WORKING PAPER 2018:4

*Cecilia Hammarlund*
*Patrik Jonsson*
*Daniel Valentinsson*
*Staffan Waldo*

# Economic Effects of Reduced Bottom Trawling

## The Case of Creel and Trawl Fishing for Nephrops in Sweden

**Economic effects of reduced bottom trawling – the case of creel and trawl fishing for Nephrops in Sweden**

*Cecilia Hammarlund[1], Patrik Jonsson[2], Daniel Valentinsson[3] and Staffan Waldo[4]*

AgriFood Economics Centre and Department of Economics, Swedish University of Agricultural Sciences

P.O. Box 730, 220 07 Lund, Sweden

**Abstract**

On the Swedish west coast Nephrops are fished using creels and trawls. Creel fishing exhibits lower seafloor pressure than trawl fishing, uses less fuel, and bycatch of other species per landed kilogram is lower. An expansion of the area for the creel fishery is thus interesting from an environmental perspective but the possibilities for policy change will also depend on the economic viability of the fishery, i.e. how incomes and costs of the fishery are affected. We investigate the economic effects on the Nephrops fishery of an expansion of the creel area and analyse how fleet structure and the net present value of profits is affected using a bio-economic fishery model (FishRent). In addition, we investigate how fuel use changes when the creel area is expanded. Our findings suggest that an area expansion would increase the number of creel fishers and decrease the number of trawl fishers. The net present value of the fishery would increase in total but a number of small trawlers leave the fishery and thus the net present value decrease for this fleet segment. Fuel use could increase or decrease depending on other policies in place for the fishery.

Key words: fisheries economics, bio-economic model, government policy

JEL:  Q28, Q22

---

[1] cecilia.hammarlund@agrifood.lu.se
[2] patrik.jonsson@slu.se
[3] daniel.valentinsson@slu.se
[4] staffan.waldo@slu.se

## 1. Introduction

The negative external effects of bottom trawling such as bycatches, seafloor pressure and intensive fuel use, have encouraged managers to legislate in favour of more selective trawls and in alternative fishing methods. In Sweden, the majority of Nephrops (Norway Lobster, *Nephrops norvegicus*) are fished using bottom trawls. To reduce the environmental impact, selective trawls have been introduced to reduce fish by-catches (Valentinsson and Ulmestrand, 2008). Recently, there has been an expansion in the use of creels for fishing Nephrops, a method that has been found to environmentally outperform the trawl fishery; the creel fishery exhibits lower seafloor pressure, uses less fuel and bycatch of most other species per landed kilogram is lower (Ziegler and Valentinsson, 2008; Hornborg et.al., 2016). Due to gear conflicts, trawl and creel fishing cannot take place simultaneously in the same geographical areas and it has been necessary to dedicate specific areas for each type of gear. In 2004 the area available for Nephrops fishing with creels was increased (Sköld et al. 2011), and a further expansion of the creel fishery has been discussed (AgriFood, 2018).

Although there appears to be environmental benefits when switching from a trawl-dominated Nephrops fishery to a creel-dominated Nephrops fishery the total benefits for society from such a switch depends also on other factors. One important aspect is the economic benefits for fishers that are engaging in the two types of fisheries. If creel fishing is economically viable an extension of the area available for creel fishing will encourage entry of creel fishers and force exit of trawlers. The net private benefits of such a change will be interesting for policy makers not least because the resistance or support for an extension of the available area for the creel fishery will depend on these benefits. In general, the success of political measures in fisheries are more likely if fishers believe that short-term losses will be compensated by medium- or long-term gains (see for example the discussion on limiting discards in Catchpole et.al 2005).

Creel-caught Nephrops receive higher prices per kilo on average than Nephrops caught with a trawl (Hornborg et.al., 2016; SCFF, 2017; Eichert et.al., 2018). It thus seems that incomes from creel fishing could potentially be higher than incomes from trawl fishing. However, it is also important to consider the scale of the fishery and the costs of it. Eggert and Ulmestrand (2000) use a bio-economic model to compare the economic performance of trawl fishing with creel fishing for Nephrops and attempt to estimate the optimal effort level for the Nephrops fishery. The creel fishery was run with a deficit according to the authors making trawl fishing more competitive during the time span of the study (1990s). More recently, Waldo and Paulrud (2013) use a model based on linear programming that optimizes profits in the Swedish demersal fishery. When economic profit is optimized Nephrops will be fished by creel fishers and small trawlers (0-12 meters) to a greater extent. This suggests that creel fishers are profitable on average in the current situation contradicting the results in Eggert and Ulmestrand (2000). However, the time periods used in the studies differ and the conditions for Nephrops fishing have changed substantially over the last 20 years making useful comparisons difficult.

The economic viability of trawl and creel Nephrops fisheries have also been discussed in the context of other European countries. Morello et al. (2009) believe that the economic viability of creel fishing in the central Adriatic Sea (the Pomo pit) is likely to be low due to high scavenger activity, high densities of small animals and long distances from ports. Leocádio et.al. (2012) compares the financial viability of trawl and creel fisheries fishing off the Portuguese coast and conclude that the net present value of profit for a typical creel vessel is higher than for a typical trawler. The consequences of a trawl ban in an area off the west coast of Portugal is discussed in Eichert et. al (2018) where economic benefits are expected since there will be no loss in catch value while operational costs will be lower when the fishery switch to creels.

The purpose of this study is to analyse the economic performance of Nephrops fishers on the Swedish west coast if the creel area is expanded. That is, we estimate the economic effects on the fishing sector of a regulation that aims at reducing the negative external effects caused by bottom trawling. We use a dynamic economic model (the FishRent Model; Frost et al. 2013) to model different scenarios with and without a creel area expansion and look at the medium and long-run effects on profits, the number of vessels, landed quanitities and fuel use. To our knowledge, this is the first study modelling the economic performance of a Nephrops fishery in a dynamic setting.

The paper is outlined as follows. In section 2 the management system of Swedish Nephrops is discussed. Section 3 contains data and indicators of the economic performance of the present Nephrops fishery. In section 4 the FishRent model is presented and assumptions for the model implementation is discussed. Section 5 contains different management scenarios, and section 6 contains results. The paper is discussed and concluded in section 7.

## 2. The management of the Swedish Nephrops fishery

Commercial fishing for Nephrops requires a fishing license and a special permit according to national legislation where every fishing license gives the owner a right to use a particular vessel for fishing (SwAM, 2014). Before 2017 the Swedish Nephrops quota was allocated between grid trawling (50 percent), mixed trawling (25 percent) and creeling (25 percent) (SwAM, 2015), and vessel quotas were allocated as weekly rations to each vessel (SwAM, 2016). On 1 January 2017 yearly individual quotas were introduced in demersal fisheries in Sweden including vessels with permits to fish for Nephrops in Kattegat and Skagerrak. The motivation behind the management change was to facilitate quota exchanges between fishers and enable them to fulfil the landing obligation that is gradually being introduced in North Sea fisheries in 2016-2019 (EU, 2013). Individual quotas are based on landing records during a reference period, currently 2011-2014, with the exception of the year with least activity. Quotas can be leased between license holders during the quota year conditional on approval of the transfer by the Swedish Agency for Marine and Water Management (SwAM). Permanent quota transfers are not allowed (i.e. this is not an ITQ system).

The new quota management system has concentration limits meaning that a single license holder is allowed to own no more than five percent of the national Nephrops quota (SwAM, 2014). Since SwAM base the initial quota allocation on quota usage in previous years (National Board of Fisheries 2004a) the quota composition between different Nephrops fishers with different gears was similar in 2017 to previous years.[5] In addition to quota restrictions fishing with creels is also limited to 800 creels when one person is taking part in the fishery and to 1400 creels when two or more persons are involved in a firm's fishery (SwAM, 2014).

Other regulations of importance to the Nephrops fishery are gear- and geographical restrictions for trawlers. Trawling for Nephrops require the use of either a sorting grid for directed Nephrops fishing or a 90 mm cod-end with a large mesh window in the top panel (SELTRA-trawl) in the mixed fishery. The purpose of the gear restrictions is to guarantee a minimum selectivity for fish by-catches and gear restrictions are regulated in both national (National Board of Fisheries, 2004b), and EU legislation (EU, 2016).

Discards of various fish by-catches is mainly a problem in the mixed trawl fishery. The grid trawl fishery exhibits much lower by-catches although catches of flatfish like dab and plaice is still an issue (Madsen and Valentinsson, 2010; Hornborg et.al., 2016). Creel fishing, on the other hand, is associated with limited by-catches. Historically, the amount of discards of Nephrops in the trawl fishery in the

[5] In 2017 there was 44 transfers of nephrops quotas and there was 556 transfers within the demersal system. Unfortunately, there is no available information about the amount in kilos that has been transferred (personal information from Qamer Chaudhry, SwAM, 2018-02-07.

Skagerrak and Kattegat has been high, on average 47 percent of the Nephrops were discarded each year between 1991 and 2015 (ICES, 2017). When the landing obligation was introduced the minimum size was lowered[6], which implied that the proportion of discards decreased substantially (ICES, 2017). In 2016 discards was around 5 percent of catches (ICES 2017). In addition, discard survival has been estimated to be around 55 percent for Nephrops discarded after trawling when using the selective trawls legislated in the Skagerrak and Kattegat. Furthermore, discard survival of creel caught Nephrops is estimated to be well over 90 percent (Valentinsson and Nilsson, 2015). Based on this, the European Commission has granted an exemption from the landing obligation for Nephrops for all gears used in the Skagerrak and Kattegat (EU, 2016).

The focus of this study is on the geographical restriction that divides the area for Nephrops fishing between trawls and creels. This is implemented using a national trawl boundary. The basic rule is that trawling is only allowed outside the boundary, i.e. the area between the boundary and the coastline is allocated to creel fisheries. In 2004, the Swedish trawl boundary was moved from two to four (three in the Kattegat) nautical miles off shore thereby increasing the area available for creel fishing by 55 percent (Jonsson and Valentinsson, 2016). To allow a continued species selective Nephrops trawl fishing inside the trawl boundary certain areas was however still open for trawlers using a sorting grid (Hornborg et.al., 2016). In total, there is about 1600 km$^2$ available for Nephrops fishing within the trawl boundary which implies that if creel fishers were allowed to use the entire area within the boundary the available area for creel fishing would approximately double (Jonsson and Valentinsson, 2016).

## 2. Data and preliminary statistics

Data on landings in kilos of Nephrops and the number of days-at-sea per vessel and year are obtained from the vessels' logbooks while price data are based on information from landing declarations. Cost data for the fleet segments originates from the EU economic data collection framework (EU, 2017). The Swedish Nephrops fishery is often divided into three parts: the creel fishery, the grid trawl fishery and the mixed trawl fishery (Hornborg et al., 2016). Our economic data does not make it possible to separate the trawl fishery between grid trawl and other types of trawls. However, the trawler segments used here mainly use grid trawls. We will work with four different segments; two trawler segments and two creel fishing segments.[7] In all segments only vessels where more than 50 percent of the landings consist of Nephrops are included. The segments and some summary statistics are presented in Table 1.

[6] The minimum conservation size was reduced from 13 cm to 10.5 cm in total length in 2016. The minimum landing size is still large compared to other European Nephrops stocks. For example, the minimum landing size in the North Sea is 8.5 cm (Hornborg et.al, 2016).

[7] For small trawlers 78 percent of the landings was with a grid trawl and the corresponding figure for large trawlers was 80 percent in 2012 (own calculations).

Table 1: Summary statistics – four segments fishing for Nephrops in Kattegat and Skagerrak, all figures are averages over 2013-2014.

| Name and vessel length | Number of vessels | Landings of Nephrops in tons per year | Share of Nephrops in total yearly landings value | Share of Swedish Nephrops landings |
|---|---|---|---|---|
| Small creel fishers (0-10 meters) | 58 | 138 | 82 % | 11 % |
| Large creel fishers (10-12 meters) | 21 | 155 | 76 % | 13 % |
| Small trawlers (0-12 m) | 32 | 219 | 82 % | 18 % |
| Large trawlers (12-18 meters) | 30 | 349 | 79 % | 29 % |
| **Total** | 141 | 861 | - | 71 % |

In total, our segments consist of 141 vessels with 79 creel fishers and 62 trawlers. In all, the modelled segments land 71 percent of Swedish Nephrops landings and Nephrops is the dominating species for all segments.[8]

To get an idea about the profitability in each of the Nephrops segments we calculate the total profit using the latest available economic data (i.e. averages from 2013-2014). The costs of each segment is thus subtracted from the revenues of each segment.[9] Revenues are calculated as the average value of landings of all species for each segment. Costs are calculated as the sum of fuel costs, other variable costs, fixed costs, crew costs, depreciation and interest payments. Other variable costs include i.e. costs of repair and maintenance.[10]

We present calculated profits for each segment in total, profit per vessel, profit per full-time equivalent (FTE)[11] and profit margins (i.e. profits divided by the landing value of the segment). Column 2 in Table 2 shows the total profit for each segment. Profits for small creel fishers is around 622 000 euros altogether and amounts to around 10 700 euros per vessel and year. Profits for large creel fishers are 27 100 euros per vessel and 23 000 euros per full-time equivalent. The calculated profit margin in Table 2 suggests that creel fishers retain around 20 percent more of the landed value than trawlers.

Table 2: Profits (1000s euros) in the Nephrops fishery, year 2013-2014.

| | Total profit for segment (1000s euros) | Profit per Vessel (1000s euros) | Profit per FTE* (1000s euros) | Profit margin |
|---|---|---|---|---|
| Small creel fishers | 622 | 10.7 | 17.5 | 29 % |
| Large creel fishers | 556 | 27.1 | 23.0 | 22 % |

[8] Other segments that catch Nephrops are mainly trawlers larger than 18 meters. For these trawlers Nephrops is a smaller part of their fishing activities. Thus, these are not included in the analysis.
[9] Since fishers sometimes have incomes and cost deriving from non-fishing activities we have used a weight on costs corresponding to the share of income that comes from fishing. We thus assume that incomes and costs are equal for non-fishing activities.
[10] Revenues and costs of the segments are presented in Table A1(total numbers) and A2 (per vessel) in Appendix A.
[11] A full-time equivalent implies work eight hours a day.

| | | | | |
|---|---|---|---|---|
| Small trawlers | 42 | 1.3 | 1.2 | 1 % |
| Large trawlers | 261 | 8.7 | 5.0 | 6 % |

* Full Time Equivalent, Note: Profits are calculated as the value of landings minus fuel costs, other variable costs, fixed costs, crew costs, depreciation and interest payments.

We find that the reported sums paid to the crew of the vessels are remarkably low for smaller vessels segments. For example, the reported crew costs of small creel fishers was around 3000 euros per year per FTE (full time equivalent) on average in 2013-2014. This corresponds approximately to the median monthly wage in Sweden[12] and is thus very low. A reason for these low labour costs could be that single owner enterprises to a larger extent chooses to not report labour costs as the owner gets parts of the profits as their income.

3. Modelling the Nephrops fishery

In this section we describe the FishRent model and how it is applied in our case study. We discuss assumptions that are necessary to fit our model to the available data and the management system that is in place for Swedish Nephrops.

### *4.1 The FishRent model*

The FishRent model is a dynamic bio-economic model allowing multiple fleets and multiple fish stocks. The model has two modes for analysis: A simulation mode and an optimization mode. In the simulation mode the fishery is projected into the future such that current fishing effort, catches and profits will affect future stock development, quotas, investments in new vessels, etc. This corresponds to the expected development under business as usual. In the optimization mode the model maximizes the net present value (NPV) of economic profits in the sector by re-allocating fishing effort among vessels. In this kind of analysis the model provides the fishing effort and fleet size that gives the largest profit to the industry over the studied period.

The NPV of economic profit is defined as

$$NPV\ \pi = \sum_{y,f} [p_f \cdot L_{y,f}(X_y, E_{y,f}) - C(E_{y,f})] \cdot (1+\rho)^{-y} \qquad (1)$$

Where $\pi$ is profit, $p_f$ is the price of nephrops for segment f. This is assumed to be constant over time. $L_{y,f}$ is the landings of nephrops in year y for segment f. $X_y$ is the nephrops stock in year y, and $E_{y,f}$ is the effort in year y for segment f. C is the cost of fishing which is dependent on the effort (E). $\rho$ is the discount rate used for calculating NPV. Further, the model restricts the fishery to keep within quota limits and not to use more effort year y than is possible using the fleet available in year y. The model contains specific modules for setting of the quotas (management module), investments (investment module), and stock development (biological module). These are not specified in detail here, but can be found in Frost et al. (2013) and Salz et al. (2011) who provide detailed information on the model.

### *4.2 Implementing the FishRent model*

We will investigate how the number of vessels, landed quantities, the net present value of the fishery and fuel consumption develop when the creel area is expanded. The number of vessels is an indicator that will tell us how the fleet is developing and if any restructuring of the fishery is taking place. Landed quantities will also add some information on how much Nephrops is landed by each segment in different scenarios. The main indicator of the economic performance of the fishery is measured as the net present

[12] https://www.scb.se/hitta-statistik/sverige-i-siffror/utbildning-jobb-och-pengar/mest-och-minst-betalda-yrkena/

value of the fishery. In our case, this is the total discounted value over a 25-year-period. Finally we will present results on how fuel consumption develops in our different scenarios as an indicator of the environmental impact of the fishery.

### *4.2.1 The landings' function*

A feature of the model that is important for this paper is the function for landings ($L$). This is the function determining the catch level based on effort ($E$) and stock ($X$). Landings are determined as

$$L_{y,f} = \alpha_f E_{y,f}^{\beta} X_y^{\gamma} \qquad (2)$$

Where $\alpha_f$ is the catch coefficient for segment $f$, $E_{y,f}$ is effort of segment $f$ in year $y$, and $X_y$ is the stock in year $y$. $\beta$ is the effort elasticity, i.e. how sensitive landings are to changes in effort. Higher $\beta$ implies that landings change more when effort changes. $\gamma$ has the same interpretation for the stock level. However, in the empirical application the stock is assumed to be constant, and therefore normalized to one, which implies that the landing function reduces to

$$L_{y,f} = \alpha_f E_{y,f}^{\beta} \qquad (3)$$

The motivation for using a constant stock is provided in the biology section below.

Effort elasticities for each segment is estimated with data for the period 1997-2016 (see Appendix B-Table B1). When the creel area is expanded we allow the effort elasticity for creel fishers to change since an increase in the area for creel fishers implies that the marginal product will not diminish at the same rate as previously. The new effort elasticity is estimated using data from the last creel area expansion (see Appendix B – Table B1). The results imply that effort elasticities increase for both creel fisher segments after the creel area expansion. The intuitive rational for this is that the expansion makes it possible to keep having high catches when expanding effort due to less crowding at good fishing grounds. When the creel area is restricted, a higher level of effort is inefficient due to a lack of suitable fishing grounds. There is a small increase in the effort elasticity for the large trawler segment whereas there is no difference in the effort elasticity for the small trawlers segment before and after the creel area expansion. We will assume that the change in elasticity of the large trawler segment is unrelated to the creel area expansion and assume that this elasticity is not changed.

### *4.2.2 Biology and quotas*

The biomass of the Nephrops stock in Kattegat and Skagerrak have been estimated using underwater TV-surveys (UWTV) since 2011 (ICES 2017).[13] Previously there were no available estimates of the stock making the period for estimating the input parameters for the biological module too short. In the model, we assume that the biomass of Nephrops as well as the total TAC for Skagerrak and Kattegat are constant over the years. The TAC has been kept at a more or less constant level in recent years. Between 2005 and 2011 it was at 5200 tons each year, in 2012 it was raised to 6000 tons, then lowered to 5200 tons again in 2013 and then lowered further to 5019 tons in 2014. In 2015 a slightly higher TAC

[13] Underwater TV-surveys (UWTV) uses an underwater video camera that is towed over the sea bed. The number of Nephrops burrows in the seabed are counted and estimates of the number of Nephrops in the entire area of the Nephrops grounds is calculated.

of 5318 tons was agreed upon. Since 2011 the TAC has not been limiting for the Swedish Nephrops fishery. Thus we do not expect the quota to be limiting for any of the segments in our model.[14]

Although Nephrops fishers also fish for other species to some extent we have chosen not to include the quotas available for other species. If bycatch of other species are high when fishing for Nephrops it is possible that the Nephrops quota will not be fished because there are no available quotas for other species. Bycatch in the creel fishery is small whereas it is higher for the trawl fishery, especially in the mixed trawl fishery (Hornborg et.al. 2016). The system of yearly quotas has the intention to prevent that lack of quotas for non-targeted species makes it difficult to take quotas of targeted species. First, grid trawl and creel fishers are guaranteed a base level of quotas of bycatch species to avoid choking i.e. prevent them from using their Nephrops quota. Second, all Nephrops fishers are able to lease quotas upon approval from the Swedish Agency for Marine and Water Management under the new system with yearly quotas. With this in mind, we assume that the possibility of bycatches preventing fishers from taking the Nephrops quota are limited and we will not use quotas of other species in the model.[15]

### *4.2.3 Management and investments*

Although we are primarily interested in the effects of a potential creel area extension the effects of this extension will also depend on other features of a future management system for demersal fisheries in Sweden. We will use two different approaches when modelling the effects of the management system for Nephrops. First, we will assume that the system with yearly quotas will not result in a restructuring of the fleet as this was not intended in the suggestion preceding the legislation (SwAM 2016)). For modelling scenarios under this assumption we use the simulation version of the FishRent-model. Second, we will assume that restructuring is possible since the system with yearly quotas in theory could result in restructuring and since it is possible that an ITQ-system is introduced in the demersal fishery in the future. For scenarios of this type we use the maximization version of the FishRent-model.

If the creel area is expanded the investment rates (measured as entry and exit of vessels) will change. For example, we expect the number of creel fishers to increase if the area for creel fishing is expanded, ceteris paribus. Investments in the FishRent model are limited to a certain percentage of profits (see Frost et al. (2013) for details) and in the simulation version of the model, investments in new vessels will occur if a segment has a positive profit and disinvestments (exit of vessels) will occur if a segment has negative profits. The model also requires that upper and lower investment limits are defined, i.e. the maximum number of vessels that can appear or disappear each year. To find reasonable investment limits we use historical data on the development of the number of vessels. Figure 1 shows the development of the number of vessels for our segments between 1996 and 2016 based on logbook data.[16]

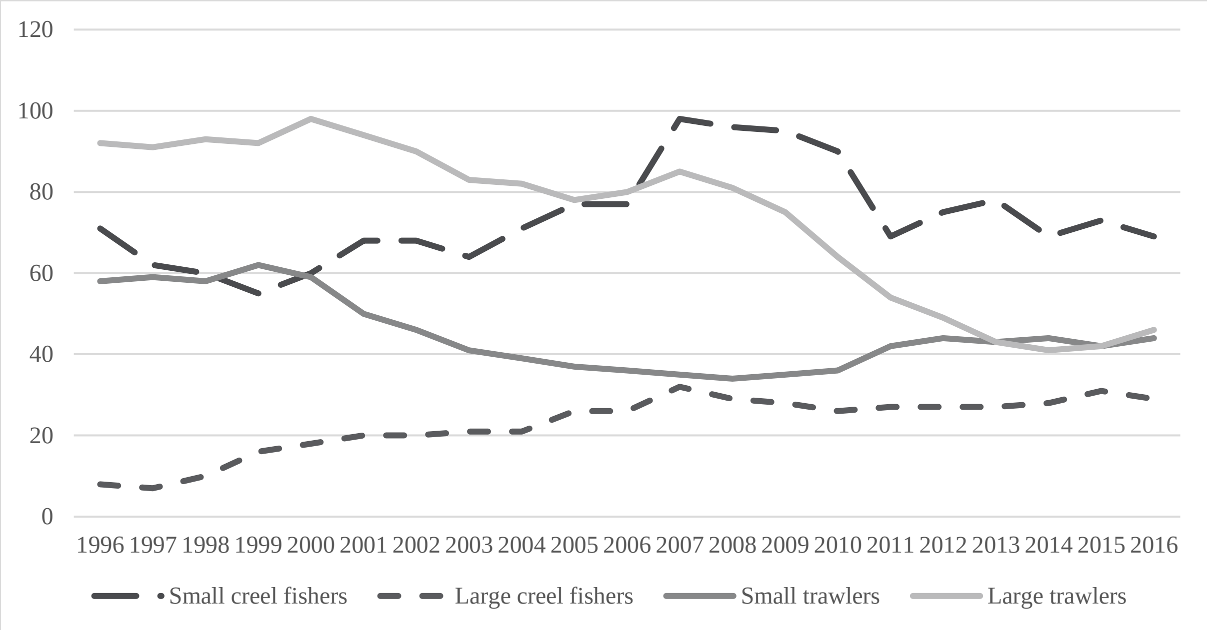
---

[14] From 2016 onwards the TAC has been set for catches rather than landings making comparisons difficult. After the catch quota was imposed (and the quota thereby increased) the reported catch has been much lower than the TAC. In 2016 around 47 percent of the quota was caught and the corresponding figure for 2017 was 42 percent (ICES 2017, SwAM 2018).

[15] It should be noted however, that revenues from other species are included in the model, thus total calculated profits are profits from all species.

[16] Since we use a different data set (logbook data) the segments in this data is not directly comparable to the segments used in the model analysis (which is based on the average of 2013 and 2014).

Figure 1: The development of the number of vessels used for Nephrops fishing, 1996-2016.




Source: Own calculations based on logbook data.

Investments in the creel fishery was small in the beginning of period and in the end of the period. The average investment rate per year was 1.6 % before 2004 and 0.2 % after 2011. In 2004, when the trawl boundary was extended the creel fishery could expand and this resulted in an increase in the number of vessels. The amount of vessels increased from 87 in 2003 to 128 in 2008. After 2008 we see a small decrease in the number of vessels but there are more vessels after the extension of the trawl boundary than before. The average investment rate four years after the last extension of the creel area, 2004-2007, was approximately 12 percent per year. We use this estimate in the model for the two creel segments to reflect an expected increase in the creel fishery if a larger area becomes available.  We will also use the prevailing investment rates of trawlers during this period. The rate of investment of trawlers was negative for small trawlers during this period and around zero for large trawlers.

During the last creel area expansion period around 45 new creel fishers entered the Nephrops fishery and the area that became available for creel fishing increased by 55 percent. If the creel area expands to cover the whole area within the trawl boundary that would imply an extension of the creel area by 108 percent. We will put an upper limit to the expansion of the creel fisher fleet that takes into consideration that eventually it will be difficult for the creel fishery to expand beyond a certain level. Assuming that the expansion in the number of vessels will be proportional to the area expansion we calculate upper limits of the number of vessels based on the number of vessels added per $km^2$ after the last creel area expansion period. For small creel fishers the limit is 121 vessels and for large creel fishers it is 44 vessels. A further expansion of creeling implicitly also rest on the assumption that these new areas are suitable for creel fishing. Creel fishing is already taking place on the boundaries to the grid areas and sometimes even outside of the trawling border on similar habitats why this seems a reasonable assumption.

*4.2.4. Other assumptions*

The model requires that the maximum number of days during a year for each segment is specified. The maximum number of days in each segment can be identified in different ways. In the simulation version of the model we will assume that fishers continue to operate at their current utilization level and hence the maximum number of days per year is equal to the current amount of days. Thus, any changes in profits will not reflect that each vessel is used more efficiently. In the maximization version of the model we will use the third quartile of the number of days reported in logbooks as the maximum number of days that can be used in a segment.[17] The idea is that when the fishery is profit maximizing it will also use its capacity (the vessel) more efficiently and hence each vessel will increase its number of days out at sea.

As mentioned above our data shows large differences in costs of the crew on board vessels. The FishRent-model uses the share of revenues that is paid to the crew. For our segments this crew cost share ranges from 5 % for small creel fishers to 17 % for large trawlers. To facilitate comparisons among segments we adjust crew costs of three of our segments (small creel fishers, large creel fishers and small trawlers) by using the crew cost share of revenues of the large trawler segment. This implies that we assume that for each segment 17 percent of revenues consist of labour costs. In appendix C profits with adjusted labour costs are presented. Finally, we use a discount rate of 3.5 percent for futures profits and thus we calculate the net present value of future profits from the Nephrops fishery. The discount rate level is within the range of values used when evaluating societal investments (Svensson and Hultkrantz 2015).

## 4. Scenarios

We have identified five scenarios that we believe are interesting for the Swedish Nephrops fishery. These are presented in Table 3 and 4 and further discussed below. The first two scenarios use the simulation version of the model were the current system with yearly quotas is assumed to have limited effects on restructuring and profit maximization of the fleet as a whole (Table 3). Thus, the system with yearly quotas has the intended effects as stated in the suggestion preceding the legislation (SwAM 2016). Technically, the different scenarios assume different values of the input parameters related to the landings function and investment function as described above.

Table 3: Scenarios under current regulation (2013-14, using a simulation version of FishRent)

**Scenario 1 - BAU - Limited space for creel fishers and low investment rate**

Simulation under the assumption that the area for the Nephrops fishery is geographically limited to the current areas. The investment rate is equivalent to the average rate of the last five years of our data (2012-2016).

**Scenario 2 – AREA - Increasing the area for creel fishers with an increase in investment rate**

Simulation under the assumption that the creel fishery is expanded such that the area for this fishery increases with 108 percent. We assume this will have three effects on the fishery:

a. The investment rate in the creel fishery will increase. Investment rates in all segments will be equal to the rates after the previous expansion of the area for creel fishers in 2004.
b. The effort elasticity will increase for creel fishers.
c. The expansion of the creel fishery will be stopped by the regulator after a level has been reached that is corresponding to the number of vessels that joined the fishery after the last expansion.

The first scenario is the Business As Usual (BAU) scenario. Here we use the average investment rate during the last five years in each of our segments and assume that these investment rates will continue in the future. If a fleet segment with positive profits was disinvesting on average during the last five years we will put the investment rate to zero (even though the segment has a positive profit we believe that there is something suggesting that there will be no newcomers entering the segment). Figure 1

[17] The large creel fishers segment will be an exception since the third quartile is smaller than the average number of days used in the model. For this segment we will assume that all vessels in the segment are already using the maximum amount of days, i.e. the average is equal to the max.

shows that investments have been limited in 2012-2016 thus we do not expect any major changes when using this scenario.

We call our second scenario AREA. This scenario represents an extension of the available area for creel fishers. We identify three different effects on the fishery that we believe are likely to occur in the event of an expansion and that are based on the discussion above. The first effect (a) is that the investment rate increases in the creel fishery. We use the investment rate that followed the previous expansion of the area for creel fishing in 2004. We also use the investment rates for trawlers that followed after the expansion. Technically, this means that we change the input values in the investment function. The second effect (b) is that the effort elasticity in the landing function changes and the last effect (c) is the limit of the number of vessels. Technically, changes in effort elasticities from Model 2 in Appendix B1 are added to the effort elasticities used in the BAU-scenario and used as input values in the landings function. Also, a new value for the constant ($\alpha_f$) is calculated and used in the function. The limit of the number of vessels is applied as a restriction in the mathematical code of the model.

As mentioned above, a restructuring the fleet was not intended when the system of yearly quotas was introduced. Continuing with the current management system of the fishery is thus not expected to result in large changes in the number of vessels of different types so as to maximize profits of the fleet. However, the management system might change and restructuring will then be possible. The maximization model is used in scenario 3-5 and presented below (Table 4).

Table 4: Scenarios maximizing economic profit

**Scenario 3 – MAX1 – Maximizing profits with limited space for creel fishers and low investment rate**

The net present value of the fishery is maximized under the assumption that the area for the Nephrops fishery is geographically limited to the current areas. The investment rate is equivalent to the average rate of the last five years of our data (2012-2016).

**Scenario 4 – MAX2 – Maximizing profits and increasing the area for creel fishers**

Maximization under the assumption that the creel fishery is expanded such that the area for this fishery increases with 108 percent. We assume this will have three effects on the fishery:

a. The investment rate in the creel fishery will increase. Investment rates in all segments will be equal to the rates after the previous expansion of the area for creel fishers in 2004.
b. The effort elasticity will increase for creel fishers.
c. The expansion of the creel fishery will be stopped by the regulator after a level has been reached that is corresponding to the number of vessels that joined the fishery after the last expansion.

**Scenario 5 – MAX3 – Maximizing profits with no investment limits and increasing the area for creel fishers**

Profits are maximized without any investment limits for the segments. The effort elasticity will increase as in scenario 2 for creel fishers.

The first scenario maximizes the net present value of the fishery assuming that there will be no creel area expansion and investments will be limited to observed investment levels. This is a restrictive assumption on investments in a profit maximization scenario and thus this scenario represents a conservative estimate of the potential increases in profits and changes in fleet structure. The MAX2-scenario will model the extension of the creel area when the fishery is also maximizing its profits. As in scenario 2 the investment level is assumed to correspond to the investments following the previous area expansion in 2004 and the same assumptions are made regarding the effort elasticity and the limitation of the number of vessels. The MAX3-scenario is based on the same assumptions as MAX2, but there are no investment limits. Thus, the fishery can freely increase/decrease the fleet size. This is a very flexible scenario and the results should be interpreted as a high estimate of the potential profit increases corresponding to the long-run equilibrium in a fishery with a fully-functioning ITQ-system and no area restrictions for fishing with different gears.

5. Results

Below, our results will be presented and discussed. We will focus on the development of the number of vessels and the quantity of Nephrops that is landed. Then we will present the net present value of each segment and of the fishery in total. Finally we will show how fuel use changes in our different scenarios. We will start by investigating the development of the number of vessels in our five scenarios (Table 5). Note that "year 1" in all tables represent the observed situation in 2013-14 (Current).

Table 5: Development of the number of vessels in five scenarios

| Scenario | | Small creel fishers | Large creel fishers | Small trawlers | Large trawlers | Total |
|---|---|---|---|---|---|---|
| Current | year 1 | 58 | 21 | 32 | 30 | 141 |
| BAU | year10 | 59 | 21 | 31 | 30 | 141 |
| | year 25 | 60 | 23 | 28 | 30 | 141 |
| AREA | year10 | 112 | 40 | 24 | 32 | 208 |
| | year 25 | 112 | 40 | 20 | 35 | 207 |
| MAX1 | year10 | 57 | 20 | 31 | 26 | 134 |
| | year 25 | 58 | 20 | 28 | 24 | 131 |
| MAX2 | year10 | 67 | 18 | 22 | 28 | 135 |
| | year 25 | 90 | 30 | 12 | 25 | 157 |
| MAX3 | year10 | 116 | 45 | 11 | 15 | 187 |
| | year 25 | 116 | 45 | 11 | 15 | 187 |

The number of vessels increases slightly for creel fishers in the BAU scenario since these segments have positive profits and thus there will be investment. However, the rate of investment is very slow since the number of new permits will be restricted without an area expansion. Small trawlers disinvest as profits are negative and large trawlers have no change in the number of vessels since the investment rate is close to zero. The small increase in the number of vessels is thus reflecting a situation where entry of vessels is heavily limited by regulations on licenses and permits.

In the AREA-scenario the area for creel fishers is expanded and further investments in the creel fishery are possible. The number of creel fishers increases from a total of 79 in the current situation to a total of 152 by year 10 in the AREA-scenario. There will be no further investments after year 10. As regards trawlers we see that the number of small trawlers decrease whereas the number of large trawlers increase slightly. It should be kept in mind that the development of the number of vessels is based on observations of investment patterns during the last creel area expansion. Changes in the number of vessels in this period could thus be related to other changes that were relevant for the fishery at the time such as technical development of the fishery.

In the MAX1-scenario we maximize profits while assuming a low investment rate. The results show that vessels will exit in all segments except in the small creel fisher segment where there will be the same amount of vessels after 25 years. Vessels will exit in the three other segments but the process will be slow.

In the MAX2-scenario we assume that the creel fishing area is expanded. This means that investment rates are higher for creel fishers and that the catch per unit effort for these fishers will not decrease as they are entering the fishery. The difference between this scenario and the AREA-scenario is that now profits are maximized. As the creel area has now expanded it eventually becomes profitable to invest in the creel fishery. The number of vessels will shrink in both trawler segments during the entire period as this will make these segments more profitable. As we are assuming a relatively low disinvestment rate for large trawlers (based on disinvestment rates during the previous creel fishing area expansion) disinvestments will be relatively small in this segment.

The final scenario presented in Table 5 is the MAX3-scenario where investment is assumed to be free, i.e. there are no limitations on the number of vessels that can enter or exit each year. We also assume that the creel area is expanded as before. This scenario might be regarded as somewhat extreme but is interesting for comparison. The changes in the number of vessels will occur in the beginning of the period, but for consistency we show the situation of the number of vessel in year 10 and year 25 as before. The results suggest that the number of creel fishers will increase by more than in any other scenario and that the disinvestments in the trawler fleet will also be higher.

Next, we turn to the development of the quantity of landings in our four segments (Table 6). In the BAU-scenario profitable segments will invest and landings will increase slightly in the creel segments. However, since small trawlers will disinvest as shown above, their landings will decrease, causing the total landings to be more or less unchanged in the BAU-scenario.

Table 6: Landings (1000s of kilos) in five scenarios

| Scenario | | Small creel fishers | Large creel fishers | Small trawlers | Large trawlers | Total |
|---|---|---|---|---|---|---|
| Current | year 1 | 138 | 155 | 219 | 349 | 861 |
| BAU | year10 | 139 | 160 | 212 | 349 | 860 |
| | year 25 | 142 | 171 | 199 | 349 | 860 |
| AREA | year10 | 236 | 278 | 170 | 365 | 1049 |
| | year 25 | 236 | 278 | 149 | 397 | 1059 |
| MAX1 | year10 | 165 | 149 | 304 | 350 | 967 |
| | year 25 | 166 | 153 | 290 | 354 | 963 |
| MAX2 | year10 | 189 | 140 | 237 | 401 | 967 |
| | year 25 | 241 | 215 | 143 | 369 | 967 |
| MAX3 | year10 | 296 | 308 | 129 | 234 | 967 |
| | year 25 | 296 | 308 | 129 | 234 | 967 |

In the AREA-scenario creel fishers will have access to a larger area thus they will be able to catch more than before. The catches of small creel fishers increase with 98 tons and the catches of large creel fishers with 123 tons by year 10 as the available stock is assumed to have doubled because of the area expansion. Although catches increase they will not increase linearly as the marginal product is diminishing. Small trawlers will catch less since some vessels will be unprofitable and leave the segment.

Maximizing profits with the restrictions assumed in the MAX-1 scenario results in higher landings in year 10 and year 25 for all fleet segments except the for the large creel fishers (Table 6). This is due to each vessel being used more efficiently. In the MAX-2 scenario the fishery as a whole is maximizing profits after the extension of the creel area and under the assumption that creel fishers can now invest more heavily. The effect on total landed quantities is very little compared to the MAX-1 scenario (last column in Table 6) but the effect is larger within segments. This is explained by the restructuring of the fishery that is enabled by allowing for larger investments and disinvestments with the expansion of the creel area. This restructuring of the fleet is further enhanced in the MAX-3 scenario where landings of creel fishers are considerably higher than in any of the other scenarios and landings of trawl fishers are much smaller. We do not claim that this is a realistic scenario in the near future but want to include this as a scenario that reflects a fully implemented ITQ-system and a private economic optimal creel area expansion.

Next, the net present value of all profits that are earned in each segment over a 25-year period is presented in Table 7. If we start by looking at the total net present value in the last column of Table 8 we see that the value is increasing with each new scenario that we model. The difference between the BAU-scenario and the AREA-scenario is around 2800 thousand euros indicating that extending the creel area will increase the private value of the Nephrops fishery in total. Assuming that the fishery becomes more economically efficient will increase profits further. The more we allow for restructuring of the fleet, the higher will be the profits. Increasing the creel area and maximizing profits will give an extra 2500 thousand euros as compared to the MAX1-scenario. Allowing for full flexibility between segments (ITQ-system with no area limitations) will give an additional 6200 thousand euros as compared to the MAX1-scenario.

Table 7: The Net Present Value (NPV) (1000s of euros) of profits over 25 years for our four segments

| | Small creel fishers | Large creel fishers | Small trawlers | Large trawlers | Total NPV |
|---|---|---|---|---|---|
| BAU | 6034 | 6541 | -1612 | 4460 | 15424 |
| AREA | 6486 | 8306 | -723 | 4199 | 18267 |
| MAX1 | 8819 | 6417 | 3545 | 6915 | 25696 |
| MAX2 | 9800 | 6377 | 3893 | 8168 | 28238 |
| MAX3 | 11767 | 9155 | 3380 | 7611 | 31913 |

Looking at the net present value of different segments we start by comparing the BAU-scenario with the AREA- scenario. We see that the value of the creel fishery would increase when the creel area is expanded. The net present value would be around 2200 thousand euros higher than in the BAU-scenario for the two creel fishing segments if the creel area is expanded as in the AREA-scenario. Disinvestments in the small trawler segment will increase when the creel area is expanded making this segment less unprofitable. As for large trawlers, these are not affected by the creel area expansion and as the number of vessels increases slightly profits will decrease.

When we introduce maximization in our model we see that profits are higher in three out of four segments already in the restrictive MAX1-scenario. In this scenario we assume that all fishing vessels are used efficiently, i.e. the maximum number of available days at sea are used by all vessels. Over time, there will be disinvestments of large creel fishers and trawlers further increasing total profitability. However, the restructuring of the fleet will be slow in this scenario and most of the difference in revenues between the BAU- and the MAX1-scenario is attributable to the increase in efficiency of each vessel.

By increasing the creel area and allowing for maximization (MAX2) we see that profits will be higher. The number of vessels and profits are higher for small creel fishers. However, profits are lower for large creel fishers in the MAX2-scenario than in the MAX1-scenario. The reason is that the total net present value of the fishery is higher when more effort is devoted to small creel fishers. As for the trawler segments the MAX2-scenario allows for further restructuring making the net present value of these two segments higher. The MAX3-scenario will allow for further restructuring of the fleets with higher profits for creel fishers and lower profits for trawlers.

Finally, we investigate how fuel use develop in our five scenarios (Table 8). We choose to analyse total fuel use rather than fuel use per kilo landed, which is also a common measure in the literature. From a policy perspective we believe that total fuel use in different scenarios is more interesting as the level of fuel use is related to the amount of emissions of greenhouse gases. The main driver behind changes in fuel use is the vessel composition meaning that fuel use will increase when the number of vessels increase in a segment.

Table 8: Development of fuel use (in 1000s of litres) in our four segments

| Scenario | | Small creel fishers | Large creel fishers | Small trawlers | Large trawlers | Total |
|---|---|---|---|---|---|---|
| Current | year 1 | 619 | 747 | 1297 | 2136 | 4799 |
| BAU | year10 | 626 | 780 | 1246 | 2136 | 4788 |
| | year 25 | 640 | 845 | 1155 | 2136 | 4776 |
| AREA | year10 | 1200 | 1452 | 965 | 2256 | 5872 |
| | year 25 | 1200 | 1452 | 826 | 2498 | 5976 |
| MAX1 | year10 | 783 | 711 | 1900 | 2141 | 5535 |
| | year 25 | 793 | 738 | 1795 | 2175 | 5501 |
| MAX2 | year10 | 911 | 667 | 1420 | 2534 | 5532 |
| | year 25 | 1230 | 1083 | 785 | 2286 | 5385 |
| MAX3 | year10 | 1588 | 1633 | 700 | 1306 | 5228 |
| | year 25 | 1588 | 1633 | 700 | 1306 | 5228 |

Compared to the current situation we see that fuel use will decrease slightly in the BAU-scenario. This is due to disinvestments in the small trawler segment. In the AREA-scenario fuel use will increase compared to the current situation as new creel fishers are entering the fishery. Although creel fishers use less fuel per vessel the increase in the number of creel fishers is substantial enough to result in a fishery that uses more fuel in total. In the MAX-scenarios we assume that each vessel will be used more efficiently and fuel use will thus increase. With a creel expansion and maximization we find slightly lower fuel use, i.e. comparing the MAX2-scenario with the MAX1-scenario. This is due to disinvestments in the fuel intensive trawler segments. The MAX3-scenario shows that fuel consumption will be lower if we allow for full flexibility of the segments. However, since we assume that each vessel is used more efficiently and there will be more vessels fuel use will be higher in the MAX3-scenario than in the current situation.

## 6. Discussion

The results of our analysis imply that allowing for an expansion of the creel fishery on the Swedish west coast will improve the economic performance of the small-scale Nephrops fishery in total. The result is valid for both the simulation scenarios and the maximization scenarios. The reason is that creel fishers are profitable but currently restricted from expanding as fishing grounds allocated to creel fishing are limited. Allowing for an expansion of the fishing grounds, and thereby increasing the number of licences, will increase profits for the creel fishing fleet. For trawlers that are currently fishing in the areas it will be necessary to fish in different areas and this could affect the possibilities to make profits. Our analysis suggest that a number of small trawlers will leave the fishery. Thus, an expansion of the creel area will not benefit all segments, i.e. a redistribution of fishing opportunities takes place.

The Nephrops fishery differs from many other Swedish fisheries where most of the total available quotas are utilized. Currently (2017), only 42 percent of the available quota is fished. Despite this the number of permits have not increased substantially in recent years. The reason is that the legislation states that the issuing of quotas to newcomers is dependent on area limitations (SwAM, 2017).

Interestingly, we find that when we maximize the net present value of the Nephrops fishery landed quantities do not change substantially. This implies that current regulations are in line with a catch level that is profitable for the fishery. In the current fishery, there are 79 creel fishers included in the analysis, and with an expanded area for creel fishing the estimated optimal number of creel fishers would be 120. This is less than a doubling of the fleet, despite an approximate doubling of the area for creel fishing. This is due to a more efficient use of vessels in the economically optimal fishery. Here, we do not discuss in depth how such efficiency gains could be encouraged by fisheries management, but the new management system with individual leasable quotas is one example where efficient vessels might lease quotas from less efficient (see also OECD (2013) for discussions on efficient fisheries management).

The results from the FishRent model are of course calculated with some caveats. The calculations of profits are dependent on the underlying data, and in particular it is difficult to measure labor costs of small-scale fishers. Small-scale fishers are often privately owned firms making it difficult to separate between wages and profits. We have approached this issue by assuming that labor costs are an equal share of each segments' revenues but other approaches are of course possible. Our approach has the advantage that it facilitates comparisons between segments but the level of the overall profit might in this case be either underestimated or overestimated.

We have assumed that the creel area expansion will affect both the investment function and the landings function. It is of course also possible that the fishery will be affected in other respects. A possible extension of the scenarios above could for example be to include increasing fuel costs for trawlers as these must move further out at sea to reach areas outside the trawl boundary. Trawling outside the trawl boundary could also imply more competition with trawlers not using the grid trawl and competition with Danish fishers. The latter are allowed to fish outside the boundary but not inside it. Thus, we acknowledge that there could be further cost increases for trawlers affecting profitability and other outcomes of the model. Estimating how these cost would increase is however outside the scope of this study and will be left to future research.

Modelling the future of the Nephrops fishery is challenging as regulations are rapidly changing over time. Our analysis is based on data from 2013-2014 and in the short period up until 2018 several regulations have changed. The most important is perhaps the regulation that introduced the system of yearly quotas, as has been discussed above, but another example is the lowering of the minimum landing size of nephrops in 2016. Smaller Nephrops that previously could not be marketed can now be sold. All such changes might influence the future development of the sector, and, more importantly, it might affect how the analysed regulation on fishing areas affects the fleets' economy. The main purpose of the model is to compare the economic outcome for different regulations on fishing areas, and not to forecast the development of the fleets. However, if e.g. new minimum landing sizes affects the relative profitability between creel and trawl segments, the results might change as well. Such interactions between policy instruments are important, but rarely analysed (see e.g. Waldo and Paulrud, 2017).

Although environmental effects of a creel area expansion are important from a societal perspective these are not the focus of our analysis. If creel fishing increases the benefits acquired from decreased bottom impact from trawl fishing these effects should be taken into account when evaluating the total benefits to society. Correspondingly, potential bottom impact from more intense trawling outside of the trawl boundary should be to taken into consideration. In our analysis we take environmental aspects into consideration by analysing how fuel use changes when the creel area is expanded. In summary, the potential environmental benefits of trawling less inside the trawl boundary must be weighed against the potential environmental costs of trawling more outside of it and the net-benefits must be added to the net-benefits generated from changes in the economic value of the fishery.

References

AgriFood (2018). AgriFood Economics Centre, Intäkter för svenska fiskare på västkusten, AgriFood Fokus Rapport 2018:2.

Catchpole, T.L., Frid, C.L.J., Gray, T.S. (2005) Discards in North Sea fisheries: causes, consequences and solutions, Marine Policy 29: 421-430.

Eggert, H., and Ulmestrand, M. (2000). A Bioeconomic Analysis of the Swedish Fishery for Norway Lobster (Nephrops norvegicus), Marine Resource Economics, Volume 14, p. 225-244.

Eichert, M., Campos, A., Fonseca, P., Lopes, P., Marques, L. and Castro, M. (2018) Effects of reallocating fishing effort from trawling to creels in a Norway lobster fishery, Marine Policy 93:142-149.

EU (2013). European Union, Regulation No. 1380/2013 on the Common Fisheries Policy.

EU (2016). European Union, COMMISSION DELEGATED REGULATION (EU) 2016/2250 of 4 October 2016 establishing a discard plan for certain demersal fisheries in the North Sea and in Union waters of ICES Division IIa.

EU (2017). European Union, REGULATION (EU) 2017/1004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008.

Frost, H., Andersen, P., Hoff, A., (2013). Management of Complex Fisheries: Lessons Learned from a Simulation Model.  Can. J. Agri. Eco. 61, 283–307

Hornborg, S., Jonsson, P., Sköld, M., Ulmestrand, M., Valentinsson, D., Ritzau Eigaard, O., Feekings, J., Nielsen, J.R., Bastardie, F. and Lövgren, J. (2016), New policies may call for new approaches: the case of the Swedish Norway lobster (Nephrops norvegicus) fisheries in the Kattegat and Skagerrak, ICES Journal of Marine Science 74(1), 134-145.

ICES (2017), Norway lobster (Nephrops norvegicus) in Division 3.a, functional units 3 and 4 (Skagerrak and Kattegat), ICES Advice on fishing opportunities, catch, and effort, Greater North Sea Ecoregion, nep.fu.3-4, published 30 June 2017.

Jonsson P., Valentinsson, D. (2016), Platsutrymme burkräfta, Institutionen för akvatiska resurser, Havsfiskelaboratoriet, Swedish University of Agricultural Sciences, 2016-05-16.

Leocádio A.M., Whitmarsh, D. and Castro, M. (2012), Comparing Trawl and Creel Fishing for Norway Lobster (Nephrops norvegicus): Biological and Economic Considerations. PLoS ONE 7(7).

Nielsen M., Flaaten O., and Waldo S. (2012). Management of and Economic Returns from Selected Fisheries in the Nordic Countries. *Marine Resource Economics* 27(1):65-88.

Madsen N. and Valentinsson D. (2010). “Use of selective devices in trawls to support recovery of the Kattegat cod: a review of experiments and experience“. ICES Journal of Marine Science 67(9): 2042-2050.

Morello E.B., Antolini, B. Gramitto, M.E., Atkinson, R.J.A. and Froglia, C. (2009) The fishery for Nephrops norvegicus (Linnaeus, 1758) in the central Adriatic Sea (Italy): Preliminary observations comparing bottom trawl and baited creels, Fisheries Research 95: 325-331.

National Board of Fisheries (2004a). Fiskeriverket, Fiskeriverkets föreskrifter om resurstillträde och kontroll på fiskets område; FIFS 2004:25, Konsoliderad elektronisk utgåva senast uppdaterad 2017-06-05.

National Board of Fisheries (2004b). Fiskeriverket, Fiskeriverkets föreskrifter (2004:36) om fiske i Skagerrak, Kattegatt och Östersjön, FIFS 2004:36, konsoliderad elektronisk utgåva senast uppdaterad 2017-09-01.

OECD (2013). The OECD Handbook for Fisheries Managers: Principles and Practice for Policy Design, OECD Publishing. http://dx.doi.org/10.1787/9789264191150-en.

SCFF (2017). Correcting the misallocation of Nephrops stocks in Scottish Inshore Waters: Untapping a vast economic (and environmental) potential, Scottish Creel Fishermen's Federation, May 2017.

Salz P., Buisman E., Soma K., Frost H., Accadia P., Prellezo R. (2011). FISHRENT- Bio-economic simulation and optimization model for fisheries. LEI-Report 2011-024. https://www.wur.nl/upload_mm/2/9/b/691d173d-db00-4f4a-b9b3-5d6edd01f0b4_2011-024.pdf

Statistics Sweden. (2015a). *Swedish sea-fisheries during 2014. Definitive data*. Sveriges officiella statistic. Statistiska meddelanden: JO 55 SM 1501.

Statistics Sweden. (2015b). *Fishing in inland waters by commercial fishermen in 2014. Preliminary data*. Sveriges officiella statistik. Statistiska meddelanden: JO 56 SM 1501.

SwAM. (2014), Swedish Agency for Marine and Water Management, Havs- och vattenmyndighetens föreskrifter om licens och tillstånd för yrkesmässigt fiske i havet, HVMFS 2014:19. Konsoliderad elektronisk utgåva senast uppdaterad 2017-01-01.

SwAM (2015), Swedish Agency for Marine and Water Management, Havs- och vattenmyndighetens föreskrifter om ändring i Fiskeriverkets föreskrifter (FIFS 2004:25) om resurstillträde och kontroll på fiskets område, HVMFS 2015:30.

SwAM. (2016). Remiss om fördelning av fiskemöjligheter för att underlätta genomförandet av landningsskyldigheten, Remiss 2016-10-21, Dnr 613-16.

SwAM (2017), Swedish Agency for Marine and Water Management, Havs- och vattenmyndighetens föreskrifter om ändring i Havs- och vattenmyndighetens föreskrifter (HVMFS 2014:19) om licens och tillstånd för yrkesmässigt fiske i havet, HVMFS 2017:18.

Swedish Parliament. (2017). *Uppföljning av systemet med överlåtbara fiskerättigheter i det pelagiska fisket*. Report 2016/17:RFR7. Riksdagstryckeriet, Stockholm.

Stage, J., Christiernsson, A., and Söderholm, P. (2016). The economics of the Swedish individual transferable quota system: Experiences and policy implications. *Marine Policy* (66):15-20.

Svensson, M. and Hultkrantz, L. (2015). Ekonomiska utvärderingar i svensk offentlig sektor – likheter och skillnader, Ekonomisk debatt (3:43):40-50.

Valentinsson D., Ulmestrand M. (2008). "Species selective *Nephrops* trawling: Swedish grid experiments." Fisheries Research 90(1-3): 109-117

Valentinsson, D. and Nilsson, H.C. (2015). Effects of gear and season on discard survivability in three Swedish fisheries for Norway lobster (*Nephrops norvegicus*). Internal Report to the Swedish Agency for Marine and Water Management.

Waldo, S., and Paulrud, A. (2013). ITQs in Swedish demersal fisheries. *ICES Journal of Marine* Science 70(1): 68–77.

Waldo, S and Paulrud, A. (2017). Reducing Greenhouse Gas Emissions in Fisheries – the Case of Multiple Regulatory Instruments in Sweden. *Environmental and Resource Economics* 68(2):275-295. doi:10.1007/s10640-016-0018-2

Waldo, S., Berndt, K., Hammarlund, C., Lindegren, M., Nilsson, A., and Persson, A. 2013. Swedish coastal herring fisheries in the wake of and ITQ system. Marine Policy (38):321-324.

Ziegler, F. and Valentinsson, D. (2008) Environmental life cycle assessment of Norway lobster (Nephrops norvegicus) caught along the Swedish west coast by creels and conventional trawls – LCA methodology with case study, International Journal of Life Cycle Assessment 13:487-497.

Appendix A

Below revenues and costs are presented. The data is based on vessels' logbooks, landing declarations and data from the EU economic data collection framework (EU, 2017).

Table A1: Revenues, costs and net profit for four Nephrops segments used in the Model. Actual data 2013/2014.

| **€ 1000s** | **Small creel fishers** | **Large creel fishers** | **Small trawlers** | **Large trawlers** |
|---|---|---|---|---|
| Value of landings | 2171 | 2491 | 2795 | 4532 |
| Fuel costs | 327 | 394 | 684 | 1127 |
| Other running costs | 494 | 632 | 729 | 1192 |
| Vessel costs | 288 | 256 | 307 | 327 |
| Crew share | 102 | 249 | 326 | 774 |
| Gross cash flow | 960 | 960 | 748 | 1111 |
| Depreciation | 326 | 391 | 682 | 821 |
| Interest | 11 | 13 | 24 | 29 |
| Net profit | 622 | 556 | 42 | 261 |

Table A2: Revenues, costs and net profit *per vessel* for four Nephrops segments in the Model. Actual data 2013/2014.

| **€ 1000s per vessel** | **Small creel fishers** | **Large creel fishers** | **Small trawlers** | **Large trawlers** |
|---|---|---|---|---|
| Value of landings | 37.4 | 121.5 | 87.3 | 151.1 |
| Fuel costs | 5.6 | 19.2 | 21.4 | 37.6 |
| Other running costs | 8.5 | 30.8 | 22.8 | 39.7 |
| Vessel costs | 5.0 | 12.5 | 9.6 | 10.9 |
| Crew share | 1.8 | 12.1 | 10.2 | 25.8 |
| Gross cash flow | 16.5 | 46.8 | 23.4 | 37.0 |
| | 0.0 | 0.0 | 0.0 | 0.0 |
| | 0.0 | 0.0 | 0.0 | 0.0 |
| Depreciation | 5.6 | 19.1 | 21.3 | 27.4 |
| Interest | 0.2 | 0.6 | 0.8 | 1.0 |
| Net profit | 10.7 | 27.1 | 1.3 | 8.7 |

Appendix B

We estimate effort elasticities to be used in the Cobb-douglas production function in the FishRent model. Data from logbooks are used covering the period 1997-2016. A fixed effect model is estimated:

$$lnq_{it} = \alpha + \beta_1 lnE_{it}S_i + \beta_2 lnE_{it}S_{it}p2_i + t + \mu_i + \varepsilon_{it} \quad \text{(A1)}$$

Where $lnq_{it}$ is the amount of landings in kilos of vessel *i* in year *t*, $lnE_{it}$ is the effort in number of days-at-sea of vessel *i* in year *t*. $S_i$ is a dummy variable indicating which segment the vessels belong, $p2_i$ is indicating if the time period is 2009-2016, i.e. the most recent time period in the data. Vessel fixed effects,$\mu_i$, and a time trend, $t$, is also used in the model. The idea of the time-period interaction is to check if the elasticity, $\beta_1$, is significantly different in the last period. The results are presented in Table A1 (Model 1).

For estimating if effort elasticities changed after the last creel expansion period we adapt the model so that only the period before and after the expansion is used, i.e. 1997-2007 and the second interaction is thus the period after the creel expansion (i.e. 2004-2007). The results are presented in Table B1 (Model 2).

Table B1: Results of estimation of effort elasticities in different periods.

| | **Model 1** | **Model 2** |
|---|---|---|
| Effort small creel fishers | 0.771*** | 0.325*** |
| Effort large creel fishers | 0.797*** | 0.286** |
| Effort small trawlers | 0.856*** | 0.406*** |
| Effort large trawlers | 0.816*** | 0.423*** |
| *Effort period 2 for…* | | |
| small creel fishers | -0.022* | |
| large creel fishers | 0 | |
| small trawlers | -0.021 | |
| large trawlers | 0.014 | |
| *Effort after creel expansion for…* | | |
| small creel fishers | | 0.061*** |
| large creel fishers | | 0.082*** |
| small trawlers | | 0.053* |
| large trawlers | | 0.025* |
| t | 0.013** | -0.005 |
| Constant | 4.576*** | 6.382*** |
| Number of observations | 1764 | 1415 |

Note: Vessel fixed effects and cluster robust standard errors are used.

The results (Model 1) suggest that effort elasticities are rather high in all segments (Model 1 – Column 2). As a rule of thumb an elasticity of 0.6-0.9 for trawlers is commonly used in the FishRent Model (Salz et.al. 2011). This is in line with our results. For fishing with passive gears effort elasticities are normally assumed to be lower. Our results imply that effort elasticities are somewhat lower for creel fishers. We use the main effects as the effort elasticities in the Cobb-douglas function of the FishRent Model.

To check if effort elasticities have changed over time and in particular if they are different in the last period of available data we interact all effort variables with the latest available time period (2009-2016). The results (Model 1) suggest the last period is not significantly different from the previous period for three segments and for one segment (the small creelers) the effort elasticity is slightly smaller (-0.02).

To find out if effort elasticities changed with the creel area expansion we use different time period but the same model as the one presented in equation A1. We are primarily interested in the changes in elasticities after the expansion (i.e. 2004-2007) of the creel area. We see that coefficients are significant and positive for all segments and that the magnitude of the coefficients are larger for creel fisher segments. Since we are modelling a creel area expansion (scenario AREA, MAX2 and MAX3) we will only use the coefficients of the creel segments and calculate the effort elasticities as the coefficients from Model 1 (the main effects) plus the additional effect from Model 2 (the additional effect of period 2). For trawler segments we will not change the elasticities in the AREA, MAX2 and MAX3-scenarios.

Appendix C

Table C1 presents the results of the profit calculations when equal crew cost share of revenues is assumed.

Table C1: Profits (1000s euros) in the nephrops fishery assuming crew costs share of revenues of large trawlers

| | **Total profit for segment (1000s euros)** | **Profit per vessel (1000s euros)** | **Profit per FTE (1000s euros)** | **Profit margin** |
|---|---|---|---|---|
| Small creel fishers | 353 | 6.1 | 9.9 | 16 % |
| Large creel fishers | 379 | 18.5 | 15.7 | 15 % |
| Small trawlers | - 109 | - 3.4 | - 3.3 | - 4 % |
| Large trawlers | 261 | 8.7 | 5.0 | 6 % |

* Full Time Equivalent, Note: Profits are calculated as the value of landings minus fuel costs, other variable costs, fixed costs, crew costs, depreciation and interest payments.

Both creel segments still appear to be profitable and are more profitable than both trawler segments. The large creel fisher segment now have higher profits per vessel and higher profit per FTE but the profit margin is somewhat lower. Small trawlers are unprofitable when higher labour costs are assumed whereas large trawlers by assumption have the same profits as in Table 2. The profit margin is still considerably higher for creel fishers than for trawlers.

## About AgriFood Economics Centre

AgriFood Economics Centre provides economic expertise in the fields of food, agriculture, fishing and rural development. The Centre is a cooperation for applied research between the Swedish University of Agricultural Sciences (SLU) and Lund University. The aim is to supply government bodies with a solid scientific foundation supporting strategic and long-term policy choices.

Publications can be ordered free of charge from **www.agrifood.se**

AgriFood economics centre