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Resource partitioning between common bottlenose dolphin (*Tursiops truncatus*) and the Israeli bottom trawl fishery? Assessment by stomach contents and tissue stable isotopes analysis

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Common bottlenose dolphin (CBD) and bottom trawlers exploit the same ecological niche. The estimated CBD population along the Israeli coastline consumes roughly 1280 t of prey annually, similar to the mean annual trawl-fishery yield of 1300 t. In the ultra-oligotrophic Levantine Basin, the potential for competition for limited resources therefore exists. We aimed to examine whether the two consumers indeed harvest the same trophic level of the food web and the same members of that level. These questions were addressed by stomach content and stable isotope ($\delta^{15}N$ and $\delta^{13}C$) analyses. The database included 26 prey-containing stomachs collected between 1996 and 2008 and muscle tissue samples of 23 dolphins and of 27 species of commercial fish and invertebrates for stable isotopes analysis. The 59.3 kg combined stomach content included at least 754 prey items, 97.3% of which were fish, belonging to 22 identified species. About half (46.4%) of the prey mass had medium-to-high commercial value. The overall similarity of the composition of the pooled biomass and that of the average commercial catch was expressed by a Pianka index of 0.49. Sparidae (sea bream) was the only family important for both consumers. The mean $\delta^{15}N$ value of CBD muscle was found to be relatively low compared to other geographical areas and the estimated mean $\delta^{15}N$ of its diet fell below that of most commercial species tested. Our findings suggest that CBD and the fisheries only partly share resources, with CBD having an overall minor effect on the bottom trawl fishery, mainly on the Sparidae catch.

Keywords: common bottlenose dolphin, bottom trawl fishery, diets, stable isotopes, Mediterranean Sea, Levantine Basin

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INTRODUCTION

Data on the foraging habits of common bottlenose dolphin (*Tursiops truncatus* Montagu, 1821), hereafter CBD, in the Mediterranean Sea are scarce. Available evidence from the Ligurian Sea and the Spanish Mediterranean coast shows it to feed mostly on demersal and benthic fish and partly on benthonic and necto-benthonic cephalopods (Orsi Relini *et al.*, 1994; Blanco *et al.*, 2001). In those regions, most items of its prey consist of commercially important species (Orsi Relini *et al.*, 1994; Blanco *et al.*, 2001). The average diet of bottlenose dolphins in the eastern Ionian Sea was assumed to be composed of 35% Merluccidae, Mullidae and Gadidae, 20% Sparidae, Mugilidae and Moronidae, 15% Congridae, 15% cephalopods, 2.5% Clupeidae, Engraulidae and Scombridae, 2.5% small Carangidae and Belonidae and 10% other families (Bearzi *et al.*, 2010). Information for the Levantine Basin is lacking.

Bottom trawlers broadly exploit the same niche as CBDs; consequently, interaction may be expected wherever the two overlap. In Israel, excluding newly introduced small-scale fish farming, bottom trawlers are the only type of fishery demonstrating a significative interaction with CBDs. Along the Israeli coastline 20–25 bottom trawlers work practically continuously throughout the year. During 232 half-day coastal surveys conducted by the Israel Marine Mammal Research & Assistance Center (IMMRAC) between 1998 and 2007, CBD was the only cetacean species sighted, sightings also spanning all seasons (Scheinin, 2010). Trawler towing tracks as well as CBD sightings practically cover the entire coastal strip, extending ~10 km from shore. Fifty-two per cent of the CBD encounters during the surveys occurred in the vicinity of bottom trawlers. Searching time from leaving port until first sighting of CBD was significantly shorter while searching near trawlers vs elsewhere. Foraging following a trawler by

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CBD was the most prevalent behavioural pattern encountered, in frequency as well as in contribution to the time-budget (Scheinin, 2010). There was no evidence indicating that this foraging mode is practised by only a fraction of the population (i.e. Corkeron *et al.*, 1990). When examining the 23 photo-identified dolphins sighted four times or more, all were observed foraging behind a bottom trawler at least once (Scheinin, 2010).

Interactions between dolphins and coastal, small-scale commercial fisheries in the Mediterranean Sea have a long history (Reeves *et al.*, 2001; Bearzi, 2002; Diaz Lopez *et al.*, 2005; Diaz Lopez, 2006; Lauriano *et al.*, 2009; Fossa *et al.*, 2011), mainly involving trammel and gill-nets. Interactions involving bottom trawlers frequently occur here as in other parts of the world, with the main species implicated being the CBD (Northridge, 1984; Consiglio *et al.*, 1992; Silvani *et al.*, 1992; Goffman *et al.*, 1995; Marini *et al.*, 1995; Fertl & Leatherwood, 1997; Trites *et al.*, 1997; Mussi *et al.*, 1998; Pace *et al.*, 1999; Bearzi *et al.*, 2008a; Gonzalvo *et al.*, 2008). Based on the available data, by-catch in trawling nets appears to be a relatively uncommon occurrence in most Mediterranean areas (Bearzi, 2002; Gonzalvo *et al.*, 2008). However, high mortality rates in bottom trawl nets have been reported from the Mediterranean coast of Israel, by-catch in inshore gill-nets, mostly calves, being rather rare (Goffman *et al.*, 1995; Kent *et al.*, 2005). Foraging behind bottom trawlers is perceived to be an obvious strategy to improve foraging efficiency by saving time and energy (Fertl & Leatherwood, 1997). The seemingly increased motivation of the local CBD population to obtain an easy but risky meal near and from the bottom trawl net may arise from a relative shortage of food in its ultra-oligotrophic (Azov, 1986; Herut *et al.*, 2000; Thingstad *et al.*, 2005) and over-fished (Pisanty & Grofit, 1991) natural marine environment.

The possibility of competition between the two 'top predators', dolphins and fisheries, for resources that are naturally limited (due to low productivity) and/or artificially limited because of over-fishing and destruction of the benthic habitat by intensive trawling (Mirarchi, 1998; DeAlteris *et al.*, 2000) is perhaps the most crucial element in the interrelationship in Israeli waters. From the fishery standpoint, questions could be posed such as: would lower numbers or total absence of CBDs allow the operation of a larger fleet? Is the current commercial value of the yield compromised by the presence of local CBDs? From the dolphin standpoint: would the partial or total shutdown of the trawler fleet increase the environment's carrying capacity for CBDs? Are local individuals nutritionally compromised due to the operation of the fleet? The complexity of marine food webs and the low accessibility of relevant data, make it difficult to provide quantitative evidence for prey depletion. Chronic nutritional stress in dolphins may be a subtle and scarcely noticeable threat, exposed only by a careful investigation of a long enough stranding record (Bearzi *et al.*, 2008b). Over-fishing is usually revealed by declining values of catch per unit effort (CPUE) in face of a constant or increased fishing effort (Beamish *et al.*, 2006). Where there is insufficient data to produce accurate time trends in CPUE, top predator population declines may be the first and only sign of over-fishing (Trites & Donnelly, 2003).

A rough estimate of the size of the local CBD population, based on (trawler unrelated) encounter rate, mean group size and effective detection distance along a cumulative track-line of 3000 km, came out to be 360 animals (Scheinin, 2010). A constant mean annual stranding rate of ~5 animals year^{-1} (IMMRAC, unpublished data) suggests that the population size is stable. This number of animals will roughly consume 1280 t of prey annually (Young & Phillips, 2002), as compared to a mean annual trawl-fishery yield of 1300 t (Shapiro & Sonin, 2006). On this account only, the scene is set for potential competition and mutual negative impact between the two actors (Bearzi *et al.*, 2010). Proving competition, however, would entail intentional removal or addition of one and monitoring the effect on the other (Schoener, 1983), a totally impractical assignment in the present setting. Another prerequisite for competition would be resource partitioning, one which is much more amenable to experimental testing.

The question of common important prey items may be addressed by analysing the stomach contents of dead animals and comparing their diet to the inventory of the trawler fish catch. Examination of stomach contents is the standard method of assessing the diet of macro-organisms in general and dolphins in particular. The residence time of food in the dolphin's stomach is not long; and hard items that are swallowed whole, such as bones and cephalopod beaks, are often regurgitated (Morris & Lockyer, 1988; Silva-Jr *et al.*, 2004; Mizrahi *et al.*, 2009). For this reason, whole prey items will be found only in individuals that have recently fed, particularly by-caught animals drowned in the act of feeding. Otherwise, elements that do tend to remain in the fore-stomach and also in the folds of the glandular second stomach are the otoliths ('ear stones') (Fitch & Brownell, 1968), which are also relatively resistant to digestion (Wijnsma *et al.*, 1999). These elements, the shape of which is species specific, together with the beaks of cephalopods, form the basis for identifying prey items by comparison to available catalogues (Lombarte *et al.*, 2006) and/or to otolith and beak collections of local species. In the present research, stomach contents of CBDs were analysed in a region from which little if any previous information on the diet of CBDs is available and for which otolith catalogues for local fish species do not exist.

Analysing diet using stomach contents has its problems, as many stomachs of stranded animals are empty, or digested materials are not suitable for dietary research (Barros & Odell, 1990; Santos *et al.*, 1994). Moreover, stranded animals may represent a potentially biased sample of the population, as sick or injured animals may not be feeding normally prior to death (Santos & Pierce, 2003). We have attempted to circumvent these problems by additionally measuring tissue levels of the naturally occurring stable heavy isotopes, Carbon-13 and Nitrogen-15 (hereinafter ^{13}C and ^{15}N), which have provided complementary data to marine mammal feeding ecology by indicating the animals' geographical food source and trophic position, respectively (Hobson & Welch, 1992). The long-term diet of cetaceans is reflected through their tissue δ^{13}C and δ^{15}N values, and the use of stable isotope analysis (SIA) is gaining popularity in studies of their ecology (Lesage *et al.*, 2001).

In the wild, polyspecific temporal associations of top predators such as dolphins, sea lions, tunas, seabirds and sharks jointly foraging on the same prey are quite frequent (Das *et al.*, 2000). Nevertheless, C and N stable isotope signatures may provide finer grading of the trophic level of marine top predators. Thus, based on δ^{15}N values of muscle tissue, the north-east Atlantic albacore tuna, *Thunnus alalunga*, was found to hold a higher trophic position than the striped dolphin, *Stenella coeruleoalba* and the common dolphin, *Delphinus delphis*; differences in their $\delta^{13}C$ muscle values, however, point toward different migration patterns (Das *et al*., 2000). The fisheries which try to target food items of high trophic position are in effect another top predator that should enter ecosystem food web analysis (Trites *et al*., 2006).

While SIA is effective at integrating long-term assimilation of nutrients, it may not necessarily reflect short-term feeding patterns (Persson & Hansson, 1999; Johannsson *et al*., 2001; Hart & Lovvorn, 2002). Also, for the case in question, another shortcoming of SIA is that while it may place two predators at the same trophic level, the two may exploit different dominant prey items with little or no competition. Therefore it is recommended that whenever possible, SIA should be combined with gut content analysis (Rau *et al*., 1983; Mihuc & Toetz, 1994; Whitledge & Rabeni, 1997; Beaudoin *et al*., 1999; Johannsson *et al*., 2001; Grey *et al*., 2002; Renones *et al*., 2002). The two techniques, in tandem, can be complementary (Yoshioka *et al*., 1994; Vaz *et al*., 1999; Davenport & Bax, 2002; Grey *et al*., 2002) and will likely aid in interpretation of processed data (Evans-White *et al*., 2001; Parkyn *et al*., 2001).

We can summarize by stating that the potential for a mutually-affecting competition exists, but that its proposed existence would first of all require knowledge about whether the two potential competitors indeed harvest the same trophic level of the food web and the same members of that level. The main aim of this research is to address the latter question by use of stable isotope and stomach content analyses. To our knowledge, such a comparison has never been attempted. Comparing the trophic position of the Israeli CBD to that of its Mediterranean and global counterparts could also prove pertinent to the studied issue.

MATERIALS AND METHODS

Study area

The study area is in the easternmost part of the Levantine Basin of the Mediterranean. The basin is warm, hyper-saline, and highly oligotrophic, as a result of high evaporation rates, very low river runoff and limited vertical mixing (Azov, 1986; Herut *et al*., 2000; Thingstad *et al*., 2005). The coastline is virtually featureless, with no significant estuarine rivers and only a few (mainly seasonal) streams. It is sandy in the south and sandy and rocky in the north, with a few small islets near the coast. The bottom is sandy near shore, and changes with depth to clay with calcareous rocky patches, mostly concentrated in the northern part of the study area (Garfunkel & Almagor, 1985). It follows a gradual slope which becomes steeper to the north.

Bottom-trawling in Israel

The bottom-trawl fishery is the major component of the Israeli commercial fishing industry, which, since 2005, is responsible for ~60% of the total landings. This very high percentage by Mediterranean standards is partly due to collapsing artisanal fisheries, which include pelagic purse seiners, inshore gill and trammel netters and inshore bottom long-liners (see Edelist *et al*., 2013a for a review of Israeli fishery takes). The Israeli trawl fleet is a multi-species fishery, targeting dozens of species. In 1991, fearing that fish stocks available for the bottom trawl fleet were being over-exploited, the Israeli Department of Fishery (IDOF) assessed the trends of the bottom trawl catch between the years 1963 and 1990 along the Israeli coastline, as available from the annual reports of the IDOF (Pisanty & Grofit, 1991). A few findings arose from this work:

1. Between those years the number of trawlers operating in the Israeli trawling grounds increased from 22 to 31. The effort, measured in fishing power units 100 Hp (horse power) day^{-1} increased from less than 4000 in 1963 to more than 10,000 in 1987, and more than 15,000 in 1990.
2. The process of increase in effort was coupled with improvements in fishing methods: introduction of shrimp nets and high-opening (Engel) trawls; the use of radar for navigations; and sonar which helped in finding additional trawling grounds.
3. The increase in fishing capacity did not cause a proportional increase in fish yield; however, there was an increase in the effort diverted to catching shrimps with a resultant increase in yield.
4. An analysis, using Fox's version of the surplus yield model (Fox, 1970), indicated maximum sustainable yield (MSY) at about 1500 t and combined efforts of 11,540 Hp day^{-1}. Since the effort at the time exceeded 15,000 Hp day^{-1}, and following a reassessment after 3 years of maintaining the 1990 level of effort, it was decided by the IDOF to permanently limit the size of the fleet at its 1990 level of 31 vessels (Pisanty, 1998). In practice, only 22 vessels are operating with revenues that barely cover the costs.

No further significant management measures in the bottom trawl fishery have been taken since. A recent unpublished new appraisal by independent local fishery experts indicated that while as yet there is no evidence for recruitment overfishing and that overall annual catch rates are stable at ~1300 t, there is an increase in discard/unit catch with a high percentage of undersized fish being discarded. The overall trophic level is stable, with the decline of some predator species being compensated by an increase in others, brought about by gear modifications and improvements in technology (Scheinin, 2010). Most experts agree that the limitation of fleet size is not enough and that a seasonal moratorium on trawl-fishing is recommended (D. Golani and D. Edelist, personal communication).

The local trawl-fishing effort originates from three main ports of departure: Haifa (Kishon), Jaffa and Ashdod (since 1966) (Figure 1). It is mostly done between the 20 m bottom contour to the 400 m contour, giving a total fishing-ground of roughly 2500 km^2. A bottom trawl operating full-time would, on average, work 250 days per year, 24 h a day. The duration of a single tow, commonly between 3–5 h, mainly depends on the expected density of fish (aggregated or dispersed), on the slope and on features of the benthos. The catch is sorted into commercial species and size, by-catch (non-commercial species and undersized commercial species) is discarded at sea. Similar commercial species with a similar expected market price are commonly boxed and weighed together and therefore are at best reported at the family rank (Shapiro & Sonin, 2006).

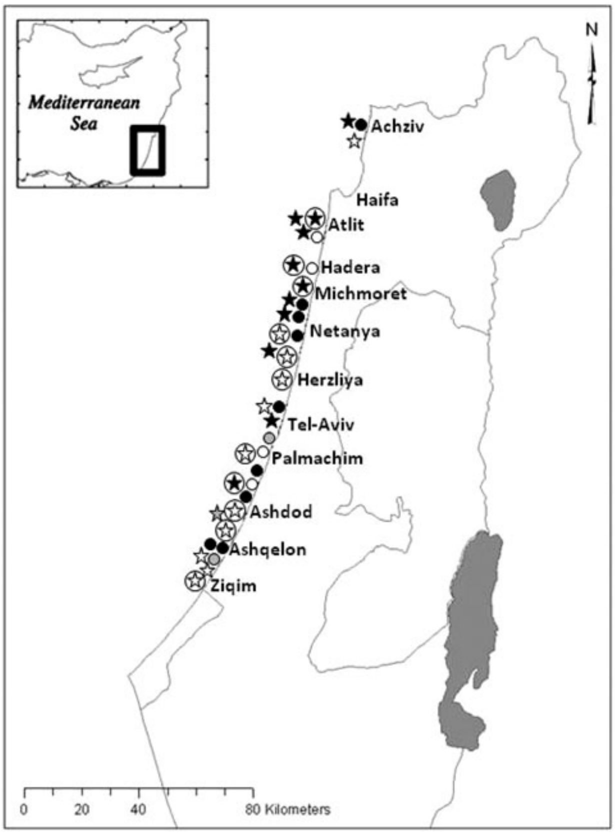

Fig. 1. Geographical locations along the Israeli coastline of stranded/by-caught common bottlenose dolphins from which samples were collected. Symbol key: ★ – stable isotopes; ● – stomach contents; ✪ – specimens checked for both. Gender: female – white; male – black; unknown – grey.

Fishery data sources used or consulted in this study include:

1. Annual reports of the IDOF, in particular that of 2006 (Shapiro & Sonin, 2006), the annual data of which were collected for the Department by the senior author and which also summarizes the annual data of the previous decade. IDOF catch analysis is performed at the port, as sorted and boxed by the fishers. This is the source that was used to conduct all comparisons with the fisheries catch and is reported in the text and Tables as IDOF together with years or year range.
2. Data obtained from catch analysis of 266 hauls conducted on-board nine different commercial trawlers, three from each of the major fishing ports, in ~100 sea days, between October 2008 and December 2011 (Edelist, 2013). A representative sample of 4–12 kg from each haul was taken on deck and items, including ones to be discarded were identified to species level, measured and weighed. These data were not used in the actual study but rather consulted to try to clarify and explain some results. As such, they are referred to as ‘unpublished personal communications by D. Edelist’ in the Discussion.

Stomach content

The data-base for this aspect of the study included 26 prey-containing CBD stomachs collected between 1996 and 2008 by IMMRAC researchers working within the framework of the University of Haifa. Of these, 18 stomachs were excised from beached carcasses and eight from fresh by-caught animals handed over by trawler crews (Figure 1). Morphometric measures of the animals were obtained (Norris, 1961) and teeth for age determination were extracted from all specimens. Age determination was performed by C. Lockyer (Age-Dynamics, Denmark) and P.E. Gol’din (Department of Zoology, V.I. Vernadsky Taurida National University, Simferopol, Ukraine). Following standard methodology of decalcification, freeze-microtomy and light microscopy of haematoxylin-stained thin sections (Hohn *et al.*, 1989; Hohn, 1990; Gol’din, 2004), age was estimated as the number of complete growth layer groups (GLG) (Hohn *et al.*, 1989; Hohn, 1990). The following exceptions were made for some animals <4 years old:

1. Animals were judged to be neonates from external appearance: fetal folds, folded dorsal fin and/or presence of umbilical cord.
2. Animals were judged to be 0.25 years old if they were non-neonates, had a neonatal line present in the tooth section and had a thinner layer of postnatal compared to prenatal dentine.
3. Animals were judged to be 0.5, 1.5, 2.5 or 3.5 years old if their latest GLG was forming but not completed.

During the necropsy of the dolphins, intact stomachs were ligated at the oesophagus (cephalad to any prey items present in the latter) and at the duodenum, removed, and stored at about −20°C until further analysis. During later examination, all stomach compartments were opened along a midline incision that followed its curvature. The bulk of the content (usually partly frozen) was manually removed and the rest was rinsed out through a 0.5 mm mesh size sieve. Prey items were subsequently sorted and preserved. Whole or partially digested prey items were identified and preserved in 70% ethanol. Identifiable bone elements and cephalopod beaks were removed and preserved in 70% ethanol. Fish otoliths removed from whole skulls or found free, were collected and stored dry in plastic vials to await species identification.

All prey remains were identified to the most specific taxonomic rank possible. A binocular microscope (Olympus SZX7 Stereo Microscope) was used to examine the fish’s sagittal otoliths. Otoliths were first compared to a self-prepared reference collection of 28 fish species. The latter was assembled by extraction of sagittal otoliths from fresh specimens of commercial and non-commercial species obtained from the bottom trawler catch (Table 1). Identification of otoliths not found in the reference collection was then attempted by use of a published guide (Lombarte *et al.*, 2006), aided by a guide to eastern Mediterranean fish species (Golani *et al.*, 2006). Cephalopod beaks were identified using the reference collection (Table 1). Fish nomenclature and details on fish habitat were derived from Golani *et al.* (2006) and www.fishbase.com. Details on cephalopod habitat were derived from Norman (2000). Weights, fish total length and cephalopod mantle length of the specimens in the reference collection are presented as ranges (minimum and maximum values) (Table 1). Total length (TL) in fish refers to the length from the tip of the snout to the tip of the longer lobe of the caudal fin. Mantle length in cephalopods was measured along the dorsal midline from the mantle margin to the posterior tip of the body, excluding long tails.

Table 1. List of the reference collection (fish otoliths and cephalopod beaks) assembled from the bottom trawler fish and invertebrate catch.

Species	Common name	N	Total length (cm)	Weight (g)
Ariosoma balearicum	Balearic conger	3	21.0–25.1	55–70
Boops boops	Bouge	8	14.2–19.3	30–60
Caranx rhonchus	False scad	5	20.2–24.8	125–205
Citharus linguatula	Spotted flounder	7	14.5–19.4	25–50
Cynoglossus sinusarabici	Red Sea tonguesole	4	8.1–10.7	10–14
Dussumieria acuta	Rainbow sardine	5	12.8–14.1	15–20
Echelus myrus	Bluntsnout snake eel	3	32.3–58.2	75–120
Epinephelus aeneus	White grouper	5	26.6–38.1	221–590
Lithognathus mormyrus	Striped sea bream	6	16.4–21.0	55–125
Liza ramada	Thinlip gray mullet	4	34.2–35.3	255–315
Merluccius merluccius	European hake	6	21.7–33.0	82–295
Mullus surmuletus	Striped red mullet	8	14.9–17.6	35–60
Ophidion barbatum	Cusk eel	1	19.1	44
Pagellus erythrinus	Common pandora	7	13.2–20.6	32–129
Pagrus coeruleostictus	Blue-spotted sea bream	5	20.2–23.6	145–200
Sardinella aurita	Round sardinella	5	12.1–20.2	10–50
Saurida undosquamis	Brushtooth lizardfish	5	26.2–30.3	145–210
Scomber japonicus	Chub mackerel	7	15.5–20.4	30–70
Scomberomorus commerson	Narrow-barred Spanish mackerel	1	53	915
Sillago sihama	Silver sillogo, whiting	6	15.8–18.6	25–45
Sphyraena chrysotaenia	Obtuse barracuda	6	20.2–23.5	49–77
Sphyraena sphyraena	Great barracuda	7	31.2–37.2	125–215
Sphyraena viridensis	Yellowmouth barracuda	2	42.7–50	274–290
Spicara flexuosa	Picarel		12.0–14.0	20–34
Spicara maena	Blotched picarel	4	15.5–16.5	38–47
Spicara smaris	Picarel	8	14.5–15.0	29–33
Trachurus mediterraneus	Mediterranean horse mackerel	6	15.3–19.2	30–60
Upeneus moluccensis	Goldband goatfish	8	10.6–15.5	10–45
			Mantle length (cm)	
Loligo vulgaris	European squid	7	10.5–22.6	70–150
Sepia officinalis	Common cuttlefish	6	12.0–16.0	225–415
Octopus vulgaris	Common octopus	4		145–360

The total number of prey items per identified species and per alimentary tract was recorded. Sagittal otoliths were relied upon to estimate the minimum number of consumed individuals (MNI) per species. Otoliths were identified as right or left, and the MNI was estimated by the larger number of either side. In cases where separation of otoliths by side was not possible, MNI was estimated by halving the number of otoliths. Cephalopod beaks were sorted into upper and lower, and the largest count of either provided the estimate of the MNI ingested.

The following form of the Shannon–Wiener diversity index (SWDI) (Krebs, 1999) was used to estimate the diet diversity of individual stomach contents as well as that of the combined content:

$$\mathrm{SWDI} = -\sum_{i=1}^{n} (P_i)(\ln P_i)$$

where n = number of species (species richness), P_i = proportion of total sample belonging to ith species.

Where species-level identification of remains was not possible, species richness was defined as the number of distinct and differentiable taxa within the sample. To characterize the overall diet of the sampled population in biological terms, we derived three standard indices of importance for individual prey taxa: (1) frequency of occurrence (the percentage of stomachs in which it was found); (2) fraction of the total number of prey items; and (3) percentage of total prey weight; lacking an otolith-size: specimen–weight relationship, weight was estimated from the mean mass of items in the reference collection. A combined index of relative importance (IRI) for each prey species was calculated, modified from Pinkas *et al.* (1971), as:

$$\mathrm{IRI} = [(\%\ \text{number} + \%\ \text{weight}) \times \text{frequency of occurrence}]/100$$

One general index that is used as a measure of resource overlap between two species occupying the same niche and which may be adapted to assess the degree of prey-species overlap between the CBD's stomach contents and bottom trawl fishery catches (Bearzi *et al.*, 2010) is a modification of the Pianka niche overlap index α (Pianka, 1974):

$$\alpha = \frac{\sum_{i=1}^{c} P_{ij}P_{ik}}{\sqrt{\sum_{i=1}^{n} (P_{ij})^2 \cdot \sum_{i=1}^{m} (P_{ij})^2}}$$

where n = number of different prey items in the diet of predator j (CBD), m = number of different prey items in the 'diet' of 'predator' k (bottom trawl fleet) c = number of prey items common to both predators, P_{ij} and P_{ik} = percentages of prey item i in the diets of predator j and predator k, respectively.

The index ranges between 0 and 1, and the similarity is higher the closer the index is to 1. The combined stomach contents (j) and the mean total annual catch (k) were used

Table 2. Data on stranded and by-caught common bottlenose dolphins for which stomach contents were analysed (N = 26). TL, total length in centimetres; G, gender; S, site of stranding; C, cause of death; No. PS, number of prey species; No. PI, number of individual prey items; W, estimated total weight of prey content in kilograms; Taxa, F-fish, C-cephalopod; SWDI, Shannon–Wiener diversity index; CV, commercial value of stomach content.

Age	TL	Season	G	S	C	No. Sp	No. P	W	Taxa	SWDI	CV
2	223	Su	?	Tel-Aviv		5	8	0.6	F	1.386	0.08
2.5	230	Sp	?	Ashqelon		3	5	0.9	F, C	1.055	1.52
3.5	173	Su	♀	Palmachim	Trawl	2	9	1.0	F	0.349	0.33
0.5	170	Sp	♀	Ashdod		1	1	0.0	F	0.000	0.08
5	260	W	♀	Ziqim	Net	2	6	0.6	F, C	0.637	0.44
16	267	Su	♀	Palmachim	Trawl	3	8	0.6	F	0.974	0.75
1.5	220	Su	♀	Netanya		1	1	0.4	F	0.000	1.20
1.5	194	A	♂	Hadera		6	57	5.5	F	0.962	0.21
6	240	A	♀	Tel-Aviv	Trawl	9	65	5.0	F, C	1.864	11.31
14	303	W	♀	Michmoret	Net	1	1	0.2	C	0.000	0.49
5	275	Sp	♀	Hadera		7	136	9.6	F	0.985	14.23
8	262	Su	♀	Atlit		3	63	5.1	F	0.222	10.33
8	244		♀	Tel-Aviv		5	76	5.1	F	0.715	2.25
2	–	Su	♂	Ashdod	Trawl	1	1	0.4	F	0.000	1.20
3	200	Su	♂	Hadera		1	1	0.1	F	0.000	0.16
0.5	187	Sp	♂	Atlit		3	21	1.4	F	0.381	0
5	250	Su	♂	Palmachim		5	10	2.7	F	1.228	7.43
5	270	A	♀	Ashdod	Trawl	8	53	2.8	F	1.207	3.71
4	240	Sp	♂	Michmoret	Trawl	2	5	0.3	F	0.673	0.32
3	212	Su	♂	Palmachim	Trawl	8	92	7.2	F	1.459	7.43
22	287	A	♂	Ashdod		11	102	6.8	F	1.160	2.82
3	220	A	♂	Hadera		3	11	0.7	F, C	1.036	1.99
>25	238	W	♂	Ashdod		3	9	1.4	F, C	0.995	1.74
1	225	Sp	♂	Achziv		5	8	0.6	F	1.494	0.24
1.5	209	Su	♂	Netanya	Trawl	1	2	0.1	F	0.000	0.09
2.5	230	A	♂	Herzliya		1	3	0.1	F	0.000	0.14

to calculate α. Since the commercial annual catch is most often reported as tonnage at the family level, for consistency, we used families as prey items for both predators and %weight for P_{ij} and P_{ik}, respectively.

A further assessment of dolphin–fishery competition in economic terms (what we termed 'commercial competition') may be gained by evaluating the potential commercial value of the dolphins' diet. Towards this end, reconstructed prey items in dolphin stomachs were allocated relative commercial importance (RCI) values, ranging between 0 and 3, as derived from the average prices to retail sellers in Israel's main fish auctions. A 0 value meant no commercial importance and values of 1, 2 and 3 were allotted to items selling for <5, 5–10 and >10 $ kg^{-1}, respectively. While prices constantly fluctuate, the relative values of the categories are maintained.

The RCI values were used for three purposes. The first was to find out whether demographic characteristics influence the commercial importance of an individual's diet. For that purpose, individual stomach contents were assigned commercial values (CV), computed as:

$$\mathrm{CV} = \sum_{i=1}^{n} (W_i)(\mathrm{RCI}_i)$$

with W_i and RCI_i being the weight and RCI values of the ith prey item in a given stomach content, respectively (Table 2). The second, more qualitative evaluation of commercial competition was to allocate commercial values (product of weight and RCI) to items in the combined stomach content, so as to judge which are the main contributing items (last two columns in Table 3). The last purpose was an actual comparison of the pooled diet to the mean annual catch in terms of commercial importance (Tables 4 & 5; Figure 2). For this purpose the mean annual catch in the years 1995–2000, 2005 and 2006 was sorted by contribution to the gross income and each contributing item was allotted a RCI. The contribution of categories 1, 2 and 3 (0 is discard) to the gross income was then computed (last column of Table 4). For comparison, prey species in the combined content were partitioned by RCI values. Unidentified fish species, which by definition have zero or low commercial importance were allotted a value of 1. Each category received a CV, being the product of its combined weight and its RCI value (Table 5). The partitioning of the pooled content into the four categories by CV, by frequency of occurrence and by mass could then be used to evaluate the commercial impact of dolphin food consumption.

Stable isotopes

Epaxial muscles of 23 CBDs, 20 beached and three freshly by-caught animals along the Israeli Mediterranean coastline were sampled between 2001 and 2007 (Figure 1). Eleven individuals were analysed for both stomach content and stable isotopes. Between 2 and 8 specimens each of 23 fish species, three cephalopod species and one crustacean (shrimp), representing the commercial catch, were collected on-board commercial bottom trawlers during five regular fishing sorties (Table 7). The latter were spread over the year 2006 and spanned most of the coastline. These specimens were also used to create the bulk of the otolith and beak reference database described above. The arm region of the epaxial muscle beneath the dorsal fin was sampled from the fish, mantle samples were

Table 3. Prey found in pooled stomach contents of 26 common bottlenose dolphins from the Israeli coastline between the years 1996 and 2008. MNI, minimum number of individuals; %N, percentage of total number of prey individuals (754); W, weight (kg); % W, percentage of total weight (59.3 kg); Fr, frequency of occurrence; IRI, index of relative importance; RCI, relative commercial importance; CV, commercial value; %CV, percentage of combined CV (70.52). Table sorted by IRI.

	MNI	%N	W	%W	Fr	IRI	RCI	CV	%CV
Ariosoma balearicum	212	28.1	13.14	22.2	46.2	23.2	0	0	0
Lithognathus mormyrus	100	13.3	8.0	13.5	38.5	10.4	2	16	**22.68**
Boops boops	119	15.8	5.36	9.0	30.8	7.6	1	5.36	7.6
Pagellus erythrinus	66	8.8	5.41	9.1	23.1	4.1	3	16.24	**23.02**
Echelus myrus	23	3.1	2.07	3.5	19.2	1.3	0	0	0
Epinephelus aeneus	9	1.2	3.6	6.1	15.4	1.1	3	10.8	**15.31**
Upeneus moluccensis	16	2.1	0.43	0.7	19.2	0.54	3	1.30	1.84
Sphyraena sphyraena	7	0.9	1.19	2.0	11.5	0.33	2	2.38	3.37
Solae sp.	33	4.4	1.16	1.9	3.9	0.27	2	2.31	3.28
Mugilidae	8	1.1	2.24	3.8	3.9	0.25	2	4.48	6.35
Caranx rhonchus	4	0.5	0.66	1.1	7.7	0.12	2	1.32	1.87
Citharus linguatula	5	0.7	0.185	0.3	11.5	0.11	2	0.37	0.53
Sphyraena chrysotaenia	4	0.5	0.216	0.4	7.7	0.07	2	0.43	0.61
Pagrus coeruleostictus	2	0.3	0.344	0.6	7.7	0.07	3	1.03	1.46
Scophthalmidae sp.	5	0.7	0.5	0.8	3.9	0.06	2	1	1.42
Spicara flexuosa	5	0.7	0.135	0.2	3.9	0.04	1	0.135	0.19
Spicara maena	2	0.3	0.086	0.1	7.7	0.03	1	0.086	0.122
Saurida undosquamis	3	0.4	0.9	0.2	3.9	0.02	2	0.18	0.26
Sphyraena viridensis	1	0.1	0.283	0.5	3.9	0.02	2	0.566	0.803
Cynoglossus sinusarabici	2	0.3	0.024	0.0	3.9	0.01	1	0.024	0.034
Spicara smaris	1	0.1	0.031	0.1	3.9	0.008	1	0.031	0.044
Trachurus mediterraneus	1	0.1	0.045	0.1	3.9	0.008	2	0.09	0.13
Unidentified fish	106	14.1	10.92	18.4	19.2		1		
Total fish	734	97.3	56.115	94.6	86			64.13	
Loligo sp.	15	2.0	1.65	2.8	5	0.255	2	3.3	
Sepia sp.	4	0.5	1.3	2.2	2	0.057	2	2.6	
Octopus sp.	1	0.1	0.245	0.4	1	0.005	2	0.49	
Total cephalopods	20	2.7	3.195	5.4	8				

Table 4. Partitioning by taxa of the trawl fishery mean gross income, as reported by the Israeli Department of Fishery (1995–1999; 2005–2006). CC, contribution by relative commercial importance (RCI) category (C).

Common name	**Species**	**Family**	**RCI**	**% of income**	**CC**	
					C	**%**
Mullets	Multi-species	Mullidae	2	30.4	1	17.9
Tiger prawn	Multi-species	Penaeidae	3	18.8		
Sea Breams	Multi-species	Sparidae	2	8.8		
Brushtooth lizardfish	*Saurida undosquamis*	Synodontidae	2	6.1		
European Squid	*Loligo vulgaris*	Loliginidae	2	5.8	2	59.2
European hake	*Merluccius merluccius*	Merlucciidae	2*	5.1		
White grouper	*Epinephelus aeneus*	Serranidae	3	4.1		
Barracudas	Multi-species	Sphyraenidae	2	3	3	22.9
Others, marginally commercial	Multi-species	Multi-family	1	17.9		

*, large fish would merit an RCI of 3, but are rare in the catch.

Table 5. The combined stomach contents of the 26 common bottlenose dolphins examined, categorized by the relative commercial importance (RCI) of the contained species. Fr(2), % stomachs containing only this category (other abbreviations as in Table 3).

RCI	MNI	%N	Fr	Fr(2)	W	%W	CV	%CV
None [0]	234	31.3	46.2	0	15.21	25.6	0	0
Low [1 + unidentified]	236	31.1	42.3	3.9	16.63	28.0	31.84	32.92
Medium [2]	191	25.3	76.9	11.5	17.76	29.9	35.52	36.72
High [3]	93	12.3	46.2	15.4	9.79	16.5	29.37	30.36
Total	754	100			59.31	100	96.73	100

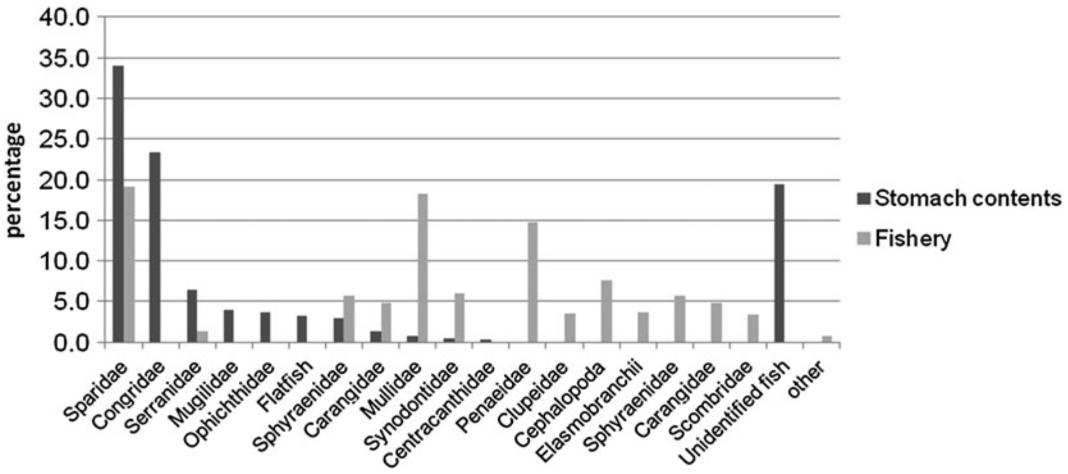

Fig. 2. Comparison between the percentages by reconstructed weight of different fish families in the common bottlenose dolphin stomach contents and in the local trawl fishery catch between the years 1996–2006 (Shapiro & Sonin, 2006).

taken from the cephalopods and abdominal muscle from the crustacean. It was important to sample the same tissue from similar anatomical sites, since each tissue has different isotope-enrichment values (Lesage *et al.*, 2001). Phytoplankton was sampled using a 55 µm mesh plankton net, during a cruise of EcoOcean's RV 'Mediterranean Explorer' over the Israeli shelf in June of 2007. All samples were stored frozen at −20°C and later lyophilized.

It is common practice to remove lipids from samples of fish muscles prior to stable isotope analysis or to adjust the data for lipid content (using the formulae of McConnaughey & McRoy, 1979). When the fat content in the sample is low, however, this is unnecessary (Davenport & Bax, 2002), and as fish and crustaceans along the Israeli coastline which had been analysed for fat content were found to have low lipid levels (Herzberg, 1965a, b), reflecting the generally oligotrophic waters in the Levantine Basin, we did not follow this procedure. Lipids were also not extracted from dolphin muscle.

Nitrogen and carbon stable isotope composition (δ^{15}N and δ^{13}C) were determined using a continuous flow isotope ratio mass spectrometer Europa 20–20 with ANCA SL preparation module (PDZ Europa Ltd., UK). Laboratory working standards for N (urea and ammonium sulphate solutions) were calibrated vs IAEA N-1 and IAEA N-2 $(NH_4)_2SO_4$ with δ^{15}N +0.4 and +20.3‰, respectively. Standards were calibrated and results were reported relative to atmospheric nitrogen. For C isotope analyses, urea and cane sugar were used as working standards, calibrated vs IAEA-CH7 (polyethylene) and USGS24 (graphite) standards. Standard deviations (SDs) of the measurement of both isotopes were determined on multiple analyses of working standards and were generally ≤0.2‰, while the SD of samples was ≤0.3‰.

The results are expressed in per ml as relative δ values:

$$\delta = \left(\frac{R_{\text{sample}}}{R_{\text{standard}}} - 1\right) \times 1000 \quad [‰]$$

where R represents the ^{15}N/^{14}N or ^{13}C/^{12}C ratio.

The δ^{15}N signatures were converted to trophic level, TrL, according to the relationship (Hobson & Welch, 1992):

$$\mathrm{TrL} = 1 + (D_m - P)/\mathrm{TEF}$$

where: $D_m = \delta^{15}$N value of the consumer's muscle tissue (‰); $P = \delta^{15}$N value of phytoplankton; and TEF = trophic enrichment factor in ^{15}N for a particular tissue.

The latter value was set to 3.4‰ for all community components except marine mammals (Lesage *et al.*, 2001), which represents the average TEF obtained for muscle tissue or whole animals of a variety of freshwater and marine species other than marine mammals (Lesage, 1999). The TEF for muscle tissue of marine mammals is generally accepted to be 2.4‰ (Hobson *et al.*, 1996). The TrL of CBD was calculated using:

$$\mathrm{TrL} = 2 + (D_m - P - \mathrm{TEF})/\mathrm{TEF}$$

Statistical analysis

In an attempt to relate the derived parameters associated with prey consumption to dolphin demographic attributes, four dependent variables, the SWDI and the CV of the stomach contents and the stable isotope ratios, δ^{15}N and δ^{13}C, were evaluated by means of generalized linear models (GLMs) (McCullagh & Nelder, 1989), using the Gaussian distribution family and the identity link function. Stomach contents with an estimated total weight of less than half a kilogram were excluded from the statistical analysis, leaving a sample of 19 stomachs. The independent variables: gender, body length, age categories (0–3, 3–10 and older than 10 yr), season and stranding location (due to the small sample size, locations of stranding were partitioned into North & South, dividing the Israeli coastline into two sections of equal lengths), were entered step-wise (forward) as covariates. All subsets were considered and the best-fitted model was chosen by comparing Akaike's information criterion (AIC) values (Burnham & Anderson, 2002). The P value of the omnibus test which is a likelihood-ratio chi-square test of the current model vs the null model was assessed too. A value of less than 0.05 indicates that the current model outperforms the null model. Distributions of the dependent variables were tested for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests. All were found to be normally distributed except CV which required log-transformation in order to pass the normality test. Due to the small sample and the dubious interpretation vis-á-vis the main research topic, interactions between covariates were not considered. All analyses were performed using SPSS software 19th edition (IBM$^{\circledR}$).

RESULTS

Stomach contents

Stomach contents of 26 CBDs (11 females, 13 males and 2 of unknown gender), stranded or by-caught over the course of 14 years were examined (Table 2; Figure 1). These dolphins ranged from 170 to 303 cm in total length and were between 1 and 25 years of age. Twenty-five out of 26 individuals had preyed on fish (Table 2), and four of these had also preyed on cephalopods. One individual's stomach contained only cephalopod remains, though this gut may not be representative since the dolphin also had a mass of fishing net in its fore-stomach which had also strangulated its larynx. Judging from this individual's cachectic condition, it had probably starved to death over a very long period (Levy *et al.*, 2009). The mean number of unique prey taxa in each stomach was 3.9 (±SD 2.8), and the number of prey items found per stomach ranged from 1 to 136 (mean 29 ± SD 38.3). The estimated weight of prey in each stomach varied considerably, ranging between 27 and 9618 g (mean 2281.1 g ± SD 2717.6) (Table 2).

The best fitted GLM for assessing the SWDI of the stomach contents (AIC: 21.785; Omnibus test likelihood ratio chi-square: 10.33 $P = 0.035$) indicated that gender, location of stranding (north/south), age categories and body length, all had a significant effect on the model ($P = 0.039$, 0.006, 0.018 and 0.019, respectively). Male, longer, older and south-stranded CBD had significantly higher mean SWDI values. Most prey species were found both on the northern and on the southern coast of Israel, apart from the *Loligo* sp. beaks which were found in five different stomachs in the south and none in the north of Israel. No significant effects of any of the tested co-variates were found on the log CV of the stomach contents.

Remains of at least 754 prey items with an estimated combined weight of 59.3 kg were retrieved, of which 734 prey items (97.3%) were fish and 20 prey items (2.7%) were cephalopods. The most important prey species, both numerically and by weight was the Balearic conger *Ariosoma balearicum*, a non-commercially important fish (Table 3). The unidentified fish comprised 10 distinct species with a combined count of 106 prey items. The sparids *Pagellus erythrinus* and *Lithognathus mormyrus* were the most commercially important dietary items consumed by the bottlenose dolphins (Table 3 in bold). The only other commercially important dietary item is the serranid *Epinephelus aeneus*, but it showed a rather low IRI, having occurred in only four (15%) of the examined stomachs (Table 3 in bold).

The overall similarity of biomass composition between dolphin stomach contents and fisheries catch in the study area was expressed by a Pianka index of 0.49.

Since the catch composition data collected from the fishing fleet by the IDOF was mainly reported at the family rank, fish species data from gut analyses were also grouped into families for comparison (Figure 2). The sea breams (family Sparidae) were the only taxon showing considerable preponderance in the stomach contents of the dolphins as well as in the commercial catch. The mullets (family Mullidae) were rarely found in dolphin guts, despite their major importance to the fishery. Shrimps and prawns (Penaeidae), another prevalent item in the catch were totally lacking in dolphin stomachs as were representatives of Clupeidae, Scombridae and Elasmobranchs, all being part of the catch.

Commercial competition may be appraised by comparing Tables 4 and 5. Mullets and prawns, on which CBD do not

Table 6. Summary of the δ ^{15}N and δ ^{13}C values from the 23 common bottlenose dolphins sampled along the Israeli coastline. Age (years); length (cm); N, north; S, south.

Age	Gender	Season	Location	N/S	δ ^{13}C (SD)	δ ^{15}N (SD)
Newborn	♂	A	Michmoret	N	−16.36 (0.13)	15.05 (0.05)
0.25	?	W	Ashdod	S	−15.48 (0.25)	14.56 (0.07)
0.25	♀	W	Ashqelon	S	−14.66 (0.42)	14.67 (0.17)
0.25	♂	Sp	Netanya	N	−17.16 (0.78)	13.79 (0.02)
0.5	♀	Sp	Ashdod	S	−15.85 (0.08)	11.93 (0.10)
0.5	♂	W	Michmoret	N	−15.71 (0.25)	13.78 (0.01)
0.5	♂	Sp	Atlit	N	−14.76 (0.08)	13.85 (0.18)
1.5	♂	A	Hadera	N	−15.89 (0.05)	12.94 (0.11)
1.5	♀	Su	Netanya	N	−15.82 (0.07)	10.32 (0.05)
2	♀	Sp	Achziv	N	−15.61 (0.03)	12.08 (0.04)
2.5	♀	A	Herzliya	S	−20.16 (0.06)	14.32 (0.20)
4	♂	Sp	Atlit	N	−16.76 (0.01)	10.49 (0.24)
4	♂	Sp	Michmoret	N	−15.97 (0.01)	12.55 (0.23)
5	♀	W	Ziqim	S	−15.72 (0.12)	14.18 (0.08)
5	♂	Su	Palmachim	S	−17.25 (0.01)	12.91 (0.28)
5	♀	A	Ashdod	S	−15.78 (0.11)	12.94 (0.08)
6	♀	A	Michmoret	N	−16.60 (0.11)	13.01 (0.06)
9	♂	A	Achziv	N	−16.68 (0.13)	13.63 (0.05)
11	♂	Sp	Atlit	N	−15.80 (0.09)	11.32 (0.01)
14	♀	W	Hadera	N	−16.52 (0.05)	10.23 (0.26)
14.5	♀	W	Ashqelon	S	−15.78 (0.13)	12.31 (0.32)
16	♀	Su	Tel-Aviv	S	−15.57 (0.08)	12.62 (0.11)
23	♂	W	Herzliya	S	−15.14 (0.59)	12.21 (0.14)

Table 7. Diet, length, weight, stable-isotopic composition (mean of N sampled specimens) and computed trophic level (TrL) of selected commercial fish and invertebrates in the Israeli bottom-trawl fishery catch. Diet information from Golani *et al.* (2006) and Norman (2000).

Species	Code	Common name	Family	Diet	N	Total length (cm) (SD)	Weight (g) (SD)	Δ^{13}C (SD)	δ^{15}N (SD)	TrL
Boops boops	Bb	Bouge	Sparidea	Vegetation and invertebrates	8	16.3 (1.8)	41.9 (11.9)	−18.23 (0.37)	9.74 (0.90)	2.6
Caranx rhonchus	Cr	False scad	Carangidae	Invertebrates and small fish	5	22.4 (2.2)	167 (34.7)	−17.16 (0.79)	11.54 (0.96)	3.1
Citharus linguatula	Cl	Spotted flounder	Citharidae	Benthic invertebrates	7	16.9 (1.9)	40 (10)	−18.16 (0.67)	11.76 (0.8)	3.2
Dussumieria acuta	Da	Rainbow sardine	Clupeidae	Zooplankton and small pelagic fish	5	13.4 (0.6)	18 (2.7)	−17.30 (0.07)	9.56 (0.53)	2.5
Epinephelus aeneus	Ea	White grouper	Serranidae	Fish, shrimps, crabs and squids	5	31.8 (4.1)	379.8 (136.7)	−18.16 (0.81)	12.20 (0.78)	3.3
Lithognathus mormyrus	Lm	Striped sea bream	Sparidae	Mollusks, crustaceans, worms and echinoderms	6	17.9 (1.7)	76.7 (24.6)	−16.94 (1.79)	12.13 (1.87)	3.3
Merluccius merluccius	Mm	European hake	Merlucciidae	Crustacean (young), fish	6	26.7 (4.9)	169.8 (105.2)	−17.47 (0.18)	8.97 (0.66)	2.4
Mullus surmuletus	Ms	Striped red mullet	Mullidae	Benthic and sub-benthic crustaceans, polychaetes and molluscs	6	15.9 (0.9)	47.5 (8.0)	−18.45 (0.59)	12.02 (0.88)	3.3
Pagellus erythrinus	Pe	Common pandora	Sparidea	Demersal invertebrates and fish	7	17.1 (2.5)	75.8 (31.9)	−16.61 (0.66)	11.69 (0.79)	3.2
Pagrus coeruleostictus	Pc	Blue-spotted sea bream	Sparidea	Molluscs, crustaceans	5	22 (1.3)	176 (23.3)	−16.27 (0.27)	12.34 (0.78)	3.4
Sardinella aurita	Sa	Round sardinella	Clupeidae	Zooplankton	5	15.1 (3.1)	26 (15.1)	−17.55 (0.25)	8.74 (0.82)	2.3
Saurida undosquamis	Su	Brushtooth lizardfish	Synodontidae	Maily fish to lesser extent on shrimps and squids	5	27.8 (1.7)	166 (30.1)	−17.78 (0.48)	12.25 (0.84)	3.3
Scomber japonicus	Sj	Chub mackerel	Scombridae	Small schooling fish and planktonic crustaceans and squids	7	16.9 (1.7)	38.6 (14.3)	−17.47 (0.29)	8.36 (1.08)	2.2
Scomberomorus commerson	Sco	Narrow-barred Spanish mackerel	Scombridae	Schooling fish, squids and shrimps	1	53	915	−18.23	12.62	3.4
Sillago sihama	Ssi	Silver sillogo, whiting	Sillaginidae	Polychaetes and small crustaceans	6	16.9 (1.0)	35 (7.1)	−15.86 (0.56)	12.31 (0.94)	3.3
Sphyraena chrysotaenia	Sch	Obtuse barracuda	Sphyraenidae	Near substrate schooling fish and crustaceans	6	22.4 (1.3)	65.6 (10.9)	−16.97 (0.37)	10.96 (0.27)	3.0
Sphyraena sphyraena	Ssp	Great barracuda	Sphyraenidae	Schooling fish (sardines, anchovies and horse mackerels)	7	34.6 (2.4)	167.1 (37.3)	−16.96 (0.24)	10.79 (0.46)	2.9
Sphyraena viridensis	Sv	Yellowmouth barracuda	Sphyraenidae	Fish and large invertebrates	2	46.3 (5.2)	281.8 (11.5)	−16.60 (0.61)	11.53 (0.76)	3.1
Spicara flexuosa	Sf	Picarel	Centracanthidae	Small invertebrates	8	13 (0.7)	25.6 (4.5)	−18.42 (0.22)	7.67 (1.26)	2.0
Spicara maena	Sm	Blotched picarel	Centracanthidae	Benthic organisms	4	16 (0.4)	41.9 (4.0)	−18.23 (0.35)	10.96 (2.49)	3.0
Spicara smaris	Ssm	Picarel	Centracanthidae	Benthic invertebrates	8	14.6 (0.2)	31.5 (1.7)	−18.69 (0.31)	7.76 (0.22)	2.0
Trachurus mediterraneus	Tm	Mediterranean horse mackerel	Carangidae	Crustacean (mainly shrimps and mysids) and schooling fish	6	16.4 (1.4)	37.5 (11.7)	−16.94 (0.41)	10.97 (0.98)	3.0
Upeneus moluccensis	Um	Goldband goatfish	Mullidae	Benthic invertebrates and fish	8	12.2 (1.6)	19.4 (11.5)	−17.91 (0.91)	9.75 (0.69)	2.6
Loligo vulgaris	Lv	European squid	Loliginidae	Fish and crustaceans	7	17.3 (4.3)	96.4 (41.4)	−17.38 (0.36)	10.67 (0.88)	2.9
Octopus vulgaris	Ov	Common octopus	Octopodidae	Fish, bivalves and crustaceans	4		219.7 (120.8)	−17.48 (0.54)	13.10 (1.93)	3.6
Sepia officinalis	So	Common cuttlefish	Sepiidae	Small molluscs, crabs, shrimps, other cuttlefish, and juvenile demersal fish	6	13.6 (1.6)	315.8 (73.5)	−17.45 (0.54)	11.31 (1.03)	3.1
Penaeus japonicus	Pj	Kuruma prawn	Penaeidae	Humus, algae, benthic invertebrates	7		25 (12.6)	−16.28 (0.37)	10.15 (0.53)	2.7
Plankton	Pl				1			−21.34 (0.01)	4.33 (0.42)	

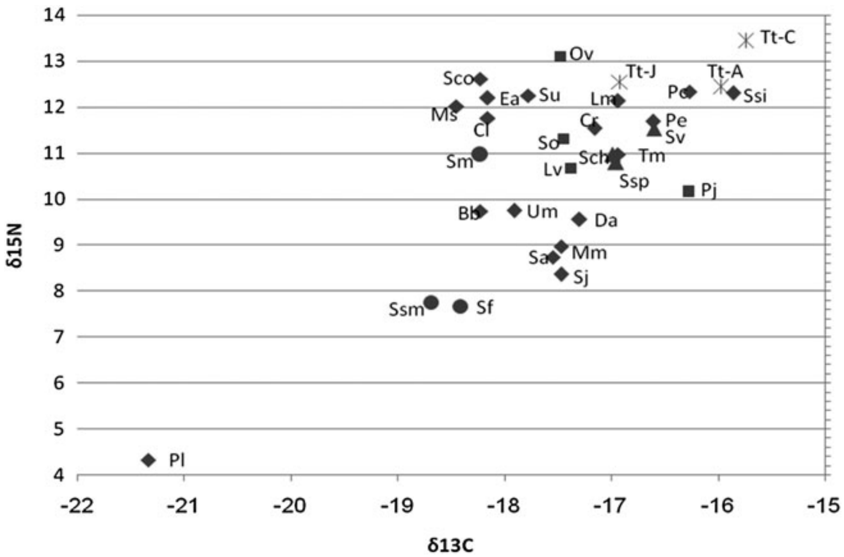

Fig. 3. Mean δ ^{13}C and δ ^{15}N in the muscle of invertebrates, fish and common bottlenose dolphins (CBDs). For abbreviations of the fish and invertebrates see Table 6. Symbols: * – CBD Tt-C = CBD calves, Tt-J = CBD juveniles, Tt-A = CBD adults; ■ – invertebrates; ▲ – Sphyraenidae family; • – Centracanthidae family; ◆ – all the rest.

compete, together comprise 50% of the gross income of the trawl fishery. Sparidae, with the highest potential degree of competition accounts for less than 10% of the income. Sixty per cent of the gross income derives from the Medium category (RCI = 2), with the rest almost equally divided between the Low and the High categories (Table 4).

Table 5 shows 46.4% of the combined mass and 66% of the combined commercial value of the dolphin's stomach content, to have medium to high commercial value. A quarter of the reconstituted mass would be considered discard by the fishery. Each of the three CV categories contributes almost equally to the pooled CV of the contents. Most individual contents of full stomachs had representation of two or of all three categories and only one or two individuals could be considered as seemingly showing preference for either 'high quality' or 'low quality' prey.

Stable isotopes

The isotopic composition of CBD and their potential prey (commercial fish and invertebrates) are summarized in Tables 6 and 7 and in Figure 3.

Table 8. Summary of the δ ^{15}N values found in common bottlenose dolphin tissues from the literature.

Location		Sea	N	Tissue sampled	δ ^{15}N (SD)	Reference
Israel		Mediterranean Sea	15	Muscle	12.34 (1.29)	This study
Italy	Genova	Mediterranean Sea	1	Muscle	12.6	Capelli *et al.* (2008)
Spain	Catalonia	Mediterranean Sea	7	Skin	12.68 (0.91)	Borrell *et al.* (2006)
Spain	Valencia	Mediterranean Sea	6	Skin	13.24 (1.06)	Borrell *et al.* (2006)
Spain	Balearic Islands	Mediterranean Sea	7	Skin	11.76 (1.42)	Borrell *et al.* (2006)
Spain	Huelva	Atlantic Ocean	5	Skin	15.38 (0.48)	Borrell *et al.* (2006)
Portugal	Huelva	Atlantic Ocean	7	Skin	13.06 (1.02)	Borrell *et al.* (2006)
Spain	Southern Galicia	Atlantic Ocean	26	Muscle	13.9 (0.9)	Fernández *et al.* (2011)
Spain	Southern Galicia	Atlantic Ocean	26	Skin	14.2 (1.0)	Fernández *et al.* (2011)
Spain	Northern Galicia	Atlantic Ocean	10	Muscle	13.0 (0.7)	Fernández *et al.* (2011)
Spain	Northern Galicia	Atlantic Ocean	11	Skin	13.2 (0.7)	Fernández *et al.* (2011)
USA	Virginia and North Carolina	Atlantic Ocean	60	Outer teeth	17.6 (0.2)	Knoff *et al.* (2008)
USA	Virginia and North Carolina	Atlantic Ocean	60	Inner teeth	16.8 (0.2)	Knoff *et al.* (2008)
USA	Virginia and North Carolina	Atlantic Ocean	117	Skin	17.0 (0.1)	Knoff *et al.* (2008)
USA	Coastal	Western North Atlantic Ocean	6	Teeth	16.8 (0.9)	Walker *et al.* (1999)
USA	Offshore	Western North Atlantic Ocean	9	Teeth	14.8 (0.8)	Walker *et al.* (1999)
USA	Coastal (1884)	Western North Atlantic Ocean	6	Teeth	15.9 (0.8)	Walker *et al.* (1999)
USA	Coastal (1927)	Western North Atlantic Ocean	8	Teeth	16.3 (0.5)	Walker *et al.* (1999)
USA	Sarasota Bay	Atlantic Ocean	39	Teeth	12.1 (0.4)	Barros *et al.* (2010)
USA	Gulf of Mexico	Atlantic Ocean	36	Teeth	12. 7 (0.2)	Barros *et al.* (2010)
USA	Offshore	Atlantic Ocean	7	Teeth	13.2 (0.7)	Barros *et al.* (2010)
USA	Virginia and North Carolina	Atlantic Ocean	37	Teeth	18.0 (2.0)	Cortese (2000)
Australia	Spencer Gulf and Investigator Strait	Southern Ocean	14	Teeth	14.29 (0.83)	Gibbs *et al.* (2011)
Japan		Pacific Ocean	10	Muscle	13.1 (0.6)	Endo *et al.* (2010)

The best fitted GLM for assessing the $\delta^{15}N$ (AIC: 48.404, omnibus test likelihood ratio chi-square: 13.2; $P = 0.067$) indicated that location of stranding (north/south) and season had a significant effect on the model ($P = 0.029$ and 0.038, respectively). CBD specimens stranded in the southern part of Israel showed a significantly higher mean $\delta^{15}N$ value than their counterparts in the north. Dolphins which have stranded in the autumn had the highest mean $\delta^{15}N$ value, followed by winter, summer and dolphins stranded during spring had the lowest value. No significant effects of any of the co-variates were found for the $\delta^{13}C$ of the CBD tissue.

The average trophic level calculated for the non-suckling CBD was 4.35 (SD: 0.52). No significant difference was found between mean $\delta^{15}N$ values of calves (0–2 years) and of all the other age classes (3–25 years) (*t*-test, $P = 0.11$), although the trend was in line with higher values in the calves. The average value for the $\delta^{15}N$ for the Israeli CBD older than 2 years was 12.34 (SD: 1.29) which is relatively low when comparing to values in other world regions, taken from the literature, as summarized in Table 8. Looking at Figure 3, there is no distinct gap in $\delta^{15}N$ values as would have been expected from a top predator and its potential prey, with some predatory species such as *Octopus vulgaris* and *Scomberomorus commerson* holding similar or slightly higher trophic positions.

DISCUSSION

Stomach contents

Competition with fisheries for limited resources is one of the main potential threats to Mediterranean CBD (Bearzi *et al.*, 2008b). Both an overall reduction in available prey mass and a reduction in the mean trophic level of the food web caused by over-fishing, if carried far enough, might force dolphins to spend more time foraging at the expense of socializing and courting and may compromise the accumulation of energy reserves needed for thermoregulation, lactation, etc. (Bearzi *et al.*, 1999). By comparing the diet of the local CBD, as reflected by stomach contents, to the commercial trawler catch, it was found that little less than half of the diet's computed mass was of medium-to-high commercial importance to the local fishery (Table 5). The Pianka niche overlap index showed similar overlap (0.46). Bearzi *et al.* (2010) found in Greece (Ionian Sea) an overlap of 0.75 in this index between the assumed CBD diet and the local bottom trawl fishery catch. However, in the Greek case the total biomass removed by fisheries exceeded that computed to be removed by dolphins by a factor of 33 (Bearzi *et al.*, 2010).

When comparing the partitioning of the CBD stomach contents and the local trawl fishery catch to the different fish families (Figure 2), Sparidae was the only family consumed appreciably by both potential competitors. Sparidae is a very diverse family in terms of commercial value and when summing all members of this family in the bottom trawl catch, a medium commercial value is obtained (Scheinin, 2010). Since Sparidae accounts for only 8.8% of the annual gross income (Table 4), it follows that the local CBD population may have a considerable impact on the Sparidae catch of the local bottom trawl fishery fleet but only a minor direct effect on the total catch.

Analysis of dietary diversity (SWDI) indicated ontogenetic shifts in diet, with older and larger animals eating a more diverse diet. This is likely to reflect age-related increasing experience, improved diving and prey-catching abilities and increased stomach capacity (Santos *et al.*, 2007). The fact that the majority of animals in our sample were juveniles would point to the gain of experience occurring rather early in life. Inclusion of a larger number of mature animals may have extended the age range of this trend, or else may have shown adults to mainly eat bigger specimens of the same species, as was found for CBD on the Spanish Mediterranean coast (Blanco *et al.*, 2001). The commercial value of the contents was age independent, meaning that any potential impact on the fishery and whatever competition that may exist involves all age-classes.

There are conflicting reports as to gender differences in diet. Barros & Odell (1990) reported a lack of such differences for CBD stranded in the south-eastern United States. On the Israeli coast, males ate a more diverse diet than females. Blanco *et al.* (2001) concluded that there are sexual intraspecific differences in the diet of CBD in the western Mediterranean, with males eating bigger but fewer fish and that it is possible to infer interdependence between feeding and social behaviour of this dolphin, as also described in other marine mammals (Bowen & Siniff, 1999).

Common bottlenose dolphins which stranded in the southern part of Israel had significantly higher mean SWDI values than those stranding in the north. These findings are not in line with an observed lack of difference in SWDI values of the bottom trawl catch in the south and north of Israel (D. Edelist, personal communication of unpublished data). The finding could be explained by the fact that there were many more full stomachs in the south than in the north (Table 2). *Post hoc* correlation analysis between SWDI and stomach contents weight gave a very significant correlation ($P = 0.001$).

As for the actual composition of the diet, previous studies on CBD diets in other parts of the world showed them to take advantage of locally abundant prey: demersal and pelagic fish species, cephalopods and crustaceans (Shane *et al.*, 1986; Barros & Odell, 1990; Barros & Wells, 1998; Barros *et al.*, 2000; Santos *et al.*, 2001). This led some authors to consider bottlenose dolphins as opportunistic in their feeding habits. However, feeding experiments carried out by Corkeron *et al.* (1990) in Australia showed that although 'bottlenose dolphins are wide-ranging feeders, they demonstrate clear preferences when given a choice of food items'.

The diet of CBD along the Israeli coastline is mainly composed of fish, cephalopod prey being much less abundant. This finding matches the results of previous studies in the western Mediterranean Sea (Blanco *et al.*, 2001), in Scottish waters (Santos *et al.*, 2001) and in Sarasota Bay, Florida (Barros & Wells, 1998). Evidence of CBD feeding on shrimp and following shrimping boats has been widely reported (Gunter, 1951; Leatherwood, 1975; Barros & Odell, 1990). In Israel, while shrimp is a major catch of the bottom trawl (Shapiro & Sonin, 2006), no evidence of shrimp was found in any of the stomach contents.

Considering single species, two are of particular interest. The European hake *Merluccius merluccius*, which has been reported to be an important part of the CBD diet in the Spanish Mediterranean (Blanco *et al.*, 2001), the Ligurian Sea (Orsi Relini *et al.*, 1994) and the Adriatic Sea (Miokovic *et al.*, 1997), was not found in any stomach in Israel. This is consistent with the low numbers of hake caught by the Israeli bottom trawl fleet (Shapiro & Sonin, 2006), suggesting that this taxon may be locally rare and relatively unavailable as prey. Conversely, the Balearic or bandtooth conger *Ariosoma balearicum*, a sand burrowing littoral species which occurs throughout the Mediterranean, was the dominant item in the Israeli CBD diet but absent in the diets of the above-mentioned more western Mediterranean CBD populations. This rather small (~25 cm) and slender fish is abundant in the local trawler catch but is discarded. We believe that the dolphins either forage on fish disturbed from their burrows by the net, or else on fish that escape/protrude through the mesh of the cod-end.

Always when dealing with stomach contents, the question arises as to whether it represents the diet of healthy dolphins. Leatherwood & Reeves (1978) compared stomach contents of three netted and two stranded dolphins from North Carolina and New Jersey, and found that the most abundant fish species were shared, with comparable representation, among both groups of dolphins. In contrast, Ross (1984) reported differences in the percentage of fish and squid in the stomach of nine stranded dolphins and nine netted bottlenose dolphins in southern Africa. He suggested that cephalopod beaks may be retained for a longer period in the stomach of stranded dolphins than are fish remains such as otoliths. This has been shown experimentally to be true of northern fur seals (*Callorhinus ursinus*), where passage rates for squid beaks and fish otoliths were shown to differ by at least 9 h (Bigg & Fawcett, 1985). This could result in an overestimation of the proportion of cephalopods consumed by stranded animals (Finely & Gibb, 1982; Ross, 1984). The local CBD did not show a preference for cephalopods (Table 3).

Out of 26 stomach contents, 10 were reported to belong to trawl by-caught animals. Typically trawler by-caught dolphins show no external marks, yet the stomachs of six more individuals were full of relatively fresh food remains, suggesting that they too were (unreported) by-catch victims. This would bias the results towards the diet of the dolphins feeding from and around trawl-nets, where some form of commensalism seems inevitable. However, behavioural data from the local population (Scheinin, 2010) show that the entire resident population tends to engage in this feeding mode, so the sample may indeed be representative of the local healthy population.

Stable isotopes

The CBDs show opportunistic feeding behaviour and a diverse diet, especially when bottom trawlers operate within their home range (Barros & Odell, 1990), as a consequence of which it is impossible to define a universal TEF value between the CBD and its prey. Published values of $\delta^{15}N$ TEFs of marine mammals range between 2 and 3‰ (reviewed in Lesage, 1999), a range similar to estimates of overall trophic-level enrichments in marine food webs (Schoeninger & DeNiro, 1984; Fry, 1988; Hobson *et al.*, 1994). The constancy of this relationship for high-protein tissues is probably related to basic kinetic processes associated with nitrogen enrichment during protein synthesis (Macko *et al.*, 1983; Galimov, 1985). Hobson *et al.* (1996), when examining captive seals, found that a $\delta^{15}N$ TEF of 2.4‰ is expected between the seals and their potential prey. The mean $\delta^{15}N$ of adult CBD from the present study was 12.34‰ (SD = 1.29). When subtracting a TEF of 2.4‰, a mean $\delta^{15}N$ for its prey of about 9.9‰ is arrived at. From Figure 3 and Table 7, it is evident that muscle tissue levels of most commercial species are above this $\delta^{15}N$ value, confirming the stomach content result that CBD along the Israeli coast taps a lower trophic level than the trawl fishery, thereby being of less concern to the latter. While 46.5% of the pooled stomach content mass comprised commercially important fish, all or part of the latter might have been smaller than commercial size and therefore having lower $\delta^{15}N$ values. This point should be settled through size measurements of sufficiently large samples of otoliths, both from stomach contents and trawler-catch items, which is the subject of a planned follow-up study.

When comparing the mean $\delta^{15}N$ value of Israeli CBD to published values of $\delta^{15}N$ for other CBD populations (Table 8), it is clear that the Israeli population lies at the lowest end of the trophic scope of the species. While caution is needed when comparing results of SIA performed by different laboratories, since there is expected variation, the overall trend probably holds. Any one or a combination of the following may explain this finding:

1. The fish stocks in the Levantine Basin are at a relatively low mean trophic level due to oligotrophy.
2. The local CBD is ‘foraging down the food web’, targeting species of lower trophic levels than its worldwide counterparts due to over-exploitation and benthic habitat destruction/deterioration caused by the bottom-trawler fleet.
3. The local CBD, being relatively small (Sharir *et al.*, 2011), feeds on smaller-sized fish
4. The local CBD habitually feeds on small fish that escape the trawl-net cod end and that are discarded during on-deck sorting of the catch.

The contribution of the fisheries will be hard to prove, as $\delta^{15}N$ values of dolphins with the fisheries out of the picture are lacking.

Common bottlenose dolphin specimens stranded in the southern part of Israel showed a significantly higher mean $\delta^{15}N$ value than those stranded in the north. When assessing the trophic level of the bottom trawl fish catch, based on IDOF records, there was no significant difference between the south and north of Israel. Yet, when evaluating regional differences in total lengths of representatives of the Sparidae family, southern individuals were found to be significantly longer (D. Edelist, personal communication of unpublished data). Since this family forms an important part of local CBD diet and since larger fish of the same species have a higher $\delta^{15}N$ value (Renones *et al.*, 2002), this finding might have contributed to the regional difference in $\delta^{15}N$ that was found. In this regard, it should be stressed that all or part of the Israeli CBD population are most probably not confined by international borders and that the sampled animals may very well have foraged in Lebanese, Gazan and/or Egyptian waters. Even assuming that the ichthyofauna is similar throughout the Levantine Basin, diets may change regionally as, for instance, there are no bottom trawlers operating in Lebanon. Any bias that may have been introduced by this fact has not been accounted for other than noting that such bias would have been expected to elevate the trophic position of local CBD, such that the reported low value may even be conservative.

The question of the suitability of using stranded marine mammals for isotopic studies is raised, as many of them may have poor body condition (Das *et al.*, 2003). $\delta^{15}N$ values might increase in starving animals as they are forced to use their own tissue proteins for survival (Gannes *et al.*, 1998). In birds, nutritional stress has led to a substantial increase in diet-fractionation values (Hobson & Clark, 1992; Gannes *et al.*, 1998). In contrast, Arctic ground squirrels *Spermophilus parryii plesius* in poor and excellent body condition had similar $\delta^{15}N$ values (Ben-David *et al.*, 1999) and muscle and $\delta^{13}C$ values did not differ between porpoises from the North Sea displaying poor, moderate and good body condition (Das, 2002). In the present study, an adult dolphin with very poor physical body condition (Levy *et al.*, 2009) had the lowest $\delta^{15}N$. As noted above, it is assumed that the majority of the sampled dolphins were healthy by-caught victims. Another potential confounding effect, the possible change of $\delta^{15}N$ during the decay process of a beached animal, has recently been shown not to exist (Payo-Payo *et al.*, 2013).

Finally one should acknowledge an inter-annual variability in stable isotope values in the marine environment as well as within prey sources. Stable isotope samples of prey items were obtained during a short time period while samples in dolphins were collected over several years. During that time span, there is the potential for water body isotope composition, the feeding habits of prey, and the actual composition of prey to change considerably. The Levantine Basin in particular is during the last decades in an enhanced dynamic state of warming (Somot *et al.*, 2006) and of species invasions from the Red Sea (Galil & Rilov, 2009). Yet, even though such invasions are expected to lower the trophic levels of indigenous ecosystems (Byrnes *et al.*, 2007), it has been suggested that within the Levantine fish assemblage, invasion has actually maintained existing trophic levels by replacing indigenous species with invaders that utilize similar niches and resources in a nutrient-deprived ecosystem near or at its carrying capacity (Edelist *et al.*, 2013b).

CONCLUSIONS

In general, a trawler might be considered by the dolphins a moving patch of food. By moving with it, dolphins may presumably save foraging time and energy (Fortuna *et al.*, 1997). Interacting with trawlers incurs a variable risk. While in the Balearic Islands in the western Mediterranean Sea, cetacean by-catch in trawling nets appears to be a relatively uncommon occurrence (Gonzalvo *et al.*, 2008), in Israel the danger of being by-caught in a bottom trawl rig is more acute, as roughly a third of the reported annual CBD mortality is by-caught victims (Kent *et al.*, 2005).

The stomach contents and the stable isotope analysis show that the local CBD diet mainly includes low trophic level fish. Comparing the diet of the local CBD to the commercial catch of the trawl fleet, it was found that a little less than half of the CBD diet was of medium-to-high commercial importance to the local fishery (Table 5), suggesting that the local CBD population has a minor to moderate direct effect on the local bottom trawl fishery fleet in general, however it may have a major direct effect on the Sparidae catch.

Does the bottom trawl fleet in Israel have a major impact on the local CBD population? Does it indeed offer an attractive foraging option or are its benefits partly or wholly off-set by forcing the dolphins to forage down the food web, thereby actually increasing the temporal and energetic investments of foraging? Fishing may reduce food availability by decreasing the size and abundance of preferable prey (Trites *et al.*, 2006) but may also increase food availability if dolphins learn how to get fish entangled in nets and/or discarded from fishing vessels. CBDs are known to interact with trawlers to forage on the discarded fish (Corkeron *et al.*, 1990; Svane, 2005; Gonzalvo *et al.*, 2008), to manipulate the cod-end to gain access to the catch (Broadhurst, 1998), to swim or perhaps even draft at the mouth of the net, catching the fish that do not keep pace with the net just before being sucked inside (Stephenson *et al.*, 2008) and to enter the net to feed on captured fish (Jaiteh *et al.*, 2013), at times resulting in entanglement and death by drowning.

Bottom trawling, in bad company with other fishing modes, is threatening coastal fish stocks as well as the industry itself with the spectre of biological and commercial collapse through habitat destruction, overcapacity and overfishing (Pauly *et al.*, 2002; Worm *et al.*, 2009). Meanwhile, even in oligotrophic and heavily trawled areas such as Israel, the generalist, resilient and resourceful CBD seems to maintain a sizable population that successfully shares the benthic niche with the trawlers. One should even keep an open mind to the seemingly absurd possibility that applying a moratorium on trawl-fishing would in the short run adversely affect the local CBD population.

Several research avenues may be pursued in order to expand the research presented and to improve our knowledge on the topic of cetacean – fisheries interaction in general: as far as stomach contents go, a larger database needs to be assembled to allow the use of clustering and multi-dimensional scaling analyses in order to fine-structure the dietary habits of the population. Whenever possible, the composition of the unsorted content of the haul should be sampled and analysed in instances of dolphin by-catch. Constructing growth curves for all commercially important catch items should be performed in order to allow a better assessment of the sizes preyed upon by the dolphins. Regarding stable isotopes, using teeth and bone from recent and museum-stored specimens (Walker *et al.*, 1999) or better still, archaeological remains (Schwartz, 1991), may allow isolation of the fishery effect on the diet. Teeth from old animals store the isotopic ratio record from several decades and may also be used to reveal more recent historical trends in dietary habits (Mendes *et al.*, 2007). Finally, once dietary items have been defined through stomach content, bone and teeth material and mixing model SI analysis may be used to identify the fractional contribution of a number of prey sources that are actually assimilated by the consumer (Hall-Aspland *et al.*, 2005).

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REFERENCES

Azov Y. (1986) Seasonal patterns of phytoplankton productivity and abundance in nearshore oligotrophic waters of the Levant basin (Mediterranean). *Journal of Plankton Research* 1, 41–53.

Barros N.B. and Odell D.K. (1990) Food habits of bottlenose dolphins in the southeastern United States. In Leatherwood S. and Reeves R.R. (eds) *The bottlenose dolphin*. San Diego, CA: Academic Press, pp. 309–328.

Barros N.B., Ostrom P.H., Stricker C.A. and Wells R.S. (2010) Stable isotopes differentiate bottlenose dolphins off west-central Florida. *Marine Mammal Science* 26, 324–336.

Barros N.B., Parson E.C.M. and Jefferson T.A. (2000) Prey of offshore bottlenose dolphins from the South China Sea. *Aquatic Mammals* 26, 2–6.

Barros N.B. and Wells R.S. (1998) Prey and feeding patterns of resident bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Journal of Mammalogy* 79, 1045–1059.

Beamish R.J., McFarlane G.A. and Benson A. (2006) Longevity overfishing. *Progress in Oceanography* 68, 289–302.

Bearzi G. (2002) Interactions between cetaceans and fisheries in the Mediterranean Sea. In Notarbartolo di Sciara G. (ed.) *Cetaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies*. A report to the ACCOBAMS Secretariat, Monaco, February 2002. Section 9, 20 pp.

Bearzi G., Agazzi S., Bonizzoni S., Costa M. and Azzellino A. (2008a) Dolphins in a bottle: abundance, residency patterns and conservation of bottlenose dolphins *Tursiops truncatus* in the semi-closed eutrophic Amvrakikos Gulf, Greece. *Aquatic Conservation* 2, 130–146.

Bearzi G., Agazzi S., Gonzalvo J., Bonizzoni S., Costa M. and Petroselli A. (2010) Biomass removal by dolphins and fisheries in a Mediterranean Sea coastal area: do dolphins have an ecological impact on fisheries? *Aquatic Conservation: Marine and Freshwater Ecosystems* 20, 549–559.

Bearzi G., Fortuna C.M. and Reeves R.R. (2008b) Ecology and conservation of common bottlenose dolphins *Tursiops truncatus* in the Mediterranean Sea. *Mammal Review* 39, 92–123.

Bearzi G., Politi E. and Notarbartolo di Sciara G. (1999) Diurnal behaviour of free-ranging bottlenose dolphins in the Kvarneric (Northern Adriatic Sea). *Marine Mammal Science* 4, 1065–1097.

Beaudoin C.P., Tonn W.M., Prepas E.E. and Wassenaar L.I. (1999) Individual specialization and trophic adaptability of northern pike (*Esox lucius*): an isotope and dietary analysis. *Oecologia* 120, 386–396.

Ben-David M., McColl C.J., Boonstra R. and Karels T.J. (1999) ^{15}N signatures do not reflect body condition in Arctic ground squirrels. *Canadian Journal of Zoology* 77, 1373–1378.

Bigg M.A. and Fawcett I. (1985) Two biases in the diet determination of northern fur seals (*Callorhinus ursinus*). In Beddington J.R., Beverton R.J.H. and Levigne D.M. (eds) *Marine mammal and fisheries*. London: George Allen and Unwin, pp. 284–291.

Blanco C., Salomon O. and Raga J.A. (2001) Diet of the bottlenose dolphin in the western Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom* 81, 1053–1058.

Borrell A., Aguilar A., Tornero V., Sequeira M., Fernandez G. and Alis S. (2006) Organochlorine compounds and stable isotopes indicate bottlenose dolphin subpopulation structure around the Iberian Peninsula. *Environment International* 32, 516–523.

Bowen W.D. and Siniff D.B. (1999) Distribution, population biology and feeding ecology of marine mammals. In Reynolds J.E. III and Rommel S.A. (eds) *Biology of marine mammals*. Washington, DC: Smithsonian Institution Press, pp. 423–484.

Broadhurst M.K. (1998) Bottlenose dolphin, *Tursiops truncatus*, removing bycatch from prawn-trawl codends during fishing in New South Wales, Australia. *Marine Fishery Review* 60, 9–14.

Burnham K.P. and Anderson D.R. (2002) *Model selection and inference: a practical information-theoretic approach*. 2nd edition. New York: Springer-Verlag.

Byrnes J.E., Reynolds P.L. and Stachowicz J.J. (2007) Invasions and extinctions reshape coastal marine food webs. *PLoS ONE* 2, e295. doi:10.1371/journal.pone.0000295.

Capelli R., Das K., De Pellegrini R., Drava G., Lepoint G., Miglio C., Minganti V. and Poggi R. (2008) Distribution of trace elements in organs of six species of cetaceans from the Ligurian Sea (Mediterranean), and the relationship with stable carbon and nitrogen ratios. *The Science of the Total Environment* 390, 569–578.

Consiglio C., Arcangeli A., Cristo B., Marini L. and Torchio A. (1992) Interactions between *Tursiops truncatus* and fisheries along north-eastern coasts of Sardinia, Italy. *European Research on Cetaceans* 6, 35–36.

Corkeron P.J., Bryden M.M. and Hedstrom K.E. (1990) Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia. In Leatherwood S. and Reeves R.R. (eds) *The bottlenose dolphin*. San Diego, CA: Academic Press, pp. 329–336.

Cortese N.A. (2000) *Delineation of bottlenose dolphin populations in the western Atlantic Ocean using stable isotopes*. MSc thesis. University of Virginia, Charlottesville, Virginia, USA.

Das K., Beans C., Holsbeek L., Maguer G., Berrow S.D., Togan E. and Bauquegneau J.M. (2003) Marine mammals from northeast Atlantic: relationship between their trophic status as determined by δ^{13}C and δ^{15}N measurements and their trace metal concentrations. *Marine Environmental Research* 56, 349–365.

Das K., Lepoint G., Loizeau V., Debacker V., Dauby P. and Bouquegneau J.M. (2000) Tuna and dolphin associations in the north-east Atlantic: evidence of different ecological niches from stable isotope and heavy metal measurements. *Marine Pollution Bulletin* 40, 102–109.

Davenport S.R. and Bax N.J. (2002) A trophic study of a marine ecosystem off southeastern Australia using stable isotopes of carbon and nitrogen. *Canadian Journal of Fisheries and Aquatic Sciences* 59, 514–530.

DeAlteris J.T., Skrobe L.G. and Castro K.M. (2000) Effects of mobile bottom fishing gear on biodiversity and habitat in offshore New England waters. *Northeastern Naturalist* 7, 379–394.

Diaz Lopez B. (2006) Interactions between Mediterranean bottlenose dolphins (*Tursiops truncatus*) and gillnets off Sardinia, Italy. *ICES Journal of Marine Science* 63, 946–951.

Diaz Lopez B., Marini L. and Polo F. (2005) The impact of a fish farm on a bottlenose dolphin population in the Mediterranean Sea. *Thaiassas* 21, 65–70.

Edelist D. (2013) *Fishery management and marine invasion in Israel*. PhD dissertation. University of Haifa, Israel.

Edelist D., Rilov G., Golani D., Carlton J.T. and Spanier E. (2013a) Restructuring the sea: profound shifts in the world's most invaded marine ecosystem. *Diversity and Distributions* 19, 69–77.

Edelist D., Scheinin A., Sonin O., Shapiro J., Salameh P., Rilov G., Benayahu Y., Schulz D. and Zeller D. (2013b) Israel: reconstructed estimates of total fisheries removals in the Mediterranean, 1950–2010. *Acta Adriatica* 54, 3–12.

Endo T., Hisamichi Y., Kimura O., Haraguchi K., Lavery S., Dalebout M.L. and Baker C.S. (2010) Stable isotope ratios of carbon and nitrogen and mercury concentrations in 13 toothed whale species taken from the western Pacific Ocean off Japan. *Environmental Science and Technology* 44, 2675–2681.

Evans-White M., Dodds W.K., Gray L.J. and Fritz K.M. (2001) A comparison of the trophic ecology of the crayfishes (*Oronectes nais* (Faxon) and *Oreonectes neglectus* (Faxon)) and the central stoneroller minnow (*Campostoma anomalum* (Rafinesque)): omnivory in a tallgrass prairie stream. *Hydrobiologia* 462, 131–144.

Fernández R., García-Tiscar S., Santos M.B., López A., Martínez-Cedeira J.A., Newton J. and Pierce G.J. (2011) Stable isotope analysis in two sympatric populations of bottlenose dolphins *Tursiops truncatus*: evidence of resource partitioning? *Marine Biology* 158, 1043–1055.

Fertl D. and Leatherwood S. (1997) Cetacean interactions with trawls: a preliminary review. *Journal of Northwest Atlantic Fishery Science* 22, 219–248.

Finley K.J. and Gibb E.J. (1982) Summer diet of the narwhal (*Monodon monoceros*) in Pond Inlet, northern Baffin Island. *Canadian Journal of Zoology* 60, 3353–3363.

Fitch J.E. and Brownell R.L. (1968) Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. *Journal of the Fisheries Research Board of Canada* 25, 2561–2574.

Fortuna C.M., Bearzi G. and Delfino G. (1997) Surfacing pattern of bottlenose dolphins following bottom trawlers in the Kvarneric (northern Adriatic Sea). *European Research on Cetaceans* 10, 244.

Fossa F., Lammers M.O. and Orsi Relini L. (2011) Measuring interactions between common bottlenose dolphin (*Tursiops truncatus*) and artisanal fisheries in the Ligurian Sea: 2) net damage and catch variations. *Biologia Marina Mediterranea* 18, 182–183.

Fox W.W. (1970) An exponential surplus-yield model for optimizing exploited fish populations. *Transactions of the American Fisheries Society* 99, 80–88.

Fry B. (1988) Food web structure on Georges Bank from stable C, N and S isotopic compositions. *Limnology and Oceanography* 33, 1182–1190.

Galimov E.M. (1985) *The biological fractionation of isotopes*. Orlando, FL: Academic Press, 261 pp.

Gannes L.Z., Del Rio C.M. and Koch P. (1998) Natural abundance variations in stable isotopes and their potential uses in animal physiological ecology. *Comparative Biochemistry and Physiology* 119A, 725–737.

Garfunkel Z. and Almagor G. (1985) Geology and structure of the continental margin off northern Israel and the adjacent part of the Levantine Basin. *Marine Geology* 62, 105–131.

Gibbs S.E., Harcourt R.G. and Kemper C.M. (2011) Niche differentiation of bottlenose dolphin species in South Australia revealed by stable isotopes and stomach contents. *Wildlife Research* 38, 261–270.

Goffman O., Kerem D. and Spanier E. (1995) Dolphin interactions with fishing-trawlers off the Mediterranean coast of Israel. Abstract. In *11th Biennial Conference on the Biology of Marine Mammals, 14–18 December 1995*. Orlando, FL: The Society for Marine Mammalogy.

Golani D., Öztürk B. and Başusta N. (2006) *Fishes of the Eastern Mediterranean*. Istanbul, Turkey: Turkish Marine Research Foundation, 259 pp.

Gol'din P.E. (2004) Growth and body size of the harbour porpoise, *Phocoena phocoena* (Cetacea, Phocoenidae) in the Sea of Azov and the Black Sea. *Vestnik Zoologii* 38, 59–73.

Gonzalvo J., Valls M., Cardona L. and Aguilar A. (2008) Factors determining the interaction between common bottlenose dolphins and bottom trawlers off the Balearic Archipelago (western Mediterranean Sea). *Journal of Experimental Marine Biology and Ecology* 367, 47–52.

Grey J., Thackeray S.J., Jones R.I. and Shine A. (2002) Ferox trout (*Salmo trutta*) as 'Russian dolls': complementary gut content and stable isotope analyses of the Loch Ness foodweb. *Freshwater Biology* 47, 1235–1243.

Gunter G. (1951) Consumption of shrimp by the bottlenose dolphins. *Journal of Mammalogy* 32, 465–466.

Hall-Aspland S.A., Hall A.P. and Rogers T.L. (2005) A new solution to the linear mixing model for a single isotope: application to a top order predator. *Oecologia* 143, 143–147.

Hart E.A. and Lovvorn J.R. (2002) Interpreting stable isotopes from macroinvertebrate foodwebs in saline wetlands. *Limnology and Oceanology* 47, 580–584.

Herut B., Almogi-Labin A., Jannink N. and Gertman I. (2000) The seasonal dynamics of nutrient and chlorophyll a concentrations on the SE Mediterranean shelf-slope. *Oceanologica Acta* 23, 771–782.

Herzberg A. (1965a) Preliminary data on the fat content of *Sardinella aurita*, *Mullus barbatus* and *Scomber japonicus*. *General Fisheries Council for the Mediterranean* 8, 417–420.

Herzberg A. (1965b) Preliminary data on proximate composition of some Mediterranean and Red sea fishes. *C.I.E.S.M.M.* 18, 253–255.

Hobson K.A. and Clark R.G. (1992) Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. *Condor* 94, 189–197.

Hobson K.A., Piatt J. and Pitocchelli J. (1994) Using stable isotopes to determine seabird trophic relationships. *Journal of Animal Ecology* 63, 786–798.

Hobson K.A., Schell D., Renouf D. and Noseworthy E. (1996) Stable-carbon and nitrogen isotopic fractionation between diet and tissues of captive seals; implications for dietary reconstructions involving marine mammals. *Canadian Journal of Fisheries and Aquatic Sciences* 13, 114–132.

Hobson K.A. and Welch H.E. (1992) Determination of trophic relationships within a high Arctic food web using δ13C and δ15N analysis. *Marine Ecology Progress Series* 84, 9–18.

Hohn A.A. (1990) Reading between the lines: analysis of age estimation in dolphins. In Leatherwood S. and Reeves R.R. (eds) *The bottlenose dolphin*. New York: Academic Press, pp. 575–586.

Hohn A.A., Scott M.D., Wells R.S., Sweeney J.S. and Irvine A.B. (1989) Growth layers in teeth from known-age free-ranging bottlenose dolphins. *Marine Mammal Science* 5, 315–342.

Jaiteh V.F., Allen S.J., Meeuwig J.J. and Loneragan N.R. (2013) Subsurface behaviour of bottlenose dolphins (*Tursiops truncatus*) interacting with fish trawl nets in northwestern Australia: implications for bycatch mitigation. *Marine Mammal Science* 29, E266–E281.

Johannsson O.E., Leggett M.F., Rudstam L.G., Servos M.R., Mohammadian M.A., Gal G., Dermott R.M. and Hesslein R.H. (2001) Diet of *Mysis relicta* in Lake Ontario as revealed by stable isotope and gut content analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 58, 1975–1986.

Kent R., Leibovitch M., Goffman O., Elasar M. and Kerem D. (2005) Bycatch of dolphins is Israeli fisheries. In *19th Annual Conference of ECS, La Rochelle, France*, 67 pp.

Knoff A., Hohn A. and Macko S.A. (2008) Ontogenetic diet changes in bottlenose dolphins (*Tursiops truncatus*) reflected through stable isotopes. *Marine Mammal Science* 24, 128–137.

Krebs C.J. (ed.) (1999) *Ecological methodology*. Menlo Park, CA: Addison Wesley Longman.

Lauriano G., Caramanna L., Scarno M. and Andaloro F. (2009) An overview of dolphin depredation in Italian artisanal fisheries. *Journal* *of the Marine Biological Association of the United Kingdom* 89, 921–929.

Leatherwood S. (1975) Some observations of feeding behaviour of bottle-nosed dolphins (*Tursiops truncatus*) in the Northern Gulf of Mexico and (*Tursiops cf T.* gilli) off Southern California, Baja California, and Nayarit, Mexico. *Marine Fishery Review* 9, 10–16.

Leatherwood S. and Reeves R.R. (1978) Porpoises and dolphins. In Haley D. (ed.) *Marine mammals of Eastern North Pacific and Arctic waters.* Seattle, WA: Pacific Search Press, pp. 97–111.

Lesage V. (1999) *Trophic relationships, seasonal diving activity and movements of harbour seals,* Phoca vitulina concolor, *in the St Lawrence River Estuary, Canada.* PhD thesis. University of Waterloo, Canada.

Lesage V., Hammill M.O. and Kovacs K.M. (2001) Marine mammals and the community structure of the Estuary and Gulf of St Lawrence, Canada: evidence from stable isotope analysis. *Marine Ecology Progress Series* 210, 203–221.

Levy A., Kerem D., Brenner O., Scheinin A.P., Morick D., Ratner E. and Goffman O. (2009) Laryngeal snaring by ingested fishing net in a common bottlenose dolphin (*Tursiops truncatus*) off the Israeli shoreline. *Journal of Wildlife Diseases* 45, 834–838.

Lombarte A., Chic Ò., Parisi-Baradad V., Olivella R., Piera J. and García-Ladona E. (2006) A web-based environment for shape analysis of fish otoliths. The AFORO database. *Scientia Marina* 70, 123–132.

Macko S.A., Estep M.F., Hare P.E. and Hoering T.C. (1983) Stable nitrogen and carbon isotopic composition of individual amino acids isolated from cultured microorganisms. *Carnegie Institution of Washington Year Book* 82, 404–410.

Marini L., Consiglio C., Arcangeli A., Torchio A., Casale M., Cristo B. and Nannarelli S. (1995) Socio-ecology of bottlenose dolphins, *Tursiops truncatus*, along the northeastern coast of Sardinia (Italy): preliminary results. *European Research on Cetaceans* 9, 139–141.

McConnaughey T. and McRoy C.P. (1979) Food-web structure and the fractionation of carbon isotopes in the Bering Sea. *Marine Biology* 53, 257–262.

McCullagh P. and Nelder J.A. (1989) *Generalized linear models.* 2nd edition London: Chapman & Hall.

Mendes S., Newton J., Reid R.J., Frantzis A. and Pierce G.J. (2007) Stable isotope profiles in sperm whale teeth: variations between areas and sexes. *Journal of the Marine Biological Association of the United Kingdom* 87, 621–627.

Mihuc T. and Toetz D. (1994) Determination of diets of alpine aquatic insects using stable isotopes and gut analysis. *American Midland Naturalist* 131, 146–155.

Miokovic D., Kovacik D. and Pribanic S. (1997) Stomach content analysis of a bottlenose dolphin (*Tursiops truncatus*) from the Adriatic Sea. In *11th Annual Conference of ECS, Stralsund, Germany*, 149 pp.

Mirarchi F. (1998) Bottom trawling on soft substrates. In Dorsey E.M. and Pederson J. (eds) *Effects of fishing gear on the sea floor of New England.* Boston, MA: Conservation Law Foundation, pp. 80–84.

Mizrahi N., Kerem D., Goffman O., Lernau O. and Spanier E. (2009) Identified fish remains regurgitated by a solitary Indian Ocean Bottlenose Dolphin, *Tursiops aduncus*, in the Gulf of Aqaba (Mammalia: Delphinidae). *Zoology in the Middle East* 46, 19–28.

Morris R.J. and Lockyer C. (1988) Twenty-two months in the life of a juvenile wild bottlenose dolphin. *Aquatic Mammals* 14, 46–62.

Mussi B., Gabriele R., Miragliuolo A. and Battaglia M. (1998) Cetacean sightings and interactions with fisheries in the archipelago Pontino Campano, southern Tyrrhenian Sea, 1991–1995. *European Research on Cetaceans* 12, 63–65.

Norman M. (2000) *Cephalopods: a world guide.* Debelius H. (ed.) Hackenheim: Conch Books.

Norris K.S. (1961) Standardized methods for measuring and recording data on the smaller cetaceans. *Journal of Mammalogy* 42, 471–476.

Northridge S. (1984) *World review of interactions between marine mammals and fisheries. FAO Fisheries Technical Paper 251.* Rome: FAO, 190 pp.

Orsi Relini L., Cappello M. and Poggi R. (1994) The stomach content of some bottlenose dolphins (*Tursiops truncatus*) from the Ligurian Sea. *European Research on Cetaceans* 8, 192–195.

Pace D.S., Pulcini M. and Triossi F. (1999) Interactions with fisheries: modalities of opportunistic feeding for bottlenose dolphins at Lampedusa Island (Italy). *Marine Mammal Science* 15, 102–122.

Parkyn S.M., Collier K.J. and Hicks B.J. (2001) New Zealand stream crayfish: functional omnivores but trophic predators? *Freshwater Biology* 46, 641–652.

Pauly D., Christensen V., Guènette S., Pitcher T.J., Sumaila U.R., Walters C.J., Watson R. and Zeller D. (2002) Towards sustainability in world fisheries. *Nature* 418, 689–695.

Payo-Payo A., Ruiz B., Cardona L. and Borrell A. (2013) Effect of tissue decomposition on stable isotope signatures of striped dolphins *Stenella coeruleoalba* and loggerhead sea turtles *Caretta caretta. Aquatic Biology* 18, 141–147.

Persson A. and Hansson L.A. (1999) Diet shift in fish following competitive release. *Canadian Journal of Fisheries and Aquatic Sciences* 56, 70–78.

Pianka E.R. (1974) Niche overlap and diffuse competition. *Proceedings of the National Academy of Sciences of the United States of America* 71, 2141–2145.

Pinkas L., Oliphant M.S. and Iverson I.L.K. (1971) Food habits of albacore, bluefin tuna and bonito in California waters. *California Department of Fish and Game, Fish Bulletin 152*, 105 pp.

Pisanty S. (1998) Amendments in the fisheries regulations in Israel. *Fisheries and Fishbreeding in Israel* 31, 116–129. [In Hebrew.]

Pisanty S. and Grofit E. (1991) Limiting effort in the Israeli trawl fishery. *Fisheries and Fishbreeding in Israel* 24, 100–112. [In Hebrew]

Rau G.H., Mearns A.J., Young D.R., Olson R.J., Schafer H.A. and Kaplan I.R. (1983) Animal $^{13}C/^{12}C$ correlates with trophic level in pelagic food webs. *Ecology* 64, 1314–1318.

Reeves R.R., Read A.J. and Notarbartolo di Sciara G. (2001) Report of the workshop on interactions between dolphins and fisheries in the Mediterranean: evaluation of mitigation alternatives. In *ICRAM Workshop, Rome, May 2001*. Doc. SC/53/SM3 presented at the 53rd Meeting of the International Whaling Commission, London, July 2001.

Renones O., Polunin N.V.C. and Goni R. (2002) Size related dietary shifts of *Epinephelus marginatus* in a western Mediterranean littoral ecosystem: an isotope and stomach content analysis. *Journal of Fish Biology* 61, 122–137.

Rilov G. and Galil B.S. (2009) Marine bioinvasions in the Mediterranean Sea—history, distribution and ecology. In Rilov G. and Crooks J.A. (eds) *Biological invasions in marine ecosystems: ecological, management and geographic perspectives. Ecological Studies Series 204.* Berlin: Springer-Verlag, pp. 549–575.

Ross G.J.B. (1984) The smaller cetaceans of the south east coast of southern Africa. *Annals of the Cape Provincial Museums Natural History* 15, 173–410.

Santos M.B., Fernández R., López A., Martínez J.A. and Pierce G.J. (2007) Variability in the diet of bottlenose dolphin, *Tursiops truncatus*, in Galician waters, north-western Spain, 1990–2005. *Journal of the Marine Biological Association of the United Kingdom* 87, 231–241.

Santos M.B. and Pierce G.J. (2003) The diet of harbour porpoise (*Phocoena phocoena*) in the Northeast Atlantic. *Oceanography and Marine Biology: an Annual Review* 41, 355–390.

Santos M.B., Pierce G.J., Reid R.J., Patterson I.A.P., Ross H.M. and Mente E. (2001) Stomach contents of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. *Journal of the Marine Biological Association of the United Kingdom* 5, 873–878.

Santos M.B., Pierce G.J., Ross H.M., Reid R.J. and Wilson B. (1994) *Diets of small cetaceans from the Scottish coast.* International Council for the Exploration of the Sea Committee Meeting No 11.

Scheinin A.P. (2010) *The population of bottlenose dolphins (*Tursiops truncatus*), bottom trawl catch trends and the interaction between the two along the Mediterranean continental shelf of Israel.* PhD dissertation. University of Haifa, Israel, 172 pp.

Schoener T.W. (1983) Field experiments on interspecific competition. *American Naturalist* 122, 240–285.

Schoeninger M.J. and DeNiro M.J. (1984) Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* 48, 625–639.

Schwartz H.P. (1991) Some theoretical aspects of isotope paleodiet studies. *Journal of Archaeological Science* 18, 261–275.

Shane S.H., Wells R.S. and Wursig B. (1986) Ecology, behaviour and social organization of the bottlenose dolphin: a review. *Marine Mammal Science* 1, 34–63.

Shapiro J. and Sonin O. (2006) *Annual report of the fishery and aquaculture of Israel ministry of agriculture, & rural development.* Department of Fishery, Haifa, Israel, 47 pp. [In Hebrew with English abstract.]

Sharir Y., Kerem D., Gol'din P., Spanier E. (2011) Small size of common bottlenose dolphin (*Tursiops truncatus*) in the eastern Mediterranean: a possible case of Levantine nanism. *Marine Ecology Progress Series* 438, 241–251.

Silva-Jr J.M., Jardim Pandolfo L. and Sazima I. (2004) Vomiting behaviour of the spinner dolphin (*Stenella longirostris*) and squid meals. *Aquatic Mammals* 30, 271–274.

Silvani L., Raich J. and Aguilar A. (1992) Bottle-nosed dolphins, *Tursiops truncatus*, interacting with fisheries in the Balearic Islands, Spain. *European Research on Cetaceans* 6, 32–34.

Somot S., Sevault F. and Déqué M. (2006) Transient climate change scenario simulation of the Mediterranean Sea for the twenty-first century using a high-resolution ocean circulation model. *Climate Dynamics* 27, 851–879.

Stephenson P.C., Wells S. and King J.A. (2008) *Evaluation of exclusion grids to reduce the catch of dolphins, turtles, sharks and rays in the Pilbara trawl fishery.* Perth, Western Australia: Department of Fisheries.

Svane I.B. (2005) Occurrence of dolphins and seabirds and their consumption of by-catch during prawn trawling in Spencer Gulf, South Australia. *Fisheries Research* 76, 317–327.

Thingstad T.F., Krom M.D., Mantoura R.F.C., Flaten G.A.F., Groom S., Herut B., Kress N., Law C.S., Pasternak A., Pitta P., Psarra S., Rassoulzadegan F., Tanaka T., Tselepides A., Wassmann P., Woodward E.M.S., Wexels Riser C., Zodiatis G. and Zohary T. (2005) Nature of phosphorus limitation in the ultraoligotrophic Eastern Mediterranean. *Science* 309, 1068–1071.

Trites A.W., Christensen V. and Pauly D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *Journal of Northwest Atlantic Fishery Science* 22, 173–187.

Trites A.W., Christensen V. and Pauly D. (2006) Effects of fisheries on ecosystems: just another top predator? In Boyd I.L., Wanless S. and Camphuysen C.J. (eds) *Top predators in the marine ecosystem.* Cambridge: Cambridge University Press, pp. 11–27.

Trites A.W. and Donnelly C.P. (2003) The decline of Steller sea lions *Eumetopias jubatus* in Alaska: a review of the nutritional stress hypothesis. *Mammal Review* 33, 335–350.

Vaz M.M., Petrere M. Jr, Martinelli L.A. and Mozeto A.A. (1999) The dietary regime of detritivorous fish from the River Jacare Pepira, Brazil. *Fisheries Management and Ecology* 6, 121–132.

Walker J.L., Potter C.W. and Macko S.A. (1999) The diets of modern and historic bottlenose dolphin populations reflected through stable isotopes. *Marine Mammal Science* 15, 335–350.

Whitledge G.W. and Rabeni C.F. (1997) Energy sources and ecological role of crayfishes in an Ozark stream: insights from stable isotopes and gut analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 54, 2555–2563.

Wijnsma G., Pierce G.J. and Santos M.B. (1999) Assessment of errors in cetacean diet analysis: *in vitro* digestion of otoliths. *Journal of the Marine Biological Association of the United Kingdom* 79, 573–575.

Worm B., Hilborn R., Baum J.K., Branch T.A., Collie J.S., Costello C., Fogarty M.J., Fulton E.A., Hutchings J.A., Jennings S., Jensen O.P., Lotze H.K., Mace P.M., McClanahan T.R., Minto C., Palumbi S.R., Parma A.M., Ricard D., Rosenberg A.A., Watson R. and Zeller D. (2009) Rebuilding global fisheries. *Science* 325, 578–585.

Yoshioka T., Wada E. and Hayashi H. (1994) A stable isotope study on seasonal food web dynamics in a eutrophic lake. *Ecology* 75, 835–846.

and

Young R.F. and Phillips H.D. (2002) Primary production required to support bottlenose dolphins in a salt marsh estuarine creek system. *Marine Mammal Science* 18, 358–373.

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