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Stakeholders' perception and willingness-to-pay for an aquaculture-based fisheries enhancement program for coastal cod in Southern Norway

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ABSTRACT

The coastal cod fishery in Southern Norway has experienced a significant decline over the last decades. Recreational fishing for cod in the eastern part of the country is currently banned. Fisheries managers have adopted a variety of strategies to sustain the populations for resource users. Aquaculture-based fisheries enhancement has been considered as an alternative intervention to rebuild overexploited cod stock or to improve the opportunity for marine fishing. However, there has been a debate regarding its ecological and social effectiveness among stakeholders. In this paper, we conducted an online contingent valuation survey aiming to understand stakeholders' perceptions and attitude towards restocking of hatchery-produced juveniles as a potential restoration approach to rebuild depleted coastal cod populations and their willingness to pay for the implementation of such an enhancement program in southern Norway. Results indicate that the public has a positive perception to the potential restocking program. The average Willingness-To-Pay (WTP), e.g. fishing license fee, is approximately 175 NOK and 693 NOK if all of the respondents, and only counting those who are willing to, contribute. The introduction of a minimum fishing license fee of 175 NOK (approximately 17€) would cover the cost of production of over 20 million juvenile cod of appropriate size for release. Age of the respondents, the frequency of their fishing trips, and their perception of the decline of coastal cod were the main drivers for the WTP contribution while the amount of the WTP was strongly correlated to targeting particular species, educational level, and place of residence. Considering the critical situation of the coastal cod populations in southern Norway, together with the significant advances in cod rearing techniques, in fish tagging technology and the maturation of fisheries enhancement as science, and the positive stakeholders' perceptions and attitudes towards such an aquaculture-based enhancement program revealed from this study, it may be the time to re-evaluate the potential integration of a holistic cod restocking program within Norwegian coastal zone management.

1. Introduction

Intensive fishing pressure together with habitat degradation have been regarded as major causes for depletion of many fishery stocks. Aquaculture production has increased steadily to overcome the limitations of capture fisheries to supply the growing demand for seafood (FAO, 2022). Additionally, hatcheries produce billions of offspring for release purposes worldwide as part of aquaculture-based fisheries enhancement systems every year (Kitada and Kishino, 2006; Blanco Gonzalez et al., 2015). A wide range of species and systems have been used in an effort to enhance or restore the biomass of depleted stocks and/or assist in conservation programs. Among different systems, stock enhancement aiming to sustain and increase fishing yields, and restocking which attempts to rebuild depleted populations have been, arguably, the two most common approaches implemented for marine fish species (Bell et al., 2008).

Initial experiences of releasing offspring of a marine fish species focused on Atlantic cod (*Gadus morhua*) yolk-sac larvae, dating back to 1878 in the USA and 1884 in Norway (Smith et al., 2002). The Norwegian cod restocking program was initiated by captain Gunder M. Dannevig at his facility in Flødevigen in Southern Norway. The program operated for several decades, releasing millions of unmarked yolk-sac

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larvae until 1971 when it was suspended. Techniques for mass production of juveniles of various species were developed in Japan, and the Japanese Marine Stock Enhancement programme was started in 1963; it has become a reference with around 80 marine species targeted since its initiation (Kitada and Kishino, 2006). The scientific progress has, however, been hindered by the absence of approaches that enable the identification of previously released organisms. Such limitations have impeded any attempts to quantify the effects of hatchery releases and fragmented the community of fisheries biologists (Leber, 1999). Indeed, it was not until 1989 that the first peer-reviewed scientific publication evaluating the effects of marine fish releases empirically was documented in English (Tsukamoto et al., 1989). Since then, technological developments to use new marine species in aquaculture together with advances in tagging technologies and changes in fisheries governance revitalized the interest to evaluate the potential of hatchery-produced offspring releases to enhance marine resources.

Scientific literature documenting various degrees of success started flourishing (Howell et al., 1999; Leber et al., 2004; Kitada and Kishino, 2006; Blanco Gonzalez et al., 2008a). A Responsible Approach compiling a series of principles to guide the successful implementation and development of marine enhancement systems was widely accepted and implemented (Blankenship and Leber, 1995; Lorenzen et al., 2010). The knowledge gained over the last three decades has prompted the development of marine fisheries enhancement science and shifted early efforts on aquaculture production and offspring survival towards the adoption of a more holistic approach. Their success to improve and restore fisheries is now measured in a broader context; including biological, social, institutional and economic criteria (Blanco Gonzalez et al., 2008a, 2008b; Loneragan et al., 2013; Lorenzen et al., 2013). Additionally, it is possible to predict the potential outcomes of these initiatives a priori and evaluate them against alternative fisheries management approaches (Garlock et al., 2019; MacNamara et al., 2022). Hence, aquaculture-based enhancement systems have become an integral part of the fisheries management toolkit and are envisioned to play a major role in seafood provision and ecosystem services in the face of climate change and increased anthropogenic pressure (Taylor et al., 2017; Lorenzen et al., 2021).

Recreational fishing holds a crucial role along the Norwegian coast with the country leading the participation rate in Europe (Hyder et al., 2018). This activity is deeply ingrained into coastal life and communities. The tradition of recreational fishing in Norway is not merely a leisure pursuit, it reflects a way of life, cultural heritage, and a source of economic subsistence for local communities. The stock of coastal cod in Norway has dwindled over the years (Vondolia et al., 2020). Particularly, the coastal Atlantic cod fishery in Southern Norway has experienced a significant decline over the last century (Jonsson et al., 2016). Fisheries managers have adopted a variety of strategies to protect and sustain populations at a healthy status. The production of juvenile cod under semi-natural mesocosm conditions promoted the establishment of the Norwegian Sea Ranching Program (PUSH) to study the biological and economic basis for enhancement from 1990 to 1997. Results at the end of this program recognized the potential for restocking to rebuild depleted cod populations and become an integrated part of coastal zone management but emphasized the need to improve rearing techniques to reduce offspring production costs and to make the programs cost-efficient (Moksness and Støle, 1997; Moksness, 2002).

Similar to other nations, introducing a fishing fee to the growing tourist fishing industry to cover the production costs of the offspring was suggested (Moksness, 2002). However, this suggestion did not come to fruition and any attempt to release cod was abandoned. More recent approaches to rebuild the depleted cod stocks, such as the establishment of no-take zones have not reverted the situation, and recreational fishing for cod in the eastern and southern part of the country is currently banned (Directorate of Fisheries, www.fiskeridir.no/Fritidsfiske/Artar/Vern-av-kysttorsk-i-soer). The dramatic situation of coastal cod in southern Norway has re-opened the previous debate regarding the implementation of proactive restoration management approaches such as restocking of hatchery-produced juveniles. Besides the significant above-mentioned advances in aquaculture-based enhancement science worldwide, the last two decades have also witnessed some major accomplishments specific to cod that have invited optimism. In 2003, the Norwegian National Cod Breeding Program was established, and it has contributed to improving rearing practices, reducing offspring production costs and closing important knowledge gaps on cod biology (Puvanendran et al., 2022). Advances in molecular technologies have also unveiled fundamental mechanisms of critical relevance for survival and adaptative fitness in cod (Barth et al., 2017; Knutsen et al., 2018).

The successful implementation of any management strategy, including marine fish restocking, involves some inherent risks and uncertainties that should not be overlooked (Blanco Gonzalez et al., 2012; Lorenzen et al., 2010). The integration of the social-economic dimension and early engagement of stakeholders in the consultation process is crucial to reach consensus decisions and set up common goals that minimize conflicts and lead to successful outcomes and effective management programs (Lorenzen, 2014; Obregón et al., 2020). To provide some insights into the restocking debate in Norway from local stakeholders' perspectives and for future management strategies, we conducted an online survey with a structured questionnaire aiming to understand stakeholders' perceptions and attitudes towards a potential restocking program to rebuild depleted coastal cod populations, as well as their opinions about the current management of the coastal fisheries in southern Norway, specifically in Agder county. The questionnaire was primarily distributed among resource users and interest groups with their residence in Agder, targeting recreational anglers in particular. Additional stakeholder groups included professional fishers, fishing tourism operators, academic professionals in marine sciences, and the local public. Further, we assessed the willingness to pay in these stakeholder groups if such a potential restocking program would be implemented. The information and knowledge generated from this study should be of interest to decision-makers regarding the potential re-establishment of a sustainable holistic restocking program.

2. Materials and methods

2.1. Survey design and implementation

A survey was designed to gather insights into local resource users' opinions and willingness to contribute to the initiation of a restocking program of coastal cod in Southern Norway. The questionnaire followed the standard contingent valuation (CV) design, meticulously planned and considered with insights and guidelines from literature (e.g., Johnston et al., 2017; Whitehead, 2006). It was specifically tailored for our case and co-designed by an interdisciplinary team including social scientists, environmental economists, biologists and ecologists. This collaborative effort aimed to mitigate confusion and bias, ensuring to fulfill our research objectives. The CV method, a stated preference approach, is employed to elicit individual preferences through a hypothetical scenario. In our study, the hypothetical scenario is relatively straightforward compared to studies estimating non-use values (Johnston et al., 2017). It involves the baseline assumption that the coastal cod stock has declined. To rebuild this declining stock and facilitate future utilization of the stock, the implementation of an aquaculture-based fisheries enhancement program is proposed.

The questionnaire starts with an introduction section that describes the potential restocking program, the purpose of the survey and other ethical issues. Through an interactive dropdown feature in the introduction, respondents are offered the possibility to obtain additional detailed information about previous restocking experiences in Norway and the current state of the coastal cod stock in Southern Norway. The main questionnaire is then structured in four short sections, including: 1) fishing experience and behavior, e.g., fishing years/times, targeted species, fishing at coast or rivers; 2) perception about the fishery resources, its situation in connection to management practices, e.g., ecosystem services provided by the cod stock and fishery, changes in stock, causes of changes, effectiveness of current management measures; 3) interest, attitude and Willingness-To-Pay (WTP) to the potential establishment of a cod restocking/enhancement program; and 4) social-demographic information of respondents. A close-ended payment card is used ranging from zero to 5000 Norwegian krone (NOK).[1] An open choice is available for those who want to pay the amount that was not listed in the payment card. This is a one-time payment without a specific payment vehicle attached. However, a following related question – "How do you want your payment to be charged?" is asked. The answers consist of four choices: 1) a management program, 2) a conservation fund; 3) a tax; 4) fishing license fee. The respondents' social-demographic questions are continuously categorized to achieve anonymization.

The reason for not directly attaching the payment card to a specific payment vehicle is that if the payment card is linked to a particular payment vehicle, it becomes nearly impossible to avoid payment (Ivehammar, 2009), considering our intention of understanding the respondents' two-step decision process. This way, it allows respondents to express their WTP without immediately committing to a particular payment method. It aligns with the goal of capturing more nuanced insights into their preferences and decision-making. By providing flexibility in payment options after indicating WTP, it creates a scenario that better reflects the real-world decision-making process. This design choice should contribute to obtaining more authentic responses from the participants, anticipating their actual WTP.

The survey was originally created in English and translated into Norwegian, and the final survey was presented in both languages. The survey was reviewed by the experts, and pre-tested with focus group stakeholders including scientists to ensure that respondents correctly understand the questions and answer them appropriately, as well as to identify unclear questions to avoid errors and produce valid results. The survey was conducted using the tool SurveyXact following the data processing agreement with the University of Agder in accordance with the Personal Data Act and the Personal Data Regulations. The survey was administered online through the University of Agder. The questionnaire was distributed through identified email lists that are related to resource users and interest groups with their residence in Agder county, particularly targeting recreational anglers from November 2022 to March 2023. We sent a few reminders during the period. SurveyXact does not store IP addresses. In addition, to meet ethical principles in light of confidentiality and informed consent, we have checked the anonymization of respondents via the Norwegian Center for Research Data (NSD), and the survey was conducted anonymously and the information provided was confidential. The participation was voluntary, and the respondents were neither strictly stratified, nor recruited from the population due to time and budget constraints. However, we consider the respondents as representative of the general population in Southern Norway.

2.2. Modeling framework

2.2.1. Theoretical framework

We used the contingent valuation method to elicit stakeholders' preferences and to determine their WTP for implementing an aquaculture-based fisheries enhancement program aimed at rebuilding overexploited or depleted coastal cod stocks in Southern Norway. Respondents were initially asked whether they would like to contribute to this program with response choices of 'yes' or 'no'. If the answer was 'yes', they were then asked about their WTP to support such a program. In our study, the response variable, WTP, displays distinctive characteristics, with a large proportion of respondents expressing unwillingness to contribute to the potential enhancement program, a phenomenon termed as 'protest' responses by consensus (Lo and Jim, 2015; Rankin and Robinson, 2018). These 'protest' responses are treated as zero values, resembling a form of censoring in academic literature. Additionally, a right-skewed distribution is observed among the positive WPT values.

It is evident that the excess zeros can be generated from two processes and modeled separately. In our case, for those who answer the question "Would you be willing to contribute to a potential cod enhancement program?" with "No", the count is always considered as zero. This is the first process – participation or not. If they choose to contribute, but the WTP values are no-negative, including zeros due to economic situations such as low income or WTP value too high or other moral, political reasons. This is the second process, called the 'count' process. The zeros generated from the first process refer to 'structure zeros' or 'excessive zeros', and the second process as 'true' or 'genuine zeros', or 'sampling zeros'. Technically there are no genuine zeros in our study because only four respondents chose other amounts that are not given. They didn't specify their WTP amount, but provided conditions, such as more research, improvement of fish life in the sea, and a good program. We treated them as 'structure' zeros, not genuine zeros. In addition, there is missing data and information because a few of the respondents answered with the 'no answer' option. This can also be considered as 'excessive zeros'.

Given the presence of excess zeros and overdispersion (right-skewed) in positive WPT values, employing ordinary least squares (OLS) with this data structure or simply excluding these zeros from the dataset might lead to biased estimation errors (Humphreys, 2013). To address excess zeros in the data, the Tobit model (Tobit, 1958) has traditionally been applied to handle censoring. However, the Tobit model assumes that the same variables influence both the likelihood of non-zero observations (participation decision) and the level of positive observations (intensity decision), assuming 'genuine' zeros. An alternative approach to address this issue is the two-stage Heckman model (Heckman, 1979) or hurdle model (Mullahy, 1986). The Heckman model aims to correct for selection bias in observed data affecting both decision processes. In contrast, the hurdle model assumes that these decisions are separate processes, governing the occurrence of zero values and modeling the level of both zero and non-zero values. Essentially, the hurdle model assumes that the zero values could be observed at both stages. Hurdle models were developed as a more flexible model to fit count data with zero-inflation or zero-deflation (Mullahy, 1986; Heilbron, 1994; Feng, 2021). Similar to hurdle model, zero-inflated (ZI) count models are used to model the zero counts deriving from a two-component mixture model. The main distinction between zero-inflated and hurdle models lies in the way the zero counts are modeled and the interpretation of model parameters (Feng, 2021).

Given the data's overdispersion and the generation process of excess zero counts, we employ zero-inflated negative binomial regression (ZINB) and Hurdle Negative Binomial (HNB) models for empirical analysis. Both ZINB and HNB models are two-part models that allow for modeling two different processes: one describing the participation part accounting for the excess zeros and the other describing positive count (amount part). The ZINB model assumes that the zero counts resulted from two distinct processes and sources while the HNB model does not separate these zeros, and assumes they originate from a single source. In practice, differentiating between these sources is challenging as they are often unobservable or missing.

The ZINB is a multiple regression allowing modeling of unobserved heterogeneity using a gamma distribution since it releases the restriction of assumption that the variance is equal to the mean made by the standard Poisson model (Lambert, 1992; Green, 1994). The ZINB model contains two components governed by two generating processes. The first process is governed by a binary distribution with a logit model for generating structural zero counts, while the second process is governed by a negative binomial model to generate counts including zeros. These

[1] 1 US$ = 10 NOK as of 31st July 2023

two model components are described with two equations. The HNB model combines a binary model to estimate binary process of predicting zero counts and a zero-truncated negative binomial model to predict nonzero positive counts. In the ZINB model, zero counts can arise from both the binomial and the negative binomial (NB) distributions, thus, the two components of the mixture distribution are estimated simultaneously. On the other hand, in the HNB model, zero counts only arise from binomial distribution, therefore, the two-part models are not estimated simultaneously, but separately.

The ZINB and HNB models combine binomial probabilities with negative binomial distributions. Let y_i, $i = 1, 2, \dots, n$, be the WTP observations. For each observation i, the first process generates only zero counts (e.g., structural zeros), with probability π_i in ZINB and p_i in HNB, while the second process generates non-negative counts, which could result in zero counts (e.g., true zeros) for a negative binomial model with probability $(1-\pi_i)$ or $(1-p_i)$. In the current study, the two possible processes are whether a respondent is willing to contribute to the cod enhancement program or not. If the answer is 'No' and WTP is equal to zero, the probability is π_i or p_i and if the WTP is not zero, the probability is $(1-\pi_i)$ or $(1-p_i)$. Then, the probability distribution of the variable y_i with the ZINB model can be written as:

$$Pr(Y_i = y_i) = \begin{cases} \left\{\pi_i + (1-\pi_i)\left[\left(\dfrac{\alpha}{\mu_i+\alpha}\right)^{\alpha}\right], if\ y_i = 0\right. \\ (1-\pi_i)\dfrac{\Gamma(y_i+\alpha)}{\Gamma(\alpha)y_i!}\left(\dfrac{\mu_i}{\alpha+\mu_i}\right)^{y_i}\left(\dfrac{\alpha}{\alpha+\mu_i}\right)^{\alpha}, if\ y_i > 0 \end{cases} \quad (1)$$

In the HNB model, the probability distribution of the negative binomial distribution is defined by,

$$Pr(Y_i = y_i) = \begin{cases} p_i,\ if\ y_i = 0 \\ \dfrac{(1-p_i)}{1-(1+\alpha^{-1}\mu_i)^{-\alpha^{-1}}}\dfrac{\Gamma(y_i+\alpha)}{\Gamma(\alpha)y_i!}\left(\dfrac{\mu_i}{\alpha+\mu_i}\right)^{y_i}\left(\dfrac{\alpha}{\alpha+\mu_i}\right)^{\alpha}, if\ y_i > 0 \end{cases} \quad (2)$$

where μ_i is the mean of the NB model, α is dispersion parameter and $\Gamma(.)$ is a Gamma function.

2.2.2. Empirical econometric models

In the ZINB and HNB models, we need to empirically estimate μ_i, π_i *and* p_i using variables identified from the questionnaires. π_i *and* p_i are modeled with a logistic regression to governing the binary outcome of whether the count variable has a zero or positive, and μ_i is modeled as a log-linear regression. Thus, these models can be specified as:

$$log(\mu_i) = log(E(Y_i|x_i)) = \alpha x_i^T = \gamma_0 + \gamma_i x_i \quad (3)$$

$$logit(\pi_i) = logit(p_i) = \beta z_i^T = \beta_0 + \beta_i z_i \quad (4)$$

where γ and β are regression coefficients for the covariates x_i^T and βz_i^T. It should be noted that the explanatory variables, x_i and z_i for determining the mean, μ_i, and the probability π_i and p_i do not need to be the same. With the HNB model, all zeros are governed by a binary regression model while positive counts are governed by a zero-truncated negative binomial regression.

In the econometric models, the dependent variable (Y) represents the respondent's WTP, while the explanatory variables include the respondents' social-demographic information, fishing behavior and attitude variables. Fishing behavior variables consist of fishing frequency (number of times going fishing in the last season), whether the respondent targeted cod or other species, and their perception of changes (e.g., decline) in the cod stock. Attitude variables include opinions on who should pay for the program and motivation or enjoyment derived from fishing in terms of ecosystem services provided by the cod stock. The latter is categorized based on the importance assigned to food (as the most important factor for fishing), considering all the services (including food, social-cultural services) as important, or prioritizing other services (such as social-cultural services) over food. A detailed description and coding for each variable are reported in Table 1.

It is important to note that a simple backward elimination strategy was used for variable selection. Starting with a full model including all the identified variables, we progressively removed the most insignificant variables until all p-values were less than a threshold of 0.5. The criteria for variable selection dependent on various factors such as the study's goal, the number of variables, and sample size (Heinze et al., 2018). In our case, we used p-value threshold of 0.5 combined with Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for variable selection. The rationale for setting a relatively high P-value is to avoid eliminating potentially important variables based on the knowledge and experience. While not a perfect solution, it is

Table 1
Social-demographic characteristics of the respondents and some variables used in the econometric models.

Variables	Frequency	Percentage (%)	Coding
Gender			Binary
Male	118	69.00	1
Female	52	31.00	0
Age			Continuous
18–24	14	8.24	1
25–34	25	14.71	2
35–44	30	17.65	3
45–54	54	31.76	4
55–65	32	18.82	5
> 65	15	8.82	6
Household income			Continuous
< 500,000	28	16.47	1
500,000–700,000	38	22.35	2
700,001–1,000,000	33	19.41	3
1,000,001–1200 000	25	14.71	4
1,200,001–1 500,000	32	18.82	5
> 1 500,000	14	8.24	6
Education			Continuous
Secondary school	2	1.18	1
High school	27	15.88	2
Technical colleges	22	12.94	3
Undergraduate (BSc)	35	20.59	4
Postgraduate (MSc/PhD)	84	49.41	5
Residence			Binary
City	100	58.82	1
Rural	70	41.18	0
Municipality			Binary
Agder	142	83.53	1
Others	28	16.40	0
Target species			Binary
Cod	25	14.71	1
Other or any species	145	85.29	0
Fishing frequency – number of times going fishing in the last fishing season			Continuous
0	31	18.24	0
1: 0 ≤ 5	53	31.18	1
2: 6–10	26	15.29	2
3: 11–20	19	11.18	3
4: 21–30	5	2.94	4
5: > 30	36	21.18	5
Changes in cod stock			Binary
Decline	100	58.82	1
Others	70	41.18	0
Pays - the program should be paid by:			Categorical
Government	73	42.94	1
Government & fishing industry	57	33.53	2
All the parties & stakeholders	40	23.53	0
Motivation factors - go fishing			Categorical
Food is the most important	25	14.71	1
All services are important	92	54.12	2
Food is not important, but other services are important	53	31.18	0

considered reasonable. Thus, the variables displaying in Table 2 were only those with a p-value <0.5.

3. Results

3.1. Respondents' profile and fishing behavior

A total of 178 responses were received. After removing those which were incomplete, a final 170 valid responses were used for the analysis. Among 170 observations, 127 (75%) of the respondents are either not willing to contribute or report zero WTPs and the data a highly skewed sequence of counts. The conditional variances (382,345 & 1,171,141) are much larger than the conditional means (175 & 693) of all the observations and of the count data, respectively. These indicate the presence of overdispersion due to excess zeros.

Table 1 reports the descriptive statistics of the respondents' social-demographic profiles and the variables that are used for the analyses. The respondents are dominated by mid-aged (35–54) males with half of them holding a graduate degree (PhD or MSc). Occupation among respondents is dominated by governmental officers (37%) and people working in the private sector (25%). Other occupations include management/executive (8%), researcher (8%), commercial fisher (7%), self-employed (7%), unemployed (4%), retired (5%) and unspecified (14%). The household income is relatively equally distributed across income groups except the highest income group. Most of the respondents live in Agder county with 59% inhabiting cities. Almost 60% of the respondents share the same view that cod has been declining. Almost half of the respondents reported no preference for target species when they went fishing. Only 16% of them (28 respondents) specifically target cod while similar numbers of respondents reported targeting mackerel (24 respondents, 13%) or sea trout (*Salmo trutta*) (23 respondents, 13%).

Half of respondents are less frequent anglers (<5 times per year). In terms of the ecosystem services (ES) generated by the cod stock and fisheries, the most important ESs that were identified are food source (provisioning service, 95%), intrinsic value (supporting service, 90%), social-cultural and recreational services (77–73%) and economic benefit (income, 67%) for related businesses in the region, commercial and recreational fishing in particular. Meanwhile, the respondents were motivated to go fishing due to a combination of factors including enjoyment of nature, relaxation, spending time outdoors, and connection with family and friends, as well as for food acquisition or simply a tradition and lifestyle. In other words, the respondents recognized the importance of cod as an essential food source (provisioning service) and its ecological role, and highlighted their recreational and cultural enjoyment more than the activity as a provisioning service such as food consumption from cod fishing.

Table 2
The estimated average marginal effects of variables for ZINB and HNB models.

	HNB (St. error)	ZINB (St. error)
Zero count models (Binary – logit)		
Age	0.0649 (0.0232)***	0.0649 (0.0232)***
Gender	−0.0821 (0.0804)	−0.0783 (0.0731)
Fishing frequency	0.0399 (0.0211)*	0.0389 (0.0208)*
Target cod	−0.0813 (0.0862)	−0.0868 (0.0978)
Decline in cod stock	−0.1790 (0.0687)***	−0.1725 (0.0642)***
City residence	−0.0679 (0.0670)	−0.0672 (0.0659)
Municipality in Agder	−0.0707 (0.0960)	−0.0667 (0.0848)
All Ess	0.0727 (0.0645)	0.0726 (0.0645)
WTP count model		
Age	75.7629 (44.1467)*	−14.4703 (14.1915)
Education	−139.1303 (53.9481)**	−28.2095 (12.0226)**
Target cod	614.6865 (314.5967)**	210.5584 (129.1524)*
Decline in cod stock	284.5584 (105.6823)***	139.7612 (41.8537)***
City residence	262.0004 (121.5783)**	85.08029 (40.6603)**
Paid by governments & industries	−426.1405 (144.4695)***	−86.3983 (32.6772)***
All Ess	−104.3498 (119.1855)	−54.5322 (38.5295)
Alpha	0.5001079	0.5001
Log-likelihood	−391.3848	−391.3845
AIC	818.7696	818.7691
BIC	862.8426	875.2135

*** $p < 1\%$; ** $p < 5\%$; * $p < 10\%$.

3.2. Perception about coastal cod stock and enhancement program

The respondents believe that the decline in cod stocks is attributable to a combination of factors. The main causes identified include industrial overfishing (81%), followed by climate change (67%), a lack of suitable food (62%) and deteriorated water quality (61%). The least mentioned factor was overfishing caused by recreational anglers (48%).

Although people in Norway are very familiar with aquaculture, especially salmon aquaculture as Norway has been the world's largest salmon aquaculture nation, they have little knowledge about aquaculture-based fisheries enhancement as a form of resource management. It is reported that only 21% respondents know it well, 49% have heard about it, but have not understood it, and 29% have not heard about it. Thus, aquaculture-based fisheries enhancement is, in general, a relatively new concept for most people. Yet, more than half of respondents (52%) expressed their support for a full-scale or small-scale cod enhancement program, while 30% of them call for more research before establishing a scaled program. Only 10 respondents (6%) opposed the implementation of such a program.

When asked about the potential benefits which such an enhancement program could bring about, respondents envisioned the potential to rebuild local cod populations as the primary benefit. Additionally, they enumerated education and research, importance for the local ecosystem and preserving fishing traditions, and generating opportunities for fishing and local business and, economic revenue in decreasing order (Fig. 1). On the other hand, their main concerns regarding any putative negative impacts of the program lie in the potential reduction of the genetic diversity of local cod stocks due to inbreeding, competition for food and space, or the risk of transfer diseases (Fig. 1).

Over 75% of the respondents believe that the national and local authorities should lead conservation efforts and that researchers should take charge in providing scientific knowledge and support. There is a prevailing sentiment that direct resource users such as commercial fishers and recreational anglers should not take the primary responsibility for conservation efforts. Similarly, the costs associated with implementing a proactive restoration management approach are expected to be mainly covered by national and local governments. Resource users, including the commercial fishing industry, professional fishers and the tourism sector, would follow in contributing to the costs, with tourists who use the resources to a lesser degree.

Overall, respondents accept current management measures implemented for cod stock although one-third are not aware of their performance. The establishment of more restricted measures such as bag limits and limited entry were also suggested.

3.3. WTP and its determinants

The mean WTP of all the observations (170) and only no-zero observations (43) are 175 NOK (≈ 17 €) and 693 NOK (≈ 67 €), respectively. We ran both hurdle negative binomial (HNB) and zero-inflated negative binomial (ZINB) regressions in Stata (www.stata.com). The estimated average marginal effects resulted from HNB and ZINB models are similar for the zero-count model, but rather different for count part model although they have very similar good fit in term of AIC and BIC values. However, the signs for the same variables used for two model components are opposite. The reasons for that are that the first stage

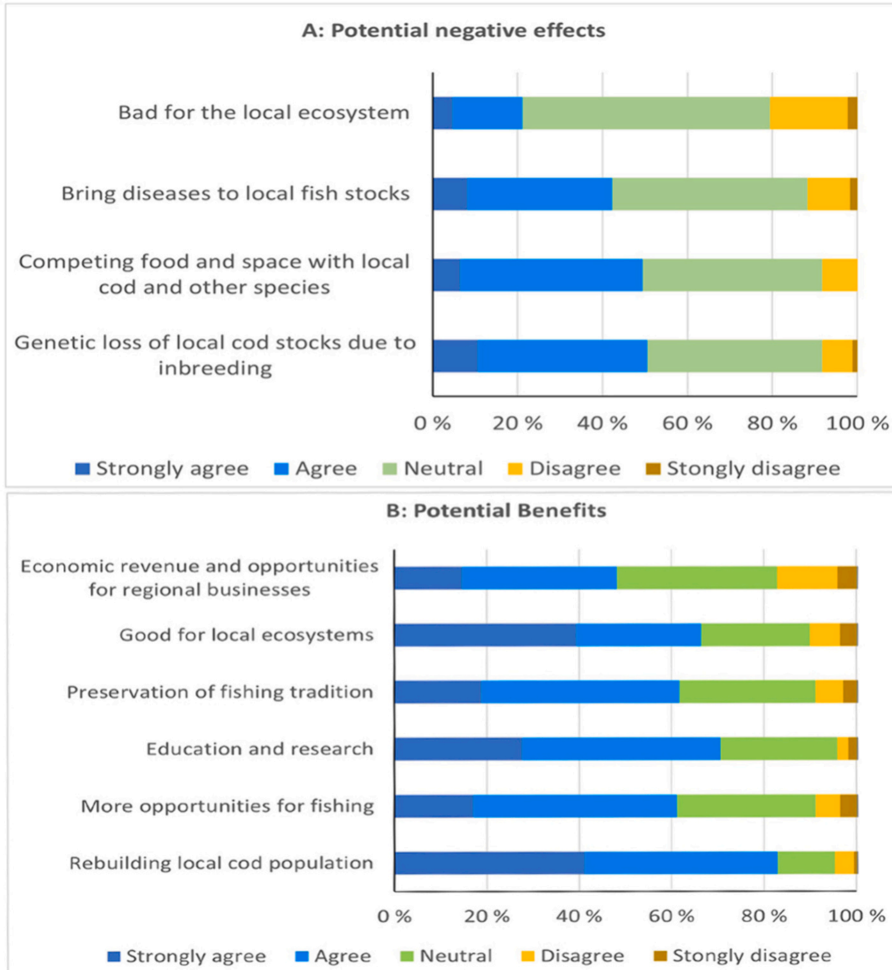

Fig. 1. Respondents' perception on the A) potential negative effects and B) potential benefits of a cod restocking program.

(binary – logit) is to predict the probability of having zero counts, i.e., it is to model whether the respondents would prefer not to contribute the program while the second stage is to predict the WTP amount for the program for those who have decided to contribute to the program. The results show that for the zero count model, the variables of age and decline in cod stock are statistically significant at 1% level while fishing frequency is statistically significant at 10% level from zero. These suggest that the people who are more willing to contribute to the potential establishment of an enhancement program are of the older generation who are less aware of the decline in cod population and go fishing more frequently (Table 2).

At the second stage for predicting the amount of WTP, the variables 'decline in cod stock' and 'paid by government and industries' are statistically significant at 1% level; education, target cod species and city residence are statistically significant at 5% level for both models; and age is at 10% from zero for HNB model. Thus, fishers targeting cod, living in urban areas and who have witnessed the decline of cod are more willing to make a larger contribution to the program. On the contrary, the respondents with higher educational degrees and the belief that the governments and industries (e.g., commercial and tourism fishing) should be primarily responsible for financing the program were less likely contribute a positive WTP amount. For the WTP count model, the average marginal effects with HNB model is higher than those with ZINB model. The different magnitudes between two models are likely due to different data generating mechanisms producing zeros as discussed earlier. In the HNB model, the distribution of the positive counts is governed by a zero-truncated negative binomial model while in the ZINB, the response variable is modeled as a mixture of a Bernoulli distribution and a negative binomial distribution. It should be noted that from an economic perspective, the participation and the amount of WTP should be correlated to the respondents' incomes; however, in our case, they were not correlated.

4. Discussion

The online survey conducted in this study revealed a general positive perception and attitude among regional stakeholders regarding the potential re-establishment of a restocking program to rebuild depleted coastal cod populations in Southern Norway. Most of the respondents either expressed their support of the establishment of the program, or requested the conducting of further research before its implementation, with the exception of only 10 respondents (6%) who opposed such efforts. In Norway, cod is considered a public good and respondents indicated that the costs involved in such initiative should be primarily covered by the government and the fishing industries. Meanwhile, approximately one out of four respondents were willing to contribute financially to the program. Notably, residents in urban areas, specifically targeting cod and having witnessed the decline in catches, were those willing to make a larger contribution to the program.

4.1. *Fishing behavior and perception about coastal cod stock*

Despite the limited number of respondents and restricted geographical scale, the results of the survey align with Norway's leading position in marine recreational fishing participation rate in Europe (Hyder et al., 2018) and the notion that coastal fishing is deeply ingrained in Norwegian culture, with its values and benefits extending beyond food provision. Fishing in southern Norway is perceived as a recreational activity, providing relaxation and an opportunity to enjoy nature and companionship outdoors. It is particularly popular during the summer months, when boats are taken out of winter storage and families revel in sunny days at sea. The festive atmosphere can explain the opportunistic fishing behavior among respondents, with approximately half not targeting any particular species during sporadic fishing trips. In fact, cod was the stated target species for only 28 respondents. This opportunistic fishing behavior contrasts significantly with the specific target species behavior commonly observed among commercial and tourist fishers who consider cod one of the most valued marine species (Vølstad et al., 2011; Kleiven et al., 2016). It is noteworthy that despite the majority of the respondents enjoying fishing only a few days last year, they expressed a strong conviction of a significant decline in their cod catches over recent years.

In agreement with recent scientific literature on cod populations from the North Sea and the Skagerrak (Bryhn et al., 2022; Kjesbu et al., 2023), respondents identified overfishing together with changes in cod larval prey biogeography associated with climate change as the main drivers for the decline in coastal cod. Nevertheless, there were contrasting perceptions of the impact of industrial (commercial and tourist) fishers and resident recreational fishers on coastal cod overfishing. While most of the respondents perceived industrial fishing as the main cause for the decline, only less than half (48%) considered recreational fishing responsible. Vølstad et al. (2011) estimated that the volume of cod caught by the marine fishing tourism industry in Norway was 1600 t in 2009, while a mark recapture study conducted by Kleiven et al. (2016) estimated that recreational fishing by both local and non-local residents accounted for 68% of the total coastal cod catches in southern Norway. The discrepancies in perceptions regarding the exploitation of cod resources, coupled with traditional rights for locals to freely catch fish for household consumption, have led to conflicts among fishing user groups (Moksness et al., 2011). This may also explain why local residents considered that the potential implementation of a restocking program should be part of the restorative efforts to manage coastal cod populations, with costs covered mainly by the government and industries.

4.2. Perception about cod restocking and WTP

The birth and development of marine fisheries enhancement as a science are tightly connected to the establishment of the local cod hatchery station at Flødevigen and to the annual beach seine survey initiated over 100 years ago to monitor the contribution of hatchery-released cod to fishery recruitment along the Skagerrak coastline (Smith et al., 2002). It was surprising that 78% of respondents were either unaware or had limited knowledge of restocking as a restorative approach for marine conservation and fisheries resource management. They acknowledged the potential of these programs to rebuild depleted populations, restore local ecosystems and improve educational and scientific knowledge of marine resources. However, they also expressed concerns about potential negative impacts on the genetic diversity of natural stocks, competition for food and space, and the risks of introducing diseases. The ecological and genetic interactions between wild and hatchery-released individuals have been a recurrent topic for debate inherent to aquaculture-based fisheries enhancement (Araki and Schmidt, 2010; Blanco Gonzalez et al., 2012; Grant et al., 2017). Hatchery juveniles are exposed to domestication selection and genetic drift forces that can reduce the adaptive response and genetic composition of the recipient wild populations (Araki and Schmidt, 2010; Christie et al., 2014). In this regard, major efforts have been directed towards the improvement of broodstock management practices and the development of specific guidelines to help managers minimize inbreeding or unwanted loss of genetic diversity (Taniguchi, 2003; Blanco Gonzalez et al., 2010; Lorenzen et al., 2010; Grant et al., 2017). Despite these concerns, respondents showed a positive perception and attitude towards investigating the potential of this restorative approach.

Unfamiliarity with marine aquaculture-based enhancement programs may be explained by a non-biological or fishery background among respondents. Alternatively, Leber (1999) argued that it may also reflect the consequences of the historical controversy (Smith et al., 2002) and the "denial phase of marine enhancement", a few decades when generations of fisheries biologists and scholars learned to reject marine enhancement approaches. At the end of the Norwegian Sea Ranching Program (PUSH) in the 1990s, the potential for cod restocking and sea ranching European lobsters (*Homarus gammarus*) and great scallops (*Pecten maximus*) was identified (Svåsand et al., 2000; Moksness, 2002). However, research funds for these initiatives were interrupted and no further attempt to release juvenile cod has been attempted over the last 25 years.

In contrast to other major fishing nations such as Japan, USA, China or Australia, none of the Norwegian universities offer specific courses introducing marine aquaculture-based enhancement systems in their marine study programs. Earlier discussions with colleagues teaching at other Norwegian universities and with students at our universities revealed that young marine biology students learn about the contribution of intentional juvenile releases to population dynamics in connection to unintentional juvenile escapees from hatchery facilities in salmonids. Emphasis is placed on the risks and putative negative impacts of genetic introgression on fitness, while their potential benefits for conservation and restoration were rarely mentioned (Blanco Gonzalez et al., 2008b; Kitada et al., 2009; Abelson et al., 2016). The extensive number of documented cases of Norwegian farmed salmon escapees and later introgression in wild populations is a major concern in Norway (Karlsson et al., 2016; Glover et al., 2020) and may partly explain the emphasis on the risks and putative negative impacts of unpredictable escapees on fitness and population integrity.

There are significant fundamental conceptual differences between unintentional farmed fish escapees and intentional hatchery-produced juvenile releases which are worth disentangling. While escaped fish (e.g. Atlantic salmon) have often undergone an exhaustive multigenerational selective breeding program to maximize the traits of interest, intentional juvenile releases as part of restocking and stock enhancement programs relies on using a relatively large number of local wild breeders of proximate genetic composition to the wild stock to produce offspring closely resembling the natural populations (Blankenship and Leber, 1995; Bell et al., 2008). Additionally, studies on reproductive fitness in connection to intentional fish release is highly skewed towards salmonids and the results have been contradictory (Araki and Schmidt, 2010 and references therein; Hess et al., 2012; Christie et al., 2014; Blanco Gonzalez et al., 2019). Salmonids, in contrast to many marine species including cod, often present short life spans, relatively small effective population sizes, moderate fecundities, accurate homing behavior, and their number of reproductive events is often limited. All of these aspects make recipient natural salmonid populations particularly vulnerable to genetic erosion. As a result, unfamiliarity with broodstock management protocols and misconceptions of the goals pursued by intentional juvenile releases are common among young marine- and fishery-biologists.

Similar to other fisheries enhancement programs conducted worldwide (Cantrell et al., 2004; Palmer and Snowball, 2009; Loneragan et al., 2013), Moksness (2004) suggested sustaining tourism fishing with the introduction of an annual fishing fee to finance the production costs of cod juveniles and to improve the economic performance of the cod restocking program. He estimated that a fee of 60 € per person would allow to cover the production costs of over 15 million juveniles considering 250,000 tourist fishers in season 2000/2001 and a production cost of 1 € per fish. Replicating Moksness' calculations (2004) using the WTP estimated from our study, and considering that the number of marine recreational fishers in Norway has increased over five-folds in the last two decades (1,285,000; Hyder et al., 2018), the introduction of a fishing fee of 17 € for all fishers would cover the production costs for almost 22 million juveniles annually. This estimate could potentially increase considering the reduction in the production costs of cod juveniles due to improvements in cod rearing practices (Puvanendran et al., 2022) and advances in fish tagging technology that allow tagging of smaller fish and reducing their time in captivity (Skalski et al., 2009); thus, making restocking programs economically more efficient.

Marine recreational fishing in Norway is generally open access, subject to few regulations and with no requirements for a fishing license, making it free for entry. Therefore, proposing a fishing fee to finance the production costs of cod juvenile production conflicts with these traditional rights. This could be one reason why 75% of the respondents were not willing to pay and considered that the production costs should be covered by the government and fishing industries. The concept of paying a license fee is more common among fishing enthusiasts targeting trophy species such as Atlantic salmon or sea trout, who value the fishing experience and joy as much or more than catching a fish (Liu et al., 2019).

The results of the analysis on determinants of the WTP amount suggest that the respondents who have witnessed the decline in coastal cod during their fishing trips feel committed and are willing to make an economic effort to revert the situation and restore depleted cod populations in neighboring coastal areas. This finding may align with the study conducted by Bell et al. (2003), which indicated that local residents were willingness to pay more when the public demonstrates that the enhance program would address salmon decline. Fishers specifically targeting cod species expressed a higher willingness to make larger economic contributions to the program than those not targeting any species in their trips. However, the analysis indicates that respondents with a higher educational degree are less likely to contribute with a large amount to the program. Possible arguments for these results include reticence among some respondents to support any juvenile releases without further research; a belief that expenses to manage fisheries resources, including the costs of such a program, should be paid by the governments and industries; and the historical denial phase of marine enhancement (Leber, 1999; Smith et al., 2002). In contrast to our results, previous studies have found a positive relation between higher educational levels among respondents and WTP, attributing this behavior to higher environmental awareness and a predisposition to contribute when economic resources are invested to preserve fishery resources (Cantrell et al., 2004; Obregón et al., 2020; Olaussen and Liu, 2011; Palmer and Snowball, 2009).

4.3. Limitations of the study

Despite being widely utilized, especially in environmental economics, the CV method has sparked considerable controversy due to concerns about its capability to produce accurate and consistent estimates. Various factors have the potential to introduce systematic biases into respondents' answers, and these issues, not unique to CV studies, often arise from challenges in survey design and implementation (Johnston et al., 2017). This study has limitations related to sample representativeness as it did not employ a stratified sampling approach; instead, a simple random sampling design, which may lead to some bias. Unfortunately, due to time and financial constraints, this study only secured 170 valid responses, primarily from Agder county. Future research should consider including a more diverse set of responses from across the entire country, possibly using a stratified random sampling approach. It is essential to acknowledge the potential self-selection bias among the respondents, as the questionnaire was primarily distributed among those associated with related organizations, potentially excluding those outside these circles. Furthermore, to enhance the study, expanding the choices for the payment card with a payment vehicle option could be beneficial in reducing vehicle bias.

5. Conclusions

Cod fisheries play a vital role in sustaining ecosystems and supporting recreational and tourism fishing. To ensure successful management and conservation of cod stocks and associated ecosystem services, it is essential to comprehend stakeholders' preferences and attitudes, as well as quantify their WTP to support a cod restocking program. The contingent valuation approach actively engages stakeholders and serves as a valuable tool for collecting data on individual preferences, providing policymakers crucial information for effective decision-making. The applications of hurdle negative binomial and zero-inflated negative binomial are appropriate for handling data with excess zero and overdispersion. The results estimated from two models exhibit similarities.

This study gains insights on the cod restocking debate in Norway from local residents' perspectives. It underscores their concerns about the current decline in coastal cod populations and showed a positive attitude towards further research to explore the potential of cod juvenile restocking as a restoration approach to rebuild local populations. Cod is considered a common good and holds significance as both a food source and a cherished recreational activity among residents. Despite advocating for government and industry funding for juvenile production costs, respondents' WTP amount would allow the production of over 20 million juveniles for release. Our results suggest a reconsideration of earlier criticisms and a re-evaluation of integrating a holistic cod restocking program within Norwegian coastal zone management, especially given the advancements in fish tagging, cod rearing techniques, and increased market prices for wild cod.

CRediT authorship contribution statement

Yajie Liu: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Trond Rafoss:** Writing – review & editing. **Luis F. Oliva Turbis:** Writing – review & editing, Methodology. **Enrique Blanco Gonzalez:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Conceptualization.

Author statement

Yajie Liu: Conceptualization, Survey design, Methodology, Formal analysis, Writing – original draft, Writing – review & editing.

Trond Rafoss: Writing – review & editing.

Luis Oliva Turbis: Writing – Survey design, Methodology & Writing – review & editing.

Enrique Blanco Gonzalez: Conceptualization, Survey design, Methodology, Writing – original draft, Writing – review & editing, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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