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Deliverable D 3.5

Report on population assessment and valuation of non-market effects of aquaculutre and capture fisheries activities

February 2018

Executive summary

There is no doubt that the European production of fish generates huge economic values and provide important proteins to the world population. Still, it is not unreasonable to ask whether this industry, or the various industries involved in production of fish, also have environmental footprints, which are not accounted for?

In this task we use two fish production activities to demonstrate typical effects on the physical environment caused by fish production. The two case studies are farmed Atlantic salmon and harvest of wild cod, and we used Scottish and Norwegian fish farmers and Icelandic and Canadian cod harvesters as empirical cases. Unfortunately, we were not able to get any responses from stakeholders within the Icelandic and Canadian cod fishing industry within due time. Hence, in this report, only results for fish farming is presented. We continue to work to get data from cod harvesters.

There is large agreement across farmers and other stakeholders within salmon farming in both countries that the present regulations fish farmers face when it comes to effects on the physical environment are good, and that they are sufficient to secure a sustainable industry. The only disagreement on this issue is about how accessible the regulations are. While the Scottish respondents and other stakeholders from Norway agree that these regulations are easily accessible, Norwegian fish farmers are less in concert on the topic.

While sea-bed and MTB (maximum total biomass) are the most important issues to secure sustainable activity, green licenses and escapees are issues assessed as the least important. Certification is assessed as slightly more important than sea-lice and the FIFO rate. Producers, producers' organization (PO) and the Government are the agents with the largest responsibility for a sustainable industry, according to the respondents. ENGOs and consumers are regarded to have little responsibility for the industry's sustainability, while certifiers are given more responsibility than ENGOs and consumers.

Stakeholders within salmon farming are willing to increase production costs by 0.335 NOK per kg (0.04 EUR) to reduce the risk for sea-lice infestation of wild salmon (and cause wild salmon smolt mortality), and 0.21 NOK (0.02 EUR) per kg to reduce the probability for accidents that cause escapees. In addition, they are willing to increase production costs with 7.09 NOK (0.7 EUR) to reduce the FIFO-rate by 45%. This may seem as a very high amount. On the other hand, reducing the FIFO rate with 45% will imply considerably lower production costs. Certification is a similar attribute, for which stakeholders are willing to increase production costs by 5.09 NOK (0.5 EUR). However, certification may lead to higher prices in the market, and if the price premium is higher than the increase in production costs, the producers are better off with certification.

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1. Introduction and background

1.1 Introduction

There is no doubt that the European production of fish generates huge economic values and provide important proteins to the world population. Still, it is not unreasonable to ask whether this industry, or the various industries involved in production of fish, also have environmental footprints, which are not accounted for?

When the production of economic goods and services has environmental effects, which are not accounted for, this is called externalities. The term reflects the fact that the production causes costs to society which are not internalized, i.e. the producers do not take any actions to neutralize the effects.

Externalities are defined as "unintended effects of production (or consumption), which are costly for the producer to neutralize." Externalities can be of both positive and negative character. An example of a negative externality of European fish production is the overfishing of some fish stocks, which disturb the ecosystem these stocks are part of and thus these ecosystems may be less productive than without overfishing. An example of a positive externality we can find in some types of fish farming, where the waste from e.g. salmon production can be used by scallops' farms. While the outcome of the mentioned positive externality is captured by economic agents and thus partly internalized, it is of less concern to society than the negative externality, which imply costs inflicted upon the whole society, without being compensated for. Hence, although we also will treat positive externalities, the main focus will be on negative externalities of fish production.

The intention was to use two case study fish industries to exemplify the role and extent of externalities in European fish production; farmed Atlantic salmon and wild cod. By the use of a methodology called choice experiment, we analyse to what extent case study producers are willing to internalise a few widely recognized externalities. The results of this analysis should be seen in relation to results from WP4.4, which is a choice experiment among European fish consumers. Taken together, the results from the two surveys will convey information of whether consumers and producers of fish agree on which are the important environmental issues in the European fish industry. Are fish producers focusing on the "right" environmental issues, and are consumers willing to pay more for the fish to encourage the producers to take environmental considerations? Unfortunately, cod fishers in the two case study countries, Iceland and Canada, were not willing to participate in the study, and hence this report only presents results from the survey among producers and other stakeholders in the farmed Atlantic salmon industry.

1.2 Background

Choice experiments have previously been applied to elicit producers' preferences for various production related issues. While the majority of these studies are within agriculture, there are a few studies of fish producers. Within fisheries, Eggert and Martinsson (2004) elicited fishers' risk preferences. The survey asked fishers to make pairwise comparisons between a production alternative with low expected outcome and low risk and an alternative with higher expected outcome and higher risk. Altogether, six such comparisons were presented in the survey.-, The results showed that the 48% of fishers could be characterized as risk neutral, whereas 26% were modestly risk-averse and another 26% strongly risk-averse. This was a postal survey sent to a sample of 600 units in the Swedish commercial fishing vessel register. This register contains names of either the owner of a fishing vessel or one of the owners of the company's vessel. By the deadline 340 had returned the questionnaire, of which only 202 could be applied for analysis purposes.

Andersen et al. (2012) applied a choice experiment to analyse fishers' short term selection of metier in the Danish gillnet fishery. Metier is the combination of fishing ground, gear and target assemblage. Commercial fishers in a mixed fishery make use of several decision variables, of which seasonal availability of individual target species and within-year changes in monthly catch ratio were the most important. Other important variables were information on the whole fishery, fish prices and distance travelled to fishing ground. The choice data applied was taken from a sub-sample of 54 gillnet fishers in a larger survey, which was distributed to 789 fishers in the Danish demersal fleet.

Turning to agriculture, Bond et al. (2011) elicit Colorado corn producers' preferences over both private and environmental public-good production system attributes. Positive preferences are found for farm profit, risk reduction and systems with lower environmental impact in terms of nitrate leaching and soil erosion. The highest utility comes from reducing the risk of losing half the crop, whereas increase in profit gave the lowest utility. The two environmental attributes, nitrate leakages and soil erosion, were preferred over profit increase, but below risk reduction. The authors emphasize that results from this kind of survey can be used by policy makers to predict behavioural responses associated with the introduction of new technologies. They can also be used to assess welfare implications of stricter environmental policy.

Another choice experiment within agriculture elicit Ethiopian farmers' preferences for crop variety (Asrat et al., 2010). They show that farmers are willing to forego some extra income or yield to obtain a more stable and environmentally adaptable crop variety. A total of 131 farmers were interviewed, and with each making 9 choices the sample encompassed 1179 observations.

We have not been able to find examples of choice experiments among fish farmers.

2. Methodology and data

2.1 Statistical model

We have applied a combination of qualitative semi-structured interviews and quantitative monetary valuation of sets of externalities relevant for each of the two fisheries productions in question (farmed Atlantic salmon).

For this industry we derived a choice experiment survey, including both qualitative questions about main environmental issues, and choice cards. In the choice cards respondents were asked to choose between three production alternatives, one of which describes a generalized present situation and two which describes alternatives with lower environmental footprints, but higher production costs (see Figure 1 below for an example of a choice card).

Based on the choice cards it is possible to derive monetary valuation of the environmental issues (named attributes). We do this by using the random utility model, assuming that the utility to a fisher/fish farmer of a production alternative depends on a set of attributes describing the environmental and other characteristics, including production costs. To take into account the influence of random components on individual utility we also add an idiosyncratic i.i.d. error term. Hence, utility of a production alternative *j* to respondent *i* can be formulated as follows;

$$U_{ijt}(b|\, X) = b * X_{jt} + \in_{ijt} \qquad (1)$$

where b is a vector of preference parameters to be estimated, X is a vector of attributes and ∈ is an i.i.d. distributed error term.

A utility maximizing agent will chose alternative when $U_{ijt} > U_{ikt}, \forall k \neq j$. Hence, production alternative j is chosen by respondent i when $b\left(X_{jt} - X_{kt}\right) > (\in_{kt} - \in_{jt})$. When the error terms are extreme value distributed, we have that the right hand side of this inequality is logistically distributed.

With logistically distributed error terms the probability for the probability for the inequality (substituted by equality) above to be fulfilled is given by

$$P_{ijt} = \frac{exp^{b\prime Xijt}}{\sum exp^{bXikt}} \qquad (2$$

Equation (2) is the probability for respondent *i* to choose production alternative *j* in choice situation *t*. With T choice situations and N respondents, the aggregate probability for all observed choices is given by

$$L = \sum_{i=1}^{N} \sum_{t=1}^{T} P_{ijt}^{\ \ y} \qquad (3)$$

where y is a dummy taking the value 1 if alternative *j* was chosen by individual *i* in choice situation t, and 0 otherwise.

Taking the log of (3) yields the log likelihood function, which is maximized to yield estimates for the b-vector. This vector of estimates can be interpreted as marginal utilities for each of the attributes.

Dividing each non-cost attribute by the cost-attribute estimate we can interpret the resulting term as marginal willingness to pay (WTP) for a change in each of the non-cost attributes. Hence,

$$WTP_m = \frac{b_m}{b_c} \qquad (4)$$

where b_m is the estimate of a non-cost attribute and b_c is the estimate of the cost attribute.

2.2 Data collection

Having decided on case studies, interviews were made with representatives of salmon farmers and other aquaculture stakeholders. These interviews were made with Norwegian agents, assuming that producers in various countries, but within the same industry, would face similar environmental challenges. Parallel with the interviews the literature was consulted. Based on the two sources of knowledge, the most important externalities in the two industries respectively were identified. Although the literature used was international, the interviews were only with Norwegian producers, and hence the identified list of externalities was shared with project partners from the other case study countries, i.e. Scotland (farmed salmon), Iceland and Canada (cod). These partners recognized the identified externalities as relevant also in their respective countries.

Next, based on industry and expert input, 3-4 of the identified externalities were selected to be used in a choice experiment survey. Having selected the externalities, the survey was developed. The first draft of the surveys was distributed to relevant stakeholders in each of the two industries, i.e. producer organisations, producers and experts (scientists). Based on feedback the surveys were modified, and sent back to the stakeholders for "approvement".

Table 1a Attributes and attribute levels for salmon survey

Attribute	**Salmon lice**	**FIFO**[4]	**Escapees**	**Certifi-cation**	**Prod.** **Costs per kg in GBP***

[4] Fish-in, fish-Out

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Level SQ	High	1.4	Every 7th year	Yes	3.20
Alt.level 1	Medium	1.0	Every 15th year	No	3.26
Alt.level 2	Low	0.6	Every 20th year		3.36
Alt.level 3					3.52
Alt.level 4					3.68
Alt.level 5					3.84

*British Pound Stirling. The Norwegian survey had costs in Norwegian kroner (NOK) starting with average production costs excluding slaughter costs at NOK 26.15, and with the same % changes as in the table.

Table 1b Attributes and attribute levels for cod survey

Attribute	**Reduction in local sea bird population**	**Discards**	**Annual variability in landings**	**Certification**	**Prod. Costs per kg in ISK***
Level SQ	60	No	Some	Yes	88
Alt.level 1	40	Yes, some	None	No	93
Alt.level 2	20				98
Alt.level 3					103
Alt.level 4					108

*Icelandic Kronur. In the Canadian survey costs were given in Canadian Dollar, and with same % increase.

Salmon lice and accidents leading to escapees were identified as focal environmental issues in the salmon industry from the literature (Svåsand et al., 2016). Other important issues are the FIFO-rate (fish-in fish-out) and sustainability certification. The former has environmental consequences in terms of sea-bed sedimentation whereas the latter yield incentives for making production environmentally sustainable in general. The two latter issues also have important economic consequences, as lower FIFO-rate will reduce production costs and certification sometimes lead to a price premium in the market. There are various certification schemes available for salmon farmers, with ASC (Aquaculture Stewardship

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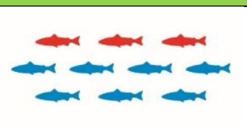
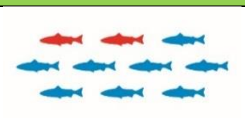
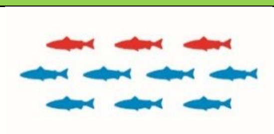
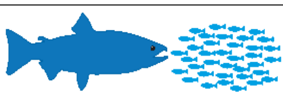
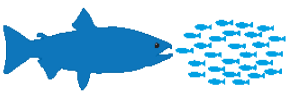
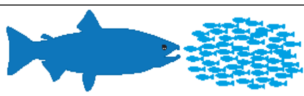
Council) as the most widely applied. Figure 1 shows an example of a choice card from the salmon survey. The present situation is described by a high probability for wild salmon to be infected by sea lice and die, a FIFO rate equal to 1.4, a probability for a major accident leading to escapees every 7th year, no certification and production costs equal to 26.20 NOK/3.20 GBP per kg (excluding slaughter costs). The alternative production scenarios are all combinations of the present situation attribute levels and the other levels. The alternative production scenarios were designed using the software Ngene and we used the D-error to choose the most efficient design (Kanninen, 2002).

It is a fact that sea bird get caught in the fishing gear and die by fisheries activities. For some fisheries the rate has been quite high, up to 60%. For others it is lower. Efforts may be taken in the fishing activities to reduce this rate. In Icelandic fisheries discards are prohibited, while this is not the case in Canadian fisheries. It is of interest to elicit the fishers assessment of this prohibition, or whether they would be willing to accept it, and the increasing costs it would imply. Industries dependent on renewable natural resources by nature are fluctuating, and in this survey we are interested in knowing whether the fishers and trawl companies were willing to accept increased harvest costs in if this could lead to lower fluctuations in annual landings. Finally, an increasing number of fisheries world-wide are getting certified as sustainable fisheries, and in this survey we tease out whether there is willingness to pay for such certification among Icelandic and Canadian representatives. Present landing costs for the cod fisheries are in Iceland 88 ISK/kg and in Canada 10 CAD$/kg. These costs are increased by 2-20% as the attributes take higher (better) levels. The alternative production scenarios are all combinations of the present situation attribute levels and the other levels. The alternative production scenarios were designed by the use of the software Ngene and we used the D-error to choose the most efficient design (Kanninen, 2002).

ATTRIBUTES	**ALTERNATIVE 1**	**ALTERNATIVE 2**	**ALTERNATIVE 3** (No further efforts taken)
Increased risk of sea-lice related death for wild migrating salmon	 30%	 20%	 30%
Fish in-fish out (FIFO) ratio	 FIFO is 1	 FIFO is 0.6	 FIFO is 1.4

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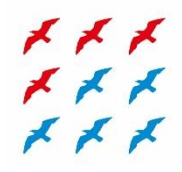
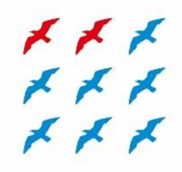
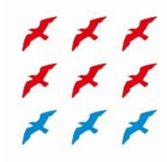
Escapee accident	 About once in every 7 years	 About once in every 20 years	 About once in every 7 years
Sustainability certification			
Production cost per kg fish	**3.52 GBP per kg**	**3.84 GBP per kg**	**3.20 GBP per kg**
Your preferred Alternative			

Figure 1A Example of choice card from the salmon survey

ATTRIBUTES	***ALTERNATIVE 1***	***ALTERNATIVE 2***	***ALTERNATIVE 3 (current situation)***
Reduction in local Seabird abundance	 40%	 20%	 60%
Bycatch (%)	Bycatch of 4%	Bycatch of 6%	Bycatch of 8%
Stability in cod landings	Unstable	Stable	Unstable
Sustainability certification			

Total landing costs per kg harvest, ISK	103 ISK	93 ISK	88 (No increases)
Your preferred production alternative		√	

Figure 1B Example of choice card from the cod survey

After revisions, the surveys were coded into electronic versions and distributed to a few test respondents. Based on their feedback the electronic version was updated.

During autumn 2017 and early 2018, the surveys were distributed to all major producers of farmed salmon in Norway and Scotland, and a sample of cod trawlers in Canada (Newfoundland) and Iceland.

Electronic surveys turned out not to be an optimal survey fashion for producers of fish. By the deadline of the salmon survey in Norway, only a few fish farms had responded. Hence, we made a follow-up data collection, by calling up and asking to interview the respondents per phone or skype. During the interview, the respondents would fill in the electronic survey, which was sent them prior to the interview. This resulted in a somewhat larger, but still very limited sample. To increase the database for the salmon survey, we decided to let various stakeholders related to the salmon farming industry answer the survey. These include scientists (fish biologists, veterinaries, food processing engineers) and producer organization employees. Other stakeholders in Norway filled in the electronic survey after we had called them and asked them to respond to the electronic survey. In Scotland we held telephone interviews with fish farmers, where the fish farmers filled in the electronic questionnaire while being interviewed on phone. In addition, we had personal interviews with other stakeholders in Scotland.

Table 2 yields an overview of the sample in Norway and Scotland.

Table 2A Sample size and distribution for salmon survey in Norway and Scotland

Norway			**Scotland**		
	Population	Sample		Population	Sample
Producers	164	12 (7.5%)	Producers	7	2 (29%)
Other		3	Other		6

The population of 164 producers in Norway is per 2016. There is an ongoing process of mergers and acquisitions taking place in the Norwegian farmed salmon industry, and the number of producers is likely to be smaller in 2017, when the data collection took place.

At the closure of the cod survey we had not been able to get any responses from Icelandic and Canadian cod fishers. This in spite of close cooperation with the Icelandic and Canadian partners in the PrimeFish project (MATIS in Iceland and Memorial University in Canada). As responsible for the task we will make an effort to collect these data ourselves, by visiting the relevant locations and recruit a number of relevant respondents.

3. Results

3.1 Farmed Salmon

3.1.1 Characteristics of the sample

The Norwegian sample of 12 producers encompass both small independent producers and subsidiaries of larger companies. Among them, we find farms, which have specialized in organic production, but the majority are "ordinary" farms. All farms have more than one production location, and most have more than one license. The average number of production locations are just above 7, while the average number of licenses are just below 20. Half of the companies were established before 1990, and the other half after. Nine of the twelve companies produce their own smolt. Half of the companies (6) have some or only green licenses. Annual production ranges from 1500 tonnes to 60,000 tonnes.

As there is only 2 Scottish producers in the sample, we cannot reveal any information about them.

3.1.2 Qualitative results

The information in this section is based on the full sample of 23 respondents.

There is large agreement across farmers and other stakeholders in both countries that the present regulations fish farmers face when it comes to effects on the physical environment are good, and that they are sufficient to secure a sustainable industry. The only disagreement on this issue is about how accessible the regulations are. While the Scottish respondents and other stakeholders from Norway agree that these regulations are easily accessible, Norwegian fish farmers are less in concert on the topic.

We named seven "environmental" issues, and asked, on a scale from 1-6, with 1 meaning little importance and 6 very important, how important each of them were. Figure 2 shows the distribution of importance weights for all respondents. Generally N=23, but for the issues green licenses, escapees, FIFO and Certification, one respondent indicated "don't know", and is not accounted for in the figure, i.e. for these issues N=22.

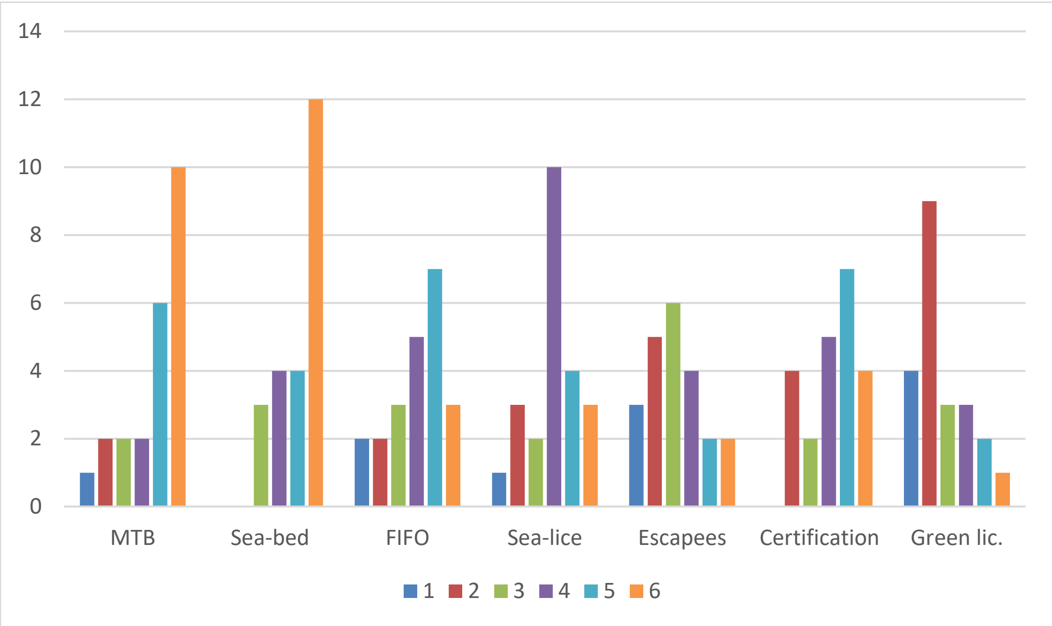


Figure 2 Importance of selected environmental and economic issues within salmon farming for Norwegian and Scottish stakeholders, number of stakeholders

While sea-bed and MTB (maximum total biomass) are the most important issues to secure sustainable activity in salmon farming, green licenses and escapees are issues assessed as the least important. Certification is assessed as slightly more important than sea-lice and the FIFO rate. Note, however, that the importance of certification is more equally distributed across all importance levels, whereas FIFO and in particular sea-lice are peaking for importance levels, 4 and 5.

We calculated an importance index for each issue, which is the aggregate of the importance level multiplied with the number of respondents choosing that particular level. The index for each issue is given in table 3. The index numbers are not comparable across stakeholder group because of varying number of respondents in each group. What can be read from the table is the relative ranking of responsibility by each of the stakeholders.

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Table 3 Importance index for the seven environmental and economic issues; NFF=Norwegian fish farmers, NOS=Norwegian other stakeholders, SFF=Scottish fish farmers, SOS=Scottish other stakeholders

Issue	MTB	Sea-bed	FIFO	Sea-lice	Escapees	Cert.	Green lic
Index, all	109	117	88	91	69	93	59
Index NFF	49	62	46	44	35	51	36
Index NOS	13	16	10	13	13	9	8
Index SFF	12	9	11	11	4	11	5
Index SOS	35	30	21	23	17	22	10

Table 3 confirms the impression given by Figure 1, that MTB and sea-bed conditions are the two most important issues when it comes to environmental and economic sustainability. Green licenses are the least important, which may be explained by the fact that this is little known among the Scottish respondents. Certification, sea-lice and FIFO is rated as relatively equally important.

There is an interesting difference between the Norwegian and the Scottish respondents. While the Scottish respondents consider the MTB (maximum total biomass) regulation as the most important, Norwegian respondents consider sea-bed regulations as most important to secure environmental sustainability. Scottish fish farms consider the FIFO-rate, sea-lice and certification as more important than sea-bed regulations to secure environmental sustainability. Escapees and green licenses are ranked the lowest of all except other Norwegian stakeholders, who rank certification lowest, together with green licenses.

We also asked who are the responsible agents when it comes to secure environmental sustainability of the farmed salmon industry, and used the same rating system with 1 indicating little responsible and 6 very responsible, 7 means "don't know". Figure 3 yields the results.

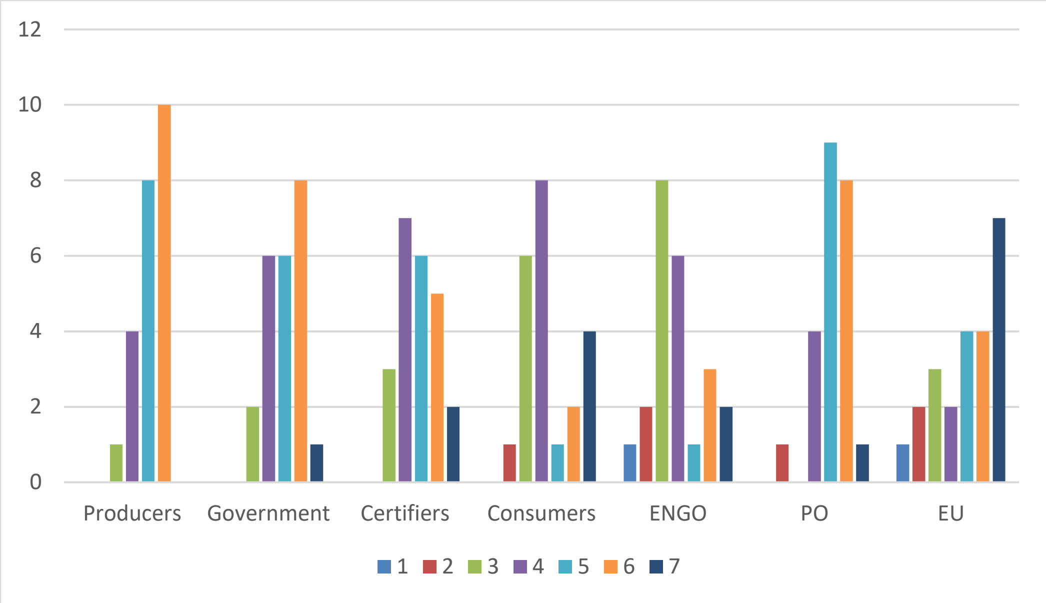

Figure 3 *Responsibility of agents within the farmed salmon industry. Norwegian and Scottish stakeholders, number of stakeholders*

Producers, producers' organization (PO) and the Government are the agents with the largest responsibility for a sustainable industry, according to the respondents. ENGOs and consumers are attributed with relatively little responsibility for the industry's sustainability, while certifiers are attributed with more responsibility than ENGOs and consumers. Regarding the EU, many respondents indicated "don't know." These were mainly Norwegian respondents, which is reasonable, as Norway is not part of the European Union (EU).

As for the importance question, we calculated a responsibility index for each of the agents, the index being the aggregate of the responsibility level multiplied with the number of respondents choosing that particular level. The "don't know" level is kept out of the calculation of the index. The index for each group of agents is given in table 4.

Table 4 *Responsibility index for seven stakeholders groups within the farmed salmon industry; NFF=Norwegian fish farmers, NOS=Norwegian other stakeholders, SFF=Scottish fish farmers, SOS=Scottish other stakeholders*

Issue	**Producers**	**Government**	**Certifiers**	**Consumers**	**ENGOs**	**POs**	**EU**
Index, all	119	108	97	69	76	111	66
Index NFF	61	49	49	42	39	59	24

Index NOS	16	15	12	8	11	17	12
Index SFF	12	10	8	6	3	12	0
Index SOS	30	34	28	19	23	27	30

Remember that the index numbers are not comparable across groups of agents because of varying number of respondents in each group. What the table shows is the relative ranking of responsibility by each of the agent groups.

Table 4 confirms the impression given by Figure 2, that the producers, the producers' organizations and the Government are those most responsible for securing sustainability of the farmed salmon industry. Consumers and ENGOs are regarded to be the least responsible for industry sustainability. The low index of EU is due to the fact that for most Norwegian respondents EU is not a relevant stakeholder and therefore the least important, which may be explained by the fact that this is little known among the Scottish respondents. Certification, sea-lice and FIFO is rated as relatively equally important.

Interestingly, while fish farmers and other Norwegian stakeholders attribute the largest responsibility to producers and producers' organizations (PO), other stakeholders in Scotland put higher responsibility on the national government and EU authorities. Fish farms attribute in general little responsibility to EU authorities. All respondents attribute relatively low responsibility to consumers and ENGOs, and assess the responsibility of certifiers to be somewhere between consumers and ENGOs on one hand, and producers and governmental bodies on the other.

3.1.3 Willingness to pay for environmental efforts

As part of the survey, respondents were asked to choose between production alternatives, where one described a "generalized present situation", based on current knowledge about the salmon farming industry in Norway and Scotland, and the two other described "improvements" in one or more of the attributes characterizing the production alternatives. An example of a choice card is shown in Figure 1. Each of the respondents were asked to fill in 9 choice cards. One respondent filled in only 6 choice cards. Hence, we have a sample of 204 choices. Based on the choices of production alternatives we can estimate the respondents' assessment of each of the attributes. Table 5 yields the results for the total sample, and for the producers and other stakeholders separately.

*Table 5 Stakeholders within the salmon farming industry's assessment of production characteristics, mean coefficient (std.error), *, **, *** implies significant at 10%, 5% and 1% level*

Attribute	Full sample	Producers	Other stakeholders
Sea-lice	-0.0825 (0.013) ***	-0.07 (0.016) ***	-0.116 (0.027) ***
FIFO	-1.75 (0.34) ***	- 1.57 (0.42) ***	-2.40 (0.69) ***
Escapees	0.051 (0.018) ***	0.087 (0.023) ***	-0.018 (0.033)
Certification	1.25 (0.262) ***	1.39 (0.34) ***	1.08 (0.437) **
Cost	-0.25 (0.091) ***	-0.27 (0.115) **	-0.27 (0.163)
LL-value	-146.17	-88.04	-53.66
R-square	0.095	0.137	0.044
N	204	123	81

The sea-lice attribute takes higher values the more likely it is that out-migrating wild salmon smolt dies from sea-lice infection. Hence, the negative coefficient of this attribute indicates that the lower the likelihood for wild salmon mortality due to sea-lice is, the more likely that this production alternative will be chosen. This effect is significant in all models, indicating that all types of agents prefer production alternatives that have lower mortality rates for wild salmon due to sea-lice. The FIFO rate also has a negative sign, indicating that production alternatives with lower FIFO-rate are preferred to alternatives with higher FIFO rate. This effect is also significantly different from zero in all models. The escapee attribute takes higher values the more rarely accidents that imply escapees happen. Hence, the positive sign of the coefficient means that production alternatives with more rare accidents that lead to escapees is preferred. The effect is significantly different from zero for producers, but not for other stakeholders. The positive sign of the coefficient for certification implies that agents prefer to certify the salmon production. This is true for all types of agents. Finally, the negative sign of the cost attribute implies that agents prefer production alternatives with lower production costs to alternatives with higher production costs. This is what we would expect by rational economic agents. Note, however, that this attribute is not significant for other stakeholders, indicating that these respondents do not consider the cost attribute important. That is not surprising, as these respondents are not producers, and thus probably more concerned about other attribute than the production costs.

The R-squared indicates the fit of the model, i.e. how much of the variation in choices can be explained by the attributes. The higher number for producers implies that the model is better to explain producers' choices than the choices of other stakeholders. This is as expected as producers is a more homogenous group than are other stakeholders. The model fit on 0.04 for other stakeholders is low, and thus these results should be interpreted with care. The model fit for producers, equal to 0.135 is reasonable for this type of models, which typically have R-square scores between 0.1-0.2.

The effects presented in table 8 can be transferred into monetary units by dividing the coefficient for the non-cost attributes by the coefficient of the cost attribute. The result is termed willingness-to-pay (WTP) estimates, and they indicate the increase in production costs the respondents are willing to accept to gain a marginal (one unit) increase or improvement in one of the other attributes. Table 6 shows the attribute WTPs for the whole sample, producers and other stakeholders respectively, and the 95% confidence interval for the WTPs.

Table 6 Willingness-to-pay estimates in NOK (Norwegian kroner) and 95% confidence intervals for production attributes, all agents, producers and other stakeholders separately*

Attributes	**Full sample**		**Producers**		**Other stakeholders**	
	WTP	95% CI	WTP	95% CI	WTP	95% CI
Sea-lice	-0.335	(-0.55, -0.125)	-0.26	(-0.45, -0.06)	-0.44	(-0.89, 0.01)
FIFO	-7.09	(-11.3, -2.9)	-5.78	(-9.9, -1.7)	-9.1	(-17.5, -0.67)
Escapees	0.21	(0.03, 0.39)	0.32	(0.05, 0.6)	-0.07	(-0.32, 0.18)
Certification	5.09	(1.39, 8.8)	5.11	(1.07, 9.15)	4.1	(-1.56, 9.76)

*the exchange rate to Euro is just below 10 (9.68), hence by dividing by 10 the units are converted into Euro.

The 95% confidence interval indicate the range of values within which we with 95% probability (certainty) will find the true value of the estimate (WTP). When the CI contains only numbers of the same sign, i.e. only positive or negative numbers, the WTP estimate is different from zero with 95% certainty (significant at 0.05 level). When the CI is overlapping zero, we cannot state that the estimated WTP with 95% certainty is not zero (but it may be different from zero at lower certainty levels).

When considering the full sample model, all WTP estimates are significant. This means that farmed salmon stakeholders are prepared to accept higher production costs to have lower probability for infesting wild salmon, lower FIFO-rate, more rare accidents that lead to escapees and to be certified.

Looking at the WTP amounts, the agents are willing to increase production costs by 0.335 NOK per kg (0.04 EUR) to reduce the risk for infestation of wild salmon (and cause wild salmon smolt mortality), and 0.21 NOK (0.02 EUR) per kg to reduce the probability for accidents that cause escapees. In addition, they are willing to increase production costs with 7.09 NOK (0.7 EUR) to reduce the FIFO-rate by on average 45%, i.e. from 1.4 to 1 (30%) or from 1.4 to 0.6 (60%). This may seem as a very high amount. On the other hand, reducing the FIFO rate with 45% will imply considerably lower production costs. Hence, although willing to increase production costs to obtain a lower FIFO, may mean that eventually production costs will come out lower than at present. Certification is a similar attribute, for which stakeholders are willing to increase production costs by 5.09 NOK (0.5 EUR). However, certification may lead to higher prices in the market, and if the price premium is higher than the increase in production costs, the producers are better off with certification.

The results above also hold for producers. The confidence intervals assure that all WTP estimates are significant, i.e. significantly different from zero. For other stakeholders, however, this is not the case. Here only the WTP for reduced FIFO rate is significantly different from zero. Hence, while the model seems to be a good predictor for salmon farmers' preferences when it comes to production attributes, it is relatively poor when it comes to explaining other stakeholders' preferences w.r.t. production attributes.

The results above must be read and interpreted with care. Although significant and relatively robust results, i.e. various sources support the same conclusions, they are based on only a few producers of farmed salmon, and other stakeholders in the farmed salmon industry.

3.2 Positive external effects

The positive externalities of salmon farming are not externalities in their original meaning, which are effects not accounted for economically. The reason is that the positive effects are internalized by utilizing them in economic production. Still, we present some positive effects, or spin-offs of aquaculture (salmon farming).

One such spin-off is integrated multi-trophic aquaculture (IMTA). There are various versions of IMTA, of which two examples are feed aquaculture and extractive aquaculture.

Concentrating on extractive aquaculture this implies that e.g. mussels and extractive inorganic species like algae are farmed close to the salmon production. The idea is that these species eat the leftover of the fish feed. With this process, the organic matter aggregating on the sea-bed of the aquaculture locations is reduced. Such a process, when working intentionally, could be of high value to salmon farmers. According to the respondents in our survey, reported above, sea-bed issues is one of the most important issues to regulate to secure sustainability of the industry.

The extractive IMTA faces some challenges, among which is that mussel production requires natural conditions not satisfied along the Norwegian and Scottish coast. This means that sea temperature must be sufficiently high for farming of mussels. This technique is therefore mostly applied in Spain and Canada, and only exceptionally in Norway and Scotland. Another challenge is that the production at an average salmon farm in Norway or Scotland is too high for mussels to be able to take up all the feed leftovers.

An example of feed IMTA is the set-up of extractive benthic feeders on the sea-bed of the aquaculture locations. Collecting the waste, from feed and other, this can be dried and used as fertilizer in agriculture. This, however, is not an example of a positive externality, as it is more an example of tidying up of the negative externalities. Also, to the extent the waste is transformed into fertilizers, the effect is internalized as the negative externality is turned into an economic good.

The aquaculture industry has shown to be an innovative industry. In the wake of the various environmental challenges the industry has faced, it has come up with a wide variety of solutions. In addition to those above we can mention the use of lumpfish and wrasse to combat sea-lice. The problem with the lumpfish is that it also eats the feed of the salmon, so by large use of lumpfish a farm may experience increased FIFO-rate. A positive effect of the use of lumpfish is that the eggs of the females can be used to produce caviar. Finally, to reduce the negative effects of escapees' innovation has led to the development of triploids. Triploids is a genetically manipulated fish where the female remain juvenile all her life. The male develops normally, but triploid males have smaller genitalia and the sperm is ineffective.

4. Conclusions

Production processes based on the exploitation of natural resources often have external effects in the form of affecting the natural environment. These may be positive or negative. As the positive external effects usually are internalized in the form of utilizing them in economic production, our main focus is on the negative external effects. By external effects we mean effects of production on the environment not accounted for by the producers in the market.

Salmon farming causes negative externalities in the form of sea-bed sedimentation, increased sea-lice densities, and genetically degradation of wild salmon from escaped farmed salmon. Some of these effects are detrimental to the farmers as they reduce the productivity of the farm and cause losses of fish. Hence, from an economic point of view it is in farmers' interest to reduce such externalities. Absence of efforts by farmers to reduce these externalities are due to two main causes; lack of technological solutions and (high) costs of such efforts.

The fact that taking efforts to prevent negative externalities of salmon farming inflicts costs upon the farmers, and therefore may prevent them from voluntarily taking such efforts, have caused governments to set up regulations to reduce the externalities. In our survey, farmers in both Norway and Scotland agree that the existing regulations of salmon farming in their respective country are good, contributing to a sustainable industry.

Both farmers and other stakeholders within the salmon farming industry agree that it is the farmers and their organizations, together with the government, who are responsible for sustainable production activities. In fact, the farmers put a larger responsibility upon producers and POs than do other stakeholders, who find governments (including EU authorities) as responsible as producers and their organizations.

All stakeholders in both countries think regulations concerning sea-bed conditions and MTB are the most important to secure a sustainable industry. Scottish respondents put some more weight on MTB, whereas Norwegian respondents think sea-bed conditions are the one most important environmental issue. This is interesting, as the focus of governments and scientists, at least in Norway, is very much on sea-lice and escapees. In a risk-perspective, both sea-lice and escapees increase the farmers' risk of losing part of the production. According to Bond et al. (2011) farmers in Colorado, USA, ranked reductions in risk for losing half of the crop first, before environmental issues and increased profit. Salmon farmers seem to prioritize otherwise. When asked to choose between various production alternatives, they seem to favour alternatives with low FIFO-rate and certified production above alternatives with lower probability of escapees and wild salmon infestation with sea-lice. One reason may be that many salmon farmers doubt the possibility of reducing the sea-lice and escapee externalities at any significant rate. A previous survey among fishers (Eggert and Martinsson, 2004) conclude that Swedish fishers are either risk averse or risk neutral, meaning that they prefer production alternatives with lower expected income and high degree of certainty to alternatives with higher expected income and lower certainty. If investing in efforts to combat sea-lice and escapees is interpreted as increasing the certainty of the production, then salmon farmers are not first and foremost risk averse, as they do not prioritize such efforts above other efforts. The efforts salmon farmers prioritize the highest are those, which reduce the FIFO-rate and certification.

On the other hand, salmon producers are willing to accept higher production costs to achieve improvements in all mentioned production conditions. This means they are willing to accept increasing the production costs to achieve reduced likelihood for sea-lice infestation of wild salmon, for reducing the likelihood for accidents leading to escapees, and for lower FIFO rate and for being certified. In other words, there is significant willingness to pay for improvements in both environmental and economic production conditions, only that the cost increase they are willing to accept is higher for the more directly economically relevant issues than for the more environmentally relevant issues. Interestingly, the same seems to be the case for other stakeholders (not including fish farms). They seem to favour the FIFO-rate, and are not willing to pay for improvements in any of the other production conditions, including sea-lice infestation of wild salmon, escapees and certification. One reason for this result may be that other stakeholders are a heterogeneous group, with quite diverse opinions about what are the important environmental challenges for salmon farming and what can be done to combat them.

Finally, the results presented in this report are based on only a few fish farms in Norway and Scotland. Although results are relatively robust, it must be taken into consideration that there may be a larger variation in opinions and viewpoints in the population. As such, we cannot guarantee that the presented results are representative. Still, they do give valid insights into priorities of stakeholders in the farmed Atlantic salmon industry when it comes to efforts to prevent negative externalities, i.e. to reduce environmental effects of the production.

The method used, choice experiment, is very efficient in teasing out respondents' preferences and viewpoints, without asking directly if they are willing to take actions to prevent such effects of the production, and if yes; how much they would be willing to spend on such efforts. We therefore hope to be able to collect sufficient data from the other case industry, the cod fisheries, to present results on this topic.

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