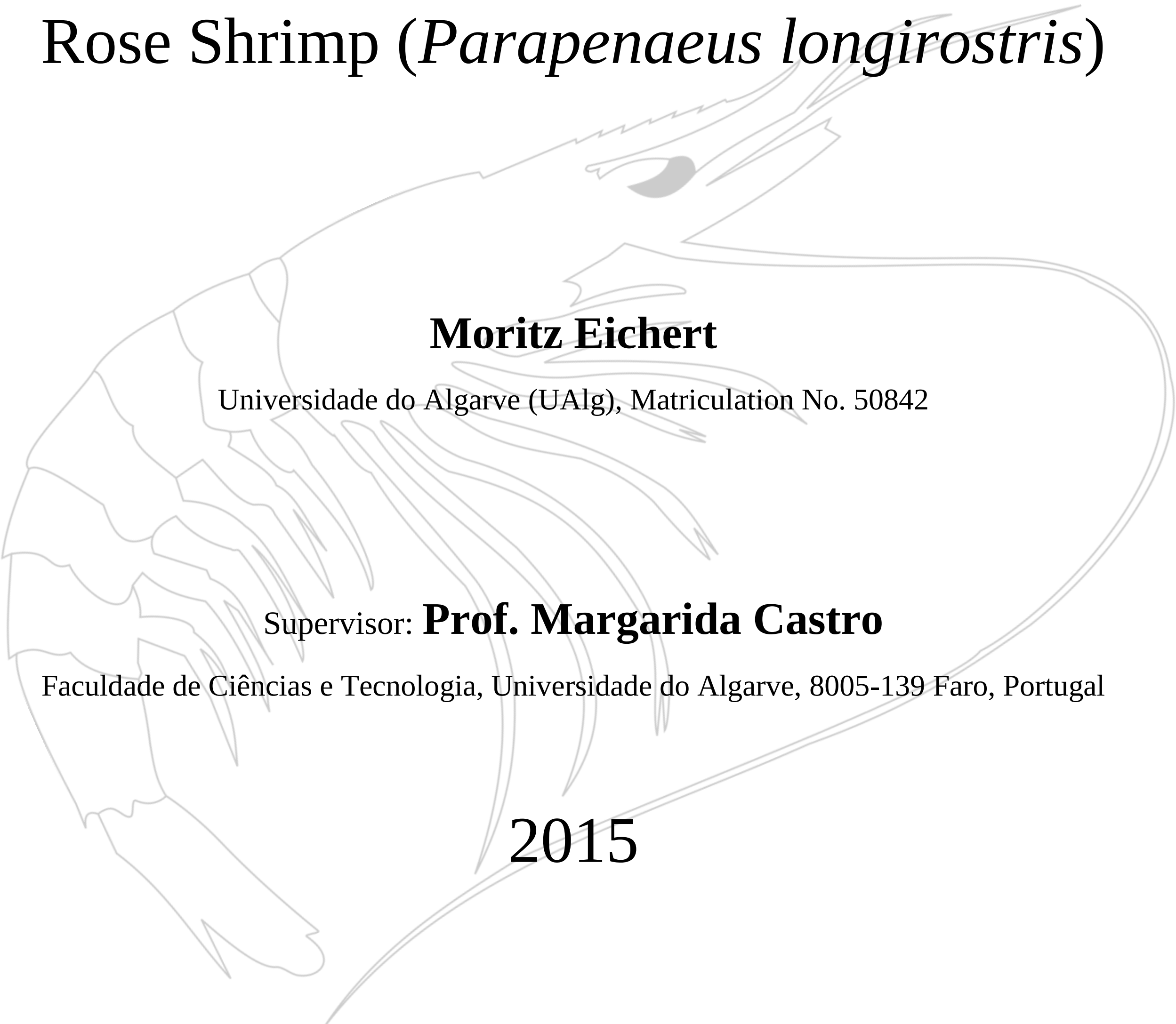
Master of Science in Aquaculture and Fisheries

Technical and Economic viability of Traps in the Portuguese Fishery of Deepwater Rose Shrimp (*Parapenaeus longirostris*)



Moritz Eichert

Universidade do Algarve (UAlg), Matriculation No. 50842

Supervisor: **Prof. Margarida Castro**

Faculdade de Ciências e Tecnologia, Universidade do Algarve, 8005-139 Faro, Portugal

2015

Declaracao de autoria de trabalho

Declaro ser o autor deste trabalho, que e original e inedito. Autores de trabalhos consultados estao devidamente citados no texto e constam da listagem de eferencias incluidas.

Copyright em nome da estudante da UAlg, Moritz Eichert

___________________	___________________	___________________
Moritz Eichert	Location	Date

Abstract

The Marine Strategic Framework Directive and the Reformed Common Fisheries Policy are following the ambitious objective to stop the loss of biodiversity and to make fisheries more sustainable. In most cases several fishing practices for one species exist, while in the exploitation of deepwater rose shrimp (*Parapenaeus longirostris*) and other nektobenthic crustacean, exploitation is exclusively reserved to the demersal trawling fleet. Because of the environmental impact of demersal trawling especially in deep waters and bycatch proportions exceeding ethical and ecological limits alternative fishing practices are needed urgently. In the Azores, Canary Islands and Cape Verde shrimp fisheries developed using semi-floating traps, the present work provides information about the feasibility of using such traps in a commonly trawling dominated fishery of the deepwater rose shrimp. However the low abundance of the specie made experimental conditions unfavorable. More frequent the golden shrimp (*Plesionika martia*), a scavenging specie was caught. A broad range of baits was tested, including fluorescent light and proceeded baits such as sardine paste (chum) with promising outcomes for future research in this field.

Keywords: gear substitution; demersal trawling; light, semi-floating traps, crustacean fisheries

Resumo

Na União Europeia, 88% dos stocks são explorados acima do rendimento máximo sustentável e 30% estão fora dos seus limites biológicos de segurança, com alterações que podem ser, em alguns casos, irreversíveis. O Comissário Europeu dos Assuntos Marítimos e das Pescas resumiu a presente situação com as seguintes palavras: “ O negócio do costume deixou de ser uma opção”.

A tentativa de reforma da Política Comum das Pescas passa pela Diretiva Quadro Estratégia Marinha (DQEM). Esta Directiva tem o ambicioso objectivo de impedir a perda de serviços dos ecossistemas e biodiversidade nas águas da UE e alcançar o Bom Estado Ambiental em 2020. Para o sector das pescas, está definido que até 2020, a captura de todos os stocks deverá estar dentro ou abaixo dos níveis de exploração que correspondem ao rendimento máximo sustentável e todos os recursos devem ser geridos através de uma abordagem ecossistémica.

O Bom Estado Ambiental é definido por onze descritores, sendo que o sexto refere o seguinte: “a integridade do fundo marinho assegura o funcionamento do ecossistema”, dando uma especial atenção à protecção dos habitats bentónicos e ênfase à sua importância para o ecossistema. A pesca de arrasto envolve a tecnologia de pesca mais destrutiva, praticada geralmente à escala industrial, com elevados impactos na comunidade bentónica e elevadas proporções de bycatch que excedem os limites ecológicos e éticos.

A pesca de arrasto demersal entra em conflito directo com as artes estáticas como palangres, armadilhas ou redes, e ocupa maioria das zonas de pesca. Devido a limitação da pesca de arrasto nos Açores, está a ser desenvolvida uma pesca com covos semi-flutuantes, com resultados promissores. As armadilhas não têm impacto na fauna e flora bentónicas. Para além das razões ecológicas e legais, outro factor importante é o benefício sócio-económico para a frota polivalente, visto que a poucos postos de trabalho. No entanto, a pesca com armadilhas é uma atividade que pode ser desenvolvida em embarcações de menores dimensões, envolvendo investimentos menores. A implementação de uma pesca de gamba com armadilhas em Portugal, iria proporcionar o aumento da rentabilidade de uma larga comunidade pesqueira que utiliza embarcações polivalentes. Assim, o presente trabalho tem como objectivo avaliar a viabilidade económica e técnica da pesca de gamba com covos semi-flutuantes.

O projecto foi desenvolvido em duas áreas a Sul e Sudoeste da costa de Portugal. No total, foram executados 35 ensaios, e colocados 3413 covos. A espécie alvo foi captura em quantidade reduzida, devido provavelmente à utilização de isco pouco adequado. Os resultados de estudos realizados com a gamba indicam que esta espécie é principalmente predadora, alimentando-se

de presas vivas, mais especificamente de um numero relativamente reduzido de poliquetas bentónicas e endobentónicos.

O camarão mais capturado pelos covos foi o camarão marreco (*Plesionika martia*). As pescarias de crustáceos de profundidade nas Ilhas Canárias, Cabo Verde e Açores, estão também concentradas em espécies de Plesionika, mas contrariamente aos estas ilhas atlânticas as densidades estimadas são demasiado reduzidas para uma exploração económica viável.

A enorme pressão sobre a gamba exercida pelo arrasto poderá estar a afectar igualmente outras espécies de crustáceos como o camarão marreco, visto que ambos os stocks se sobrepõem na mesma extensão batimétrica. Adicionalmente, o camarão marreco é uma espécie tropical que na costa portuguesa se encontra no limite Norte da sua distribuição geográfica.

O trabalho realizado forneceu informação sobre os tipos de isco adequados. Para além do isco comum (peixe gordo) foram testados peixe triturado, ração de aquacultura e atratores luminosos fluorescentes. O peixe triturado acabou por ser mais eficaz do que o isco comum. A luz também produziu capturas significativamente mais elevadas que o isco comum. Este último resultado é muito importante e requererá mais investigação no futuro, visto que a utilização de peixe como isco permanece um tema crítico e a utilização de luz poderá ser uma das possíveis soluções, como substituto do isco tradicional, numa pesca mais sustentável e para espécies com estratégias alimentares muito específicas, como a gamba.

Os crustáceos são o grupo de espécies capturadas mais rentável, tanto de captura selvagem como de produção em aquacultura. Infelizmente, são obtidos utilizando práticas de pesca e de cultivo que são destrutivas para com o meio ambiente. Os sistemas de aquacultura intensiva, na sua maioria instalados em antigas zonas de mangal, resultaram em grandes faixas de terra áridas e inférteis. Os impactos da pesca de arrasto demersal não têm o mesmo alcance visual, mas são comparáveis a actos de desflorestação. Neste contexto, o desenvolvimento de uma pescaria dirigida a camarões de profundidade utilizando artes de pesca de menores impactos, como as armadilhas, traria um enorme benefício dos pontos de vista ecológico e sócio-económico.

List of Figures

List of Tables

List of Abbreviations

CFP	Common Fisheries Policy
CL	Carapace Length
DWS	Deepwater Rose Shrimp
GES	Good Environmental Status
ICES	International Council for Exploration of the Sea
MLS	Minimum Landing Size
MSFD	Marine Strategic Framework Directive
MSY	Maximum Sustainable Yield
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch

Contents

1. Introduction

In the European Union 88 % percent of stocks are fished beyond Maximum Sustainable Yield (MSY) and 30% are outside their biological limits facing irreversible population changes (Greenpaper 2009). The commissioner of the EU for *Fisheries and Maritime Affairs* Maria Damanaki summed up the situation with the words: "*Business as usual is not an option anymore". A derivative of the reformed Common Fisheries Policy (CFP) is the Marine Strategy Framework Directive (MSFD, 2008/56/EC). The directive was released with the ambitious aim to stop the loss of ecosystem services and biodiversity in the EU waters and to establish good environmental status (GES) by 2020. For the fisheries sector it is defined that all stocks should be harvested at MSY or lower under the ecosystem approach to fisheries. GES is defined by eleven descriptors, and descriptor number six reads as follows: "seafloor integrity ensures the functioning of the ecosystem" giving a special attention to the protection of benthic habitats and emphasizing their importance for the ecosystem. Trawling is the most destructive fisheries technology practiced on industrial scale, with high impacts on the benthic community (Hall–Spencer *et al.* 2002; Jones 1992) and bycatch proportions exceeding ethical and ecological limits (Borges 2001; Kennelly 1995). Traps in contrary have very little direct impact on the benthic environment and are highly selective (species and size) towards the species targeted. Nevertheless are traps in deepwater shrimp fisheries the exception rather than the rule and receive only in recent years more attention due to the motivations of the named directives and reformations to substitute damaging fishing gears.

Crustaceans are the supreme group of marine capture and aquaculture production with over-average market values and high demand. Unfortunately they are mostly obtained by environmental destructive cultivation or fishing practices. The intensive aquaculture systems in former mangrove forests in the tropical regions resulted in large dry and unfertile land stripes. The impacts of demersal trawl fisheries are more withdrawn from our perception but they are very similar and often compared to deforestation (Kaiser 2000; Roberts 2002).

The deepwater rose shrimp (*Parapenaeus longirostris*) (DWS) is a short lived nektobenthic decapod living in depth between 20 - 750 m (Tom *et al.* 1988) with different bathymetric depth ranges in the Atlantic and Mediterranean populations. A comprehensive review about the biology and ecology of the DWS stocks in the Atlantic is available from Sobrino *et al.* (2005). According to this study in the Algarve, the highest abundance can be found between 100 – 300 m with a positive gradient towards larger carapace length (CL) with greater depth. Lifespan is expected to be shorter than three years and maturity is reached at 24 mm CL (females) and 20 mm CL (males). Females carry ovaries throughout the year except between February and April. Two spawning seasons are identified, the more important summer peak is followed by a second autumn spawning peak involving only younger individuals. Depending on size DWS feeds on a large variety of prey ranging from planktonic crustaceans to small cephalopods and fish. Sobrino *et al.* (2005) identified two feeding behaviors, one during the digging phase associated with preys living in the benthos (polychaeta, foraminifera, echinoderms) and the hunting phase, concentrating on demersal and pelagic animals such as small fish and cephalopods as well as other crustaceans. The different feeding behavior support the evidence that the specie is performing vertical migrations in 24 h cycles resulting in different catchabilities (by the trawlers) at night and day (Sonderblohm 2011).

The DWS is a specie economically exploited mainly in the Mediterranean and in a small extend in the North-East Atlantic along the coast of Portugal to the Gulf of Cadiz. In the Atlantic only Spain and Portugal conduct fishing on this specie. Sobrino *et al*. (2005) proposed on stock for the Atlantic population but detailed genetic information is missing. Portugal's demersal trawling fleet is targeting largely the named specie and Norway lobster. In recent years the shrimp fishery became more important due to cut offs in the quota of Norway lobster (*Nephrops norvegicus*). In contrary to DWS these stocks are managed at the European level under the International Council for Exploration of the Sea (ICES). Because the stock was showing signs of overfishing, in 2005, a recovery plan for norway lobster (and European hake) was implemented (Council Regulation No 2166/2005). During a period of ten years, an annual reduction of fishing effort of 10 % is aiming at restoring the stocks in West Galicia and South Portugal. Concomitantly the advised TAC is steadily decreasing.

Nevertheless is the fishing effort of the crustacean trawling fleet alternating between DWS and Norway lobster depending on the Norway lobster TAC and abundance of DWS. Because of the absence of a TAC for DWS and a series of years with great abundance, the fishery focuses more on DWS and became more important in recent years (Fig 1, Table 1).

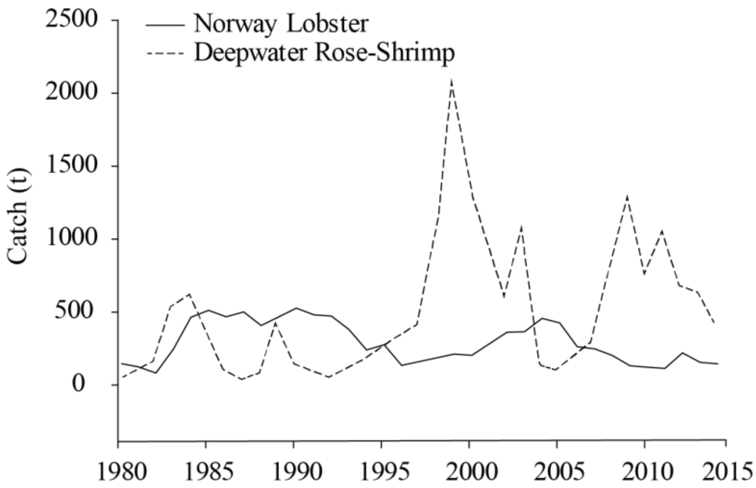


Fig 1 Landings of Norway lobster (*Nephrops norvegicus*) and deepwater rose shrimp (*Parapenaeus longirostris*) between 1980 and 2014 in Portugal (*DGRM, Recuros da Pesca*), including 2015 (until September)

Table 1 Revenues (Mio. Euros) for Norway lobster (*Nephrops norvegicus*) and deepwater rose shrimp (*Parapenaeus longirostris*) and the generated market share by deepwater rose shrimp in Portugal (*DGRM, Recuros da Pesca*)

Year	Norway Lobster (Mio. EURO)	Deepwater Rose-Shrimp (Mio. EURO)	% Deep-water Rose Shrimp
1997	2.2	4.5	55.5
1998	2.9	6.6	52.8
1999	3.9	11.2	61.5
2000	4.2	12.8	60.4
2001	5.3	11.6	54.9
2002	6.1	7.9	45.2
2003	6.1	9.6	55.5
2004	6.3	4.0	33.6
2005	5.9	2.6	28.0
2006	5.6	4.6	40.0
2007	5.2	6.6	48.9
2008	4.6	8.0	53.7
2009	2.8	10.0	63.7
2010	2.7	9.1	63.6
2011	2.2	8.7	66.4
2012	3.1	7.3	60.8
2013	2.0	5.5	56.1
2014	2.0	5.4	51.4

While the Norway lobster stocks are assessed by the ICES, the DWS assessment is carried out at the national level by the *Instituto Português do Mar e da Atmosfera* (IPMA). Data comes from the official landings and research surveys carried out once a year. According to a virtual population analyzes, over a time period of five years (1984 – 1989) the DWS stock of the Atlantic was overexploited (Pestana, 1991). Nevertheless this is a resource with short life and large fluctuations, dependent on good recruitment and therefore is strongly related to environmental conditions. This is supported by a study carried out by Ana Moreira and Borges

(2010) correlating the North Atlantic Oscillation Index (NOA), precipitation and sea surface temperature (SST) with the landings of DWS and Norway lobster. Even though the results are ambiguous a general trend shows that weak upwelling and warmer waters enhance recruitment of DWS. On the contrary, Norway lobster abundance is positively correlated with the same NOA patterns but with a preference for lower SST and stronger upwelling.

In conclusion, Sobrino *et al.* (2005) recommend an effort reduction of 10 – 15% to decrease the fishing pressure and gear modifications to respect the Minimum Landing Size (MLS) of 24 mm CL in DWS (e.g. square mesh panels with 60 mm mesh width) (Campos *et al.* 2002).

The high environmental impacts of deepwater trawling, the indiscriminate catch pattern and the high bycatch mortality are putting it under pressure of conservationists, scientist and the public media. Because trawling was strongly subsidized during the 1990's its capacity grew and became the mode of production for demersal fisheries (Sumaila 2013). This is shown by the value of the landings of different gears. Demersal trawling accounts for 38 % of total value of landings in the EU member states (STECF Report 2014). Trawling vessels are catching large quantities, relatively to the employment provided (FAO 2005). This makes the activity very questionable from a socio-economic point of view, in face of the high value of the demersal fish and crustacean stocks, but also due to the policy from the new CFP, that incentives the allocation of resources towards fisheries with less impacts on the environment and providing more livelihoods to the fishing community:

"*When allocating the fishing opportunities available to them, as referred to in Article 16, member states shall use transparent and objective criteria including those of an environmental, social and economic nature. The criteria to be used may include, inter alia, the impact of fishing on the environment, the history of compliance, the contribution to the local economy and historic catch levels. Within the fishing opportunities allocated to them, member states shall endeavour to provide incentives to fishing vessels deploying selective fishing gear or using fishing techniques with reduced environmental impact, such as reduced energy consumption or habitat damage*." - Article 17, Reformed Common Fisheries Policy

The use of gears with fewer environmental impacts, such as traps, would also add value to the catch, because fish or crustacean caught with a trawling net are in general poorer state due to the heavy physical impacts during the hauls and on deck processing (Leocádio *et al.* 2012). In terms of ecological impacts, fuel consumption and habitat destruction bottom trawling stands out (Table 2).

Table 2 Summary of the comparison between demersal trawling (DTS) and Traps, by type of impact, with list of criteria and related references

Impact Group	Criteria	Trawl	Traps	Reference
Ecological	Benthic Impact	High	Low	Eno *et al.* (2001); Coleman *et al* (2013)
	Discard Mortality	High	Low	Broadhurst et al. (2006)
	Ghost Fishing	Low	Medium	Adey *et al.* (2008); Brown *et al.*(2007)
	Fuel Consumption	High	Low	Ziegler et al. (2008)
	Size Selectivity	Medium	High	Broadhurst (2000); Leocádio *et al.* (2012)
	Specie Selectivity	Low	High	Goñi (1998); Sala *et al.* (2008)
	Areal Impact	High	Low	Eno et al. (2001)
Socio-economical	Subsidies	High	Low	Sumaila et al. (2013); Eriksson (2006)
	Catch Condition	Dead	Alive	Leocádio *et al.* (2012)
	Ecosystem Services	Weakening	Improving	Thrush *et al.*(2002)
	Resource allocation	Extensive	Dense	Hentrich *et al.*2006)
	Price per Kg	Medium	High	Fig. 2; Leocádio *et al.* (2012)
	Employment	Low	High	FAO (2005)
	Cultural Value	Low	Medium	Reed *et al.* (2013)

The impacts of trawling are mainly studied on shallow water habitats and hard bottoms because of the drastic consequences for calcified structures. Deep waters and soft bottoms are a difficult study environment with ecosystem characteristics that make them more vulnerable to any kind of disturbance (Kaiser 2000). In nature the strongest physical forces are induced by weather (e.g. wind) and the turbulence it generates is vertically transported into deeper water layers by orbital waves, but with depth the power of the waves gradually disappears. The evolutionary history of the organisms in such an environment took place without or with very infrequent impacts such as falling material from upper water layers. Besides this, other forms of energy are also scarce because of the absence of light. Low metabolic rates, late maturity and slow growth rates, make deep sea species more vulnerable to changes in the environment, reducing their ability to recover from disturbances (Collie 2000; Johnson 2002; Kaiser 2000).

Trawling is producing a climate of steady disturbance in this commonly “silent” environment with consequences for the abundance, composition and distribution of epi- and endofauna, making it less diverse and abundant (Schratzberger 2002). Macroscopic changes also take place such as the general trend towards smaller sizes of endofaunal species due to the size-selective character of the gear (Queirós 2006). Overall the ecosystem dynamic is dominated and controlled by the fishing activity itself. This includes indirect impacts such as food subsidies to the scavenging species in form of offshore discarded bycatch, resulting in greater diversity and abundance of this community (Kaiser 2000). Another reason for the increased abundance of low trophic species is the predator release due to the size selectivity towards maximum sizes.

Besides the physical impact of the otter doors and tickler chains, trawling originates the resuspension of benthic sediments in clouds of 3 – 4 m in height and 70 – 200 m wide, transporting organic and inorganic matter up to 800 g $m^{-2}s^{-1}$ in the surrounding areas (Durrieu de Madron 2011). The siphons of burrowing species are covered and the oxygenation of the sediments is reduced. Deepwater currents are able to transport these clouds and alter the sedimentation rates even in bathyal depths (Martín 2008) which makes it difficult to assess the total area impacted by a trawl besides the towed area.

The Portuguese trawl fishery for deep water crustaceans has initiated its activity in 1940's targeting exclusively Norway lobster. In the second half of that century a Portuguese-Spanish joint venture initiated the industrial exploration of DWS. At present the Portuguese trawling fleet holds licenses for fish and crustacean and comprises 186 vessels, with 26 vessels licensed for the capture of Crustacea (Wise *et al.* 2015). At present this crustacean fleet mainly targets norway lobster (*Nephrops norvegicus*) and DWS. Other deepwater crustacean species, such as red shrimp (*Aristeus antennatus*), giant red shrimp (*Aristaeomorpha foliacea*) and the scarlet shrimp (*Aristaeopsis edwardsiana*) are also targeted but in relatively small quantities.

The Portuguese trawling fleet is not allowed to operate inside 6 nautical miles from the baseline. The enforcement of this legislation was helped by the introduction of a vessel monitoring system (VMS) in 2002 for all Vessels above 15 m. Information from the system concerning the position and speed of the vessel is transmitted to shore-based facility every two hours. Using the vessel speed as a proxy, it is possible to identify individual trawl hauls. Then, this information can be matched with landings and logbook entries. The overall result is a detailed mapping of fishing effort allocation (Afonso-Dias 2008).

The Fishing trips never exceed three days (Afonso-Dias 2008) with average trawling speed of 3.0 nm/h (Sobrino 1998; Sobrino *et al*. 2005; Viriato and de Figueiredo 1991). The fishery for nektobenthic shrimp and Norway lobster takes place on soft and muddy bottoms between 200 - 600 m along the South and South-Western Coast of Portugal. Norway lobster, red shrimp, scarlet shrimp and giant red shrimp are in the deeper waters (400 – 1000 m), while the DWS is between 200 - 400 m (Campos *et al*. 2002; Sobrino *et al.* 2005). This depth spectrum is covering parts of the outer shelf but mostly the continental slope. Because each fishery is taking place predominantly in a certain depth spectrum and during day or night the bycatch composition is differing with target specie. The tows targeting Norway lobster are bringing up more deepwater species such as silvery pout (*Gadiculus argenteus*), roughtip grenadier (*Nezumia sclerorhynchus*), and mediterranean slimehead (*Hoplostetus mediterraneus*) (Monteiro 2001).

While the bycatch from shallower waters during tows for DWS are mainly consist of deep sea shark species (*Galeus melastomus, Etmopterus pusillus, Etmopterus spinax*) conger (*Conger conger*), European hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus* and *Trachuros picturatus*) monkfish (*Lophius piscatorius*) and a variety of cephalopods (Fig. *7*) (Borges 2001). Only blue whiting (*Micromesistius poutassou*) is present along the whole depth spectrum and consequently is found in both fisheries in enormous quantities (Fig. *7*).

The demersal trawling vessels are obliged by law to land at least 70% of target specie. For the crustacean fleet this means only up to 30 % of the quantity caught can be fish. This also increases the bycatch problem because the captain would violate the law when retaining fish exceeding the 30 % limit. On the other side, trawlers targeting fish can land up to 30 % of crustacean species including the closed month of January. Because of the high value of crustacean species and the low value of fish in recent years these vessels make full use of the regulation.

Both fisheries use a diamond mesh codend with a mesh width of 55mm for DWS and 70 mm for Norway lobster (stretched, diagonal). MLS of 24 mm CL for DWS and 21 mm CL for norway lobster are in place, to avoid recruitment overfishing. As said above gear modifications are necessary to respect the of DWS and Norway lobster (e.g. square mesh panels with 60 mm mesh width) (Campos *et al.* 2002).

While for fish and lobsters there is the possibility to use trammel nets, gillnets, longlines or traps, in fisheries for nektobenthic decapods such as DWS and the golden shrimp the option of using gears alternative to trawling, is yet very little investigated. Traps are one of the oldest hunting gathering techniques, with long traditions in fisheries, available in a huge variety of shapes and sizes. But for demersal fisSh and crustacean stocks the common mode of production became demersal trawling due to high catch rates (low selectivity) and relatively easy application. The expansion of trawling in demersal fisheries pushed traps back, and introduced a new level of fishing effort. Consequently nowadays most stocks are either fully or overexploited, making viable fisheries with less efficient gears more difficult due to the low densities encountered (Chuenpagdee *et al.* 2003; Myers and Worm 2003).

The largest crustacean fishery in European waters by value and quantity is for Norway lobster, a specie widely distributed over the North East Atlantic from Norway to Morocco as well as in the Mediterranean (FAO, Species Fact Sheet).

In terms of landed values it is as important as the traditional demersal finfish species such as cod, haddock or pollock. Interestingly a major trapping fleet developed in coexistence with trawling due to some specialties of the specie. Because of behavioral reasons large males are more vulnerable to traps, this results in a catch with mainly large individuals and in prime condition (alive) with a significant higher market value (Fig. ***2***) (Leocádio *et al.* 2012). In the certification process for *Loch Torridon* Norway lobster by the Marine Stewardship Council a fisherman stated (David 2003):

"*On the economic side, Loch Torridon live Nephrops fetch three and four times the price of the same creature netted by a trawler*"

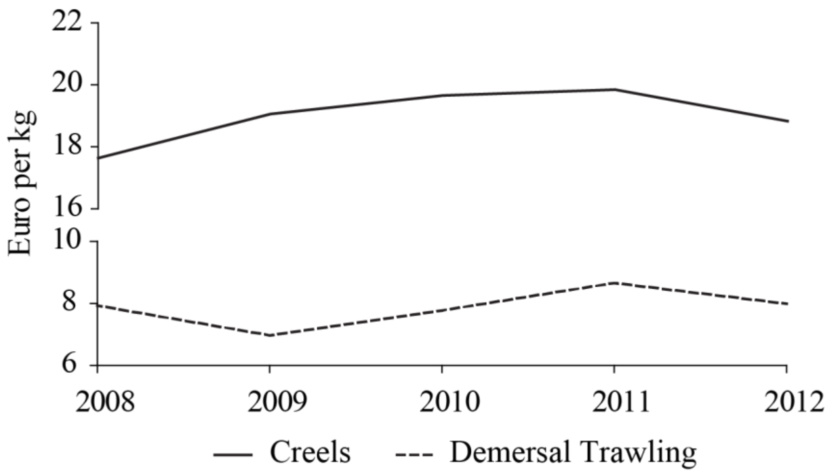


Fig. 2 Differences in Euro per kilogram for norway lobster (*Nephrops norvegicus*) caught in traps and demersal towed gears (demersal trawl and beam trawl) from five European Countries (Sweden, France, Portugal, Ireland and United Kongdom). The difference in price for demersal trawling (*pink*) and traps (*green*) is highly significant (paired t-test, p=3x10-4). (STECF 2013)

Creels and traps are common in Lobster fisheries around the world, but the catch of deepwater nektobenthic shrimp with pots or creels is less known. During the 1980's experimental trapping was conducted by NOAA to explore deep-water crustaceans (King 1981; Struhsaker 1974). In the Atlantic oceanic islands (Azores, Canary Islands and Cape Verde), where trawling is not allowed due to inadequate bottoms (steep and rocky), the local fisherman were forced to use alternative fishing methods. Arrasate-López and González (2012) conducted experiments with semi-floating traps around the Canary Islands. Between 100 – 1300 m it was possible to catch a variety of different species according to their bathymetric extend, with prospecting results for an economic exploration of golden shrimp (*Plesionika edwardsii*). Following the same concept, Cabo Verde carried out trials with the same outcomes and plans to open a commercial fishery targeting golden shrimp with traps (Gonzáles 2012).

Semi-floating traps have some advantages in comparison to common creels deployed on the bottom. The bait stays viable for a longer period because benthic scavengers (i.e. amphipods, isopods and equinoderms) are hindered to access the trap. Semi-floating traps are expected to lower the catch of other bottom crustacean species with no ability to swim (Norway lobster, spider crabs and hermit crabs) and increase the catches of nektobenthic species. A lifted trap will be better to capture DWS.

Critical issues are the use of bait and ghost fishing but in face of the enormous impacts of trawling, the damages can be considered minor. More difficult is the substitution of bait. Arrasate-López and González (2012) used chub mackerel and other species with high fat contents. These are mainly small pelagic fish species due to their availability and low value. However, these species also represent prime nourishment for human consumption due to the high content of polyunsaturated omega-3 fatty acids. Existing literature about artificial baits is very scarce and its efficacy is not yet established, therefore substitution of traditional baits is yet not in sight (Archdale 2011).

1.1 Objective

Overfishing and damaging fishing gear are responsible for the devastating state of fisheries resources in Europe and the world (Pauly *et al.* 2002). The following work aims to draw out the possibilities to use semi-floating traps in a trawling dominated fishery for the DWS in South Portugal including a preliminary evaluation of the economic viability of such a fishery.

2. Material and Methods

The absence of information on trap fishing targeting DWS required the investigation of several aspects such as, trap design, bait type, soaking time and distance of the traps from the bottom.

The project was planned in two phases, one developed on the West coast, known to have moderate conditions for DWS and the common fishing ground for the specie along the Algarve coast. The were divided into two subareas, identified in South Sines (SS) and Sines North (SN) and Portimao (PRT) and Faro (FAR) (Fig. *3*)

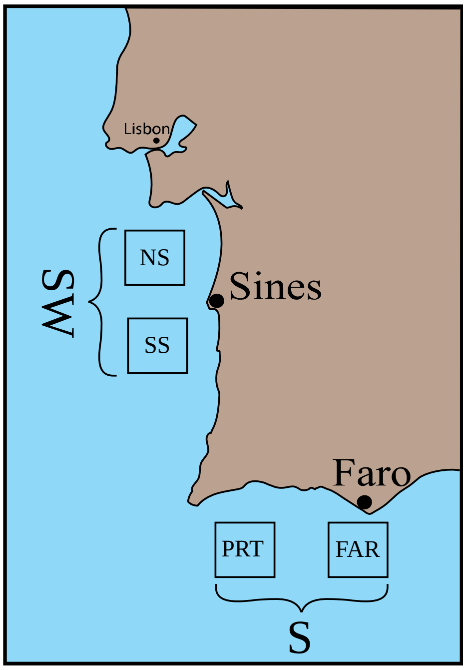


Fig. 3 The sample sites for the trapping experiments (SW &S) with the related areas: Sines North (SN), Sines South (SS), Portimão (PRT) and Faro (FAR)

In both cases trawling was undertaken in the vicinity of the trap lines, to estimate DWS abundance in the area. The comparison of DWS length distributions between trawl and trap catches would also allow the evaluation of the impact of the two gears on the population structure.

It was expected that an improvement in the trap line design could be achieved during phase one and that such information could be used in phase two to maximize the catch and obtain preliminary information on the economic viability of trap fishing for DWS.

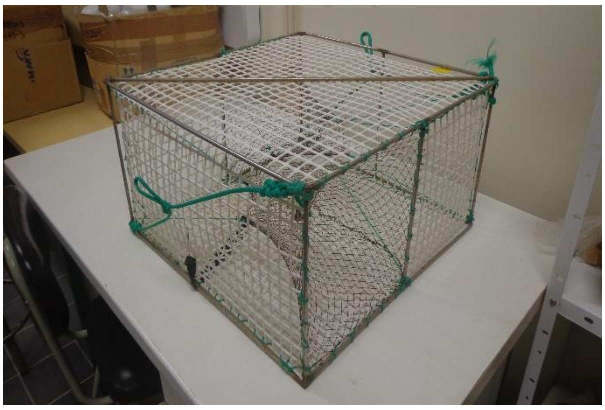
The experiments were conducted on two commercial fishing vessels. A trawler with 24.9 m using a standard codend with 55 mm diagonal mesh with a crew of seven people and a polyvalent vessel with 17. 08 m operating the traps, with a crew of six. Both vessels can be considered as representatives of their class. In the South coast, trawls were also undertaken with a fine mesh codend (28 mm), in order to obtain DWS samples not affected by the codend selectivity of the commercial net.

2.1 Trap design

Three different trap types were tested during the experimental part of the project.

- Type A – A modification of traps used for Norway lobster, but made of lighter material, a model designed in cooperation with fisherman experienced in trap fishing of Norway lobster; (Fig. 4, a);
- Type B – Light collapsible traps, originally used in nearshore fisheries of crabs in seagrass meadows, hence the structure is very fragile but the ability to fold the traps would make it also for smaller vessels to deploy larger numbers of traps (Fig. 4, b);
- Type C - conic trap type used in the shrimp fisheries in the Canary Islands and the Azores (Fig. 4, c).

a)



b)

c)

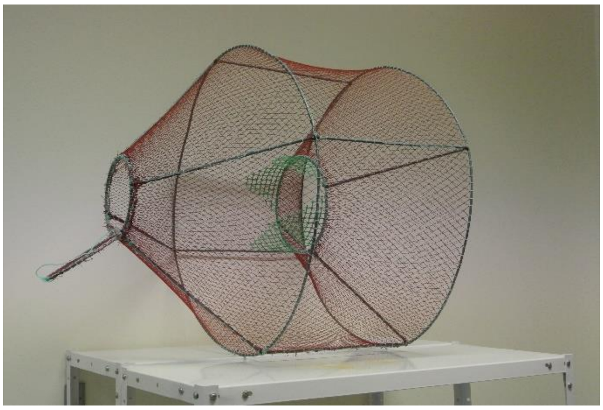


Fig. 4 a) Modified Norway lobster creel, b) collapsible trap type and c) conic shaped shrimp trap

2.2 Trap line setup

Peak density of DWS is expected between 100 and 300 m, with average size of the individuals increasing with depth. To target larger sizes, the trap lines were deployed bellow 200 meters (200 – 400 m).

Because the target species is nektobenthic, the basic design followed the description of a trap line to fish for other nektobenhtic shrimp (Arrasate-Lópes et al., 2012), described in (Fig. 5, a). To give the traps buoyancy, floaters were installed on the top of the traps (Fig. 5, b). The buoys chosen are used on the head rope of trawling nets operating at the same depth and are, therefore, resistant to high pressures. At the bottom the traps were attached to the mainline with a piece of rope of varying lengths (1, 2, 3 or 4 m). The mainline had built-in lead and concrete blocks were tied at regular spaces to guarantee it stayed in contact with the bottom.

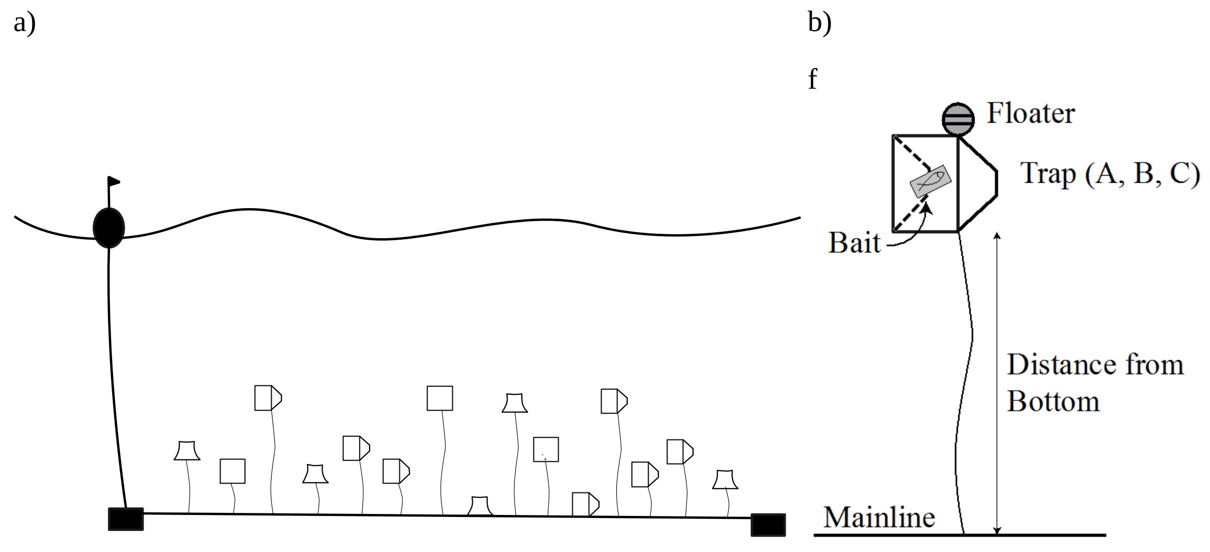


Fig. 5 Left: Scheme of a randomized trapping line with the three trap types in different distances from the seafloor. Right: Semi-floating traps used in the fishery for different nektobenthic crustaceans throughout the Atlantic Islands

2.3 Bait

To identify the optimum of bait or attractant different natural and artificial baits were tested. Fatty fish species such as sardine or mackerel were salted. Three new bait types were also tested on the South coast, chum (paste of minced sardine) used by recreational fisherman, aquaculture fish pellets and fluorescent light sticks.

Light regulates migratory movements on daily or life cycle basis in deepwater crustaceans (Aguzzi 2009). It dictates the daily vertical migrations and consequently also significantly the feeding behavior.

The condition of the bait (signs of consumption=1, no consumption=0) was registered for each trap

2.4 Soaking time

DWS concentrates on the bottom during the day to forage, mainly preying on endobenthic and benthic animals. Because of this, the trawl catches are at a peak around noon (Sonderblohm 2011). It is therefore expected that the feeding activity is highest immediately after returning from the pelagic phase, at around sunrise. To test the variation in catchability throughout the day, four time frames were tested:

I. Sunrise
II. Daytime
III. Sunset
IV. Day + Night

The soaking time varied from 2 to 48 hours. Occasionally longer times happened due to difficulties in retrieving the tarps during bad weather.

2.5 Density of DWS

The density of the DWS was evaluated using *swept method* approach, based on the trawl catches, in accordance to the FAO guidelines for trawl surveys (Sparre and Venema 1998). The estimations were done for each tow and the average for S and SE calculated. The trawled distance was calculated based on the registered vessel speed and the trawl duration. The wing spread is considered to be the best estimate of the width of the area swept by a trawl because the otter boards and bridles are much wider than the net itself and pass on the swirled-up organisms into the codend, consequently is the are-swept a function of headrope, length (h_r) and a conversion factor (X_2) correcting for the real net opening multiplied with the towed distance (D).

$$a = D \cdot h_r \cdot X_2$$

The caught biomass of DWS of each tow was simply divided by the area swept to obtain a relative abundance index of the specie.

2.6 Statistical analysis

The total number of traps in a particular line were defined by the bottom characteristics, to avoid setting the line on rocky sites. The factors being tested (trap type, distance to the bottom and bait time) were completely randomized. Fifty randomization schemes were prepared and used during the traps deployment, in order to quickly construct the line. For the identification, each trap was tagged with a individual number.

A logistic linear model (response variable presence or absence of the species) was used. The continuous variable soaking time was transformed into a two level factor DURATION: short, soaking time < 12hours, and long, soaking time ≥ than 12 hours. Other factors considered were BAIT TYPE, TRAP TYPE, TIME OF DAY (1=sunrise, 2= sunset, 3=all day and 4= night), REGION (SW=Southwest and S=South), AREA (SN, SS, PRT and FAR) and DISTANCE FROM THE SEAFLOOR (0, 1 2 and 3 meters). In the case of significant variables, contrast were used to compare the levels.

The consumption of the bait was also classified into one of two categories, *consumed* (1) and *not consumed* (0). The category *consumed* includes the fully consumed and half consumed bait. A logistic model was applied to compare regions and areas.

3. Results

The location of the trials are presented in Fig. **6**, while the characteristics of the trap and trawl essays are presented in Table 3 and Table 4. Given the lack of success in catching DWS during the first phase of the experiments on the SW coast, and the impossibility of identifying the best choice of factors to maximize DWS catches, the completely randomized set up was maintained during the trials in the South coast.

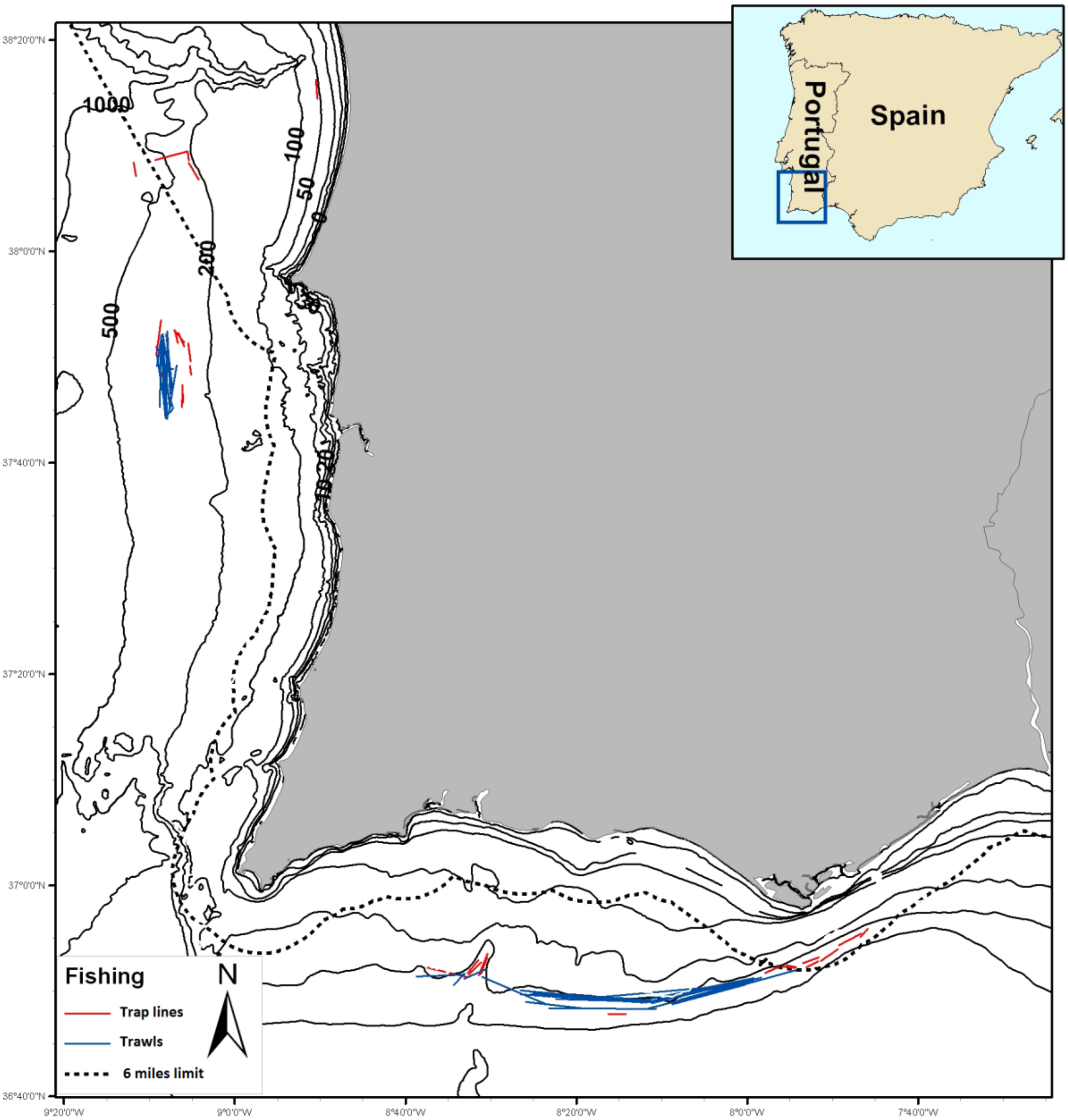


Fig. 6 Conducted field work during the experimental phase indicated by blue lines (trawls) and red lines (traps) along the South and South-West Coast of Portugal.

Table 3 Number of trials with according coordinates, duration time of day, depth and bait in the South-West coast (15) and Algarve (20). Bait types are in acronyms: C – Chub mackerel (*Scomber colias*), S – Sardine (*Sardina pilchardus*), P – Pellets, L – Fluorescent Light, CH – Chum

Trial	Site	Date	Time of Day (hh:mm)	Duration (h:m)	Depth (m)	Bait	Number of Traps
1	SS	24-Apr-15	05:00	4:05	349.46	C	132
2	SS	27-Apr-15	05:23	4:05	302.75	C	89
3	SS	27-Apr-15	06:00	9:12	-	C	94
4	SS	27-Apr-15	11:30	10:21	-	C	88
5	SS	28-Apr-15	17:31	15:00	-	C	96
6	SS	28-Apr-15	23:51	9:00	-	C	88
7	SS	29-Apr-15	11:07	10:50	-	S	87
8	SS	29-Apr-15	11:45	3:23	285.45	S	96
9	SS	30-Apr-15	17:03	15:00	302.75	C, S	64
10	SS	5-May-15	12:23	116:00	543.22	S	96
11	SN	5-May-15	05:37	11:04	245.66	C, S	144
12	SN	6-May-15	11:40	20:00	583.01	C, S	91
13	SN	6-May-15	05:43	7:17	271.61	C	276
14	SN	8-May-15	04:51	27:00	56.744	C	114
15	SN	7-May-15	05:21	5:06	64.01	C	91
16	PRT	11-May-15	04:30	5:05	273	C, S	104
17	PRT	12-May-15	05:00	8:45	273	C, S	103
18	PRT	13-May-15	12:00	21:25	294.1	C	115
19	PRT	13-May-15	05:05	11:10	209.33	C	105
20	PRT	13-May-15	14:00	7:40	294.1	P	109
21	FAR	15-May-15	02:00	12:00	268.15	P	103
22	FAR	18-May-15	12:00	96:00	280.26	P, C	123
23	FAR	18-May-15	18:00	3:30	211.06	P, C	93
24	FAR	18-May-15	19:00	4:30	335.6	P, C	78
25	FAR	19-May-15	06:40	2:40	280.26	P, C	81
26	FAR	20-May-15	09:00	26:21	335	C	82
27	FAR	20-May-15	11:00	23:00	250.85	C	82
28	FAR	21-May-15	14:00	22:00	259	CH, C	82
29	FAR	21-May-15	14:15	19:15	230.09	CH, C	88
30	FAR	25-May-15	13:40	94:40	237.01	CH, C	177
31	PRT	26-May-15	19:50	12:50	337.35	CH, C	89
32	PRT	27-May-15	19:30	37:00	301.02	CH, C	81
33	PRT	27-May-15	11:30	24:20	294.1	CH, C	90
34	PRT	28-May-15	10:00	23:10	302.75	CH, C, L	93
35	PRT	26-May-15	14:15	20:15	294.1	CH, C, L	90

Table 4 Locations, time of day, duration and vessel speed for 45 trawls in the South-West (19) and Algarve (26)

Trial	Site	Mesh Size	Date	Coordinates (DMS)		Time of Day (hh:mm)	Duration (h:mm)	Vessel Speed (kts)
				Start	End			
1	SW	Large	24-Apr-15	37°51.432	9°08.602	7:44	2:19	2.8
2	SW	Large	24-Apr-15	37°46.909	9°07.384	10:50	2:05	2.8
3	SW	Large	27-Apr-15	37°51.908	9°08.794	7:35	2:18	.
4	SW	Large	27-Apr-15	37°45.297	9°08.907	10:55	2:30	.
5	SW	Large	27-Apr-15	37°51.209	9°08.57	14:13	2:36	2.8
6	SW	Large	27-Apr-15	37°45.694	9°07.639	17:31	3:10	.
7	SW	Large	28-Apr-15	37°51.362	9°08.500	7:01	2:37	2.9
8	SW	Large	28-Apr-15	37°45.585	9°08.444	10:22	2:10	2.4
9	SW	Large	29-Apr-15	37°50.240	9°09.283	7:42	2:10	2.8
10	SW	Large	29-Apr-15	37°45.354	9°07.742	10:48	2:09	2.8
11	SW	Large	29-Apr-15	37°49.266	9°06.899	13:40	1:49	2.8
12	SW	Large	29-Apr-15	37°45.421	9°07.409	16:06	4:44	2.8
13	SW	Large	30-Apr-15	37°45.252	9°07.355	6:41	3:32	2.8
14	SW	Large	30-Apr-15	37°46.537	9°07.668	11:00	2:14	2.8
15	SW	Large	5-May-15	37°51.034	9°08.633	6:50	4:10	2.8
16	SW	Large	5-May-15	37°49.184	9°09.290	12:16	4:08	2.8
17	SW	Large	5-May-15	37°49.901	9°08.476	17:19	4:03	2.8
18	SW	Large	6-May-15	37°48.945	9°08.192	6:40	2:55	2.7
19	SW	Large	6-May-15	37°46.985	9°07.555	10:36	1:55	2.8
20	S	Large	12-May-15	36°51.114	8°33.089	6:30	3:13	2.8
21	S	Large	12-May-15	36°51.393	8°38.681	10:38	3:08	2.8
22	S	Large	12-May-15	36°50.544	8°34.276	14:40	4:31	2.8
24	S	Small	13-May-15	36°48.309	8°23.091	11:00	2:36	2.8
25	S	Small	13-May-15	36°49.033	8°07.425	14:26	1:59	2.8
26	S	Small	13-May-15	36°50.266	8°00.761	17:09	1:49	2.8
27	S	Large	14-May-15	36°50.914	7°59.120	8:07	2:50	2.7
28	S	Small	14-May-15	36°49.030	8°07.723	11:45	2:59	2.8
29	S	Large	18-May-15	36°50.364	8°00.033	8:04	2:35	2.8
30	S	Large	18-May-15	36°48.805	8°10.858	11:22	3:12	2.8
31	S	Large	18-May-15	36°49.106	8°20.474	15:15	5:47	2.8
32	S	Large	19-May-15	36°50.973	7°59.114	6:37	3:50	2.8
33	S	Large	19-May-15	36°48.800	8°11.995	11:05	3:55	2.8
34	S	Small	21-May-15	36°49.612	8°25.312	7:15	3:10	2.8
35	S	Small	21-May-15	36°49.142	8°16.778	11:10	2:50	2.4
36	S	Large	25-May-15	36°49.720	8°24.965	7:15	3:25	2.9
37	S	Large	25-May-15	36°48.745	8°11.046	11:23	3:47	2.8
38	S	Large	25-May-15	36°50.671	7°59.261	15:45	3:45	2.9
39	S	Large	26-May-15	36°50.745	8°00.253	6:37	3:25	2.5
40	S	Large	26-May-15	36°48.931	8°11.042	10:59	3:54	2.3
41	S	Small	27-May-15	36°49.472	8°22.302	9:00	2:00	2.8
42	S	Small	27-May-15	36°48.268	8°19.264	12:01	1:59	2.9
43	S	Small	27-May-15	36°49.899	8°24.936	14:46	2:02	2.9
44	S	Large	28-May-15	36°49.738	8°24.281	6:37	3:52	2.8
45	S	Large	28-May-15	36°48.894	8°12.750	11:00	3:49	2.9

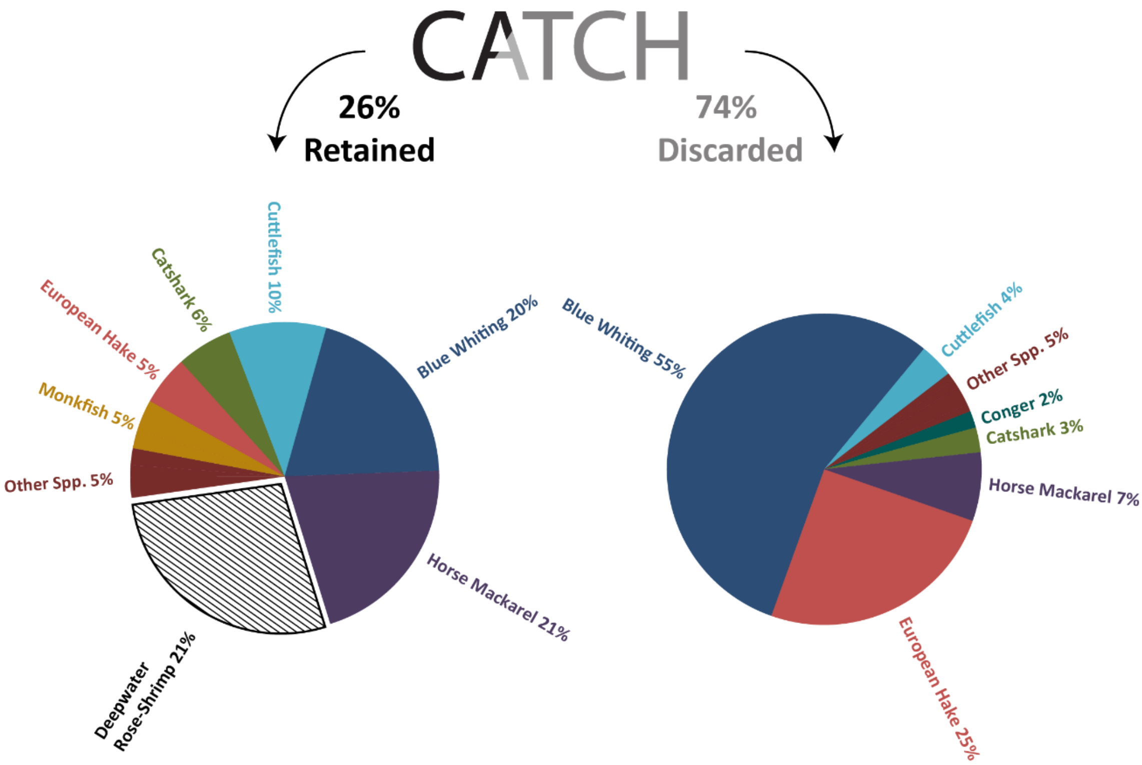


Fig. 7 The catch retained in 26 tows in a commercial codend with 55 m diamond square mesh panels directed towards deepwater rose shrimp (*pattern fill*) in the Algarve. In total the tows consisted of 30 species of which 17 are completely or partly discarded and represent ¾ of the total catch in weight. Including species for human consumption and fishing restrictions (f. e. hake, blue whiting, horse mackerel, conger)

Table 5 Density estimates for Deepwater Rose-Shrimp (DWS) (*Parapeneaus longirostris*) based on 45 trawls with the minimum (Min.), maximum (Max.) and mean for the South-West (SW) and South (S)

Area	Density of DWS (g/m^2)		
	Min.	Max	Mean
SW	0.05	0.16	0.10
S	0.03	0.23	0.12

Table 6 All species caught in respect to the different factors tested during the experimental phase. Trap type A (Box trap), B (Collapsible) and C (Conic shaped). The baits are abbreviated by C (Chub Mackerel), S (Sardine), SC (Sardine & Chub Mackerel), P (pellets) and L (light). The different soaking times were categorized in two groups short (<12h) and long (>12h)

Common Name	Scientific Name	Trap Type			Distance from Bottom				Sample Site				Bait						Duration		Total
		A	B	C	0	1	2	3	SN	SS	FAR	PRT	C	S	SC	CH	AP	L	S	L	All
DECAPODS																					
Deepwater Rose Shrimp	*Parapenaeus longirostris*	1		10		5	5	1		2	2	7	10	1					2	9	11
Golden Shrimp	*Plesionika martia*	13	2	28		29	13	1	1		12	30	23			13	4	3	4	39	43
Slender Spidercrab	*Macropodia tenuirostris*	11	1	6		15	2	1		1	6	11	11	1			6		6	12	18
Henslow Swimming Crab	*Polybius henslowii*	153	50	46	172	27	29	21	202	21	23	3		3		3	242	1	211	38	249
Hermit Crab	*Paguroidea*	1				1					1						1			1	
Norway Lobster	*Nephrops norvegicus*	1		1	1	1			1	1					1		1		1	1	2
Squat Lobster	*Galatheidae*			9		1	7	1		2		7			1		8		8	1	9
White Glass Shrimp	*Pasiphaea sivado*	1		9		6	4				7	3					10			10	10
OSTEICHTHYES																					
Black Belly Rose Fish	*Helicolenus dactylopterus*	8	2	4	3	6	2	3	4	9	1				8	1	5		11	3	14
Boarfish	*Capros aper*	1		1		1		1		2							2		2		2
Conger Eel	*Conger conger*	22	20	18	8	36	13	4	12	32	2	15			9	1	51		40	21	61
Greater Forkbeard	*Phycis blennoides*	8		3	3	6	2		3		3	5				2	9		2	9	11
OTHERS																					
Velvet Belly Lanternshark	*Etmopterus spinax*	2	2	3		2	4	1	6		1					4	3		4	3	7
Rugose bonnet	*Galeodea rugosa*	6			6				5	1					1	1	4		2	4	6
Seacucumber	*Holothuroidea*			1			1		1						1				1		1
Seastar	*Asteroidea*	3	1		3	1			3	1			4						3	1	4

The experiments included 35 trap lines in depths between 281 m and 583 m (Table 3). Each line consisted of 80 – 150 traps, of which 15 lines were placed in Sines (SN, SS) and 20 in the Algarve (FAR, PRT) (Fig. 6). In total, 16 different species were caught consisting of eight decapods species, four Osteichthyes, one Chondrithye, one gastropod and two equinoderms (Table 6).

Simultaneously, 45 trawls were conducted during this period, 19 in the Southwest Coast, and 26 in the Algarve (Table 4).

In both vessels the species caught were identified, counted and weighted. In the case of the trawler this was done on a subsample of the catch, and the numbers and weight of the subsample were extrapolated to the total catch. Samples of DWS were taken for each tow to obtain size frequencies and weight-length relationship of the population.

Densities between 0.10 and 0.12 g/m² were observed (Table 5).The densities estimated were generally higher in the South and South-West.

The target specie DWS was caught rarely with the traps. Instead of DWS, the only decapod entering the traps in amounts allowing statistical analysis was the golden shrimp, *Plesionika martia*. In particular the PRT area was showing highest catches followed by Faro and exceptional catches as well in the South-West.

To estimate the area affected by traps, sophisticated oceanographic data is necessary, such as the intensity and direction of benthic currents in the area (Miller 1990). Moreover, the area of attraction is heavily dependent on the ability of the target specie to detect the bait. Neither one of these aspects, current information nor olfactory capacity, were available.

The statistical analysis was only applied to the golden shrimp, and only for the South coast data. A total of 1965 traps were included in the analysis, 42 of them with presence of the gold shrimp.

From the factors considered in the logistic model, only bait type was significant (p.value < 0.001). Bait categories considered were: oily fish (S+C+SC), chum (CH), pellets (AF) and the fluorescent light (L) as indicated in (Fig. 7). The four bait levels were compared using contrasts (Table 7).

Table 7 Contrasts for different baits used during the experimental phase. Cavala and Sardine are summarized in the group "oily fish"

Contrast			Chi-square	p-value
Fluorescent Light	vs	Oily Fish	8.7	0.0032
Fluorescent Light	vs	Chum	4.8	0.0287
Fluorescent Light	vs	Pellets	0.5	0.4804
Oily Fish	vs	Chum	75.1	<.0001
Oily Fish	vs	Pellets	33.4	<.0001
Chum	vs	Pellets	33.3	<.0001

The results show that the differences are highest between chum and oily fish. The efficiency of the bait, from the most efficient to the least efficient are:

1. Chum
2. Fluorescent Light
3. Pellets
4. Oily fish

The scavenger activity was described as well by the condition of the bait after hauling. A total of 3321 traps were observed (1112 with sight of bait consumption). The study sites of the SW show a higher bait consumption than the South (p-value 0.0216) and Faro less scavenger activity than Portimão (p-value-0.0006). The proportion of bait consumption categories in each area are presented in Fig.7.

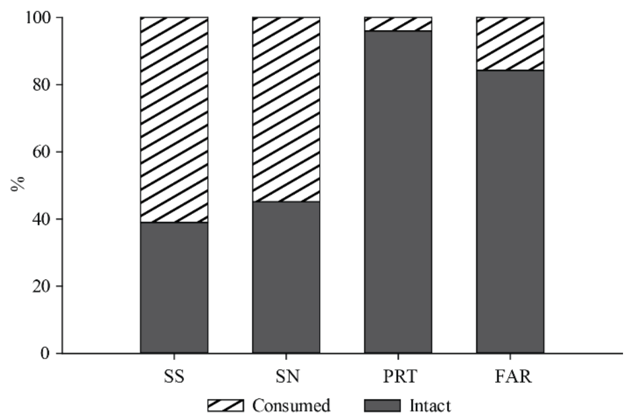


Fig. 8 Scavenger activity in the four sampling areas (SN, SS, PRT, FAR). The bait conditions was macroscopic evaluated and grouped into intact, half consumed and consumed.

Higher rates of bait consumption in the SW coast reflect the capture of more benthic species including high numbers of the henslow swimming crab, seastars and seacucumbers.

The problems encountered regarding the bait and the general low abundance resulted in catches below consideration for a viable fishing operation.

4. Discussion

The catch of DWS was more difficult than previously assumed. One reason could be the low abundance in the present year, given the fluctuating nature of this resource. This is in agreement with the decreasing tendency in the landing since 2011 (Fig 1). From 2011 to 2014, the estimated landings were, 1057, 672, 641 and 418 tones, respectively (DGRM, *Estatísticas da Pesca*). During the first 6 months of 2015 the DWS landings were 146 tones, compared with 158 for the first 6 months of 2014 (DGRM, *Data Pescas Difusão*). These values suggest that 2015 will be a year of low DWS catches, assumed to be related with low abundances of the resource.

Some simple calculations of the expected number caught in the traps, based on the DWS densities estimated with the trawling and probable trap attraction areas were performed. The attraction area was assumed to have a circular shape, in the absence of better information for a more sophisticated approach to estimate attraction area, such as current speeds, behavior of odor plumes and sensitivity of the DWS to the different baits presented (Aedo and Arancibia 2003). Assuming the area towed and the corresponding DWS catch, the estimated average density of this species was 0.10 and 0.12 g/m^2 for the SW and S coast respectively. Considering the estimated average individual weight was 11.8 g, the expected numbers caught in the traps, based on an attraction area with one meter radius, were between zero to one. The extremely low catches obtained with the raps, could therefore be the result of very low densities of the DWS.

The lifecycle of the species also impacts on trap catchability. DWS is a nectobenthic penaidae species, spending part of the day close to the bottom (day time) and scattering to layers above the bottom the rest of the day (night time) (Sobrino *et al.* 2005). DWS is feeding on a variety of organism depending on the stage of the daily cycle, but the diet is dominated by a variety of small endobenthic organisms (Bergström 2000; Sobrino *et al.* 2005).

Other deep water shrimp of the family Pandalidae, that follow the daily migration pattern of mesopelagic species, feed on a wider variety of organisms (Fanelli and Cartes 2004). Cartes (1993) pointed out that the variation in prey is much smaller in species foraging on benthic prey, such as the DWS, than pelagic hunting crustacean species (golden shrimp).

Fanelli and Cartes (2004) estimated a trophic diversity index for golden shrimp of 3.3 while in DWS it varied between 1.04 and 1.5 depending on sex and region (Kapiris 2004). The deepwater rose shrimp is focused on *Lophogaster typicus*, mysids and other amphipods but in a much smaller extent, on discarded osteichtthyes and cephalopods. In conclusion, DWS is mostly preying on a narrow range of benthic invertebrates, rather than scavenging. This may be the reason why the golden shrimp was more susceptible to the offered baits and distances to the seafloor (1 – 2 m).

When fishing in areas with high scavenging activity, the possibility of attraction by the bait scavengers, rather than the bait itself, needs to be considered. In the study area the presence of scavengers in the bait pockets, mainly small amphipods and isopods, was frequent (Fig. 8). This situation may justify the capture of a few individuals of DWS. In Kapiris (2004) stomach analysis revealed that isopods were the preferred food in "quality and quantity". The scavenging activity of isopods was very high and even after short trials of only a few hours, the bait was completely consumed, especially in the South-West (Fig. ***8***). In some cases, the whole trap was covered by a thick layer of small scavengers (amphipods) and in other cases there were just bones left in the bait pockets. The accumulation of scavengers around the cages could have acted as an indirect bait to DWS. Several studies have proven that an increased scavenger activity is typical of trawling dominated marine habitats. (Kaiser 2002; Thrush 2002).

The golden shrimp *Plesionika martia* supports commercial fisheries in the tropical and semi-tropical Atlantic and Indo-Pacific at depth between 54 - 649 m (Gonzáles-G. 1986). In Portugal (Dore 1987) the distribution of *P. martia* ranges between 180 and 680 m and experimental work done in the Tyrrhenian Sea indicates peaks of abundance between 300 and 600 m on soft benthic substrate (Maiorano 2002; Possenti 2007). Another Pandalidae species, *Plesionika edwardsii*, is targeted by trap fisheries in Atlantic Islands, namely the Canary Islands (Arrasate-López J and González 2012) and in Cabo Verde (Gonzáles 2012). The traps used correspond to one of the models used in this study (type C, conic, semi-floating traps), and the gear specifications proposed were also taken in consideration in this work.

All successful fisheries of this type developed in the absence of trawling or even targeted virgin stocks, in the case of the oceanic Atlantic islands due to inexistence of a continental platform. Given the results obtained in this study, a trap fishery targeting deep water crustaceans using semi-floating traps does not seem to be viable on the Portuguese coast, and this may be the result of depilated populations due to intensive fishing.

For the DWS Sobrino *et al.* (2005) stated that the specie is at least fully exploited or to some extent overfished. Supporting the latter is, the importance of DWS for the Portuguese demersal trawling fleet in recent years, with catches rising continuously (Table 1, Fig 1). This is not only due to the high abundance of the specie during some years, but also because of limitations set for the other important target species, the Norway lobster. Consequently, the fishing pressure for DWS is increasing and with it the mortality on bycatch species, such as the golden shrimp.

The results of bait comparison for golden shrimp are very interesting. The exploitation of golden shrimp in the Atlantic islands is done exclusively with bait composed of fatty fish species. In our study, besides fatty fish, chum (minced sardine) and light sticks were also used. Chum showed to be more effective than the fish (Table 5), likely due to a more intense and easier to disperse odor. This increases the attraction area of the bait and produces higher catches. Nevertheless, bait remains a critical issue in trap fisheries because part of it is composed by species that are deviated from human consumption and consequently the possibility of using light is of the highest importance.

Light is used in pelagic long line fisheries for the attraction of squid in several fisheries in the South West Atlantic. It was also described as an attractant for the capture of krill and small crustaceans for scientific purposes (Kawaguchi 1986). This results show the need of scientific studies on the use of light as an attractant in crustacean fisheries. The properties of visual pigments in DWS and golden shrimp are unknown but Hiller-Adams (1988) determined the visual perception of four deepwater shrimp species (Oplophoridae and Penaedea) with similar behavior (daily migrations) and overlapping depth spectrum. The maximum of absorbance was determined for all species between 450 – 550 nm (blue to green light). The used light during this experiment was yellowish therefore on the limit of perception for the named species. It is legitimate to assume that better results would be obtained if light sources were improved. Simple laboratory experiments could help define more precise wave lengths to attract DWS or golden shrimp.

Also interesting was the fact that both DWS and golden shrimp, when present, showed up in clusters up to 10 in the same trap indicating that the distribution is patchy. A similar pattern was observed for other crustaceans such as the squat lobster. Patchy distribution are described for other bottom crustaceans such as the Norway lobster (Maynou 1998).

On the bottom, along the South coast the outflow from the Mediterranean Sea is dominating the current regime (Zenk and Armi 1990) while in the South-West the predominant currents are directed poleward (Frouin *et al.* 1990). These currents can force the floating traps to lie too close to the bottom or generate spinning or erratic movements that can prevent the animals from entering the traps or cause a fleeing behavior. This is also supported by the increased scavenger activity around the traps in this regions (Fig. 8)

Recent studies stress the risk of overfishing of fast growing populations even though they are considered to be more “robust” (Pinsky 2015). The

The economic exploitation of pandalidae shrimp with traps in the Canary Islands and the Azores and prospecting results in Cape Verde, show that healthy stocks allow a n economically viable trapping fleet, but that is not possible in direct competition with demersal trawling. An often observed phenomena in fisheries is that intensified fishing practices are decreasing population abundance to such a degree that more sustainable gears become less viable or impossible (Watson *et al* 2013).

To comply with the new Common Fisheries Policy and the Ecosystem Approach to Fisheries, the trawling intensity in Portuguese waters should be questioned facing that one of the two most important species, the Norway lobster, is considered bellow biologically safe limits by the ICES (Council Regulation No 2166/2005), resulting in decreasing TAC s (10% decrease every year form 405 tons in 2005 to 168 tons in 2014, with a slight recovery to 206 tons in 2015[1]) and that DWS is facing a consistent decline in recent years. Until now the fishery is only managed by input measures (limited licenses and closed season) but the rising importance and life cycle traits of short lived species it should be considered to implement some kind of population assessment like in fisheries for DWS in the South-Central Mediterrenean to avoid overfishing or a collapse (Knittweiss *et al.* 2013)

The exploitation of deep water crustaceans with trawling is also relevant for the bycatch Campos *et al.* (2002) and Fonseca *et al.* (2005) proposed different mesh configuration and bycatch reduction devices with little acceptance from the producers. It should be stressed that crustacean fisheries provide food catering the high value markets, with little nutritive value and at the same cause great environmental damage decreasing the sustainability of other fishing gears such as the fixed gears used by the polyvalent fleet. This is the case of hake, caught and discarded in large amounts by the crustacean fleet (Borges *et al.* 2001), while the hake fishery with fixed gears was severely limited (Council Regulation No 2166/2005).

[1] DGRM, 2015. Adenda ao Plano de Ajustamento do Esforço de Pesca da Pescada Branca do Sul e do Lagostim, 4pp. Acessed 6 December 2015 at http://www.dgrm.min-agricultura.pt/xportal/xmain?xpid=dgrm&xpgid=genericPageV2&conteudoDetalhe_v2=209600

5. Conclusion

The system of exploitation and management of fisheries resources has been maintained in the present state for decades, with little changes. Policy action is needed to resolve the situation. One way could be the implementation of additional areas restricted to trawling and marine protected areas, especially outside the six miles limit. This would allow the establishment of base line studies to understand the effect of trawling and the setting of reference points.

Trawling is a technologically simple process, by sweeping the seafloor all organisms living on or near the ground are swilled inside the net. All in all the only ecological factor important is to know the whereabouts of the species. To use more sustainable passive gears, such as longlines or traps, sophisticated knowledge about the animal behavior, nutrition and life cycle information are needed. The efficiency of these fisheries depends largely on the knowledge of these factors and the resulting métiers are highly specific and consequently very selective towards the target species ad sizes. To introduce more sustainable fishing practices, knowledge of the ecology and behavior of the target species is required and financial and technical assistance for experimental work should be provided.

Further laboratory experiments and field work are needed, for both species discussed. Video observations and current measurements should be incorporated in future experiments to determine more precisely the behavior of the traps and target species. Studies on the daily migration and feeding cycle of DWS are also important as well as the behavior of the species in relation to light.

6. Acknowledgements

The work was coordinated and mentored carefully by Margarida Castro (UAlg) and Paulo Fonseca (IPMA). Furthermore I would like to thank the captain and crew of the *Gina Maria:* Bruno Domingos (Captain) Joao, Rodrigo, Jose, Viriato and Antonio for their exceptional regional ecological knowledge and motivation about the project providing valuable information for the experimental design and procedure onboard. But also the crew on the trawler under Sérgio Domingos including the hard work of my colleagues Lino Marques and Nicolas Blanc during the bycatch sampling.

Besides the project I would like to thank my mother (Maria Theresia Eichert), father (Jan Erik Lau) and sisters (Eva and Anna Eichert) for a peerless support during all my life and Werner Kleene for his insisting nature to push me steadily forward in high school and academia. Last but not least my friends during the time in Faro as well as Bremerhaven namely Jan Buschmann, Jonas Haase, Niklas Piatkowski, Laura Behrens, Matthis Obst, Fin Felix Bake, Peter Schulze Miguel Mendez Sandin, Belen Quintana, Marlene Wesselmann, Craig Alexandre, Max Mues, Timo Jurado and all folks from the Associação de Montanhismo e Escalada do Algarve (AMEA).

7. References

Aedo G & Arancibia H (2003). 'Estimating attraction areas and effective fishing areas for Chilean lemon crab (*Cancer porteri*) using traps'. Fisheries Research, 60: 267-72.

Adey JM, Smith IP, Atkinson RJA, Tuck ID, Taylor AC (2008). Ghost fishing'of target and non-target species by *Norway lobster* Nephrops norvegicus creels. *Mar Ecol Prog Ser, 366*, 119-127.

Afonso-Dias M & Pinto C (2008). 'Análise da Distribuição Espacial do Esforço e Rendimentos de Pesca das Frotas Portuguesas de Arrasto Costeiro (GeoPesca)'. Accessed 9 December 20115, http://w3.ualg.pt/~madias/geocrust/index.html.

Aguzzi J (2009). 'Chronobiology of deep-water decapod crustaceans on continental margins'. Advances in marine biology, 58: 155-225.

Moreira A, Fonseca P, Silva C, Miguel A, Santos P, Campos A, Fonseca TP, Fátima M and Borges TC (2010). 'Poster: Are there evidences of environmental-driven landings in the Portuguese trawl crustacean fishery?'. ICES 2010 - Annual Science Conference. Acessed 9 December 2015, http://www.ices.dk/sites/pub/CM%20Doccuments/CM-2010/S/S2310.pdf.

Archdale MV, Kawamura G (2011). 'Evaluation of artificial and natural baits for the pot fishery of the sand crab *Ovalipes punctatus* (De Haan, 1833)'. Fisheries Research, 111: 159-163.

Arrasate-López J, Tuset VM, Santana JI, García-Mederos A, Ayza O and González JA (2012). 'Fishing methods for sustainable shrimp fisheries in the Canary Islands (North-West Africa)'. African Journal of Marine Science, 34: 331-39.

Borges TC, Erzini K, Bentes L, Costa ME, Gonçalves JMS, Lino PG, Pais C, Ribeiro J (2001). 'By-catch and discarding practices in five Algarve (southern Portugal) métiers'. Journal of Applied Ichthyology, 17: 104-114.

Broadhurst MK (2000). Modifications to reduce bycatch in prawn trawls: a review and framework for development. Reviews in Fish Biology and Fisheries, 10: 27-60.

Brown J, Macfadyen G (2007). Ghost fishing in European waters: Impacts and management responses. *Marine Policy*, *31*(4), 488-504.

Campos A, Paulo F and Erzini K (2002). 'Size selectivity of diamond and square mesh cod ends for rose shrimp (*Parapenaeus longirostris*) and Norway lobster (*Nephrops norvegicus*) off the Portuguese south coast'. Fisheries Research, 58; 281-301.

Cartes JE (1993). 'Day-night feeding by decapod crustaceans in a deep-water bottom community in the western Mediterranean'. Journal of the Marine Biological Association of the United Kingdom, 73: 795-811.

Chuenpagdee R, Morgan LE, Maxwell SM (2003). 'Shifting gears: assessing collateral impacts of fishing methods in US waters'. Frontiers in Ecology and the Environment, 1: 517-524.

Collie JS, Hall SJ, Kaiser MJ, Poiner IR (2000). 'A quantitative analysis of fishing impacts on shelf-sea benthos'. Journal of animal ecology, 69: 785-798.

David D. 'Loch Torridon Nephrops Creel'. Certification Report

Directive 2008/56/EC of the European Parliament and of the council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Accessed 9th of December 2015: http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF

Dore I, Frimodt C, (1987). 'An Illustrated Guide to Shrimp of the World'. Scandinavian Fishing Year-Book, Denmark, 229 pp.

Durrieu de Madron X, Guieu C, Sempéré R, Conan P, Cossa D, D'Ortenzio F, Estournel C, Gazeau, Rabouille FC, Stemann L, Bonnet S, Diaz F, Koubbi P (2011). 'Marine ecosystems' responses to climatic and anthropogenic forcings in the Mediterranean'. Progress in Oceanography, 91: 97-166.

Coleman RA, Hoskin MG, von Carlshausen, Davis CM (2013). Using a no-take zone to assess the impacts of fishing: Sessile epifauna appear insensitive to environmental disturbances from commercial potting. *Journal of Experimental Marine Biology and Ecology*, *440*, 100-107.

Eriksson, S. P. (2006). Differences in the condition of Norway lobsters (*Nephrops norvegicus*) from trawled and creeled fishing areas. Marine Biology Research, 2: 52-58.

Eno NC, MacDonald DS, Kinnear JA, Amos SC, Chapman CJ, Clark RA, Munro C (2001). Effects of crustacean traps on benthic fauna. *ICES Journal of Marine Science: Journal du Conseil*, *58*(1), 11-20.

Fanelli, E and Cartes, JE (2004). 'Feeding habits of pandalid shrimps in the Alboran Sea (SW Mediterranean): influence of biological and environmental factors'. Marine Ecology Progress Series, 280: 227-238.

FAO (2005). Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Technical Guidelines for Responsible Fisheries. No. 10. Rome, FAO. 79 pp.

Fonseca P Campos A Mendes B Larsen R (2005). 'Potential use of a Nordmøre grid for by-catch reduction in a Portuguese bottom-trawl multispecies fishery'. Fisheries research, 73: 49-66.

Frouin R, Fiúza AFG, Ambar I, Boyd TJ (1990). 'Observations of a poleward surface current off the coasts of Portugal and Spain during winter'. Journal of Geophysical Research: Oceans (1978–2012), 95: 679-691.

Landeira, JM, Lozano-Soldevilla, F, González-Gordillo, JI, 2009. Morphology of first seven larval stages of the striped soldier shrimp, Plesionika edwardsii (Brandt, 1851) (Crustacea: Decapoda: Pandalidae) from laboratory reared material. Zootaxa, 1956: 51-66.

Goñi R. (1998). Ecosystem effects of marine fisheries: an overview. *Ocean & Coastal Management*, *40*(1), 37-64.

Gonzáles J, Tariche OI, Santana J (2012). 'Propuesta para un Proyecto de Evaluación de Stocks de Camarón de Profundidad en aguas de Cabo Verde (2010-2013)', 11 pp. Acesed 9 December 2015, http://www.portaldoconhecimento.gov.cv/bitstream/10961/1529/1/B_Gonzalez%C2%B4s%20et%20al_paper.pdf .

Hall–Spencer J, Allain V, Fosså JH (2002). 'Trawling damage to Northeast Atlantic ancient coral reefs', Proceedings of the Royal Society of London. Series B: Biological Sciences. 269: 507–511.

Hentrich S & Salomon M (2006). Flexible management of fishing rights and a sustainable fisheries industry in Europe. Marine Policy, 30: 712-720.

Hiller-Adams P, Widder EA, Case JF (1988). 'The visual pigments of four deep-sea crustacean species', Journal of Comparative Physiology A. 163: 63-72.

Johnson KA (2002). A review of national and international literature on the effects of fishing on benthic habitats. US Department of Commerce, National Oceanic and Atmospheric Administration, Volume 57, NOAA tech. memo. NMFS-F/SPO. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 72 pp.

Jones JB (1992). 'Environmental impact of trawling on the seabed: a review', New Zealand Journal of Marine and Freshwater Research. 26: 59-67.

Kaiser G, De Groot, SJ (eds) (2000). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science, 492 pp.

Kaiser, MJ (2000). 'Chronic fishing disturbance has changed shelf sea benthic community structure', Journal of Animal Ecology. 69: 494-503.

Kaiser MJ, Collie JS, Hall SJ, Jennings SP, Pointer IR (2002). 'Modification of marine habitats by trawling activities: prognosis and solutions'. Fish and Fisheries, 3: 114-136.

Kapiris K (2004). 'Feeding ecology of *Parapenaeus longirostris* (Lucas, 1846)(Decapoda: Penaeidae) from the Ionian Sea (Central and Eastern Mediterranean Sea)'. Scientia Marina, 68: 247-256.

Kawaguchi K, Matsuda O, Ishikawa S, Naito Y (1986). 'A light trap to collect krill and other micronektonic and planktonic animals under the Antarctic coastal fast ice'. Polar Biology, 6: 37-42.

Kennelly SJ (1995). 'The issue of bycatch in Australia's demersal trawl fisheries'. Reviews in Fish Biology and Fisheries 5: 213-234.

King M (1981).'Deepwater shrimp resources in Vanuatu: a preliminary survey off Port Vila', Marine fisheries review, 43: 10-17.

Leocádio, AM, Whitmarsh D, and Castro M (2012). 'Comparing Trawl and Creel Fishing for Norway Lobster (*Nephrops norvegicus*): Biological and Economic Considerations'. PLoS ONE, 7 (7), 1-9.

Maiorano D'O, Capezzuto S (2002). 'Life-history traits of Plesionika martia (Decapoda: Caridea) from the eastern-central Mediterranean Sea'. Marine Biology, 141: 527-539.

Martín J, Puig P, Palanques A, Masqué P, García-Orellana J (2008). 'Effect of commercial trawling on the deep sedimentation in a Mediterranean submarine canyon'. Marine Geology, 252: 150-155.

Maynou F (1998). 'The application of geostatistics in mapping and assessment of demersal resources, Nephrops norvegicus in the northwestern Mediterranean: a case study'. Scientia Marina, 62: 117-133.

Miller RJ (1990). 'Effectiveness of crab and lobster traps', Canadian Journal of Fisheries and Aquatic Sciences, 47 (6), 1228-1251.

Monteiro P, Araújo A, Erzini K, Castro M (2001). 'Discards of the Algarve (southern Portugal) crustacean trawl fishery'. Advances in Decapod Crustacean Research (Springer), 267-277.

Myers, RA & Worm B (2003). 'Rapid worldwide depletion of predatory fish communities'. Nature, 423 (6937), 280-283.

Pauly D, Christensen V, Guénette S, Pitcher TJ, Sumaila RU, Walters CJ, Watson R, Zeller D (2002). 'Towards sustainability in world fisheries'. Nature, 418 (6898), 689-695.

Pinsky ML, Byler D (2015). 'Fishing, fast growth and climate variability increase the risk of collapse'. Proc. R. Soc. B , 282 (1813) p. 20151053.

Possenti E, Sartor P, De Ranieri S (2007). 'Reproductive biology of females of *Plesionika edwardsii* (Brandt, 1851)(Crustacea, Decapoda, Pandalidae) in the northern Tyrrhenian Sea (western Mediterranean)'. Atti. Soc. tosc. Sci. nat., Mem., Serie B, 114: 91-98.

Queirós AM, Hiddink JG, Kaiser MJ, Hinz H (2006). 'Effects of chronic bottom trawling disturbance on benthic biomass, production and size spectra in different habitats'. Journal of Experimental Marine Biology and Ecology, 335: 91-103.

Reed M, Courtney P, Urquhart J, Ross N (2013). Beyond fish as commodities: Understanding the socio-cultural role of inshore fisheries in England. *Marine Policy*, *37*, 62-68.

Roberts CM (2002). 'Deep impact: the rising toll of fishing in the deep sea'. Trends in Ecology & Evolution, 17: 242-245.

Sala A, Lucchetti A, Piccinetti C, Ferretti M (2008). Size selection by diamond-and square-mesh codends in multi-species Mediterranean demersal trawl fisheries. Fisheries Research, 93: 8-21.

Schratzberger M, Dinmore T, Jennings S (2002). 'Impacts of trawling on the diversity, biomass and structure of meiofauna assemblages'. Marine Biology, 140: 83-93.

Sobrino I, Silva C, Sbrana M, Kapiris K (2005), 'A review of the biology and fisheries of the deep water rose shrimp, *Parapenaeus longirostris*, in European Atlantic and Mediterranean waters (Decapoda, Dendrobranchiata, Penaeidae)', Crustaceana, 78: 1153-1184.

Sobrino I (1998). 'Biología y pesca de la gamba blanca (Parapenaeus longirostris, Lucas 1846) en el Atlántico nororiental: 1-218'. Ph. D. Thesis, University of Sevilla, 218 pp + 1 annex.

Sonderblohm C, Pombo CA (2011). 'Diel variation in the catchability of rose shrimp, Parapenaeus longirostris, and associated species from a bottom trawl survey off the portuguese south coast'. Master Thesis in Aquaculture and Fisheries, University of Algarve, 57 pp.

Sparre P & Venema SC (1998). FAO, 'Introduction to tropical fish stock assessment-Part 1: Manual'. FAO Fisheries Technical Paper. No. 306.1, Rev. 2. Rome, FAO, 407 pp.

Struhsaker P & Aasted DC (1974). 'Deepwater shrimp trapping in the Hawaiian Islands'. Mar. Fish. Rev, 36: 24-30.

Thrush SF, Dayton PK (2002). 'Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity'. Annual Review of Ecology and Systematics, 33: 449-473.

Tom M, Goren M, and Ovadia M (1988), 'The benthic phase of the life cycle of *Parapenaeus longirostris* (Crustacea, Decapoda, Penaeidae) along the Mediterranean coast of Israel', Hydrobiologia, 169: 339-352.

Sumaila UR, Lam V, Manach FL, Swartz W, Pauly D (2013). 'Global Fisheries Subsidies'. Directorate - General for Internal Policies. Policy Department B: Structural and Cohesion Policies, IP/B/PECH/IC/2013-146, PE 513.978. Directorate-General for Internal Policies, European Parliament, 43 pp.

Viriato A & de Figueiredo MJ (1991). Topografia submarina dos fundos de crustáceos da vertente Algarvia. Relatórios Técnicos e Científicos / INIP Nº 43, 31 pp.

Wise L, Fonsea P, Murta AG, Silca C, Mendes H, Carvalho JP, Borges MF, Campos A (2015). 'A knowledge-based model for evaluating the impact of gear-based management measures under Europe's new Common Fisheries Policy'. ICES Journal of Marine Science: Journal du Conseil, 72: 1140-1151.

Zenk W and Armi L (1990). 'The complex spreading pattern of Mediterranean Water off the Portuguese continental slope'. Deep Sea Research Part A. Oceanographic Research Papers, 37: 1805-1823.

Ziegler F, & Per-Anders H (2003) Emissions from fuel combustion in Swedish cod fishery." Journal of Cleaner Production 11: 303-314.