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Review of the biology, ecology and fisheries of *Palinurus* spp. species of European waters: *Palinurus elephas* (Fabricius, 1787) and *Palinurus mauritanicus* (Gruvel, 1911)

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Abstract: *Palinurus elephas and Palinurus mauritanicus* are the only species of the family Palinuridae that occur in the Northeast Atlantic and Mediterranean. Of the two, *Palinurus elephas* is the most abundant and accessible and has traditionally been the preferred target of lobster fisheries throughout its range. *Palinurus mauritanicus* has a deeper distribution and has been an important target of fisheries mainly in the Central Eastern Atlantic. The high unit value and the relative scarcity of these species have been important obstacles to research and knowledge of their biology, ecology and fisheries is limited. Nevertheless, over time a considerable number of studies has been conducted, though most of these are contained in university theses or in publications of limited circulation. This review is an up-to-date overview of available knowledge on the biology, ecology and fisheries of the two spiny lobster species of European waters.

Résumé : *Une revue sur la biologie, l'écologie et les pêcheries des espèces de* Palinurus *des eaux européennes :* Palinurus elephas *(Fabricius, 1787) et* Palinurus mauritanicus *(Gruvel, 1911). Palinurus elephas* et *Palinurus mauritanicus* sont les seuls représentants de la famille des Palinuridés dans le Nord Est Atlantique et en Méditerranée. La langouste rouge *Palinurus elephas*, la plus abondante et la plus accessible des deux espèces, est exploitée depuis plus d'un siècle sur l'ensemble de son aire de répartition. La langouste rose *Palinurus mauritanicus*, qui vit dans des eaux plus profondes, a permis le développement conjoncturel de petites pêcheries dans les eaux européennes et d'une importante pêcherie en Atlantique Centre Est. Bien que l'acquisition de connaissances sur la biologie, l'écologie et les pêcheries des deux espèces ait été entravée par leur forte valeur économique unitaire et par leur relative rareté, de nombreuses études ont été réalisées au fil du temps. Dans la plupart des cas les résultats sont publiés dans des revues à diffusion limitée ou dans des thèses. La présente revue recense ces études et fait un point sur l'état actuel des connaissances en matière de biologie, d'écologie et de pêcheries pour chacune des deux espèces.

Keywords: Review, Spiny lobsters, European waters, Biology, Ecology, Fisheries

Introduction

This review encompasses the two spiny lobster (Family: Palinuridae) species that inhabit European waters, *Palinurus elephas* (Fabricius, 1787) and *Palinurus mauritanicus* (Gruvel, 1911). Of these, *P. elephas* is the most abundant and accessible and has traditionally been the preferred target of fisheries off Ireland, the UK, France, Portugal, Spain, Italy, Greece, Tunisia, Morocco and adjacent Mediterranean waters. The second species, *P. mauritanicus*, is less accessible due to a deeper distribution but

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has been an important target of fisheries in the Eastern Central Atlantic (mainly off Mauritania), where it reaches its highest densities. In European waters there are no established fisheries dedicated to *P. mauritanicus* which is only sought at certain times and locations, or is caught in the *P. elephas* fishery. *P. elephas* commands higher prices than *P. mauritanicus* in European markets. Neither species have been extensively studied probably because of the high costs of the animals that reduce sampling and experimental possibilities. Their high unit value also makes the fisheries economically feasible despite low yields and is the prime cause for the overfished status of their populations.

A number of studies has been conducted on *P. elephas*, mainly before the 1970s, covering various aspects of the biology and fisheries of Atlantic (Cunningham, 1892, Bouvier, 1914; Fage, 1927; Heldt, 1929; Orton & Ford, 1933; de Vasconcellos, 1960; Gibson & O'Riordan, 1965; Hepper, 1967, 1970 & 1977; Corral, 1968; Giménes, 1969; Mercer, 1973; Ansell & Robb, 1977; Hunter et al., 1996) and Mediterranean (Santucci, 1925, 1926 & 1928;

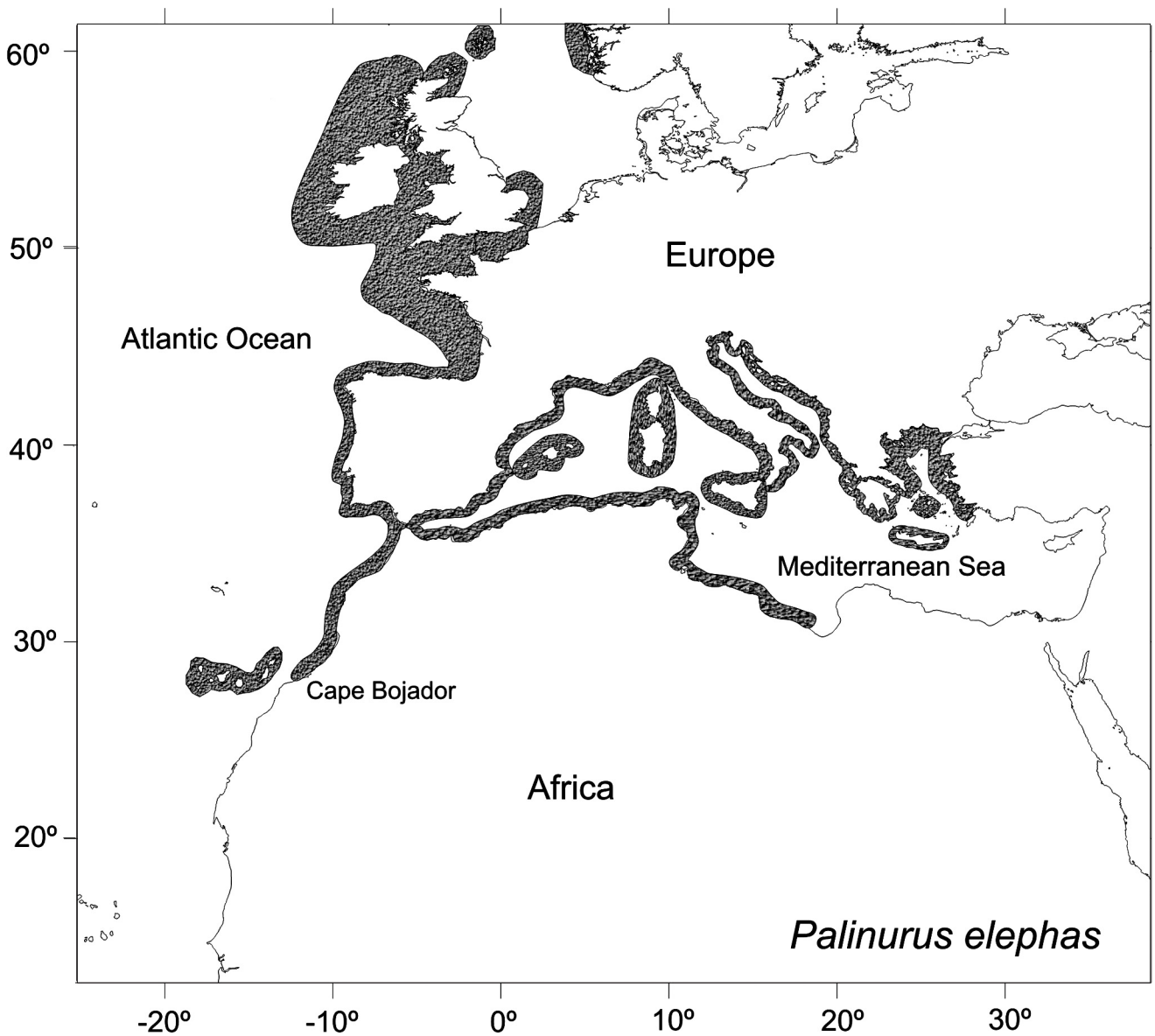

Figure 1. Geographic distribution of *Palinurus elephas*. After Holthuis (1991) except for presence in the Canary that has been recently indicated by local sources (R. Herrera, pers. comm.) and in the Azores (Udekem d'Acoz d', 1999) (not in map).

Figure 1. Distribution géographique de *Palinurus elephas*. D'après Holthuis (1991) sauf la présence aux Canaries récemment signalée de sources locales (R. Herrera, comm. pers.) et aux Açores (Udekem d'Acoz d', 1999) (hors carte).

Gamulin, 1955; Karlovac, 1965; Campillo & Amadei, 1978; Campillo et al., 1979; Campillo, 1982; Marin, 1985, 1987) populations. Many of these studies were covered in a review of the species published by Hunter in 1999. However, Hunter's review does not cover work done on Mediterranean populations after 1987, or on Atlantic populations after 1996. Yet, in recent years a good deal of new knowledge has became available on this species, particularly on larval ecology and recruitment (Kitakka & Abrunhosa, 1997; Díaz et al., 2001; Kittaka et al., 2001), adult ecology and habitat (Relini & Torchia, 1998; Cuccu, 1999; Cuccu et al., 1999; Secci et al., 1999; Quetglas et al., 2001), diet (Goñi et al., 2001a), reproduction (Latrouite & Noël, 1997; Goñi et al., 2003a), growth (Cuccu, 1999; Follesa et al., 2003), genetics (Cannas et al., 2003), fisheries (Petrosino et al., 1985; Zarrouk, 2000; Soldo et al., 2001; Gristina et al., 2002, Goñi et al., 2003b, 2003c; Gristina & Gagliano, 2004) and responses of populations to protection (Goñi et al., 2001b; Goñi et al., 2003a). Some of these studies are in unpublished reports or in publications of limited circulation. For *P. mauritanicus* the available knowledge is scattered in a series of old, poorly known documents that have never been subject of review.

Palinurus elephas

Biology and Ecology

Geographic distribution

The European spiny lobster *Palinurus elephas* is distributed in the Eastern Atlantic from Norway to Morocco and throughout the Mediterranean, except in the extreme eastern and south-eastern regions (Holthuis, 1991). Although not cited by Holthuis, it is also present in the Canary Islands (R. Herrera, pers. comm.) (Fig. 1), the Azores (Udekem d'Acoz, 1999), and probably also in the Madeira Islands.

Ecology and habitat

Palinurus elephas lives between the shore and 200 m depth on rocky and coralligenous substrates where micro-caves and natural protective holes are numerous (Ceccaldi & Latrouite, 2000). In the Western Mediterranean, post larvae settle during the summer in holes and crevices at 5-15 m depth (Díaz et al., 2001), although they have also been observed up to 35 m depth in late summer (Goñi et al., unpublished data). Early juveniles leave shelters to forage at night (Díaz et al., 2001). Little is known about the preferred habitat of juveniles but observations off Ireland by Mercer (1973) indicate that they occur in groups and tend to inhabit crevices. In contrast with this observation, Marin (1987) reported large quantities of late juveniles (modal size 60 mm CL) off Corsica in experimental trawls over *Posidonia oceanica* beds at 15-25 m depth. Their presence in *Posidonia* meadows along the Iberian Peninsula has only been reported by Jiménez et al. in one location (1996) despite intensive census work with a variety of objectives over the years.

Adult *P. elephas* are solitary, in pairs or small groups preferentially at the base of rock or boulders over gravel beds. Like the juveniles, they are primarily active at night, their movements are generally limited and seem motivated by foraging and reproduction. In the Atlantic *P. elephas* undertakes a pre-reproductive spring onshore migration and a reverse post-reproductive offshore migration in late autumn (Mercer, 1973; Ansell & Robb, 1977). A similar behaviour has been postulated for *P. elephas* off the Columbretes Islands (western Mediterranean) (Goñi et al., 2001b). Tag-recapture studies conducted both in the Atlantic and the Mediterranean indicate that adult movement is restricted, with most animals moving less than 5 km and exceptionally up to 20 km after 1 to 8 years at large (Hepper, 1967 & 1970; Marin, 1987; Goñi et al., 2001b; Cuccu, 1999). However, two reports of movements of 50 and 70 km have been made in the Mediterranean (Relini & Torchia, 1998; Secci et al., 1999).

P. elephas preys on a variety of benthic organisms. Mercer (1973) and Goñi et al. (2001a) quantitatively describe their natural diet off Ireland and the Western Mediterranean respectively. *P. elephas* is highly omnivorous and preys on hard–shelled bottom dwelling organisms, principally molluscs, echinoderms and crustaceans. It is a generalist, opportunistic feeder that appears to change its food preferences as a function of the abundance of benthic organisms. While molluscs and sea urchins are the most important prey in the diet of the species, other prey such as decapod crustaceans, ophiuroids or coralline algae are consumed in certain areas and not in others (Goñi et al., 2001a).

Growth

Ecdysis in *P. elephas* is similar to that of other Palinurids (see Mercer, 1973 for a detailed description). The lobster remains under cover without feeding for one week before moulting which would take 10-15 minutes to complete. After moulting it takes about 7-19 days (Karlovac, 1965) or 4-7 days (Cuccu, 1999) for the new shell to become hardened. The intermoult stage, when increase in weight ceases, is attained 3-5 weeks after moulting (Mercer, 1973). In the Mediterranean mature females are berried from mid summer to late winter (Goñi et al., 2003a) and moult 1-2 times per year, mainly in April-May (Marin, 1987), and possibly also in winter after hatching (Cuccu, 1999; Goñi et al., unpublished data). In the Atlantic mature females are

berried from mid-autumn to late spring and appear to moult only once a year in June-August prior to mating (Mercer, 1973; Latrouite & Noël, 1997). According to Mercer (1973), mature males off Ireland follow the same pattern but with a more extended moulting season. Off the Columbretes Islands (Western Mediterranean) males were moulting massively in February, and data from captive Columbretes males show another moulting peak in the fall (Goñi et al., unpublished data). Observations by Marin (1987) in Corsica showed that the number of moults per year is related to size and decreases after sexual maturity faster in females than in males (Cuccu, 1999; Follesa et al., 2003). Juveniles moult 2-3 (Marin, 1987) and up to 5 times (Corral, 1968; Cuccu et al., 1999) per year, decreasing to one moult or less per year in adults (Marin, 1987).

Growth in the wild

Growth studies of *P. elephas* in the wild have been conducted by means of tag-recapture experiments. Growth increments reported in different studies are difficult to interpret because of the varying size of the lobsters involved, and the different times at large and growth conditions experienced. Common to all growth studies based on tag-recapture is that growth rates will tend to be underestimated as lobsters moulting more often will be more likely to loose their tags (Hepper, 1970). Also, zero or even negative growth increments are not rare in this type of studies.

Growth per moult of males 55-100 mm carapace length (CL) and of females 55-130 mm CL off Corsica was arithmetic for both sexes, and larger for males than for females (Marin, 1987):

Males: $CL_1 = 0.99\ CL_0 + 6.97$ (mm) (n= 21) (1)

Females: $CL_1 = 0.99\ CL_0 + 5.68$ (mm) (n= 27) (2)

The parameters of the von Bertalanffy growth equation estimated by Marin (1987) resulted in an estimated life span of about 15 years:

Males: $CL_\infty = 166$ CL (mm), $K = 0.151$, $t_o = 0.348$ (3)

Females: $CL_\infty = 136$ CL (mm), $K = 0.189$, $t_o = 0.342$ (4)

Large-sized *P. elephas* tagged-recaptured by Hepper (1970 & 1977) off Cornwall indicated mean moult increments < 2 mm CL even after more than 2 years at large, while field observations by Mercer (1973) off Ireland yielded much larger growth increments (about 12 mm CL for both males and females). Assuming that it takes one year from the first larval stage to reach 35 mm CL and that juveniles moult at least twice a year up to the size at first maturity, Mercer (1973) estimated the size at age of *P. elephas* off Ireland:

Age	Male (CL-W)	Female (CL-W)
2-3 years	87 mm – 0.455 kg	86 mm – 0.510 kg
5-6 years	123 mm – 1.245 kg	122 mm – 1.225 kg
8-9 years	160 mm – 2.680 kg	158 mm – 2.350 kg

According to the above data from Marin (1987) and Mercer (1973), and contrary to Hunter's (1999) conclusion, *P. elephas* would grow faster and attain a larger maximum size in the Atlantic than in the Mediterranean:

- Western Mediterranean: 175 mm CL (n = 417) and 160 mm CL (n = 278) for males and females off Corsica (Campillo & Amadei, 1978).
- Atlantic: 200 mm CL (n = 65) and 170 mm CL (n = 70) for males and females off Brittany (Latrouite & Noël 1997); 190 mm CL (n = 298) and 153 mm CL (n = 586) for males and females off Ireland (Mercer, 1973).

Nevertheless, these estimates should be taken with caution as maximum sizes observed in different areas and times are not easy to interpret. The maximum size of lobsters in an exploited population depends on the level and pattern of exploitation and the observed values may be influenced by various factors such as sample size, sampling method, habitat, season and depth.

Biometric relationships

Total length (TL) measured from the tip of the rostrum (medial spine between the eyes) (or from the supra-orbital spine in some studies) to the posterior end of the telson has long been used as the reference for the minimum legal size (MLS), and some authors have used it in scientific publications. However, currently CL, measured from the tip of the rostrum to the posterior margin of the cephalothorax, is now employed more often. Hunter (1999) summarizes the TL-CL and CL-weight (W) relationships published before 1996 for different populations. Not covered in that review, newly available relationships (TL and CL in mm, W in g) for various areas are:

Brittany (Latrouite & Noël, 1997):

Males: $TL = 2.32\ CL + 44.2$ (n = 65, range 86-203 mm CL) (5)

$W = 0.0013\ CL^{2.856}$ (n = 65, range 86-203 mm CL) (6)

Females: $TL = 2.65\ CL + 27.1$ (n = 69, range 93-148 mm CL) (7)

$W = 0.0026\ CL^{2.726}$ (n = 70, range 94-148 mm CL) (8)

Tunisia (Quetglas et al., 2005)

Males: $TL = 2.34\ CL + 38.36$ (n = 91, range 61-167 mm CL) (9)

$W = 0.0029 * CL^{2.667}$ (n = 70, range 61-167 mm CL) (10)

Females: $TL = 2.48\ CL + 32.54$ (n = 89, range 93-148 mm CL) (11)

$W = 0.0069\ CL^{2.486}$ (n = 65, range 58-132 mm) (12)

Columbretes Islands (Central-Western Mediterranean) (Quetglas et al., 2005):

Males: $TL = 2.51\ CL + 32.04$ (n = 370, range 45-169 mm CL) (13)

$W = 0.0012\ CL^{2.882}$ (n = 370, range 45-169 mm CL) (14)

Females: $TL = 2.88\ CL + 12.51$ (n = 441, range 41-142 mm CL) (15)

$W = 0.0016\ CL^{2.834}$ (n = 442, range 41-142 mm CL) (16)

Reproduction

Mercer (1973) describes the mating process of *P. elephas* in detail. Copulation occurs, sternum to sternum, between

intermoult individuals a few weeks after the female moult. The male deposits two spermatophores of a milky-white gelatinous texture on the two sides of the female's sternum, below the genital openings. The spermatophores of *P. elephas* do not harden to form a permanent tar-spot as in other Palinurids and disappear after a short time; thus they are only occasionally observed (Hunter et al., 1996; Goñi et al., 2003a).

In the Atlantic**,** mating is reported to occur between June and October, depending on the region (De Vascondellos, 1960; Gibson & O'Riordan, 1965; Mercer, 1973; Hunter et al., 1996). In the Western Mediterranean females bearing spermatophores may be seen from July to September (Marin, 1985; Goñi et al., 2003a). Oviposition takes place shortly after mating (i.e., 2 days, Mercer, 1973; 5-10 days, Ansell & Robb 1977) and eggs are shed across the spermatophoric masses while the female scratches them with the 5th walking leg and the eggs are fertilised; egg extrusion may take place in less than two hours (Mercer, 1973). Egg-laying peaks in September in the Western Mediterranean (Gamulin, 1955; Campillo & Amadei, 1978; Marin, 1985; Goñi et al., 2003a) and in September-October in the Atlantic (Mercer, 1973; Hunter et al., 1996; Latrouite & Noël, 1997). In Greece, females with eggs have been observed from August to November (Moraitopoulou-Kassimati, 1973).

Egg incubation lasts 4-5 months in the Western Mediterranean (Campillo & Amadei, 1978; Marin, 1985; Goñi et al., 2003a) and 6-10 months in the Atlantic (Mercer, 1973; Latrouite & Noel, 1997; Hunter, 1999). Hatching occurs in December-February in the Mediterranean (Gamulin, 1955; Campillo & Amadei, 1978; Goñi et al., 2003a) and in March-June in the Atlantic (Mercer, 1973; Hunter et al., 1996; Latrouite & Noël 1997). Hatching may be completed in 24 hours (Mercer, 1973), although in aquaria it may last up to 8 days (Karlovac, 1965).

The mean size at maturity also varies regionally. In Brittany, the mean size of functional maturity (ability to mate and lay eggs) of *P. elephas* was estimated at 95 mm CL (Latrouite & Noël, 1997; smallest berried: 92 mm CL). In Ireland**,** Mercer (1973) estimated the size of 50% physiological maturity of females by the presence/absence of ovigerous setae to be 82 mm CL; he estimated male size of 50% physiological maturity at 84.5 mm CL. In the Western Mediterranean**,** a recent study of the reproductive biology of a protected *P. elephas* population concluded that the physiological and functional maturity of females was attained simultaneously at a mean size of 76-77 mm CL, while the male physiological maturity was attained at a larger size (82.5 mm CL) but at the same age (Goñi et al., 2003a). However, off Corsica, Marin (1987) observed a 1-year lag between female physiological (ovary maturation) and functional maturity (86 mm CL), and estimated male physiological maturity at a mean size of 76 mm CL. Discrepancies between the size at maturity values provided by different authors and between regions are difficult to explain because estimates of size-at-maturity differ depending on the maturity criteria used as well as on the sampling period, and the number and size range of the specimens (Chubb, 2000). Furthermore, factors such as food availability, population density, or water temperature are known to influence growth rates and thus size at maturity (Goñi et al., 2003a).

P. elephas is 3 to 5 times less fecund than other commercial lobsters of the family Palinuridae, such as the genera *Jasus* or *Panulirus* and only one clutch is incubated annually (Hunter, 1999). Fecundity of *P. elephas* from the Atlantic was studied by Mercer (1973) and the relationship of number of eggs laid and body size was described by the linear equation:

$$F = 2552\ CL - 165602 \quad (n = 254, \text{range: } 80\text{-}154 \text{ CL mm}) \qquad (17)$$

In the Western Mediterranean, the fecundity-body size relationship of *P. elephas* has been studied in the exploited population off Corsica (Campillo, 1982) and in the protected population of the Marine Reserve of Columbretes Islands: (Goñi et al. 2003a):

Corsica:

$$F = 3003\ CL - 229809 \quad (R^2 = 0.97, n = 24) \qquad (18)$$

Columbretes Islands:

$$F = 2428\ CL - 148988 \quad (R^2 = 0.85, n = 70) \qquad (19)$$

These equations show that absolute fecundity increases with body size up to the maximum size and, hence, that senescence does not occur. However, maximum relative fecundity (nb eggs/body gram) in Western Mediterranean *P. elephas* is reached at intermediate sizes (100-110 mm CL) (Campillo, 1982; Goñi et al., 2003a). For most of the mature female size range, individual fecundity in the Corsica population was lower than in the protected population. This could be due to the greater availability of large males in the unfished population and to their potential greater contribution to reproduction relative to small males (MacDiarmid & Butler 1999). Interestingly, size-specific fecundity in the protected population coincides with that estimated by Mercer (1973) on the then lightly fished population off Ireland. These studies do not support either the hypothesis of density dependence of spiny lobster fecundity nor that of higher size-specific female fecundity following exploitation (Goñi et al., 2003b). Nevertheless, factors such as increased variation in fecundity among larger females and small sample sizes (in the case of Campillo's sample) complicate attempts to compare size-specific fecundity between populations (Somers, 1991).

Egg loss during incubation was estimated at 10% by Mercer (1973) in Atlantic *P. elephas* and at 26-28% by Marin (1985) and Goñi et al. (2003a) in Mediterranean

specimens. The lower water temperature and the means of capture (by hand instead of netting) may explain the much lower rate of egg loss in the Atlantic study (Goñi et al., 2003a).

Larval ecology and larval settlement

As all Palinurids, the larva of *P. elephas* is a leaf-like, transparent planktonic zoea called phyllosoma (Cunningham, 1892), which is adapted to a long offshore drifting life, and is a poor horizontal swimmer, more competent at vertical movements. *P. elephas* larvae measure 2 to 3 mm TL at hatching (Mercer, 1973; Kittaka & Ikegami, 1988) and are larger than those of other species within the Palinuridae (Kittaka & Ikegami, 1988). Based on the morphology of the mouthparts and on their low survival with diatom culture water, Kittaka & Abrunhosa (1997) surmised that *P. elephas* phyllosomas are rapacious predators.

By comparison with other spiny lobster species, *P. elephas* has an exceptionally short larval cycle under cultured conditions, ranging from 149 days (9 instars) to 65 days (6 instars) depending on food type (Kittaka et al. 2001). In natural plankton samples, Bouvier (1914) described 10 phyllosoma stages, the last of which was found moulting into the puerulus stage. Santucci (1925, cited in Orton & Ford, 1933) described phyllosoma stages I-IX, corresponding to those of Bouvier. However, uncertainties remain in the descriptions of progressive phyllosoma stages because of their reliance on wild source material (Kittaka et al., 2001).

Phyllosomas appear to exhibit positive phototropism (Bouvier, 1914; Fage, 1927; see also Hunter, 1999) and hundreds of early larvae were collected in surface towed nets by Cunningham (1892). In contrast, Russell (1927) indicated that phyllosomas were rarely found above 10 m and described a large catch of 75 specimens at 36 m in July in the Plymouth area. Thus, it is not known when they become negatively phototropic, as has been reported for larvae of other Palinurids (Fage, 1927). Based on known behaviour of phyllosomas of *Scyllarus arctus* (Linnaeus, 1758) and *Palinurus gilchrist* (Stebbing, 1900), Fage (1927) suggested that the weight gain through development forces late instars to sink, and that *P. elephas* puerulii are poor swimmers for whom staying in midwater becomes an increasingly difficult task as they gain weight. Because puerulii are very rarely observed and the few existing records originate primarily from midwater trawls (or from stomachs of pelagic fishes, Fage, 1927; Heldt, 1929), Bouvier (1914) and Fage (1927) concluded that puerulii must spend most of their time sheltered in crevices or among weed, although they are prepared for swimming (Caroli, 1946). Puerulii were recorded off England in July and September (Bouvier, 1914; Orton & Ford, 1933), from the Tyrrhenian Sea and the Gulf of Naples in April (Santucci, 1926; Caroli, 1946) and measure 17.5 to 21 mm TL (Orton & Ford, 1933; Caroli, 1946). The puerulus has a well-developed abdomen and a translucent exoskeleton that acquires a darker colour and moults (10-15 days later) into the postpuerulus, a young lobster about 2 cm long (Santucci, 1926; Orton & Ford, 1933). Strikingly, no new knowledge of the larval life of *P. elephas* has been acquired since these early studies.

Eggs apparently hatch inshore, where the early larval stages are common (Mercer, 1973). Yet, late larval stages may be found offshore at variable distances (up to 100 nautical miles); thus metamorphosis to the natant puerulus stage may occur at a considerable distance from the shore (Mercer, 1973). The puerulii are again found inshore (Bouvier, 1914; Fage, 1927; Caroli, 1946; Mercer, 1973). Since phyllosomas are not capable of swimming large distances, it is thought that water movements govern their movements. Mercer (1973) hypothesizes that off Ireland early larvae are carried offshore and caught up in a series of circular slow-moving currents, where larval development continued, and the late larval or puerulus stages are returned by offshoots of the main currents to coastal waters. In the Atlantic, Bouvier (1914) found instars I to X in summer and Mercer (1973) found early instars (I-III) from June and later stages (VII onwards) from July. In the Adriatic, different stage phyllosomas have been recorded from December to March (Gamulin, 1955) and in the Western Mediterranean from January to March (references in Hunter, 1999). Based on these observations and the hatching periods, the duration of the pelagic larval life has been estimated in 5-6 months in the Mediterranean (Marin, 1985) and 10-12 months in the Atlantic (Mercer, 1973). However, that post-embrionic development in captivity has been as short as 2 months (Kittaka et al., 2001) suggests great plasticity of larval development and raises questions about the validity of these estimated periods.

Settlement of puerulii, measuring 7-8 mm CL, in the North-western Mediterranean has been observed in date (*Lithophaga lithophaga* Linnaeus, 1758) holes of limestone rocks from June to July, a few weeks after sea surface temperature starts to rise (Díaz et al., 2001). However, underwater visual censuses in different Western Mediterranean locations indicate that post-puerilii may also be found in crevices of volcanic rocks, apparently concentrating in shallow depths (10-30 m, Díaz et al., 2001; Goñi et al., unpublished data) and relocating to deeper waters as they grow. On this basis and to explain the observed concentrations of late juveniles in 60-80 m depth off the Columbretes Islands (Western Mediterranean), Goñi et al. (2001b) postulated that a migration of juveniles takes place from the shallow settlement habitats to deeper habitats, presumably during winter or spring. From late June to August many hundreds of juveniles (20-50 mm CL) lying in crevices off

Ireland were reported by Mercer (1973). Apart from these few accounts, the life of post-larvae and juvenile *P. elephas* through adulthood remains virtually unobserved.

Natural mortality

As for many other species, predation is probably the major cause of natural mortality of *P. elephas*, particularly during moulting and juvenile stages (Marin, 1985). Both the octopus (*Octopus vulgaris* Cuvier, 1797) and the dusky grouper (*Epinephelus marginatus* Lowe, 1834) are known predators of *P. elephas* in the Western Mediterranean (Quetglas et al., 2001). Other known predators in the region are *Labrus* spp., *Scorpaena* spp., and *Serranus* spp. (Marin, 1987) but pelagic fishes also predate on puerulii (Fage, 1927; Heldt, 1929; Legendre, 1936 cited in Caroli, 1946). A study of *P. elephas* diet did not reveal cannibalism under natural conditions (Goñi et al., 2001a) although it has been observed in captivity (Marin, 1987). Based on knowledge of the life cycle of the species – slow growth, large size – Marin (1987) estimated the instantaneous coefficient of natural mortality to be in the range of 0.15-0.30. By means of tag-recapture experiments Hepper (1977) estimated a coefficient of natural mortality of 0.11 for *P. elephas* in the Atlantic.

Fisheries

Fishing methods

Traditionally *P. elephas* was captured by means of traps/pots and sometimes by diving (Hepper, 1977; Hunter, 1996; Goñi et al., 2003a; Gristina & Gagliano, 2004). A major change in the exploitation strategy took place during the 1960s and 1970s with the progressive introduction of trammel-nets that virtually replaced other fishing methods. This change in fishing strategy not only had an impact on exploitation levels, demography and sex composition of the exploited populations (e.g. Hunter et al., 1996; Goñi et al., 2003b), but also on the image that we may obtain from the population by sampling commercial catches as they are strongly influenced by the selectivity of the gear and gear-related catchability. A comparative study of the catchability of *P. elephas* in traps and trammel-nets (Goñi et al., 2003b) demonstrated similar catchability for males and females in trammel-nets and reduced catchability of large males in traps. Comparing the selectivity of those two gears, the same study indicated that small lobsters (< 70 mm CL) are poorly retained in traps while large (> 130 mm CL) ones are less likely to enter traps due to behavioural factors, physical limitations or because they are able to feed without entering. Ongoing studies also demonstrate that, by comparison with traps, trammel-nets have poor species selectivity generating higher bycatch rates and greater physical impacts on benthic habitats through the incidental catch of structure forming species, such as sponges, bryozoans, corals and coralline algae (Goñi et al., 2003c).

Structure of exploited populations

Knowledge of the structure of exploited *P. elephas* populations comes from data of commercial or survey catches carried out in different regions since the early 1950s. These data are scant and discontinuous, therefore temporal and spatial assessments of populations' size or sex structure are difficult. In Corsica, Campillo (1982) first studied the size composition of trammel-net commercial catches through a sampling programme in 1977. The maximum sizes observed were 160 and 175 mm CL in females and males respectively, and the corresponding modal sizes were 96 and 104 mm CL. The size composition of the commercial catches in Corsica was again established through a two-year sampling program in 1983-1984. Results indicate that both modal - around 75 mm CL in both males and females - and maximum sizes - 120 and 140 mm CL in females and males respectively - had decreased substantially (Marin, 1987). Although Campillo (1982) acknowledges that in 1977 the fishery already showed signs of overexploitation, effort intensification and the widespread introduction of trammel-nets in the late 1970s and early 1980s had reduced the number of large lobsters in the population. As the traps used in the Western Mediterranean exclude, and thus protect, large *P. elephas* (mostly males), it is plausible that the change of gear, as well as the increased fishing effort, tapered the demographic structure of the fished population. The size structure of a population of *P. elephas* 10 years after the establishment of the marine reserve of Columbretes Islands (Western Mediterranean) presented modes around 100 and 100-130 mm CL for females and males. The maximum sizes were 148 and 173 mm CL in females and males (Goñi et al., unpublished data) that resembled the sizes observed earlier by Campillo (1982).

The earliest published data on the structure of Atlantic populations come from Portugal and date back to 1958 (de Vasconcellos, 1960); the modal size was 120 mm CL for males and females and the maximum sizes were 190 and 180 mm CL respectively. Hepper (1977) studying the size structure of commercial trammel-net catches from Cornwall in 1965-1975, observed male mean and maximum sizes of 145-160 mm CL and 182 mm CL, and female mean and maximum sizes of 122-134 mm CL and 152 mm CL. Ansell & Robb (1977) also found similar maximum size lobsters off Scotland during 1972-1975. Later field observations by Hunter et al. (1996) off Cornwall (1993-1994) showed that the size structure of the male Cornish populations had altered dramatically (the mean size had declined to 126 mm CL) since Hepper's (1977) study while

the female mean size has not changed (132-135 mm CL). A comparison of the Cornish with the less exploited Welsh populations and with Hepper's (1977) data from Cornwall led Hunter et al. (1996) to conclude that the reduction in mean male size was due to the change in exploitation pattern brought about by trammel-nets replacing pots during the 1970s. In Brittany, occasional samplings of trammel-net catches during 1983-2003, show that few individuals smaller than 100 mm CL are caught, modal sizes fall between 120 and 150 mm CL for males and females and maximum sizes reach 200 and 170 mm CL in males and females respectively (Latrouite & Noël, 1997). These large maximum sizes in Brittany are unexpected given the alleged overexploited status of the populations in the area.

National fisheries

Published data on *P. elephas* fisheries are scant despite their past and present socio-economic importance. Most of the following information has been found in unpublished reports or has been obtained through personal communications (Dr Oliver Tully for Ireland, Dr. Margalida Castro for Portugal, Dr. Hicham Masski for Marocco and Dr Christina Mytilineou for Greece). We are confident that the major historic and present fisheries are covered here; nevertheless, there may be fisheries of lesser but significant local importance that have not been brought to our knowledge and are not included in this overview.

Irish fisheries: presently a small fleet of 20-25 vessels target *P. elephas* from May to September with trammel-nets, although bycatch in static net fisheries, and to a lesser extent in trawls, also occurs. As in other fisheries, a major change occurred in the 1970s when pots were replaced by trammel-nets that lead to a depletion of the stocks and a very significant reduction in lobster mean size. During the period between 1990-2000 annual official landings have declined from 175 to 33 t. The MLS is currently 110 mm CL (15 mm over the EC MLS) and there are two areas closed to fishing with nets. Attempts are being made by the authorities to revert to fishing with pots.

British fisheries: in the UK, targeted *P. elephas* fisheries are restricted to Cornwall and Western Wales with occasional catches from the Scottish Western Isles (Hunter, 1999). In common with fisheries elsewhere, the species was traditionally fished with pots (and occasionally by diving), and although traps are still used in some areas, tangle and trammel-netting is now the principal means of capture. Pot CPUE declined steadily during the period 1979 to 1997 and the populations are depleted (Hunter et al., 1996).

French fisheries: according to several authors (Dupouy, 1920; Postel, 1962; Gloux & Manach, 1976), while *P. elephas* and *Homarus gammarus* (Linnaeus, 1758) had been appreciated and marketed in France for several centuries, directed fisheries in the Atlantic only started at the end of the 19th century, when a small specialised fleet developed in Brittany and fished coastal grounds. At the beginning of the 20th century, a fleet of larger boats expanded its activity to England, Ireland, Scotland, Spain, Portugal, Morocco and Tunisia. After 1960, impoverishment of the lobster stocks and closure of some foreign grounds led most vessels to shift from lobster to crab (*Cancer pagurus* Linnaeus, 1758 and *Maja brachydactyla* Balss, 1922) fishing. Currently *P. elephas* is primarily a bycatch, though economically important, of some 150 boats (12 meters in average) netting for monkfish (*Lophius piscatorius* Linnaeus, 1758*)*, rays (*Raja spp*.), turbot (*Psetta maxima* Linnaeus, 1758*)* and brill (*Scophtalmus rhombus* Linnaeus, 1758*)* with trammelnets of 240-320 mm stretched mesh (inner panel). Catches from potters and trawlers are anecdotic. Landings in 2003 were estimated at around 50 tons (Latrouite, unpublished data). Although fishing occurs year round, 80% of the fishing occurs between April and November. The MLS of 95 mm CL (EC regulation) is the only regulatory measure in place.

In the Mediterranean, a small-scale fishery developed around Corsica at the end of the 19th century (Marin, 1985). In the 1960's introduction of more efficient fishing methods (echo-sounders, net-haulers, nylon trammel-nets) led to a substantial effort increase (Giménes, 1969) followed by a sharp decline in catches. Currently the fleet is composed of about 200 boats (average 8 meters) fishing mainly in coastal waters with trammel-nets of 125-160 mm stretched mesh (inner panel). Landings were estimated at 65 t in 2004 (A. Pere, pers. comm.). The MLS is 80 mm CL, the fishery is closed from September to March and eight sanctuaries covering about 80 km^2 in total are distributed around the island.

Administration and industry reports indicate that national landings (Atlantic plus Mediterranean) were over 1000 tons between 1920 and 1925, peaked in 1947 with 2678 tons, and have decreased continuously since then. Mean annual landings were 867 tons in the 1950s, 360 tons in the 1970s, 160 tons in the 1990s and around 50 tons in recent years. Even if the accuracy of the official data is poor, the trend is robust and reflects a drastic decline of the stocks primarily due to fishing mortality, especially with nets (even if not always targeting spiny lobsters).

Portuguese fisheries: in Portugal, *P. elephas* is currently fished on the southwest coast by an artisanal fleet of around 40 vessels owning a "more than one gear" licence. During spring and summer, when catches are higher, this fleet targets spiny lobster with tangling or trammel-nets, which they haul at 1 to 4 day intervals. During the last decade, *P. elephas* landings have declined sharply from an average of 400 t in 1990-1992 to an average 6 t in 2000-2002, and the

species has virtually disappeared from depths shallower than 30 meters. The decline in the fishery can in part be accounted for by an increase in the proportion of lobsters sold outside the legal market, but the main reason is the depletion of the resource following the change from traps to gillnets and trammel-nets during the late 1960's and 1970s, and a substantial increase in fishing effort over the last 10 years due to the modernization of the fleet. The only pieces of legislation specifically geared for spiny lobster are the MLS (95 mm CL) and the prohibition of landing ovigerous females.

Spanish fisheries: lobster fishing has a long tradition off the coasts of Spain (Von Salvador, 1895; Iglesias et al., 1994). Presently, *P. elephas* fisheries are mostly restricted to the Mediterranean while in the Atlantic the species is caught as bycatch in finfish gillnet fisheries. In the Spanish Mediterranean, over 600 artisanal vessels and some 1100 fishermen engage in lobster fishing every year (Alarcón, 2001). As occurred elsewhere, trammel-nets have replaced traps in all areas, except for a relict, vanishing trap fishery in the Balearic Islands. Massuti (1973) collected catch and effort data of the lobster fishery in the Balearic Islands from 1940-1970. Mean annual catches in the period 1940-1945 were around 90 t, declining to 40-50 t in 1950-1955 and to 20 t in 1965-1970 while fishing effort tripled. As trammel-nets replaced traps at the end of that period, catches increased.

Official landings in 2000 amounted to some 2 t in the Atlantic and around 98 t in the Mediterranean. However, ongoing studies of some local fisheries in the Mediterranean indicate that official figures underestimate lobster landings because significant but variable portions are sold directly to consumers (mostly restaurants) and go unreported. Use of correction factors developed for particular locations suggest that annual *P. elephas* landings in Spain reach 200 t. It is suspected that fishing mortality rates have increased in all grounds and that most fisheries are overexploited. As no reliable fishery statistics are available, it is not possible to estimate exploitation levels, however the high recapture rates (up to 61%) of lobsters released in grounds near the Columbretes Islands (Western Mediterranean) suggest high rates of fishing mortality in that area (Goñi et al., 2000).

In the Mediterranean, fishing effort is regulated by an annual 6-month closure during the egg-bearing period (September to February), the prohibition of fishing on weekends, and caps on the amount of gear fished per boat (4500 m trammel-nets or 350 traps). The mesh size of the trammel-net outer and inner panels (minimum of 200 and 65 mm respectively) is also regulated. Finally, it is forbidden to land lobster smaller than 24 cm TL (approximately 80 mm CL) or berried females.

Italian fisheries: no information on *P. elephas* fisheries is available in the literature at a national level. In Sardinia, where *P. elephas* fishing is important, the fishery started at the end of the 19th century, mainly with traps (Secci et al., 1995), and catches showed continuous growth. During the 1970's increased fishing effort led to a depletion of the stocks and at present mean yields are lower than those recorded in the 1920s and 1970s. Nowadays about 250 artisanal boats (average 7 meters) exploit this resource with trammels nets (only two fishermen are still using traps). In Southern Italy (Golfo di Taranto and Sicily) *P. elephas* was fished exclusively with traps until the 1950s when they were replaced by trammel-nets (Petrosino et al., 1985; Gristina & Gagliano, 2004). The MLS is 300 mm TL (or 107 mm CL), the fishery is closed from January to April and berried females are to be returned to the water (Gristina et al., 2002).

Croatian fisheries: in the eastern Adriatic, the most important *P. elephas* fishing grounds are the southern sides of distant islands (Soldo et al., 2001). High product value, small catches and multiple fishing gear characterizes the commercial fishery in the area. Historically, *P. elephas* was caught using lobster pots and gillnets. In recent years, due to deficient legislation, the mesh size of lobster gillnets have been reduced from 240 mm to 120 mm and trammel-nets of 80 mm mesh (inner panel) have been introduced (Soldo et al., 2001). Reported annual landings were highest in 1953 with 83 t, while they ranged between 23 and 43 t in the period 1985-1998. Although official landings have not declined in the last decade, all evidence (fishermen, inspections, market figures) indicates that the resource is heavily exploited and that total catches, mean lobster size and CPUE have declined significantly (A. Soldo, pers. comm.). The MLS is 240 mm TL (approximately 80 mm CL), the fishery is closed from October to April and berried lobsters must be returned to the sea (A. Soldo, pers. comm).

Greek fisheries: a census of the Greek artisanal fisheries carried in 2001 led to an estimate of 18 000 small coastal fishing boats but the number of those involved in lobster fishing is not known. Trammel-nets and gill-nets are the main gears used to fish lobster but bycatch by trawlers appears also significant. *P. elephas* and *Homarus gammarus* are fished together and official statistics merge landings of the two species; the estimated proportions of the species are 80% and 20% respectively. Mean annual landings for the 1990s have been estimated at 200 t while official figures are only 23 t, indicating that a large amount of lobsters are directly sold to consumers or restaurants. The fishery is regulated by a MLS of 85 mm CL, prohibition of landing berried females, and a four-month (September-December) closed season.

Tunisian fisheries: the Tunisian lobster fleet grew rapidly

during the 1990s, reaching over 80 vessels, although currently has only 56 vessels (mean size 14 meters) operating primarily in the grounds of La Galite and Esquerquis (Quetglas et al., 2004). As in other fisheries, trammel-nets (75 mm stretched mesh size inner panel) have progressively replaced traps. Tunisia has a reliable series of statistics because the species is exported for foreign consumption. Annual landings during the period 1990-2002 peaked at 74 t in 1993, declining gradually to 33 t in 2002 (Quetglas et al., 2004). Stocks are considered overexploited and protective measures such increasing MLS, extending the closed season and reintroducing traps are being proposed (Zarrouk, 2000). The fishery is regulated by a 200 mm TL MLS (67 mm CL), an annual closure from mid September to February and the prohibition of landing berried females (Zarrouk, 2000).

Moroccan fisheries: *P. elephas* is fished all along the Moroccan coastline, but abundance is higher in the Atlantic than in the Mediterranean. In addition to *P. elephas* and *P. mauritanicus*, *Panulirus regius* (Brito Capello, 1864) inhabits Moroccan waters. The three species are fished with nets or traps by a fleet of large (15-23 m long) wood arti-

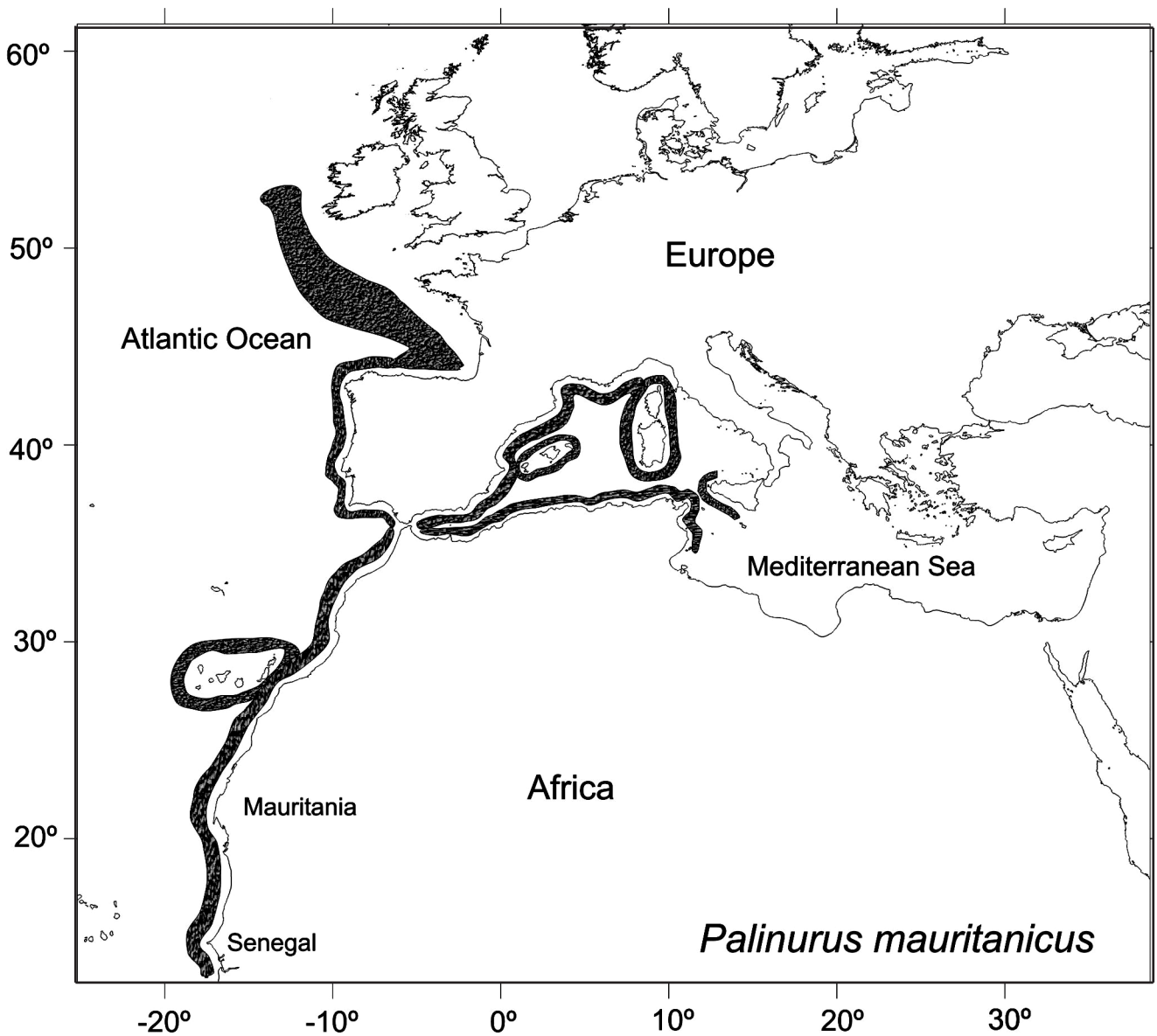

Figure 2. Geographic distribution of *Palinurus mauritanicus*. After Holthuis (1991).
Figure 2. Distribution géographique de *Palinurus mauritanicus*. D'après Holthuis (1991).

sanal vessels based in fishing harbours and by a fleet of small boats (less than 6 m) based near specific fishing locations. The first data on lobster landings date from the 1960s and concern the Mediterranean and the Atlantic (from Tanger to Agadir) and amount to 12 and 17 t respectively in 1966 and 1967 (Collignon, 1966 & 1967). National statistics for the recent period are 166 t in 2002 and 112 t in 2003 but they include the three spiny lobster species and the proportion of *P. elephas* is not known. A MLS of 170 mm TL is the only piece of regulation of the *P. elephas* fishery.

Palinurus mauritanicus

Biology and Ecology

Geographic Distribution

The pink spiny lobster *Palinurus mauritanicus* occurs in the Northeast Atlantic from western Ireland to southern Senegal and in the western Mediterranean as far as the West of Sicily up to 16ºE, but not in the Adriatic (Holthuis, 1991) (Fig. 2).

Ecology and Habitat

P. mauritanicus lives between 180 m and 600 m (Holthuis, 1991), with greatest densities occurring between 200 and 400 m (Postel, 1966). This species inhabits the edge of the continental shelf, especially the canyons, and prefers muddy and coralligenous substrates near rocky outcrops (Postel, 1966). Sex and size appear to vary with depth with males being more abundant above 250 m depth and large females and juveniles predominating between 250-300 m (Maigret, 1978). In the Bay of Biscay, they have been observed sheltering at the entrance of circular holes dug at the base of compact mud cliffs (Latrouite et al., 1999). Off Mauritania, the mean size of fished *P. mauritanicus* was smaller to the north of Cape Blanc (20°45) than to the south, which could indicate that the north of this area is a nursery resulting from a northward drift of the larvae due to bottom currents, and that adults would migrate southward (Maigret, 1978). It appears that groups primarily composed of females undergo migrations in late autumn. These migrations are probably linked to reproduction and increase their catchability in bottom trawls (Maigret, 1978).

In tropical African waters, *P. mauritanicus* feeds primarily on dead fish, live molluscs (bivalves and gastropods), crustaceans, polychaetes and echinoderms (ophiuroids and echinoids) (Maigret, 1978).

Growth

Growth in the wild: according to Maigret (1978), who studied this species off the Mauritanian coast, males and females only moult once a year between September and December. Moult increments, as deduced from recapture of a few tagged males of initial size 25-27 cm TL, were 3 to 4 cm TL. Vincent-Cuaz (1966) estimated a moult increment of 3 cm and divided the sizes comprised between 27 and 49 cm TL in 8 age groups (ages 9-16) for both males and females. Maigret (1978) estimated that *P. mauritanicus* could attain at least 21 years. Using Maigret's (1978) data, Boitard (1981) proposed the following growth parameters for females:

$$CL_\infty = 202.8 \text{ mm}, K = 0.169, t_0 = 0.227 \quad (20)$$

Biometric relationships

The following equations relate TL to CL (in mm) (Maigret, 1978) and CL to W (in g) (Boitard, 1981) for populations off Northeast Africa:

Males: $TL = 2.15\ CL + 24.1$ (n = 131, range: 30-175 mm CL) (21)

$W = 0.001826\ CL^{2.756}$ (n = 160, range: not indicated) (22)

Females: $TL = 2.33\ CL + 15.2$ (n = 135, range: 35-170 mm CL) (23)

$W = 0.002156\ CL^{2.729}$ (n = 140, range: not indicated) (24)

Reproduction

According to Maigret (1978) and Boitard (1981), *P. mauritanicus* reproduces in late summer and fall. Mating takes place shortly after moulting in the manner described in other Palinuridae and spawning occurs shortly after mating. Egg incubation lasts about three months. Mean female physiological maturity deduced from the gonad index occurs around 90 mm CL (Boitard, 1981). Data on fecundity are scant and rather inconsistent as Maigret (1978), working on a small sample, reports 60 000 eggs in females of 340-380 mm TL (or 140-157 mm CL) while M. Diop and A. Kojemiakine (pers. comm.) found relative fecundity of 136 000 eggs per kg (n = 92). Hatching in captivity has been observed to last 14 hours (Maigret, 1978).

Larval ecology

Knowledge of the larval ecology of *P. mauritanicus* is scant. Maigret (1978) collected one phyllosoma of *P. mauritanicus* in December off Mauritania. It was a stage I larva and measured 2.9 mm TL. The almost total absence of larvae of this species in the plankton during the months of January to April (reproductive period: August-January) suggests that phyllosomas are probably offshore from the continental shelf. Maigret (1978) reported that fishermen have observed phyllosomas hanged on their pots and he suggested that the larvae could possibly develop near the bottom. No studies have addressed the settlement of *P. mauritanicus*.

Fisheries

The main commercial fishery of *P. mauritanicus* developed off northwest Africa. At its inception, the fishery was mainly operated by Spanish and Portuguese trawlers fishing shallow grounds. In 1955, a dedicated French fleet developed along the Mauritanian coast and in the first years of the 1960s more than 40 boats (25-38 meters) were fishing with cylindrical baited traps and bottom trawls that served both to catch fish bait and lobsters (Maigret, 1978). Most fishing took place on the edge of the continental shelf at 150-300 m and occasionally down to 600 m. French landings peaked in 1961 with 3600 t but catch rates dropped soon after and fishing shrank substantially due to both overfishing and habitat deterioration by trawling (Maigret, 1978). In the 1970_S landings dropped to 200 t, and in following years the fishery collapsed despite a reduction of fishing effort (Maigret, 1978). In the 1970s the stock started to recover and in 1986 French landings from 10 boats reached 900 t (Boitard, 1981). In 1987, in agreement with Mauritania, the European Commission allocated lobster-netting rights to Portugal but an escalation of poaching rapidly led to a new collapse of the fishery, and French boats abandoned the fishery in 1990. Since 1995 *P. mauritanicus* is a by-catch of boats trawling or netting demersal fish and cephalopods in Mauritanian waters (M. Diop, pers. comm.) but excess fishing and undersized catches have thwarted stock recovery.

In the Bay of Biscay, sporadic *P. mauritanicus* netting occurs on coral grounds at 300-400 m off Brittany, but good spots are very restricted and rapid decreases of catch rates prevent this activity from remaining economical for long. Trawlers also occasionally land *P. mauritanicus* as by-catch. In the western Mediterranean, the commercial importance of the species is not high. It is regularly taken by bottom trawlers as by-catch (Holthuis, 1991) and occasionally targeted with trammel-nets; however, as in the Atlantic, high yields followed by low catches characterize this fishery.

Size structure data for the catches of *P. mauritanicus* are limited. In the case of Mauritania, a study of commercial landings carried in 1972-1974 indicated modal sizes at 96 and 119 mm CL for males (maximum 217 mm) and at 83 mm CL for females (maximum 195 mm) while experimental catches sampled in 1975 showed a size range of 77-198 mm CL for males and 75-197 cm CL for females (Maigret, 1978). No sampling of the catches from the Bay of Biscay sporadic net fishery has been carried out, but commercial data indicate that more than a half of the landings lie within the weight category >2 kg (~ CL > 155 mm) and some males are as big as 7 kg (CL over 230 mm).

MLS of *P. mauritanicus* in European Atlantic waters is 95 mm CL, as for *P. elephas*. In other areas it is established nationally: 24 cm TL in French and Spanish Mediterranean waters and 17 cm TL in Marocco.

Discussion

The *Palinurus* genus is composed of five species of temperate, deep-water spiny lobsters (Phillips et al., 1980), two of which, *P. elephas* and *P. mauritanicus*, are present in European waters. Like other marine living resources, their abundance, depth and geographic distributions are being shaped by environmental conditions and fisheries exploitation. Of the two, *P. elephas* inhabits shallower habitats and was formerly common near the coast, but is now rare at less than 40 m and fisheries that in the past were productive have now virtually disappeared; viable fisheries remain only in the most remote traditional fishing grounds of the Mediterranean. Understanding the possible causes, including climate change, of these trends will require reliable information on past and current geographic limits of the species. Uncertainty about these is illustrated by lack of reference by Holthuis (1991) of *P. elephas* in the Canary Islands where it was traditionally fished (R. Herrera, pers. comm.) as well as in the Azores (d'Udekem d'Acoz, 1999).

The high unit value together with the biological and ecological characteristics of *Palinurus* spp. in the Eastern Atlantic and Mediterranean makes them highly vulnerable to overexploitation. *P. elephas* has a low growth rate, a long life-span and low fecundity by comparison to most other commercial spiny lobsters. Additionally, the amplitude of adult movements is small. Although nothing is known about the stock-recruitment relationship in either *P. elephas* or *P. mauritanicus*, the duration of the pelagic larval life of *Palinurus* spp. is long and dispersal by ocean currents may be extensive. As recruitment may occur far from the parental grounds, decoupling between spawning stock biomass and recruitment is likely.

Although reports of overfishing of *P. elephas* appear as early as the 1930s (e.g., Ninni, 1934), the widespread decline of *P. elephas* fisheries may be traced back to the period of 1960-1980 depending on the area. During those years, fishing effort increased dramatically as pots (and diving) were replaced by trammel-nets and hauling gear and other technological advances were introduced. However, lack of reliable historical catch and effort data prevents testing the hypothesis that these changes led to overfishing. In all European and African countries where *P. elephas* and *P. mauritanicus* are fished, FAO landing statistics between 1984 and 1996 are registered as "*Palinurus* spp » (distinction only in France). These cumulative annual landings range between a maximum of 8710 t and a minimum of 4242 t, and show a decreasing trend from 1988 to 1996. Unfortunately, no confidence can be placed on any of these figures, which may be overestimated, underestimated,

irregularly reported (most countries), or include other species. Based on the best available information, rough estimates of current landings of *P. elephas* range between 500-800 t/year in the Mediterranean and between 150-300 t/year in the Atlantic. These values are in striking contrast to landings of several thousand tones in the first half of the 20th century (e.g. French landings alone reached 3000 t in the 1940s).

All circumstantial evidence points the blame at the great efficiency of nets in catching lobsters, excessive fishing effort and to the poor selectivity of trammel-nets relative to pots. Also, recent studies indicate that trammel-nets catch a greater proportion of large lobsters than pots, and that their impact on lobster habitats and benthic communities is far greater. In the Atlantic, the problem is exacerbated by the fact that lobsters are also a substantial bycatch in nets dedicated to fishes (monkfish, rays, turbot, brills, etc.). *P. elephas* is fished by a large number of artisanal vessels typically distributed in many ports along the coastline. Therefore, at-sea effort control of fisheries is difficult and it is common for the limits on net length per boat to be amply exceeded. Additionally, while pots had to be hauled every day to restock the bait, trammel-nets are left in the water two or more days (to bait the net with fishes entangled during the first day). Due to bad weather conditions, nets are often soaked for longer periods resulting in loss of catch and return of undersized specimens to the water in poor survival condition if returned.

The MLS of *P. elephas* in most Mediterranean fisheries barely exceeds the size of physiological maturity. A recent study of the reproductive potential of a protected population of *P. elephas* shows that such MLS protects only about 1% of the potential population egg production (Goñi et al., 2003a). Lacking estimates of fishing mortalities, and thus of full assessment of the impact of various MLS on the reproductive potential of *P. elephas* populations, the study points to the need to increase the MLS to allow lobsters to reproduce a minimum of once or twice before becoming eligible for fishing. However, larger MLS in some fisheries (e.g. Croatia) alone does not appear to have protected the populations from overfishing. A similar observation comes from Brittany where an increase of MLS above the mean size at maturity did not prove to be sufficient to restore the stock. Thus, a larger MLS may be seen as a necessary technical measure, but is far from sufficient.

Our knowledge is inadequate to discriminate between increased fishing mortality due to greater fishing effort and the changes in size and sex related catchability associated with trammel-netting as the factors responsible of the depleted status of *P. elephas* fisheries. As a high value commodity, *P. elephas* continues to be pursued despite low yields and rapidly growing prices maintain viable fisheries. Due to this, fishermen are requesting managers to impose more restrictions to help rebuild stocks (Hunter, 1996) and additional measures, such as areas open only to pots and programmes to promote the reintroduction of pot fishing should and are being considered in some areas (e.g. Balearic Islands, Corsica, Ireland, Brittany). In this context, permanent closures of fractions of the fishing grounds or of spawning grounds may provide the solution. Relatively small marine protected areas (MPA) enhance *P. elephas* adult stock biomass (e.g., Goñi et al, 2001b) and it is known that MPAs are most effective in species of intermediate movements (e.g., Russ, 2002), such as *P. elephas*. However, for MPAs to be effective their implementation must be based on genetic studies (e.g. Cannas et al., 2003) and on a good understanding of the connectivity among metapopulations (e.g., Tuck & Possingham, 2000).

Much less information is available about the biology and fisheries of *P. mauritanicus*. However, its high unit value has led to a history of fishery depletions in the eastern central Atlantic and suggests low resilience of this species. Its distribution over muddy bottoms, despite the greater depths where it occurs, and the rapidly declining catch rates suggest high catchability in both trawls and nets.

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