A Bioeconomic model for Norway lobster (*Nephrops norvegicus*) fishery

By

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INTRODUCTION AND OVERVIEW

The Norway lobster (*Nephrops norvegicus* Linneaus, 1758) is the most valuable crustacean landed in Europe. The Scandinavian stock is shared by three countries, see figure 1. Annual landings during the 1990s have been fully 4000 tons to a value of about US$ 30 000 000.¹ Danish fishermen take about 70%, Swedes almost 30%, while Norwegian landings amount to no more than a few percent of the total catch. A Total Allowable Catch (TAC) of 4200 tons was agreed upon in 1992, but has so far not been restrictive in any year. The concern of this study is the Swedish commercial Norway lobster fishery, where 80% of the landings are taken by *Nephrops* trawlers, 15% by creel fishers and the rest is landed as by-catches by fish and shrimp trawlers. Up till the mid 1980s *Nephrops* were solely caught by trawlers, but at that time a coastal creel fishery evolved. This was due to the existence of unexploited *Nephrops* grounds inside the trawling border and the experiences from profitable creel fisheries around Scotland. Before the creel fishery achieved any economic significance, the trawl border was moved closer to the shoreline. The two separate fisheries are characterized by differences in exploitation pattern, fuel consumption, and impact on the benthic communities. As the creel fishery has established as a minor, but stable fishery and with a growing awareness of potential damages from repeated demersal trawling, the discussion on where to place the trawling border has been revived. In for example the Faeroe islands a complete ban on trawling in inshore areas was imposed in 1980 (Anon., 1990).

¹ $1 = 8 SEK
The purpose of this study is two folded. First, to apply a bioeconomic model to empirical data from the trawl fishery. For this objective a modified version of Jones’ length based cohort model is linked to a net revenue function. Second, to compare the two fisheries in terms of qualitatively aspects as well as the economic performance.
The Swedish trawl fishery for *Nephrops* amounted to 366 tons in 1978 and then gradually increased to 1024 tons in 1984. During the period 1984-1991 the landings were stable despite an 100% increase in trawling effort. The increased landings are likely caused by the inshore move of the trawl border in 1984, the improvement of navigation equipment, and the introduction of twin trawls in 1989. The period of high landings was followed by some years of reductions and in 1995 landings were 803 tons, see figure 2.

![Figure 2. Landings and effort of Swedish *Nephrops* trawl fishery 1978-95.](image)

The lives of *Nephrops* are still obscured to a large extent and stock assessments are uncertain. Yet, time series on overall landings per unit effort from Skagerrak/Kattegat log book data suggest a drastic reduction with landings from 10-12 kg/hour in the early 1980s and down to 3-6 kg/hour during 1992-95, see figure 3. During the same period annual trawling effort increased by about 200%.
Regular measurements on size compositions from the Scandinavian commercial trawlers in Skagerrak/Kattegat show that 78% in numbers are undersized and discarded back to the sea. The discard mortality from trawl fishery is approximately 75%, which means that for every landed *Nephrops* almost three dies (Anon., 1998). In fact, the figure is even higher as 10% of the escapees die due to gear infliction leading to about three and a half dead for every landed lobster (ibid.). The figures for the Swedish trawl fishery are almost as alarming, the fraction of undersized *Nephrops* amounts to about 55% in numbers. The high by-mortality in addition to the likely stock reduction imply that the present 70 mm diamond mesh in use means a drastic cutback of the potential harvest in the future. The minimum landing size of 40 mm carapace length in the Skagerrak-Kattegat area is the result of a historical regulation but is, see figure 4, supported by recent studies of the length at on set of female’s sexual maturity. A reduction of the minimum landing size would lead to a larger fraction of female *Nephrops* being caught without reproducing a single time.

**Figure 3.** Landings per unit effort (kg/hour) 1978-95.
Figure 4. Onset of sexual maturity (green ovary) for female *Nephrops* (N=11 514). Minimum landing size (MLS) = 40 mm carapace length.

To improve the gear selectivity different adjustments, like square meshes and size sorting grids, have been tested. The most promising approach is to install an eight meter section with 60 mm square mesh all around the cod end of the trawl. The proportion undersized *Nephrops* in the currently used 70 mm diamond mesh trawls amounts to 55% in number, which corresponds to 35% in weight. Preliminary results show that for the 60 mm square mesh, the fraction of undersized *Nephrops* is reduced to about 20% in weight and by-catches of other species like whiting, haddock and cod are drastically reduced (Ulmestrand and Valentinsson, in prep.).

**THE BIOLOGICAL MODEL**

Virtual Population Analysis (Gulland, 1965) and its approximation, Cohort Analysis (Pope, 1972), are standard techniques for stock assessment when historical catch-at-age data are available. In absence of age data, which is the case for *Nephrops*, Jones (1979, 1984) suggested a Length-Cohort Analysis (LCA) in which length-frequency data are used to construct a synthetic cohort. This method has its limitations (Lai and Gallucci, 1988; Hilborn and Walters, 1992), but has been established for assessment of *Nephrops* stocks. The International Council for Exploration of the Sea (ICES) Working Group on *Nephrops* Stocks use a modified version of LCA, when age data are
missing, as an instrument for their management considerations to the Advisory Committee for Fisheries Management.

The crucial assumptions underlying LCA are constant recruitment, that the numbers caught can be used to calculate annual removals per length group, that the input length composition is representative of a steady state situation, and that the growth of the species can be characterized by a von Bertalanffy curve. A steady state length composition is not likely to occur in practice, but according to Jones: "a useful approximation can be obtained by determining the average length composition over a period of as many years as possible. In this way the effect of fluctuations in year-class strength and mortality rates should be minimized." (Jones, 1984, p. 27). This study uses length composition data from the years 1992-96, which was sampled from commercial trawlers.

Computation in the LCA starts with the largest individuals, $\lambda$, in a length-frequency histogram and uses (Lai and Gallucci, 1988)

$$N_{\lambda} = C_\lambda Z\lambda / F\lambda$$

and

$$N_l = N_{l+\Delta l} A_i^{M/k} + C_\lambda A_l^{M/2k}$$

and the corresponding fishing mortality over each length interval ($l, l+\Delta l$)

$$F_l\Delta t = \ln(N_l / N_{l+\Delta l}) - M\Delta t_l$$

where

$N_\lambda$ is the number of individuals attaining terminal length $\lambda$

$N_l$ is the stock size at the beginning of the length interval ($l, l+\Delta l$)

$C_\lambda$ is the catch in number of individuals in the terminal length interval ($\lambda, L_\infty$)

$C_l$ is the catch in number assumed to occur at the middle of the length interval ($l, l+\Delta l$)

$Z_i\Delta t_l$ is the total mortality of individuals in the terminal length interval ($l, l+\Delta l$)
\( F_\lambda \) is the instantaneous fishing mortality rate of individuals in the terminal length interval \((\lambda, L_\infty)\)

\[ A_t = \frac{(L_\infty - l)}{(L_\infty - (l, l+\Delta l))} \]

\( \Delta t_i = \ln A_t / k \), which is the time required for a fish to grow from length \( l \) to \( l+\Delta l \).

where

\( L_\infty \) and \( k \) are von Bertalanffy growth parameters and \( M \) is the instantaneous natural mortality rate assumed constant over all lengths,

With a constant fishing effort and a steady state stock, the numbers caught and the average numbers in sea will remain constant over the years for each length class. The model takes into account by-mortality caused by discard practice due to the minimum size regulation of Nephrops.

The growth of a single lobster is assumed to follow the von Bertalanffy growth function, where the length at age \( t \), \( l_t \), is estimated by

\[ l_t = L_\infty \left[ 1 - e^{-k(t - t_0)} \right] \quad (4) \]

where \( t_0 \) is the age at which growth according to the growth equation is initiated. The length data can be converted to weight data by using the relationship

\[ W_t = a l_t^b \quad (5) \]

where \( W_t \) is the weight at age \( i \) and \( a \) and \( b \) are constants. Using equation (4) the length groups can be converted to age groups. Then an algebraic formulation of the yield, following the modified Thompson and Bell yield per recruit model by Christensen and Vestergaard (1993) is:

\[ Y = \sum R_i [1 - e^{(F_i S_i + M)}] F_i S_i / (F_i S_i + M) w_i \quad (6) \]

where
$R_i$ is recruitment at age $i$
$F_i$ is fishing mortality rate at age $i$
$S_i$ is gear selectivity at age $i$
$w_i$ is average weight at age $i$

The recruitment for year class $i+1$ can be expressed as:

$$R_{i+1} = R_i \times e^{-F_i (S_i \times D) - M}$$  \hspace{1cm} (7)

Where $D$ takes on the value 0.75 for year classes smaller than 40 mm CL to account for discard mortality and 1.0 for year classes larger than 40 mm CL.

The fishing mortality values for year classes smaller than 40 mm, do not add to the yield but lead to an extra mortality on top of the natural one. In this study we follow the approach described by Jones (1984) where the various computational steps are combined into a single sequence. The figures for male and female Norway lobsters differ and have been estimated for the area (Anon., 1997). $L_\infty$ is 78 and 67 mm, respectively, $k_{\text{male}}$ is 0.16 and $k_{\text{female}}$ is 0.1 while $t_0$ is -0.05, $a$ is 0.00045 and 0.00108 and $b$ is 3.11 and 2.85, respectively. The terminal $F$ is assumed to be 0.3 for both sexes. The figures of natural mortality, $M_{\text{male}}$ and $M_{\text{female}}$, for the area are still not accurately determined, which leaves us with the estimates from the Scottish Nephrops fishery (Anon., 1997), $M_{\text{male}} = 0.3$ and $M_{\text{female}} = 0.2$. The necessary input data are values for $L_\infty$, the values for $M/k$, and a value for $F_{\lambda}/Z_{\lambda}$.

**STANDARDIZATION OF FISHING EFFORT**

The link between the biological model in the previous section and the economic model is provided by the fishing mortality, $F$. A proportional relationship between fishing mortality and effort is assumed. The Swedish Nephrops trawling fleet encompass approximately 200 vessels with various characteristics. Gross register tons (GRT) span from 3 to 200 GRT, crew from one to three people and horse power from 50 to 500 hp. In empirical studies an aggregate measure of fishing effort for the whole fleet is often used, while sometimes a group of similar reference trawlers can be identified to calculate the total effort as the ratio between total landings and landings per unit effort (LPUE) for the reference fleet. In this study we use the latter approach described by Gulland (1983).
A thorough examination of the 67 vessels that landed more than 5000 kg *Nephrops* in 1995 showed that the LPUE is independent of boat size, see figure 5. The fluctuation in LPUE around the average of 8.5 kg/trawl hour is approximately the same for different vessel sizes. Since 1989 an increasing part of the fleet have shifted from single to twin trawls and in 1995 roughly half of the trawl landings came from twin trawl vessels. The LPUE ratio between twin and single trawls is constant at about 1.7 and the twin trawl effort has been converted to single trawl effort and summed to a total Swedish trawl effort (Anon. 1997). The average specialized *Nephrops* trawler spent 1280 standardized trawl hours, landing 10 880 kg in 1995.

**Figure 5.** LPUE vs vessel size (GRT).

**THE ECONOMIC MODEL**

A fish stock can be considered a capital stock. Increases in the stock size can be seen as investment in the stock and vice versa. Since the paper by Clark and Munro (1975) much attention have been given to discussions on the optimal path to the optimal stock level. As noted above LCA is based on the assumption of a Steady State equilibrium, for the case of *Nephrops* a change in effort or selection pattern will lead to a new equilibrium after five or six years. Here, the focus is on determining the long-run optimal steady state stock. For the purpose of this analysis, we assume that the resource is managed by a sole owner whose objective is to maximize the net revenue and that all costs are variable.
Detailed information on costs of and revenues were achieved from a sample of 20 trawlers with an average LPUE of 8.5 kg/ std trawl hour, where *Nephrops* landings accounted for more than 40% of total earnings. These figures were used to determine the costs of a trawler specializing in *Nephrops* fishery, on average 60% of the income comes from *Nephrops* while the rest is from demersal species where cod is the single most important species. We use the simplifying assumption of perfect foresight, i.e. fishermen allocate their effort in the same proportion as the actual landings in monetary terms. The consequence is that 60% of the total costs are assumed to correspond to the annual landings of *Nephrops*.

### Table 1.


<table>
<thead>
<tr>
<th></th>
<th>low</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>15'</td>
<td>15'</td>
</tr>
<tr>
<td>Operation cost,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td>34'</td>
<td>34'</td>
</tr>
<tr>
<td>Variable</td>
<td>25'</td>
<td>25'</td>
</tr>
<tr>
<td>Labor cost</td>
<td>25'</td>
<td>50'</td>
</tr>
<tr>
<td>Total</td>
<td>99'</td>
<td>124'</td>
</tr>
<tr>
<td>60%</td>
<td>59.4'</td>
<td>74.4'</td>
</tr>
</tbody>
</table>

Table 1 summarizes the cost figures for a representative *Nephrops* trawler, which on average earned US$ 124 000. The user cost of capital is calculated by using the average insurance value of the vessels, assuming linear depreciation over 20 years, and calculating the imputed opportunity cost for a real interest rate of 5%. Operation costs are average values including maintenance, fuel, water, ice, administration etc. As in most fisheries wages in the *Nephrops* fishery are based on a share system, remuneration of US$ 50 000 per vessel with two persons on board correspond to a monthly salary of about US$ 1600. This is a quite low figure compared to fully US$ 1800 for an average Swedish non skilled worker in 1995 (Statistics Sweden, 1997). Two major factors that may explain these conditions are the accounting of capital and operation costs and unreported landings. The cost
figures for some of the vessels covered 1992-96 and showed that the real insurance value was constant. This observation was also supported by personal communication with several fishermen and despite the limited second hand market for trawlers, a few actual transactions took place and were settled at prices close to the insurance value. In 1995 the scrap premium from the European Union was US$ 1500/GRT which implied a scrap value close to the insurance value for most vessels. The oldest vessel in the fleet was almost 70 years old while the average age was 30 years. The overall impression is that individuals do not perceive a depreciation cost, but also that the capital cost may be overestimated from a social point of view. Possible reasons are that part of the maintenance costs are in fact reinvestments and the cost of increased risk for breakdown with age is borne via a higher insurance premium. The scrap premium has probably influenced the second hand price of vessels. However, in 1996 the scrap premium was reduced by 35% but neither a change in insurance values nor in transaction prices was observed. There is of course a social depreciation cost but partly it may be double accounted as reinvestment and higher insurance premiums are not identified properly. We have no reasons to believe that the actual cost figures are exaggerated, but possibly underestimated as some maintenance work may be carried out by the fishermen themselves or as non taxed work. A major part of trawl landings, 60-70%, come from vessels located in the northern part of the Swedish west coast, which is entitled to rural support according to the European Union. Given that alternative employment opportunities are scarce, the social opportunity cost of labor is significantly lower than the actual earnings. The low cost alternative represents such a situation where only half of the actual labor cost is accounted for.

On the revenue side our figures are more likely to be uncertain. The occurrence of unreported landings have been much debated in Sweden recently (Hultkrantz et al, 1997). Exact assessments are absent, but there is a consensus of the existence. Trawl fishermen can be said to have a quite high opportunity cost of time, but for a valuable species like *Nephrops* the profits from selling without paying tax, social insurance etc. are high. A 7-8% unreported landings of *Nephrops* would correspond to a monthly salary before tax of about US$ 2000, which is significantly higher than the average Swedish non skilled worker. It should be noted that potential unreported landings do not affect the stock assessment, which are based on repeated length analysis of the complete catches, including under sized individuals, from a sample of fishermen. There is no enforcing element in the

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2 The average real rate of return on Swedish government bonds during 1990-96 was 5%. 

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length analysis reports as the link to total catches is hard to establish and with no incentive for misreporting, the underlying figures for the biological parameter estimates are judged to be precise. The open access equilibrium is determined as the zero profit case for the high cost alternative, while maximum economic yield is achieved from maximizing the profit for the static case. Sandal and Steinshamn (1997) have recently shown that in case of inelastic demand and/or increasing marginal cost, a higher discount rate can imply a larger standing stock and the same applies for Hannesson’s (1986) model which takes capital dynamics into account. But for a valuable species, assuming linear effort costs and a constant price the result of Clark (1990) that a positive discount rate implies a smaller standing stock is most likely to be valid. In this study no discounted equilibrium is determined, but for policy guidance it can be concluded that the MEY figures represent minimum figures for optimal effort levels. As a comparison Clarke, Yoshimoto and Pooley (1992) calculated the optimum effort for various discount rates for five different simple stock growth models. The 5% discount rate level compared to the zero case implied increases in the optimum effort level, ranging from one to eight percent.

RESULTS

The estimated revenue curves are shown in figure 7 together with two different cost curves. The yield curves 60 square and 60b square represents the higher and the lower limits from the results of square mesh tests, respectively. We find that the Swedish Nephrops trawler fleet applied an effort of 94 000 standard trawl hours, leading to landings of 803 000 kg at a value of US$ 5.6 million which corresponds to an open access equilibrium where profits are zero. For the low cost alternative the current situation implies a social rent due to the fact that unemployment is reduced. Using the high cost figures, Maximum Economic Yield is found at a level of 35 000 standard trawl hours where the resource rent is estimated to US$ 2.9 million. If a square mesh regulation is introduced, we expect the MEY to be found in the interval of 38 500-43 500 std trawl hours and the resource rent to be slightly increased to US$ 3 million. However, with a single mesh regulation effort and landings are expected to increase, producing a value of US$ 6-7 million but with the rent still completely dissipated.
Table 2 provides a sensitivity testing of the robustness of the results with respect to the natural mortality. In case of a higher natural mortality than the assumed 0.2/0.3, MEY effort levels are slightly higher, while the potential rent is drastically reduced. Even for the highest natural mortality level combined with the low cost figures, MEY requires a drastic reduction of the effort level and there is a significant potential resource rent to be earned. It should be stressed that the natural mortality and the von Bertalanffy parameters are assumed constant, regardless of stock size. In reality increased natural mortality and reduced individual growth are likely effects of a major increase in stock size, which imply a higher Maximum Economic Yield effort level and a lower rent.

Table 2 Maximum economic yield effort levels, Long term increase in landings, and Long term resource rent for different values of the natural mortality rate and two levels of costs

<table>
<thead>
<tr>
<th>M</th>
<th>Costs</th>
<th>Maximum Economic Yield effort (standard trawl hours)</th>
<th>Long term annual resource rent ($US thousand)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>70</td>
<td>60b</td>
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</tbody>
</table>

Figure 7. Estimated yield and cost curves for M=0.2/0.3
<table>
<thead>
<tr>
<th>(fem/male)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1/0.2</td>
<td>High</td>
<td>28 500</td>
<td>31 000</td>
<td>35 000</td>
<td>5 050</td>
<td>5 370</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>24 000</td>
<td>25 500</td>
<td>28 000</td>
<td>5 180</td>
<td>5 420</td>
</tr>
<tr>
<td>0.2/0.3</td>
<td>High</td>
<td>35 000</td>
<td>38 500</td>
<td>43 500</td>
<td>2 920</td>
<td>3 060</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>39 500</td>
<td>43 000</td>
<td>50 500</td>
<td>3 370</td>
<td>3 550</td>
</tr>
<tr>
<td>0.3/0.4</td>
<td>High</td>
<td>38 000</td>
<td>41 500</td>
<td>43 000</td>
<td>1 700</td>
<td>1 720</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>45 500</td>
<td>51 000</td>
<td>57 000</td>
<td>2 200</td>
<td>2 270</td>
</tr>
</tbody>
</table>

Lai and Gallucci (1988) derive the analytical expressions for the errors in stock abundance and fishing mortality that would result from different deviations of estimates from true parameter values. The most sensitive parameter is the natural mortality, where a difference of ±0.1 in M leads to a 40-50% error in the estimates. It is obvious that LCA results must be taken with great caution and that the MEY figures of effort levels and rent are most uncertain. Still, with all reservations in mind, a large body of empirical studies imply that the value of M is within the range given in table 2 and the evidence for a reduction in effort is unambiguous.

THE IN-SHORE CREEL FISHERY FOR NEPHROPS

Commercial creel fishery for *Nephrops* has taken place in coastal Scottish waters for more than 30 years. Using the Scottish experience, a creel fishery evolved in the mid 1980s in Sweden. As trawlers are banned within the archipelago, this was exploitation of virgin areas leading to profitable landings with a large fraction of big and valuable specimen. Entry is free, but landings have been fairly stable at roughly 100 000 kg during the 1990s and in 1995 the number of vessels had stabilized at approximately 40 engaged in creel fishery for *Nephrops*. A few vessels have two crew members, but most of the vessels have one single fisherman. Total catch in 1995 amounted to 111 000 kg and thanks to the more lenient method these earned about US$ 8.5 per kg, giving a total landing value of almost US$ 1 million. The creel fishery has several attractive features. First, mortality rates for undersized discards are almost zero (Anon 1998). Second, the lenient method leads to more vivid individuals which is reflected by the higher price. Third, it has a minimum environmental impact.
compared to trawl fishery. The fuel consumption is much lower and the impact on the benthic fauna and flora is very small. The latter is a factor which has increased importance, securing biodiversity is an obligation for the Government of Sweden vis-à-vis the European Union and the Rio Agreement. However, *Nephrops* trawling is only undertaken outside the archipelago and preliminary results from a study of in-shore demersal trawling in the area indicates that the impact on biodiversity is minor (Hansson et al, 1997).

The negative external effects on the environment from fossil fuels have raised to the top of the political agenda during the last decade. Most concern is given to the green house gas effect, but emissions of volatile organic compounds (VOC), nitrogenous gases (NOx) and particles are also regarded as severe health problems. A growing literature try to quantify and value these effects, which are most significant in larger cities but also exist in rural areas. Johansson (1995) surveys recent attempts to quantify in monetary terms such effects from road transport. The external cost for minor diesel trucks, due solely to particle emissions, in rural areas is estimated to approximately US$ 74 per consumed cubic meter. As the effects from CO2, VOC, and NOx are disregarded, the figure is in the lower part of a likely interval. Annual consumption of diesel for a creel fisher is about five to ten cubic meters, implying a minor external cost. The corresponding figure for a trawler is 40-50 cubic meters which means a small, but existing cost to society. Recalling that the landing value of a trawler is more than four times of a creel fisher, the external cost from fuel emissions is 2-3% of the total landing value for a trawler while the corresponding figure for a creel fisher is 1-2% and hence the difference is minor.

There is one factor in favor of trawl fishery, the sex composition of catches. During the period December to February the females are fertile and the natural behavior for them are to stay below the bottom surface, which is reflected by a composition of 80% males in the trawl catches for the given period. Creels are baited with fresh meat and the females cannot resist such temptation, leading to a fifty-fifty composition for creel landings even during the fertile period. An intensive creel fishery may in this manner have a negative impact on the stock via recruitment overfishing. Given the current knowledge it is impossible to judge whether the creel fishery during previous years have had an impact on recruitment for the stock within the archipelago.
Table 3 shows the economic figures of an average full time creel fisherman, which is based on 12 observations from six vessels. Annual landings amount to a value of US$ 30 000, while costs are divided into capital costs, fixed and variable operation costs and labor costs using the same figures as for trawlers, except for a lower labor cost.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>5'</td>
<td>5'</td>
</tr>
<tr>
<td>Operation cost,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fixed</td>
<td>11'</td>
<td>11'</td>
</tr>
<tr>
<td>variable</td>
<td>4'</td>
<td>4'</td>
</tr>
<tr>
<td>Labor cost</td>
<td>10'</td>
<td>20'</td>
</tr>
<tr>
<td>Total</td>
<td>30'</td>
<td>40'</td>
</tr>
</tbody>
</table>

As can be seen in table 3, the high cost alternative leads to a deficit. If we assume a lack of alternative job opportunities and use the low cost alternative, income equals costs. A lower labor cost, compared to trawl fishers, can be motivated by the fact that creel fishermen generally work notably less hours and are exposed to a lower risk thanks to lower fixed costs. However, the labor cost figure corresponds to a monthly salary less than US$ 1300 which is way below the average income of non skilled workers. In fact, we find that reported average income minus reported average costs, excluding labor cost implies a monthly salary less than $ 700. These extremely low wages figures imply the occurrence of unreported landings and several additional factors support such assumption. First, creel fishers have shorter working hours and possibly lower opportunity cost of time. Second, earlier careful studies carried out at the Institute of Marine Research, Lysekil, indicate that the daily catch per creel figures imply higher total landings. Finally, there are annually repeated reductions in reported landings during July when the most frequent landing port is crowded by summer visitors and tourists. With these factors in mind, we have good reasons to believe that unreported landings are more extensive among creel fishers than among trawlers. In case of 20% unreported landings, earnings would correspond to a monthly salary of almost US$ 1600 which is more in line with wages from alternative job opportunities. The open access characteristics of the
creel fishery seem to imply non-profitable conditions for the fishermen. This situation could possibly be improved if the number of creel fishermen were restricted, but the overall impression is that the fishery is partly dependent of the possibility of unreported landings.

DISCUSSION AND CONCLUSION

The Swedish Nephrops fishery is the country's most valuable coastal fishery. It encompasses a great variety of vessels, from 200 GRT trawlers down to single operated 3 GRT boats. For the trawl fishery we estimate a potential annual resource rent of almost US$ 3 millions for the Maximum Economic Yield equilibrium. To achieve the MEY a 60% reduction of the long term effort level, compared to the present, is necessary. Given the uncertainty of biological parameters and the likely political resistance to carry out such drastic reduction of effort, a successful regulation is likely to be designed to approach this level gradually.

In case of a gear regulation, introducing an overall use of the 60 mm square mesh, a further increase of the rent is possible. Bearing in mind that the current fishery is roughly characterized as an open access regime, a single management measure of a mesh regulation would only lead to an increased effort where the higher landings will be offset by larger costs and the resource rent will remain completely dissipated. The mesh regulation is in itself amiable but should be accompanied by a set of measures. At present new vessels are heavily subsidized by 25% grants from the European Union, such policies are not in accordance with economic theory. They are also likely to increase the average size of the vessels while the economic figures collected for this study show that smaller vessels may well outperform the large ones. Most of the Nephrops trawlers are partly dependent on landings of other demersal species, with cod as the most valuable one. As cod repeatedly has been objected to a binding TAC, an increase of catch capacity would be unfortunate. Individual Transferable Quotas is an often advocated policy instrument in the literature, another suggestion is Territorial Use Rights in Fisheries which could be allocated among local fishing communities (See e.g. Hannesson, 1993). It is beyond the scope of this study to judge which policy instrument is the most adequate for the Scandinavian Nephrops trawl fishery. Yet, given that the suggested mesh
regulation is imposed in both Denmark and Sweden, it is an important task for future research to investigate which policy instrument is the most suitable for this specific fishery.

The second objective of this study was to compare the different Swedish fisheries for *Nephrops* by creel and by trawl. Several attractive features of the creel fishery were identified. The discard mortality is almost zero, creel caught *Nephrops* earn a higher price per kg and the negative external effects to the environment are less, compared to trawl fishing. However, the economic performance of the creel fishery is very poor, despite the two favorable arguments above. Concerning the negative impact on the environment, it was noted that the difference in emission levels is not that big when related to total landings. The possible risks from repeated demersal trawling remain, even though preliminary results from a study indicate a minor impact. There is an urgent need for adequate regulation to improve the economic performance of the open access creel fishery. From the reported figures, the impression that the fishermen are partly dependent on unreported landings is unambiguous. As it stands, the current creel fishery is not a rationale for an expansion of the trawl protected area.

REFERENCES


