Population models as basis for sustainable eel management
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<tr>
<td>G. Kruitwagen PhD</td>
<td>M. Krige MSc</td>
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1. GENERAL INTRODUCTION

Sustainable recovery of the wild eel stocks requires sufficient escapement of silver eels. Focus on maximisation of the escapement should therefore for all efforts regarding eel recovery. The maximisation of the silver eel escapement is also a key element of the Dutch Eel Management Plan. The Dutch eel sector aims to increase its contribution to the recovery of the eel stocks by increasing the sustainability of eel sector. The sector intends to combine the increase in contribution to recovery with strengthening the sector. To achieve these goals a collective effort is made by eel fisheries, eel farms and eel traders. In this report a English summary on the project “Duurzaam aalbeheer op basis van balansberekeningen” is presented. In this DUPAN project an assessment on the feasibility to increase the sustainability of eel farming and eel fisheries was made.

The following organisations have participated in the DUPAN project:
- DUPAN foundation.
- Vereniging Kust & Zee.
- Ursa Major Services B.V. on behalf of Producers Organisation IJsselmeer.
- Association of Inland Fishermen “Noordwest Overijssel”.
- Witteveen+Bos Consulting Engineers.
- Aquaculture Experience.
- NIOZ.
- IMARES.
- Associated Professional Fishermen “De Grevelingen”.
- DLV Plant.

1.1. Eel fisheries

The first part of the DUPAN project focussed on the eel fisheries (summarised in chapter 2). This section explores the possibilities to apply decentralised eel management in three fishery regions in the Netherlands as an alternative to the closed season. Model calculations based on the actual stocks revealed that in one catchment (de Grevelingen) the sustainability criterium is already met. In Northwest Overijssel and the lakes IJsselmeer and Markermeer a further reduction in fishery intensity is needed to meet the 40% escapement target. Decentralised eel management could provide an effective regulatory framework for each of these areas. The report highlights the differences between the various fishery regions and illustrates the applicability of eel management based on the regional characteristics of fisheries and eel stocks.

1.2. Eel farming

The second part of the DUPAN project focussed on eel farming (summarised in chapter 3). To achieve a more sustainable farming sector eel farms strive to reach a “zero-balance”. This implies that the farming activity and the use of glass eels for that activity has no negative impact on the wild eel stocks and spawning stock in particular. In the DUPAN project 5 scenario’s for compensation of the intake of glass eels are proposed. Compensation could occur through restocking of glass eels, restocking of pregrown eel fingerlings or elvers, “trap and transfer” of glass eels or silver eels in the Netherlands or by exclusive intake of glass eels from SEG certified fisheries and traders. Subsequently several projections were made to determine the required compensation for glass eel usage by the eel farms. Based on data obtained from literature and people in the field of the glass eel catchment areas the number and weight of eels to be restocked or trapped and transferred. For each of these scenarios the consequences for the farms in terms of a financial compensation were determined. The report concludes that the required
compensation can be calculated and that zero-balance in eel farms is practically achievable.

1.3. **Sustainability of the eel sector**

Both the farming and the fishery part of this project show clear opportunities for a more sustainable future. However considerable investments from the fisheries as well as the farming sector will be required. In many cases the fishermen need to reduce their activities to meet the requirements for decentralised eel management. Eel farmers need to find methods to finance compensation measures and develop an implementation program. Several opportunities for joint efforts of farming and fisheries appeared during the development of the project.

Fishermen could be instrumental in the trap and transfer of glass eels and silver eels and being paid by the compensation funds originating from sales of farmed eels. Thus a part of the income loss of the fishermen could be mitigated. DUPAN established the “Duurzaam Paling Fonds”, the sustainable eel fund with the purpose to finance measures for eel recovery.

Eel recovery measures are ideally applied in catchment areas where decentralised eel management for eel fisheries is implemented. These catchments provide the best guarantee that the efforts actively contribute to the recovery of the spawning stocks. Eels stocked in recovery programs would have to be excluded from the total allowable catch for the fishermen through quota, unlike glasses eels stocked by fishermen.

1.4. **Policy development on sustainable eel management**

After many years of declining glass eel recruitment in the last 3 years apparently glass eel runs are improving. This increase has already led to a decrease in the market prices for glass eels in France and the UK and benefits restocking projects. Continuation of the current trend would lead to increased production of red and silver eels in the mid long term. The current improvement is however still fragile and it is too early to draw any conclusions on the recovery of the eel stocks. Yet, the current observations stress the importance of effective policies on eel management. Only enforcement of effective policies can guarantee that recovery of eel stocks also translates into increase in the escapement of silver eels. In anticipation of the long term developments it is advisable to further explore the possibilities for practical implementation of decentralised eel management in fisheries.
2. **EEL FISHERIES**

2.1. **Introduction**

One of the prominent generic measures in the national eel management plan for the Netherlands is the yearly closure of all eel fisheries from September 1st to December 1st. As a result of regional differences in the set-up of the eel fisheries there are large differences in the impact of the closure on the fisheries. In 2010 a study has been executed to assess the feasibility of a decentralised eel management. In this management strategy tailor-made regional management plans substitute the current generic management plan, thus avoiding imbalance in the impact of the enforcement of the Dutch eel management plan on the fisheries in the various regions.

Since 2011 the feasibility of decentralised eel management is being tested in the field in the Dutch province of Friesland. This province was specifically selected for the pilot because of the relatively closed character of the water system in the province and the well organised fisheries. DUPAN foundation has commissioned a study aimed at feasibility of decentralised eel management in other fishery regions. This study explores the applicability of decentralised eel management in fishery regions with differences in connectivity to other water bodies. For this study the following fishery regions have been selected:
- Northwest Overijssel.
- Lake Grevelingen.
- IJsselmeer and Markermeer.

2.2. **Decentralised eel management**

The basis for decentralised eel management is the introduction of a total allowable catch (TAC) for regulation of the eel fisheries. This TAC is defined through the application of a population model that has specifically been developed for decentralised eel management. The model makes predictions on the growth and survival of eel based on the recruitment (glass eels and elvers) in the preceding years.

The model based approach of decentralised eel management provides a tool for regulation of eel fisheries. Depending on the sustainability standards that are used the TAC can be adjusted within the same management strategy. In the feasibility studies regarding decentralised eel management an escapement target of 40% of the current eel production is used as a preliminary standard.

According to the population model the escape target of 40% translates into a maximum fishing intensity (F) of 0.05 for yellow eel for situations where there is also fishery on silver eels. Higher fishing intensity on yellow eel can only be allowed in absence of fishery on silver eels and a sufficient escapement of silver eels.

**Model application**

In the population model the following assumptions have been made:
- Growth is non linear and follows the Bertalanffy growth model.
- Yearly natural mortality is 0.138.
- Conversion coefficient c is 1/625 g per cm3.
- Weight of individual glass eels is 0.33g.
- Silvering occurs at a length of 45 cm in males and 65 cm in females.
- No density depending effects occur.
In the study the model was applied to the eel populations of Northwest Overijssel, lake Grevellingen, and IJsselmeer/Markermeer to assess:
- The biomass production of silver eel.
- The current fishery mortality (F), consisting of the instantaneous fishery mortality for yellow eels plus the fraction of the migrating silver eels that is caught.
- Whether the eel fishery is sustainable according to the precondition of a 40% successful escapement of the potential silver eel production.
- If applicable, to what extent the fishery has to be reduced to comply with the escapement target.

Because of differences in the available fishery data of the fishery regions, the model application also differs per region.

2.3. Case 1: Northwest Overijssel

The fishery region in the northwest of the province of Overijssel consists of a 2,803ha marsh area in the Wieden and Weerribben National Park. A regional eel management plan has been set as precondition for prolongation of the fishery rights in 2016 by the park management authority.

The marsh area forms a single water body in which the water quantity is managed by the Stroink pumping station. Connections to the hinterland are closed off by navigation locks. The pumping station therefore is a key element in the migration of eel to and from the area. The migration through the pumping station was investigated in 2006. The study implies that silver eel migration through the pumping station is limited, but does not provide clear insight due to technical difficulties during the execution of the study. To support the eel stock in the area traditionally the fishermen have stocked large amounts of glass eel in the period 1975-1990. Since 2000 the stock material has consisted of pregrown elvers. In 2004 stocking was suspended following the increase of the price for glass eels.

The closure of eel fisheries from September 1st to December 1st, as described in the Dutch national eel management plan, has limited the fisheries in Northwest Overijssel to yellow eel fisheries. Since the options for migration from the area are limited, it is expected that the closure of the silver eel fisheries does not result in a significant increase in silver eel escapement from the region.

Model input
For Northwest Overijssel data were available on the stocking of glass eels and elvers in the past, yearly yields of yellow eels and silver eels and length-frequency data in 5 cm intervals for one company.

In the population model for Northwest Overijssel the following assumptions were made:
- In years with silver eel fisheries all silver eels escaping from the region are caught by fisheries in front of the pumping station.
- No natural recruitment occurs. Recruitment only consists of stocking of glass eels and/or elvers.

Model results
- Based on the data on stocked eels predictions of the yellow eel and silver eel yields at different fishery intensities (F) have been made. The results show that the eel production in the area can easily be explained by the stocked material. Therefore no natural recruitment is assumed.
- The predicted eel production in the period 1980-2000 is higher than the actual yields. This indicates that density dependent effects have occurred following large scale stocking. The natural (instantaneous) mortality (rate) in this period must have been higher than the assumed 0.138.

- The length frequencies that were observed in the fishery region match the model predictions when a fishery mortality $F$ of 0.1 is assumed. The fishery yield in the years since 2000 could be predicted quite well at the assumed $F=0.1$, thus supporting the assumption.

**Figure 2.1.** Stocking of glass eel and elvers (red line), reported yearly catches (black dots), and predictions of yellow eel (black line) and silver eel catches by the population model (green line) for Northwest Overijssel

The model results indicate that the fisheries in Northwest Overijssel are not yet sustainable according to the criterion used in this study. The fishery mortality is estimated to be 0.1, whereas it should be 0.05 at maximum. Furthermore, no silver eel escapement occurs whilst this is an important precondition to allow a fishery mortality of $F=0.05$ for yellow eel fisheries. For more detail in the model prediction data on fishery selectivity, length at silvering and sex ratio are required.

**Effective measures**

The fishery mortality in northwest Overijssel has to be reduced to increase the sustainability of the fisheries. To achieve this, the fisheries could be regulated through the introduction of quota, similar to the situation in the pilot study in Friesland. For the calculation of quota the TAC would have to be derived from the recruitment in the past. In this option the TAC could actively be influenced by stocking glass eels and elvers. An
Alternative method of regulation could consist of limitation of fisheries to silver eel fisheries in combination with the transfer to downstream waters of 4 out of every 10 eels caught.

2.4. Case 2: Lake Grevelingen

Lake Grevelingen is one of the former estuaries in the Dutch river delta. The lake has been created by the closure of the connection to the hinterlands by the construction of the Grevelingendam in 1964 and closure of the connection to the North Sea by the construction of the Brouwersdam in 1971. In 1978 the construction of a spill sluice in the Brouwersdam was initiated. To limit the implications of the spill sluice on the fisheries an arrangement was made in which the spill sluice was closed on request of the fishermen during the silver eel migration. Up to 1999 the fishermen were allowed to select 60 days in which the sluice would be closed. From 1999 to 2006 this was limited to 30 days. In 2006 the arrangement was terminated. Since 2006 the sluice is almost permanently opened.

Up to 1997 the eel stocks have been supported by the stocking of glass eels and elvers. Since 1997 no stocking has occurred because it is expected that the natural recruitment through the open sluices exceeds the past recruitment through stocking.

The collective of fishermen that exploits Lake Grevelingen has made specific agreements to increase the sustainability of their fisheries including the use of larger escape rings than required by law and limitation of the allowed fishery effort. The eel fisheries on Lake Grevelingen have been hit hard by the national closure of eel fisheries from September 1st to December 1st because the eel fisheries have always focussed on the catch of silver eel in autumn. Earlier in the season the fishermen are mainly involved in crab fisheries.

Model input

For lake Grevelingen data were available on the stocking of glass eels and elvers in the period up to 1997, yearly yields of yellow eels and silver eels, yields in number of fish per catch and data on spill volumes for the spill sluices.

Model results

- Combination of data on fishery yield and the use of the spill gates had enabled estimation of the yearly silver eel escapement. The combination of data indicates that only 37% of the escaping silver eels are caught in periods when the spill sluices are opened. Using this result the average silver eel migration in 2002-2007 was estimated to be 90.4 metric tons.
- The population model has been used to make a prediction on the yellow eel and silver eel catches based on the glass eel index for Den Oever (with a correction factor), the actual yellow eel catches and the fishery mortality. At a fishery mortality \( F \) of 0.04 the model predicts an average yearly silver eel migration of 94 metric tons, which closely resembles the 90.4 tons estimate based on the data on the fishery yield and the sluice management.
- The average yearly silver eel yields are about 37 tons. In combination with the yearly silver eel migration this results in an expected yearly silver eel escapement of 57 tons. This equals 43% of the model prediction for potential silver eel escapement at \( F=0 \) of 132 tons.

The predicted fishery mortality for the period 2002-2007 of \( F=0.04 \) is lower than the threshold value of 0.05 for sufficient silver eel escapement. The lower fishery mortality corresponds to an escapement of 43%, which is higher than the 40% that is used as a preliminary criterion for sustainability in this study. In the model there are uncertainties...
regarding the magnitude of the natural recruitment and escapement, and the eel biomass in Lake Grevelingen.

For the period after 2007 there is no insight in the silver eel escapement. However, it is to be expected that the permanent opening of the spill sluice and the closure of the eel fisheries from September 1st to December 1st have resulted in an increase in silver eel escapement from Lake Grevelingen.

**Measures**

The model predictions suggest that the fisheries on Lake Grevelingen are sustainable according to the used definition. Nonetheless a transfer to decentralised eel management will require the introduction of mechanisms for regulation and control of the eel fisheries. This could be achieved by introduction of quota or by regulation of the fishing capacity similar to the existing regulation mechanism on the IJsselmeer and Markermeer.

2.5. Case 3: IJsselmeer and Markermeer

The lakes IJsselmeer and Markermeer are sections of the former South Sea (Zuiderzee) that have been created by the construction of the Afsluitdijk (between the Waddensea and Lake IJsselmeer) and the Houtribdijk (between the IJsselmeer and Markermeer). In both the Afsluitdijk and the Houtribdijk spill gates for water level regulation are present that provide opportunities for fish migration. IJsselmeer and Markermeer have open connections to the hinterland through a number rivers and canals. The fisheries on both lakes are regulated by the Ministry of Economic Affairs. Both lakes have a fishery of the commons.

The fisheries on both lakes are coping with an overcapacity. In an effort to reduce the fishery intensity several reductions in fishery capacity have taken place. The reductions have effectively targeted the number of fishing gears, but due to the overcapacity this has not resulted in reduction of fishing intensity. In addition to the previous reduction efforts, the fishermen have to apply reductions in their efforts annually.

Most fisheries on IJsselmeer and Markermeer consist of yellow eel fisheries in spring and months. These companies are only affected to a limited extend by the closure of the eel fisheries between September 1st and December 1st. The small number of fisheries that specifically target silver eel is strongly affected by the introduction of the closed season.

In 2012 the IMARES research institute made an evaluation of the Dutch eel management plan. Part of the evaluation is an estimate of the intensity of the yellow eel fisheries on the lakes IJsselmeer and Markermeer. For the evaluation a population model (yellow eel model) has been developed that resembles the model used for decentralised eel management.

**Model input**

IMARES has made an effort to obtain region specific data on the various parameters used in the population model:

- The length at silvering, the fishery selectivity, and sex ratio have been obtained through sampling of the landed catches.
- Growth data have been obtained from extensive research on otoliths.
- For natural mortality the assumption of M=0.138 was used.
- The glass eel index of Den Oever was used as a reference measure for recruitment.
Model result
The yellow eel model was used to make a prediction of the length frequency distribution in the eel stocks of IJsselmeer and Markermeer. This length frequency distribution has been compared to the length frequency distribution in the landed eels. For the periods after reductions in fishery capacity separate comparisons in length frequency data have been made.

Table 1.1. Estimate of the fishery mortality for yellow eel according to the IMARES yellow eel model

<table>
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<th>Year</th>
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<th>Markermeer</th>
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<tr>
<td>&lt;1989</td>
<td>0.92</td>
<td>0.55</td>
</tr>
<tr>
<td>1990-1999</td>
<td>0.67</td>
<td>0.33</td>
</tr>
<tr>
<td>2000-2005</td>
<td>0.43</td>
<td>0.47</td>
</tr>
<tr>
<td>2006-2010</td>
<td>0.10</td>
<td>0.30</td>
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The yellow eel model predicts a fishery mortality of 0.10 for Lake IJsselmeer and 0.30 for Lake Markermeer. For both lakes the fishery mortality exceeds the threshold of 0.05 for yellow eel fisheries that corresponds to the target of 40% silver eel escapement. Both fishery mortalities also exceed the threshold of F=0.09, which applies in absence of fisheries on silver eels.

Measures
Introduction of decentralised eel management on IJsselmeer and Markermeer would require changes to the regulation of the fisheries to guarantee sustainability. Regulation could consist of the introduction of quota or closed seasons and/or areas. Alternatively the current method of regulation based on fishery capacity could be maintained, but this would require careful assessment of the maximum capacity that can be allowed without introducing the risk of overexploitation. The sustainability of the fisheries can additionally be stimulated by stocking of glass eels and/or elvers and by the introduction of larger escape rings in the fyke nets.

Important remark
The eel fisheries on the Dutch rivers have been closed to prevent human health risks resulting from high dioxin concentrations in eels. The IJsselmeer and Markermeer are outside the closed area, but function as a migration route for eels from the rivers. It is therefore likely that at least a section of the IJsselmeer and Markermeer would be closed for eel fisheries to prevent landing of contaminated eels that migrate downstream from the rivers in case decentralised eel management is introduced in these lakes.

2.6. Considerations
This study illustrates that a model approach to decentralised eel management is feasible. The reliability of the model predictions is however strongly dependent on the amount of available data on the fisheries. In absence of data assumptions have to be made that introduce uncertainty, but also reduce the acceptance of model results by the fishermen. The model predictions also show the importance of insight in the escapement of silver eel. For most areas this insight is absent, thus introducing more uncertainties. As a result the extent of the uncertainties in a model prediction largely correlate to the connectivity of fishery regions to the adjacent water bodies.
The model results illustrate that the sustainability of the fisheries strongly varies between regions. Of the four fisheries that were considered in this study, only the fisheries on Lake Grevelingen have a fishery mortality that is below the threshold for sustainability that is used in this study. In the other fishery regions the fishery mortality has to be reduced to comply with the set criterion. High fishery mortality does not necessarily mean that no recovery of the eel stocks can take place, but it will result in a longer recovery time.

The differences in model results for the various regions are a reflection of the diversity of the eel fisheries in the Netherlands. The differences illustrate that a region specific approach to eel management would enable a more balanced distribution of the effects of the Dutch eel management plan than the current generic closure of the eel fisheries from September 1st to December 1st.
3. EEL FARMING

3.1. Introduction

To date it is not yet possible to reproduce eels artificially and to grow them to glass eels. As a result eel farms depend on glass eels caught in the wild for their production. The implication of the intake in the eel farms is that these glass eels no longer contribute to the eel stock in the river basin where they initially arrived, but also that the glass eels are not available to support “natural eel stocks” through restocking programmes. The Dutch eel farms strive to increase the sustainability of their production and aim at a “zero balance”, thus annihilating the impact of their production on the natural eel stock and the spawning stock in particular. The efforts required to achieve a “zero balance” depend on the chance the glass eels had for successful development to silver eels at the place where the glass eels were caught. Ideally the farms not only annihilate their impact, but even positively contribute to eel stocks and catalyse recovery of the natural eel stocks. In this project the feasibility of the following 5 scenarios for increase of the sustainability of eel farms through compensation of the impact of glass eel intake were considered:
1. The farm re-stocks glass eel in nature from European catchments.
2. The farm re-stocks elvers from the farm in nature.
3. The farm traps and transfers silver eel (“Eels over the Dyke”).
4. The farm traps and transfers glass eel at the Dutch coastal barriers (“Glass eels over the Dyke”).
5. The farm only uses glass eels from sustainable glass eel fisheries.

The scenarios are further explained in the following paragraphs.

3.2. Scenarios

3.2.1. Scenario 1 - The farm re-stocks glass eel in nature from European catchments

The extraction of glass eels from nature by the eel farms is compensated by restocking natural water bodies with glass eels. For re-stocking water bodies are selected that have good escapement possibilities, but insufficient natural recruitment of glass eels and an eel stock below the carrying capacity for eels.

3.2.2. Scenario 2 - The farm re-stocks elvers from the farm in nature

The extraction of glass eels from nature by the eel farms is compensated by re-stocking natural water bodies with farmed elvers (eel fingerlings). For re-stocking water bodies are selected that have good escapement possibilities, but insufficient natural recruitment of glass eels and an eel stock below the carrying capacity for eels.

3.2.3. Scenario 3 - The farm traps and transfers silver eel (“Eels over the Dyke”)

In this scenario the impact of the intake of glass eels is compensated by trap and transfer of wild silver eels. The farm can achieve a “zero balance” if the number of silver eels that is transferred and released is at least equal to the number of silver eels that would have escaped had the glass eels not been caught at their origin. This scenario requires knowledge of the chances glass eels have to grow into silver eels at the location where they were caught. An additional precondition is that silver eels for “trap and transfer” should be caught at location where the chances for successful escapement are absent of marginal due to the presence of lethal pumping stations, hydropower plants, dykes or other barriers on the route to open ocean.
3.2.4. **Scenario 4 - The farm “traps and transfers” glass eels at the Dutch coastal barriers ("Glass eel over the Dyke")**

In this scenario the impact of the intake of glass eels is compensated by trap and transfer of wild glass eels. The farm can achieve a “zero balance” if the number of glass eels that is transferred is at least equal to the amount of glass eels that have been used for stocking the farm. Precondition is that the glass eels are transferred to natural water systems with suitable conditions for development of the glass eels. A second precondition is that the glass eels should be caught at locations along the Dutch coast for which it can be presumed that the glass eels would not be able to reach suitable water systems for growth without human interference or financing thereof by the farm. This scenario is relevant to eel farms because glass eel fisheries for stocking of eel farms is not allowed in the Netherlands.

3.2.5. **Scenario 5 - The farm only uses glass eels from sustainable glass eel fisheries**

The farm only stocks its facilities with eels that are obtained from fisheries certified by the Sustainable Eel Group (SEG). SEG certifies glass eel fisheries and traders for which it can be assumed that their fisheries have no significant impact on the natural eel populations and that the 40% escapement target in the catchment of collection is met. Since the supply of glass eels through a SEG certified trader already complies with the basic preconditions for a “zero-balance” no additional compensation efforts by the farm are required. However if the farm is to be certified under the Sustainable Eel Standard (SES) developed by SEG it needs to restock 10% of its total intake.

3.3. **Calculation of compensation**

To calculate the required effort by farms in the scenarios 1 (stocking of glass eels), 2 (stocking of elvers) and 3 (trap and transfer of silver eels) extensive research of scientific literature was performed. Additional data were collected by communication with scientists and professionals from the field, attending a conference of the Sustainable Eel Group, etc. For the actual calculations data concerning the sourcing catchments of glass eel in France and England were used since these countries are the main source of glass eels used for farming in the Netherlands. To increase the reliability and comparability of the calculations, all data were converted into in population biology generally accepted parameters: instantaneous mortality rate of the eels in river basins (Z) and the instantaneous, specific, growth rate (SGR) that is also used in fish farming. The amount of glass eels and elvers to be stocked in nature as well as the amount of silver eels to be trapped and transferred was calculated based on these Z and SGR values. In this way the restocking obligations for compensation of the intake of glass eels by the farms were calculated and translated into financial consequences. To increase the insight in the financial implications of the various scenarios, the impact of the financial compensation on the price of the final product, the smoked eel fillet, was also calculated. For validation of the calculated parameters in this study also a comparison was made with data from a recently much used model for eel populations namely that of Bevaqua. It was concluded that the outcomes of these calculations are in the same order of magnitude as the outcomes found in this study and thus support the approach of this study.

3.4. **Comparison with decentralised eel management**

In the part of this report dealing with eel fisheries in The Netherlands the possibilities for decentralised management of several areas have been investigated. In decentralised eel stock management the 15-grams principle is used which states that for each glass eel
recruit 15 grams of silver eel must escape. Because of the similarities with scenario 3 also a calculation based on this method was made for comparison.

3.5. Results

The calculations are summarized in the below table.

**Table 2.1. Compensation of the eel farming sector to compensate for glass eel usage per 100 gram smoked eel fillet**

<table>
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<tr>
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<th>scenario 2</th>
<th>scenario 2</th>
<th>scenario 3</th>
<th>scenario 4</th>
<th>scenario 5</th>
<th>comparison</th>
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<tbody>
<tr>
<td>The farm restocks glass eels</td>
<td>The farm restocks elvers of 2.5 gram per piece</td>
<td>The farm restocks elvers of 5 gram per piece</td>
<td>The farms traps-and transfers silver eels</td>
<td>The farms uses certified glass eels (SES)</td>
<td>The farms principle of decentralised eel management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bodyweight of glass eel, elver or silver eel in gram</td>
<td>0.3</td>
<td>2.5</td>
<td>5</td>
<td>700</td>
<td>0.3</td>
<td>0.3</td>
<td>700</td>
</tr>
<tr>
<td>Cost of restocked or transferred eel per kg</td>
<td>€ 400</td>
<td>€ 79</td>
<td>€ 47</td>
<td>€ 10</td>
<td>€ 50</td>
<td>€ 400</td>
<td>€ 10</td>
</tr>
<tr>
<td>Z (instantaneous mortality over the growth period)</td>
<td>2.30</td>
<td>1.61</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted number surviving eels at time t (Nt) = number of eels to be restocked or transferred</td>
<td>330</td>
<td>132</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kg of eels of the indicated size to be restocked or transferred</td>
<td>1.50</td>
<td>0.82</td>
<td>0.66</td>
<td>63.12</td>
<td>1.00</td>
<td>0.10</td>
<td>49.50</td>
</tr>
<tr>
<td>Compensation per kg glass eel taken in by the farm</td>
<td>€ 600.00</td>
<td>€ 65.17</td>
<td>€ 31.02</td>
<td>€ 631.18</td>
<td>€ 50.00</td>
<td>€ 40.00</td>
<td>€ 495.00</td>
</tr>
<tr>
<td>Total kg glass eel, elvers or silver eel to compensate for 7000 kg glass eel in take in The Netherlands</td>
<td>10,500</td>
<td>5,775</td>
<td>4,820</td>
<td>441,825</td>
<td>7,000</td>
<td>700</td>
<td>346,500</td>
</tr>
<tr>
<td>Fillet yield in kg per kg glass eel taken in by the farms</td>
<td>175</td>
<td>175</td>
<td>175</td>
<td>175</td>
<td>175</td>
<td>175</td>
<td>175</td>
</tr>
<tr>
<td>Compensation per kg smoked eel fillet</td>
<td>€ 3.43</td>
<td>€ 0.37</td>
<td>€ 0.18</td>
<td>€ 3.61</td>
<td>€ 0.29</td>
<td>€ 0.23</td>
<td>€ 2.83</td>
</tr>
<tr>
<td>Compensation or levy per 100 gr. eel fillet</td>
<td>€ 0.34</td>
<td>€ 0.04</td>
<td>€ 0.02</td>
<td>€ 0.36</td>
<td>€ 0.03</td>
<td>€ 0.02</td>
<td>€ 0.28</td>
</tr>
<tr>
<td>Total theoretical contribution of the Dutch eel sector to “Sustainable Eel Fund”</td>
<td>€ 4,200,000</td>
<td>€ 456,225</td>
<td>€ 217,140</td>
<td>€ 4,418,246</td>
<td>€ 350,000</td>
<td>€ 280,000</td>
<td>€ 3,465,000</td>
</tr>
</tbody>
</table>
The above table confirms that it is possible to apply a “zero-balance” to the eel farms. In other words, it is possible to calculate the cost to pay for the compensation of the different scenarios.

Also it becomes clear that the compensation per kg glass eel used by the farms shows a huge variation between the different scenarios and ranges from € 31 when elvers of 5 gram are restocked till € 631 when silver eels are trapped and transferred. Regarding scenario 5 it’s worth mentioning that the first farms in The Netherlands have been certified by the Sustainable Eel Group. Farms can be certified if they comply with the Sustainable Eel Standard that states that 10% of the glass eel used by the farm needs to be restocked. For the eel farms certification involves the cost for certification as well as the cost of obligatory restocking of glass eels would amount € 40 per kg glass eel (at a glass eel price of € 400 per kg).

From the calculations it may be concluded that the most “expensive scenario”, trap and transfer of silver eel may be financed with a levy of € 0.36 per 100 gram smoked eel fillet. If all eels that are farmed in the Netherlands today would be sold as smoked eel fillets in The Netherlands and a surcharge of € 0.50 would be applied to every 100 gram of fillet sold, a total amount of € 7.5 million would be collected. With revenues of this magnitude application of a zero-balance in eel farms would become feasible and could be financed irrespective of the scenario that would be chosen.

Most likely the number of silver eels and/or glass eels that can be caught for use in trap and transfer would not be enough to enable compensation of the total glass eel intake by farms through scenario’s 3 or 4 only. Therefore combinations of measures will have to be taken to compensate for the total intake of glass eels.

For the sake of recovery of the eel stocks it should be determined which of these scenarios would have the biggest and fastest effect on recovery of the eel stocks. Saving adult (silver) eels (scenario 3) contributes immediately to the spawning stock heading for reproduction, whereas the other scenarios directly contribute to the recovery of the inland eel stocks. Assessment which scenario has the best contribution to eel recovery was not part of this study. This assessment may be determined by the different stakeholders as follow-up to this study.

Joint discussion by stakeholders on the most appropriate recovery measures to be taken by the farming eel sector will stimulate the cooperation between leisure fisheries (monitoring), professional fishermen, (catch of glass and silver eels, conservation), farms (pre-growing of elvers) and smokeries and trade (financing). Also the conservation assignments of fishermen may be financeable in this way.
4. REFERENCES


25. Feunteun, E. (sd). E-mail message March 26 2013.
27. Gascoigne, J. (sd). E-mail messages 17 July - 29 August 2012.
33. Knights, B. (sd). E-mail messages 27 May - 28 June 2012.
47. Michelet, N. N. (sd). E-mail messages 25 April - 31 May 2013.
50. Moreau, D. (sd). E-mail messages from June 2012 till April 2013.