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Cephalopod biology and fisheries in Europe:
II. Species Accounts.

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Editors

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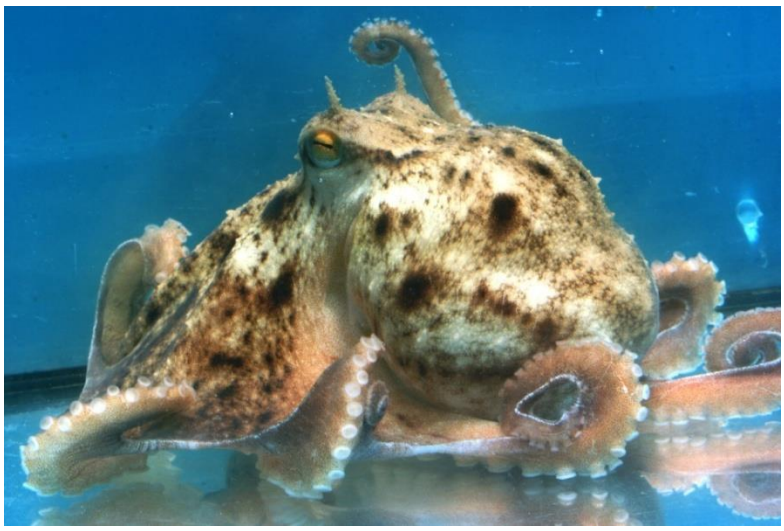
Cephalopod biology and fisheries in European waters: species accounts



Eledone moschata

Musky octopus

5 *Eledone moschata* (Lamarck, 1798)

Ignacio Sobrino, Ana Moreno, Patrizia Jereb, Eduardo Balguerias, Sonia Seixas, Graham J. Pierce, Evgenia Lefkaditou, and A. Louise Allcock

Common names

Elédone musquée (France); Μοσκιός [moschios] (Greece); moscardino rosso, moscardino muschiato (Italy); polvo cabeçudo, polvo-mosqueado, polvo-de-cheiro (Portugal); pulpo cabezón, pulpo almizclado (Spain); musky octopus (UK) (Figure 5.1).

Synonyms

Octopus moschatus Lamarck, 1798, *Eledona moschata*: Risso (1854).

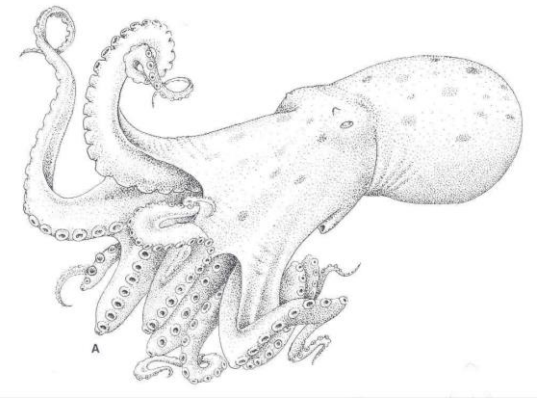


Figure 5.1. *Eledone moschata*. Dorsolateral view. From Guerra (1992).

5.1 Geographic distribution

The musky octopus, *Eledone moschata* (Lamarck, 1798), lives in the Northeast Atlantic and in the Mediterranean Sea (Norman *et al.*, 2014; Figure 5.2). In the Northeast Atlantic, it is occasionally found off Portugal as far north as ca. 40°N (Lourenço *et al.*, 2008) and is abundant in Portuguese and Spanish waters of the Gulf of Cádiz (Guerra, 1982, 1992; Reis *et al.*, 1984). It is widespread throughout the Mediterranean Sea (Mangold and Boletzky, 1987; Bello, 2004; Salman, 2009), including western and central Mediterranean waters (Mangold-Wirz, 1963a**;** Sánchez, 1986a; Belcari and Sartor, 1993; Jereb and Ragonese, 1994; Giordano and Carbonara, 1999**;** Relini *et al.*, 2002; Cuccu *et al.*, 2003a), the Adriatic Sea (Casali *et al.*, 1998; Krstulović Šifner *et al.*, 2005; Piccinetti *et al.*, 2012)**,** and, though occasionally less abundant, the Ionian Sea (Tursi and D'Onghia 1992; Lefkaditou *et al.*, 2003a; Krstulović Šifner *et al.*, 2005), the Aegean Sea, and the Levant Basin (D'Onghia *et al.*, 1992; Salman *et al.*, 1997, 1998; Lefkaditou *et al.*, 2003b; Duysak *et al.*, 2008). The species has been recorded in the Sea of Marmara (Katağan *et al.*, 1993; Ünsal *et al.*, 1999). Primarily a Mediterranean species, the southern limits of the Northeast Atlantic distribution of *E. moschata* remain uncertain.

Figure 5.2. ***Eledone moschata.*** **Geographic distribution in the Northeast Atlantic and Mediterranean Sea.**

5.2 Taxonomy

5.2.1 Systematics

Coleoidea – Octopodiformes – Octopoda – Octopodidae – *Eledone.*

5.2.2 Type locality

Not stated in original description.

5.2.3 Type repository

Muséum National d'Histoire Naturelle, Laboratoire Biologie Invertebres Marins et Malacologie, 55, rue de Buffon, 75005 Paris 05, France. The type does not appear to be extant (see Lu *et al.*, 1995).

5.3 Diagnosis

5.3.1 Eggs and hatchlings

Eggs are joined by their short stalks in clusters and attached to a substratum. The clusters contain 3–10 eggs, and they have no central stem. The eggs are elongate, measure 12–16 mm long and 4–5 mm wide (Mangold, 1983b). In the Gulf of Cádiz, mature eggs are generally smaller, on average 10.9 mm long (Silva *et al.*, 2004). Hatchlings measure 25–30 mm TL and 10–12 mm ML, ca. 10% of the adult size. At hatching, each arm already bears 30 suckers and is longer than the body (Mangold, 1983b).

5.3.2 Juveniles and adults

The skin is smooth to very finely granulose; there is no ridge around the lateral periphery of the mantle. The arms are subequal in length with uniserial suckers. The web is moderately deep, ca. 30% of arm length. In mature males, the third right arm is hectocotylized (Figure 5.3) and is 85–90% of the length of the third left arm. The ligula is

short (ca. 3% of arm length), and there is no calamus. The distal tips of all other arms of males are modified with two parallel series of flattened laminae or platelets. Internally, the gills have 11–12 filaments per demibranch. Live animals exude a very prominent, musk-like odour, reportedly from glands in the skin. Live animals are greyish-brown with blackish-brown blotches on the dorsum (Mangold and Boletzky, 1987; Relini *et al.*, 1999; Norman *et al.*, 2014). The beaks are illustrated in Figure 5.4.

Figure 5.3. ***Eledone moschata*****. Right arm III hectocotylized. Photo: Carlos Farias.**

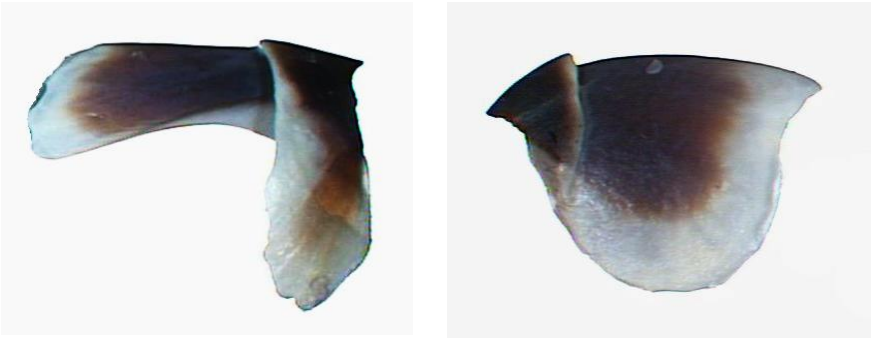


Figure 5.4. ***Eledone moschata*****. Lower beak (left) and upper beak (right). Photos: Evgenia Lefkaditou.**

5.4 Remarks

Norman *et al.* (2014) list no synonyms. Norman and Hochberg (2005) listed *Eledonenta microsicya* Rochebrune, 1884 as a synonym of *Eledone moschata*. Robson (1932) suggested that "*Eledonenta microsicya*" should be placed in *Eledone* and that it was more similar to *E. moschata* than to other species of *Eledone*. Nonetheless, he did not synonymize the two species. Silas (1968) treats the species as *Eledonenta microsicya*, but noting Robson's (1932) opinion. The original description (Rochebrune, 1884) is strongly suggestive of *Eledone* (e.g. "*cupules... sur un seul rang*"), but his description of a dirty yellow animal with small black dots and large bluish spots "*jaune sale, finement piquete de tres petits points noirs et orne de larges taches bleuatres*" does not match *E. moschata*. Therefore, the identity of *E. microsicya* remains unsolved, but we do not believe it to be synonymous with *E. moschata*.

5.5 Life history

In contrast to *E. cirrhosa*, hatchlings of *E. moschata* immediately adopt a benthic mode of life. The breeding cycle is seasonal, with one or two peaks in activity, the main one often during the first quarter of the year. There may be alternating long and short life cycles.

5.5.1 Egg and juvenile development

Few records have been published on naturally occurring eggs. Egg masses have been collected in shallow waters in the northern Adriatic Sea. In captivity, embryonic development lasts 4–6 months, depending on temperature (Mangold, 1983b).

After hatching, animals adopt the adult benthic mode of life and immediately begin to feed on live crabs of their own size. A preference for a crustacean diet is clear from the very early stages on (Boletzky, 1975a). Mean growth rate of hatchlings is ca. 6.2% of body weight d^{-1} up to 10 g, 3% d^{-1} between 10 and 100g, and 0.8% d^{-1} thereafter (Mangold, 1983b).

5.5.2 Growth and lifespan

Eledone moschata reaches a maximum size of 150 mm ML and 640 g body weight in the Atlantic (Silva *et al.*, 2004) and 188 mm ML and 1414 g body weight in the Mediterranean Sea (Akyol and Şen, 2007). Boletzky (1975a) reared it, recording a growth rate of 6.6% BW d^{-1} for the first month after hatching and 3.6% BW d^{-1} for the subsequent 3 months. Hatchlings weighed 0.3 g, reaching 2.2 g BW after 1 month and 55 g at 4 months. Forsythe and van Heukelem (1987) give values for instantaneous relative growth rates ranging from 6.94% BW d^{-1} in the smallest animals to 0.99% BW d^{-1} in animals of 50 g BW. Length–weight relationships show some regional variation (Table 5.1).

The proposed life cycle model of this species in the northwestern Mediterranean is based on the alternation of short-lived and long-lived life cycles (Mangold, 1983b; Silva *et al.*, 2004). This model seems to apply in the Gulf of Cádiz. Recruitment is in September and October and presumably originates from the long-living fraction of mature females that spawned at the beginning of the spawning season. Another recruitment pulse is detected in January and February, which is related to the short-lived fraction of the population that spawned at the end of the spawning season. Favourable environmental conditions may lead to faster growth and more rapid sexual development of the short-lived fraction of the population. The smaller spawning peak observed in October in the Gulf of Cádiz could be a consequence of this phenomenon (Mangold, 1983b; Ezzeddine-Najai, 1997; Silva *et al.*, 2004). Lifespan is probably up to 2 years (e.g. Mangold, 1983b).

Table 5.1. ***Eledone moschata*****. Length–weight relationships in different geographic areas for females (F), males (M), and sexes combined (All). Original equations converted to $W = aML^b$ where W is body mass (g) and ML is dorsal mantle length (cm).**

Region	*a*	*b*	Sex	Reference
Portugal	1.0048	2.4	F	Lourenço *et al.* (2008)
	0.6325	2.5	M	
	0.8652	2.46	All	
Gulf of Cádiz	0.3573	2.660	F	Silva *et al.* (2004)
	0.2613	2.794	M	
	0.3233	2.702	All	
Thracian Sea (northeastern Aegean Sea)	0.3323	2.814	F	E. Lefkaditou, pers. comm.
	0.2371	2.960	M	
Adriatic Sea	0.6002	2.6644	F	Krstulović Šifner and Vrgoč (2009a)
	0.5246	2.7665	M	

	0.3233	2.702	All	
Montenegro	0.7712	2.4558	M	Ikica *et al.* (2011)
(Adriatic Sea)	1.1185	2.2291	F	
	0.9407	2.33	All	
Izmir Bay (eastern Aegean Sea)	0.3083	2.797	F	Akyol *et al.* (2007)
	0.2548	2.885	M	
	0.2836	2.836	All	
Iskenderun Bay (northeastern Levant Sea)	0.0906	3.324	F	Duysak *et al.* (2008)
	0.2704	2.7902	M	
	0.5645	2.4281	All	

5.5.3 Maturation and reproduction

Sex ratio apparently varies seasonally and with depth, as well as between areas, perhaps indicating geographic variation in the timing of life cycle events, reproductive migrations, and differential survival of the sexes, but also suggesting an incomplete understanding of the life cycle in many areas. Off the Mediterranean French coast and the Gulf of Gabes (Tunisia), males significantly outnumber females, especially during the reproductive season (Mangold-Wirz, 1963a; Ezzeddine-Najai, 1997). In the Adriatic Sea, the overall sex ratio is normally close to 1:1, but males dominate during summer, soon after the spawning season (Krstulović Šifner and Vrgoč, 2009a). Conversely, both commercial and survey trawl data from the Gulf of Cádiz show a clear female dominance in catches throughout the year (Silva *et al.*, 2004). In Portuguese waters, males and females are equally abundant up to 100 m depth, but between 100 and 200 m, females outnumber males (Lourenço *et al.*, 2008). Females outnumber males (1.31:1) at all depths year-round in the eastern Mediterranean (Akyol *et al.*, 2007). Ikica *et al.* (2011) found a sex ratio close to 1:1 in Montenegrin waters.

Weight and size at maturity vary geographically. In the Gulf of Cádiz, the length and weight at maturity ($MLm_{50\%}$ and $BWm_{50\%}$) were estimated to be 12 cm (274 g) in females and 7.8 cm (97 g) in males (Silva *et al.*, 2004). The $MLm_{50\%}$ was estimated to be 11 cm (females) and 9 cm (males) in Tunisian waters (Ezzeddine-Najai, 1997), and 9.5 cm (females) and 8.5 cm (males) in the Adriatic Sea (Krstulović Šifner and Vrgoč, 2009a). Also in the Adriatic Sea, Ikica *et al.* (2011) gives estimates of 7.2 cm and 9.5 cm for $MLm_{50\%}$ in females and males, respectively.

In the Gulf of Cádiz, the spawning season extends throughout most of the year, although there is little or no spawning during summer (Silva *et al.*, 2004). Most spawning is during February–May, but with a secondary peak in September in southern Portuguese waters (Lourenço *et al.* 2008) or in October in the Gulf of Cádiz (Silva *et al.*, 2004). Southwestern and central Mediterranean populations have similar spawning seasons, although slightly time-shifted relative to the Atlantic populations: spawning females are found from November to June–July, peaking between February and May in the Gulf of Gabes (Ezzeddine-Najai, 1997) and between January and April in the Adriatic Sea (Krstulović Šifner and Vrgoč, 2009a). In the eastern Mediterranean, the reproductive season is also extended, with two spawning peaks in the Aegean Sea: one in January and the other in June (Akyol *et al.*, 2007). In contrast, in the northwestern Mediterranean, the reproductive season seems to be restricted to the period January–May (Mangold, 1983b).

As in other cephalopods, various environmental variables, particularly temperature, influence the reproductive biology of this species. Higher temperatures extend the reproductive period and affect the precocity of sexual development (Ezzeddine-Najai, 1997).

Fecundity studies undertaken throughout the distributional range of *E. moschata* indicate substantial variability in the number of oocytes per female and a relationship with the size of the animal. Mean total fecundities were estimated to be 100–500 oocytes in the western Mediterranean (Mangold, 1983b), 210–459 oocytes (mean = 310 ± 60) in the Adriatic Sea (Krstulović Šifner and Vrgoč, 2009a), 273–2896 oocytes (836 ± 193) in the Aegean Sea (Akyol *et al.*, 2007), and 187–944 oocytes (443 ± 154) in the Gulf of Cádiz (Silva *et al.*, 2004). As in other octopus species, there are usually residual oocytes in the ovaries, especially in more mature females. The observed mean number of residual oocytes in females from the Gulf of Cádiz was 295.73 ± 132.079 (6.6% ± 2.91 of the total number of oocytes). There, the average relative fecundity was estimated to be 1.43 ± 0.36 oocytes g^{-1} of female total weight. In the Gulf of Cádiz, the mean size of the largest oocytes was 10.90 ± 1.22 mm, with a maximum size of 14.8 mm. The mean size of all the sampled non-residual oocytes was 10.24 ± 1.07 mm (Silva *et al.*, 2004). In the Adriatic Sea, mean oocyte length and width were 9.39 ± 1.99 mm and 2.57 ± 0.72 mm, respectively (Krstulović Šifner and Vrgoč, 2009a). In the Aegean Sea, Akyol *et al.* (2007) reported an average oocyte length of 6.26 ± 0.10 mm, with a range of 2.6–10.7 mm.

In the Gulf of Cádiz, the mean length of fully developed spermatophores was 13.88 ± 1.60 mm (Silva *et al.*, 2004). The maximum and minimum spermatophore lengths were 17.5 and 10.9 mm, respectively, which were found in two males of 240 (100 mm ML), and 98 g (60 mm ML), respectively. In the Aegean Sea, the average number of spermatophores ranged between 6 and 172 (mean = 52 ± 6), with a mean length of 13.66 ± 0.08 mm (range = 7.3–18.3 mm) (Akyol *et al.*, 2007). In the Adriatic Sea, the number of spermatophores was 45–287 (mean = 120 ± 60), with mean length of 17.71 ± 3.27 mm (range = 9–23 mm) (Krstulović Šifner and Vrgoč, 2009a). In the western Mediterranean, the mean number of spermatophores is ca. 106, with lengths (range = 15–20 mm (Mangold-Wirz, 1963a). The number and size of both oocytes and spermatophores depend mainly on the size of the animal.

Internal insemination has been confirmed by the presence of sperm sacs in the ovaries of some females. However, the number of females found in that state has been small, indicating that the number of spermatophores that reach the ovary is low and that copulation takes place shortly before spawning (Mangold, 1983b).

5.6 Biological distribution

5.6.1 Habitat

Eledone moschata is a coastal species, living on soft sandy and muddy bottoms, occasionally on gravel. It does not seem to live in rocky areas, except possibly when spawning (Gamulin-Brida and Ilijanić, 1972; Mangold, 1983b). It is mainly distributed at depths of 15–200 m in both Mediterranean waters and Iberian waters of the Gulf of Cádiz, where it is most abundant in shallow waters down to 100 m (Gamulin-Brida and Ilijanić, 1972; Salman *et al.*, 1997; Lefkaditou *et al.*, 1998a; Belcari *et al.*, 2002a; Silva *et al.*, 2004). In the northern Adriatic, densities were nearly 700 km^{-2} at 10–50 m, but decreased to <300 km^{-2} at 50–100 m and to ca. 30 km^{-2} at 100–200 m (Krstulović Šifner *et al.*, 2011). In some areas, it is found at greater depths: to 450 m in the Gulf of Cádiz (Silva *et al.*, 2004), 612 m in southern Portuguese waters (Lourenço *et al.*, 2008), and 320

m in the Aegean Sea (Salman *et al*., 2000). In the western Mediterranean, it is found in water temperatures of 12–23°C and salinities of 36.5–38.5 (Mangold, 1983b).

5.6.2 Migrations

In the Mediterranean Sea, *E. moschata* seems to undergo horizontal migration related to reproduction, moving inshore to spawn (Mangold, 1983b; Mandić and Stjepcević, 1981). According to Mangold (1983b), when not migrating inshore and offshore, *E. moschata* is a truly sedentary species, but it does not seem to be solitary. In the laboratory, the animals seem to be active at night, but quiescent during the day (Mangold, 1983b).

5.7 Trophic ecology

5.7.1 Prey

Eledone moschata preys mainly on crustaceans (Table 5.2). In the Adriatic Sea, there were crustaceans in 65.0% of stomachs that contained food, and fish and cephalopods were present in 37.8 and 21.8% of stomachs, respectively (Krstulović Šifner and Vrgoč, 2009b). That study also showed that the diet of *E. moschata* varies according to body size. Small animals (<80 mm ML) fed mainly on crustaceans (which represented 69% by weight of prey), and larger ones on both fish (37%) and crustaceans (31%). In Izmir Bay (Aegean Sea), prey was dominated by crustaceans, but also included fish, gastropods, bivalves, and urchins. Differences in stomach fullness were observed between morning and midday periods (Şen and Akyol, 2011).

Table 5.2. Prey composition of *Eledone moschata*, as known from studies in the central and eastern Mediterranean (compiled from Krstulović Šifner and Vroč, 2009b[1]; Şen and Akyol, 2011[2]).

Taxon	Species
Osteichthyes	indet.[1,2]
Cepolidae	*Cepola macrophthalma* (as *C. rubescens*) (red bandfish)[1]
Clupeidae	*Sardina pilchardus* (European pilchard)[1]
Engraulidae	*Engraulis encrasicolus* (European anchovy)[1]
Gobiidae	*Gobius* spp.[1], indet.[1]
Merlucciidae	*Merluccius merluccius* (European hake)[1]
Crustacea	indet.[2]
Decapoda	
Dendrobranchiata-Penaeiodea	*Penaeus* spp.[1]
Pleocyemata-Anomura	*Anapagurus laevis*[1], *Munida rugosa*[1], Paguridae indet.[1]
Pleocyemata-Brachyura	*Liocarcinus depurator*[1], *Macropodia longirostris*[1], *Portunus* spp.[1]
Pleocyemata-Caridea	*Alpheus glaber*[1], *Macrobrachium sintangense* (as *Palaemon elegans*)[1], *P. adspersus*[1], Palaemonidae indet.[1]
Amphipoda	indet.[1]
Mysida	indet.[1]
Ostracoda	indet.[1]
Copepoda	*Ctenocalanus vanus*[1], indet.[1]
Cephalopoda	indet.[1]
Myopsida	*Alloteuthis media*[1], *Loligo vulgaris*[1], Loliginidae indet.[1]

Octopoda	*Eledone moschata*[1], indet.[1]
Sepioidea	*Sepietta oweniana*[1], Sepiolidae indet.[1]
Gastropoda	indet.[2]
Bivalvia	indet.[2]
Echinodermata	
Echinoidea	indet.[2]

5.7.2 Predators

Octopod beaks in stomach contents have not always been identified to species level. Clarke (1986) indicated that it was difficult to distinguish lower beaks from the three subfamilies of the Octopodidae, although some species can certainly be separated (e.g. *Octopus vulgaris* from *E. cirrhosa* (M. B. Santos, pers. comm.). Nonetheless, this species is known from cephalopod, fish, seal, turtle, and cetacean stomachs (Table 5.3).

Table 5.3. Known predators of *Eledone moschata* in the Mediterranean Sea and Northeast Atlantic.

Taxon	Species	References
Cephalopoda	Common octopus (*Octopus vulgaris*)	Kallianiotis *et al.* (2001)
Chondrichthyes	Bull ray (*Pteromylaeus bovinus*)	Capapé (1977)
	Smooth-hound (*Mustelus mustelus*)	Saïdi *et al.* (2009)
Osteichthyes	Common dolphinfish (*Coryphaena hippurus*)	Massutí *et al.* (1998)
	Swordfish (*Xiphias gladius*)	Salman (2004)
Pinnipedia	Monk seal (*Monachus monachus*)	Salman *et al.* (2001), Pierce *et al.* (2011)
Cetacea	Bottlenose dolphin (*Tursiops truncatus*)	Blanco *et al.* (2001), Poldan (2004)
Turtles	Loggerhead sea turtle (*Caretta caretta*)	Katić (2006)

5.8 Other ecological aspects

5.8.1 Parasites

Hochberg (1983) documents the presence of fungi, ciliates, dicyemids, helminths (including digeneans and cestodes), nematodes, and copepods in *Eledone* spp. Parasites specifically identified in *E. moschata* include the sporozoan *Aggregata "octopiana"*; dicyemids *Dicyema moschatum* and *Dicyemennea eledones*; the helminths *Scolex p. unilocularis*, S. *p. quadrilocularis*, *Acanthobothrium* sp., *Orygmatoscolex pusillum*, *Phyllobothrium pusillus*, and *Nybelinia lingualis*; the nematode *Ascaris moschata*; and the copepod *Pennella varians* (Hochberg, 1983, pers. comm.).

5.9 Fisheries

In the Atlantic (where it is found in the Gulf of Cádiz and along the adjacent Iberian and African coasts), *E. moschata* is taken as bycatch by the Portuguese and Spanish bottom-trawl fleets, although in many cases it is discarded because of its low commercial value. In Portugal, for example, 80–100% of *E. moschata* catches taken by the trawl fleets are usually discarded (Moreno *et al.*, 2010). In recent years (1996–2010), annual landings of musky octopus in the main Spanish ports of the Gulf of Cádiz have averaged ca. 100 t (50–230 t), with a peak between January and April.

Eledone moschata is commercially important throughout the Mediterranean, where it is fished mainly with bottom trawls. Catches obtained with other gear are of lesser importance (Relini *et al.*, 1999). Its economic importance in many Mediterranean countries reflects its great abundance, particularly along the southern and eastern coasts and in the Adriatic Sea (Belcari *et al.*, 2002a). It is especially abundant in the northern Adriatic, where, in early winter, bottom-trawl yields of up to 53 kg h^{-1} may be achieved (Manfrin-Piccinetti and Rizzoli, 1984). However, *E. moschata* is discarded as bycatch by Turkish bottom trawlers because of its poor commercial value (Akyol *et al.*, 2007).

Eledone moschata catches are generally pooled with those of *E. cirrhosa* and *O. vulgaris* in commercial landings and in Mediterranean fishery statistics (Sánchez and Martín, 1993; Belcari *et al.*, 1998). For a summary of recent FAO statistics on octopod catches in the Mediterranean, see the chapters on *E. cirrhosa* and *O. vulgaris*; even when distinguished from landings of *O. vulgaris*, landings for both *Eledone* species are pooled in the FAO database. Although *E. moschata* is a separate category in landings for the Northeast Atlantic, the only record of this species in the FAO database is 1 t landed by Portugal in 2006.

5.10 Future research, needs, and outlook

Important topics for future research on the species include stock separation and investigations of spawning sites. Little is known about its ecology. As is the case for other exploited European cephalopods, separate recording of landings statistics would both enhance our understanding of stock status and help facilitate routine stock assessment. Previous taxonomic work (F. G. Hochberg, pers. comm.) suggests that *E. moschata* is sufficiently different from other *Eledone* species to warrant being placed in a separate genus. This possibility should be pursued with molecular techniques.