Discards regulation vs Mediterranean fisheries sustainability
M. Demestre and F. Maynou (eds)

SCIENTIA MARINA 82S1
December 2018, 121-129, Barcelona (Spain)
ISSN-L: 0214-8358
https://doi.org/10.3989/scimar.04734.16B

Reduction of by-catch and discards in the Algarve small-scale coastal fishery using a monofilament trammel net rigged with a guarding net

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Summary: Experimental fishing was conducted off the port of Quarteira (southern Portugal) from October 2016 to February 2017 using standard trammel nets and modified nets rigged with a guarding net. The commercial catches of trammel nets rigged with a guarding net were 46.1% and 38.0% less than those of the standard net in numbers and economic value. However, there were significantly fewer commercial discards in biomass in the modified trammel nets (68.2%) and by-catch abundance and biomass were also lower in the modified nets (41.8% and 17.3% less, respectively). For the two main fish by-catch species, the modified net caught 62.2% fewer longfin gurnards (*C. obscurus*) and 33.1% fewer greater weever (*T. draco*) than the standard nets. Timing the removal from the nets of the main by-catch and discards species revealed savings in time associated with the use of modified nets. However, net damage occurred twice as much as in the modified net, probably contributing to the reduced commercial catches. The results indicate that trammel nets with the guarding net reduce by-catch and discards and save time, but are unlikely to be adopted by fishers targeting soles due to the higher costs of the modified nets and losses in commercial catches and earnings.

Keywords: trammel net; guarding net; by-catch; discards; small-scale fisheries.

Reducción de la captura secundaria y los descartes en la pesquería costera de pequeña escala del Algarve utilizando una red de trasmallo de monofilamento equipada con una red de protección

Resumen: La pesca experimental se llevó a cabo frente al puerto de Quarteira (sur de Portugal), de octubre de 2016 a febrero de 2017, utilizando redes de trasmallo estándar y redes modificadas con una red de protección llamada “faldón”. Las capturas comerciales de redes de trasmallo equipadas con una red de protección fueron 46.1% y 38.0% menores que las de la red estándar en número y valor económico. Sin embargo, hubo significativamente menos descartes comerciales en biomasa en las redes de trasmallo modificadas (68.2%) y la abundancia de las capturas secundarias y su biomasa también fueron menores en las redes modificadas (41.8% y 17.3% menos respectivamente). Para las dos principales especies de la captura secundaria de peces, la red modificada capturó un 62.2% menos de arete oscuro (*C. obscurus*) y un 33.1% menos de araña (*T. draco*) que las redes estándar. El tiempo necesario para quitar las especies principales de las redes reveló ahorros en el tiempo asociados con el uso de redes modificadas. Sin embargo, hubo el doble de daño neto en las redes modificadas en comparación con las redes estándar, lo que probablemente contribuyó a la reducción de las capturas comerciales. Los resultados indican que las redes de trasmallo con la red de protección reducen la captura fortuita y los descartes y ahorran tiempo, pero es poco probable que sean adoptadas por los pescadores que buscan lenguados debido a los mayores costos de las redes modificadas y las pérdidas en las capturas comerciales y las ganancias.

Palabras clave: trasmallo; red de protección “faldón”; pesca incidental; descartes; pesca artesanal.

Citation/Cómo citar este artículo: Szynaka M.J., Bentes L., Monteiro P., Rangel M., Erzini K. 2018. Reduction of by-catch and discards in the Algarve small-scale coastal fishery using a monofilament trammel net rigged with a guarding net. Sci. Mar. 82S1: 121-129. https://doi.org/10.3989/scimar.04734.16B

Editor: M. Demestre.

Received: November 29, 2017. **Accepted:** June 25, 2018. **Published:** September 3, 2018.

INTRODUCTION

By-catch consists of marine species that are caught unintentionally alongside targeted species that live in the same environment, due to a lack of selectivity of fishing gears. By-catch may consist of undersized or juvenile target species as well as non-target commercial species and a wide variety of species of no value that are subsequently discarded. Commercial species may also be discarded for various reasons, including quota limitations, being undersize, or being unfit for sale because of damage or parasites (Hall et al. 2000). Although discarding in fisheries is considered a problem that should be reduced, the precise definition of by-catch and its significance in terms of the discarding and impact on ecosystems and populations is yet to be agreed upon (Borges et al. 2001). However, there is growing interest in by-catch and mitigation of by-catch by the fishing industry due to legislation concerning discarding (CEC 2007), increased public awareness and concern regarding impacts of overfishing (Gelcich et al. 2014), and more practical considerations such as the time expended in disentangling by-catch species from nets and the damage they cause to gear (Metin et al. 2009).

Trammel nets have discard rates ranging from 0% to 66% worldwide (Kelleher 2005) and a discard rate of about 13% in the Algarve region in Portugal (Borges et al. 2001). The monofilament trammel nets used in Portugal have low size selectivity compared with gillnets, catching wide size ranges of most species (Erzini et al. 2006). Currently, legislation such as that of the European Union Common Fishery Policy (CEC 2007) is seeking to encourage the development of technologies that can result in elimination or reduction of discards and unwanted by-catch in general.

There have been several successful approaches to the management of harvesting commercial catch while decreasing by-catch and discards. Gökçe et al. (2016), using a trammel net rigged with a guarding net in the northeastern Mediterranean, reported that the modified net exhibited 83% less by-catch and 16% less commercial catch than the standard commercial net. A 1.5% decrease in the catch rate of the main target species, green tiger prawn, *Penaeus semisulcatus* and a 66% to 85% decrease in the three main by-catch species were also reported. In Antalya Bay (eastern Mediterranean) Olguner and Deval (2013) found that a smaller mesh size of the inner panel (40 or 44 mm) provided higher amounts of commercial catch in both abundance and biomass for *Pagellus acarne* and a decrease in by-catch for *Citharus linguatula*.

In Izmir Bay (Aegean coast of Turkey), a guarding net was added to the common trammel net used for the commercial prawn *Melicertus kerathurus* (Metin et al. 2009). The study reported a 0.99% decrease in the prawn catch and a reduction in catch of three main by-catch taxa from 17% to 51%. In another study performed in Izmir Bay on *Mullus* spp. fishery (Aydin et al. 2013), discard rates decreased to about 55% to 63%, and the guarding net reduced the catches of the three main by-catch taxa (*Hexaplex trunculus, Bolinus brandaris*, *Maja* spp.).

The specific objectives of the present study were to compare a standard trammel net with a modified trammel net rigged with a guarding net, in terms of catch composition (commercial, by-catch and discard), economic yield, time needed to "clean" the nets (removal of by-catch and discard species), and net damage.

MATERIALS AND METHODS

Net design

Two types of net were rigged: a standard trammel net (T) and a modified trammel net (M), a standard trammel net with a guarding net, consisting of a single layer of netting three meshes high, placed between the trammel net and the footrope (Fig. 1). The experimental nets consisted of fifteen 45-m sheets of nets per net type, with three standard and three modified nets interchanging five times, giving ten sections (T1...T5 and M1...M5) with two metres in between each section to reduce bias (fish guidance effect), for a total of approximately 1.5 kilometres of net. The small mesh inner panel consisted of 120-mm stretched mesh, 0.30-mm diameter monofilament, 40 meshes high. The large mesh outer panels were constructed of 600-mm stretched mesh, 0.60-mm diameter monofilament. The floatline was 52 m long and was made of 7-mm diameter polyester, while the leadline was 55.2 m long and made of 7-mm diameter polyester (braided line with lead core). The inner panel of the standard net (Fig. 1A) was 40 meshes high (4.80-m stretched mesh) and 995 meshes long, or 119.4 m stretched meshes long. The outer panels were three meshes high (1.8-m stretched mesh) and 199 meshes long (119.4-m stretched mesh). The donut-shaped polyethylene floats were 50 mm in diameter. The modified trammel net differed only in the addition of a guarding net at its base, constructed of three meshes of 140-mm stretched mesh (210/12

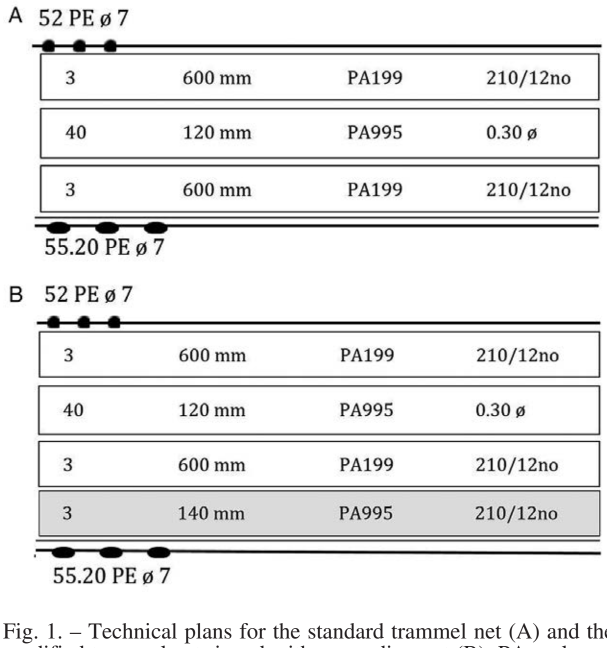

Fig. 1. – Technical plans for the standard trammel net (A) and the modified trammel net rigged with a guarding net (B). PA, polyamide; PE, polyester.

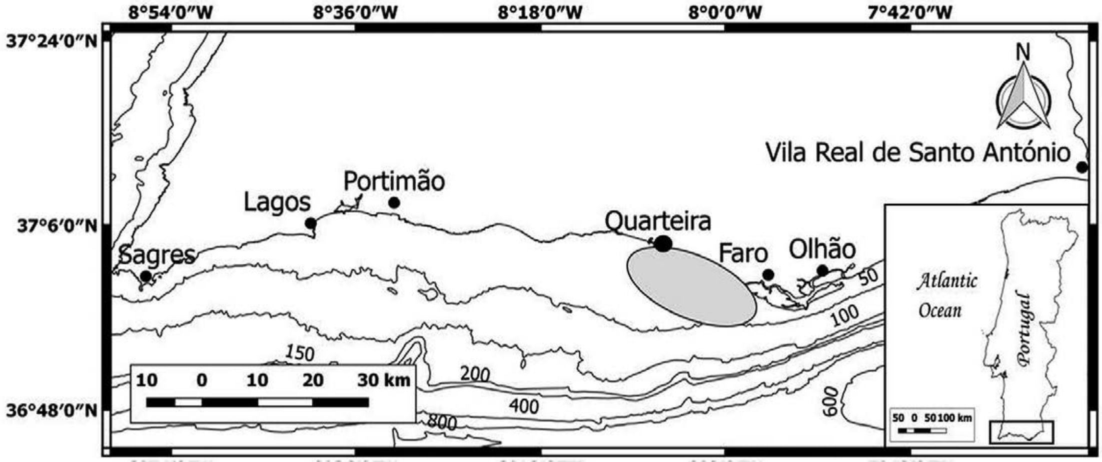

Fig. 2. – Location of the experimental fishing trials (the shaded area indicates the area off the port of Quarteira, south of Portugal) and the main ports of the Algarve region.

polyamide) between the footrope and the trammel net (Fig. 1B). Both the standard net and the modified net had a vertical slack (inner panel stretched mesh height/outer panel stretched mesh height) of 2.7. The trammel net used is characteristic of the nets used in the multi-species inshore fisheries of the Algarve, southern Portugal (Carneiro et al. 2006). Given the seasonality in abundance of cuttlefish (*Sepia officinalis*), this is the target species in late autumn-winter, while for the rest of the year trammel nets target a variety of species, especially soles (Soleidae).

Experimental fishing

Experimental fishing took place off the coast of Algarve (southern Portugal), using a fishing vessel belonging to the port of Quarteira (Fig. 2). Twenty experimental fishing trials were conducted from October 2016 to February 2017 at depths ranging from 10 to 30 m. The first ten fishing trials (autumn) targeted soles, while the other trials in late autumn and winter targeted cuttlefish (*S. officinalis*). The nets were set at dawn and hauled the next morning, usually before sunrise (for approximately 24 hours fishing time). Two GoPro filming cameras were set up on board to record any overlooked individuals in the net, and to evaluate the time required to clean the two different nets. The net was hauled using a hydraulic hauler, and each individual was removed manually by the fishermen. Each individual caught by each net was identified (to species level, if possible). In the case of the modified net, the catches were recorded whether they occurred in the upper trammel net part or in the guarding net. Individual size was taken as total length, carapace length and width. Each individual was registered as ‘by-catch’ or ‘commercial’ based on the decisions of the fishermen sorting the catch, and if considered ‘commercial discard’, the reason was noted (e.g. undersized, scavenged or with parasites). Some by-catch species were immediately killed by the fishermen to facilitate removal from the net and to continue hauling at a moderate pace. This was the case of *Trachinus draco* and *Torpedo torpedo,* which had their heads crushed to avoid onboard injuries and some invertebrates such as sea urchins and crabs, which were usually crushed. Special care was taken with species such as *Rhizostoma pulmo*, the barrel jellyfish, to avoid stings.

Net damage assessment

The damage occurring to the nets was assessed at the end of the experimental fishing trials by counting each visible “hole” or broken piece across the span of the entire 1.5-km net. Four observers checked each section of net for possible damage and recorded the damage according to the two types of net used. Upon observing a hole, a 20-cm ruler was placed within the hole and a picture was taken for later analysis of the diameter. Each hole was classified according to its position (e.g. guarding net, inner small mesh panel or outer large mesh panel; lower or upper half of the net) and size (small if <20 cm, large if >20 cm).

Data analysis

The weight of each fish was estimated using species weight-length relationships parameters. The weight of invertebrates was estimated by the fishermen directly on board. The total catch (kg) of each species was converted to value in euros using the average price per kg obtained from the mandatory first fish auction in Quarteira. The weight of each by-catch species was also recorded to compare the two net types, M and T. Trammel net catches were converted to catch per unit effort in numbers ($CPUE_n$) and biomass ($CPUE_{kg}$) and mean value (€) per 1000 m of trammel net.

Data were analysed using cluster analysis, multidimensional scaling (MDS) implemented in PRIMER 6 (Clarke and Gorley 2006) and the PERMANOVA+ add-on, in order to evaluate differences between the two net types (M and T) as regards catch compositions of discards, commercial catch and the combined catch data. Biomass and abundance data of each experimental trial were analysed according to target species (10 trips targeting sole, 10 targeting cuttlefish), season (15 trips in autumn, 5 in winter), and depth range (12 trips from 10 to 20 m and 8 trips from 20 to 30 m) as factors. Net type (M and T) was also used as a factor, but only for the combined catch data and for the analyses with the two-way PERMANOVAs, aimed at evaluating interaction effects: net type *vs.* depth, net type *vs.* season, and net type *vs.* target catch. Cluster analysis, MDS, analysis of similarities (ANOSIM), and similarity percentage analysis (SIMPER) were also conducted. Two-way PERMANOVAs were used to evaluate the interaction between net type and the three main factors. Square-root transformation of data was applied when necessary to reduce skewness of data distribution.

RESULTS

Catch composition and discarding

The standard (T) and the modified (M) trammel nets caught a total of 40 commercial species, 19 of them in common with the two nets (Table 1). The $CPUE_n$ values for M and T nets were 16.2 and 28.3, respectively, while the corresponding $CPUE_{kg}$ values were 6.5 and 10.0. The values of the landings per 1000 m were €50.3 and €67.2 for the M and the T nets, respectively. The standardized values of discarded commercial species and discarded by-catch species (non-commercial) are shown in Table 2. Discard values were lower for M than for T nets: 38.4 and 68.2 for $CPUE_n$ and 71.7 and 124.0 for $CPUE_{kg}$, respectively. The ratios of M to T net $CPUE_n$ and $CPUE_{kg}$ for discards were 0.56 and 0.57, respectively, meaning that the standard trammel net caught more than the modified one. As regards the three most important fish species of the by-catch, more *Chelidonichthys obscurus* (n=288) and *Trachinus draco* (n=202) were caught by the T than the M (M:T $CPUE_n$ ratio =0.4 and 0.7 respectively), while *Scomber colias* was caught in greater numbers by the M (M:T $CPUE_n$ ratio =1.3).

The M net caught 35% (n), 39% (kg) and 38% (value) of the total landed catch of the two nets. The most lucrative species caught in the M net were *Homarus gammarus* (€121.7), *Microchirus azevia* (€87.5), and *S. officinalis* (€77.3). The highest earnings per species for the T net were obtained for *M. azevia* (€237.3), *Solea*

Table 1. – Mean catches per 1000 m of trammel net in numbers ($CPUE_n$) and biomass ($CPUE_{kg}$) and mean value (€) per 1000 m and standard deviations (sd) of landed species for modified trammel net (M) and standard trammel net (T).

Class		Modified trammel net (M)						Standard trammel net (T)					
Family	Species	$CPUE_n$	sd	$CPUE_{kg}$	sd	€	sd	$CPUE_n$	sd	$CPUE_{kg}$	sd	€	sd
Actinopterygii													
Balistidae	*Balistes capriscus*	0.78	1.34	0.46	0.77	2.1	3.57	0.67	1.48	0.62	1.42	2.9	6.62
Batrachoididae	*Halobatrachus didactylus*							0.07	0.33	0.05	0.23	0.1	0.40
Belonidae	*Belone belone*	0.08	0.34	0.02	0.10		0.08	0.07	0.33				
Carangidae	*Trachurus trachurus*	0.31	0.62	0.02	0.04		0.10	0.22	0.54	0.02	0.05	0.0	0.11
Centracanthidae	*Spicara maena*							0.07	0.33	0.01	0.05	0.0	0.13
Clupeidae	*Alosa fallax*	0.16	0.47		0.18		0.18	0.22	0.99	0.08	0.37	0.0	0.03
Clupeidae	*Sardina pilchardus*	0.08	0.34	0.01	0.02								
Congridae	*Conger conger*							0.07	0.33	0.03	0.11	0.1	0.31
Haemulidae	*Plectorhinchus mediterraneus*							0.30	1.33	0.18	0.82	0.6	2.89
Gadidae	*Trisopterus luscus*	0.78	1.67	0.07	0.16	0.3	0.61	0.89	1.39	0.07	0.13	0.3	0.51
Merlucciidae	*Merluccius merluccius*	1.01	1.92	0.31	0.62	0.9	1.81	1.19	2.57	0.30	0.69	0.9	2.00
Mullidae	*Mullus surmuletus*	0.23	1.02	0.05	0.22	0.8	3.29	0.15	0.46	0.15	0.14	0.7	2.08
Phycidae	*Phycis phycis*							0.44	1.19	0.07	0.17	0.2	0.52
Pomatomidae	*Pomatomus saltatrix*	0.08	0.34	0.04	0.16			0.07	0.33	0.03	0.13	0.0	0.01
Sciaenidae	*Argyrosomus regius*	0.08	0.34	0.08	0.34	0.7	3.08						
Scombridae	*Sarda sarda*	0.08	0.34	0.06	0.26	0.2	0.75						
Scophthalmidae	*Scophthalmus rhombus*							0.15	0.46	0.07	0.22	0.9	2.88
Serranidae	*Serranus cabrilla*	0.16	0.47	0.01	0.05								
Sparidae	*Dentex dentex*	0.08	0.34	0.04	0.18	0.5	2.27						
	Diplodus bellottii	0.23	0.74	0.01	0.04	0.2	0.49						
	Diplodus sargus	0.08	0.34	0.07	0.32	0.6	2.53						
	Diplodus vulgaris							0.30	0.78	0.04	0.13	0.1	0.26
	Pagellus acarne	0.23	0.74	0.04	0.12	0.2	0.56	0.30	1.03	0.07	0.28	0.3	1.28
	Pagellus bellottii							0.07	0.33	0.01	0.03	0.0	0.17
	Pagellus erythrinus	1.09	2.25	0.14	0.27	0.8	1.52	1.11	3.33	0.13	0.35	0.7	1.97
	Pagrus auriga	0.23	0.74	0.20	0.62	2.4	7.46						
	Spondyliosoma cantharus	0.08	0.34	0.02	0.07		0.13						
Soleidae	*Microchirus azevia*	4.99	9.54	0.74	1.40	6.8	12.86	13.11	27.53	1.91	3.73	17.6	35.04
	Pegusa lascaris	0.86	1.51	0.17	0.29	1.2	2.05	2.22	3.24	0.52	0.72	3.7	5.12
	Solea senegalensis	0.86	1.34	0.31	0.57	3.8	6.96	2.59	3.59	1.29	1.68	15.7	20.45
	Solea vulgaris	0.16	0.47	0.05	0.18	0.8	2.70	0.30	1.33	0.09	0.38	1.3	5.72
	Synapturichthys kleinii	0.23	0.56	0.14	0.39	1.7	4.70	0.22	0.54	0.25	0.61	3.0	7.46
Cephalopoda													
Loliginidae	*Loligo vulgaris*	0.08	0.34	0.20	0.89	2.3	10.17						
Octopodidae	*Octopus vulgaris*	0.46	0.96	0.86	1.93	4.6	10.44	0.52	0.99	1.11	2.03	6.0	10.97
Sepiidae	*Sepia officinalis*	1.48	2.61	1.16	2.07	6.0	10.74	1.93	2.77	1.44	2.16	7.5	11.25
Elasmobranchii													
Rajidae	*Raja undulata*	0.55	1.13	0.55	2.51	3.1	6.52	0.37	0.81	1.08	2.39	2.8	6.20
Torpedinidae	*Torpedo marmorata*							0.15	0.46	0.16	0.51	0.4	1.44
Torpedinidae	*Torpedo torpedo*	0.08	0.34	0.16	0.25	0.2	0.71	0.07	0.33	0.07	0.33	0.2	0.94
Malacostraca													
Majidae	*Maja squinado*	0.31	1.06	0.09	0.36	0.5	2.11	0.44	1.09	0.19	0.47	1.1	2.74
Nephropidae	*Homarus gammarus*	0.31	0.34	0.37	1.60	9.5	41.35	0.07	0.33	0.42	1.88	10.8	48.43

Table 2. – Commercial (C) and non-commercial (NC) mean discards per 1000 m of trammel net in numbers ($CPUE_n$) and biomass ($CPUE_{kg}$) and associated standard deviations (sd) for the modified trammel net (M) and the standard trammel net (T).

Class Family	Species	C/NC	Modified trammel net $CPUE_n$	 sd	 $CPUE_{kg}$	 sd	Standard trammel net $CPUE_n$	 sd	 $CPUE_{kg}$	 sd
Actinopterygii										
Balistidae	*Balistes capriscus*	C	0.08	0.34	0.15	0.63	0.23	0.74	0.14	0.44
Callionymidae	*Callionymus lyra*	NC					0.08	0.34	0.01	0.03
Carangidae	*Carnx rhonchus*	C	0.08	0.34	0.03	0.15				
	Trachurus trachurus	C	1.01	1.11	0.08	0.12	0.70	1.25	0.04	0.07
Clupeidae	*Alosa fallax*	C	0.16	0.68	0.03	0.13	0.31	1.06	0.08	0.24
	Sardina pilchardus	C								
	Sardinella aurita	NC					0.08	0.34		
Congridae	*Conger conger*	C	0.23	0.56	0.01	0.06	0.08	0.34	0.05	0.24
Gadidae	*Trisopterus luscus*	C	0.78	2.72	0.06	0.27	1.56	3.97	0.06	0.24
Merlucciidae	*Merluccius merluccius*	C	0.47	1.40	0.05	0.21	0.16	0.68	0.05	0.22
Moronidae	*Dicentrarchus labrax*	C					0.08	0.34	0.14	0.60
Mullidae	*Mullus surmuletus*	C	0.08	0.34						
Phycidae	*Phycis phycis*	C					0.08	0.34	0.08	0.33
Sciaenidae	*Argyrosomus regius*	C					0.08	0.34	0.03	0.15
Scombridae	*Sarda sarda*	C	0.08	0.34	0.07	0.29	0.08	0.34	0.06	0.27
	Scomber colias	NC	10.21	16.05	0.50	0.74	7.95	13.12	0.46	0.70
Scorpaenidae	*Scorpaena notata*	NC	0.16	0.68	0.01	0.05	0.39	1.19	0.02	0.09
	Scorpaena porcus	NC					0.08	0.34	0.02	0.10
Serranidae	*Serranus cabrilla*	C	0.08	0.34			0.08	0.34		
Sparidae	*Boops boops*	C	1.17	2.13	0.06	0.15	1.48	2.88	0.09	0.16
	Diplodus annularis	C	0.23	0.74	0.01	0.06	0.31	0.79	0.03	0.10
	Diplodus bellottii	C	0.16	0.47	0.01	0.03	0.23	0.74	0.01	0.03
	Diplodus vulgaris	C					0.16	0.68	0.01	0.07
	Lithognathus mormyrus	C	0.16	0.47						
	Pagellus acarne	C	0.23	0.74			1.09	2.41		
	Pagellus bellottii	C					0.16	0.47		
	Pagellus erythrinus	C	1.25	2.17	0.07	0.16	2.73	3.17	0.20	0.30
	Spondyliosoma cantharus	C	0.23	0.56	0.05	0.23	0.39	0.83	0.07	0.25
Soleidae	*Microchirus azevia*	C	1.01	3.09			2.65	7.30		
	Pegusa lascaris	C	0.16	0.47	0.03	0.09	0.47	1.40	0.09	0.26
	Solea senegalensis	C			0.00	0.00	0.39	1.38	0.09	0.30
	Synapturichthys kleinii	C	0.08	0.34	0.08	0.36	0.08	0.34	0.03	0.14
Syngnathidae	*Hippocampus hippocampus*	NC					0.23	0.74		
Trachinidae	*Trachinus draco*	NC	6.32	10.11	0.55	1.19	9.36	14.12	0.87	1.58
Tetraodontidae	*Lagocephalus lagocephalus*	NC	0.23	1.02						
Triglidae	*Chelidonichthys cuculus*	NC	0.39	1.38			0.62	2.38		
	Chelidonichthys lastoviza	NC	0.08	0.34			0.31	0.79		
	Chelidonichthys lucerna	NC					0.08	0.34		
	Chelidonichthys obscurus	NC	6.16	4.79			16.30	13.97		
	Trigla lyra	NC					0.08	0.34		
Uranoscopidae	*Uranoscopus scaber*	NC					0.16	0.47		
Anthozoa										
Gorgoniidae	*Leptogorgia lusitinia*	NC								
	Leptogorgia sarmentosa	NC	0.08	0.34			0.08	0.34		
Hormathiidae	*Calliactis parasitica*	NC	0.16	0.47			0.47	1.49		
Veretillidae	*Veretillum cynomorium*	NC					0.23	0.74		
Ascidiacea										
Ascidiiae	*Phallusia mammillata*	NC	0.31	0.79			1.17	2.69		
Asteroidea										
Asteriidae	*Marthasterias glacialis*	NC	0.08	0.34			0.08	0.34		
Astropecrinidae	*Astropecten aranciacus*	NC	0.39	0.67			0.47	1.11		
Ophidiasteridae	*Ophidiaster ophidianus*	NC					0.23	1.02		
Bivalvia										
Pinnidae	*Atrina pectinata*	NC	0.39	1.19			0.86	2.38		
Cephalopoda										
Loliginidae	*Loligo vulgaris*	C					0.07	0.33	0.07	0.30
Sepiidae	*Sepia officinalis*	C	0.08	0.34			0.70	1.34		
Crinoidea										
Antedonidae	*Antedon mediterranea*	NC	0.08	0.34						
Echinoidea										
Toxopneustidae	*Sphaerechinus granularis*	NC	0.55	1.33			6.00	10.76		
Elasmobranchii										
Carcharhinidae	*Prionace glauca*	NC	0.08	0.34	0.69	3.02				
Myliobatidae	*Myliobatis aquila*	NC	0.31	0.79			0.23	0.56		
Rajidae	*Raja undulata*	C					0.47	0.71	0.44	1.12
Gastropoda										
Aplysiidae	*Aplysia punctata*	NC					0.08	0.34		
Muricidae	*Murex brandaris*	NC					0.08	0.34		
Ranellidae	*Charonia lampas*	NC	0.08	0.34			0.23	0.74		
Volutidae	*Cymbium olla*	NC	1.09	3.42			3.04	6.60		
Gymnolaemata										
Bitectiporidae	*Pentapora foliacea*	NC					0.08	0.34		
Holothuroidea										
Holothuriidae	*Holothuria arguinensis*	NC					0.31	1.06		
Stichopodidae	*Stichopus regalis*	NC	0.08	0.34			0.08	0.34		
Malacostraca										
Crangonidae	*Crangon crangon*	NC					0.08	0.34		
Diogenidae	*Dardanus arrosor*	NC	0.08	0.34			0.08	0.34		
Majidae	*Maja squinado*	C					0.23	0.74		
Polychaeta										
n.i.	n.i.	NC					0.08	0.34		
Scyphozoa										
Rhizostomatidae	*Rhizostoma pulmo*	NC	1.09	1.90			0.94	2.22		
Phylum: Porifera	n.i.	NC	2.18	4.75			2.57	5.84		

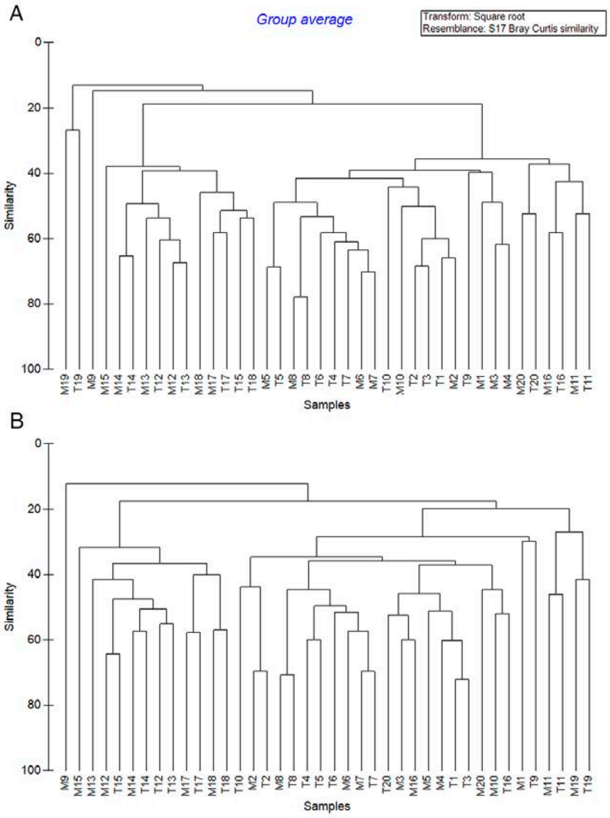

Fig. 3. – Dendrogram (square root transformed data) of the abundance (A) and biomass (B) of all species caught in the 20 trips with the two types of net: M, modified trammel net; T, standard trammel net.

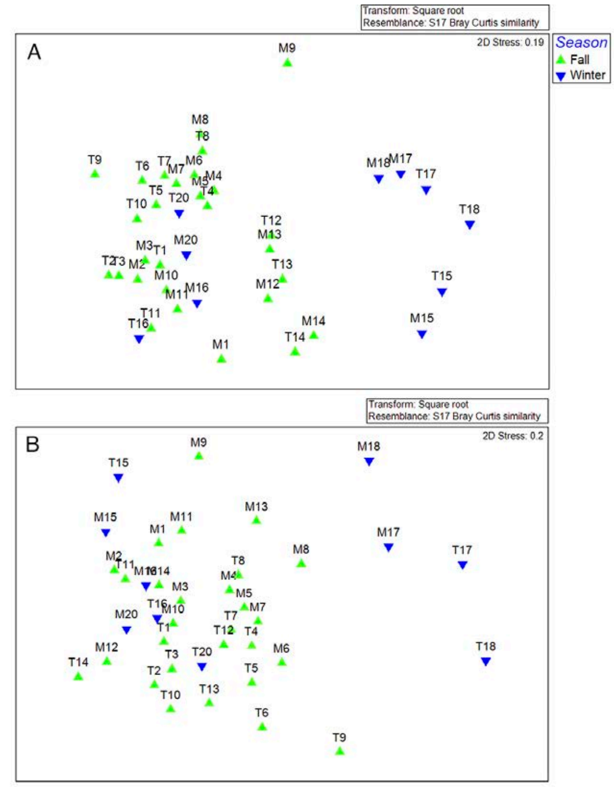

Fig. 4. – MDS plot (square root transformed data) of the abundance (A) and biomass (B) of discarded species caught in 19 trips with the two types of net by season (autumn or winter).

senegalensis (€192.6) and *H. gammarus* (€146.3). The overall value of the catch of the M net was €647.2, while that of the T net was €1043.1 (ratio of 0.6).

The M:T discard ratios were 0.3 for commercial discards and 0.8 for non-commercial by-catch. The species with the highest discards in weight in M nets were *Balistes capriscus* (1.9 kg) and *M. azevia* (1.5 kg), while those in T nets were *Raja undulata* (5.7 kg), *S. officinalis* (5.5 kg), and *M. azevia* (3.6 kg).

Regarding by-catch species, 14.5 kg of *C. obscurus* was discarded from M nets and 33.3 kg from T nets. A total of 7.1 kg of *T. draco* was discarded from M nets and 11.2 kg from T nets. Finally, 6.5 kg of *S. colias* was discarded from M nets and 5.9 kg from T nets.

Combined catch (commercial catch, commercial discards and by-catch) composition showed high similarities within trips for both abundance and biomass data (Fig. 3). Two-way PERMANOVAs with net type, season, depth and target species as factors showed no significant interaction between any of the four factors, while net type was not significant and season, depth and target species were significant (Supplementary Material, Table S1).

The analyses based on the square root transformed data showed high significance levels in PERMANOVA and ANOSIM. The MDS plots for the abundance and biomass of discards with season as a factor are given in Figure 4. The results of ANOSIM for commercial species abundance and biomass provided global R values of 0.438 and 0.308 and significance levels of 0.1% and 1.3%, respectively, showing significant seasonal effects on catch composition. The result is furtherly supported by the p-values of 0.002 and 0.016 obtained by PERMANOVA. The results of SIMPER (Tables S2 and S3 in Supplementary Material) showed strong dissimilarity between autumn and winter for both abundance and biomass. The four most important species contributing to the dissimilarities were *S. colias*, *C. obscurus*, *T. draco* and *M. azevia*, with fewer discards in autumn than in winter only in the case of *M. azevia.*

The MDS plots for the abundance and biomass of discards with target species as the factor are shown in Figure 5. ANOSIM, applied for abundance and biomass of commercial species, showed global R values of 0.368 and 0.154 with significance levels of 0.1%. This result is supported by p-values of 0.001 and 0.002 of PERMANOVA. The results of SIMPER (Tables S4 and S5 in Supplementary Material) show strong dissimilarities between trips targeting sole species and those targeting cuttlefish, both in terms of abundance and biomass. As regards abundance, only Porifera and *M. azevia* were discarded in greater numbers in the nets targeting cuttlefish. As regards biomass, only *S. officinalis* and *M. azevia* were discarded more in the nets targeting cuttlefish.

Figure 6 shows the MDS plots for the abundance and biomass data of the combined catch, with depth as the factor. ANOSIM gave global R values of 0.660 and 0.683, with significance levels of 0.1%, indicating significant differences between the two depth ranges.

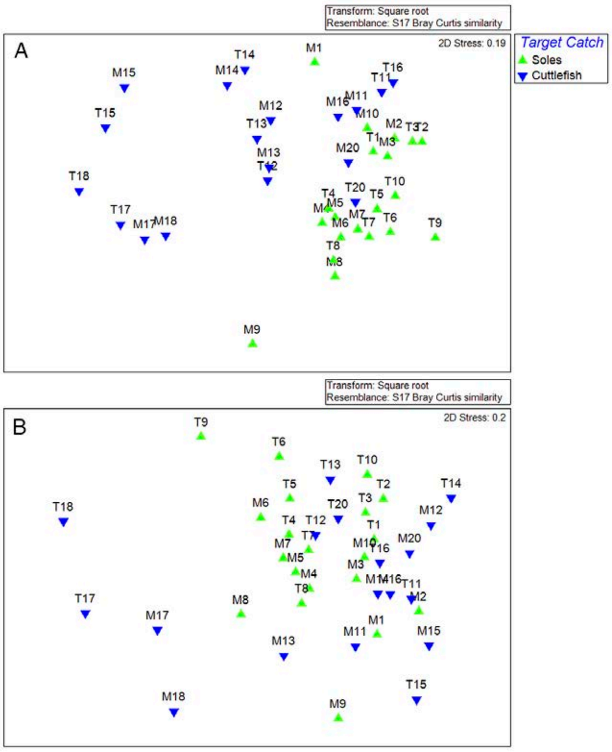

Fig. 5. – MDS plot (square root transformed data) of the abundance (A) and biomass (B) of discarded species caught in 19 trips with the two types of net, with the target species (sole or cuttlefish) as factor.

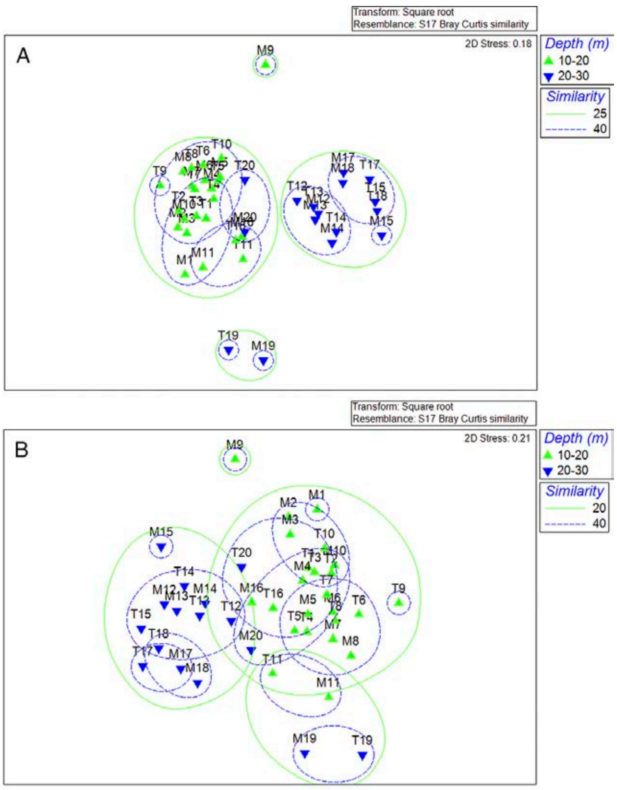

Fig. 6. – MDS plot (square root transformed data) of the abundance (A) and biomass (B) of all species (commercial catch, by-catch, commercial discards) caught in 20 trips with depth range (10-20 m and 20-30 m) as the factor and a cluster overlay.

This is supported by a p-value of 0.001 obtained with PERMANOVA. SIMPER results (Tables S6 and S7 in Supplementary Material) also provide support for strong dissimilarity between the two depth ranges (10-20 m and 20-30 m) for both abundance and biomass. *M. azevia* was the species most contributing to the cumulative percentage, and was caught in greater numbers and biomass in the 20-30 m depth range. In terms of abundance, five of the six most important species contributing to dissimilarity between the two depth ranges were the discard species *C. obscurus, S. colias, T. draco*, Porifera n.id. and *S. granularis*. As regards biomass, five of the six most important species contributing to the cumulative dissimilarity were commercial (*M. azevia, S. officinalis, Raja undulata, Octopus vulgaris* and *Solea senegalensis*).

At a resemblance level of 25% there was similarity among depth ranges (10-20 m and 20-30 m) for both abundance and biomass of combined catch data (Fig. 6).

Discard removal times

Overall, 23 individuals per species/taxa were used to monitor the average time needed to remove the catch of the six most abundant by-catch species/taxa, which represented 85% of the by-catch in number for the M nets and 73% for the T nets. The removal time for *R. pulmo* was 18.0 s on average, followed by *T. draco* (14.0 s) and *Cymbium olla* (12.5 s). The average removal times for the other species/taxa (*C. obscurus*, *S. colias* and Porifera) were less than 10 s.

Net damage assessment

At the end of the fishing trials, the 1.5 km of trammel net had 127 holes, of which 84 were detected in the M net. Approximately 80% of the holes in the M net occurred in the lower half of the net, about 60% were larger than 20 cm, and 62% of the holes were found in the guarding net. Forty-three (34% of the total) holes occurred in the T net; about 90% of them were in the upper part of the net, 58% were larger than 20 cm in width/diameter, and 50% were in the inner layer and 50% in the outer layer.

DISCUSSION

Guarding net: a successful modification?

Mitigation of by-catch of sea birds, turtles and cetaceans in set nets has been widely studied (e.g. Melvin et al. 1999, Gilman et al. 2010, Wang et al. 2013, Martin and Crawford 2015). However, there have been relatively few studies on mitigation of non-commercial fish and invertebrate by-catch in set nets, especially trammel nets.

Compared with previous studies such as those performed in Izmir Bay and Antalya in Turkey (Metin et al. 2009, Olguner and Deval 2013, Aydin et al. 2013), the modified trammel net used in the present study did not provide similar successful outcomes; although there was a reduction in by-catch, there was also a loss of earnings of target species and commercial by-catch. Vecchioni et al. (2016) also reported decreased discard rates for modified trammel nets and decreased yield of commercial species in experimental trials with modified and standard trammel nets in the Egadi marine protected area in Italy, while Sartor et al. (2007) found that trammel nets with a guarding net from the Livorno coast (Italy) had lower catches of more benthic commercial species than standard trammel nets.

In the present study the greatest decrease in commercial catch was observed for the sole species, especially the bastard sole *M. azevia*. It should be noted that although *S. officinalis* was considered a target species, during the period of study an unusually poor cuttlefish season occurred, because water temperatures were warmer than usual. According to the records of the tuna trap net company Tunipex (http://www.tunipex.eu/pt/information_oceanic.php) in Olhão (southern Portugal), the average sea surface temperature recorded in the five months of the experimental fishing trials was 2.6°C higher than the average for the same five months over the past 14 years.

Because the majority of the trammel net sets targeted soles rather than cuttlefish, the landed catches of the modified nets had lower total value per unit effort than the standard trammel nets without the guarding net. This is a not unexpected result, because soles and bastard soles are more likely to come into contact with the nets near the footrope. Thus, the guarding net reduces catch rates of these species as the netting is thicker and more visible than the monofilament trammel net. However, we believe that in years of greater abundance of cuttlefish, which come into contact with and are caught higher in the net, when this species is truly the target species, there would be less difference in the catch value per unit effort between modified and traditional trammel nets. Excluding the three main sole species, the modified net caught nearly the same amount of commercial species as the standard net (ratio of 0.84:1).

In this study it was left up to fishers to decide the fate of the catches. Thus, Atlantic chub mackerel, *Scomber colias*, although commonly sold in the market, was discarded by the fishermen as it was caught in insufficient quantities to warrant sale at auction. Had this species been landed and sold rather than discarded, modified net discards in numbers would have been 46% those of the standard net, while the abundance of commercial landed species of the modified net would have increased from 54% to 70% that of the standard net.

By-catch in number of the guarding net was 41.8% less than that of the standard net. By-catch of non-commercial species is a problem in terms of taking up net area that could be catching commercial species, especially if the by-catch is being caught in relatively large quantities. Of the three most important by-catch species, the longfin gurnards (*C. obscurus*) have many spines that entangle in the net and cause damage, possibly explaining why nearly all of the holes found in the standard net were in the upper part of the net, especially in the inner fine mesh layer where this species was often caught. Atlantic chub mackerel (*S. colias*), the second most important discarded by-catch species, did not pose a threat of physical damage to the net and was the species that took the least amount of time on average to be removed from the net. The third most important by-catch species was the greater weever (*T. draco*), with 202 individuals (33.1% less than the standard net catch). The reduction in catch rates of this species is important due to the danger it poses to the fishermen, as its venomous sting can cause long-term impairment (Dekker 2001), and it was the second most time-consuming species to remove, with an average of 14.0 seconds per individual.

Net damage

Previous studies comparing standard trammel nets to modified trammel nets also assessed damage (Gökçe et al. 2016, Maccarrone et al. 2014). However, Gökçe et al. (2016) only recorded whether damage was in the upper or lower halves of the inner panel and did not take into consideration the size of the hole, while Maccarrone et al. (2014) simply measured the sizes of the holes in the net but not where the hole occurred. The holes in the guarding net were most likely due to the material not being strong enough against demersal species with spikes, or that fact that fishermen were less careful because they knew they would not be using the guarding net again after the experimental fishing trials. Given that the cost of the guarding trammel net (material and labour) was 105 euros per net (45 m), while that of the standard trammel net was only 58 euros per net, there were twice as many holes in the guarding net, and the catches of the modified net were worth less than those of the standard trammel net, there is little incentive to repair the damaged modified nets.

Savings in labour

As stated above, by-catch removal can be laborious and therefore reduction in catches of discard species would reduce time spent cleaning the net and removing catches. *R. pulmo*, the barrel jellyfish, was the most time-consuming to remove from the net, with the fishermen stopping hauling the net completely to release the jellyfish while it was still in the water. While the average times to remove a single individual may seem insignificant, the time accumulates if we take into consideration that commercial trammel netters fish many kilometres of nets in a single set (more than 10 km for the larger vessels), which means that considerable amounts of time and manpower are required to remove species such as the weever fish from the nets if we extrapolate the estimates obtained in this study based only on 1.5 km of trammel nets per set.

CONCLUSIONS

As in other studies (Sartor et al. 2007, Vecchioni et al. 2016), although the modified trammel nets reduced by-catch and discarding, commercial catches were less than those of standard trammel nets. However, we believe that there is a strong case from both ecologic and economic perspectives for promoting the use of modified standard nets. The use of modified nets should be advocated in sensitive habitats and in marine protected areas. Likewise, in fisheries with high by-catch and discard rates, savings in time and reduced gear damage may compensate for loss of commercial catch. The effectiveness and suitability of modified trammel nets should be assessed by fishery/*métier*. For example, trammel net catch composition varies strongly with season and depth (Stergiou et al. 2006), so studies should be carried out in the spring and summer and include a greater depth range than that of this study.

Since this study was conducted on a commercial fishing boat, we received feedback on the guarding net from the fishermen as well as an understanding of their willingness to use modified trammel nets. While the fishermen were not convinced by the results, had the fishing trials been carried out during a normal cuttlefish season and had the Atlantic chub mackerel, *S. colias*, been considered a commercial species, the difference in earnings between the standard and modified nets would have been much smaller, and the benefits of using the guarding net clearer. Switching from guarding net to the standard net over the course of the year according to *métier* may also be an option.

ACKNOWLEDGEMENTS

We would like to thank the skipper and crew of the fishing vessel *Alfonsinho* for their collaboration and support in the trammel net fishing trials, and Frederico Oliveira for his help in the data analysis. We are also grateful to two referees whose comments and suggestions contributed to improving the manuscript. This research has received funding from the European Commission's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 634495 for the project Science, Technology, and Society Initiative to Minimize Unwanted Catches in European Fisheries (MINOUW).

REFERENCES

Aydin I., Gokce G., Metin C. 2013. Using guarding net to reduce regularly discarded invertebrates in trammel net fisheries operating on seagrass meadows (*Posidonia oceanica*) in İzmir Bay (Eastern Aegean Sea). Mediterr. Mar. Sci. 14: 282-291. https://doi.org/10.12681/mms.425

Borges T.C., Erzini K., Bentes L., et al. 2001. By-catch and discarding practices in five Algarve (southern Portugal) métiers. J. Appl. Ichthyol. 17: 104-114. https://doi.org/10.1111/j.1439-0426.2001.00283.x

Carneiro M., Martins R., Rebordão F.R. 2006. Contribuição para o conhecimento das artes de pesca utilizadas no Algarve. Publicações Avulsas do IPIMAR Nº 13, 76 pp. + 57 planos técnicos.

Clarke K.R., Gorley R.N. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, 192 pp.

Commission of the European Communities (CEC). 2007. Communication from the Commission to the Council and the European Parliament - A policy to reduce unwanted by-catches and eliminate discards in European fisheries {SEC (2007) 380} {SEC(2007) 381}, EUR-Lex COM/2007/0136 final.

Dekker C.J. 2001. Chronic pain and impairment of function after a sting by the great weaver fish (*Trachinus draco*). Ned. Tijdschr. Geneeskd. 145: 881-884.

Erzini K., Gonçalves J.M.S., Bentes L., et al. 2006. Size selectivity of trammel nets in southern European small-scale fisheries. Fish. Res. 79: 183-201. https://doi.org/10.1016/j.fishres.2006.03.004

Gelcich S., Buckley P, Pinnegar J.K., et al. 2014. Public awareness, concerns, and priorities about anthropogenic impacts on marine environments. Proc. Natl. Acad. Sci. USA 111: 15042-15047. https://doi.org/10.1073/pnas.1417344111

Gilman E., Gearhart J., Price B., et al. 2010. Mitigating sea turtle by-catch in coastal passive net fisheries. Fish Fish. 11: 57-88. https://doi.org/10.1111/j.1467-2979.2009.00342.x

Gökçe G., Bozaoğlu A.S., Eryaşar A.R., et al. 2016. Discard reduction of trammel nets in the Northeastern Mediterranean prawn fishery. J. Appl. Ichthyol. 32: 427-431. https://doi.org/10.1111/jai.13015

Hall M.A., Alverson D.L., Metuzals K.I. 2000. By-catch: problems and solutions. Mar. Pollut. Bull. 41: 204-219. https://doi.org/10.1016/S0025-326X(00)00111-9

Kelleher K. 2005. Discards in the world's marine fisheries. An update. FAO Fish. Tech. Pap. 470: 131 pp.

Maccarrone V., Buffa G., Di Stefano V., et al. 2014. Economic assessment of dolphin depredation damages and pinger use in artisanal fisheries in the archipelago of Egadi Islands (Sicily). Turk. J. Fish. Aquat. Sci. 14: 173-181.

Martin G.R., Crawford R. 2015. Reducing bycatch in gillnets: A sensory ecology perspective. Global Ecol. Conserv. 3: 28-50. https://doi.org/10.1016/j.gecco.2014.11.004

Melvin E.F., Parrish J.K., Conquest L.L. 1999. Novel Tools to Reduce Seabird Bycatch in Coastal Gillnet Fisheries. Cons. Biol. 13: 1386-1397. https://doi.org/10.1046/j.1523-1739.1999.98426.x

Metin C., Gökçe G., Aydın İ., et al. 2009. By-catch reduction in trammel net fishery for prawn (*Melicertus kerathurus*) by using guarding net in Izmir Bay on Aegean Coast of Turkey. Turk. J. Fish. Aquat. Sci. 9: 133-136.

Olguner M.T., Deval M.C. 2013. Catch and selectivity of 40 and 44 mm trammel nets in small-scale fisheries in the Antalya Bay, Eastern Mediterranean. Ege J. Fish. Aquat. Sci. 30: 167-173.

Sartor P., Silvestri R., Sbrana M., et al. 2007. Experimentation of technical devices for the discard reduction in the set net fishery along the Livorno coast, Italy. Biol. Mar. Mediterr. 14: 360-361.

Stergiou K.I., Moutopoulos D.K., Soriguer M.C., et al. 2006. Trammel net species composition, catch rates and métiers in southern European waters: a multivariate approach. Fish. Res. 79: 170-182. https://doi.org/10.1016/j.fishres.2006.03.003

Vecchioni L., Milisenda G., Massi D., et al. 2016. Can we reduce fishing discard in trammel nets? The case study in the MPA Egadi. Biol. Mar. Mediterr. 23: 47-48.

Wang J., Barkan J., Fisler S., et al. 2013. Developing ultraviolet illumination of gillnets as a method to reduce sea turtle bycatch. Biol. Lett. 9: 20130383. https://doi.org/10.1098/rsbl.2013.0383

SUPPLEMENTARY MATERIAL

The following supplementary material is available through the online version of this article and at the following link:
http://scimar.icm.csic.es/scimar/supplm/sm04734esm.pdf

Table S1. – Two-way PERMANOVA table with factors net type (Ne) and depth (De), net type (Ne) and season (Se), and net type and target catch (Ta) for abundance of combined catch (includes commercial, commercial discard and by-catch).

Table S2. – SIMPER analysis for the discards (commercial discards and by-catch) data for abundance with the factor season (autumn and winter).

Table S3. – Simper analysis for the discards (commercial discards and by-catch) data for biomass with the factor season (autumn and winter).

Table S4. – Simper analysis for the discards (commercial discards and by-catch) data for abundance with the factor target catch (sole season and cuttlefish season).

Table S5. – Simper analysis for the discards (commercial discards and by-catch) data for biomass with the factor target catch (sole season and cuttlefish season).

Table S6. – Simper analysis for the combined catch (commercial catch, commercial discards, and by-catch) data for abundance with the factor depth (10-20 m and 20-30 m).

Table S7. – Simper analysis for the combined catch (commercial catch, commercial discards and by-catch) data for biomass with the factor depth (10-20 m and 20-30 m).

Discards regulation vs Mediterranean fisheries sustainability
M. Demestre and F. Maynou (eds)

SCIENTIA MARINA 82S1
December 2018, S1-S5, Barcelona (Spain)
ISSN-L: 0214-8358

Reduction of by-catch and discards in the Algarve small-scale coastal fishery using a monofilament trammel net rigged with a guarding net

Monika J. Szynaka, Luís Bentes, Pedro Monteiro, Mafalda Rangel, Karim Erzini

Supplementary material

Table S1. – Two-way PERMANOVA table with factors net type (Ne) and depth (De), net type (Ne) and season (Se), and net type and target catch (Ta) for abundance of combined catch (includes commercial, commercial discard and by-catch).

Source	df	SS	MS	Pseudo-F	P(perm)	perms
Ne	1	3252.9	3252.9	1.5533	0.104	999
De	1	23236	23236	11.096	0.001	998
Ne×De	1	1317.8	1317.8	0.62927	0.828	999
Res	36	75389	2094.1			
Total	39	1.04E+05				
Ne	1	2806.5	2806.5	1.1325	0.282	999
Se	1	10077	10077	4.0661	0.002	999
Ne×Se	1	650.25	650.25	0.26239	0.994	998
Res	36	89215	2478.2			
Total	39	1.04E+05				
Ne	1	3455.5	3455.5	1.4542	0.131	997
Ta	1	21301	21301	8.964	0.001	999
Ne×Ta	1	1088.8	1088.8	0.45821	0.935	999
Res	36	85546	2376.3			
Total	39	1.11E+05				

Table S2. – SIMPER analysis for the discards (commercial discards and by-catch) data for abundance with the factor season (autumn and winter).

Autumn and winter groups Average dissimilarity = 75.87 Species	Autumn group Av.Abund	Winter group Av.Abund	Av.Diss	Diss/sd	Contrib%	Cum.%
Scomber colias	1.76	1.36	6.08	1.15	8.01	8.01
Chelidonichthys obscurus	2.6	1.77	5.6	1.35	7.38	15.39
Trachinus draco	2.11	0.83	5.37	1.35	7.08	22.47
Microchirus azevia	0.09	1.43	4.12	1	5.43	27.9
Porifera n.i.	0.5	0.97	3.71	1.03	4.89	32.8
Trisopterus luscus	0.05	1.17	3.42	1.04	4.51	37.31
Sphaerechinus granularis	0.99	0.1	3.25	0.74	4.28	41.59
Pagellus erythrinus	0.99	0.3	2.94	1.07	3.88	45.48
Cymbium olla	0.81	0.1	2.45	0.77	3.23	48.71
Boops boops	0.69	0.1	2.27	0.85	2.99	51.7
Rhizostoma pulmo	0.52	0.2	2.15	0.79	2.83	54.53
Chelidonichthys cuculus	0	0.66	2.1	0.64	2.77	57.3
Trachurus trachurus	0.48	0.48	2.09	0.95	2.75	60.05
Calliactis parasitica	0	0.54	1.77	0.73	2.33	62.38
Pagellus acarne	0.24	0.46	1.74	0.76	2.3	64.68
Atrina pectinata	0.15	0.44	1.49	0.65	1.96	66.63
Astropecten aranciacus	0.24	0.3	1.45	0.75	1.91	68.54
Merluccius merluccius	0	0.49	1.42	0.6	1.87	70.41
Scorpaena notata	0	0.46	1.38	0.62	1.81	72.23
Phallusia mammillata	0.37	0.1	1.3	0.6	1.71	73.94
Charonia lampas	0	0.34	1.07	0.6	1.41	75.35
Sepia officinalis	0.23	0.1	1	0.54	1.32	76.68
Alosa fallax	0.06	0.24	0.94	0.51	1.24	77.92
Raja undulata	0.14	0.2	0.86	0.61	1.13	79.05
Spondyliosoma cantharus	0.26	0	0.84	0.54	1.11	80.16
Myliobatis aquila	0.19	0.1	0.79	0.52	1.05	81.2
Diplodus bellottii	0.11	0.14	0.77	0.45	1.01	82.21
Marthasterias glacialis	0	0.2	0.75	0.48	0.99	83.21
Pegusa lascaris	0.21	0	0.69	0.45	0.91	84.12
Diplodus annularis	0.21	0	0.66	0.43	0.87	84.98
Conger conger	0.07	0.2	0.63	0.55	0.83	85.81
Chelidonichthys lastoviza	0.12	0.1	0.63	0.46	0.82	86.63
Dardanus arrosor	0	0.2	0.57	0.48	0.75	87.39
Veretillum cynomorium	0.04	0.14	0.56	0.38	0.74	88.13
Leptogorgia sarmentosa	0	0.2	0.56	0.48	0.74	88.87
Serranus cabrilla	0.04	0.1	0.53	0.37	0.7	89.57
Stichopus regalis	0.04	0.1	0.51	0.36	0.67	90.24

Table S3. – Simper analysis for the discards (commercial discards and by-catch) data for biomass with the factor season (autumn and winter).

Autumn and winter groups Average dissimilarity = 73.89 Species	Autumn group Av.Abund	Winter group Av.Abund	Av.Diss	Diss/sd	Contrib%	Cum.%
Chelidonichthys obscurus	34.21	19.83	10.39	1.32	14.07	14.07
Trachinus draco	18.64	5.75	6.97	1.18	9.43	23.49
Scomber colias	12.64	9.08	6.47	0.99	8.76	32.26
Microchirus azevia	0.97	12.69	4.79	0.78	6.48	38.74
Raja undulata	3.5	5.68	3.35	0.49	4.53	43.26
Pagellus erythrinus	6.52	1.94	3.03	0.82	4.1	47.37
Pagellus acarne	1.4	5.8	2.9	0.62	3.93	51.3
Sepia officinalis	5.72	1.39	2.8	0.52	3.79	55.08
Trachurus trachurus	3.92	2.55	2.6	0.7	3.51	58.59
Merluccius merluccius	0	5.92	2.29	0.61	3.1	61.7
Boops boops	4.64	1.08	2.29	0.66	3.1	64.79
Trisopterus luscus	0	6.44	2.17	0.57	2.93	67.72
Alosa fallax	0.9	3.83	1.81	0.51	2.45	70.17
Pagrus auriga	0	3.89	1.66	0.32	2.25	72.42
Dicentrarchus labrax	0	4.2	1.63	0.32	2.2	74.62
Myliobatis aquila	2.96	0	1.38	0.38	1.86	76.48
Balistes capriscus	3.69	0	1.37	0.32	1.85	78.33
Pegusa lascaris	3.05	0	1.33	0.42	1.8	80.14
Conger conger	0.17	3.93	1.33	0.49	1.8	81.94
Prionace glauca	3.37	0	1.26	0.19	1.7	83.64
Scorpaena notata	0	2.87	1.16	0.48	1.57	85.21
Phycis phycis	0	3.11	1.11	0.32	1.5	86.71
Synapturichthys kleinii	1.89	0	1.1	0.24	1.49	88.2
Spondyliosoma cantharus	2.52	0	0.93	0.35	1.25	89.46
Sarda sarda	2.04	0	0.86	0.27	1.16	90.62

Table S4. – Simper analysis for the discards (commercial discards and by-catch) data for abundance with the factor target catch (sole season and cuttlefish season).

Soles and cuttlefish group Average dissimilarity = 73.64 Species	Soles group Av.Abund	Cuttlefish group Av.Abund	Av.Diss	Diss/sd	Contrib%	Cum.%
Scomber colias	2.19	1.06	6.66	1.21	9.05	9.05
Trachinus draco	2.41	1.07	5.31	1.26	7.21	16.26
Chelidonichthys obscurus	2.53	2.21	5.2	1.28	7.06	23.33
Porifera n.i.	0	1.31	4.21	0.92	5.71	29.04
Sphaerechinus granularis	1.08	0.4	3.83	0.83	5.2	34.24
Pagellus erythrinus	1.26	0.3	3.65	1.28	4.96	39.2
Cymbium olla	1.13	0.06	3.37	1	4.58	43.78
Boops boops	0.97	0.06	3.11	1.13	4.23	48.01
Microchirus azevia	0	0.93	2.72	0.73	3.69	51.7
Rhizostoma pulmo	0.63	0.22	2.33	0.88	3.16	54.86
Trisopterus luscus	0	0.73	2.09	0.7	2.84	57.7
Trachurus trachurus	0.51	0.46	2.09	0.94	2.83	60.53
Phallusia mammillata	0.05	0.58	1.83	0.74	2.49	63.02
Pagellus acarne	0.1	0.53	1.73	0.78	2.35	65.36
Atrina pectinata	0	0.48	1.41	0.56	1.92	67.29
Astropecten aranciacus	0.24	0.28	1.36	0.72	1.85	69.14
Chelidonichthys cuculus	0	0.37	1.16	0.44	1.58	70.72
Sepia officinalis	0.1	0.31	1.14	0.6	1.54	72.26
Spondyliosoma cantharus	0.32	0.06	1.11	0.65	1.51	73.77
Myliobatis aquila	0.05	0.3	1.03	0.59	1.4	75.17
Calliactis parasitica	0	0.3	0.98	0.49	1.33	76.5
Pegusa lascaris	0.3	0	0.97	0.55	1.32	77.82
Diplodus annularis	0.24	0.06	0.89	0.51	1.2	79.02
Raja undulata	0.2	0.11	0.83	0.58	1.13	80.16
Merluccius merluccius	0	0.27	0.78	0.41	1.06	81.22
Scorpaena notata	0	0.25	0.76	0.42	1.03	82.25
Chelidonichthys lastoviza	0	0.25	0.75	0.51	1.02	83.27
Diplodus bellottii	0.1	0.13	0.74	0.45	1.01	84.28
Alosa fallax	0.09	0.13	0.66	0.4	0.89	85.17
Charonia lampas	0	0.19	0.59	0.42	0.81	85.98
Balistes capriscus	0.17	0	0.53	0.4	0.71	86.69
Conger conger	0.1	0.11	0.51	0.47	0.69	87.39
Veretillum cynomorium	0	0.13	0.46	0.34	0.63	88.01
Serranus cabrilla	0	0.11	0.45	0.34	0.61	88.62
Marthasterias glacialis	0	0.11	0.42	0.34	0.57	89.19
Holothuria arguinensis	0.14	0	0.41	0.3	0.56	89.74
Stichopus regalis	0	0.11	0.4	0.33	0.54	90.28

Table S5. – Simper analysis for the discards (commercial discards and by-catch) data for biomass with the factor target catch (sole season and cuttlefish season).

Soles and cuttlefish group Average dissimilarity = 70.88 Species	Soles group Av.Abund	Cuttlefish group Av.Abund	Av.Diss	Diss/sd	Contrib%	Cum.%
Chelidonichthys obscurus	33.93	26.54	9.28	1.26	13.09	13.09
Trachinus draco	21.55	8.26	7.2	1.22	10.16	23.24
Scomber colias	14.86	8.19	6.72	1	9.48	32.72
Pagellus erythrinus	8.42	1.86	3.59	0.96	5.06	37.79
Sepia officinalis	2.25	7.17	3.19	0.58	4.51	42.29
Microchirus azevia	0	8.56	3.11	0.61	4.39	46.68
Raja undulata	4.9	3.15	3.04	0.51	4.29	50.97
Boops boops	6.5	0.6	2.91	0.81	4.1	55.07
Trachurus trachurus	3.86	3.24	2.53	0.76	3.57	58.65
Pagellus acarne	0.37	4.98	2.19	0.58	3.09	61.74
Balistes capriscus	5.17	0	1.86	0.39	2.63	64.37
Myliobatis aquila	0.31	4.26	1.84	0.5	2.6	66.97
Pegusa lascaris	4.28	0	1.8	0.51	2.53	69.5
Prionace glauca	0	5.24	1.79	0.24	2.52	72.03
Synapturichthys kleinii	2.65	0	1.48	0.28	2.08	74.11
Merluccius merluccius	0	3.29	1.26	0.42	1.78	75.89
Spondyliosoma cantharus	3.53	0	1.26	0.43	1.77	77.66
Alosa fallax	1.27	2.13	1.25	0.41	1.76	79.42
Trisopterus luscus	0	3.58	1.19	0.4	1.69	81.1
Lagocephalus lagocephalus	4.04	0	1.15	0.23	1.62	82.72
Sarda sarda	1.4	1.62	1.14	0.32	1.6	84.33
Diplodus annularis	1.87	0.53	1.04	0.38	1.47	85.8
Chelidonichthys lastoviza	0	2.66	0.99	0.42	1.4	87.19
Pagrus auriga	0	2.16	0.91	0.23	1.29	88.48
Dicentrarchus labrax	0	2.33	0.9	0.24	1.26	89.74
Conger conger	0.23	2.18	0.8	0.38	1.13	90.88

Table S6. – Simper analysis for the combined catch (commercial catch, commercial discards, and by-catch) data for abundance with the factor depth (10-20 m and 20-30 m).

10-20 and 20-30 groups Average dissimilarity = 85.09 Species	10-20 group Av.Abund	20-30 group Av.Abund	Av.Diss	Diss/sd	Contrib%	Cum.%
Microchirus azevia	0.13	17.81	14.92	1.01	17.53	17.53
Chelidonichthys obscurus	8.83	4.75	8.2	1.14	9.64	27.17
Scomber colias	7.42	3.44	7.9	0.85	9.29	36.46
Trachinus draco	7.21	1.81	6.22	0.93	7.31	43.77
Porifera n.i.	0	3.81	4.19	0.7	4.92	48.69
Sphaerechinus granularis	3.42	0.13	3.55	0.55	4.18	52.87
Sepia officinalis	0.38	2.94	3.05	1.16	3.59	56.46
Trisopterus luscus	0.04	3.13	2.85	0.9	3.35	59.8
Pagellus erythrinus	2.92	0.63	2.62	0.89	3.08	62.88
Merluccius merluccius	0.08	2.19	2.1	0.82	2.46	65.34
Pegusa lascaris	2.04	0	2.09	0.96	2.45	67.79
Cymbium olla	2.17	0.06	1.92	0.54	2.26	70.05
Solea senegalensis	1.92	0.31	1.86	0.87	2.19	72.24
Boops boops	1.38	0.06	1.43	0.73	1.68	73.92
Maja squinado	0.21	0.69	1.32	0.4	1.55	75.47
Rhizostoma pulmo	0.92	0.31	1.22	0.71	1.43	76.9
Trachurus trachurus	0.75	0.69	1.11	0.82	1.3	78.21
Phallusia mammillata	0.04	1.13	1.07	0.65	1.26	79.47
Pagellus acarne	0.17	1.25	1.03	0.74	1.21	80.68
Chelidonichthys cuculus	0	0.81	0.96	0.39	1.13	81.82
Atrina pectinata	0	1	0.96	0.51	1.13	82.95
Balistes capriscus	0.88	0.13	0.94	0.73	1.1	84.05
Raja undulata	0.63	0.19	0.74	0.67	0.87	84.92
Alosa fallax	0.29	0.25	0.59	0.4	0.69	85.61
Octopus vulgaris	0.33	0.25	0.57	0.66	0.66	86.27
Astropecten aranciacus	0.29	0.31	0.56	0.72	0.66	86.93
Calliactis parasitica	0	0.5	0.53	0.45	0.62	87.56
Myliobatis aquila	0.04	0.44	0.53	0.58	0.62	88.18
Phycis phycis	0	0.44	0.5	0.44	0.58	88.76
Scorpaena notata	0	0.44	0.5	0.4	0.58	89.35
Mullus surmuletus	0.04	0.38	0.47	0.42	0.55	89.89
Pagrus auriga	0	0.25	0.45	0.33	0.52	90.42

Table S7. – Simper analysis for the combined catch (commercial catch, commercial discards and by-catch) data for biomass with the factor depth (10-20 m and 20-30 m).

10-20 and 20-30 groups Average dissimilarity = 87.25 Species	10-20 group Av.Abund	20-30 group Av.Abund	Av.Diss	Diss/sd	Contrib%	Cum.%
Microchirus azevia	15.85	2499.54	11.84	0.95	13.57	13.57
Sepia officinalis	209.26	2190.07	10.4	1.17	11.92	25.48
Raja undulata	1205.35	420.62	7.19	0.66	8.24	33.73
Chelidonichthys obscurus	1448.58	810.74	6.49	1.2	7.44	41.16
Octopus vulgaris	750	500	5.65	0.67	6.47	47.63
Solea senegalensis	837.04	159.86	4.29	0.87	4.92	52.55
Balistes capriscus	679.23	97.33	3.6	0.72	4.13	56.69
Homarus gammarus	0	649.24	3.13	0.35	3.59	60.28
Trachinus draco	658.73	153.81	3.12	0.7	3.58	63.86
Merluccius merluccius	31.22	536.23	2.76	0.73	3.17	67.02
Pegusa lascaris	451.02	0	2.46	0.99	2.82	69.84
Scomber colias	369.54	216.24	2.46	0.75	2.82	72.66
Prionace glauca	0	555.37	2	0.25	2.29	74.95
Pagrus auriga	0	257.62	1.94	0.35	2.22	77.17
Maja squinado	79.97	235.24	1.8	0.47	2.06	79.23
Synapturichthys kleinii	277.38	0	1.52	0.41	1.74	80.97
Trisopterus luscus	4	213.27	1.26	0.63	1.44	82.42
Pagellus erythrinus	239.96	72.44	1.18	0.83	1.35	83.77
Plectorhinchus mediterraneus	0	155.27	1.12	0.24	1.29	85.06
Lagocephalus lagocephalus	272.32	0	0.96	0.2	1.11	86.16
Loligo vulgaris	38.11	163.81	0.87	0.32	0.99	87.16
Pagellus acarne	4.59	191.11	0.85	0.52	0.97	88.13
Alosa fallax	84.92	74.45	0.85	0.41	0.97	89.1
Dicentrarchus labrax	0	110.38	0.77	0.24	0.88	89.98
Torpedo marmorata	0	133.97	0.65	0.35	0.75	90.73