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Trade-offs in the transition to a blue economy - Mapping social acceptance of aquaculture expansion in Norway

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Abstract: Aquaculture is currently the fastest growing food industry globally, and proposed expansion plans include substantial increases in production over the next decades. While this will improve global food security, contribute to the blue economy and create jobs locally, the potential negative impacts on the marine environment could be massive. The existing literature suggests that further research needs to be conducted into the dynamic nature of the social-ecological systems which host aquaculture. This paper presents the results of a choice experiment survey of Norwegian households' trade-offs between salmon production and job creation, and the detrimental impacts on the marine environment. Most respondents were at the outset neutral or supportive of plans for a substantial increase in aquaculture production. However, when informed about potential environmental impacts in terms of marine plastics and salmon lice affecting wild salmon stocks, and asked to trade these off against the positive effects, the majority opposed the plans and expressed a positive willingness-to-pay to avoid the planned expansion. Applying a hybrid mixed multinomial logit model we find that income, education and to some extent age, along with environmental attitudes, explain most of the variation in people's preferences. Support for large aquaculture expansion is higher among people who consume farmed salmon frequently and those living in areas with a high density of aquaculture farms. Hence, we do not find the so-called "not in my backyard" (NIMBY) effect. These results, which arguably contrast with previous studies of environmental impacts from aquaculture, can be useful for public planners globally as they consider expanding the blue economy.

Keywords: aquaculture expansion, environmental impacts, inhabitants' preferences, choice experiment

JEL codes: Q22, Q28, Q51

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1. Introduction

Growing human populations demand increased production of food, and an increasing share of the food needs to come from the marine hydrosphere (Lillebø et al., 2017, Soma et al., 2018). This shift is already underway, and currently aquaculture is the fastest growing food production sector globally (Council of European Union, 2017, FAO, 2020, Venier, 2021). However, aquaculture does not come without a potentially significant environmental footprint. The sector releases huge amounts of organic waste in the form of faeces and surplus feed, leading to modified biogeochemical processes (Nordi et al., 2011), modified sediment conditions (Valdemarsen et al., 2012), stimulating phytoplankton growth and plankton blooms (Gowen and Ezzi, 1994) and changes in the composition of seaweed communities in the littoral zone (Krause-Jensen et al., 2007). Another severe effect is sea-lice infestation of wild Atlantic salmon, a red-listed species (Thorstad et al., 2021). Finally, marine plastic waste is an increasing problem, and although the share originating from aquaculture is small (Skirtun et al, 2022), the sector has not taken control of this pollution problem (op cit), which is unfortunate given the prospective expansion. Efforts to avoid or mitigate these environmental impacts are of crucial importance for a sustainable expansion of the aquaculture sector. However, previous research demonstrates that the industry itself has identified people's risk perceptions and local social acceptability as key factors in the sustainable growth of aquaculture (Joyce and Satterfield, 2019, Billing, 2018). Hence, in addition to knowledge about both actual environmental impacts from aquaculture and ways to avoid and mitigate these, what is needed to ensure sustainable aquaculture growth is research into people's perceptions of the impacts and risks, and the conditions required for the social acceptance of further growth of the sector.

According to the UN, United States has the largest marine aquaculture potential (Kapetsky et al., 2013), but to realize this potential it is necessary to include local and national interest groups in the planning and implementation of the expansion and the governance system needs to be reformed (Knapp and Rubino, 2016). Another promising country for Atlantic salmon growth is Norway (Kapetsky et al., 2013, p.31, fig.30). Due to comparative and natural advantages Norway has become world leading in production of farmed Atlantic salmon, producing around 50% of global supply (FAO/GLOBEFISH, 2021). Moreover, there are administrative plans, supported by leading politicians, for an expansion equal to one million tons each decade up to 2050, starting from a baseline production equal to about 1 million tons in 2010 (Olafsen et al., 2012).

Norwegian aquaculture is divided into 13 production areas, as shown in Figure 1. Expansion may only take place in green production areas, which are areas where the probability that wild migrating salmon dies due to sea lice infestation is less than 10%. Hence, currently expansion may not take place in production areas 3-5 and 11. There are two ways expansion takes place; 1) production levels at existing sites/locations and within existing licenses is increased, and 2) new licenses are issued which are used at new sites/locations. The main share of the production of farmed salmon in Norway currently takes place in production areas 3-10. However, it is expected that relative more of future growth will come in the north, i.e. production areas 11-13 compared to areas 3-10. Production areas 1-2 are of less importance both with respect to current production and future growth.

Figure 1. Production areas for marine aquaculture in Norway. Source: Norwegian Directorate of Fisheries.

The planned expansion calls for considerations regarding sustainability. While the concept of aquaculture carrying capacity (CC) has existed for more than 30 years, CC estimates remain very much industry focused with only limited consideration for the marine environment. The CC concept has been less able to take account of the dynamic nature of the social-ecological systems which host aquaculture, incorporating the ecological, social and economic costs and benefits of aquaculture development (Kluger and Filgueira, 2021). In a more holistic analysis it is important to understand the role of the public, but only a few papers emphasise the importance of public perceptions when it comes to success for aquaculture growth. For example, Joyce and Satterfield (reported in Anderson et al., 2019) find that the public risk perceptions of aquaculture have been a more important indicator of the potential for aquaculture growth than capacity or cost-benefit assessments. Furthermore, Billing (2018) reports that public perception and local social acceptability have been identified by the industry as key factors in the sustainable growth of finfish aquaculture (Billing, 2018).

This paper presents the results of a survey among the Norwegian population on their knowledge and acceptance of aquaculture production, its ecological impacts, and the planned expansion of the sector. Whether people support aquaculture expansion or not likely depends on, among others, their assessment of the sector and general environmental beliefs. It has been demonstrated that perceptions towards aquaculture not necessarily only depend on traditional socio-demographic variables like gender, age, income and education, but rather is related to general environmental beliefs and place (residency) (Murray and D'Anna, 2015). Hence, we hypothesize that among the Norwegian population preferences for the planned aquaculture expansion is strongly correlated with attitudes towards the environment, as measured by the NEP (new environmental paradigm) index,[1] and residency in the sense of proximity of aquaculture facilities to own home or cabin (H1). Furthermore, we hypothesize that traditional socio-economic measures like age, gender, education and income play a subordinate role in explaining preferences for aquaculture expansion (H2). The paper continuous with presentation of data and methodological approach (section 2), results (section 3), discussion (section 4), and conclusions (sections 5).

[1] This is a set of 15 statements where even numbers represent the dominant social paradigm (DSP) and odd numbers represent the (current) new environmental paradigm (NEP). From these 15 statements we chose 3 DSP statements and 3 NEP statements.

2. Data and methods

2.1. Impacts from aquaculture as basis for the survey instrument

To test the hypothesis above, we chose to design and implement a choice experiment among the Norwegian population, following best practice in the field (Mariel et al. 2021, Khan et al., 2019, Zhang et al., 2020). A survey eliciting preferences for aquaculture growth needs to take into consideration both pros and cons of such growth. To have a balanced presentation of potential economic and environmental effects of aquaculture growth, we chose to include two of each as attributes in the choice experiment. The choice of attributes was based on a review of existing literature and interviews with experts in marine biology and aquaculture technology.

Norway hosts the largest stocks of wild Atlantic salmon globally, but in most fjords the number of fish returning to the river from which they originated to spawn has been decreasing, and the number of Norwegian salmon in the ocean is less than half of what it was in the 1980s (Thorstad, et al., 2020). While threats like acidification, parasites and overfishing have substantially decreased and are currently not regarded as critical to the populations, the largest threat to the wild Atlantic salmon now comes from aquaculture, mainly in the form of increased density of sea lice in Norwegian fjords with salmon farms. As a consequence, public policy to regulate aquaculture growth is currently based mainly on one environmental indicator; the probability that a young wild salmon will die due to sea-lice infestation during the trip from the river, through the fjord, and into the ocean.

Other, less prominent effects of salmon farming are its effects on commercial marine species. High density of aquaculture pens may contribute to displace species like cod from their traditional spawning places (Brattland et al., 2016), but this has so far not been verified scientifically. Furthermore, some emerging evidence has been found that commercial marine fish harvested in the proximity of salmon farms (SF) has a lower quality compared to fish harvested in areas without salmon farming (WSF). One study found that the proportion of fish with substantially reduced quality was 4-5 times higher for SF saithe compared to WSF saithe, but controlling for other factors, the differences due to diet are not significant (Uglem, et al., 2021).

Plastics are widely used in current aquaculture practices, and examples include ropes, buoys, PVC pipes and packaging materials for feed and chemicals (Skirtun et al., 2022). The wide application increases the risk of waste or loss, and the problem is amplified by inadequate waste management facilities and low staff awareness (op cit.). Still, the share of aquaculture-related litter as portion of all beach litter recovered is reported to be relatively low. For example, in the North Sea region it amounts to 12.4%, which includes items commonly used in aquaculture, but also in fisheries (Sandra et al., 2020). When adjusted to only include the four item categories in the OSPAR beach litter database specific to aquaculture the figure drops to 0.34%. On the other hand, abandoned and lost fishing gear, also commonly used in aquaculture, like netting for cages, ropes and line fragments, are often documented as a key source of marine life entanglement (Butterworth et al., 2012, Parker et al., 2019). Furthermore, floating plastic debris or sunken litter that forms new artificial habitats is a threat to the marine environment and biodiversity through altering or modifying assemblages of species (Werner et al., 2016). Most of the few initiatives to reduce the amount of plastic waste originating from aquaculture are local level initiatives. On national and international level responses to plastic pollution from aquaculture are almost absent (Skirtun et al., 2022). In Norway marine plastic is neither among the environmental issues which is obligatory to report on for aquaculture farms, nor is it strictly regulated and enforced by environmental authorities. This is unfortunate given the huge expansion that is planned for this sector in Norway the coming decades[2].

Although Norway is the largest producer of farmed Atlantic salmon, with about 50% of global supply, the industry is relatively modest when it comes to employment. The roughly 18,000 persons directly employed by the industry constitute 0.7% of total employment in Norway. Including employees in supply industries etc. add another 6650 (Robertsen and Iversen, 2021). While the total number of jobs in or related to the industry is relatively low, they are important for rural communities facing out-migration and dwindling populations. Total production in 2019 was 1,364,000 tons round weight (WFT) and using a conversion factor of about 0.2 (one meal includes 200 grams fish), this amounts to 33 million daily meals.

2.2 Survey design and impact attributes

We started out with a survey including a CE with the following attributes; sea-lice induced mortality for wild salmon, effects on other commercial species, marine plastic waste, jobs, and production. This DCE was used as a point of departure for discussion in three focus groups; one in each of an urban and rural coastal community, and one in an urban community in the interior of Norway. The focus groups were implemented in February, June and September 2020.

[2] There is, however, a hope that the recent initiative by UNEA (United nations environment assembly) of making a binding agreement to combat plastic pollution globally.

While the coastal municipality participants were mainly concerned with the environmental impacts and sustainability of aquaculture expansion, the inland participants pointed to the large contribution to global proteins from Norwegian aquaculture. All focus groups were concerned about jobs, but this was more prevalent in the rural municipality compared to the two urban municipalities.

Based on analysis of the focus group data we reformulated the survey and designed a choice experiment, which included sea-lice, marine plastic, jobs and meals as attributes. In a choice experiment, people are asked to choose one among typically 2 or 3 scenarios for a change in a commercial or non-commercial activity or sector. The scenarios are described by typically 4-6 characteristics, called attributes, describing the effects of the change. We used official plans suggesting a target for farmed salmon production of about 3 million tons in 2030 as the "business as usual" (BAU) scenario. The alternative scenarios all had lower expansion, as higher expansion is not realistic. As all attributes are positively correlated with production, the attribute levels were lower, or equal, in the alternative scenarios compared to the BAU. The attribute levels were decided as follows: For sea-lice, governmental regulations are set for aquaculture expansion in the form of upper limits for wild salmon mortality due to sea-lice infestation. The limits are 10%, 20% and 30% respectively, and thus we used these as attribute levels. We used the number of items identified as originating from the aquaculture industry by beach cleaning in the Lofoten islands in northern Norway to estimate levels for plastic waste. It is not obvious which type of waste originate from aquaculture, but a very conservative method was applied. First, items that potentially could originate from aquaculture was identified. Next, only if all other sources could be ruled out, the item was identified as originating from aquaculture. Out of 51,490 identified and registered items originating from industrial activities, 203 (0.4%) was defined as originating from aquaculture (Clean up Lofoten, 2019). We combined this estimate with data on the number of facilities in the area (10) and their aggregate production and calculated a "marine-plastic/production" ratio for aquaculture production. This ratio was multiplied by the current total production at national level to estimate the number of plastic waste items from aquaculture in Norway. Next, this was scaled up according to the growth scenarios. For the economic variables, we used current numbers of total production, as measured in volume (tons) and employees (number of people employed irrespective of whether on a full- or part-time basis) (Directorate of Fisheries, 2021). These numbers were scaled up linearly according to the expansion assumed in the scenarios. We converted production (in tons) into the corresponding number of meals using a factor of 0.2 as discussed above. The attributes and their levels used in the choice experiment are given in Table 1.

Finally, as results from choice experiments are usually expressed in monetary terms (i.e. willingness- to-pay, WTP), choosing scenarios other than the BAU has a cost. This is to assess whether people are willing to pay for changing current policy or plans.[3] The cost vector should start at a level that is assumed to be affordable for most participants, and take as it's highest-level an amount that is assumed acceptable to very few. To derive the cost vector, we used experiences from recent CE in Norway on marine and coastal issues (Aanesen et al., 2018, Dugstad et al., 2020).

Respondents were presented with alternative expansion scenarios and asked to choose the one they preferred. Alternative scenarios were described using various combinations of the attribute levels summarized in Table 1. The combinations of attribute levels presented in each of the choice tasks (i.e., the experimental design) were selected so as to optimize the D-efficiency of the multinomial logit (Ferrini and Scarpa 2007; Scarpa and Rose 2008), with priors based on the results of a pilot study.

Table 1 Attributes and attribute levels

Attribute	BAU level	Alternative levels, wave 1	Alternative levels, wave 2	Alternative levels, wave 3
Meals	33 (million)	16, 20, 27	16, 20, 27	16, 20, 27
Jobs	18 (thousand)	9, 12, 15, 18	9, 12, 15, 18	9, 12, 15, 18
Plastic	28 (thousand units	16, 20, 24, 28	16, 20, 24, 28	16, 20, 24, 28
Sea lice	30% (mortality)	10, 20, 30	10, 20, 30	10, 20, 30
Cost (in thousand NOK)	0	1, 2, 4, 6, 8	1, 2, 4, 6, 8, 16	1, 2, 4, 6, 8, 10, 12, 14, 16

Each respondent was presented with 6 choice cards, and each card had 2 or 3 alternatives.[4] Every choice card included a *BAU* scenario which corresponded with the current development plan and the cost of such an alternative was 0 NOK. An example choice task for choosing

[3] This assumes that there is a right assigned to those who are promoting the expansion, rather than the population having a right to a status quo situation without the aquaculture expansion. The focus groups did test whether such a formulation of the situation would be acceptable and realistic for the respondents.

[4] As part of the survey we implemented an experiment testing for variation in results for WTP depending on whether there were 2 or 3 alternatives to choose among in the choice cards. This experiment is analysed elsewhere.

participants' preferred aquaculture development scenarios at a given cost to them is presented in Figure 2. The translation of the survey instrument is available in the online supplement to this paper.

Figure 2 Example of choice card

	CURRENT PLAN	LOWER GROWTH 1	LOWER GROWTH 2
Meals per day based on Norwegian farmed salmon 	33 million	27 million	16 million
Number of jobs in the aquaculture sector 	18 thousand	9 thousand	12 thousand
Effects on wild salmon 	30% of young wild salmon in an area die	20% of young wild salmon in an area die	30% of young wild salmon in an area die
Annual release of marine plastic from the aquaculture sector 	28 thousand units	28 thousand units	24 thousand units
Annual increase in your personal income tax until 2030	0	4000	8000

2.3 Data collection

The survey instrument, including the 6 choice cards, was finalized in December 2020, and a pilot including 362 respondents, was implemented in December 2020 and January 2021. We used one of Norway's leading professional survey companies, which has a randomly recruited internet panel encompassing about 40,000 respondents covering the whole country, to conduct the pilot and then the full survey electronically.

Based on pilot results, the CE design was updated, and the main survey was implemented in three waves; one in February, one in early March, and one in late March 2021. Between each wave the CE design was updated, based on results from the previous waves.

Results from the first wave indicated that the cost of choosing a scenario with lower expansion was too low, as people seemed not to pay much attention to the cost attribute (we ask about this as part of the survey). Hence, the cost vector was increased, with more and higher levels in the two subsequent waves (see Table 1).

The main survey was closed on 16 April 2021, by which time 4713 respondents had been surveyed. The main survey was distributed among 11,035 panel participants, of which 5,289 actually opened it. Of these, 576 withdrew from the survey due to self-screening, which yields a response rate of 42.7%, a contact rate of 47.9%, and a completion rate (of those who actually opened the survey) of 89.3%. The sample is characterised as shown in Table 2.

Table 2 Characteristics of the sample and the Norwegian population (not complete)

Variable	Sample (n=4713, only main survey)	Population (Norway)
Female share	49.5%	50%
Age		
- Below 30	13.2	20.3
- 30-44	24.1	25.7
- 45-59	28.5	25.7
- Above 60	34.2	28.3
Education		
- Basic (10 years or less)	23.0	28.3
- Secondary (11-13 years)	38.9	37.0
- Tertiary, lower (14-16 years)	21.0	24.3
- Tertiary, higher (more than 16 years)	17.1	10.3
Geographic location		
- Oslo and capital area	24.7	24.5
- Rest of eastern Norway	25.7	26.4
- Southern and western Norway	31.0	31.1
- Mid and northern Norway	18.5	18.0
Livelihood		
- Employee	56.4%	60.5% [1]
- Self-employed	2.7%	
- Student	6.1%	6.9%
- Other*	34.8%	32.6%
Income		
Share of people living in the vicinity of aquaculture plant and where there are #x pens in a surrounding of 5 km from their home		
- More than 5	5.8%	
- 5 or less	9.6%	
- None	71.3%	
- Don't know	13.2%	
Own consumption of salmon		
- Yes	85.3%	
- No	7.4%	
- Don't eat fish	3.4%	
- other	3.9%	

*this includes retired people, people on social security, non-paid home work, and categories not included above

[1] includes self-employed

Table 2 shows that the sample is slightly older than the population, and somewhat better educated. Still, the differences are moderate, and we consider the sample to be reasonably representative for the Norwegian population.

2.4 Econometric framework

The theoretical foundations for the quantitative modelling of consumer preferences are provided by the random utility theory (McFadden 1974). In this model, the utility of individual i resulting from choosing alternative j in situation t can be expressed as:

$$V_{ijt} = a_i c_{ijt} + \mathbf{b}_i \mathbf{X}_{ijt} + e_{ijt} \tag{1}$$

where the utility expression is assumed additively separable in the cost of the alternative, c_{ijt}, and other attributes, $\mathbf{X}_{ijt}$; a_i and $\mathbf{b}_i$ denote parameters; and e_{ijt} is a stochastic component allowing for factors not observed by the econometrician to affect individuals' utility and choices. Note that a_i and $\mathbf{b}_i$ are *individual*-specific, thus allowing for heterogeneous preferences amongst respondents and leading to a Mixed Logit Model (MXL; Revelt and Train 1998). Assuming instead that parameters are the same for all respondents implies homogenous preferences and leads to the usual (conditional) Multinomial Logit Model (MNL; Greene 2018) as a special case.

The logit probability requires a specific distribution for the variance of the stochastic component of the utility function e_{ijt}. Without a loss of generality, this can be achieved by normalising utility function coefficients, leading to the following specification:

$$U_{ijt} = \sigma_i a_i c_{ijt} + \sigma_i \mathbf{b}_i \boldsymbol{X}_{ijt} + \varepsilon_{ijt} \tag{2}$$

It should be noted that due to the ordinal nature of utility, this specification still represents the same preferences as (1). The estimates $\sigma_i a_i$ and $\sigma_i \mathbf{b}_i$ do not have direct interpretation, but if interpreted in relation to each other, the scale coefficient σ_i cancels out.

Given that we are interested in the marginal rates of substitution with respect to the monetary attribute c_{ijt}, it is convenient to introduce the following modification of (2), which is equivalent to using a money-metric utility function (in our case, it means estimating the parameters in WTP space; Train and Weeks 2005; Scarpa, Thiene, and Train 2008):

$$U_{ijt} = \sigma_i a_i \left(c_{ijt} + \sigma_i \mathbf{b}_i \boldsymbol{X}_{ijt} \right) + \varepsilon_{ijt} = \lambda_i \left(c_{ijt} + \boldsymbol{\beta}_i \boldsymbol{X}_{ijt} \right) + \varepsilon_{ijt} \tag{3}$$

In this specification (rescaling the utility function), the vector of parameters, $\boldsymbol{\beta}_i = \mathbf{b}_i / \alpha_i$ can be directly interpreted as a vector of the implicit prices (marginal WTPs) for the non-monetary attributes, $\mathbf{X}_{ijt}$, facilitating an interpretation of the results.

In addition to estimating WTP for choice attributes, best achieved by the MXL model in WTP-space, our goal is to investigate the influence of a range of behavioural and socio-demographic drivers of preferences/WTP. Considering different ways in which these drivers are measured and the associated measurement errors, they can conveniently be included in the model is by using a hybrid choice model (Ben-Akiva et al. 1999; Ben-Akiva et al. 2002). A hybrid choice model is a flexible tool that incorporates perceptions and cognitive processes into a random utility framework. Indicator variables used to measure psychological or sociological constructs enter the model through latent variables, rather than being directly interacted with choice attributes – the model can thus be viewed as a combination of a classical MXL with a Multiple Indicators, Multiple Causes (MIMIC) model (Jöreskog and Goldberger 1975). In our case, the MXL links the utility maximization process and observed explanatory variables (attributes of alternatives, socio-demographics) to the observed choices, whereas the MIMIC component identifies latent factors linked with observed indicator variables (e.g., answers to attitudinal questions in the survey). The hybrid choice framework has been extensively used over the last decade to better understand the attitudes and psychological factors that drive individuals' preferences towards non-market goods and policies. In the environmental context, applications include stated preference studies on individuals' choices regarding improvement of coastal water quality, land-use policies, conservation policies and recycling (Hess and Beharry-Borg 2012; Hoyos, Mariel, and Hess 2015; Mariel, Meyerhoff, and Hess 2015; Lundhede et al. 2015; Bartczak et al. 2016; Czajkowski, Hanley, and Nyborg 2017; Zawojska, Bartczak, and Czajkowski 2019; Boyce, Czajkowski, and Hanley 2019).

Formally, the random parameters $\boldsymbol{\beta}_i$ and λ_i depend on individual-specific socio-demographic $\mathbf{SD}_i$ and latent variables $\mathbf{LV}_i$. The functional form of this dependence may vary due to distributional assumptions. For a normally distributed $\boldsymbol{\beta}_i$, this dependence is of the form:

$$\boldsymbol{\beta}_i = \boldsymbol{\chi}\mathbf{SD}_i + \boldsymbol{\gamma}\mathbf{LV}_i + \boldsymbol{\beta}_i^*, \quad (4)$$

where $\boldsymbol{\chi}$ and $\boldsymbol{\gamma}$ are matrices of estimable coefficients and $\boldsymbol{\beta}_i^*$ has a multivariate normal distribution with a vector of means and a covariance matrix to be estimated. For the log-normal distribution we have:

$$\lambda_i = \exp\left(\boldsymbol{\delta}\mathbf{SD}_i + \boldsymbol{\eta}\mathbf{LV}_i + \lambda_i^*\right), \tag{5}$$

where $\boldsymbol{\delta}$ and $\boldsymbol{\eta}$ are vectors of estimable coefficients and λ_i^* follows a normal distribution with the parameters describing its mean and standard deviation to be estimated. As a result, the conditional probability of individual i's t choices is given by:

$$P\left(y_i \mid \mathbf{X}_i, \boldsymbol{\beta}_i^*, \lambda_i^*, \mathbf{SD}_i, \mathbf{LV}_i, \boldsymbol{\chi}, \boldsymbol{\delta}, \boldsymbol{\gamma}, \boldsymbol{\eta}, \boldsymbol{\theta}\right) = \prod_{t=1}^{T_i} \frac{\exp\left(\lambda_i\left(c_{ijt} + \boldsymbol{\beta}_i \mathbf{X}_{ijt}\right)\right)}{\sum_{k=1}^{C} \exp\left(\lambda_i\left(c_{ikt} + \boldsymbol{\beta}_j \mathbf{X}_{ikt}\right)\right)} \tag{6}$$

where $\boldsymbol{\theta}$ is a vector of parameters on which $\boldsymbol{\beta}_i^*$ and λ_i^* depend.

The measurement component of the hybrid choice model can be specified as follows:

$$\mathbf{I}_i^* = \boldsymbol{\psi}\mathbf{LV}_i + \boldsymbol{\eta}_i, \tag{7}$$

where $\mathbf{I}_i$ represents indicator variables, $\boldsymbol{\psi}$ is a matrix of coefficients and $\boldsymbol{\eta}_i$ denotes a vector of error terms assumed to come from a multivariate normal distribution with zero means and an identity covariance matrix.[5] Essentially, we assume that indicators $\mathbf{I}_i$ are driven by (and hence they are used to measure) unobserved latent variables $\mathbf{LV}_i$ while allowing for measurement error, represented by the errors component $\boldsymbol{\eta}_i$. The model choices for the indicator equations depend on the particular application. The measurement equations could be linear, ordered, binary, multinomial, or count regressions, whatever best fits/suits the interpretation of each indicator.

Finally, after combining equations, we obtain the full-information likelihood function for our hybrid mixed logit (HMXL) model, where for ease of exposition we stack the parameter vectors $\boldsymbol{\chi}, \boldsymbol{\delta}, \boldsymbol{\gamma}, \boldsymbol{\eta}, \boldsymbol{\psi}$ into the single vector $\boldsymbol{\Omega}$:

$$L_i = \int P\left(\mathbf{y}_i \mid \mathbf{X}_i, \boldsymbol{\beta}_i^*, \lambda_i^*, \boldsymbol{\Omega}\right) P\left(\mathbf{I}_i \mid \boldsymbol{\Omega}\right) f\left(\boldsymbol{\beta}_i^*, \lambda_i^* \mid \boldsymbol{\theta}\right) d\left(\boldsymbol{\beta}_i^*, \lambda_i^*\right). \tag{8}$$

[5] It is important to note that the number of measurement equations need not equal the number of latent variables. For instance, cases may arise where more than one indicator for a latent variable may be available (This framework can accommodate such a setting by specifying multiple measurement equations for a single latent variable.

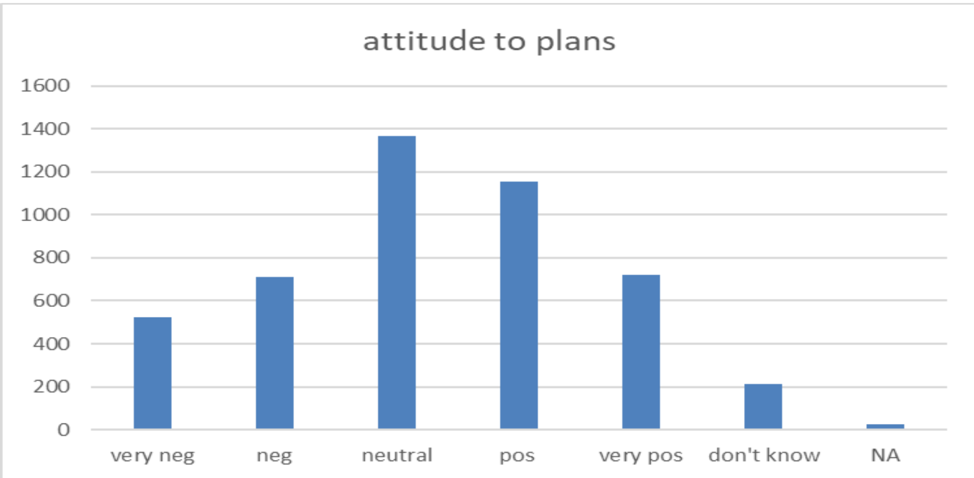
As random disturbances of $\boldsymbol{\beta}_i^*, \lambda_i^*$ are not directly observed, they must be integrated out of the conditional likelihood. This multidimensional integral can be approximated using a simulated maximum likelihood approach.[6]

3 Results

3.1 Attitudes to aquaculture expansion and knowledge of environmental and economic effects.

To assess pre-experiment attitudes to aquaculture expansion among the sample we started by giving a short introduction to the expansion plans, followed by question about whether they knew about these plans and how they assessed them. Just above 50% of the respondents either had heard about the plans or were very familiar with them. The answers to their assessment of the plan is given in Figure 3. They show that at the outset people are more on the positive side than on the negative side.

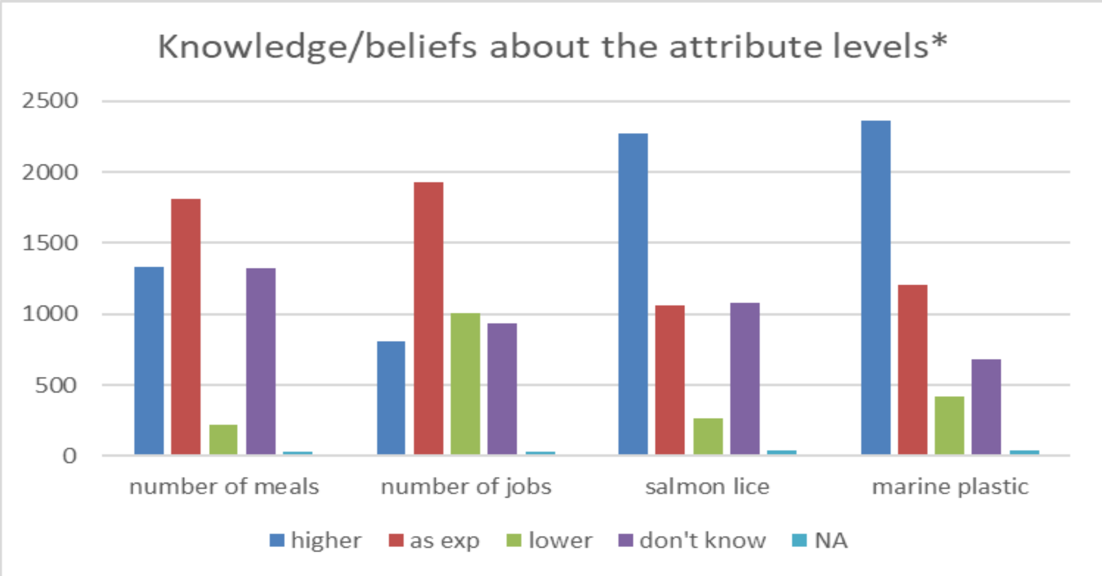
Figure 3 Pre-DCE attitudes to the plan among respondents, number of respondents reporting the various answer categories, N=4713



Prior to the choice cards we explained each of the four attributes separately, and asked respondents whether they knew about these potential effects. The replies are given in Figure 4 and shows that a majority of the participants were unaware of the magnitude of the environmental impacts of aquaculture. On the other hand, they were far better informed about the magnitude of the economic impacts.

[6] The models were estimated using maximum simulated likelihood techniques, using 10,000 scrambled Sobol draws (Czajkowski and Budziński 2019). The software used here (estimation package for DCE data) was developed in Matlab and is available at https://github.com/czaj/DCE under CC BY 4.0 license. The dataset, additional results and estimation codes are available from http://czaj.org/research/supplementary-materials.

Figure 4 Pre-survey knowledge of attributes and attribute levels, number of respondents reporting if they thought the attribute levels were higher, lower, or as expected, N=4713



*these are the levels that we used to describe the situation if the planned aquaculture expansion up to 2030 is implemented.

3.2 Willingness to pay for the future development of aquaculture in Norway

Respondents' choices regarding future development policies and the associated cost were used to formally model their preferences. The parameters of their utility functions were estimated using the MXL model, which accounts for preference heterogeneity by assuming the preference parameters are random and follow a specific distribution in the population. We found that the best model fit is achieved if the status quo parameter is normally distributed, while meals, jobs, plastic waste and sea-lice and cost are negative log-normally distributed. All random parameters were assumed correlated, which further increases flexibility (and realism) of the model. The MXL model is estimated in WTP-space (Train and Weeks, 2005; Scarpa et al., 2006), so that the estimated means and standard deviations of preference distributions can readily be interpreted as WTP (in thousands of NOK per household per year). The results are presented in Table 3.

Table 3. The results of MXL model in WTP space, representing the estimated means and standard deviations of the distributions of respondents' WTP for the attributes of the new policy [thousands of NOK / household / year]

	Mean (st.err.)	St.dev. (st.err.)
Current expansion plans (SQ) (alternative specific constant)	-8.2754*** (0.7500)	29.9368*** (1.5997)
Meals = 20 (vs. 27)	0.6345** (0.3095)	1.0975*** (0.4064)
Meals = 16 (vs. 27)	1.7423*** (0.3156)	2.3486*** (0.4191)
Jobs = 15 (vs. 18)	-0.7774* (0.4357)	3.8452*** (0.8090)
Jobs = 12 (vs. 18)	0.6697 (0.4180)	2.7349*** (0.6792)
Jobs = 9 (vs. 18)	2.4366*** (0.4174)	2.6094*** (0.5423)
Plastic = 24 (vs. 28)	8.6284*** (2.5449)	1.9409*** (0.1175)
Plastic = 20 (vs. 28)	11.7534*** (2.9740)	1.8603*** (0.1130)
Plastic = 16 (vs. 28)	13.7421*** (2.9217)	31.9824*** (12.1216)
Lice = 20 (vs. 30)	9.4641*** (1.6284)	16.5463*** (4.8022)
Lice = 10 (vs. 30)	14.2773*** (2.1159)	25.7089*** (6.6925)
Model diagnostics		
LL at convergence	-16,726.52	
LL at constant(s) only	-27,595.49	
McFadden's pseudo-R^2	0.3939	
Ben-Akiva-Lerman's pseudo-R^2	0.5761	
AIC/*n*	1.2281	
BIC/*n*	1.2554	
n (observations)	27,388	
r (respondents)	4,780	
k (parameters)	91	

Notes: ***, **, * represent significance at 1%, 5%, 10% level, respectively. In the MXL model all utility function parameters are modelled as random and correlated. Status quo, meals and jobs are assumed normally distributed, while plastic lice and cost were assumed log-normally distributed actual means and standard deviations of the WTP distribution are provided). Full estimation results are available in the online supplement.

We found that the respondents were generally against the current development plan, as indicated by the negative coefficient of the alternative specific constant associated with the status quo (-8,275 NOK per household per year). However, there was large heterogeneity in this respect – the estimated standard deviation of this normally distributed parameter (29,937 NOK) was over three times larger than the absolute value of the mean. Regarding the attributes, Norwegians were most sensitive to the reductions in plastic pollution (from 8,628 to 13,742 NOK for reductions to 24, 20 or 16 thousand units, relative to the predicted level given the current plan, which equal 28 thousand units) and sea-lice infestation (9,464 NOK for a reduction to 20% and 14,277 NOK for a reduction to 10%, relative to the current limit of 30% mortality rate of migrating young salmon before reductions in the number of farmed salmon is required).

Interestingly, we found that the economic effects of the current and alternative plans for aquaculture expansion were valued much lower than the environmental effects, and in fact the respondents preferred lower expansion levels than those set out in the Norwegian government's current plans. Mean WTP for reducing annual number of meals provided by Norwegian farmed salmon to 20 million was estimated at 634 NOK per household per year, and for the reduction to 16 million at 1,742 NOK. Mean WTP for the number of jobs associated with salmon farming was also much lower, and only significant for alternative plans involving the creation of 9 thousand jobs, relative to the predicted 18 thousand jobs in the current plans.

Overall, the aggregated WTPs for future policies show that the Norwegian population prefer plans that are lower in scale and more sensitive to environmental issues (plastic and sea-lice) rather than economic (the number of salmon-meals and jobs) attributes. However, there is a large heterogeneity in this respect, as evidenced by relatively high and statistically significant coefficients of standard deviations of the estimated WTP distributions.

3.3 Behavioural and socio-demographic drivers of willingness to pay

The relatively high and statistically significant coefficients of standard deviations of the estimated WTP distributions demonstrated in Table 3 indicate substantial heterogeneity of preferences for aquaculture expansion in Norway. Previous work on people's perceptions of aquaculture, which likely constitute personal assessments of aquaculture expansion, demonstrate that there are no typical groups that "like" or "dislike" the industry. Rather, such perceptions are related to respondent's beliefs regarding several dimensions of the issue (e.g., environmental attitudes, past experiences, the scale of being affected), as well as driven by their socio-demographic characteristics (e.g., Faccioli et al. 2020; Murray and D'Anna 2015). In our case, we consider the following main drivers:

1. Ecological attitudes – measured using a bundle of 6 attitudinal statements regarding human beings and the natural environment, which were extracted from the validated scale of revised new environmental paradigm (NEP) statements (Anderson, 2012).[7]
2. Consumption – experience eating salmon and the role salmon play in one's diet. This includes how often the respondent eats farmed salmon, and how often the rest of the household eats farmed salmon
3. Proximity – respondents' subjective and objective relation and distance to aquaculture. This includes whether there are aquaculture facilities within 5 km of their home, whether they can see aquaculture facilities from their home or cabin, and finally the coastal line as measured in km of the county where they live. The latter is positively correlated with the probability for new aquaculture facilities being established in the county.
4. Education
5. Income
6. Age
7. Gender

Items 1-3 are attitudinal, based on the available literature and conclusion from qualitative pre-testing of the survey instrument. Items 4-7 cover the main socio-demographic drivers of respondents' preference heterogeneity. The hybrid choice modelling framework allows to include unobserved (latent) drivers to be included as explanatory variables of choice, as long as they are measured using one or more indicator variables. In our case, we adopt this approach with respect to items 1-5, which are modelled as latent variables (LV). This approach has several advantages (Boyce, Czajkowski, and Hanley 2019; Vij and Walker 2016), including (1) the possibility of using more than one indicator per latent variable (i.e. a particular driver of preferences), (2) using a well-suited model for each indicator variable, rather than directly interacting the variable with choice attributes, which implicitly assumes the effect of the variable is continuous and linear, and (3) avoiding the measurement error associated with the direct inclusion of indicator variables in the model, which was shown to potentially lead to bias (Budziński and Czajkowski forthcoming). Items 6-7, on the other hand, are socio-demographic variables that are likely measured without error, and hence they are modelled as direct interactions of the choice attributes in our model ($\mathbf{SD}_i$ in (4) and (5)).

[7] This is a set of 15 statements where even numbers represent the dominant social paradigm (DSP) and odd numbers represent the (current) new environmental paradigm (NEP). From these 15 statements we chose 3 DSP statements and 3 NEP statements.

Table 4. The results of the Hybrid Mixed Logit model, investigating the relative strength of behavioral and socio-demographic drivers of respondents' WTP for the attributes of the new policy [thousands of NOK / household / year]

Discrete choice component	Mean (st.err.)	St.dev. (st.err.)	Interactions of means						
			LV1 – Ecological attitudes	LV2 – Consumption	LV3 – Proximity	LV4 – Education	LV5 – Income	Age[8]	Gender[9]
Current expansion plans (SQ) (alternative specific constant)	-2.40***	2.93***	-2.06***	0.48***	0.40***	-2.62***	0.37*	-0.85***	-0.37***
	(0.16)	(0.18)	(0.15)	(0.10)	(0.14)	(0.21)	(0.19)	(0.10)	(0.10)
Meals	-6.34***	0.65***	0.23***	0.47***	-0.65***	0.48***	1.79***	-1.87***	0.20**
	(0.35)	(0.09)	(0.09)	(0.08)	(0.08)	(0.12)	(0.11)	(0.14)	(0.08)
Jobs	-5.00***	1.97***	-1.50***	-0.32***	-0.15*	-0.75***	1.39***	-0.16**	0.07
	(0.28)	(0.15)	(0.16)	(0.07)	(0.08)	(0.15)	(0.10)	(0.08)	(0.07)
-Plastic	-3.48***	1.15***	0.51***	0.05	-0.38***	0.83***	1.77***	-0.75***	0.27***
	(0.09)	(0.08)	(0.06)	(0.05)	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)
-Lice	-3.35***	1.06***	0.53***	0.03	-0.34***	0.70***	1.41***	-0.63***	0.17***
	(0.07)	(0.06)	(0.06)	(0.04)	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)
-Cost	-2.53***	1.44***	-0.11*	0.18***	-0.54***	2.23***	1.10***	-0.46***	0.21***
	(0.07)	(0.08)	(0.06)	(0.04)	(0.05)	(0.06)	(0.07)	(0.05)	(0.05)

Measurement component	Coef. (st. err.)	Indicator variable definition, possible responses and modelling approach
LV1 in RNEP1	0.44***	Likert-scale (1 – "strongly disagree" to 6 – "strongly agree") agreement with the statement
	(0.03)	"We are approaching the limit of the number of people the Earth can support." modelled as ordered probit
LV1 in RNEP2	-0.67***	Likert-scale (1-6) agreement with the statement
	(0.03)	"Humans have the right to modify the natural environment to suit their needs." modelled as ordered probit

[8] Respondents' age (normalized)
[9] Respondents' gender (female = 1; normalized)

LV1 in RNEP3	0.81*** (0.03)	Likert-scale (1-6) agreement with the statement “When humans interfere with nature it often produces disastrous consequences.” modelled as ordered probit
LV1 in RNEP4	-0.52*** (0.03)	Likert-scale (1-6) agreement with the statement “Human ingenuity will insure that we do not make the Earth unlivable.” modelled as ordered probit
LV1 in RNEP14	-0.54*** (0.03)	Likert-scale (1-6) agreement with the statement “Humans will eventually learn enough about how nature works to be able to control it.” modelled as ordered probit
LV1 in RNEP15	0.99*** (0.05)	Likert-scale (1-6) agreement with the statement “If things continue on their present course, we will soon experience a major ecological catastrophe.” modelled as ordered probit
LV2 in Own consumption	-3.72*** (0.78)	Likert scale (1 – “Yes, at least once a week” to 6 – “No, do not eat fish at all”) responses to the question “Do you eat Norwegian farmed salmon, and if so, how often?” modelled as ordered probit
LV2 in Household consumption	-2.08*** (0.16)	Likert scale (1-6) responses to the question “Do others in your household eat Norwegian farmed salmon, and if so, how often?” modelled as ordered probit
LV3 in Subjective proximity	-1.98*** (0.34)	Likert scale (1 – “Yes, many (more than five)”, 2 – “Yes, some (five or fewer)”, 3 – “No ”) responses to the question "Are there any sea-based salmon farms within 5 km from where you live?" modelled as ordered probit
LV3 in Sites visible from home	-0.57*** (0.16)	Likert scale (1 – “Yes, I see many (more than five)”, 2 – “Yes, I see some (five or fewer)”, 3 – “No, no one sees”) responses to the question “Can you see cages for salmon farming from the house where you live?” modelled as ordered probit
LV3 in Sites visible from cabin	-0.52*** (0.05)	Likert scale (1 – “Yes, I see many (more than five)”, 2 – “Yes, I see some (five or fewer)”, 3 – “No/do not have a cabin”) responses to the question “Can you see cages for salmon farming from your cabin / holiday home?” modelled as ordered probit
LV3 in Coastline length	0.50*** (0.02)	Respondent’s municipality coastline length (including islands) modelled as a continuous variable (linear regression)
LV4 in Education	0.06* (0.03)	Respondents’ education level (1 – Primary school education, 2 – Upper secondary general education, 3 – Upper secondary vocational education, 4 – Vocational school, 5 –University / college education with up to 4 years duration, 6 – University / college education with a duration of more than 4 years) modelled as ordered probit

LV5 in Income	0.14*** (0.04)	Respondents' income (1 – under 200,000 kroner, 2 - 200,000 - 299,999 kroner, ... 9 - 1,000,000 kroner or more) modelled as ordered probit
Model diagnostics		
LL at convergence	-93,834.23	
LL at constant(s) only	-109,115.87	
McFadden's pseudo-R^2	0.1400	
Ben-Akiva-Lerman's pseudo-R^2	0.5821	
AIC/*n*	6.8627	
BIC/*n*	6.9056	
n (observations)	27,388	
r (respondents)	4,780	
k (parameters)	143	

Notes: ***, **, * represent significance at 1%, 5%, 10% level, respectively. In the MXL discrete choice component all utility function parameters are modelled as random and correlated. Status quo is assumed normally distributed, while meals, jobs, plastic, lice and cost are assumed log-normally distributed (means and standard deviations of the underlying normal distribution are provided). Full estimation results (including constants and thresholds of the ordered probit models) are available in the online supplement.

The results of our HMXL model are presented in Table 4. For simplicity and to facilitate interpretation, we now make the choice attributes enter the model continuously (rather than dummy-coded, as in Table 3). In this specification, a (positive or negative) log-normal distribution fitted all attributes best, except for the alternative specific constant, which was modelled as normally distributed (allowing for some probability density of WTP on both sides of zero). The mean WTPs estimated from this model are of secondary importance, as they are likely less precise than the results of the MXL model with dummy-coded attributes and no interactions (Mariel et al. 2020). However, the estimated interactions of the means with latent and socio-demographic variables allow for an insight into their relative importance for explaining preference heterogeneity. Note that all LVs, as well as socio-demographic variables in our model are normalized for zero mean and unit standard deviation. As a result, the coefficients of the interactions can readily be compared with each other to gauge the relative importance of each of our 7 drivers of preference heterogeneity.

Interpreting the qualitative results, we find that LV1 – the first latent variable – was positively related with all pro-environmental attitudinal statements (NEP 1, 3, 15) and negatively related with all anti-environmental statements (NEP 2, 4, 14). At the same time, we find that this LV reduced respondents' WTP for the SQ policy and made them less positive about the jobs created, while being positively linked with higher WTP for the number of meals produced, and more concerned about plastic and lice, as indicated by the signs of the interactions of this LV with respective/relevant attributes. The second LV represented more frequent consumption of salmon and was positively linked with the SQ policy and meals while also being negatively associated with the concern for the jobs created by expanded aquaculture production, and no statistically significant effects for other choice attributes. LV3 can be interpreted as a higher subjective or objective proximity to aquaculture sites (including potential visual intrusion). Interestingly, the interactions of this LV with choice attributes indicate that respondents who live in more aquaculture-heavy regions are generally more in favour of the expansion plans, less concerned with its effects in relation to plastic or lice, but also care less about new jobs and increased production of meals associated with the expansion plans.

Looking at the socio-demographic variables, we noted that respondents who were better educated were also less positive to the planned expansion, and the number of jobs it is likely to create, while being relatively more concerned with the number of meals created and environmental effects (plastic, lice). Similar tendencies were noted in relation to respondents' income, except for a no statistically significant effect for the alternative specific constant associated with implementing the expansion as originally planned and a positive, instead of negative effect for the number of jobs created. We find that older respondents were, ceteris paribus, willing to pay less for all attributes. Female respondents were more negative about the expansion plans and more concerned about the number of meals and environmental impact than men.

Following Murray and D'Anna (2015), we are able to compare the relative explanatory power of each of our 7 factors considered. We find, that the highest share of variation in respondents' preferences (WTP) is explained by their income and education, followed by environmental attitudes and age. Looking at the average absolute effect of each of these variables in the total heterogeneity explained in the model, each of these variables contributes to over 15% of explained variation (26, 21, 19 and 17%, respectively). On the other hand, the importance of proximity, consumption and gender is considerably lower (8, 5 and 4%, respectively). The relative importance of these explanatory variables is similar, if the effects for the alternative specific constant are excluded.

4 Discussion

The implementation of the expansion planned for farmed salmon in Norway over the next decades could be reduced and cause less detrimental environmental impacts, if decision makers take into consideration preferences stated by the Norwegian population in a large, nationwide survey. Our survey demonstrates that people throughout Norway, although more positive than negative when it comes to aquaculture expansion, do not unconditionally support these plans. When made aware of the potential negative environmental impacts due to increased sea lice infestation among wild salmon and more marine plastic, they demonstrate on average a significant willingness to pay to reduce these effects by limiting the planned growth. The positive WTP for a lower number of meals and jobs shows that people accept, and are willing to pay for lower economic output in the form of production (number of meals) and jobs. Hence, people are on average willing to forego economic benefits if this means that the environmental impacts are reduced. That said, the survey results also demonstrate that the heterogeneity in preferences is large, and for example, despite respondent on averabe being in favor of reducing the number of meals produced, 23% of the respondents would not find limiting the production to 16 (from the planned 27) beneficial. Similarly, despite respondents being in favor of extension programs involving fewer jobs, our model indicates that 17% of the respondents would find reducing the number of jobs to 9 (from the planned 18) unfavorable.

While environmental beliefs (i.e. that humans are over-exploiting natural environment) lead to more negative preferences for the current expansion plan and larger WTP to reduce the detrimental effects on the wild salmon and from marine plastic, higher consumption of farmed salmon and proximity to aquaculture facilities lead to more positive preferences for the current expansion plan. Actually, proximity to aquaculture facilities leads to lower concerns for detrimental environmental and ecological impacts. These findings are partly in concert with those of Murray et al. (2015), which showed that the most important predictor variables of attitudes to the aquaculture sector were those related to shellfish consumption, environmental beliefs and place of living of the respondent. For example, more frequent shellfish consumption was associated with more positive attitudes to aquaculture, more pro-ecological world views were correlated with more negative views of the sector. Although the results of Murray et al. (2015) are in concert with ours regarding the direction of the correlation, they differ when it comes to the importance of the various factors. In our survey income and education, in addition to environmental beliefs, are the most important factors to explain heterogeneity in preferences for aquaculture expansion, whereas income and education turned out not to be very important explanatory factors in the survey of Murray et al. (2015). Hence, we can reject both our hypothesis that preferences towards aquaculture expansion are more correlated with environmental attitudes, salmon consumption and proximity to aquaculture facilities (H1), and less correlated with socio-demographics like age, education and income (H2).

Interacting the attributes with the age variable shows that younger people are more positive than older people about reducing the detrimental environmental effects of the expansion. One the other hand, they are also more positive towards the current expansion plan and the new jobs that will be created. Hence, younger people do welcome the current plan more strongly than older people do, but at the same time they are willing to make larger efforts than older people to reduce the detrimental environmental effects in the form of sea lice infestation of wild salmon and plastic waste from salmon farms. These insights are important because the current plan is scheduled to be implemented during the next decade, and then from 2030 to 2050 there are plans for another 2 million tons expansion in the Norwegian production of farmed salmon (Olafsen et al., 2012). Hence, it is the younger generations, rather than the older, that will be the ones to experience most of the expansion. Our results then predict, or suggest, that aquaculture expansion can be relatively smoothly carried out if greater consideration is given to the avoidance or mitigation of detrimental environmental effects.

Another result of particular interest is the spatial variation, which indicates that people who live in immediate proximity to aquaculture facilities and/or in coastal areas that will host new aquaculture facilities are more positive about the current plan compared to people living in other parts of Norway. This includes coastal parts of Northern Norway, and under the current growth plans, it is assumed that this part of the country will host a super-proportional share of the expansion. As of today, Western Norway is the main area where marine salmon farming is carried out, but in the future, this may shift north. Hence, the viewpoint of the population in the north is especially relevant. Although they, at least those living along the coast, are less skeptical about the current growth plans, they also state higher WTPs to reduce the environmental effects of the planned expansion compared to people in other regions where there is no current or planned salmon farming.

Finally, we do demonstrate some differences in preferences for aquaculture expansion across gender and age, showing that women and younger persons are more negative to the planned expansion and more concerned about the environmental effects. This is in concert with Ruiz-Chico et al. (2020) showing that some groups were more sceptical to aquaculture expansion, e.g. women and low-income consumers. Ruiz-Chico et al. (2020) recommend implementing informative campaigns to improve consumers' knowledge and thereby their perception of aquaculture food. Taking into account the low awareness about environmental impacts of aquaculture expansion in Norway, and the current governmental plans of substantial expansion of the sector, being open about and bring into the public debate environmental issues connected to aquaculture is a strategy that should be considered. This may hinder popular resistance and increasing societal costs connected to the implementation of the sector's expansion plans in the future.

For future research, it could be of interest to implement this survey in countries that have the most important markets for farmed Norwegian salmon. For people in these countries, larger production of farmed salmon in Norway may mean lower market prices on farmed salmon, and if the salmon is further processed in the import country, which is the case for e.g. Poland, it would mean more jobs in the import country. This would have to be traded off for less wild Atlantic salmon spawning in Norwegian rivers and more marine plastic along the Norwegian coast. Due to so-called distance decay, we would expect lower (absolute value) WTP for avoiding the environmental impacts (sea-lice and marine litter). It is more unclear what should be hypothesized for the economic variables.

5 Conclusions

This paper reports results from a survey implemented among about 4700 Norwegian inhabitants, asking their knowledge of and preference for aquaculture expansion plans in Norway. As part of a discrete choice experiment (DCE) they were asked to trade off the positive effects of aquaculture expansion such as increased global food production and more jobs (in Norway) against negative externalities like increased density of sea-lice and increased marine plastic litter.

The estimated WTPs for the food production and jobs variables were positive, but in magnitude they were substantially smaller than the sea lice and marine plastic variables. This implies that for Norwegians the positive effects in terms of increased global food security and creating new jobs in Norway are not large enough to outweigh the social costs connected to the increased threat to wild Atlantic salmon stocks (due to increased sea-lice density) and the increased amount of marine plastic along the coast emanating from expanded aquaculture production.

Even though the industry complies with environmental regulations in their expansion efforts, other issues may be of equal importance for the success of these efforts. Strong public risk perceptions, and thus resistance, could mean delays and increased transaction costs for the industry due to continuous protests against expansion. Moreover, it has been verified that the industry is sensitive to negative publicity in international markets (Amberg and Hall, 2008, Olsen and Osmundsen, 2017), and controversies between the local population and the industry will easily reach markets where the salmon is sold. Hence, a “social contract” with the population may be preferable for the future performance of the industry, even if this contract implies a lower expansion in production than the current plans.

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