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# **A review of biology, fisheries and population structure of *Dentex dentex* (Sparidae).**

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## **Abstract**

The common dentex *Dentex dentex* (Linnaeus, 1758) is an iconic marine coastal fish in the Mediterranean Sea. It is a demersal sparid fish (0–200 m), that grows to a maximum length of 100 cm and a weight of 13 kg, with a relatively long life span (more than 20 years). As a high trophic level predator, it holds a key position in the coastal marine food webs. The common dentex is of great economic importance for both artisanal (small-scale coastal fisheries) and recreational fishing. Despite its economic and ecological importance, scientific data on this species in its natural environment are still very scant. The global commercial catch of common dentex has fluctuated over the last sixty years on a multidecadal time scale, and has declined significantly since the 1990s. There are few data regarding fishing effort and total catch from recreational fishing for common dentex, but it appears that this species is particularly targeted by this activity. The common dentex is now classified as “vulnerable” in the Red List of Threatened Species in the Mediterranean Sea. This review summarizes the current literature on *D. dentex* as regards biology, ecology, parasitology, population structure, commercial and recreational fishing, regulation and minimum fish sizes, and management through marine protected areas. It is suggested future research directions to fill the gaps in current knowledge.

**Keywords:** *Dentex dentex*, biology, population structure, fisheries, parasitology, conservation.

## **Introduction**

The common dentex *Dentex dentex* (Linnaeus, 1758) is an iconic marine coastal bony fish in the Mediterranean Sea. It holds an important place as a fishery resource for both professional and recreational fishing, and a key position at the top of the food chain in coastal ecosystems. It belongs to the Sparidae family (Bauchot and Hureau 1986), which is represented in the Mediterranean Sea by 10 genera and 22 species that usually inhabit coastal areas (Arculeo et al. 2003). It was first described in the 18th century as *Sparus dentex* Linnaeus, 1758, then *Sparus cetti* Risso 1810 or *Dentex vulgaris* Cuvier & Valenciennes, 1839 and finally *Dentex dentex* (Linnaeus, 1758) (Tortonese 1973; Bauchot and Hureau 1986; Bauchot and Hureau 1990). This species is of great economic interest and high commercial value for artisanal fishing (Morales-Nin and Moranta 1997; Loir et al. 2001; Chemmam-Abdelkader et al. 2007). *Dentex dentex* is considered as a "noble" species given its high market value (Chemmam-Abdelkader et al. 2006). Prices may range from a minimum of 15 €/kg for whole fish to a maximum of 38 €/kg for fillets and sliced fish. It is a highly prized catch in recreational fishing (Morales-Nin et al. 2005; Font and Lloret 2011); and is also appreciated by scuba divers (Cadiou et al. 2009).

As a top predator, the common dentex occupies a key position at the top of the trophic pyramid, and so is a potential indicator species for the structure and functioning of the coastal ecosystems on which it depends (Macpherson et al. 2002; Seytre & Francour 2009; Valls et al 2012).

*Dentex dentex* is classified by the International Union for the Conservation of Nature (IUCN) as "vulnerable" in the Red List of Threatened Species in the Mediterranean Sea (Abdul Malak et al. 2011). There are several reasons for this ranking: the Food and Agriculture Organization (FAO) has reported that landings for this species have steadily declined over a recent 15-year period, from a peak of ~7,000 tons in 1990 to less than 1,000 tons in 2005. In addition, it is a highly sought-after food fish targeted by recreational fishing. It is relatively long-lived, and its populations are slow to recover. Other "vulnerable" bony fish species in Mediterranean include the dusky grouper *Epinephelus marginatus* (Lowe, 1834), and the brown meagre *Sciaena umbra* Linnaeus, 1758, so that *D. dentex* is the only Sparidae species with this conservation status (Abdul Malak et al. 2011). The common dentex is also considered as a potential candidate for aquaculture, due to its commercial success, ease of reproduction in captivity and high growth rates during the first years (Abellán 2000; Loir et al. 2001; Rueda and Martinez 2001; Giménez and Estévez 2008; Tomas et al. 2009). Accordingly, a considerable number of studies have been published concerning the biology of common dentex in captivity (e.g. Rueda and Martinez 2001; Koumoundouros et al. 2004; Suarez et al. 2009; Rigos et al. 2012).

Despite its economic and ecological importance, scientific peer-reviewed papers on the biology of this species in its natural environment are still very scant. The most important study described the fishing and biology of *Dentex dentex* from the Balearic Islands off Mallorca (Morales-Nin and Moranta 1997), and another on its age and growth on the Tunisian coast (Chemmam-Abdelkader 2004; Chemmam-Abdelkader et al. 2004). While specific studies on this species are scarce, there is piecemeal information on it in scientific reports and in peer-reviewed papers, regarding its morphology and geographical distribution (Bauchot and Hureau 1986; Morales-Nin and Moranta 1997), the range of habitats it occupies (Bayle-Sempere et al. 1991; Ramos-Esplà and Bayle-Sempere 1991), its reproduction and growth (Morales-Nin and Moranta 1997; Chemmam-Abdelkader 2004), parasite communities (Radujkovic and Euzet 1989; Euzet et al. 1993; González et al. 2004; Bartoli et al. 2005), the fishing gear used (Cetinic et al. 2002; Lelli et al. 2006; Sacchi et al. 2010; Sacchi and Dimech 2011), catches and annual production (FAO 2012), regulations and management through marine protected areas (e.g. Francour 1994; Cacaud 2003; Sahyoun et al. 2013), and on its population structure and stock discrimination (Bargelloni et al. 2003; Palma and Andrade 2004; Chemmam-Abdelkader et al. 2007). There is a lack of basic biological studies for several Mediterranean fish populations, and yet this information is most important for the conservation of biodiversity and sustainable fishery management (Tzanatos et al. 2008; Damalas et al. 2010). This review summarizes the current literature on *D. dentex* biology, ecology, stock structure, and fisheries, and suggests future research directions to fill the gaps in current knowledge.

## **1. General description**

The common dentex has a rather short compact oval body (Bauchot 1987). Its head profile is straight in juveniles and convex in adults (Bauchot 1987; Bayle-Sempere et al. 1991). The oldest specimens have a slight hump at their forehead (Bauchot and Hureau 1986). It has several rows of teeth, with 4–6 well-developed anterior teeth on each jaw (Bauchot 1987), and a succession of canine teeth that are much smaller than the frontal ones (Bayle-Sempere et al. 1991). Its gillrakers are present on the first arch, 9 or 10 lower and 8 or 9 upper (Bauchot and Hureau 1986; Bauchot 1987). Its dorsal fin has 11 spines of increasing length up to the fourth or fifth, and subequal thereafter (Bauchot and Hureau 1986). Its ventral fins are characterized by one spine and five radii, the pectoral fins are composed of an average of 15 radii, and the caudal fin present 17 radii (Chemmam-Abdelkader 2004). On the anal fin, there are three spines, and between seven and nine radii (Bayle-Sempere et al. 1991). Its lateral line is composed of 62 to 68 scales to the caudal base (Bauchot and Hureau 1986). Its colour changes with age, the young of the year displaying yellow fins (Louisy 2005) or even appearing entirely yellow (Cheminée,

2012); older juveniles are greyish with vertical black bars and are blue-spotted, turning pinkish at maturity, with yellow areas on the ventral part of the head, then grey-blue in the oldest specimens. There are also dorsal spots that are variably shaded with age (Bauchot and Hureau 1986; Bauchot 1987), and green, blue, gold and purple iridescence, especially in the head region (Gonzales 2005). For *Sparidae* in general and in particular *Dentex dentex*, there are no characters that distinguish between sexes. The common dentex is often confused, especially in fisheries statistical data, with other *Sparidae* such as the red porgy (*Pagrus pagrus*), which resembles it in shape and body colour. This precise morphological description of the species can be a reliable tool for its identification, for both biologists and MPA managers.

## **2. Distribution and habitat**

*Dentex dentex* is a Mediterranean and Atlantic species (Bayle-Sempere et al. 1991). It inhabits the Mediterranean Sea most frequently south of 40°, it is found occasionally in the Black Sea, and occurs in the Atlantic Ocean exceptionally around the British Isles, and also Cape Blanc, the Bay of Biscay, Madeira, the Canary Islands and southward to Senegal (Fig.1; Bauchot and Hureau 1986; Morales-Nin and Moranta 1997; Bat et al. 2005). In 2008, small juvenile *Dentex dentex* were observed in the Arcachon basin (Quero et al. 2009). This observation implies that common dentex may spawn in the Bay of Biscay. It has been reported 12 times in all: five times in the 19th century with large erratic individuals, six times in the 20th and once in the 21st century also with the presence of juveniles (< 20 cm) in the Basque country (Quero et al. 2009). *Dentex dentex* is a demersal sparid fish found from 0 to 200 m depth, living on various substrates such as *Posidonia oceanica* meadows, rocky bottom with *P. oceanica* patches, coastal detritic areas, ripples of coarse sand, sandy habitats with *Caulerpa* and *Cymodocea* and in the coralligenous community (Ramos-Esplà and Bayle-Sempere 1991; Abellán 2000; Guidetti 2000; Rueda and Martinez 2001; Ballesteros 2006; Stobart et al. 2012). Juveniles of common dentex (20–50 mm TL, during June-August) inhabit shallow water (2–4 m depth), at the edge between *Posidonia oceanica* meadows and sand, or close to crevices and small caves (Dulčić et al. 2002; Valle and Bayle-Sempere 2009). From the perspective of behavioural ecology, the juveniles are gregarious; observations of shoals of *Dentex dentex* have been made, with individuals of medium size (1–5 kg) especially in summer around rocky outcrops at depths between 20 and 50 m, but also found in shallow waters (–8 to –10 m) (Bauchot and Hureau 1986; Bayle-Sempere et al. 1991; Ramos-Esplà and Bayle-Sempere 1991; Francour 1994; Chemmam-Abdelkader 2004; Sahyoun et al. 2013). Behaviour changes with age; the oldest adults animals are solitary (Bauchot and Hureau 1986).

### **3. Feeding and behavioural ecology**

Morales-Nin and Moranta (1997) reported that in the Balearic Islands, the adults feed mainly on fish from the coastal zone (74%) and on cephalopods (26%) as secondary prey. The smaller individuals had species from the *Posidonia* meadow in their stomachs: sparids, clupeids, gadoids, and more frequently labrids such as the peacock wrasse (*Symphodus tinca*, 22.58%). In larger specimens, fish were the predominant prey, mainly sparids, picarel and anchovy. Whole cephalopods, remains of sepia bone and unidentified beaks were also found (25.62%). However, their prey species are diverse, probably depending on availability (Morales-Nin and Moranta 1997). On the Tunisian coast the common dentex feeds preferentially on fish (84%), crustaceans (9%), cephalopods (5%) and plant remains (2%) (Chemmam-Abdelkader 2004). Pelagic fish (eg *Trachurus* sp, *Sardina pilchardus*) constitute the majority of prey (56.1%), compared with other fish. The group "Crustacea" is composed mainly of the caramota prawn (*Penaeus kerathuru*), the group "Cephalopods" of the common cuttlefish (*Sepia officinalis*), and the European squid (*Loligo vulgaris*), and the group "Plants" of the *Posidonia oceanica* and *Caulerpa* genus. The common dentex is a high level tropic predator (4.5 TL), and the large size of the adults probably limits the number of predators (Morales-Nin and Moranta 1997; Stergiou and Karpouzi 2001; Froese and Pauly 2012). However, a study on the food and feeding habits of the amberjack *Seriola dumerili* (Risso, 1810) indicates that the common dentex, probably at the juvenile stage, may be considered as an occasional prey for this species (Andaloro and Pipitone 1997).

### **4. Reproduction**

There is almost no information on the reproductive biology of common dentex in the natural environment. Based on the macroscopic examination of gonads from 210 fish caught from the waters off Mallorca, they reported an equal sex distribution and a gonochorism for the common dentex (Morales-Nin and Moranta 1997). Seasonal variations in the sex ratio of the common dentex were observed on the Tunisian coasts, with an apparent dominance of females compared with males all year round, and a dominance of males during the spawning period (April-June) (Chemmam-Abdelkader 2004). This dominance of males during the spawning period could be explained by fertilization of eggs of one female by several males (Chemmam-Abdelkader 2004). In addition, macroscopic examination of *D. dentex* gonads throughout its life cycle revealed rare cases of hermaphroditism. In this study 3727 individuals were examined, and only 14 immature individuals (with sizes between 17.5 and 24.8 cm) were presented with gonadal parts more developed in females than in males or vice versa.

The species *D. dentex* can be characterized by a rudimentary nonfunctional hermaphroditism. The reproduction occurs from the end of March until June (Morales-Nin and Moranta 1997). In winter most of the specimens are immature, with the development of the gonads starting in January, the first mature specimens appearing in March. The size at which 50% of the population is mature is estimated at 34.60 cm for females and 52.02 cm for males for the Balearic Islands (Morales-Nin and Moranta 1997), and 23.32 cm for males, 22.58 cm for females, for a total of both sexes of 22.95 cm for the Tunisian coast (Chemmam-Abdelkader 2004). Along the Tunisian coast, at 26 cm TL, 75% of the population is mature, and at 33 cm TL 100% of the population is mature for both sexes (Chemmam-Abdelkader 2004). The maximum maturity occurred in the second quarter of the year, with the first post-spawn specimens appearing in the third quarter (Morales-Nin and Moranta 1997). Examination of the ovaries during the spawning period shows that they have different amounts of oocytes corresponding to different stages of oocyte release (nearly full, half full, almost empty) (Chemmam-Abdelkader 2004). The analysis of the frequency distribution of egg size shows the existence of four modes corresponding to four categories of oocytes issuable at four different periods (Chemmam-Abdelkader 2004). The common dentex is a partial spawner, it emits eggs of the same spawning for several days (Chemmam-Abdelkader 2004). Absolute fecundity of *Dentex dentex*, on average, is equal to 164,195 eggs per fish, and the average relative fecundity is estimated at 217 eggs per gram of fish (Chemmam-Abdelkader 2004).

Concerning the spawning areas, there is no information reported in the literature, but we collected information in Corsica (France) based on fishermen's knowledge. According to their observations during the spawning period, the populations of common dentex gather periodically on spawning sites at between 40 and 100 m depth to form shoals. These sites are characterized by hard substrates such as rocky outcrops or wrecks. Most of these sites are identified by fishermen, and each year groups of common dentex come to spawn. Observations made by seine fishers using sonar suggest that the reproductive act occurs mainly during the day, but also at night at full moon.



## **5. Age, growth and condition**

*Dentex dentex* may reach a maximum length of 100 cm and a weight of 13 kg (Ramos-Esplà and Bayle-Sempere 1991; Morales-Nin and Moranta 1997). There are no morphological differences between the two sexes, and the size-weight relationship is similar in both (Morales-Nin and Moranta 1997).

Growth is rapid in the first 2 years of life, 31% of the maximum length being reached in the first year (24.1 cm) (Morales-Nin and Moranta 1997). Reported estimates of von Bertalanffy growth parameters are similar among studies (Table 1; Culioli 1986; Morales-Nin and Moranta 1997; Chemmam-Abdelkader et al. 2004).

The fish has the physiological capacity to withstand long periods of fasting, which can actually form part of its life cycle (Vigliano et al. 2002; Navarro and Gutierrez 1995). Several factors, such as seasonal fluctuations, reproduction, including pre-spawning and migration, or availability of prey are responsible for this natural fasting (Pérez-Jiménez et al. 2012). Results suggest that it possesses a high capacity to face this nutritional challenge, given that the reduction in body mass induced by prolonged starvation is far lower than that reported for other sparid fish (Pérez-Jiménez et al. 2012). It is relatively long-lived species, its maximum lifespan exceeding 20 years (Morales-Nin and Moranta 1997), with up to 33 years reported (Chemmam-Abdelkader et al. 2004). It exhibits a low  $P/B$  value (0.24; Valls et al. 2012) and a low resilience, with a minimum population doubling time of 4.5–14 years (Froese and Pauly 2012). For these reasons, its populations are considered as slow-recovering (Abdul Malak et al. 2011). However, the calculated values of mortality (0.201 for both sexes combined, Morales-Nin and Moranta 1997; 0.24, Valls et al. 2012) indicated a relatively low natural mortality.

Age information forms the basis for calculations of growth rate, mortality rate and productivity, ranking it among the most influential of biological variables (Campana 2001). Several calcified structures produce periodic growth increments useful for age determination in fish (Campana 2001). One of the main problems in ageing is selecting the most suitable and accurate structure (Machias et al. 2002). For common dentex, like for most fish, two main structures are used to determine age: scales and otoliths. The direct method by scale reading has been widely used for ageing because scales are easily collected, prepared and read (Machias et al. 2002). Chemmam-Abdelkader et al. (2004) showed in *D. dentex* the presence of a strong positive correlation between scale radius and the standard length of fish. The limitation of this method is that the scales of the common dentex older than five years are illegible owing to the poor definition of the annual rings and the abundance of false rings (Morales-Nin and Moranta 1997). The use of hard structures such as sagittal otoliths is generally the most reliable method for quantifying age and growth in fishes (Zischke 2012). Sagittal otoliths appear to be more reliable than scales for ageing dentex, especially for older individuals. The formation of annuli on scales and the

hyaline or opaque zones on otoliths have been attributed to various factors such as seasonal temperature, wet and dry seasons, fish feeding and reproductive cycles (Simkiss 1973; Beckman and Wilson 1995). The results of Morales-Nin and Moranta (1997), on the common dentex indicate a period of hyaline zone formation in autumn-winter and an opaque zone formation in spring-summer. The formation of the hyaline rings in the otoliths, as in most fishes, is probably related to the decrease in the temperature and reduction in food availability (Morales-Nin and Moranta 1997). Apparently, reproduction does not influence the type of ring deposited, since during the period of maximum spawning an opaque ring is formed (Morales-Nin and Moranta 1997).

## **6. Parasitology**

Parasites have been widely used as biological tags to provide information for fisheries management on the movements and population discreteness of their fish hosts (Williams et al. 1992). Along with the need to correctly identify a stock before it can be appropriately managed, parasites also need to be correctly identified before they can be applied as biological tags (Catalano et al. 2013). The main factor limiting the use of marine parasites as biological tags is insufficient information on their complex biology and ecology (MacKenzie et al. 2008). Numerous investigations concerning the parasite fauna of several sparid fishes from the Western Mediterranean have been published (e.g. Brian 1906; Yamaguti 1963; Bartoli et al. 1989; Ternengo et al. 2009; Kaouachi et al. 2010; Marzoug et al. 2012). There have been no specific studies on the parasite communities present in the common dentex, but much reported data are nevertheless available. A set of reported parasite species from *D. dentex* is given in Table 2. There are some studies on abundance, intensity, prevalence, and their descriptions for digeneans (Bartoli and Bray 1987; Bartoli et al. 1989; Bartoli et al. 2005; Foata et al. 2012; Greani et al. 2012). For ectoparasites, there are references to the gill parasites, especially copepods (Brian 1906; Raibaut et al. 1998; Bailly 2012), but data on monogeneans are scant (Radujkovic and Euzet 1989; Euzet et al. 1993; González et al. 2004).

## **7. Fisheries**

Fish from the Sparidae family are widely distributed along the coastal waters of the Mediterranean Sea, being considered traditionally as an important resource for small-scale fishing (Coppola 2001). Common dentex are of great economic importance as fished species (Chemmam-Abdelkader et al. 2006).

FAO data on global capture production for the last sixty years for *D. dentex* (Fig.2) show interannual fluctuations. Time-series analyses show four peaks of production, the first between the years 1950 and 1953 with a maximum production of 5400 T/year, the second during the years 1962–64 with a production that reached 8700 T/year, the third between 1976 and 1980 with a production of 4143 T/year and finally between 1990 and 1994 with a production of 10329 T/year.

Assuming that fishing effort did not fluctuate, we note the marked demographic changes experienced by populations every few years. At the national level only two countries contribute significantly to catches of common dentex. The main one is Spain, which alone accounted for almost all the overall common dentex production until 1980, when its production declined until 2010. Considering in detail the catch data for Spain during the years 1950 to 1980, it appears that most fish were caught in Eastern, Central and Northeast Atlantic regions. These areas are not usually the main areas for common dentex; hence caution is needed in data interpretation. From the years 1965–70 Italian production increased, with peaks and troughs, reaching its highest level in 1992. Production then declined abruptly until 2000, to stabilize at lower levels until 2010. It seems that the rapid increase in the exploitation rate observed during the years 1956–63 in Spain, and 1981–92 in Italy seems to have had the major effect of causing sudden depletion, a scenario already reported for other demersal species (e.g. Hidalgo et al. 2009; Quetglas et al. 2012). These two countries have successively dominated production from 1950 to 2000, although at the national level there is broad heterogeneity of the catches over time. It seems that researchers and artisanal fishermen share the same opinion on the existence of cyclic fluctuations of *D. dentex* populations, giving years without catches of this species (Bayle-Sempere et al. 1991).

The main fishing gear specifically targeting the common dentex is: bottom long-lines, trammel nets and medium-large mesh gillnets (Morales-Nin and Moranta 1997; Lelli et al. 2006; Vandeperre et al. 2006; Sacchi and Dimech 2011). However, it can also be targeted by other fishing gear such as bycatch, especially at the juvenile stage, by traps nets, fyke net, basket traps, bottom-trawl, purse and beach seines, "Tramata" fishing used only in the eastern Adriatic, or "Gangui" fishing used along Mediterranean north coastline (Cetinic et al. 2002; Akyol 2003; Quero et al. 2009; Vandeperre et al. 2006; Sacchi et al. 2010). **Trammel nets** are gangs of three rectangular nets made up of two outer, large-mesh panels and one inner panel (Goñi et al. 2003). For the

common dentex fishery, the smaller mesh panel reaches a size of 40 mm stretched, and large-mesh up to 150 mm stretched. It is composed of a bottom rope with sinkers, and a head rope equipped with floats (Leleu 2012), to deploy the net vertically (up to 5.8 m), with a length of 500 m (3–4 units per vessels). In addition to wedging, gilling and entangling (i.e., held by teeth, spines or other protrusions), trammel nets also catch fish in the pocket formed by the inner smaller mesh wall of netting being pushed through one of the larger mesh outer walls (Erzini et al. 2006). It is usually installed in the evening and retrieved at dawn (between 12 and 24 hours). **Medium mesh size gillnets** are built with a single wall of monofilament net with a stretched mesh size of 48–120 mm, and target medium size fish such as sparids on shallow sandy and mixed sandy rocky bottoms (Lelli et al. 2006). The length of these nets ranges from a few hundred meters to more than 1000 m (Sacchi and Dimech 2011). **Bottom longlines** consist of monofilament mainline to monofilament snoods with hooks about 1 m long, attached at regular intervals (Lelli et al. 2006). The most common gear used is 1.2 mm diameter mainline with 0.6 mm snood and hooks of length 3 cm and width 1.5 cm (Sacchi and Dimech 2011). The bait is mainly cephalopods and sardines (Sacchi and Dimech 2011). During the same fishing day typical artisanal Mediterranean vessels (generally less than 12 m in length) can deploy more than one longline unit (2–3 per vessel) of 200–300 hooks each, for a length of about 1 km of longlines (Lelli et al. 2006). In sum, the common dentex is targeted by artisanal fisheries throughout the year using different gear. We note that there is an alternation and/or combined use of this gear (top three: longline, trammel and gill net), depending on the season, habitat and geographic areas (Table 3). However, for common dentex fishing, peaks of exploitation were observed, with maximum efficiency between May and September by trammel net/gill nets and between September and April by bottom long-line. The fishing depth is mostly in the range 15–80 m, with a mean value around depth 30 m. The composition by size class also shows broad variations in terms of catches (14–83 cm). Juvenile stages (mean value 30 cm) are captured especially on the *Posidonia oceanica* meadows (by trammel net and gill net) or as by-catch (e.g. Tramata, gangui), whereas adult specimens are caught mainly on the rocky bottoms (by long-line).

## **8. Recreational fishing**

Recreational fishing has economic, social, and cultural roles in the Mediterranean (Morales-Nin et al. 2005). It has been recognized as one of the most common leisure activities in coastal zones (Albouy et al. 2010). One of the possible definitions that can be given for recreational fishing is: “Fishing activities exploiting marine living aquatic resources from which it is prohibited to sell or trade the catches obtained” (Anonymous 2011). The

common dentex, due to its large size, flesh quality, and high commercial value, is considered as a "noble" species, and is therefore also targeted by recreational fishing. There are few data regarding fishing effort, total catch from most recreational fishing (Lloret and Font 2013), and fishing for common dentex suffers from similar deficiencies. The most common methods used in recreational fishing for *D. dentex* are boat fishing, spear fishing, line and shore fishing (Morales-Nin et al. 2005; Lloret et al. 2008; Gordo 2009; Abdul Malak et al. 2011; Font and Lloret 2011). The angling techniques used generally to catch *D. dentex* are varied; bait can be alive or dead, or artificial lures can be used. Along the coast of the marine reserve of Cap de Creus, live fish such as *Serranus cabrilla* or *Coris julis* are used to catch valuable fish such as *D. dentex*, and represented 9.9% of the total bait used by shore anglers in 2007 and 2009. For the common dentex, cephalopods (body portions or dead animals) such as squid, cuttlefish, octopus and bobtail squid, constitute 15.5% of the total baits used, and sardine (*Sardina pilchardus*) with 13.7% (Font and Lloret 2011). The results highlight the relatively high mean vulnerability and trophic level of rocky benthic fish species caught by shore fishing and spear fishing; this is mainly due to relatively large catches in terms of weight of top predators such as *D. dentex* (Lloret et al. 2008; Font and Lloret 2011). Commercial and recreational fishing have similar demographic and ecological effects on fished populations, and they can have equally serious ecological and economic consequences (Cooke and Cowx 2004; Font and Lloret 2011). In some geographic areas the spear fishermen are perceived as the main competitors by artisanal fishing, who become strong market competitors by selling their catches (illegally) to local restaurants at a high price without a commercialization license, therefore affecting demand (Maynou et al. 2013). There is clear evidence that recreational activities not only impact marine resources quantitatively, but in addition modify their structure (Rocklin et al. 2011). In particular, the removal of large individuals can adversely affect the reproductive potential of these vulnerable fish populations (Lloret et al. 2012; Prato et al. 2013).

## **9. Regulation and minimum fish sizes**

The common dentex seems to be a heavily exploited species, and it is considered to be threatened in the Mediterranean Sea (Abdul Malak et al. 2011). Considering the effect of the professional fishing exploitation combined with recreational fishing on coastal ecosystems, it seems important to create new regulation policies (Albouy et al. 2010; Lloret and Font 2013) for both these activities. The measures should consider limiting or banning catching through permanent or seasonal closures during the spawning season, the establishment of a minimum legal length (based on species size at maturity) and/or the enlargement of no-take in critical areas (Lloret et al. 2008; Abdul Malak et al. 2011). For recreational fishing (including spear fishing), as stated

previously, there is a general lack of knowledge on this activity, and it seems urgent, in the light of its impact, particularly on populations of common dentex, to implement effective measures of regulation and control. For commercial fishing, in some Mediterranean countries, there is a regulation imposing a minimum landing size of common dentex (Table 4). Unfortunately, depending on the country, even when there is a minimum landing size, this remains well below the size at which 50% of the population is mature, namely 34.60 cm for females and 52.02 cm for males (Morales-Nin and Moranta, 1997).

## **10. Marine protected areas**

There are important differences in the fish assemblages inhabiting protected and unprotected areas (e.g. Macpherson et al. 1997, 2002; Pinnegar et al. 2000; Guidetti and Sala 2007; Garcia-Charton et al. 2008). The impact of protection, or the 'reserve effect', can be observed as a clear increase in abundance, the average and maximum individual sizes of most target species, and changes in the spatial distribution through recovery of shallow water habitats (e.g. Francour et al. 2001; Garcia-Charton et al. 2008). The common dentex is one those that benefits from these protection measures, being especially threatened by recreational and professional selective and effective fishing (Macpherson et al. 2002). However, results indicate that some relatively high-mobility species have benefited from habitat protection, whereas less mobile ones have suffered (Gomez et al. 2006). In Port de la Selva (Spain), the proportion of top predators such as *D. dentex* in total landings increased after the establishment of the MPA at the expense of octopus (*Octopus vulgaris*), white seabream (*Diplodus sargus*), scorpionfish (*Scorpaena* sp), and spiny lobster (*Palinurus elephas*) (Gomez et al. 2006). In the Bonifacio straits (France) the significant decrease in *Serranus cabrilla* could be linked to the significant increase in *D. dentex* (Rocklin et al. 2011). In the fishing reserves located in Calvi (France), a rearrangement of the demographic structure of some species was also found, with lower ratios of small species to large (Pelaprat 2000). The explanation for this difference was based on increased predation within the reserve due to a number of larger predators such as *D. dentex* (Francour et al. 2010; Prato et al. 2013). Such a trend is generally not expected after MPA implementation, but can be explained by trophic interactions between species through a top-down effect, where an increase in predators would lead to a decrease in their prey (Pinnegar et al. 2000; Pinnegar and Polunin 2004; Seytre and Francour 2009).

## **11. Stock structure and assessment**

An important first step toward assessing the sustainability of an exploited population is to define the geographic boundaries, or stock units, for the species (Quinn II and Deriso 1999). Unfortunately, little is known of the global stock structure and movement of *D. dentex*.

There is only one study on the population genetics of *D. dentex* at the global level. This study describes the phylogeography of three sparids including *D. dentex* based on three geographic areas: the Northeast Atlantic, and the Western and Eastern Mediterranean Sea (Bargelloni et al. 2003). For the *D. dentex*, mitochondrial DNA and allozymes have revealed a higher degree of genetic differentiation between the Atlantic and Mediterranean samples. Morphometric measurements were performed on these same samples of *D. dentex* (Palma and Andrade 2004). A significant degree of morphological dissimilarity between samples, and a geographical gradient were found (Palma and Andrade 2004). These results based on genetic and morphological analysis are evidence for a sharp phylogeographic break between the Atlantic and the Mediterranean for populations of common dentex (Bargelloni et al. 2003; Palma and Andrade 2004). Reported differences in fish size and growth may be due to fishing pressure, changes in oceanographic conditions, food availability, and season (Shelton and Mangel 2011). There seems to be an effective boundary between the Atlantic and Mediterranean populations of dentex, both morphologically and genetically (Bargelloni et al. 2003; Palma and Andrade 2004). It can be hypothesized that the history of the Mediterranean Sea, combined with the present hydrographic patterns, may have promoted and maintained the differentiation of the Mediterranean samples (Bargelloni et al. 2003; Palma and Andrade 2004). However, there is a severe lack of information on population structure, and it would require further studies including a higher spatial resolution and more accurate molecular markers (e.g. microsatellites).

To date, the only studies on the stock assessment of common dentex were conducted in Tunisia; three stocks were separately addressed according to different regions: Northern, Eastern and South (Chemmam-Abdelkader 2004; FAO 2008). These are the first studies on the analysis of the pseudo-cohort of this species in the Mediterranean, which yielded the main components of the stock in Tunisia. In the North, the yield by recruit value was below the optimal level; the stock seems to be under-exploited. The exploitation profile in the Eastern region was in optimal conditions. By contrast, the stock of the southern region is strongly overexploited, with a current yield above the optimum performance (Chemmam-Abdelkader 2004). The results obtained in the South Tunisian sector show that fishing is carried out on small size classes composed mainly of juveniles (Chemmam-Abdelkader et al. 2007). The current average age of the stock is estimated at 1.9 year, and is very low if we consider the longevity of the species, which can be more than 30 years. The effort to ensure stock replenishment

or "turnover" was 48%. For losses, the fishing mortality (63%) outweighed the natural mortality, probably because of overfishing. The profile of Southern stock was characterized by a young average age, a critical size close to that of sexual maturity, reflecting a state of overfished stock. To remedy this, the reduction of the current fishing effort by 44% compared with the optimal effort is recommended (Chemmam-Abdelkader et al. 2007). The recommendations include as a precautionary measure not increasing the fishing effort in both areas (FAO 2008). At a global level, efforts are to be made on the stock assessment of the common dentex, to better understand its movement and how the individuals comprising the various *D. dentex* aggregations in different localities are related.

### **Conclusion and directions for future research**

Here we have shown that although the common dentex species is of great interest, both economically and ecologically, some very important questions still remain unanswered about the life of this iconic fish.

As a top predator, it is a key species in the functioning of coastal food webs, and for this reason there is a need to improve the state of knowledge on the biology and ecology of the common dentex. In order to implement proper fishery management strategies aimed at avoiding stock decline, information about connectivity among stocks and populations is critical. There is still great progress to be made in understanding the larval and juvenile stages and the reproductive behavior of the common dentex. There should also be a clear vision of the population state (demographic parameters) and the spatial and temporal structure of the stocks, to implement sustainable management of fisheries in the Mediterranean Sea. Consequently, more specific methods may be more helpful in defining stock boundaries for population models. Genetic techniques using specific microsatellite loci may provide a more comprehensive analysis of the genetic population structure of the common dentex (Bargelloni et al. 2003). Some other specific approaches could be relevant in determining the stock structure of the common dentex, such as parasite abundances (e.g. Williams et al. 1992; MacKenzie and Abaunza 1998; Williams and Lester 2006), stable isotope analysis (e.g. Rooker et al. 2007) and otolith shape and/or microchemistry (e.g. Turan 2006; Hamer et al. 2012). From the perspective of behavioral ecology, one path of research that can be developed is to investigate the movement of individuals, for example using electronic tagging, especially for aggregations at the time of reproduction (e.g. Pastor et al. 2009). However, the development of simultaneous multiple approaches such as analysis of fisheries data, population genetics, and otolith chemistry is probably the most relevant way to favour the efficient management of an exploited species (see Pappeti et al. 2013).



In terms of exploitation, for recreational fishing, it is necessary to have short-term, accurate biological, social and economic data to evaluate this activity (Pitcher and Hollingworth 2002; Arlinghaus et al. 2010). Recreational catches are often poorly quantified, but such catch data are essential for estimating total mortality in stock assessment, especially where the recreational catch is high compared with the commercial catch (Lloret and Font 2013). Despite its importance, knowledge about fleets and their characteristics, fishing gear, seasonality, catches, and the yields of the professional artisanal sector is still limited (Battaglia et al. 2010). It is necessary to develop standardized data collection routines and indicators of fishing effort for Mediterranean artisanal fishery that make data comparable on a spatial and temporal basis (Colloca et al. 2004). Data on global catch of common dentex suggests a cyclic fluctuation of the populations, with the appearance of multiannual peaks of activity. The abundance of common dentex has fluctuated over the last sixty years on a multidecadal time scale and has declined significantly since the 1990s. In some areas, populations have decreased significantly in recent years, due to overfishing by artisanal and recreational fishing. Fishing gear such as trawl or seine may make a particular impact on these populations, especially in spawning areas (mature adults) or nursery areas such as in the *Posidonia oceanica* meadows (juveniles and young of the year). However, the interaction between fishing exploitation and environmental variables can have synchronic effects on the population dynamics of exploited marine fishes (Quetglas et al. 2012). The improved management of fisheries and marine ecosystems can undoubtedly play an important role in adapting to the impacts of climate change (Brander 2010). Managers should consider the implementation of specific measures to safeguard the reproductive potential of coastal top predator species, such as *D. dentex* (Lloret et al. 2012). There is an urgent need to implement effective protection measures for this species, whether based on a maximum daily catch, minimum catch size, protection through marine protected areas, or period of biological recovery, because recently *D. dentex* has been classified as “vulnerable” in the Red List of Threatened Species in the Mediterranean Sea and so effective management is now required.

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## **Table captions**

Table 1. Growth parameters of Von Bertalanffy equation estimated for *Dentex dentex*.  $L_{\infty}$  = theoretical maximum size, TL = total length,  $K$  = growth rate,  $t_0$  = age at which the length at age  $t$  is theoretically equal to 0, M = Male, F = Female, M/F = Male and Female.

Table 2. Bibliographical review of the known parasites of *Dentex dentex*; geographical location, position of the parasites and references.

Table 3. Summary of the exploitation of *Dentex dentex* (abundance), according to the season, sizes class composition, different gear, main depth range of operations and habitat.

Table 4. Minimum landing sizes of *Dentex dentex* for commercial fishing in some Mediterranean countries.

Table 1.

<b>Lt <math>\infty</math> (cm)</b>	<b>Length type</b>	<b>K</b>	<b><math>t_0</math> (years)</b>	<b>Sex</b>	<b>Country</b>	<b>Locality</b>	<b>Citations</b>
110.000	TL	0.077	-2.304	M/F	France	Calvi	(Culioli 1986)
84.400	TL	0.100	-2.854	M	Spain	Mallorca	(Morales-Nin and Moranta 1997)
85.622	TL	0.102	-2.874	F	Spain	Mallorca	(Morales-Nin and Moranta 1997)
95.051	TL	0.077	-1.796	M	Tunisia	Tunisian coasts	(Chemmam-Abdelkader et al. 2004)
97.354	TL	0.072	-1.933	F	Tunisia	Tunisian coasts	(Chemmam-Abdelkader et al. 2004)
96.804	TL	0.073	-1.892	M/F	Tunisia	Tunisian coasts	(Chemmam-Abdelkader et al. 2004)

Table 2.

Parasite species	Class	Geographical location	Position	Citations
<i>Allopodocotyle jaffensis</i> (Fischthal, 1980)	Digenea	France, Scandola	Posterior intestine	(Bartoli et al. 2005)
<i>Aphallus rubalo</i> (Bray, 1986)	Digenea	France, Scandola	Duodenum, rectum	(Bartoli et al. 2005)
<i>Aphallus tubarium</i> (Rudolphi, 1819)	Digenea	France, Scandola	Posterior intestine, rectum	(Bartoli and Bray 1987; Bartoli et al. 2005)
<i>Cainocreadium dentecis</i> Jousson & Bartoli, 2001	Digenea	France, Scandola	Pyloric caeca, Duodenum, mid-intestine	(Jousson and Bartoli 2001; Bartoli et al. 2005)
<i>Hemiurus communis</i> Odhner, 1905	Digenea	France, Scandola	Stomach	(Bartoli et al. 2005)
<i>Metadena depressa</i> (Stossich, 1883)	Digenea	France, Scandola	Pyloric caeca, Duodenum, mid-intestine, Posterior intestine	(Bartoli and Bray 1987; Bartoli et al. 2005)
<i>Pachycreadium carnosum</i> (Rudolphi, 1819)	Digenea	France, Scandola	Duodenum, mid-intestine, Posterior intestine	(Bartoli et al. 2005)
<i>Stephanostomum</i> sp. (Metacercariae)	Digenea	Spain, Balearic Islands	Gills	(González et al. 2004)
<i>Lecithochirium musculus</i> (Looss, 1907)	Digenea	Adriatic Sea		(Carreras-Aubets et al. 2012)
<i>Timoniella imbutiforme</i> (Molin, 1859)	Digenea	Italy, Triest	Intestine	(Stossich 1905)
<i>Microcotyle erythrini</i> Van Beneden & Hesse, 1863	Polyopisthocotylea	Spain, Balearic Islands	Gills	(González et al. 2004)

<i>Cathucotyle acanthura</i> (Parona & Perugia, 1896)	Polyopisthocotylea	Mediterranean Sea		(Euzet et al. 1993)
<i>Udonella caligorum</i> Johnston, 1835	Monopisthocotylea	Spain, Balearic Islands	Gills	(González et al. 2004)
<i>Encotyllabe vallei</i> Monticelli, 1907	Monopisthocotylea	Montenegro		(Radujkovic and Euzet 1989; Euzet et al. 1993)
<i>Dinemoura producta</i> (Mueller, 1785)	Copepoda	Spain, Balearic Islands	Gills	(González et al. 2004)
<i>Caligus dakari</i> Beneden, 1892	Copepoda	Montenegro Kotor	Gills	(Radujkovic and Raibaut 1989)
<i>Caligus diaphanus</i> Von Nordmann, 1832	Copepoda	Spain, Balearic Islands	Gills	(González et al. 2004)
<i>Clavella denticis</i> (Krøyer, 1863)	Copepoda	Montenegro		(Yamaguti 1963)
<i>Clavellotis fallax</i> (Heller, 1865)	Copepoda	Spain, Balearic Islands, Montenegro, Kotor	Gills	(Radujkovic and Raibaut 1989; Raibaut et al. 1998; González et al. 2004)
<i>Colobomatus denticis</i> (Richiardi, 1877)	Copepoda	Mediterranean Sea		(Raibaut et al. 1998; Bailly 2012)
<i>Caligus vexator</i> Heller, 1865	Copepoda	Italy, Genoa, Montenegro, Kotor	Gills	(Brian 1906; Radujkovic and Raibaut 1989; Raibaut et al. 1998; Bailly 2012)
<i>Parabrachiella exigua</i> (Brian, 1906)	Copepoda	Mediterranean Sea		(Bailly 2012)
<i>Ceratothoa parallela</i> (Otto, 1828)	Eumalacostraca Isopoda	Mediterranean Sea		(Trilles 1994)
<i>Gnathia vorax</i> (Lucas, 1849, praniza larvae)	Eumalacostraca Isopoda	Spain, Balearic Islands	Gills	(González et al. 2004)

Table 3.

Geographic Area	Sampling strategy	Sampling techniques	Sampling year	Abundance Index: Biomass (Contribution to total biomass of the catch %; total biomass kg, tons, CPUE)	Abundance Index: Number (Occurrence frequencies %, CPUE)	Size class composition (cm)	Stage of life and capture	Main depth range of operations (m)	Main month activity	Habitat	Citations
Croatia (Eastern Adriatic)	Landing	Tramata	1986-99	2.4%	0.22%	Length range 14.0-40.8, Mean length 28.350 ± 0.381; Modal length 29	Juveniles (By-catch)	0-50	July-September	-	Čerinać et al. 2002
Croatia (Vía)	Experimental fishing	Trammel net	1995-2009	-	1.7%	-	-	0-40	-	-	Mazi-Stokoe et al. 2011
France (Bonifacio, MPA)	Onboard fishing vessel Landing	Long line	1992-93, 2000-06	6.7 kg/100 hooks	-	-	Target species	-	-	-	Ganado 2007
France (Bonifacio, MPA)	Onboard fishing vessel Landing	Trammel net	1992-93, 2000-06	70 g/70 m of net/24h	-	-	Target species	-	-	-	Ganado 2007
France (Bonifacio, MPA)	Onboard fishing vessel Landing	Trammel net	2004-2006	4.8%	-	-	Target species	-	-	-	Rocklin 2010
France (Bonifacio, MPA)	Onboard fishing vessel Landing	Trammel net	2001, 2007	4.04 % (2001); 4.03% (2007)	-	-	Target species	-	-	-	Rocklin 2010
France (Cala Galéria)	Landing	Trammel net, long line	1986	-	-	Length range 14-74, Median 30	Juveniles (By-catch)	-	-	-	Cubiò 1986
France (Corsica outside Scandola MPA)	Underwater visual census	SCUBA diver	1988	4.9 g/10 m <sup>2</sup>	0.08 ind/100 m <sup>2</sup>	-	-	10-30	July	Rocky areas	Francour 1991
France (Corsica Scandola MPA)	Underwater visual census	SCUBA diver	1990-2009	-	0.14 ind/100 m <sup>2</sup>	-	-	10-30	June-August	Rocky areas	Francour 2004
France (Corsica Scandola MPA)	Underwater visual census	SCUBA diver	1988	19.1 g/10 m <sup>2</sup>	0.2 ind/10 m <sup>2</sup>	-	-	10-30	July	Rocky areas	Francour 1991
France (Corsica)	Onboard sampling	Trammel net, gill net	2009-10	0-150 g/50 m of net; 2009 (28.3 tons); 2010 (26.5 tons)	-	-	Target species	-	-	-	Francour 2011
France (Côte Bleue, MPA)	Landing	Trammel net	2009-10	-	-	-	Target species	37.6 (mean value)	-	-	Leleu 2012
France (Cros de Cagnes)	Landing	Trammel net, long line	2002-2005	0.19%	-	-	Target species	-	-	-	Leroy 2009
France (Lavezzi Islands)	Onboard fishing vessel	Trammel net, long line	1992-93	1316 kg (5.64 %)	0.74 % (n=445)	Length range 0-40 (41%); 40-60 (27%); 60-80 (22%)	Target species	-	-	-	Cubiò 1995
France (National Park of Port-Cros)	Underwater visual census	SCUBA diver	1989-1990	92.4 g/10 m <sup>2</sup>	0.47 ind/100 m <sup>2</sup>	-	-	10-30	June-September	Rocky areas	Francour 1992
France (National Park of Port-Cros)	Underwater visual census	SCUBA diver	2005-2006	-	0.1 ind/250 m <sup>2</sup>	-	-	20-40	April-July	Rocky areas	Francour and Bonhomme 2006
France (National Park of Port-Cros)	Landing	Small-scale fisheries (all gears combined)	2005	1.30 %	-	-	-	-	-	-	Cadoux and Bonhomme 2006
France (Vie)	Experimental fishing	Gampan	2010	-	-	-	Juveniles (By-catch)	15-35	January-December	<i>Posidonia oceanica</i> meadow	Sacchi et al. 2010
France (Vie)	Onboard fishing vessel	Angling	2010-2012	14%	-	-	-	-	-	-	Boëlle et al. 2012
France (Var, Cap Roux Fisheries Reserve)	Experimental fishing	Trammel net	2011-2012	-	0.3 ind/100 m of net (0.77%)	-	-	0-40	-	Rocky areas and <i>Posidonia</i>	Arcoe 2012
France, Corsica (NW coast)	Landing	Trammel net, long line	1988-1989	-	-	-	-	-	-	-	Rutten 1989
Greece	Declarative survey	Small-scale fisheries (all gears combined)	1993-99	Winter (1.63%); Spring (2.64%); Summer (2.13 %); Autumn (2.37 %); (mean value all the year 2.27%)	-	-	-	-	January-December	-	Tranatos et al. 2005
Greece (Korinthiakos)	Onboard fishing vessel/ Experimental fishing	Trammel net, gill net	2008-09	-	-	Length range 17.1-48.0; Median 28.1	-	-	June-September	-	Moutopoulos et al. 2013
Greece (Patraikos)	Onboard fishing vessel	Trammel net	2004-05	-	-	-	Target species	0-25	September-July	-	Tranatos et al. 2008
Greece (Patraikos)	Onboard fishing vessel	Long line	2004-05	-	-	-	Target species	20-56	March-November	-	Tranatos et al. 2008
Italy (North-Western Ionian Sea)	Experimental fishing	Experimental bottom trawl	1985-2008	-	0.3%	-	-	15-25%	-	-	Mascorano et al. 2010
Italy (Otranto)	Underwater visual census	SCUBA diver	1997	-	0.1 ± 0.1 ind/40 m <sup>2</sup>	-	-	6.5-4.0	-	Seagrass and Rocky-algal	Quatini 2000
Lebanon (Tyre)	Landing	Monie-Mulhiflament gill nets (with large mesh size)	2005-06	-	-	-	By-catch	-	October-July	-	Lebl et al. 2006
Lebanon (Tyre)	Landing	Bottom longline	2005-06	-	-	-	Target species	-	January-December	-	Lelli et al. 2006
Portugal (Setúbal and Sesimbra)	Onboard fishing vessel	Trammel net	2004-05	20.2 g/10.000 m of net	-	-	By-catch	-	-	-	Batista et al. 2009
Spain (Cabo de Gata, A pulas, Cabo de Palos, Isla Girona, Cabrera, Mallorca and Columbretes, MPA)	Underwater visual census	SCUBA diver	1996	6.9 ± 1.8 g/250 m <sup>2</sup>	3.6 ± 1.2 ind/250 m <sup>2</sup> (18%)	-	-	10	-	Rocky bottom	Garcia-Charton et al. 2004
Spain (Cabo de Palos, MPA)	Onboard fishing vessel/ Declarative survey	Trammel net	2005-08	6.6%	-	-	Target species	30 (mean value)	April-October	-	Esparraco-Alamino 2010
Spain (Cabo de Palos, MPA)	Onboard fishing vessel/ Declarative survey	Long line	2005-08	8.7%	-	-	Target species	-	February-April; October-November	-	Esparraco-Alamino 2010
Spain (Cabo de Palos, MPA)	Onboard fishing vessel/ Declarative survey	Gill net	2005-08	13.3%	-	-	Target species	-	February-June	-	Esparraco-Alamino 2010
Spain (Cala Rajada, MPA)	Experimental fishing	Bottom long line	2008-09	460.5 kg (40.3%)	(n=150)	Length range 30-75; Mean length 54	-	31 (median)	-	<i>Posidonia oceanica</i> meadows, Rocky bottom with <i>P. oceanica</i> patches, Coastal detritus, Deft Bipples of coarse sand and sediments	Stobart et al. 2012
Spain (Cap Creus, MPA)	Onboard fishing vessel	Trammel net, gill net, long line/ basket traps	2008-10	-	-	Mean length 37.5 cm	-	-	-	-	Lloret et al. 2012
Spain (Cap Creus, MPA)	Landing	Long line, gill net	1991-2003	1 % (1991-98); 1.6% (1999-2002)	-	-	Target species	-	April-November	-	Gomez et al. 2006
Spain (Columbretes Islands, MPA)	Experimental fishing	Trammel net	1998-2006	-	0.461 ind/600 m of net	-	-	20-30	-	-	Stobart et al. 2009
Spain (Columbretes Islands, Nearby fishery area of the MPA)	Onboard fishing vessel	Trammel net	1998-2006 (except 2004)	-	0.103 ind/600 m of net	-	-	50-100	-	-	Stobart et al. 2009
Spain (Demia)	Declarative survey	Small-scale fisheries (all gears combined)	1995-2009	2760 kg (2003); 5000 kg (2009)	-	-	-	-	March-May; October-December	-	Oroozo et al. 2011
Spain (L. Estaritz)	Underwater visual census	SCUBA diver	1997-99	696.0 g/1000 m <sup>2</sup> (SD=1391.9)	-	-	-	0-30	-	Gently sloping rock	Morales-Nin and Moranta 1997
Spain (Mallorca)	Landing	Trammel net	1993-95	-	-	Length range 17.5-30	Juveniles	-	September-March	<i>Posidonia oceanica</i> meadow	Morales-Nin and Moranta 1997
Spain (Mallorca)	Landing	Long line	1993-95	-	-	Length range 17-83	Adult	-	April-June	-	Morales-Nin and Moranta 1997
Spain (Santa Pola)	Declarative survey	Trawl	1995-2009	2500 kg (2003); 5500 kg (in 2009)	-	-	-	-	March-May; October-December	-	Oroozo et al. 2011
Spain (Santa Pola)	Declarative survey	Small-scale fisheries (all gears combined)	1995-2009	7000 kg (2003); 19800 kg (2009)	-	-	-	-	March-May; October-December	-	Oroozo et al. 2011
Spain (Tabarca, MPA)	Underwater visual census	SCUBA diver	2005-06	110.84 ± 44.67 (g/125 m <sup>2</sup> ); (5.95 %)	-	-	-	-	-	<i>Posidonia oceanica</i> meadow	Forcada et al. 2008
Spain (Tabarca, MPA)	Underwater visual census	SCUBA diver	2005-06	486.22 ± 2002.24 (g/125 m <sup>2</sup> ); (11.90 %)	-	-	-	-	-	Rocky bottom	Forcada et al. 2008
Spain (Tabarca, MPA)	Landing	Small trap net (Moranas)	1988-1989	less than 1%	-	-	-	-	-	-	Ramos-Espila & Bayle-Sempere 1990
Spain (The Medes Islands, MPA)	Underwater visual census	SCUBA diver	1997-99	622 g/1000 m <sup>2</sup> (SD=28.7)	-	-	-	0-30	-	Gently sloping rock	Macpherson et al. 2002
Spain (The Medes Islands, MPA)	Underwater visual census	SCUBA diver	1997-99	38456.7 g/1000 m <sup>2</sup> (SD=3847.6)	-	-	-	0-30	-	Large broken rocks	Macpherson et al. 2002
Spain (The Medes Islands, MPA)	Underwater visual census	SCUBA diver	1997-99	3191.3 g/1000 m <sup>2</sup> (SD=24.6)	-	-	-	0-30	-	<i>Posidonia oceanica</i> meadow	Macpherson et al. 2002
Spain (Tossa)	Underwater visual census	SCUBA diver	1997-99	2186.5 g/1000 m <sup>2</sup> (SD=173.9)	-	-	-	0-30	-	Gently sloping rock	Macpherson et al. 2002
Spain (Vilanova la Geltrú, MPA)	Cabled video observatory	Digital image acquisitions	2009-10	-	1.6% (individuals detected in digital images taken at hourly intervals during daytime over the course of 12 months; n = 366)	-	-	20	May-November	Close to an artificial reef	Coufal et al. 2012
Tunisia	Landing/ Declarative survey	Trammel net, gill net, long line	1995-2002	301.484 tons	-	Mean length 31.32 (1997-98)	Trammel net and gillnets (Juveniles); Long line (Adult)	-	May-July; November-January	-	Chemman 2004
Tunisia	Landing/ Declarative survey	Trawl	1995-2002	27.643 tons	-	Mean length 31.32 (1997-98)	-	-	May-July; November-January	-	Chemman 2004
Tunisia	Landing/ Declarative survey	Basket traps, traps net, fyke net	1995-2002	3.259 tons	-	Mean length 31.32 (1997-98)	Juveniles (By-catch)	-	May-July; November-January	-	Chemman 2004
Tunisia (Southern region)	Landing	Trammel net, long line, trawl	2004	-	-	Length range 13-73 (18-25 represents 69%)	Juveniles	-	-	-	Chemman-Abdelkader et al. 2007
Turkey (Antalya)	Landing	Bottom trawl net	2009	16.5 kg/m <sup>2</sup> (SE=9.92)	248.8 ind/m <sup>2</sup>	-	-	25-200	August	-	Kebapçioğlu et al. 2010
Turkey (South of Izmir)	Landing	Beach seine	1996	1.75%	0.49%	-	-	4-30	May-September	-	Akyol 2003

Table 4.

<b>Country</b>	<b>Minimum fish sizes (cm)</b>	<b>References</b>	<b>Citations</b>
<b>Morocco</b>	12	Decree No. 1154-1188 of 3 October 1988 (as amended and supplemented by decree No. 352-89 dated 2 February 1989, by decree No. 652-92 of 1 October 1993 and decree No. 373-01 dated 21 February 2001),	(Cacaud 2002)
<b>Algeria</b>	15	Decree No. 04-86 of 26 Moharram 1425 corresponding to 18 March 2004 fixing the minimum market sizes of biological resources.	Official Journal of the Republic of Algeria (24/03/2004)
<b>Mauritania</b>	15	Decree No. 2002-073 of 1 October 2002 laying down general rules for the application of Law No. 2002-025 of 24 January 2000	Official Journal of the Islamic Republic of Mauritania (30/10/2002)
<b>Turkey</b>	20	Act fisheries No. 1380 of March 22, 1971 as amended, supplemented with fisheries regulations No. 22223 of March 10, 1995 and section 15 of circular No. 33/1	(Cacaud 2003)
<b>Tunisia</b>	22	Decree of 28 September 1995 regulating the practice of fishing is the main text of application of Law No. 94-13 of January 31, 1994	(Cacaud 2002)
<b>Albania</b>	25	Law No. 7908 of 5 April 1995 on fisheries and aquaculture Regulations No. 1 of March 26, 1997	(Cacaud 2003)
<b>Croatia</b>	30	Based on the Article 48 paragraph 3 bullets 1, 2 and 3 of the Marine Fisheries Act (Official Gazette No. 46/97).	(Martín and Kekez 2009)



## **Figure caption**

**Fig. 1** Global geographical range of *Dentex dentex* (updated from Bauchot and Hureau 1986; Morales-Nin and Moranta 1997; Bat et al. 2005; FAO 2012).

**Fig. 2** Annual catch of common dentex for all nations (grey bars), for Spain and Italy, the two highest contributor nations (lines) and the other nations (lines; Albania, Croatia, Cyprus, Egypt, France, Greece, Latvia, Libya, Malta, Montenegro, Portugal, Romania, Serbia, Tunisia, Turkey, Yugoslavia SFR), for the years 1950–2010 (based on FAO 2012).

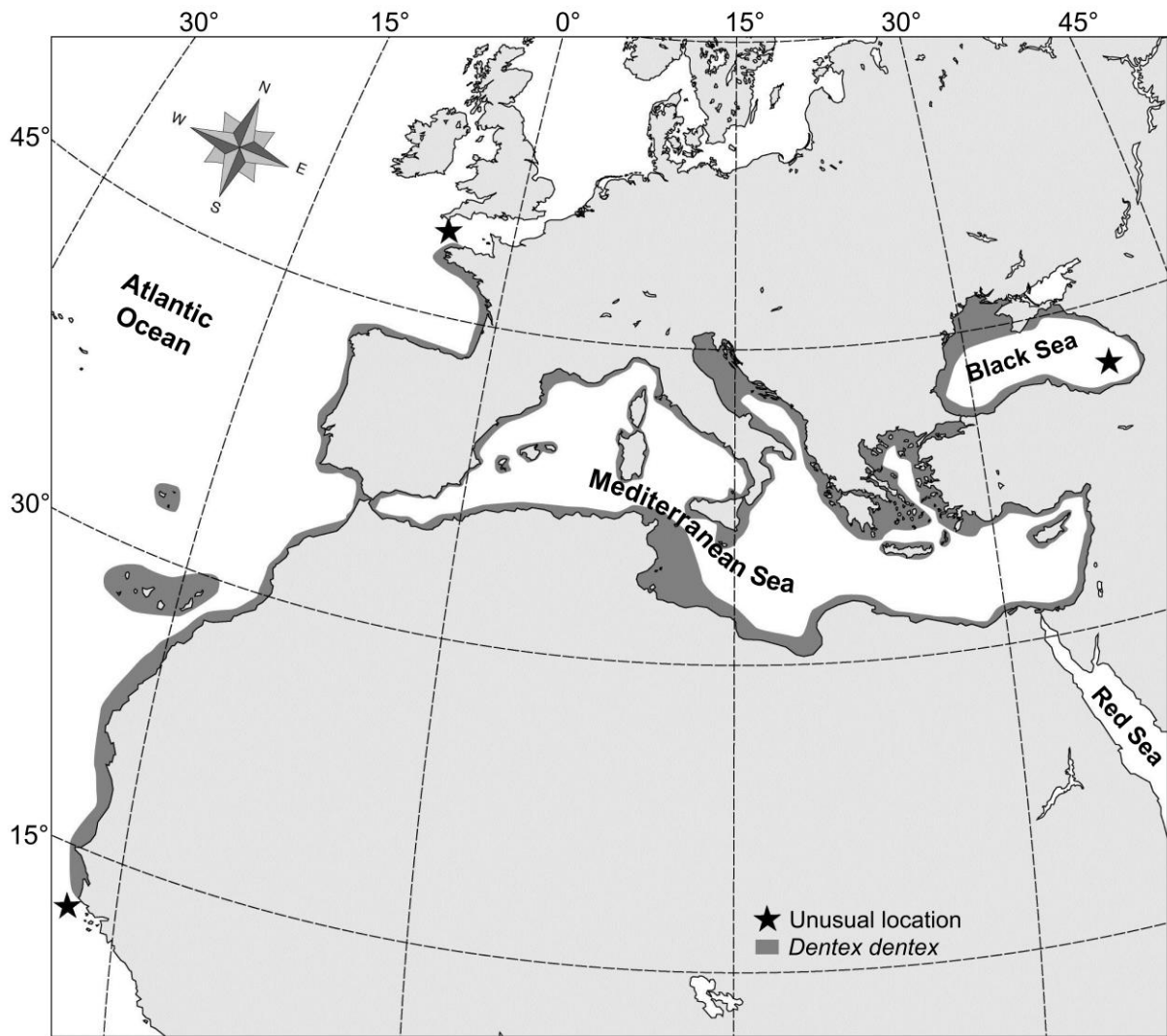
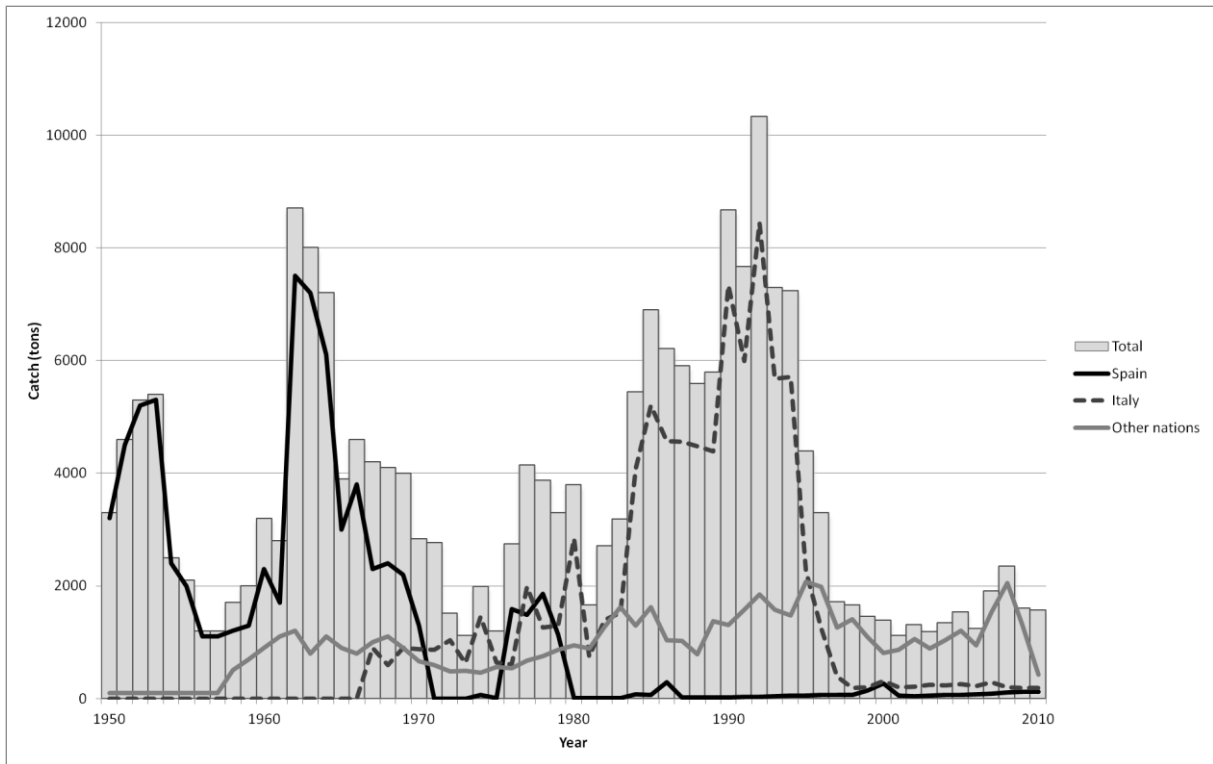


Fig. 1



**Fig. 2**