# Catches in ghost-fishing octopus and fish traps in the northeastern Atlantic Ocean (Algarve, Portugal)

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Ghost fishing is the term used to describe the continued capture of fish and other living organisms after a fisherman has lost all control over the gear. Traps may be lost for a variety of reasons including theft, vandalism, abandonment, interactions with other gear, fouling on the bottom (i.e., traps and ropes are caught on rocky substrate), bad weather, and human error (Laist, 1995). Annual trap loss can be as high as 20% to 50% of fished traps in some fisheries (Al-Masroori et al., 2004). Because lost traps can continue to fish for long periods, albeit with decreasing efficiency over time (e.g., Smolowitz, 1978; Breen, 1987, 1990; Guillory, 1993), ghost fishing is a concern in fisheries worldwide.

Few studies on the ghost fishing of lost traps have been carried out in European waters, and there has been no information from southern European waters. Ghost fishing of parlour pots used to catch lobsters and crabs off the south-west coast of the United Kingdom was studied by Bullimore et al. (2001), and Godøy et al. (2003) carried out an experimental study on much larger, deliberately lost pots for red king crab (*Paralithodes camtschaticus*) in Norwegian waters. In both cases the effect of ghost fishing by parlour pots was deemed to be relatively small compared to the effects of other types of traps used in Canadian and American fisheries (Brown and Macfadyen, 2007).

In southern Portugal, pots and traps of various types are among the most widely used gears in the small-scale fisheries. Fishing vessels <9 m (local category) can legally fish up to 500 traps, and coastal category vessels (9–12 m and >12 m in total length) are allowed up to 750 and 1000 traps, respectively. The most widely used traps in the Algarve are 1) metal frame, hard plastic netting, single entry traps for octopus (covo), 2) large, metal frame traps for catching cuttlefish and fish (armadilha), and 3) wire traps (murejona) for catching fish. However, only the covo traps and murejona traps were used in our study.

Under the Common Fisheries Policy and the European Community directive on habitats and species, member states are responsible for local fisheries and are obliged to take measures to minimize or mitigate the negative effects of fishing activity. Concern over the effects of lost gear in European waters has led the European Commission to finance two pan-European projects on ghost fishing. The first project focused only on gill nets and trammel nets (Erzini et al., 1997), and the second project included studies on lost traps in several European areas (Godøy et al., 2003). Here we report the results from one of the studies carried out with two types of traps in the northeast Atlantic (south coast of Portugal) (Fig. 1). The catches of deliberately lost traps were monitored and estimates of the number of trap losses and causes of trap losses were obtained through surveys of commercial fishermen.

## Materials and methods

### Catches in deliberately lost traps

The main gear used to catch octopus is the octopus trap (covo), a small metal framed trap with a single entrance on the top (Fig. 2). To make escapement more difficult, the entrance is partially blocked by plastic strips that are easy to push through when entering the trap but not when exiting. A total of 60 octopus traps, each baited with two sardines, were deployed on August 11, 1999, at two sites off Faro where normal fishing activities with octopus traps takes place. The depth at one site was 20 m, and 50 m at the other, and both were situated near rocky reefs. At each location 30 traps were deployed, 15 on soft bottom and 15 on rocky bottom. Because the traps set at 50 m were difficult to retrieve with a grapnel from the hard bottom or were all lost within one month after deployment (on soft bottom), an additional 30 octopus traps were deployed at the shallower depth on soft and hard bottom on 18 May, 2000 and were monitored weekly for 14 weeks.

In addition to the 90 octopus traps, 10 fish traps of the murejona type were also deployed on 25 May 2000 at the shallower site (20 m depth) and monitored by scuba divers on a weekly basis for three months. Murejona traps are round, wire traps with a single funnel-shaped

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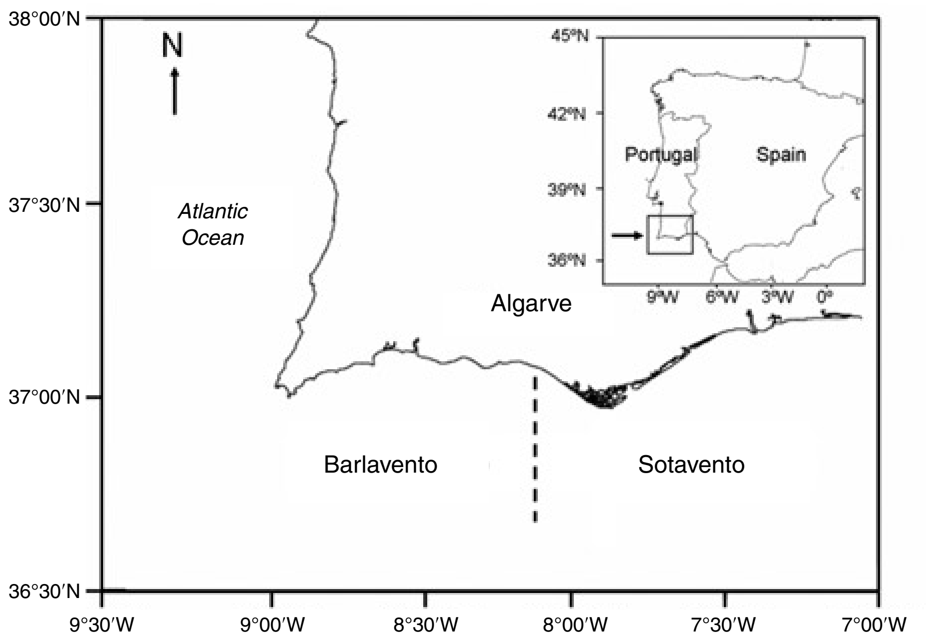


**Figure 1**

Map of the Algarve region and the Barlavento and Sotavento areas where the catches of deliberately lost traps of two types were quantified in 1999 and 2000, and where information on the numbers of traps lost by commercial fishermen and the reasons for trap loss were obtained by means of questionnaire surveys.

opening at the top (Fig. 3). Murejonas targeting sea breams (Sparidae) were baited with approximately 0.5 kg of crushed common cockle (*Cerastoderma edule*).

The octopus traps located in shallow waters were monitored by scuba divers using slates, video, and still photography cameras. Acoustic pingers, an acoustic receiver, and a GPS differential antenna were used to aid divers in locating the experimental traps. Data recorded consisted of the number of the trap, number and identification of the species captured, as well as an estimate of the total length of each individual caught. In order to estimate the total catch (numbers of fish), traps were also inspected for remains of fish that might have died or been eaten while inside the traps. The structural integrity of the traps was evaluated by divers one year after their deployment.

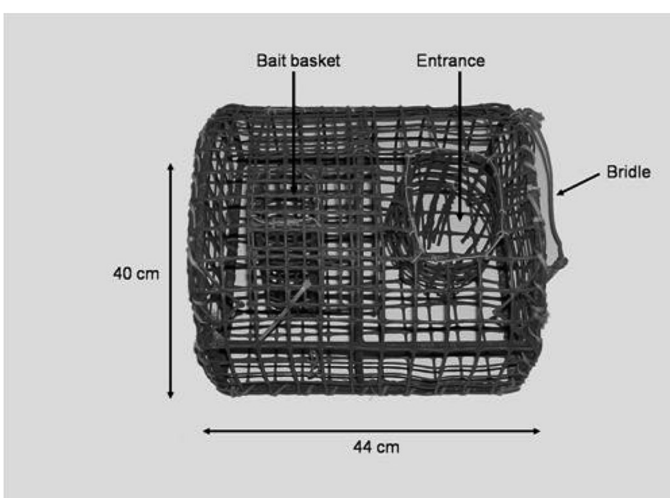


**Figure 2**

View from the top of an iron frame, plastic mesh octopus trap (covo) of typical dimensions (40 × 44 × 25 cm) and mesh size (4-cm plastic square mesh).

The catches were analyzed in terms of target vs. nontarget and prey (both target and nontarget) vs. predator species. The target species were common octopus (*Octopus vulgaris*) for the octopus traps, and Sparidae (axillary seabream (*Pagellus acarne*), common pandora (*P. erythrinus*), striped seabream (*Lithognathus mormyrus*), annular seabream (*Diplodus annularis*), Senegal seabream (*D. bellottii*), common seabream (D. *sargus*), two-banded seabream (*D. vulgaris*), black seabream (*Spondyliosoma cantharus*), and blotched picarel (*Spicara maena*) for the murejona fish traps. Conger eel (*Conger conger*), Mediterranean moray eel (*Muraena helena*), forkbeard (*Phycis phycis*), and *O. vulgaris* were considered predator species that would feed on trapped small fish and in the case of conger and moray eels, also on octopus.

For each trap type, the Zhou and Shirley (1997) model for the relationship between catch and soak time for baited traps where escapement is possible was fitted by nonlinear least squares regression to the catch-per-trap data with PROC NLIN software (SAS Institute Inc., Cary, NC.) and the equation:

$$C(t) = ab + a(t - b)e^{-ct},$$

where $C(t)$ = catch in numbers per trap haul;
$t$ = soak time in days; and
$a$, $b$, and $c$ are parameters to be estimated.

For this model, catch is zero at $t = 0$, the asymptotic catch after an infinite soak time is the product $ab$, and maximal catch $C_{\max}$ is attained at a soak time of $t_{\max} = 1/c + b$:

$$C_{max} = ab + ac^{-1}e^{-(1+cb)}.$$

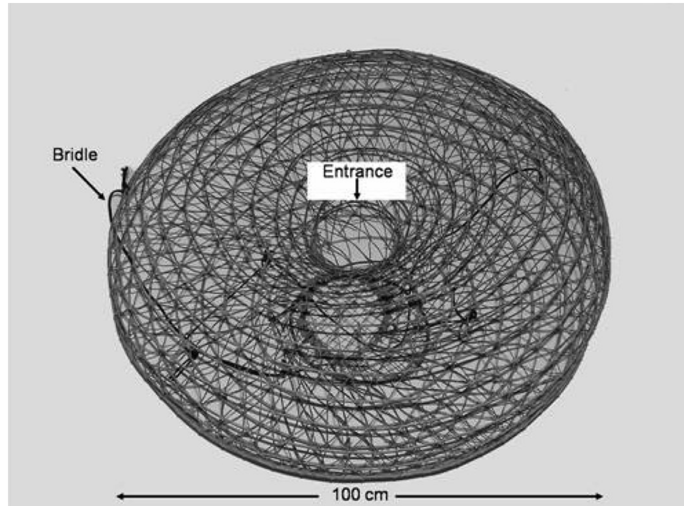


**Figure 3**

View from the top of a wire fish trap (murejona) showing the funnel-shaped entrance. The diameter is 100 cm, the height 35 cm, and the sides of the triangular wire meshes are approximately 2.5 cm.

### Quantification of trap loss

Questionnaires were used to survey fishing-boat skippers at ten ports of the Algarve, South of Portugal. The questionnaires were divided between the following areas (area—Barlavento, western Algarve and Sotavento, eastern Algarve) and by port and fishing vessel (local or coastal). The questionnaires were designed to quantify the number and type of traps used, the number lost per year, reasons for loss, and the degree of success in recovery attempts.

## Results

### Catches in deliberately lost traps

Lost octopus traps caught six species: *O. vulgaris, C. conger*, *M. helena*, red scorpionfish (*Scorpaena notata*), comber (*Serranus cabrilla*), and *P. phycis*. Catch rates were generally low and highly variable (Fig. 4). Most octopus were captured in the first two weeks after trap deployment, and few catches were observed thereafter. For other fishes, namely small red scorpionfish, occasional catches were recorded up to three months after deployment. The estimated parameters of the Zhou and Shirley (1997) model were $a$ = 3.8576, $b$ = 0.0318, and $c$ = 2.292. Based on these parameters the maximal catch is attained within 24 hours after deployment (0.47 days), and the asymptotic catch rate is 0.12 individuals per trap.

In addition to all six species caught by the octopus traps, fish traps caught damselfish (*Chromis chromis*), Mediterranean rainbow wrasse (*Coris julis*), *D. annularis, D. bellottii, D. vulgaris, S. cantharus,* Baillon's wrasse (*Symphodus bailloni*), and axillary wrasse (*S. mediterraneus*) and a maximum diversity of 10 species was attained 27 days after deployment. The most abundantly caught species was *D. vulgaris* that accounted for 43% of the fish observed in the traps, followed by *D. bellottii* (16%). Although most of the species were small, some larger fish, namely *C. conger,* were also found in the traps.

The mean number of individuals per trap peaked approximately two weeks after deployment and was followed by a sharp decrease from week 4 to 5, and then averaged approximately one fish per trap up to the end of the three month monitoring period (Fig. 5). The estimated maximal catch, based on the parameters of the Zhou and Shirley (1997) model ($a$=1.5397, $b$=0.5669, and $c$=0.1101) occurred 9.7 days after deployment, and the asymptotic catch rate was 0.87 individuals per trap. The same pattern of an initial increase in catches, followed by a decline, was seen in the catches of the most abundantly caught species (*D. vulgaris*) in individual fish traps (Fig. 6).

The fish trap predator-to-prey ratio, with predators considered to be *C. conger*, *O. vulgaris*, *M. helena*, and *P. phycis*, showed an opposite trend, increasing sharply from week 4 to 5 to a maximum of 2.0 35 days after deployment, then leveling off (Fig. 5). The initial high number of fish observed in the fish traps was largely due to the presence of the target species (Sparidae), whereas the predators, especially the three fish species *C. conger, M. helena, and P. phycis* were relatively more abundant 55, 71, and 89 days after deployment.

Whereas the iron frame octopus traps retained their structural integrity 12 months after deployment, the wire fish traps were completely destroyed.

### Quantification of trap loss

A total of 84 interviews were conducted, representing 19.4% of the boats registered in the Algarve (southern

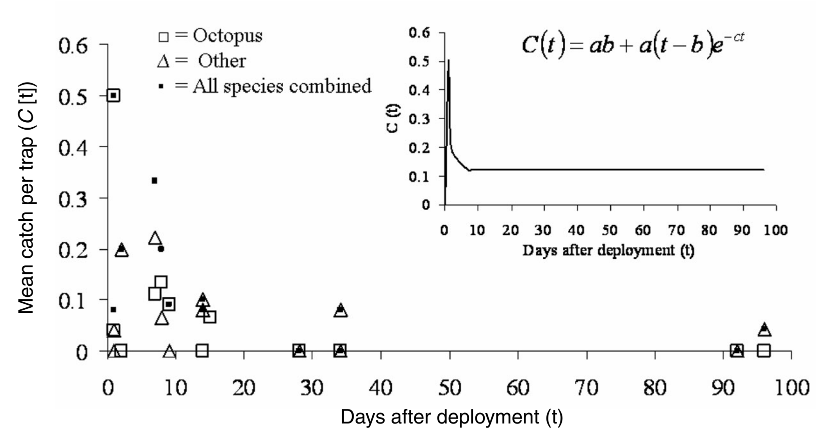


**Figure 4**

Octopus trap catch rates (mean number per trap) over time. Inset figure is the fitted catch model of Zhou and Shirley (1997) with $a$ = 3.8576, $b$ = 0.0318, and $c$ = 2.292.

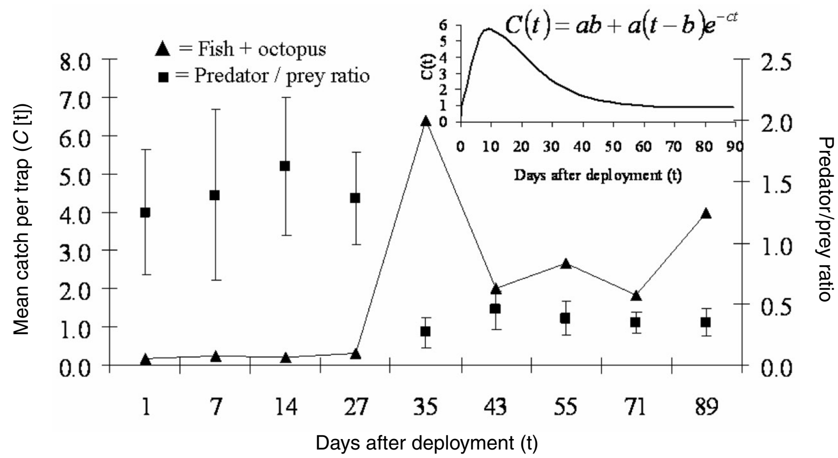


**Figure 5**

Murejona catch rates ($C$) (mean number per trap) over time. Mean ±SE (standard error) number of fish and octopus per trap, and the predator-to-prey ratio. Predators were conger eel (*Conger conger*), forkbeard (*Phycis phycis*), Mediterranean moray eel (*Muraena helena),* and common octopus (*Octopus vulgaris*), whereas prey were all other finfish species. Inset figure is the fitted catch model of Zhou and Shirley (1997) with $a$ = 1.5397, $b$ = 0.5669, and $c$ = 0.1101.

region of Portugal) with licenses for fishing with traps. Of these, 13 boats had to be excluded from the survey because traps had not been used during the past year. Thus, questionnaire surveys were completed for 71 fishing boats that had been used to fish with traps. The results of the questionnaire survey are summarized in Tables 1 and 2.

All skippers surveyed that had fished with octopus traps had the particular type of small trap (covo) used to catch octopus. However, some of the boats also possessed other types of traps, generally of a larger size that were used to target other species. Thus, 16 (22.5 %) of the skippers interviewed had also used larger traps, mostly to catch cuttlefish, and two (2.8 %) of the skippers from the western area (Barlavento), had used murejona wire fish traps to capture fish, especially sea breams. These results confirmed the relative importance of covo-style traps as a gear.

**Table 1**

Summary of survey information collected from 84 interviews with skippers: mean depth fished, mean number of traps used by the different fleets (local and coastal) in the two areas (Barlavento and Sotavento), and mean numbers of traps lost per year per fishing vessel. SD = standard deviation.

| | | Mean number (±SD) of traps fished | | | Mean number (±SD) of traps lost | | |
|---|---|---|---|---|---|---|---|
| Fleet region and area | Mean (±SD) depth (m) fished | Octopus trap | Cuttlefish trap | Fish trap | Octopus trap | Cuttlefish trap | Fish trap |
| Local (<9 m) | | | | | | | |
| Barlavento | 19.1 ±5.7 | 270.3 ±200.5 | 149.0 ±145.2 | 190 ±7.1 | 30.9 ±55.5 | 78.8 ±147.5 | 13.5 ±10.6 |
| Sotavento | 21.1 ±5.0 | 644.4 ±261.7 | 112.5 ±75.0 | | 145.6 ±102.2 | 13.5 ±11.1 | |
| Coastal (>9m) | | | | | | | |
| Sotavento | 25.0 ±5.0 | 903.8 ±227.7 | 80.0 | | 318.5 ±207.8 | 10.0 | |

**Table 2**

Estimates of numbers of octopus traps lost per year off the coast of Barlavento and Sotavento of southern Portugal based on national statistics and questionnaire surveys. Fleet was separated into a local and coastal category. Number of licenses was the number of trap licenses issued (from national statistics). Number fishing was the number of boats fishing traps (from national statistics), Mean number of traps/boat was the mean number of traps fished per year (determined from questionnaires). Total number of traps in use was the product of the mean number of traps fished and the number of fishing vessels. Proportion of traps lost was estimated from the number of traps lost (from questionnaires) divided by the number of traps fished. Traps lost per year was the product of the proportion lost and the total number used.

| Fleet | Area | Number of Licenses | Number of boats fishing | Mean number of traps/boat | Total number of traps used | Proportion of traps lost | Number of traps lost per year |
|---|---|---|---|---|---|---|---|
| Local (<9 m) | Barlavento | 190 | 161 | 270.3 | 43,518 | 0.11 | 4975 |
| | Sotavento | 103 | 87 | 644.4 | 56,063 | 0.23 | 12,667 |
| Coastal (>9 m) | Barlavento | 58 | 49 | 995 | 48,755 | 0.21 | 10,437 |
| | Sotavento | 91 | 77 | 903.8 | 69,593 | 0.35 | 24,525 |
| Total | | 442 | 374 | 2813.5 | 217,929 | 0.24 | 52,604 |

Although fish traps are relatively less important compared to the octopus traps, they are restricted to a particular use by the Algarve fishing fleet. The use of large fish traps in the Barlavento area is favored because of the hard bottom where there are larger concentrations of fish. The average numbers of traps used per boat for the three types of traps commonly used in the fishery, by port category (local or coastal) and coastal zone area, are given in Table 1. The octopus traps are by far the most common of all the traps used.

We estimated that 52,604 octopus traps were lost in Algarve waters in 2000, with the coastal fleet accounting for more losses than the local fleet, and higher losses in the Sotavento than in the Barlavento area (Table 2). Regarding the big traps used mostly to catch cuttlefish the local fleet lost more such traps than the coastal fleet, and there were more losses in the Sotavento than in the Barlavento area.

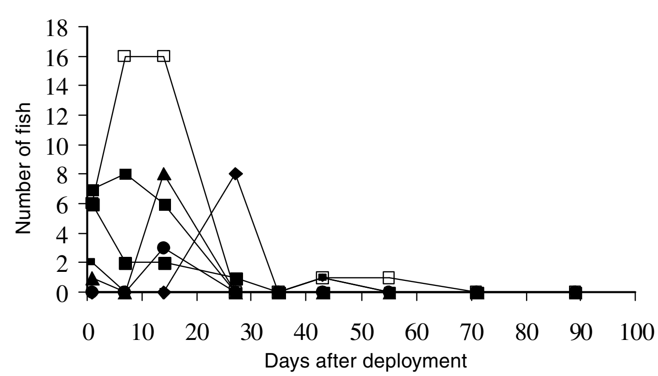


**Figure 6**

Number of two-banded sea bream (*Diplodus vulgaris*) observed in eight different traps over three months. Each symbol represents the catches of one trap.

The most important cause for the loss of traps was interaction with other gears (41%), followed by bad weather (39%), and fouling on rough bottom (18%). Skippers also indicated that gear loss could be caused by other factors (2%), especially theft. The main reason for trap loss in the local fishery was interference with other gears (42.6%) and fouling on rough bottom (42.4%) in the Sotavento and Barlavento areas. In the case of the coastal fishery, the main reasons for trap loss were bad weather (40.4 %) in the Sotavento area and interference with other gears in the Barlavento area (40.0 %).

## Discussion

In comparison to the octopus traps, fish traps caught a greater variety of species and the average catch per trap (in the period of days to weeks after deployment) was much greater. Groups of individuals of the same species of Sparidae were recorded in the same trap, often on subsequent monitoring dates, indicating that escapement rates were low or that individuals that died or escaped were replaced by conspecifics (Bullimore et al., 2001). Abrasions on the head and snout from attempts to escape through the wire mesh also indicated that escapement rates were probably low (Bullimore et al., 2001; Al-Masroori et al., 2004). There was a succession in the capture of species; there were initially high catches of the target sea bream species, followed by the entry of larger predator-type species such as conger eel and fork beard. The predators were probably attracted by the smaller prey species within the trap, and the same individual predators were observed in the traps over weeks and in some cases for more than a month.

There have been relatively few studies on fish escapement rates from traps, and comparisons have generally not been possible because of differences in trap design and size. Munro (1974) reported that escapement from Antillean fish traps used in the Caribbean averaged 11.6% per day. Scarsbrook et al. (1988) reported a 0% escapement rate for sablefish (*Anoplopoma fimbria*). Al-Masroori et al. (2004) assumed a 10% escapement rate from large, single opening wire traps in Oman, and a 95% mortality rate for ghost-fishing traps. Given the design of the fish traps, our own observations of trapped fish, and the typical escapement rates reported in the literature, we believe that ghost fishing mortality rates of fish in the murejona traps are high and are caused by predation in the trap or are the result of injuries and starvation. On the other hand, we assume that octopus escapement rates were 100%. There may have been some trap-related mortality caused by predation because octopus require several minutes to exit a trap through the mesh and are therefore susceptible during that time to the attack of a moray eel or conger eel inside the trap.

Catches in octopus traps decline sharply 24 hours after deployment, whereas fish trap catches peak one to two weeks after deployment, and long after the bait has been consumed or has deteriorated. Rapid consumption of bait has been supported by the findings of Castro et al. (2005), who reported that fish discards in this region are completely scavenged within 24 hours, and by the general knowledge that octopus fishermen must rebait their traps frequently.

Optimal trap soak times of days or even weeks with asymptotic catch rates have been reported in a number of studies (Munro, 1974; Mahon and Hunte, 2001; Al-Masroori et al., 2004). Typically, as seen with our fish traps, catches tend to decline and stabilize at low rates for long soak times. Munro (1974) reported that for long soak times, catch rates in Antillian fish traps stabilized at the point where daily escapement equaled daily ingress.

Based on the relationship between rates of ingress, escapement, catch, and soak time, a variety of models have been used to model trap catches over time (Fogarty and Addison, 1997; Zhou and Shirley, 1997; Al-Masroori et al., 2004). The Zhou and Shirley (1997) is the only model where catches increase to a maximum of days or weeks after deployment and then decline, stabilizing at a low level. This model gave a good fit to the murejona data, where catches peaked two weeks after trap deployment, and then stabilized at a mean of approximately one fish per trap. Octopus trap catches also stabilized at very low catches per trap, but were highest 24 hours after deployment. A simple exponential model (Al-Masroori et al., 2004) adequately describes the catches over time but does not model the low residual catches. Thus, we opted to use the Zhou and Shirley (1997) model for the octopus trap data as well.

The results of the questionnaire survey showed that interaction with other gears (gear conflict) was the most important cause of trap loss. The large number of traps (often deployed without buoys at the surface to avoid theft) within a limited area where many other fishing vessels are operating simultaneously, coupled with long soak times, may explain these results. From our experience, fishermen who catch a longline of traps in their own gear often will simply cut the lines to disentangle the gears. Thus, the traps are often cut loose but fall close to where they had been fishing. The other major cause of trap loss was bad weather, often leading to the loss of entire longlines of traps. This cause is particularly important for the larger coastal vessels, which tend to fish further from their homeports and in deeper waters.

Given the fact that fishing with traps in the Algarve takes place in relatively shallow water, underwater surveys with divers are an appropriate method for monitoring catches in deliberately lost traps and for quantifying gear loss. Despite the problem of the loss of traps due to bad weather and interaction with commercial gear, it is possible to monitor both octopus and fish traps for prolonged periods. The use of divers permits the monitoring of traps and their catches without disturbance. This method is vital for understanding trap catch dynamics and the changes in catches after the bait used to attract fish and cephalopods is no longer present in the traps. However, in order to be able to fully evaluate the effects of ghost fishing from the large number of traps that are lost each year in the coastal waters of southern Portugal, it will be necessary to investigate escapement rates, and to estimate mortality rates. Such investigations can be done by tagging trapped fish and monitoring their escapement and survival by divers.

Bycatch and ghost fishing mitigation measures for traps generally involve the use of escape mechanisms and the use of degradable materials (e.g., Scarsbrook et al., 1988). In the case of the fish traps, mitigation options are limited because the entire trap is made from wire and the trap door is on the bottom of the trap. Octopus traps have a hatch that can be attached with degradable material and the plastic netting could be replaced with biodegradable netting. However, perhaps the most important measure to reduce mortality would be the implementation of a code of conduct leading to less gear loss from gear interaction and theft.

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