



Estimations of length-weight relationships and consumption rates of odontocetes in the Mediterranean Sea from stranding data

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ABSTRACT

Stranding data provide fundamental information on biometric traits of cetaceans useful to increase knowledge on ecological traits and their consumption patterns. In this study, the length weight (L-W) relationships through the power regression model ($W = a \times L^b$) were calculated for three dolphin species (the striped dolphin, the common bottlenose dolphin and the Risso's dolphin) in several Mediterranean subregions and at the scale of the entire basin. Length (L) and weight (W) data were collected from stranding records during the period from 1983 to 2021 acquired from several databases and the literature. Starting from L-W relationships, a bootstrap method was applied to estimate the mean body weights, the daily ingested biomass (IB) and annual food consumption (AFC) rates of different dolphin species. In particular, four different equations were used to estimate the IB rates. Prey consumption by dolphin species was calculated through AFC rates and the available diet information (expressed in weight fractions) of dolphin species for different Mediterranean subregions.

Considering the L-W relationships in the Mediterranean Sea, *b* coefficient values were equal to 2.578, 2.975 and 2.988 for the striped, the common bottlenose and the Risso's dolphin, respectively. At the Mediterranean scale, the AFC values estimated were 3913 kg (CI 2469–5306) for the Risso's dolphin, 2571 kg (1372–3963) for the common bottlenose dolphin and 1118 kg (531–1570) for the striped dolphin. Prey consumption pattern showed a clear partitioning among the investigated species, where the common bottlenose dolphin exploits neritic demersal and pelagic fishes (e.g. eel fishes, sparids), the striped dolphin exploits mesopelagic fishes and myctophids, and the Risso's dolphin was specialized on bathyal cephalopods of Histioteuthidae family.

The results obtained in this study provide new information for the investigated species in several Mediterranean subregions providing a first consistent baseline to support the population dynamics modelling. At the same time, the wide uncertainty ranges of some parameters, as well as the lack of information for some species, stress the necessity of improving the data collection associated to stranding events, especially in the southern Mediterranean areas.

1. Introduction

Cetaceans represent an important component of the marine biodiversity of the Mediterranean region supporting the ecosystem functioning and providing several ecosystem services (Pace et al., 2015; Kiszka et al., 2022). They play the role of keystone predators in the food web contributing to stability of the ecosystem structure (Hammerschlag et al., 2019; Kiszka et al., 2022), and in climate regulation mechanisms mitigating global warming (Roman et al., 2014). At the same time, as charismatic species, they help to promote ecotourism and citizen science activities, which represent an important recreational ecosystem service (Mazzoldi et al., 2019). Despite their key ecological role, studies on cetacean species are focused mainly on providing information on their presence, distribution, abundance, and habitat use, but are rarely referred to the collection of data on morphometric and demographic parameters and processes (recruitment, survival, emigration, and

immigration, Sibly and Hone, 2002), probably due to objective difficulties in collecting such information (Chivers, 2009). This condition prevents the full understanding of anthropogenic impact effects at population levels and consequently makes the implementation of effective mitigation and conservation measures difficult (Jsseldijk et al., 2020).

Biometric traits of cetacean populations can provide important ecological insights, such as the estimation of length-weight relationships (Trites and Pauly, 1998; Perrin et al., 2005), the assessment of the relationship between heavy metals and/or contaminant concentration and body length, weight, and age (i.e., Honda et al., 1983; André et al., 1991; Marsili et al., 2018), as well as the estimation of the food consumption rate (Bearzi et al., 2010; Giménez et al., 2021). This last element can be used to quantify the competition between cetaceans and the fishery together with fishing catches information (Bearzi et al., 2010), and is required in the trophodynamic modelling approach used to

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evaluate the ecological role of cetaceans in the food web (Piroddi et al., 2011). Moreover, morphometric data can be used as an indicator of the nutritive condition, not only for the single individual, but also for the entire population (Hart et al., 2013).

In recent decades, a general decline in abundance of the cetaceans has been caused by different adverse conditions driven by human pressures and climate change in progress (Simmonds and Elliott, 2009; ACCOBAMS et al., 2021). Therefore, the implementation of conservation strategies for cetaceans is urgent, and these measures should be adapted to the biological features of the investigated populations and emerging human pressures in the spatial context of reference. From this point of view, biometric data provide critical elements in the process of analysis aimed at estimating cetacean ecological traits. Unfortunately, the monitoring and data collection supporting the conservation and management of wildlife organism populations is particularly challenging, especially for the cetaceans. The elusive nature of these animals and their high mobility make the detection of their life-history traits and the acquisition of knowledge about their ecological characteristics difficult. In general, knowledge on the size-weight relationships of cetaceans is acquired from stranded individuals (Clarke et al., 2021). In addition, indirect estimates of consumption rates can be derived from these data. Of course, this type of data suffers from different sources of uncertainty, such as the representativeness of the population at sea, hydrodynamic effects on the spatial distribution of strandings, as well as differences in the stranding data collection protocols of monitoring systems on large spatial scales and their ability to share information among institutions. Despite these limitations, these data can be considered among the most effective sources of information for estimating biometric population traits of cetaceans.

In the Mediterranean Sea, studies reporting cetacean biometric data are rather scarce (Carlini et al., 2014) and when present, they are in the form of ancillary information often contained in ecotoxicological studies (André et al., 1991; Marsili et al., 1997; Cardellicchio et al., 2000; Bilandžić et al., 2012), in assessments of microplastic contamination (Novillo et al., 2020), or in causes of death analysis (Guarino et al., 2021). In addition, information on the length-weight relationships is often fragmented and spatially limited at small areas. Similarly, the consumption rates on prey by cetaceans are reported for few regions and small portions of some Mediterranean regions (Laran et al., 2010; Bearzi et al., 2010; Ricci et al., 2020; Giménez et al., 2021; Ingrosso et al., 2022).

Therefore, this study has the goal to provide estimates of length-weight relationships, consumption rates, and feeding footprint on prey by odontocetes in several Mediterranean regions and at the basin scale. Estimates were obtained from stranding records collected from several data sources (online database and literature) for the period 1983–2021. The analysis was performed for the species characterized by the completeness of biometric data (length and weight) and a statistical procedure was applied to calculate uncertainty ranges of each estimated parameter. In addition, for the prey consumption, diet information was collected for analysed odontocetes species to investigate similarities and differences in the prey consumption patterns.

2. Materials and methods

2.1. Data collection and study areas

The Mediterranean Sea is inhabited by 21 species of cetacean showing different occurrence and permanence in the basin (Notarbartolo di Sciara, 2016). Stranding records were collected for the widespread and regularly occurring species in the Mediterranean Sea, which are the striped dolphin (*Stenella coeruleoalba*) and the common bottlenose dolphin (*Tursiops truncatus*) both listed as “Least concern” in the IUCN Red List; the sperm whale (*Physeter macrocephalus*), the Risso’s dolphin (*Grampus griseus*), the common dolphin (*Delphinus delphis*) and the fin whale (*Balaenoptera physalus*) all listed as “Endangered”, and the

Cuvier’s beaked whale (*Ziphius cavirostris*) listed as “Vulnerable” (ACCOBAMS et al., 2021).

Stranding data were collected from the Italian Stranding Network database (CIBRA, 2006; <http://mammiferimarini.unipv.it/index.php>; accessed 10/2021), the open database Geocetus (2023; <https://geocetus.spaziogis.it/>; accessed 10/2021) and the scientific literature in the period ranging from 1983 to 2021 (Cardellicchio et al., 2000; Blanco et al., 2001; Güçlüsoy et al., 2004; Francese et al., 2007; Öztürk et al., 2007, 2011; Bilandžić et al., 2012; Berti et al., 2013; Mancusi et al., 2014; Dede et al., 2016; Caracappa et al., 2018; Milani et al., 2018; Cuvertoret-Sanz et al., 2020; Esposito et al., 2020; Novillo et al., 2020). For each stranded individual, the date, geographical coordinates (or any spatial information), name of the species, body length (L, cm), body weight (W, kg), maturity, state of decomposition, presumed cause of death, and the source of the recording information were collected. In particular, the state of decomposition is reported according to decomposition condition categories (DCC) reported in ACCOBAMS-MOP7/2019/Doc 33 (2019) (DCC from 1-extremely fresh to 5-mummified or skeletal remains). A preliminary analysis was carried out on the entire data collection focused on deleting duplicate records between different data sources or incomplete biometric data, in order to obtain a consistent database for successive analysis. In addition, recordings were classified, according to the proposal for the planning of Specially Protected Areas of Mediterranean Importance (SPAMIS, UNEP-MAP-RAC/SPA et al., 2010), as belonging to the following sub-regions: the Adriatic Sea (AdS), the Aegean Sea (AeS), the Alboran Sea (AIS), the Algero-Provençal Basin (APB), the Ionian Sea (IoS), the Levantine Sea (LeS), the Tyrrhenian Sea (TyS), the Tunisian Plateau/Gulf of Sidra (TuP), and the entire Mediterranean basin (Med) (Fig. 1). Considering the consistency of data in terms of number of records, biometric data completeness, and geographical distribution, the analysis was conducted on three dolphin species: the striped dolphin, the common bottlenose dolphin and the Risso’s dolphin (Table 1; Supp. Mat. Table S1). Other species detected in the stranding data collection were the sperm whale, Cuvier’s beaked whale and the common dolphin, which were characterized by the absence of weight data.

2.2. Methodological approach

The methodological approach adopted in this study is based on previous analysis conducted in the Mediterranean Sea (Bearzi et al., 2010; Ricci et al., 2020; Giménez et al., 2021; Ingrosso et al., 2022) and is reported in Fig. 2.

2.3. Biometric traits analysis and Length-Weight relationships

The length distribution of each investigated dolphin was estimated within the geographic areas calculating the median, I and III quartiles, minimum and maximum values. Differences between areas were tested according to the non-parametric Kruskal-Wallis (KW) test and *post hoc* multiple comparison Mann-Whitney (U) test, with the Bonferroni correction (McDonald, 2014). The choice of a non-parametric test was due to the non-normal distribution of data tested by means of the Shapiro-Wilk test (Shapiro and Wilk, 1965; Supp. Mat. Table S2). The same analysis was carried out for the weight data and to investigate differences in length and weight between the sexes in the entire Mediterranean Sea. Statistical analyses were conducted when the minimum number of 7 recordings was available for each geographical area. Therefore, the analysis of weight data was only possible for the striped dolphin. Statistical tests were carried out using PAST software (v. 4.14) (Hammer et al., 2001).

Length-Weight (L-W) relationships were calculated for each dolphin species investigated through a power regression model described through the following equation:

$$W = a \times L^b(1) \quad \text{eq. 1}$$

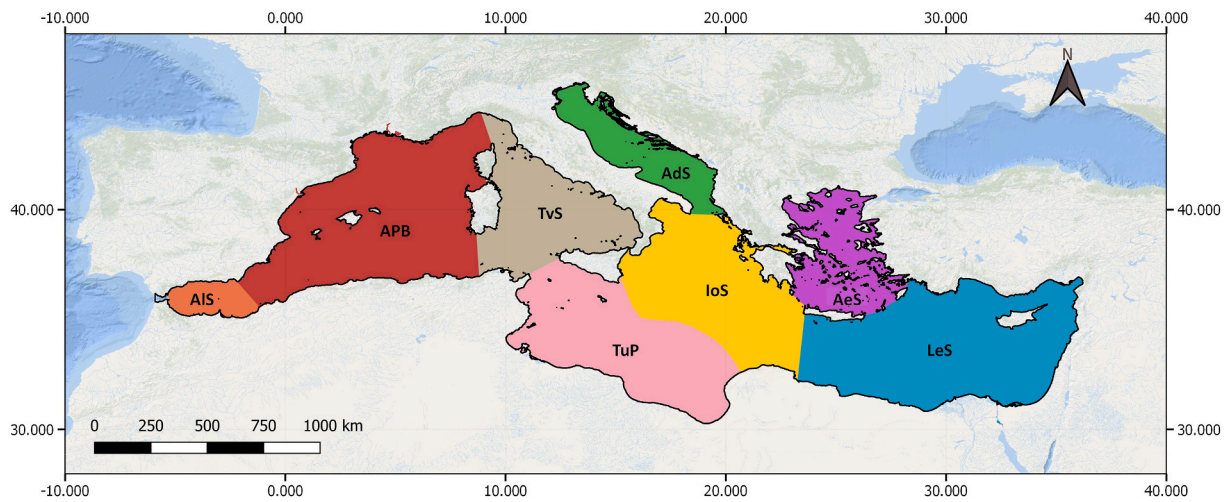


Fig. 1. Subregions considered in the analysis: the Adriatic Sea (AdS, green), the Aegean Sea (AeS, purple), the Alboran Sea (AIS, orange), the Algero- Provençal Basin (APB, red), the Ionian Sea (IoS, yellow), the Levantine Sea (Les, blue), the Tyrrhenian Sea (TyS, grey), the Tunisian Plateau (TuP, pink). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1

Number of stranding events recorded (No.), number of individuals of which body length (L, cm) and body weight (W, kg) were measured in relation to the three species investigated in each subregion. Body weights refer to individuals with the decomposition state ranging from extremely fresh (1), recent (2) and moderate decomposition state (3). Subregions are coded as follows: the Adriatic Sea (AdS), the Aegean Sea (AeS), the Alboran Sea (AIS), the Algero-Provençal Basin (APB), the Ionian Sea (IoS), the Levantine Sea (LeS), the Tyrrhenian Sea (TyS), the Tunisian Plateau/Gulf of Sidra (TuP), and the Mediterranean Sea (Med).

Subregion	<i>Stenella coeruleoalba</i>			<i>Tursiops truncatus</i>			<i>Grampus griseus</i>			<i>Physeter macrocephalus</i>			<i>Ziphius cavirostris</i>			<i>Delphinus delphis</i>			
	No.	L	W	No.	L	W	No.	L	W	No.	L	W	No.	L	W	No.	L	W	
AIS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
APB	336	318	71	137	103	4	30	21	8	13	9	–	8	6	–	11	5	–	
TyS	871	748	16	353	281	2	25	23	–	66	53	–	15	9	–	5	5	–	
AdS	106	98	6	746	696	11	19	19	6	17	17	–	5	5	–	2	2	–	
TuP	59	54	2	39	37	–	4	4	–	7	7	–	6	5	–	2	2	–	
IoS	280	272	30	53	51	–	10	8	–	7	7	–	14	13	–	3	3	–	
AeS	12	12	–	4	4	–	3	3	–	–	–	–	–	–	–	–	–	–	
LeS	–	–	–	–	–	–	4	4	1	–	–	–	–	–	–	–	–	–	
Med	1664	1502	125	1332	1172	17	95	82	15	110	93	–	48	38	–	29	23	–	

where W is the weight (kg), a is a scaling coefficient for the weight at length of the species, L is the length (cm), and b is the growth coefficient. In addition, the coefficient of determination (R²) and confidence intervals for the growth coefficient were calculated. For this analysis, only records with a decomposition state from 1 to 3 were considered, aiming to exclude unrealistic weight values for a living individual that could be due to post-mortem autolysis (Perrin et al., 2005). In addition, the L-W relationships were calculated starting from a minimum number of weight recordings (n = 7) available for each geographical area (Table 1). This analysis was carried out by means of the PAST software (v. 4.14).

2.4. Food consumption analysis

The mean annual food consumption (AFC, kg y⁻¹) and its confidence limits, referred to the mean size of each investigated dolphin species, was calculated adopting a combined bootstrap procedure, according to the method developed in other similar studies (Santos et al., 2014; Giménez et al., 2021). AFC is described by the following modified equation from Santos et al. (2014):

$$AFC = mIB \times T \tag{eq. 2}$$

where mIB (kg day⁻¹) is the mean daily-ingested biomass (or daily food consumption) from an average-size dolphin and T is the number of feeding days (considered as 365 in this study, under the assumption of full availability of the resource). The mIB is generally estimated as the

daily energetic requirements of predators depending on their weight, requiring scaling equations that relate food consumption to body mass. To take into account the uncertainty of such allometric scaling and the poor information on the best scaling equation available for the investigated species, the four most widely used scaling equations were applied (Bearzi et al., 2010; Innes et al., 1987; Leaper et al., 2002; Kaschner, 2004; Tamura, 2003; Trites et al., 1997):

$$IB = 0.123 \bullet W^{0.8} \tag{eq. 3}$$

$$IB = 0.482 \bullet W^{0.524} \tag{eq. 4}$$

$$IB = 0.035 \bullet W^{0.524} \tag{eq. 5}$$

$$IB = 0.1 \bullet W^{0.8} \tag{eq. 6}$$

where, W is the body mass weight of a weaned dolphin. Body weight biomass data are not available for all length data, thus, L-W relationships previously calculated for each dolphin were applied to obtain the W data distribution. Weaned individuals of all species collected in the dataset were selected through the following length cut-offs: 110 cm for the striped dolphin (Guarino et al., 2021), 180 cm for the common bottlenose dolphin (Rossi et al., 2017) and 212 cm for the Risso's dolphin (Huang et al., 2009). Therefore, W data distributions were used to estimate scaling equation IB values of each, which were averaged to obtain the mIB in Eq. (1). Finally, the AFC (mean value and 95% confidence intervals) were estimated by a combined bootstrap procedure, based on

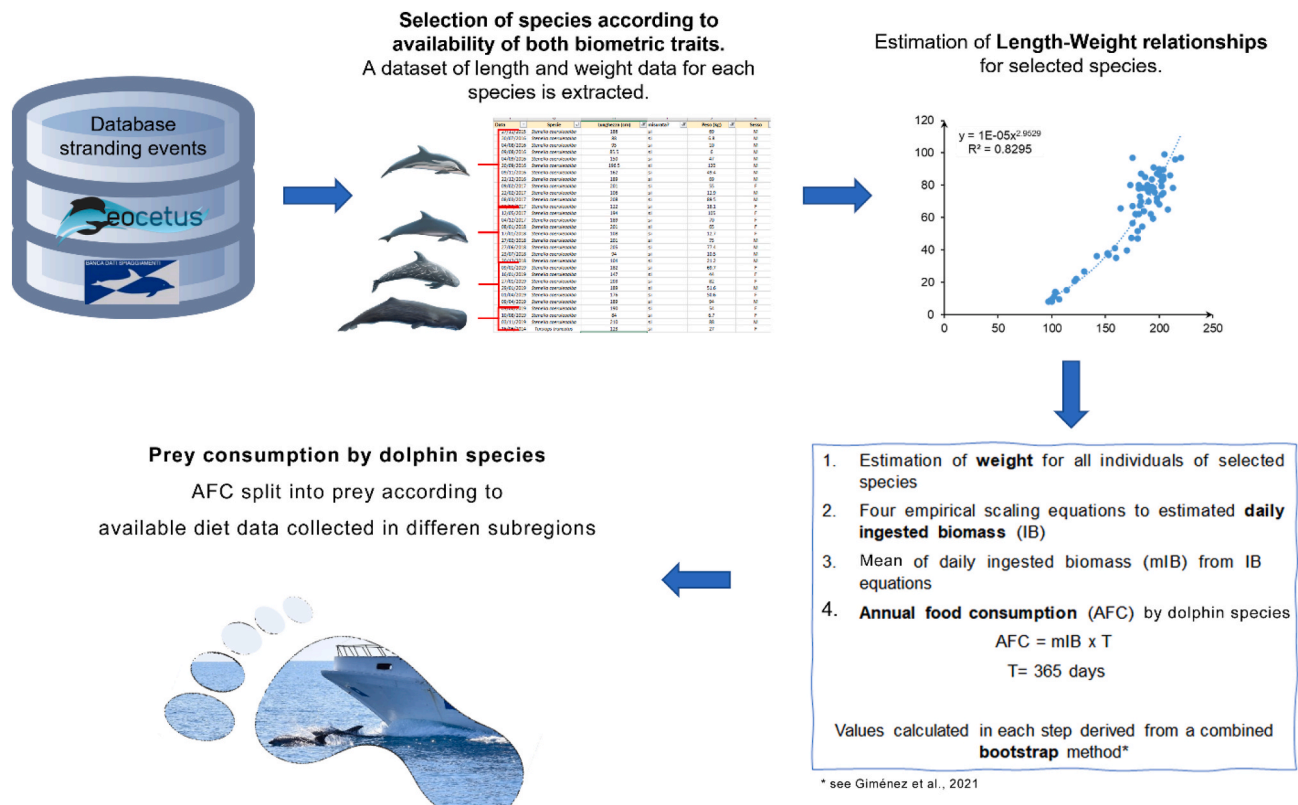


Fig. 2. A schematic description of the methodology adopted in the analysis of biometric data addressed to estimate Length-Weight relationships, mean weights of selected dolphin species and daily and annual consumption rates. More details on the analysis are described in the following sections.

10,000 replicates. This method consisted of resampling with replacement of W and IB data, providing an integrated assessment of the uncertainty of the annual food consumption (see Giménez et al., 2021). The method was carried out using PAST software (v. 4.14) and Excel (Microsoft 365 MSO v. 2307).

To estimate prey consumption by each investigated dolphin within subregions, information from stomach contents were acquired from the literature (Supp. Mat. Table S3). In particular, diets were selected exclusively considering food items expressed as relative weight (ratio between prey weight and the total weight of all prey), to maintain a metric consistency with the AFC estimates. A total of 10 diets were selected from literature, which were represented by 4 diets for both the striped and common bottlenose dolphin, and 2 diets for the Risso's dolphin. Diets of the striped dolphin correspond to AeS, AIS APB and TyS subregions, while diets of the common bottlenose dolphin correspond to AeS, IoS, LeS and TyS subregions. Diets of Risso's dolphin was found for AeS and TyS subregions. Overall, 125 food items (prey) were found in the diets collection represented by several taxonomic levels (species, genus, family, etc.). To standardize the diets with each other, food items were aggregated into 39 common categories (or prey groups), according to several criteria (e.g., faunistic category, family, bathymetric domain, species of ecological importance, etc.; see Tables 2–3). Thus, the amount of prey consumed by each dolphin species in each subregion was calculated multiplying the AFC (mean value and 95% confidence intervals) for the prey weight fraction, according to the considered diet. Notably, it was used the estimated AFC of a specific subregion, when available, otherwise it was used the estimated AFC for the Mediterranean area. To better understand the prey category consumption patterns of investigated dolphins' species among subregions, a multivariate analysis based on the Bray-Curtis similarity index was carried out on root-square transformed consumption data. In particular, the prey categories for dolphins' species of each subregion were disposed in a matrix

(37 × 10). Notably, the prey group categories named “unidentified cephalopods and fishes” were excluded by the analysis. Then, the unconstrained ordination method, namely Principal COordinate analysis (PCO, Gower, 1966), was performed visualizing the relative prey groups contribution to the data ordination through the Spearman's correlation coefficient (rs). This analysis was conducted by means PRIMER 6 + PERMANOVA software (Anderson et al., 2008; Clarke et al., 2014).

3. Results

A total of 1502, 1172 and 82 stranded individuals of striped dolphins, common bottlenose dolphins and Risso's dolphins, respectively, were selected for the analysis of the length values. The area with the highest recorded strandings of the striped (N = 748) and the Risso's dolphin (N = 23) was the TyS, while the Ads was the area with the highest recorded strandings of the common bottlenose dolphin (N = 696). Areas for which W recordings were available were the IoS (N = 30), the TyS (N = 16), the APB (N = 71) and the Med (N = 125) for the striped dolphin; the AdS (N = 11) and the Med (N = 17) for the common bottlenose dolphin, and the APB (N = 8) and the Med (N = 15) for the Risso's dolphin.

Considering all the recordings in the Mediterranean Sea, the median L value was 170 cm for the striped dolphin (Interquartile Range, IR = 66), 238 cm for the common bottlenose dolphin (IR = 91), and 300 cm for the Risso's dolphin (IR = 65) (Fig. 3). The striped dolphin showed the highest median L values in the AdS (L = 188 cm; IR = 50) and in the AeS (L = 183 cm; IR = 51). The median L values observed for this species TuP (151 cm, IR = 66) and IoS (L = 168 cm; IR = 73) were significantly lower than those estimated in the AdS (U = 1701, p < 0.01, U = 10381, p < 0.05, respectively. Table S2). The common bottlenose dolphin showed the highest median L value in the APB (L = 250 cm; IR = 99), while the lowest was in the TyS, with 210 cm (IR = 100). In addition, a significant

Table 2

Prey taxa included in the Prey groups used in the analysis of consumption rates of each investigate dolphin.

Prey Group	Taxa
Other Teuthida	<i>Abralia veranyi</i> , <i>Abraliopsis morisii</i> , <i>Ancistroteuthis lichtensteini</i> , <i>Brachioteuthis riisei</i> , <i>Brachioteuthis</i> spp., <i>Chiroteuthidae</i> , <i>Chiroteuthis veranii</i> , <i>Galiteuthis armata</i> , <i>Onychoteuthis banksii</i> , <i>Pyroteuthis margaritifera</i>
Other Loliginidae	<i>Alloteuthis</i> spp.
Slope Octopoda	<i>Argonauta argo</i> , <i>Ocythoe tuberculata</i> , <i>Pteroctopus tetracirrhus</i>
Shelf Octopoda	<i>Eledone cirrhosa</i> , <i>Eledone moschata</i> , <i>Scaevargus unicolor</i>
Sepiolidae	<i>Heteroteuthis dispar</i> , <i>Neorossia caroli</i> , <i>Sepietta oweniana</i>
Histioteuthidae	<i>Histioteuthis bonnelli</i> , <i>Histioteuthis reversa</i> , <i>Histioteuthis</i> spp.
<i>Illex coindetii</i>	<i>Illex coindetii</i>
<i>Loligo</i> spp.	<i>Loligo forbesi</i> , <i>Loligo</i> sp., <i>Loligo vulgaris</i>
<i>Octopus vulgaris</i>	<i>Octopus</i> sp., <i>Octopus vulgaris</i>
Ommastrephidae	Ommastrephidae, <i>Todarodes sagittatus</i> , <i>Todaropsis eblanae</i>
Sepiidae	<i>Sepia officinalis</i> , Sepiidae
Unidentified cephalopods	Unidentified cephalopods
Benthopelagic shrimps	<i>Acanthephyra pelagica</i> , <i>Pasiphaea multidentata</i> , <i>Sergia robusta</i>
Mesopelagic fishes	<i>Arctozenus risso</i> , <i>Chauliodus sloani</i> , <i>Lepidopus caudatus</i> , <i>Lestidiops</i> spp., <i>Maurolicus muelleri</i> , <i>Paralepis</i> sp., <i>Stomias boa</i>
Other Demersal fishes	<i>Argentina</i> sp., <i>Chelidonichthys lucerna</i> , <i>Epigonus</i> spp., <i>Pomadasy incisus</i> , <i>Umbrina cirrosa</i> , <i>Symphodus</i> sp.
Eel fishes	<i>Ariosoma balearicum</i> , <i>Conger conger</i> , <i>Echelus myrus</i> , <i>Gnatophis mistax</i> , <i>Ophidion barbatum</i>
Flatfishes	<i>Arnoglossus</i> sp., <i>Bothus podas</i> , <i>Citharus linguatula</i> , <i>Microchirus variegatus</i> , <i>Monochirus hispidus</i> , <i>Scophtalmidae</i> , <i>Solea</i> sp.
<i>Belone belone</i>	<i>Belone belone</i>
<i>Boops boops</i>	<i>Boops boops</i>
Other Benthic fishes	<i>Callionymus</i> sp., <i>Cepola macrophthalma</i> , <i>Saurida undosquamis</i> , <i>Synodus saurus</i>
Carangidae Scombridae	Carangidae, <i>Caranx ronchus</i> , <i>Scomber scombrus</i> , <i>Trachurus mediterraneus</i> , <i>Trachurus</i> sp., <i>Trachurus trachurus</i>
Centranchidae	<i>Centranchus cirrus</i> , <i>Spicara flexuosa</i> , <i>Spicara smaris</i>
Prey Group	Taxa
Myctophidae	<i>Ceratoscopelus maderensis</i> , <i>Diaphus</i> sp., <i>Diaphus metopoclampus</i> , <i>Hygophum</i> sp., <i>Lobianchia gemellarii</i> , <i>Lampanyctus crocodilus</i> , <i>Lampanyctus</i> sp., <i>Myctophidae</i>
Mugilidae	<i>Chelon ramada</i> , <i>Liza ramada</i> , <i>Mugilidae</i>
Clupeidae	<i>Clupeidae</i> , <i>Sardina pilchardus</i> , <i>Sardinella aurita</i> , <i>Sprattus sprattus</i>
Other Sparidae	<i>Dentex dentex</i> , <i>Oblada melanura</i> , <i>Pagrus coeruleostolicus</i> , <i>Pagrus pagrus</i> , <i>Sparidae</i> , <i>Spondyliosoma cantharus</i>
Moronidae	<i>Dicentrarchus labrax</i> , <i>Moronidae</i>
<i>Diplodus</i> spp.	<i>Diplodus annularis</i> , <i>Diplodus</i> sp., <i>Diplodus vulgaris</i>
<i>Engraulis encrasicolus</i>	<i>Engraulis encrasicolus</i>
Serranidae	<i>Epiphenelus aeneus</i> , <i>Serranus</i> sp.
Other Gadidae	<i>Gadiculus argenteus</i> , <i>Gadidae</i> , <i>Phycis</i> sp., <i>Trisopterus minutus</i>
Gobiidae	<i>Gobiidae</i> , <i>Gobius niger</i> , <i>Lesuerigobius</i> sp.
<i>Lithognatus mormyrus</i>	<i>Lithognatus mormyrus</i>
<i>Merluccius merluccius</i>	<i>Merluccius merluccius</i>
<i>Micromesistius poutassou</i>	<i>Micromesistius poutassou</i>
Mullidae	<i>Mullus</i> spp., <i>Upeneus moluccensis</i>
<i>Pagellus</i> spp.	<i>Pagellus acarne</i> , <i>Pagellus erythrinus</i>
Sphyraenidae	<i>Sphyraena sphyraena</i> , <i>Sphyraena viridensis</i>
Unidentified fish	Unidentified fish

difference in the median lengths was observed between stranded individuals in the TyS compared to those stranded in the AdS ($U = 81126.5$, $p < 0.001$), APB ($U = 11410$, $p < 0.05$) and Med ($U = 143528$, $p < 0.05$). The Risso's dolphin showed the highest median L value in the IoS ($L = 310$ cm; $IR = 54$) and the lowest in the TyS, equal to 289 cm ($IR = 104$). No significant differences in the median L were observed between geographical areas.

Exploring the differences in length between the sex of stranded individuals in the entire Mediterranean Sea, the females of striped dolphin showed a median length significantly longer than males (F Length = 183 cm; M Length = 175 cm; $H = 4.09$, $p < 0.05$; see Supp. Mat. Table S2). On the other hand, the median length calculated for the common bottlenose dolphin males was longer than that of females (F Length = 240 cm; M Length = 250 cm; $H = 7.24$, $p < 0.01$). No difference in length was detected between the sexes of *G. griseus*.

The highest median value of striped dolphin's weight was recorded in the APB ($W = 70$ kg; $IR = 40$) while the lowest one was in the TyS ($W = 46$ kg; $IR = 64$). The median value of the striped dolphin's weight in the entire Mediterranean basin was 68 kg ($IR = 45$) (Fig. 3). No significant difference was detected for this species (Table S2). For the common bottlenose dolphin, the median value of weight recorded in the AdS ($W = 199$ kg, $IR = 110$) is similar to those obtained including all the Mediterranean observations ($W = 200$ kg, $IR = 117$). The median value of the Risso's dolphin's weight in the Med was equal to 250 kg ($IR = 130$), whereas the median weight in APB was 223 kg ($IR = 210$).

L-W relationships estimated for the striped dolphin showed values of the b coefficient ranging from 2.578 (95% CI: 2.367–2.803) in APB to 2.716 (95% CI: 2.418–3.051) in TyS, with a value of the b coefficient for the entire Med equal to 2.644 (95% CI: 2.485–2.802) (Fig. 4). Regarding the common bottlenose dolphin, the b coefficient value estimated for the Med was 2.975 (95% CI: 1.102–3.736). Finally, the b coefficient value estimated for the Risso's dolphin was equal to 2.988 (95% CI: 2.478–3.762) in Med area.

3.1. Food consumption rates

Estimations of the variables (L, W, IB, mIB and AFC) used in the food consumption analysis of three dolphins are reported in Table 4.

Considering the entire Mediterranean Sea, the four scaling equations showed mean values of IB ranging from 2.19 ± 0.89 kg day⁻¹ (IB3) to 4.12 ± 0.91 kg day⁻¹ (IB2) for the striped dolphin; from 6.44 ± 2.28 kg day⁻¹ (IB4) to 7.96 ± 2.80 kg day⁻¹ (IB1) for the common bottlenose dolphin, and from 9.74 ± 1.41 kg day⁻¹ (IB2) to 12.23 ± 2.60 kg day⁻¹ (IB1) for the Risso's dolphin (Table 4). Based on these four equations, the mean daily ingested biomass was estimated at 3.09 ± 0.95 kg day⁻¹ for the striped dolphin, 7.04 ± 2.40 kg day⁻¹ for the common bottlenose dolphin, and 10.75 ± 2.28 kg day⁻¹ for the Risso's dolphin. Therefore, the annual removal of biomass by a striped dolphin was estimated at 1118 kg y⁻¹ (95% CI: 531–1570) of food. For the common bottlenose dolphin, the AFC corresponded to 2571 kg y⁻¹ (95% CI:

Table 3

Diets from subregions of the investigated dolphins (common bottlenose dolphin, CBD; striped dolphin, SD; Risso's dolphin, RD) reported as prey groups detailed in Table 2. Diet references are reported: 1. Milani et al., 2018; 2. Bearzi et al., 2010; 3. Scheinin et al. (2014); 4. Neri et al. (2023); 5. Saavedra et al., 2022; 6. Aznar et al. (2017). 7. Würtz and Marrale, 1993. 8) Würtz et al. (1992). Subregions codes are: Aegean Sea (AeS), Alboran Sea (ALS), Algero-Provençal Basin (APB), Ionian Sea (IoS), Levantine Sea (Les), the Tyrrhenian Sea (TyS).

Prey Group	Dolphins species (Ref.)	CBD (1, 2, 3, 4)				SD (1, 5, 6, 7)				RD (1, 8)	
	Subregion	AeS	IoS	LeS	TyS	AeS	ALS	APB	TyS	AeS	TyS
Other Teuthida		0	0	0	0.0043	0.18	0.031	0.013	0.063	0.0205	0.049
Other Loliginidae		0	0	0	0.0008	0	0.001	0	0.003	0	0
Slope Octopoda		0.029	0	0	0	0	0.001	0	0	0.0298	0
Shelf Octopoda		0	0	0	0.0832	0	0	0	0.001	0	0
Sepiolidae		0	0.03	0	0.0001	0.019	0.01	0.004	0.0045	0	0.001
Histioteuthidae		0	0	0	0.0007	0	0.001	0.028	0.153	0.9497	0.818
<i>Illex coindetii</i>		0	0	0	0.0637	0.191	0	0.169	0.014	0	0
<i>Loligo</i> spp.		0.073	0.03	0.028	0.0509	0.045	0.004	0.006	0.0001	0	0
<i>Octopus vulgaris</i>		0.02	0.03	0.004	0.1063	0	0	0	0	0	0
Ommastrephidae		0	0.03	0	0	0.067	0.2	0.036	0.26	0	0.132
Sepiidae		0.036	0.03	0.022	0	0	0.01	0	0	0	0
Unid. cephalopods		0	0	0	0	0	0.01	0	0	0	0
Benthopelagic shrimps		0	0	0	0	0	0	0	0.0102	0	0
Mesopelagic fishes		0	0	0	0	0.018	0.005	0.072	0.062	0	0
Other Demersal fishes		0.002	0	0	0.0121	0	0	0.005	0	0	0
Eel fishes		0.242	0.15	0.257	0.1185	0.021	0.001	0	0	0	0
Flatfishes		0	0	0.03	0.0042	0.016	0	0.0001	0	0	0
<i>Belone belone</i>		0.001	0.0125	0	0	0	0	0	0.031	0	0
<i>Boops boops</i>		0.208	0	0.09	0.0142	0.275	0.15	0.084	0.142	0	0
Other Benthic fishes		0	0	0.002	0.0006	0	0	0.002	0	0	0
Carangidae Scombridae		0.041	0.025	0.012	0.0265	0	0.005	0.001	0	0	0
Centranchidae		0.012	0	0.004	0.0089	0	0	0	0	0	0
Myctophidae		0	0	0	0	0.13	0.29	0.0935	0.0142	0	0
Mugilidae		0.059	0.065	0.038	0.1189	0	0	0	0	0	0
Clupeidae		0.085	0.0125	0	0.0056	0.037	0.01	0.0066	0	0	0
Other Sparidae		0.016	0.04	0.006	0.0121	0	0	0	0	0	0
Moronidae		0	0.065	0	0.0015	0	0	0	0	0	0
<i>Diplodus</i> spp.		0.001	0.03	0	0.0398	0	0	0	0	0	0
<i>Engraulis encrasicolus</i>		0	0	0	0.0023	0	0	0.052	0.013	0	0
Serranidae		0.012	0	0.061	0.0005	0	0	0	0	0	0
Other Gadidae		0	0.11	0	0.008	0	0.001	0.0088	0	0	0
Gobiidae		0.001	0	0	0.0049	0.001	0.05	0.007	0	0	0
<i>Lithognathus mormyrus</i>		0.016	0	0.135	0.0369	0	0	0	0	0	0
<i>Merluccius merluccius</i>		0.08	0.12	0	0.2278	0	0.05	0.409	0.039	0	0
<i>Micromesistius poutassou</i>		0	0	0	0.0002	0	0	0.003	0.19	0	0
Mullidae		0	0.12	0.007	0.0007	0	0	0	0	0	0
<i>Pagellus</i> spp.		0.057	0	0.091	0.0333	0	0	0	0	0	0
Sphyraenidae		0.009	0	0.029	0.0125	0	0	0	0	0	0
Unid. fish		0	0.1	0.184	0	0	0.17	0	0	0	0
Total		1	1	1	1	1	1	1	1	1	1

1372–3963), while for the Risso's dolphin it was equal to 3913 kg y⁻¹ (95% CI: 2469–5306).

The prey groups consumption by dolphins among the subregions is reported in Fig. 5a–j and Table S4. The differences observed through the PCO analysis showed a clear separation among the dolphins' species, while differences among subregions resulted low for the striped and common bottlenose dolphin (Fig. 6). In particular, the explained variations of the first and second axes were of 47.6% and 26.6%, respectively. Along the first axis, the main prey groups correlated ($r_s > 0.55$) to the consumptions of the common bottlenose dolphin were several bony fishes of demersal (Sparidae, Mullidae, Serranidae, eel fishes) and pelagic habitus (Sphyraenidae), and benthic cephalopods (*Octopus vulgaris* and Sepiidae) (Fig. 6, right side of the plot). This prey groups seem to be more associated to Aegean and Levantine Sea, while both pelagic squids (*Loligo* spp.) and bony fishes (Carangidae- Scombridae) resulted more correlated to TyS and IoS subregions. On the contrary, in the left side of the plot, the Risso's dolphin consumptions were characterized by the family of Histioteuthidae and taxa belonging to Other Teuthida. In the upper side of the plot, the consumptions of striped dolphin resulted very similar among all subregions, excepted for the TyS, which was slightly separated. The main correlated prey group to these consumptions were Gobiidae, *I. coindetii*, Myctophidae, Mesopelagic fishes, and Sepiolidae. These last three prey groups seem to be more abundant in the consumptions of the TyS subregion than others. Finally, *Merluccius*

merluccius, *Boops boops* and Clupeidae were associated to both striped and common bottlenose dolphins.

4. Discussion

The knowledge of life-history traits and feeding interactions represents a fundamental point for the biological and ecological study of cetaceans. However, the estimation of several biometric traits for cetaceans in the Mediterranean area is limited by fragmented data, often based on small samples and without validation procedures and estimation of ranges of variability (e.g. Duyar and BİLGİN, 2018; André et al., 1991). The attempt of this study is to provide biometric traits estimates and consumption rates of stranding information inherent to three dolphin species at the Mediterranean and regional scale collected in a period of more than 35 years. In this analysis, procedures to select robust data and estimate range of variability of several parameters were adopted, following methods applied at small spatial scales (Bearzi et al., 2010; Giménez et al., 2021). Stranding data suffer of several sources of uncertainty, linked to the influence of environmental factors on the stranding dynamics, such as wind and current direction, or sinking process of carcasses (see Peltier et al., 2012). Other critical points in the use of stranding information could occur in the reliability of some body parameters, such as the weight (Valsecchi et al., 2004; Perrin et al., 2005). In this case, standard procedure based on the selection of

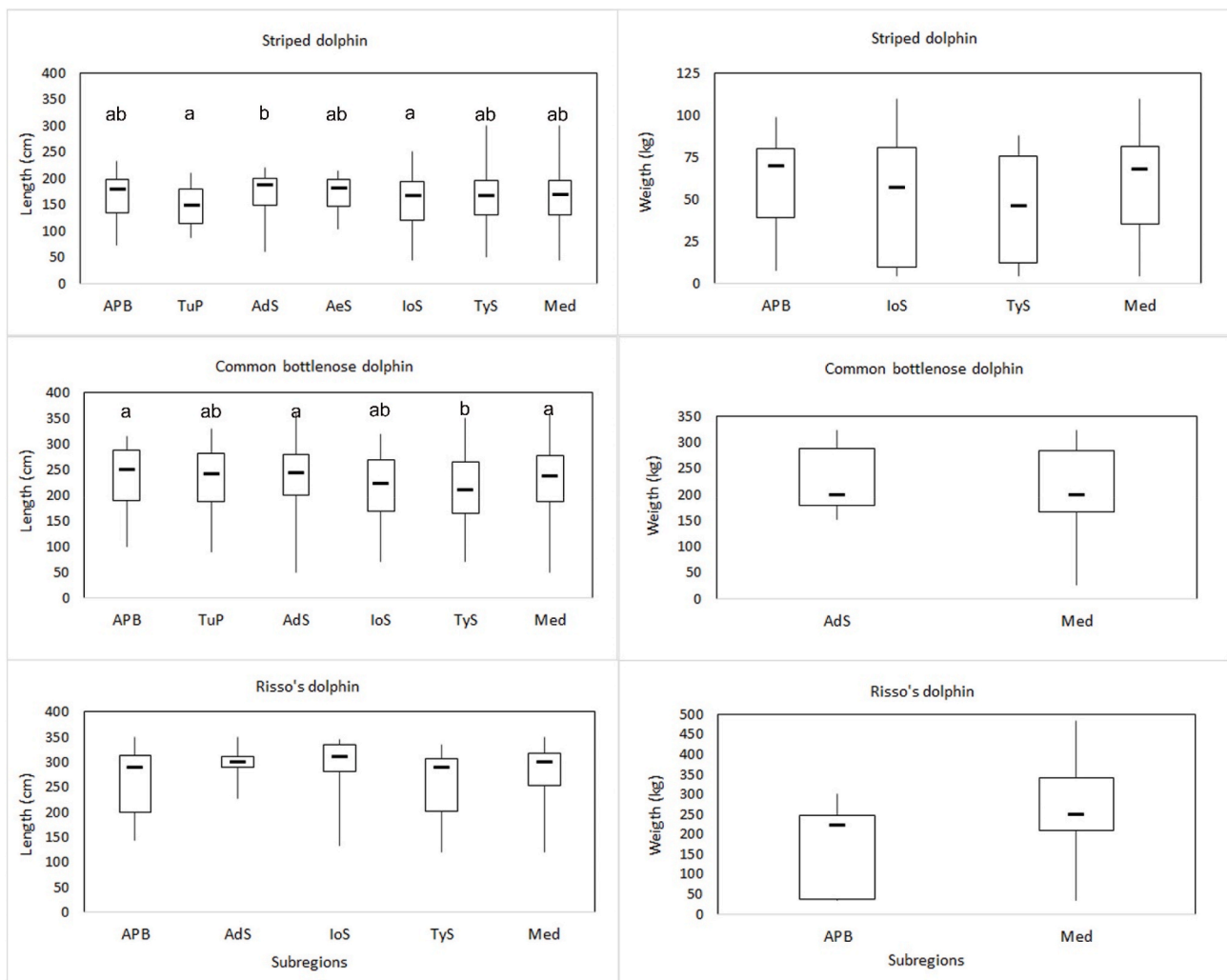


Fig. 3. Boxplots indicate the Length (cm, left) and Weight (kg, right) distributions related to the striped dolphin, the common bottlenose dolphin and the Risso's dolphin in all subregions. The median values (bold line), minimum and maximum values (whiskers), and I-III quartiles (lower and upper limits of boxes) are reported. Letters (a, b, c) refer to groups that are statistically significant.

stranding data according to decomposition status was adopted in this analysis limiting potential bias on weight data (ACCOBAMS-MOP7/2019/Doc 33, 2019). In general, these issues highlight the need to handle with caution the possible inference on the living populations.

Overall, the stranding data collected and analysed in this study provide a framework of knowledge on the biometric and consumption traits of three common dolphins species in the Mediterranean Sea, representing a first baseline of data to support future analysis on the ecology of this species addressed to assess their conservation status. Nevertheless, the estimations of the consumption rates could represent useful information to improve the quantitative analysis on the interaction between cetaceans and the fishery in the Mediterranean region.

Concerning the analysis of stranding data by subregions, the spatial displacement of biometric information showed a good coverage in all areas, excepted for the Alboran Sea, where stranding events of several species are documented (Rojo-Nieto et al., 2011), however length and weight data are lacking. In addition, from the analysis of stranding sites aggregation in sub regions, a lack of information was detected for the southern coastal zones of the Tunisian Plateau, the Ionian Sea and the Algero- Provençal Basin, likely due to the absence of an effective stranding monitoring system, as reported by the recent assessment of ACCOBAMS et al. (2021).

4.1. Biometric traits and L-W relationships

The analysis of the size and weight distributions highlights some geographical differences for each investigated species. For instance, the striped dolphin shows significantly smaller sizes in the Ionian Sea and the Tunisian Plateau region than the Adriatic Sea. On the other hand, the length size of *T. truncatus* in the Adriatic Sea was higher than that estimated in the Tyrrhenian Sea.

In general, the size difference detected in the stranding data analysis can be affected by several external factors acting on the transport and stranding of carcasses, such as hydrographic traits of a basin (Peltier et al., 2012; Carlucci et al., 2020), as well as the variation of mortality rates among the subregions. Our results seem to highlight higher sizes of the striped and common bottlenose dolphins the semi-enclosed basin of Adriatic Sea than other subregions. Another potential environmental driver, affecting the difference in sizes, could be represented from different primary productivity and trophic conditions, which demonstrate affecting ecological traits of cetacean populations, such as the spatial variation of the cetaceans' diversity in the Mediterranean region (Gnone et al., 2023). Indeed, the Ionian and the Strait of Sicily are oligotrophic zones, with complex food webs regulated by the deep energy flows (Agnetta et al., 2019; Ricci et al., 2022). On the other hand, the Adriatic basin is characterized by high primary productivity (Salgado-Hernanz, et al., 2022), which sustains pelagic and benthic food

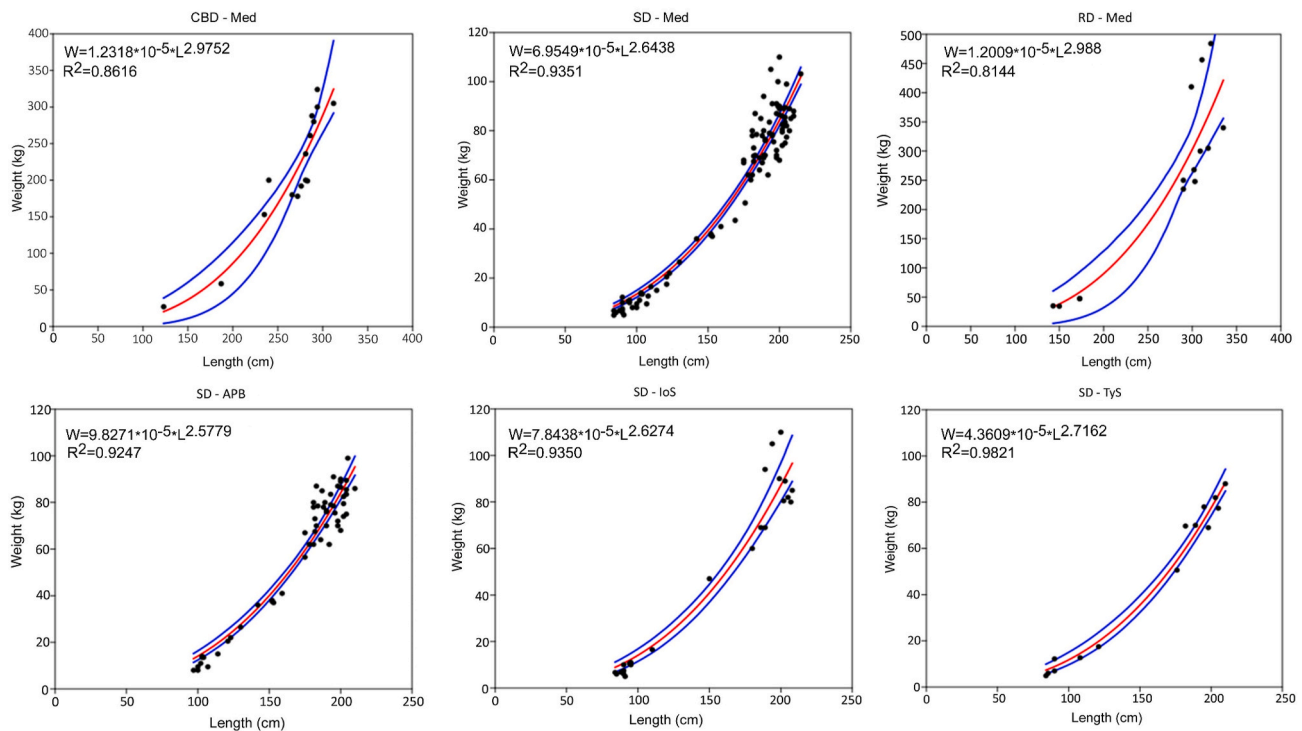


Fig. 4. L-W relationships estimated for the common bottlenose dolphin (CBD), the striped dolphin (SD) and the Risso's dolphin (RD) in all subregions. Power equations and the coefficient of determination (R^2) are reported with representation of observed values (black points), power equation line in red (95%Confidence Intervals, lines in blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 4

Mean Weight (mW, \pm standard deviation SD, kg), mean Ingested biomass (IB, \pm SD, kg day^{-1}) obtained from different equations (see the main text), the mean IB (mIB, \pm SD) and annual food consumption rates (AFC, with 95% confidence intervals in brackets, kg y^{-1}) estimated for each investigated dolphin species within subregions.

Subregion	mW	IB1	IB2	IB3	IB4	mIB	AFC
Striped dolphin							
APB	65.3 \pm 21.77	3.45 \pm 0.95	4.24 \pm 0.81	2.29 \pm 0.76	2.81 \pm 0.77	3.20 \pm 0.82	1160 (585–1533)
IoS	56.9 \pm 27.43	3.08 \pm 1.19	3.88 \pm 1.02	2.00 \pm 0.97	2.49 \pm 0.97	2.87 \pm 1.03	1051 (547–1609)
TyS	55.9 \pm 25.04	3.06 \pm 1.12	3.87 \pm 0.96	1.97 \pm 0.89	2.47 \pm 0.90	2.84 \pm 0.99	1041 (488–1522)
Med	62.6 \pm 25.32	3.32 \pm 1.11	4.12 \pm 0.93	2.19 \pm 0.89	2.69 \pm 0.91	3.09 \pm 0.95	1118 (531–1570)
Common bottlenose dolphin							
Med	184.9 \pm 81.29	7.96 \pm 2.80	7.28 \pm 1.73	6.53 \pm 2.85	6.44 \pm 2.28	7.04 \pm 2.40	2571 (1372–3963)
Risso's dolphin							
Med	317.2 \pm 81.66	12.23 \pm 2.60	9.74 \pm 1.41	11.07 \pm 2.90	9.94 \pm 2.12	10.75 \pm 2.28	3913 (2469–5306)

webs distributed on a very broad shelf platform (Libralato et al., 2010). However, other factors affecting the biometric differences detected in the analysis could be the genetic traits and demographic characteristics, which contribute to distinguish management units (see Moritz, 1994) for conservation of these dolphins, as observed in other Mediterranean studies (Calzada and Aguilar, 1995; Sharir et al., 2011; Esteban et al., 2016; Giménez et al., 2018; Guarino et al., 2021). The difference between the sexes of the striped dolphin is consistent with the estimation carried out for this species in the French Mediterranean coast, reported in Di-Meglio et al. (1996). Similarly, sexual dimorphism in the *T. truncatus* is reported by several authors (Jefferson et al., 2008; Reeves et al., 2002).

The L-W relationships of the striped dolphin calculated in this study show b coefficient values lower than those reported by Miyazaki et al. (1981) for striped dolphin populations of the Pacific coast of Japan, with values ranging between 2.910 and 2.920. Other studies conducted on the Mediterranean France coast estimated similar b coefficient values (2.517, André et al., 1991; 2.602, Viale, 1985) to that estimated for the Algero- Provençal Basin in this study (2.578), and these values are included in the range of variability estimated in this study. Concerning this aspect, confidence intervals estimated for the b coefficient for the

striped dolphin in this study showed small and very similar ranges of variability among investigated subregions, indicating acceptable robustness of the estimates. The b coefficient estimated for *T. truncatus* at the Mediterranean scale (2.975) showed a similar value to those estimates in the U.S. mid-Atlantic waters for female (2.998) and male (3.021) specimens, respectively (Malette et al., 2016). Similar values are reported in Hart et al. (2013) for the same area, with coefficient values of 2.87 for the female and 3.29 for the male. However, the small sample size and the large range of variability estimated for the L-W relationships parameters in this study, indicate a low robustness in the estimates obtained for *T. truncatus* in Mediterranean regions. Thus, to increase the effort in the management of the stranding events, addressing the operation towards a more detailed detection of biometric data is required. Finally, the b coefficient value estimated for the Risso's dolphin in Mediterranean region (2.988) is lower than the b coefficient estimated in the Faroe Islands (3.556, see Bloch et al., 2012), likely due to lack of weight records in correspondence with the length range 200–300 cm in our Mediterranean data collection.

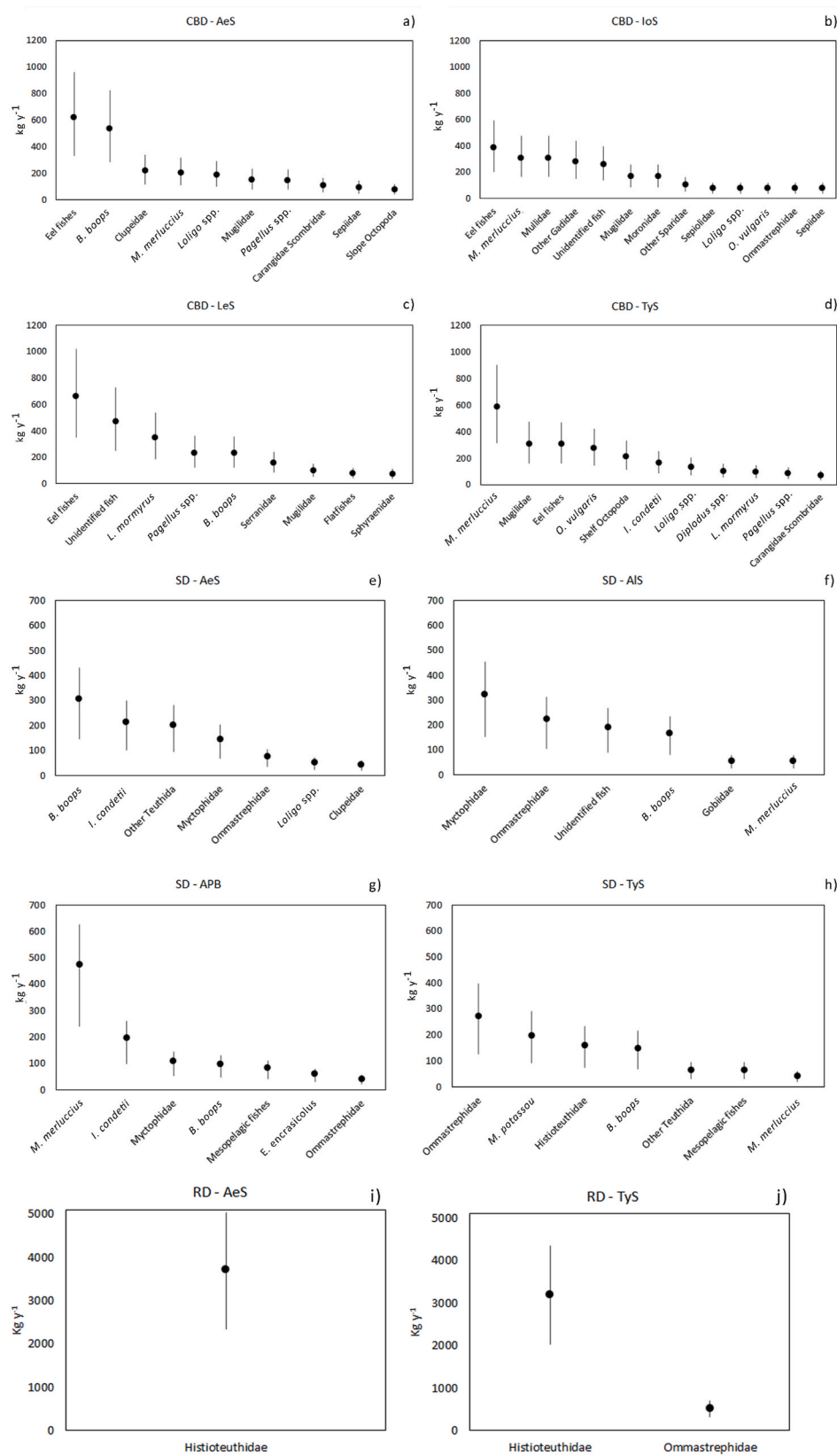


Fig. 5. a-j. Estimates of annual prey groups consumptions (AFC in kg y⁻¹; mean value, black circles; 95% confidence intervals, dashed lines) by a-d) the striped dolphin, e-h) the common bottlenose dolphin, and i-j) the Risso's dolphin in different subregions (see Fig. 1 for the subregions codes). Prey groups with values contributing to the 90% of the total consumption are reported. For details of species included within prey groups see Table 2.

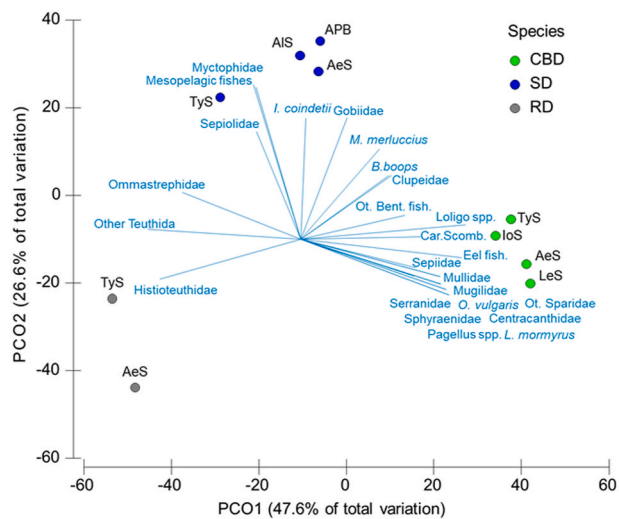


Fig. 6. PCO plot of prey group consumptions by dolphins (common bottlenose dolphin, CBD blue; striped dolphin, SD green; Risso's dolphin, RD grey). The percentages of explained variance (%) of both PCO1 and PCO2 axes are reported, and blue vectors represented the main correlated prey groups to the two axes ($r_s > 0.55$). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

4.2. Food consumption patterns

Estimating the daily and annual food consumption of cetaceans represents an essential element in the quantitative assessment of cetaceans-fishery competition for trophic resources (Kaschner et al., 2006; Jusufovski et al., 2019). This assessment requires quantitative information on prey consumption and fishing catches, and it can be performed by several methodological approaches (Bearzi et al., 2010; Spitz et al., 2018). In our study, the analysis was focused on a basic calculation of total consumption rates, in order to provide a snapshot of consumption patterns in the Mediterranean Sea, also quantifying a range of uncertainty around the mean consumption values (Santos et al., 2014).

The mean daily consumption rate estimated for *T. truncatus* in the Mediterranean Sea (7.04 ± 2.40 kg day⁻¹) was higher than the values of 6.1 and 5.4 kg day⁻¹ reported for the northern Ionian subregion by Bearzi et al. (2010) and Ricci et al. (2020), respectively. Differences observed among these values can be due to the different sample sizes used in these studies, but the Ionian values are included in the range of variability estimated for the Mediterranean region. Other information on the food consumption for this species is absent at Mediterranean scale, while some estimates have been performed through bioenergetic models in American Atlantic waters (Bejarano et al. 2017) and the Biscay Bay (Spitz et al., 2018). In the former study, the annual food consumption ranged between 3052 and 5336 kg per individual, which was higher than that estimated by our analysis in the Mediterranean region (1372–3963 kg). In the latter study, mean daily food consumption showed a value of 14.5 kg (12.0–17.1), resulting two times higher than that estimated in Mediterranean region. Another estimation of the mean daily food consumption conducted with the same our method, in Northeastern U.S. continental shelf, showed a daily value of 8.7 kg per individual (Smith et al., 2015). These differences could be driven by differences between the biometric and genetic traits of Mediterranean and Atlantic populations (Viaud-Martinez et al., 2008; Sharir et al., 2011), but further analyses should be carried out given the use of different approaches in estimating consumption.

Considering the striped dolphin, the mean body weight estimated for the APB subregion was consistent with that reported for the same species in the Ligurian Sea (north-eastern side of APB region), with mean values of 65–66 kg (Laran et al., 2010). The mean daily food consumption

estimated in the Biscay Bay for the striped dolphin (6.3 kg) was higher than that of Mediterranean region (Spitz et al., 2018). Although the methodological approaches are different, the highest food consumption value in European Atlantic waters is explained by a higher mean body mass (80 kg) of the dolphins in this area. In addition, the consumption rate of the striped dolphin in APB was similar to reported for the common dolphin in the Alboran Sea (3.35 ± 0.67 kg day⁻¹), which in size and feeding habits is a similar species to the striped dolphin (Giménez et al., 2021). Finally, the Mediterranean mean IB values estimated for the Risso's dolphin (10.75 ± 2.28) were included in the range of values reported for the Ligurian Sea (7.6 – 17.0 kg day⁻¹, Laran et al., 2010), and slightly higher than the mean value estimated in the Biscay Bay (9.3 kg day⁻¹; Spitz et al., 2018).

The estimation of the total food consumption should be integrated from information on the prey consumed by dolphins, in order to support several research perspectives, such as estimating trophic niche size and overlap with other predators (Carlucci et al., 2021), as well as in the competition between dolphins and fisheries for food resources (Bearzi et al., 2008; Kaschner et al., 2006; Piroddi et al., 2011). Unfortunately, to detail the prey consumption by cetaceans is affected from several issues in the selection of adequate dietary information from the literature, which must satisfy criteria of metric consistency (e.g. diet expressed in weight fractions), and representativeness, such as the number of stomachs analysed in each study. The first criterion is linked to diet collection, and, many stomach content analyses were excluded from our study, because they were expressed in numerical fractions, such as diets reported in Blanco et al. (2001, 2006) and Luna et al. (2022). The second criterion assesses the reliability of the selected studies that might be unrepresentative of the real feeding habits of a given dolphin species. In our study, the information on the diet of Risso's dolphin can be considered less representative, as a single stomach was analysed in two studies acquired from the Aegean and Tyrrhenian Sea (Milani et al., 2018; Würtz et al., 1992). However, to the best of our knowledge, this is the only information available for this species that is rare in the Mediterranean area. For *T. truncatus*, the diet of the Adriatic Sea was excluded from the analysis, as it was characterised by a single stomach (Mioković et al., 1999), being poorly representative of the entire trophic spectrum of this dolphin compared to that found in other areas (e.g. Tyrrhenian Sea, Neri et al., 2023). Finally, this screening on the reliability of diet information highlights a lower number of stomachs analysed in Aegean Sea (Milani et al., 2018) than that of other Mediterranean areas, and lack of specific quantitative studies on the feeding habits of cetaceans in the Ionian Sea, except for the study carried out by Bearzi et al. (2010). Some information could be acquired by food-web models developed in this subregion (Piroddi et al., 2011; Carlucci et al., 2021), but the resolution of prey categories is often too broad and obtained from indirect estimates.

Concerning the common bottlenose dolphin, demersal and pelagic prey of neritic areas represent the main important food resources, with the highest consumption estimated for eel fishes, several species belonging to Sparidae family (e.g. *L. mormyrus*, *B. boops*, *Pagellus* spp.), Mugilidae, *M. merluccius*, and benthic cephalopods of the Octopoda family. Similar observations are reported for the diet of *T. truncatus* in the Gulf of Cadiz, where a combination of different methods (e.g., stomach content analysis and stable isotope analysis) have detected the European hake and sparids as the most important prey (Giménez et al., 2017). Similar findings are reported for stomach content analysis conducted on stranded individuals in the Tyrrhenian Sea (Scuderi et al., 2011), and Western Mediterranean Sea (Blanco et al., 2001), although these studies are based on the numerical fraction of prey. Overall, the wide range of prey exploited by this dolphin reflects its opportunistic nature, which could be affected by local ecological features of habitats, the spatial distribution of dolphins' groups, as well as the human pressures such as the fishery (Carlucci et al., 2016; Gnone et al., 2022; Pace et al., 2022).

Differently, the striped dolphin showed the highest consumptions of

myctophids, mesopelagic fishes, *I. coindetii* and cephalopods of the Ommastrephidae family, and *B. boops*. This pattern of prey seems to be consistent with other observations on diets analysed in Atlantic waters (Marçalo et al., 2021), and in the eastern Mediterranean Sea (Dede et al., 2016). In this latter diet, the mesopelagic fishes seem to be more important than cephalopods, but this difference is affected by the analysis of prey in numerical percentage. Overall, the striped dolphin exhibits a feeding habit based on the mesopelagic prey distributed in the upper slope, where the myctophids are an essential prey in the consumption estimated in the Alboran and Aegean Sea, and APB subregion. In particular, this prey category accounted for around 300 kg per year in the Alboran Sea, and this observation seems to be consistent with the prey consumption pattern of the common dolphin in the same area, where its annual consumption of the myctophids (e.g. *Ceratoscopelus maderensis*) is around 385 kg per individual (Giménez et al., 2021). Notably, the common and striped dolphin are characterized by a high trophic similarity with a potential interspecific competition, as revealed from study conducted through stable isotope analysis in the western Mediterranean region (Borrell et al., 2021).

Considering the Risso's dolphin, the prey consumption is based on the bathyal cephalopods (Luna et al., 2022). According to our results, the main squids consumed by *G. griseus* are those belonging to the genus *Histiotheuthis* spp., as observed in other studies (see Chen et al., 2013). However, diet information available for this species is extremely limited with a low representativeness on the overall feeding habits (Lanfredi et al., 2021). In particular, Luna et al. (2022) reports the occurrence of shelf cephalopods (*O. vulgaris*, *Eledone* spp.) and *I. coindetii* in the trophic spectrum of the Risso' dolphin, which seem to exhibit an opportunistic behaviour, varying its feeding preferences towards other pelagic and benthic cephalopods. Not less relevant, observations in the Spanish Mediterranean waters have detected the sensitivity of this species to the squids adopted as baits for the longlines (Macías Lopez et al., 2012). This evidence points out the need to urgently investigate the effects of interactions in the food web between environmental and anthropogenic pressures (Giralt Paradell et al., 2021; Piroddi et al., 2017; Ricci et al., 2023).

Considering the comparison among prey consumption patterns, the dolphins' species resulted clear separated one from each other in terms of exploit food resources. The bathymetric gradient from shelf to slope grounds can be considered an important driver in the differences, affecting the distribution of prey, as observed in the Ionian Sea (Carlucci et al., 2021; Ricci et al., 2021). Not less important, a stable isotope analysis performed on the same three species, in the Northwestern Mediterranean Sea, indicated a niche partitioning among them with predation on different trophic levels (Borrell et al., 2021). In particular, the striped dolphin exploits prey of intermediate trophic levels, as myctophids, mesopelagic fishes, *I. coindetii* and Sepiolidae, which have also been observed in this study. On the other hand, the common bottlenose and Risso's dolphins feed on higher trophic levels, but the former exploits demersal and pelagic fishes (eel fishes, Sphyrenidae, Sparidae) and squids (e.g. Loliginidae) in the neritic zone, while the latter is teutophagus (Luna et al., 2022). Differences in prey consumption among the investigated subregions seem to be scarcely relevant, and the limitations of data do not allow to understand the occurrence of relevant spatial differences.

Overall, these estimates provide a first baseline of information on the consumption rates of these dolphins in several Mediterranean regions, contributing to support quantitative analysis on the ecological traits of cetaceans, and fishery-cetaceans competition assessed through the food web modelling approach (Morissette et al., 2012; Ricci et al., 2021), or overlap indices (Kaschner et al., 2006). Interpretations on the status of cetacean populations from stranding data should be managed with caution, but they often represent the exclusive information source to fill knowledge gaps related to biometric traits and consumption rates of cetaceans. In this study, the method adopted to assess the uncertainty range according to the bootstrap procedure proposed by Giménez et al.

(2021) allowed us to enforce the estimates of daily and annual consumption rates and their ranges of variability, which could be reference points for several Mediterranean subregions and at the basin scale.

5. Conclusions

Information on biometric traits is a fundamental element to investigate the ecological dynamics of cetaceans' populations, supporting the evaluation of their conservation status at different regional scales. The availability of information and parameters related to the population size, growth rate and consumption rates is important in the assessment required by protocols oriented to establishing conservation measures (Agardy et al., 2019; Tetley et al., 2022). In this framework, stranded animals represent an important source of data for the analysis of biometric traits and consumption patterns developed in this study. More effort to collect data regarding the biometrics of the species inhabiting the Mediterranean is required, especially for those areas located in the southern part of the basin. Furthermore, encouraging the enhancement and training of local monitoring networks would provide important ecological information about Mediterranean cetacean populations and represent a useful contribution for planning conservation and management actions at several spatial scales.

Thus, these results could be a baseline for future studies aimed at supporting the modelling of population dynamics of cetaceans for better understanding of population structures, as well as the consumption of dolphins in relation to their competitive interaction with the Mediterranean fishery. Furthermore, as stated by Karns et al. (2019), a good knowledge of the local morphometrics of cetacean populations can be used as an indicator of the nutritive condition of the stranded and thus prioritizing individuals which are more likely to survive after reintroduction to the sea.

CRediT authorship contribution statement

R. Carlucci: Writing – review & editing, Resources, Conceptualization. **P. Ricci:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **M. Ingresso:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Data curation. **D. Cascione:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Data curation. **C. Fanizza:** Writing – review & editing, Resources, Investigation, Funding acquisition. **G. Cipriano:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data availability

Data are reported in the article

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecss.2024.108622>.

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