not included in the adult computation, because these values probably referred to young animals including calves [8].

C. Dolphins species abundance estimates

Abundance values used in the calculation of IB were obtained by multiplying the mean values of density estimated for both species in the Gulf of Taranto in the period 2009-2016 [15] for the surface of the study area. These mean values of density were estimated by the application of the Delta approach on Random Forest to sighting data collected in the Gulf of Taranto and they were 0.72±0.26 (individual/km^2) for *S. coeruleoalba* and 0.47±0.09 (individual/km^2) for *T. truncatus*. Consequently, the mean abundances considered in this study were 5576±2014 and 3640±697, for striped and common bottlenose dolphin, respectively.

D. Fishing data

In order to estimate the biomass removed by the local fishery, landing and discard data were considered. The landing data by species were provided from the EU Data Collection Framework reporting the landings during the period 2009-2016 in the sub regions of Puglia and Calabria included in the Geographical Sub Area 19 (GSA 19). The fishing is characterized by trawl (OTB), passive nets (GN), longlines (LL), purse seine (PS) and mixed gears (MG, traps, beach seine and lines) [10]. In addition, discard was estimated applying discard rates by fishing gears available from the literature at local and Mediterranean scale [35 and reference therein].

E. Resource overlap

The overlap between diet composition of the two dolphin species and the landings composition of each fishing gear occurring in the study area has been assessed by means a modified version of Pianka niche overlap index (α) [36]:

$$\alpha = \sum_{i=1}^{n}\left(P_{ji} * P_{ki}\right) / \sqrt{\sum_{i=1}^{n}\left(P_{ji}^{2} * P_{ki}^{2}\right)} \quad (7)$$

where P_{ji} e P_{ki} are the proportions of the resource *i* exploited by *j* and *k*, respectively.

Diet composition of dolphins in the study area is still not known, therefore dietary preferences were derived from studies conducted in close areas. In particular, diet information for striped dolphin has been obtained from the Ionian Sea [37] and the North Aegean Sea [38], and those for the common bottlenose dolphin has been inferred from the Eastern Ionian Sea [8] and the North Aegean Sea [38].

The average diet of *S. coeruleoalba* was assumed to be composed of 29% Commercial Squids (C Squids, *Illex* spp., *Loligo* spp., *Todaropsis eblanae*), 27% Sparids and

Mullets (SM, *Boops boops*, *Diplodus* spp., *Pagellus* spp., *Mugil* spp.), 21% Other Cephalopds (OC, *Todarodes sagittatus*, *Histioteuthis* spp., *Abralia verany*, *Heteroteuthis dispar*), 17% Other fishes (OF, *Gobius* spp., Myctophidae, *Stomias boa*), 4% Small pelagic fishes (SpelF, Clupeidae, Engraulidae) and 2% Flatfishes (F, *Microchirus* spp.). The average diet of *T. truncatus* was assumed to be composed of 35% Sparids and Mullets, 15% Other Commercial fishes (OCF, *Conger conger*, *Spicara* spp.), 12% Other fishes (OF), 8% Small pelagic fishes (SpelF, Clupeidae, Engraulidae), 9% Hake and Red Mullet (HRM, *Merluccius merluccius* and *Mullus barbatus*), 7% Commercial Squids, 6% Commercial Cephalopods (C Ceph, *Eledone* spp., *Octopus vulgaris*, *Sepia officinalis*), 4% Mackerels (Mack, *Scombrus* spp., *Trachurus* spp.), 3% Other Cephalopods and 1% Medium pelagic fishes (MpelF, *Belone belone*, *Sphyraena sphyraena*).

Table 1. The body length (cm) of stranded individuals of S. coeruleoalba and T. truncatus and stranding area were reported.

Length (cm)	Area	Length (cm)	Area	Length (cm)	Area
Stenella coeruleoalba		*Stenella coeruleoalba*		*Stenella coeruleoalba*	
208	Apulia	186	Calabria	133	Calabria
190	Apulia	185	Calabria	113	Calabria
107	Apulia	184	Calabria	112	Calabria
216	Sicily	182	Calabria	91	Calabria
207	Sicily	181	Calabria	*Tursiops truncatus*	
206	Sicily	181	Calabria	320	Apulia
205	Sicily	181	Calabria	320	Apulia
203	Sicily	180	Calabria	295	Basilicata
202	Sicily	180	Calabria	290	Apulia
199	Sicily	180	Calabria	270	Apulia
98	Sicily	175	Calabria	270	Calabria
95	Sicily	174	Calabria	263	Apulia
91	Sicily	170	Calabria	260	Apulia
90	Sicily	167	Calabria	250	Apulia
90	Sicily	163	Calabria	243	Basilicata
85	Sicily	163	Calabria	240	Apulia
210	Apulia	150	Calabria	236	Apulia
204	Apulia	146	Calabria	224	Calabria
180	Apulia	137	Calabria	206	Apulia
155	Apulia	133	Calabria	200	Apulia
125	Apulia	125	Calabria	200	Apulia
110	Apulia	113	Calabria	195	Apulia
110	Apulia	112	Calabria	188	Apulia
109	Apulia	110	Calabria	185	Apulia
110	Apulia	91	Calabria	182	Basilicata
213	Calabria	74	Calabria	180	Apulia
210	Calabria	193	Calabria	173	Apulia
206	Calabria	206	Calabria	168	Apulia
197	Calabria	186	Calabria	160	Calabria
196	Calabria	185	Calabria	152	Apulia
196	Calabria	184	Calabria	152	Apulia
195	Calabria	181	Calabria	150	Apulia
195	Calabria	180	Calabria	129	Calabria
193	Calabria	180	Calabria	103	Apulia
190	Calabria	137	Calabria		

III. RESULTS

Undersized individuals, such as 19 striped dolphins and 5 common bottlenose dolphins, have been excluded from the average body-length calculation. The mean adult length (L) was 182 cm for the striped dolphins (95% CI=135–229, n=55) and 230 cm for the common bottlenose dolphins (95% CI=131–329, n=24). Thus, the average body mass (M) was of 67 kg for the striped dolphin (CI=47–91) and 130 kg for the common bottlenose (CI=60–283). Average per-capita daily food consumption was therefore, 3.30 (±0.87) kg for striped dolphin (CI=1.56–5.04) and 5.43 (±0.79) kg for bottlenose dolphin (CI=3.85–7.01). The biomass consumed (Q) by the striped dolphin and the common bottlenose dolphin in the study period from 2009 to 2016 was estimated equal to 6712 tons (±1773) and 7219 tons (±206), respectively. The biomass removal by the fishery in the same period was estimated equal to 43310 tons (±246). Thus, on the total of estimated biomass removed from dolphin species and fishery, the biomass removed by dolphin species was 24% whereas those removed by fisheries was 76% (Table 2 and Fig. 2). The overlap of food resources between *T. truncatus* and fisheries (α=0.53) was higher than that *S. coeruleoalba* and fisheries (α=0.24) (Fig. 3). The common bottlenose dolphin showed the highest overlap with the passive nets (α=0.54) and the longline (α=0.47). Differently, the striped dolphin showed overlap values less than or equal to 0.22 for all fishing gears.

Table 2. Code of prey target of dolphins/fishing and estimates of total biomass removed (tons) during the period 2009-2016 reported for each fishing gears, dolphin species (Sc, striped dolphin, Tt, common bottlenose dolphin) and as a total for the overall fleet (OvFleet) and both dolphin species (TotD). Code: Anglers (Ang, Lophius *spp.); Commercial Crustaceans (Crust, Aristeus antennatus, Aristaeomorpha foliacea, Parapenaeus longirostris, Squilla mantis); Sharks and Rays (ShaRay, Galeus melastomus, Raja sp., Squalus acanthias).*

Prey code	OTB	PS	GN	LL	MG	Tt	Sc	OvFleet	TotD	Total
Ang	861	0	135	8	24	0	0	1028	0	1028
SpelF	68	2537	1122	4	305	578	268	4036	846	4882
C Ceph	1896	14	3236	0	365	361	0	5511	361	5872
Crust	7235	0	142	0	150	0	0	7527	0	7527
C Squids	940	25	110	0	66	505	1946	1141	2451	3592
F	4	0	95	2	4	72	134	105	206	311
MpelF	6	296	258	111	63	72	0	734	72	806
HRM	3457	43	2459	911	405	578	0	7275	578	7853
OCF	183	2	294	157	50	1083	0	686	1083	1769
Mack	1949	921	443	83	154	289	0	3550	289	3839
ShaRay	7	0	4	1	1	0	0	13	0	13
SM	1189	314	1592	280	197	2527	1812	3572	4339	7911
OF	0	0	0	0	0	866	1141	0	2007	2007
OC	0	0	0	0	0	217	1410	0	1627	1627
Tot landing (tons	17795	4152	9890	1557	1784	-	-	35178	-	35178
Discard (tons)	6050	228	1761	50	41	72	0	8130	72	8202
Tot catch (tons)	23845	4380	11651	1607	1825	7220	6711	43308	13931	57239
Tot catch (%)	41.7	7.7	20.4	2.8	3.2	12.6	11.7	75.7	24.3	100

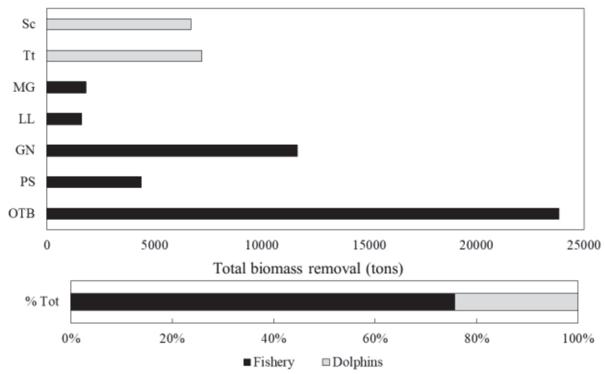

Fig. 2. Estimates of total biomass removed (tons and %) by striped and common bottlenose dolphin and fishing gears in the study area for the period 2009-2016.

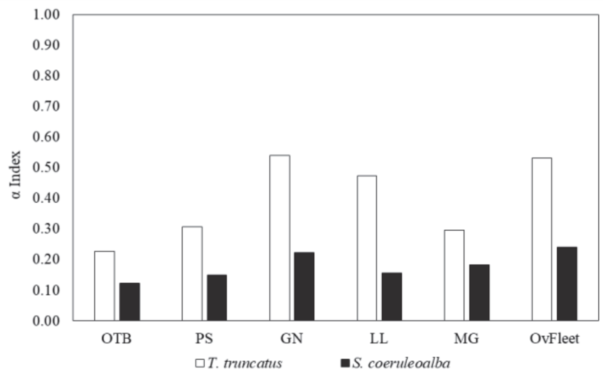

Fig. 3. Overlap index (α) estimated to assess the food resources overlap between the dolphins, the fishing gears and the overall fleet on the basis of the diet/landing composition.

IV. DISCUSSION

The assessment of the dolphins-fishery competition in the Gulf of Taranto has been performed by means of a quantitative analysis estimating the biomass removal and the food resources' overlap in a period of 8 years. The comparison of the biomass removal from dolphin species and fishery highlighted the higher impact of fishery on the local resources, with the trawl and the passive nets as the most important gears in the study area. The value of biomass consumed by dolphin species in the Gulf of Taranto was higher than those reported for the Eastern Ionian Sea [8]. This difference is mainly due to different extension of study areas (Gulf of Taranto 7745 km^2 and Eastern Ionian Sea 1100 km^2, respectively) and to values of estimated abundance. In fact, the mean body length and the average daily consumption of the common bottlenose dolphin calculated in the Gulf of Taranto was lower than those estimated in the Eastern Ionian Sea (243 cm and 6.1 kg/day) [8]. Otherwise, its abundance value estimated in the study area was higher than those reported for the Eastern Ionian Sea, in line with the difference between Ionian and Adriatic Region [15 and reference therein]. Concerning *S. coeruleoalba*, its mean body length was comparable with *D. delphis* considered in [8], but the former species showed a higher abundance value in the study area than those reported for *D. delphis* in Eastern Ionian Sea. The higher total biomass removed by dolphins from the system "Gulf of Taranto" is mainly determined by those conditions.

The striped dolphin showed a very low overlap index than fisheries, stressing the absence of competition with the fishing gears in the study area. This condition is due to its feeding preferences mainly represented by the Myctophidae and bathyal squids distributed in the upper slope of the study area [15]. Differently, the common bottlenose dolphin showed a consistent overlap with passive nets and longlines. In particularly, *T. truncatus* shared the sparids and the mullets with the passive nets and the longlines, the European hake and the red mullet with the trawl and the small pelagic fishes with the passive nets. A similar pattern, in the food resources overlap, between *T. truncatus* and different fishing gears was observed in the Eastern Ionian Sea and in the Thracian Sea [8,9], with the exception of the trawl. In fact, in the Eastern Ionian Sea the overlap index for this species with trawl resulted higher than those calculated for the Gulf of Taranto. This difference could be due to the wider spatial and bathymetric distribution of the trawl fishing effort in the study area. Differently in the Eastern Ionian Sea, a high probability of interactions with the common bottlenose dolphin is due to the exploitation of trawl fishing resources in shallower grounds. The competition by *T. truncatus* with trammel nets and gears belonging to the small-scale fishery has been observed in several Mediterranean areas [39]. However, the results obtained in this study indicated a condition of scarce competition in the Gulf of Taranto confirming the observations reported for the eastern area of the gulf by [40]. This condition could be favoured by a spatial segregation between feeding areas exploited by *T. truncatus*. In particular, a differentiation in the feeding strategy among the common bottlenose dolphin groups could arise reducing the interactions with passive or trawl nets as observed in the Aeolian Archipelago and Ligurian Sea [41,42].

V. CONCLUSIONS

In contexts of the exploited marine ecosystems by fishing activities, the competition between small cetacean species and fishery should be investigated addressing the acquisition of new knowledge useful to quantify the impacts on the resources. In particular, the bio-geographical features, the ecological traits of these species and their consumption rates, as well as the displacement of the fishing effort by different gears and the catches rates, result fundamental elements to understand the level of interactions and competitions between small cetacean species and fishery. The acquisition of these information would allow to implement effective conservation measures of these top-predators, which are keystone species able to control the food web dynamics and to support the processes required by the maintaining of the ecosystem services [43].

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