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The fishery for Norway lobster off the Portuguese coast: a biological and economic assessment

Tese de Mestrado em Aquacultura e Pescas (especialização Pescas)

Ana Maria Colaço Leocádio - Faro, 2009

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- PDCT/MAR/59366/2004: *Nephrops* survival when escaping from trawl nets and by-catch escaping devices.

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Abstract

Norway lobster (*Nephrops norvegicus*) is mainly caught off the South and Southwest coasts of Portugal, using two different types of gear, bottom trawling and creels. Trawling is the traditional fishing method, where *Nephrops* can be either a target species or by-catch of shrimp trawling. Creels are only used in areas unavailable to trawlers, either due to legislative restrictions on access or to unsuitable seabed. Creels have *Nephrops* as the only target species, but the fleet uses other gears to target other species.

During the lasts decades, the modernisation of the trawling fleet with the resulting technological improvements, has lead to an increase in fishing effort. Nowadays, the two populations on the South and SW coast are considered outside biological safe limits, and a recovery plan is underway.

Two typical vessels, in each fleet (trawling and creels), were selected to collect biological and economic data. Results show that the size composition of the catches is very different for the two gears used. Trawl catches are composed of small individuals usually in bad condition, while creel catches are composed of large and alive individuals (very high commercial value). It is assumed that the size composition obtained with creels results from the selectivity of the creel and the fact that these populations are exploited at much lower fishing levels.

An assessment was made of the lobster fishery in order to evaluate its economic potencial. Results suggest that creels should be the only gear used, as it represents a very selective gear that could help the recovery of *Nephrops* stocks and allows a good economic return for the vessels involved. Thus, transference of fishing effort from trawling to creels is recommended.

Keywords

Norway lobster – *Nephrops* – Trawls – Creels – Financial analysis – Net present value – Sensitivity analysis – Portugal

Resumo

O lagostim (*Nephrops norvegicus*) é principalmente capturado ao largo das costas Sul e Sudoeste de Portugal, por dois tipos de artes de pesca, o arrasto e os covos. O arrasto é o método de pesca tradicionalmente usado, podendo direccionar a pesca ao lagostim ou capturá-lo como espécie acessória em arrastos dirigidos à gamba. Os covos são usados apenas em áreas inacessíveis ao arrasto que não opera nestas devido às restrições legislativas ou ao tipo de fundo (irregular e rochoso). A pesca artesanal dirige a pesca a várias espécies mas quando opera covos de lagostim estes são restritos a esta espécie.

Durante as últimas décadas, a modernização da frota de arrasto com o consequente aperfeiçoamento tecnológico, levou a um aumento do esforço de pesca. Actualmente, as duas populações na costa Sul e Sudoeste estão consideradas fora dos limites biológicos de segurança, em consequência desta esta situação, está em curso um plano de recuperação.

Foram seleccionadas duas embarcações típicas em cada frota (arrasto e covos) para a recolha de dados biológicos e económicos. Os resultados revelam que a composição do tamanho das capturas é muito diferente para as duas artes utilizadas. No arrasto as capturas são compostas por indivíduos pequenos, geralmente em mau estado, enquanto que os covos capturam indivíduos vivos sem danos e grandes (com alto valor comercial). Assume-se que a composição de capturas obtidas com os covos se deve à selectividade desta arte e ao facto destas populações estarem sujeitas a um menor esforço de pesca.

Foi realizada uma análise custo-benefício para avaliar o potencial económico desta pescaria. Os resultados sugerem que os covos deveriam ser a única arte de pesca utilizada, pois são uma arte muito selectiva que poderá a longo prazo ajudar na recuperação das populações de lagostim na costa Portuguesa, permitindo além disto um bom retorno económico. Sendo assim, recomenda-se a transferência do esforço de pesca do arrasto para as armadilhas.

Palavras-chave

Lagostim – *Nephrops* – Arrasto – Covos – Análise financeira – Valor actualizado líquido – Análise de sensiblidade - Portugal

1 Introduction

In Portugal, the Norway lobster (*Nephrops norvegicus* Linnaeus, 1758) is distributed along the entire coast (Holthuis, 1991), being mainly caught in the South and Southwest regions. Two different types of gears are used, baited traps (creels) and bottom trawling (traditional method), this letter being the more common (Anon., 2004a).

The Norway lobster is one of the most valuable species landed in Portugal, generating an annual average income of 5.1 million Euros (2004-2007, DGPA[1] data base). Of these, 4.0 M Euros came from trawl catches, and 1.1 M Euros from creels. In weight, trawl landings represented 89% of the total while creel landings represent only 11%.

Until the 80s *Nephrops* was the target species of crustacean trawling. This scenario has changed with the expansion to other crustaceans, mainly to the rose shrimp (*Parapenaeus longirostris*) and the red shrimp (*Aristeus antennatus*). Since then, *Nephrops* can be either a target species or by-catch of shrimp trawling.

During the lasts decades, the trawling fleet underwent considerable technological improvements (new boats are larger, better equipped and with more powerful engines) (Anon., 2006), resulting in an increase in fishing effort. Landings of *Nephrops* have decreased abruptly from annual totals of around 1500t in 1987 to a level of around 350t in the 1989 (DGPA data base). After this period, the reported landings never recovered to past values, staying below 400t since the 90s. The impact produced by this fleet, composed of roughly 30 vessels, has contributed to the reduction of *Nephrops* stocks and, nowadays, the two populations on the South and Southwest

[1] DGPA. General Directorate for Fisheries and Aquaculture (Direcção Geral das Pescas e Aquicultura – DGPA)

coast are considered outside biological safe limits (Anon., 2004a). A recovery plan was approved in December 2005 which aims at reducing fishing mortality by establishing an interdiction area to trawling fleet off Sines, between May 1st and August 31st. (Council Regulation (CE) Nº 2166/2005).

Trawling nets affect the bottom communities due to their non-selective characteristics: high by-catch levels of undersized individuals and of undesired species with low commercial value (such as Electric ray (*Torpedo nobiliana*); Small-spotted catshark (*Scyliorhinus canicula*); Blue whiting (*Micromesistius poutassou*); Boarfish (*Capros aper*); Silvery pout (*Gadiculus argenteus*); Mediterranean slimehead (*Hoplostethus mediterraneus*)) (Borges *et al*., 2001; Monteiro *et al*., 2001; Erzini *et al*., 2002). In addition, due to its mechanical action, bottom trawling causes direct bottom destruction and damage of benthic communities (Jones, 1992; Nilsson and Rosenberg, 2003; Queirós *et al*., 2006; Dounas *et al*., 2007; Olsgard, 2008).

Despite all recent attempts to increase selectivity in crustacean bottom trawl fisheries (Madsen *et al*., 1999; Graham & Fryer, 2006; Catchpole & Revill, 2008; Fonseca *et al*., 2007; ICES, 2007), trawl still has low selectivity, generating considerable amounts of discards. Besides that, *N. norvegicus* individuals caught by trawling were found to be in worse condition than their conspecifics from creeled areas (Eriksson, 2006; Ridgway *et al*. 2006). Value of first sale is also influenced by the gear used, since less damaged and live individuals from creels reach higher values.

Despite the over exploitation of traditional trawling fishing grounds, there are still refuges where trawlers cannot operate, due to irregular and rocky bottoms. In these areas, a very valuable creel fishery takes place, with catches of very large, live individuals. Creels have always contributed a small proportion of total landings, but since 2003 the importance of this fishery increased, reaching and maintaining levels of around 11% in weight and over 21% in value. At present, there are roughly 10 artisanal vessels that use creels (DGPA data base).

Creel fishing is restricted to refuges on the Southwest coast, since setting creels outside these areas is risky due high chances of having the gear destroyed by trawlers. In the South coast the lack of refuge sites has discourage the practice of creeling.

In the past, another gear was used by the artisanal fishery to catch Norway lobster, consisting of tangling nets made of natural fibers. This gear was gradually replaced by creels and is today abandoned. The precise date of creel introduction in this fishery is uncertain, but fishermen report that it happened on the Southwest coast around 30 years ago. (Captain Alberto Filipe, personal communication).

In Europe, creels have been implemented locally to fish *Nephrops* in some inshore areas around the west coast of Scotland (Adey, 2007) and Sweden (Eggert and Ulmestrand, 2000), and since 1980, after the complete interdiction of trawling, in inshore areas, off the Faeroe Islands (Anon., 1990).

Effects of *Nephrops* creel fishery on sea-pen communities were studied in Scotland (Kinnear *et al*., 1996; Adey, 2007). These studies suggest that, although not free of impact, *Nephrops* creeling causes little damage to the benthic communities when compared with trawling.

In the absence of data to build a bio-economic model (stock assessment data), economic performance was evaluated using a simple approach consisting in the comparison of costs and revenues of each fishing method in order to establish the net present value (NPV). The financial analysis also integrated a sensitivity analysis. A descriptive characterization of both fleets (including biological aspects of the catches produced) was also undertaken.

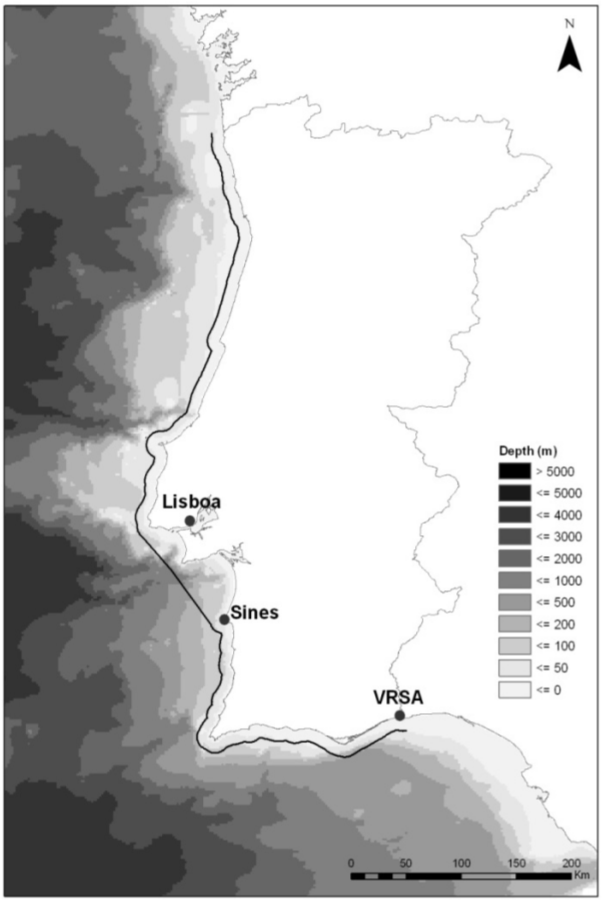


Figure 1 - Map of Portugal. Bathymetric layer's reference came from ETOPO1[2] (NOAA, 2008) and the 6 miles line (defined in Artº 8º - Portaria nº 1102-E/2000) was set from the coast line for the entire coast, except among capes Raso, Espichel and Sines where it was set from the territorial sea base line, both lines are defined by the Marine Hydrographic Institute. VRSA is the abbreviation of Vila Real de Santo António, location of the most important trend market for crustaceans.

[2] Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis, National Geophysical Data Center, NESDIS, NOAA, U.S. Department of Commerce, Boulder, CO, August 2008

2 Methods

To compare the fishery using trawl and creels a typical vessel from each fleet was chosen and as much information as possible was gathered for each one. These vessels were tracked and detailed information regarding biological and economic aspects was obtained. The average catches of *Nephrops* for each one of these vessels are similar to the average catches of the fleet they represent.

The technical characteristics of both vessels under study were obtained from the DGPA. The trawler has a crew of 6 – 7 (including the Captain), a total length of 24.80 meters with an engine of 600 HP, gross tonnage of 215 ton and was constructed in 2000. The artisanal vessel was constructed in 1993 and works with a crew of 6 (including the Captain); it has a total length of 17.08 meters with a 134.23 HP engine and gross tonnage of 26.71 ton.

2.1 Data

2.1.1 Fishing characterization

This section aims at giving an overall view of the *Nephrops* fishery for the trawling and artisanal fleets.

Information of the Portuguese commercial fisheries was obtained from the DGPA database. This database provides individual data by vessel, including: fishing gear used, total trips per year, landings per trip, gross revenue per trip, species landed per trip and fishing port used for landing. This information is given on a trip-by-trip basis, between 1998 and 2007.

The sale values of landings (Euros) presented in nominal terms were converted to real terms using the Harmonised Index of Consumer Prices (HICP) (source Eurostat: http://epp.eurostat.ec.europa.eu). The HICPs are economic indicators constructed to measure the changes over time in the prices of consumer goods and services acquired by households, providing the official measure of consumer price inflation in the euro-zone (Anon, 2004b).

HICPs deflators are given monthly by Eurostat. Since Eurostat figures only extend to November 2007 an estimation for December 2007 was made, based on the November-December change of previous years.

2.1.2 Structure of the catches

Information on the catch composition of trawlers was obtained from sampling onboard of the commercial vessel selected. Samples were collected along a 6 day period in the summer 2007, on the south coast of Portugal, at depths ranging from 350 to 650 m, using the commercial 70 mm mesh size[3].

Creel catch structure for the artisanal vessel selected was obtained by sampling the landings of this vessel at different fishing ports at the southwest coast, during the summer of 2007. Catches were obtained at depths ranging from 600 to 650 m, using 1000 creels with 40 mm mesh size.

For each individual sampled, standard length was measure with callipers, to the lowest mm (carapace length from the inferior border of the left eye socket to the centre of

[3] Samples supported by the following project: *Nephrops* survival when escaping from trawl nets and by-catch escaping devices. PDCT/MAR/59366/2004 (Funded by Foundation for Science and Technology).

the posterior border of the carapace). Sex and ovigerous conditions of females were also registered.

2.1.3 Samples at fish auction (first sale)

Length distributions of *Nephrops* landed at the fish auction of Vila Real de Santo António (VRSA) were taken in June and July of 2007. Here, landings are sold sorted by size categories (from 1 to 4, 1 being the largest category and 4 the smallest). These samples were used to estimate probabilities to classify landings in each size category. These were afterwards applied to the *Nephrops* size frequencies distributions obtained for both gears.

2.1.4 Condition (quality) of the landings

Information about individual condition of *Nephrops* caught by both gears was obtained sampling onboard. The basic experimental design consisted in recording the *Nephrops* condition on arrival on deck, during regular fishing operations. The experiments were conducted in July 2007 for trawl and in July 2008 for creels.

The condition of the individuals was measured by a scale indicating vitality (adapted from Castro *et al*., 2003), defined from 0 to 2 (0= showing no signs of life; 1= showing some movement of the appendages; 2= assuming aggressive posture).

2.2 Economic Assessment

2.2.1 Financial viability

The basic criterion used to assess the sustainability of the trawl and creel fishery was based on a measure of financial viability of capital investment, the net present value (NPV). NPV is defined as the present value of net cash flows. It is a standard method for using the time value of money to appraise long-term projects (Desai, 1997; Lumby, 1984).

For trawl, *Nephrops* is the second most important target species (the rose shrimp being the first). For creels *Nephrops* is the most important target species. This fleet targets other species with other gears, but when setting creels, *Nephrops* only is target. Therefore, for both fleets, only a part of the fishing effort is allocated to *Nephrops*. For the trawling fleet (based on the hours trawling) it is estimated that 1/3 of the fishing effort is allocated to *Nephrops*. In the creel fishery, since trips to retrieve/set creels are not used to operate other gears, the effort allocated for *Nephrops* correspond to the proportion of days fishing this species, and is estimated to be 1/5 of the fishing effort.

Despite the multi-specific nature of the fishery carried out by both fleets, the aim of this work is to compare financial viability for the *Nephrops* fishery only. Thus, the NPV represents the financial worth of investment of fishing *Nephrops* by trawl and creels. Through comparisons of costs and revenues it is possible to establish whether the NPV is greater than zero (positive financial viability – the returns exceed the opportunity cost of capital) and to find out which type of vessel has the highest NPV.

The NPV can be calculated by the following expression:

$$\mathbf{NPV} = \sum_{i=0}^{n} \frac{(R_i - C_i)}{(1 + r)^i}$$

Where

R_i is the revenue earned in year i,

C_i is the costs incurred in year *i*,

r is the discount rate (the opportunity of capital is represented by the discount rate) and

n is the investment time horizon in years.

The time horizon for the project was of 10 years, considering a discount rate of 5%.

The input data used to calculate the NPV was obtained, for the sampled vessels for the year 2007, by interviewing the owners and consulting the DGPA landings data base. Data includes running costs (proportional to vessel utilization rate), fixed costs (those incurred regardless of the amount of fishing activity) and labor costs based on a share of net revenue (gross revenue minus running costs) for the artisanal fishery, and a fixed value plus a share of the net revenue for the trawl fishery. Data regarding price per Kg, fishing days per year and catch rate (Kg per fishing day) were also included.

The decision regarding which costs and revenues should be included was entirely based on the *Nephrops* fishery. Thus, it was assumed that the relevant running costs for catching *Nephrops* with trawl were essentially the fuel and lubricants, as the trawling process force the engine to very high rotations consuming very large quantity of diesel. On the other hand, the bait and the fuel (basically used for traveling) were the relevant running costs associated with the creel fishery. Other costs were allocated to the *Nephrops* fishery proportionally to the fraction of the fishing effort (hours of fishing for trawl and days of fishing for creels) dedicated to catch *Nephrops*. These values were 1/3 for the trawling fleet and 1/5 for the creel fleet.

2.2.2 Sensitivity analysis

Sensitivity analysis is a simple technique to assess the economic or financial viability of a given project under different circumstances. It involves changing the values of the variables and calculating the resulting change in the NPV. Changes in variables can be evaluated one at a time to identify the key variables (Desai, 1997; Lumby, 1984).

The results of the sensitivity analysis are summarized in a switching value. Here, the switching value identifies the level change in a given variable required for the NPV to become zero, under the assumption that all other parameters remain unchanged.

3 Results

3.1 Fishing characterization

Trawlers work throughout year, except during January (Portaria nº 43/2006) and are not allowed to fish within the 6 miles limit (Portaria nº 1102-E/2000) (see 6 miles limit at Figure 1). Fishing trips last usually from 1 to 3 days, fishing occurs at depths ranging from 150-700 m (Figueiredo and Viriato, 1989; Viriato and Figueiredo, 1991). Vessels target mostly the rose shrimp (legal mesh size = 55 mm (Portaria nº 1102-E/2000), maximum abundance from 150 to 300 m (Viriato and Figueiredo, 1991). Due to the vertical migrations related to lunar rhythms, this species can only be caught in abundance during day time (Cartes and Sarda 1989). Thus, during the night, the target species may switch to the Norway lobster (legal mesh size = 70 mm Portaria nº 1102-E/2000), depth range 500 to 700 m (Figueiredo and Viriato, 1989) and the red shrimp which can be found together with *Nephrops* but extends to even greater depths (Figueiredo *et al*., 2001).

Creels for *Nephrops* are set at depths ranging from 500 to 700 meters, and are typically hauled once a week. Since these depths are uncommon within 6 miles limit, creels can only be set in refuge areas where trawlers cannot operate, due to irregular and rocky bottoms.

General characteristics of the fishing operation in both fleets are presented in Table 1. Crustacean trawl fishery has, potentially, more negative environmental impacts, high fuel consumption, lower selectivity and higher discards. Creel fishing is highly selective and discarding is negligible, therefore, environmental impacts are considerably lower.

Table 1 – Some aspects describing the trawl and the creel *Nephrops* fishery by the industrial and the artisanal fleet, showing the main differences. Data collected from the DGPA data base.

	Industrial	**Artisanal**
Vessels size	> 25 m	< 20 m
Fuel consumption	High	Low
Number of vessels	~ 30	~10
Area	Offshore (6 miles)	In areas inaccessible to trawling
Fishing period	Range 1 to 3 days	1 day
Target species	Mixed fishery	Selective to *Nephrops*
Selectivity	Low	High
Discards (*)	> 60% (1)	Almost inexistent (2)
Environmental impacts (*)	High (3)	Low (4)

Source: DGPA data base.

(*) Evaluation based on literature review:

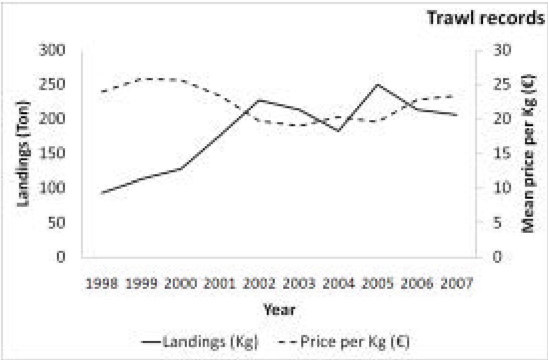
(1): Borges *et al*., 2001; Monteiro *et al*., 2001; Erzini *et al*., 2002

(2): Evans *et al*., 1994; Bergmann *et al*., 2002; Ziegler and Valentinsson, 2008

(3): Jones, 1992; Nilsson and Rosenberg, 2003; Queirós *et al*., 2006; Dounas *et al*., 2007; Olsgard, 2008

(4): Kinnear *et al*., 1996; Adey, 2007; Ziegler and Valentinsson, 2008

Overall landings (for all vessels engaged in the *Nephrops* fishing) and mean annual prices per Kg are given in Figure 2. Over the period of interest, from 1998 to 2007, trawl landings (maximum of 250 000 Kg in 2005), always exceed in weight creel landings (maximum 32 000 Kg). However, concerning prices, creel landings always obtained higher prices per Kg (difference in price per Kg consistently larger than 15€ during the last 7 years). In the given period, *Nephrops* landings from trawling showed an increasing trend with fluctuations around 200 tones. For the creel fishery, landings rose sharply until 2003 and reached a plateau, but in 2007 landings decreased to 13 tonnes.



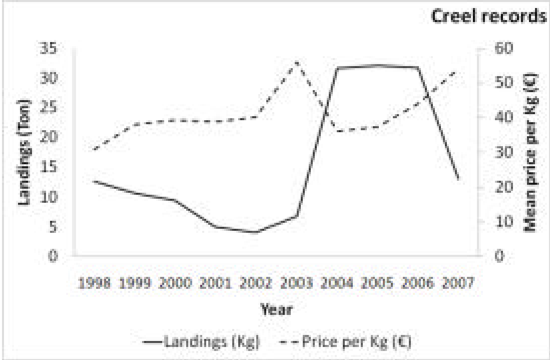


Figure 2 – Evolution of annual total landings with the mean price per Kg, for total trawl (left) and creel (right) vessels engaged in the *Nephrops* fishery, 1998 - 2007. Prices are given in real terms.

3.2 Structure of the catches

Size composition of catches was compared in percentage for both gears (Figure 3 and Figure 4). The catch size structure is very different for the two gears used. Trawl catches are composed by small individuals (range from 20 – 58 mm CL, with a mean size of 37 mm CL). Creel catches are composed by large individuals (range from 45 – 84 mm CL, with a mean size of about 58 mm CL) reaching higher prices in the fish market (Table 2).

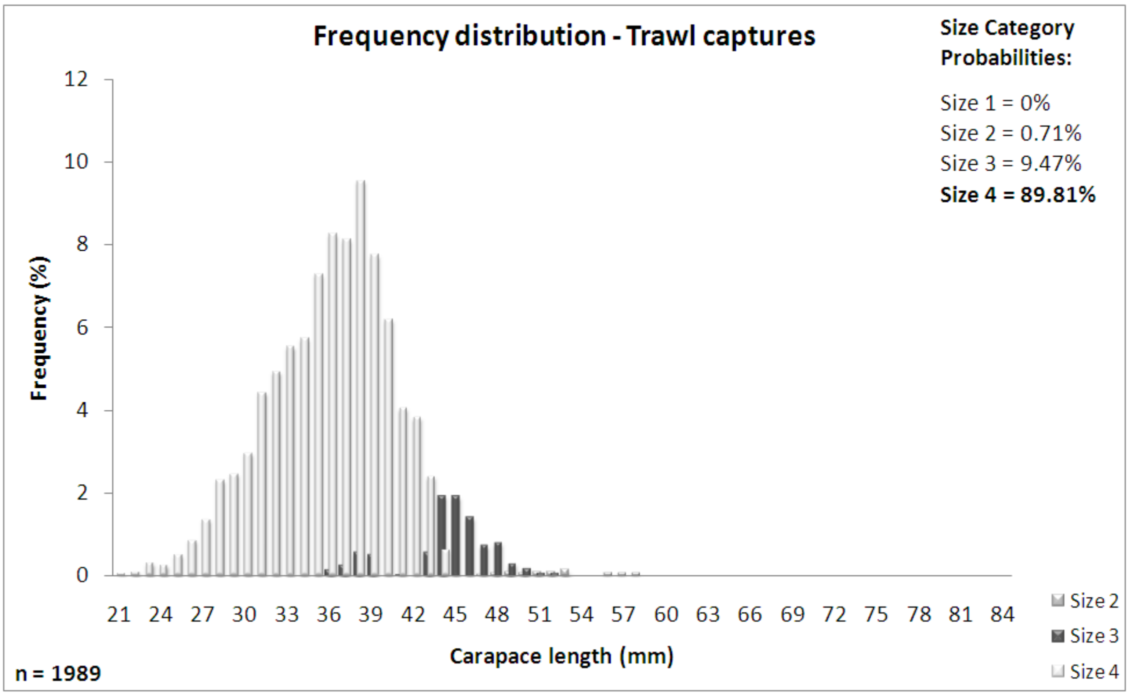


Figure 3 - Size frequency distribution (in percentage) of trawl catches, including size probabilities for each size category.

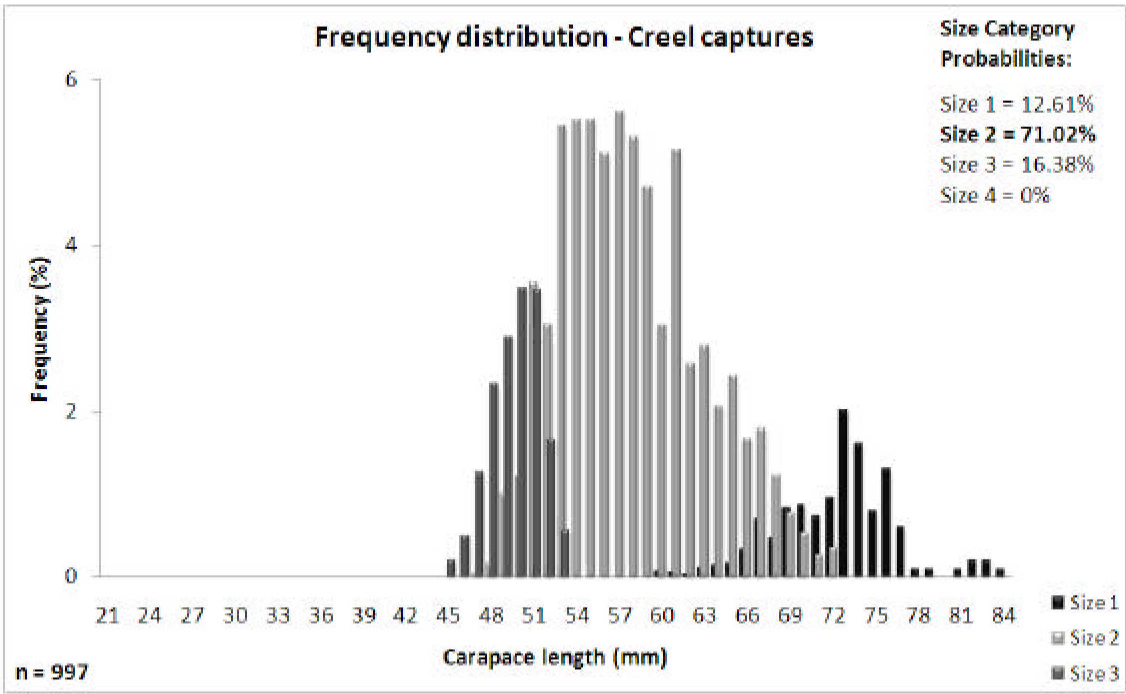


Figure 4 - Size frequency distribution (in percentage) of creel catches, including size probabilities for each size category.

Results from the length composition data were interpreted in conjunction with fish auction data. The landings of 10 vessels, already sorted by size category, were sampled at the fish auction and the probability of a length class falling into a given size category, was estimated and extrapolated to the total *Nephrops* catch. These results are presented in Figure 3 and Figure 4, and show that 90% of the trawl catches are traded in size category 4, which has the lowest value (see Table 2), and category 1 is absent. On the other hand, 13% of the creel catches are sold in size category 1, while 71% are in size category 2 and 16% in size category 3.

Table 2 – Approximate range of *Nephrops* price's per Kg, given by each size category and carapace range. Data collected at the auction market of Vila Real de Santo António (VRSA) in June and July of 2007.

Size categories	Carapace range (mm)	Approximate range (€/Kg)
1	> 60	47 – 130 (higher values at particular times)
2	47 - 72	23 – 67
3	36 - 53	7 – 24
4	< 44	2 – 10

3.3 Condition (quality) of the landings

Global conditions at arrival on deck are presented in Table 3, showing a remarkable difference between individuals caught by trawl and by creels.

In trawl catches, 16% of the individuals had no sign of life, 39% showed some movement and 45% were very active. On the other hand, creeled individuals arrived on deck all showing clear signs of life, 70% aggressive posture and just 30% with less activity.

Table 3 – Description of the condition (in percentage) on arrival on deck for trawl (net mesh size = 70 mm) and creel catches (net mesh size = 40 mm).

Condition Trawl (%) **n = 186**	**0**	**1**	**2**
arraival on deck	16	39	45
Condition Creels (%) **n = 56**	**0**	**1**	**2**
arraival on deck	0	30	70

3.4 Economic Assessment

In this study NPV was used as the criterion to assess the sustainability of the trawl and creel fisheries. The relation between discount rate and NPV is given in Table 4, which shows NPV values for different discount rates. Results show that NPV outcomes do not depend on the choice of discount rate because NPV is always positive for the creel fishery and negative for the trawl fishery. The rate used was based on recommendations for Portugal and the year 2007 by Watson Wyatt (2008): between March and December of 2007 the discount rate, over a 10-year period, ranged from

4.6% to 5.6%. Based on these values a discount rate of 5% was applied to determine NPV.

Table 4 – NPV outcomes for different discount rate values, presented for trawl and creel *Nephrops* fishery.

DISCOUNT RATE	NPV_TRAWL	NPV_CREELS
1%	-960 351	885 543
2%	-915 529	844 213
3%	-874040	805956
4%	-835 584	770 495
5%	**-799 893**	**737 585**
6%	-766 726	707 001
7%	-735 864	678 543
8%	-707 112	652 031
9%	-680 293	627 301
10%	-655 247	604 206

Data for costs and earnings are from different sources; interviews to the owners and captains of the sampled vessels were complemented with information extracted from the DGPA data base (Table 5 and Table 6). The annual average selling price of Norway lobster (per Kg), landed in 2007, was remarkably different for trawls (15€) and creels (80€). The catch rate (catch per unit effort as kg/day of fishing) was also higher for the artisanal vessel (70kg) than for the trawler (26kg). When the total fishing effort was considered, the trawler targeted *Nephrops* for 198 days against 45 days for the artisanal vessel. The average annual running costs were 76 545€ for the trawler and 18 000€ for the artisanal vessel, with total fixed costs of 35 457€ and 12 000€ respectively.

The total benefit of fishing Norway lobsters with creels was estimated at 737 585€ (net present value over 10 years, 5% discount rate). These gains occur because of the higher value of the catch and the low costs required to obtain it. On the other hand, *Nephrops* trawling turned out to be an unprofitable fishery, with losses of the order of 799 893€ in net present value (NPV over 10 years, 5% discount rate). However, when the NPV is estimated for the total catch, where the rose shrimp represents the most important fraction, the analysis has estimated considerable financial gains, with a benefit estimated at 921 821€ (NPV over 10 years, 5% discount rate).

The sensitivity of these results to changes based on the input variables was tested. Table 5 and Table 6 presents the switching value (measure selected for project sensitivity) for each parameter for trawl and creel *Nephrops* fishery, respectively. The switching value is the level of the variable that makes NPV equal to zero, assuming that all other variables remain unchanged. For example, in the case of Norway lobsters, the prices per kg would have to change from 15€ to 33€ in order to switch the NPV from -799 893€ to zero. This measure of assessing sensitivity is particularly enlightening and very simple to interpret, revealing which variables require attention in order to improve the project viability.

As the results are clear regarding the profitability of creelling and unprofitability of trawling, it was considered unnecessary to extend the results of the project appraisal with a risk analysis.

Table 5 - Sensitivity analysis presented for the trawl *Nephrops* fishery, showing the switching values for all parameters. The NPV in the base case was -799 893€.

Parameters	Units	Base case (units)	Switching value (units)
Price	€ per kg	15	33
Vessel utilisation	Fishing days per year	198	434
Catch rate	Kg per fishing day	26	57
Running costs	€ per year	76 545	-15 167
Fixed costs	€ per year	35 457	-56 255
Labor costs	€ per year	69 714	-21 998
Financial support (subsidies)	€ per year	13 217	104 930
Discount rate	Percent per year	5%	

Table 6 - Sensitivity analysis presented for the creel *Nephrops* fishery, showing the switching values for all parameters. The NPV in the base case was 737 585€.

Parameters	Units	Base case (units)	Switching value (units)
Price	€ per kg	80	54
Vessel utilisation	Fishing days per year	45	30
Catch rate	Kg per fishing day	70	47
Running costs	€ per fishing day	400	2 279
Fixed costs	€ per year	12 000	96 569
Crew share	Proportion-net revenue	0.50	0.94
Taxas and social security	Proportion-gross revenue	0.17	0.83
Discount rate	Percent per year	5%	

4 Discussion

The two fisheries are distinguished by differences in exploitation pattern, size and condition of landings, economic performance and impact on the benthic communities.

Nephrops trawling caches are influenced by biological rhythmicity of burrow occupation and emergence, since they are caught when out of their burrows (Newland and Chapman, 1989, Newland *et al*. 1992, Aguzzi and Sardà, 2008). Thus, trawls tend to capture a wide range of sizes, including small individuals down to the minimum landing size (20 mm CL). No large animals (above 60 mm CL) were caught, probably due to the exhaustive exploitation of the south coast stock.

As a result of the size and condition of the trawled individuals, a relatively high proportion of these landings (mostly small sizes) are processed (António Martins, DocaPesca VRSA, personal communication) and the return is not as desirable as it is in the trade of larger animals, with better appearance, which are mostly provided by creel catches.

Creel catches are not influenced by burrow emergence patterns in the same way that trawl catches are, but creel catches do still depend on individual animal behavior likely related to feeding activity when attracted to bait in creels (Bell *et al*., 2006). Adey (2007) observed that creels select larger individuals, verifying that larger animals are more likely to enter the creel. In addition, it was found that interspecific interactions (with crabs) discourage *Nephrops* from entering the creel Adey (2007). It is possible that dominance and aggressive behavior of larger animals inhibits smaller individuals from entering the creels. Due to these behavioral factors and the use of 40 mm mesh size in the creels, few animals below 45 mm CL were caught, either because they do not enter the creels, or escape through the mesh.

Creel catches were characterized by generally larger animals, of higher unit value, and are in part traded alive (António Martins, DocaPesca VRSA, personal communication). The absence of large sizes from trawl catches indicates that these populations are subjected to higher mortality rates than those from areas were only creels operate. Creels do not catch small individuals, allowing them to grow to larger sizes, making this a more appropriate gear for the conservation and recovery of this resource.

In this study only qualitative comparisons were possible, as trawling and creeling take place in different areas and exploit different *Nephrops* populations. Thus, it is not possible, at the moment, to compare the exploitation pattern of both gears directly. To make this possible, it would be necessary to evaluate the variation in the Norway lobster catches by experimentally fishing with both gears within the same fishing grounds. This would allow a direct comparison of the catch composition, and by-catch species of the two gears.

Opposite to the main Norway lobster producers that have specific *Nephrops* trawlers, like the United Kingdom (41 384 ton in 2006), Ireland (6 337 ton in 2006) and Sweden (1 152 ton in 2006) (FAO, 2007), Portugal does have a mixed crustacean fleet. In the last two decades the interest in the rose shrimp rose and this fleet, that typically targeted *Nephrops,* changed the preference to the rose shrimp. Owning to remarkable selling prices (200€ per Kg in particular times, António Martins, DocaPesca VRSA, personal communication) the rose shrimp became the main target species, representing the central economical return of this fleet (around 70% in value of the gross revenue of sales, from 1996 to 2007, DGPA data base).

The crustacean trawl fishery, as all other industrial fisheries, has been subsidized in recent years, mostly through development funds from the EU (vessel construction and subsidies during immobilization of the fleet for conservation purposes). Recently, even fuel is subsidized, maintaining fishing operations that otherwise would be compromised. Fishing *Nephrops* is seen by the fishermen only as simple supplement of the shrimp fishery, taken with the purpose of enhancing the returns, by fishing during the night when the rose shrimp catches are very low.

Results from this study suggest that fishing *Nephrops* with trawls is not profitable, in fact the industry loses money every time it targets Norway lobster it was estimated to have losses of the order of 799 893€ in terms of net present value (NPV over 10 years, 5% discount rate). Thus, there is no reason for the fishery to continue if unprofitable. To corroborate these results a more comprehensive study should be done encompassing the entire fleet.

The funds of the EU financial support along with the shrimp returns cover the main costs. This is the reason why NPV estimation for the complete fishery is positive, but becomes negative when *Nephrops* fishery is considered on its own.

The great dependence of the crustacean fleet on rose shrimp makes this fleet highly vulnerable. Results of NPV calculations reveal that profitability of crustacean trawling is strictly related with shrimp catches and could not be sustained just with *Nephrops* catches, at least with the present fishing effort.

On the other hand, a fishing day targeting *Nephrops* by the artisanal fishery has proven to be very profitable. The total benefit was estimated at 737 585€ (net present value over 10 years, 5% discount rate). Here, costs are low and revenues are high; the fuel consumption is manly accounted for by the journey to the fishing area, as the fuel use in hauling creels is almost insignificant. Catches are composed by large and live animals which give excellent return on the market.

The creel fishery has several attractive features. It has a minimum environmental impact compared to trawl fishery (base on literature review – see table 1 for references). Fuel consumption is lower and the impact on the benthic communities is small, important for conservation of biodiversity. It is very species and size selective, catching almost exclusively large *Nephrops*, allowing small individuals to survive to larger sizes. Catches are composed of vivid individuals reaching higher prices. High benefits are expected in net present value terms, giving good returns to this fishery.

Based on the environmental live cycle assessment of Norway lobster in Sweden, Ziegler and Valentinsson (2008) stated that there are many advantages from replacing bottom trawling with creels, leading to less seafloor impact, less fish and undersized *Nephrops* discarded, as well as a decrease in fuel consumption. Some of these aspects are also addressed by Eggert and Ulmestrand (2000) as potential advantages of the creel fishery over the trawl fishery.

At the moment, the biggest limitation for the expansion of the creel fishery is gear conflict. Since the depths where *Nephrops* occur are uncommon within the 6 miles limit, creel fishing is restricted to refuge areas where trawlers cannot operate, due to irregular and rocky bottoms. There are not many of these areas and territorialism or lack of information among fishermen might also hold back the expansion of creels use.

In the present context, creels may provide a more sustainable and profitable alternative to trawls for *Nephrops*, contributing to the recovery of the resource. However, there are few studies and consequently there are still large gaps in the present knowledge of how *Nephrops* creel fisheries exploit the stock and how this varies in different fishing areas. Hence, there is a need for continued research in this field, to provide more information essential for future management of this potentially expanding fishery. Ongoing studies should also comprise demand and supply analyses, to evaluate the needs of the market and possible changes that might occur from switching from trawls to creels.

5 Conclusions

- The different selection properties of creels and trawls and the behavioral differences of *Nephrops* in the presence of these gears, create differences in catch composition, showing that different gears exploit different parts of the populations.
- Creels have demonstrated to be a more gentle catch method getting more vivid lobsters and in better condition.
- The financial analysis is revealed a non-profitable trawl *Nephrops* fishery. On the other hand, fishing the Norway lobster with creels happens to be very profitable.
- Considering the current condition of the Portuguese *Nephrops* populations in the South and Southwest coasts and the negative impacts that trawling has on the environments, creels may provide a more sustainable alternative to *Nephrops* fishing, contributing to the recovery of the resource.

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