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Catching the future: Applying Bayesian belief networks to exploratory scenario storylines to assess long-term changes in Baltic herring (*Clupea harengus membras*, Clupeidae) and salmon (*Salmo salar*, Salmonidae) fisheries

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Abstract

Fisheries management aims to ensure that the fishing activities are environmentally sustainable in the long term, while also achieving the economic, social and food security related management objectives. To facilitate this, both the ecological and human dimensions of sustainability need to be included in fisheries assessment. In addition, assessing long-term sustainability calls for taking into account plausible changes in the surrounding societal conditions that shape the characteristics of the fisheries governance system, as well as the ecological conditions. The paper uses a combination of qualitative exploratory scenario storylines (ESS) and Bayesian belief networks (BBN) to integrate the environmental, economic, social and food security dimensions in an interdisciplinary assessment of the future sustainability of Baltic herring (*Clupea harengus membras*, Clupeidae) and salmon (*Salmo salar*, Salmonidae) fisheries. First, four alternative ESS were created based on plausible changes in societal drivers. The ESS were then formulated into a BBN to (a) visualize the assumed causalities, and (b) examine quantitatively how changes in the societal drivers affect the social-ecological fisheries system and ultimately the fisheries management objectives. This type of probabilistic scenario synthesis can help in thinking qualitative scenarios in a quantitative way. Moreover, it can increase understanding on the causal links between societal driving forces and the complex fisheries system and on how the management objectives can be achieved, thereby providing valuable information for strategic decision-making under uncertainty.

KEYWORDS

interdisciplinary assessment, long-term sustainability, management objectives, probabilistic scenario synthesis, strategic decision-making, uncertainty

1 | INTRODUCTION

The EU Common Fisheries Policy (CFP) aims to ensure long-term environmental, economic and social sustainability of fishing activities (European Commission, 2013). This necessitates a holistic approach to governance and management, which acknowledges that the human and the ecological dimension of fisheries systems are integrated (Berkes, 2012; Folke, Pritchard, Berkes, Colding, & Svedin, 2007). This also implies that the focus of fisheries sustainability assessments should not only be on the ecological aspects, which is often the case (Hilborn et al., 2015), but also on the human dimension of sustainability. Thus, long-term sustainability assessment requires that in addition to environmental changes, such as those caused by climate change, changes in the surrounding societal conditions and their impacts on fisheries governance and thereby the fisheries system are taken into account (Sarkki & Pihlajamäki, 2019). For instance, a changing political situation (caused by e.g. Brexit) may have significant implications to the formal fisheries governance. In addition, fisheries systems are affected by human behaviour, which may or may not move towards greater environmental awareness and engagement, thereby affecting the fish stocks directly or indirectly.

However, the existing fisheries management assessments in the EU and the Baltic Sea focus primarily on the trade-offs between ecological objectives and to some extend between ecological and economic objectives and related uncertainties (Diekmann & Möllmann, 2010; Kulmala, Peltomäki, Lindroos, Söderkultalahti, & Kuikka, 2007; Möllmann et al., 2014; Voss, Quaas, Schmidt, & Hoffmann, 2014), while the inclusion of the human dimension that extends beyond the economic interest (i.e. to social and food security) is limited (Benson & Stephenson, 2018; ICES, 2016a; Levontin, Kulmala, Haapasaari, & Kuikka, 2011). This has been explained by the long tradition of ecological assessments, but also by the challenges of defining and quantifying social objectives to make them comparable with the ecological and economic ones (Benson & Stephenson, 2018; Rindorf, Dichmont, Levin, et al., 2017; Rindorf, Dichmont, Thorson, et al., 2017; Stephenson et al., 2017). In recent years, the challenge to evaluate social objectives in integrated fisheries management assessments has been responded to by applying, for example, multicriteria analysis (Fletcher, Shaw, Metcalf, & Gaughan, 2010), Bayesian belief networks (BBN) (Haapasaari, Kulmala, & Kuikka, 2012; Levontin et al., 2011) and management strategy evaluation (*MSE*) (Plaganyi et al., 2013).

To overcome some of the challenges related to the inclusion of the social dimension in fisheries management models, a combination of qualitative and quantitative methods has been suggested (Haapasaari et al., 2012; Haapasaari, Michielsens, Karjalainen, Reinikainen, & Kuikka, 2007; Röckmann, Leeuwen, Goldsborough, Kraan, & Piet, 2015). In this paper, we integrate the ecological and human dimensions, the latter encompassing economic, social and food security aspects, as well as societal drivers, in the assessment of long-term fisheries sustainability by translating four qualitative exploratory scenario storylines (ESS) (Wade, 2012) into a quantitative scenario synthesis model using BBN (Jensen & Nielsen, 2007). ESS are narratives on how the future might unfold (Kok, Biggs, & Zurek, 2007). Coupling the inclusivity and creativity of qualitative scenarios with the specificity of quantitative modelling can increase the value of scenario planning (Mallampalli et al., 2016). The use of BBN requires transparent and precise formulation of the scenarios and supports thinking of the complex, uncertain systems by facilitating the recognition of indirect dependencies. Vlek, Prakken, Renooij, and Verheij (2014) applied the method for translating narratives of the alternative crime scenarios to a legal evidence. They found the approach useful in the sense that, (a) by enabling the simultaneous analysis of multiple scenarios, it prevents tunnel vision; (b) it enables structured and quantitative comparison of the mutual plausibility of the scenarios and (c) provides for identifying, which variables of the potentially complex scenarios are the most critical for the output evidence.

The research question guiding our analysis is how changes in societal drivers and their impact on the plausibility of alternative management decisions affect a fisheries system and achieving the management objectives acknowledged in the EU CFP (European Commission, 2013). These management objectives relate to (a) ecological sustainability (i.e. sustainability of fish populations), (b) economic benefits (e.g. increasing income and employment), (c) social benefits (e.g. fostering livelihoods, justice and traditions) and (d) contribution of fisheries to food security (i.e. increasing fish food availability and self-sufficiency) (European Commission, 2013). We also examine (a) management decisions from the perspective of integrating multiple objectives in the assessment, and (b) the uncertainties inherent to the expected utilities underlying the four ESS.

We use commercial Baltic herring (*Clupea harengus membras*, Clupeidae) and salmon (*Salmo salar*, Salmonidae) fisheries as a case study. Baltic salmon and herring have a predator–prey relationship (Jacobson, Gårdmark, Östergren, Casini, & Huss, 2018). Herring is the most abundant commercial catch species in the Baltic Sea (ICES, 2016b), and it is considered an environmentally friendly source of food, but its contribution to the food security objective is low as the majority of the catch is used for industrial purposes, namely to feed farmed fur animals (e.g. minks) and in aquaculture (Lassen, 2011; Pihlajamäki, Sarkki, & Haapasaari, 2018). In comparison, owing to the depletion of the salmon stocks in the 20th century and the consequent tight fishing restrictions, the catches of salmon are at the all-time low (ICES, 2016c) indicating smaller economic and employment value for the commercial fishery; still the cultural value of salmon remains strong (Ignatius, Delaney, & Haapasaari, 2019; Ignatius & Haapasaari, 2018). In addition to fishing pressure (Aps, Kell, Lassen, & Liiv, 2007), the state of the two fish stocks has been affected by human-induced changes in the marine ecosystem (Möllmann, Muller-Karulis, Kornilovs, & St John, 2008; Österblom et al., 2007; Salmi & Salmi, 2005). As fatty fish, Baltic herring and salmon also share a dioxin problem, that is, the accumulation of dioxins in adipose tissues, which restricts the use of the fish as food and feed and hampers their marketing (Haapasaari, Ignatius, Pihlajamäki, Tuomisto, & Delaney, 2019; Pihlajamäki et al., 2018).

2 | METHODS AND MATERIALS

2.1 | Exploratory scenario storylines (ESS)

ESS are visions of plausible pathways and future states (Kahn & Wiener, 1967; Kok et al., 2007) to explore the uncertainties relating to the environmental impact of human behaviour (IPCC, 2001; Millennium Ecosystem Assessment (MA) 2005; EEA, 2015). ESS are considered useful for strategic planning regarding adaptation to and mitigation of undesirable impacts of environmental change (Kriegler et al., 2012; Rounsevell & Metzger, 2010). However, many of the existing scenario studies focus on large geographical areas and address various environmental elements (Millennium Ecosystem Assessment (MA) 2005; European Commission, 2012; O'Neill et al., 2017; IPCC, 2019) and cannot therefore address the specificities of regional seas and their fisheries in required detail to inform fisheries science and governance (McDonald et al., 2019; Zandersen et al., 2019).

To address this gap in the context of Baltic Sea, we built four contrasting storylines for the future of Baltic herring and salmon fisheries using 2040 as the target year. The storylines were created following the matrix logic approach (Wade, 2012), which involved: (a) framing the focus of the ESS, (b) identification of social, technological, economic, environmental, political and value-based driving forces that affect the fisheries directly or indirectly, (c) determination of two critically uncertain driving forces (key uncertainties) to build a scenario cross and (d) creating ESS for the four state combinations of the scenario cross based on assumed changes in the driving forces. The materials used to develop the ESS included policy documents, previous scenario studies, literature on the dynamics of the fisheries and information collected from an international expert workshop on the dioxin problem of herring (Pihlajamäki et al., 2018). The paper focuses on the fisheries at the Baltic Sea scale, and therefore the specificities of different Baltic Sea basins were not taken into account.

The two key uncertainties identified using the matrix logic approach are: (a) whether governance in the EU and the Baltic Sea is integrated or fragmented and (b) whether environmental awareness and engagement in the Baltic Sea region is high or low. The rationale behind the former is that the implementation of ecosystem-based fisheries and marine management necessitates sectoral and regional integration (Hammer, 2015; Kern & Löffelsend, 2004; Ramirez-Monsalve et al., 2016), but such changes in governance and management practices are uncertain owing to the recently increased political instability and decreased security in the EU and the Baltic Sea region (Archick, 2016; Etzold & Opitz, 2015; Iso-Markku, Jokela, Raik, Tiilikainen, & Innola, 2017). The latter draws from the need for changes in environmentally significant behaviour to achieve ecological sustainability (EEA, 2015; HELCOM, 2013; MA, 2005). Such changes are highly uncertain owing to the underlying requirement for fundamental changes in attitudes, values and habits (Gardner & Stern, 1996; Stern, 2000).

The four contrasting ESS, titled "*Increasing societal stratification*", "*Sustainability transformation*", "*Transformation to protectionism*" and "*Business-as-usual*", are shown in Figure 1. The ESS were created based on assumed changes in the driving forces (Table 1) as presented in previous scenario studies (Millennium Ecosystem Assessment (MA) 2005; WWF, 2012; European Commission, 2012; Kriegler et al., 2012; O'Neill et al., 2017) and elaborated based on the assumed impacts on the fisheries as described in literature. In other words, the ESS were developed following the logics and assumptions of global and Baltic Sea level scenarios, which describe similar contrasting pathways (Pihlajamäki et al., forthcoming). The EES presented here thus reflect the generally recognized trends and environmental scenario archetypes, namely inequality, sustainability, regional competition and business-as-usual (Harrison et al., 2019) accompanied with detailed elaborations on two Baltic fisheries. The ESS include the assumption that integrated governance, which implies international collaboration, increasing international trade, equity and development of science and technology, improves the management of global environmental issues and the use of

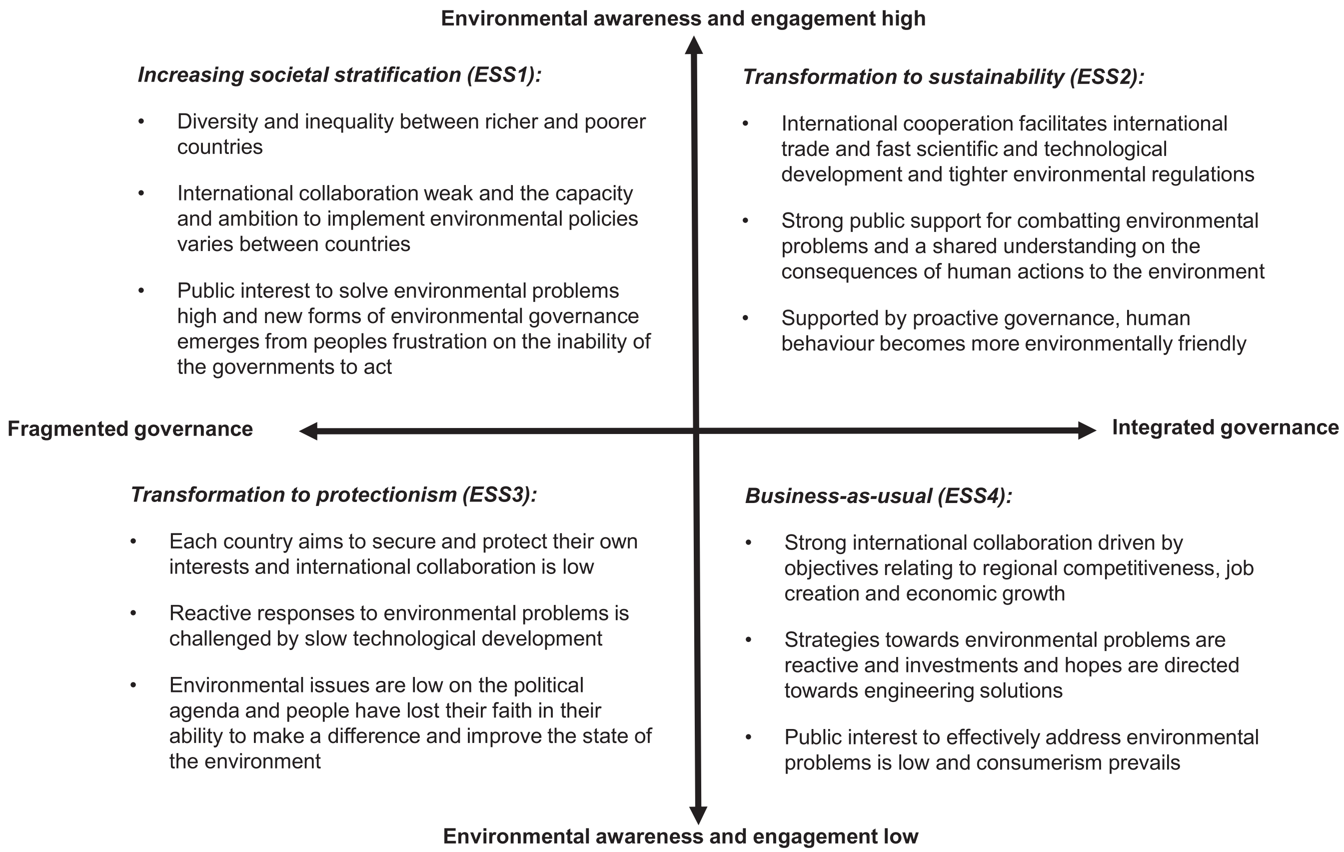

FIGURE 1 Scenario cross based on the two critically uncertain driving forces and the four contrasting storylines (ESS1-4)

science for policy making. Similarly, high environmental awareness and engagement is assumed to promote environmentally friendly consumption and production, as well as stakeholder participation in decision-making and policy implementation.

2.2 | Bayesian belief networks (BBN)

BBN is a graphical approach for causal reasoning under uncertainty (Jensen & Nielsen, 2007). A BBN consists of a graphical and a numerical element. The former maps the causal dependencies (arrows) among a set of probabilistic random variables (nodes). The numerical element is represented by the marginal distributions of the root nodes (i.e. the nodes that has no incoming arrows) and conditional probability tables (CPT) that quantify the probabilistic nonlinear dependencies between the variables. The probabilities in a BBN are defined using best available knowledge from a variety of sources including literature, domain experts and datasets from field monitoring, laboratory studies or other models (Korb & Nicholson, 2011). The modeller can also define the probabilities by herself, based on literature, interviews and other available sources of information (e.g. Lecklin, Ryömä, & Kuikka, 2011; Lehikoinen, Luoma, Mäntyniemi, & Kuikka, 2013).

Influence diagram (ID) is a BBN capable of solving decision-making problems under uncertainty (Jensen & Nielsen, 2007). In addition to random nodes, an ID includes decision nodes that can be controlled (e.g. policy options, management options), as well as utility nodes that measure the utility (or loss) to be achieved by the alternative decisions. The utility nodes express the relative preferences for all the alternative output combinations of the target variables. An ID computes the expected utilities given the state of knowledge and the decisions made in the network.

2.3 | Formulating ESS as BBN

We used Hugin (Educational 8.3) software (Madsen, Jensen, Kjaerulff, & Lang, 2005) to formulate an ID that represents the ESS for Baltic herring and salmon fisheries (Figure 2). In the ID, the *root nodes* are the key uncertainties concerning the type of governance and the level of environmental engagement, and the level of impact climate change will have in the system. The *output (i.e. target) nodes*, that is, the management objectives, represent different aspects of measuring the utility or harm experienced by the society, following the state of the system. A set of mutually interlinked *context nodes* link the root variables with the target variables. The context nodes were seen by the modeller as the most relevant variables representing the mechanism that generate the utilities and harms, given the states of the key uncertainties. To evaluate the controllability of the system under divergent conditions, a set of *control (i.e. decision) nodes* were added to control the state of the related *controllable nodes*. (for the terminology, see Korb & Nicholson, 2011).

TABLE 1 The assumed changes in the driving forces across the alternative ESS (modified from Pihlajamäki et al., forthcoming)

Driving forces	Increasing societal stratification (ESS1)	Transformation to sustainability (ESS2)	Transformation to protectionism (ESS3)	Business-as-usual (ESS4)
Governance integration between sectors and countries	Fragmented	Integrated	Fragmented	Integrated
Environmental awareness and engagement	Medium–high, varies between countries	High	Very low	Medium–low
Policy orientation	No common agenda	Environmental sustainability	National security	Economic growth
International collaboration	Weak, mainly bilateral	Very strong	No collaboration, closed borders	Strong
Technological development	Slow	Fast	Very slow	Very fast
Production	Only few industries and farms able to improve environmental friendliness of production	Most industries and farms are implementing environmentally friendly production	No attempts to improve environmental friendliness of production	Increased efficiency more important than environmental friendliness
Participation (inclusion of stakeholders in decision-making)	Medium–high, varies between countries	High, decision-making is inclusive	Low, decision-making is top–down	Medium–low, stakeholders consulted, but decision-making is exclusive
Food consumption	Divided between consumers making economic vs green and healthy choices	High demand for locally and sustainably produced environmentally friendly products	Meat intensive diets, national products	Meat intensive diets, cheap products from the global market

The modelled system can be divided to subsystems as visualized by the means of colour and shape coding in Figure 2. *The driving forces* correspond to those presented in Table 1. *Ecological system* includes the key ecological elements that affect the state of the Baltic herring and salmon stocks and the dynamics between them. *Social system* represents the social dimension and comprises the elements relating to fishing activities and market conditions, and their impacts on achieving the utilities, that is, *management objectives*. Following the logic of the ESS, the *decision* nodes are treated as variables whose state depends on the prevailing societal conditions; that is, the probability of a certain management response to take place is affected by the societal driving forces. Thus, the ID presented in this paper is not a decision optimisation model, instead it simulates likely decisions. The alternative decisions included in the ID are: (a) management approach (single sector/species versus ecosystem-based management approach (EBM)), (b) Total Allowable Catch (TAC) (comply with versus exceed scientific advice), (c) governance (reactive versus proactive) and (d) strategy to use the catch (aquaculture versus human consumption and aquaculture versus no strategy).

The arrows in the ID represent the causal relationships between the defined key variables (the nodes). The variables and the links between them were ultimately determined by the logic and framing of the ESS. There are typically many alternative ways to orient the arrows in a BBN, to represent a system. Causal orientation is not the only option, but it maximizes the representation of conditional independence and this way leads to simpler model structure (Korb & Nicholson, 2011). The less complex a model structure, the fewer probability values need to be specified. This is important especially in the cases, where the probabilities are defined "manually". In addition, overly dense network is computationally less efficient and fails to represent independencies explicitly (Korb & Nicholson, 2011). For these reasons, it is desirable to keep the BBN as simple as possible. When defining the parents of each node in the ID, we identified, which other variables could cause the variables in focus to take a particular state, or prevent it doing so. To keep the number of parents modest, we only included those links that were seen as the most important, keeping the maximum number of the incoming links under five. If needed, the *divorcing of multiple parents* –technique (Korb & Nicholson, 2011) was used, where an intermediate node is added to summarize the effect of a subset of the parents to the child node. The logic behind the causal structuring of the model is explained in the Supplementary Material A, together with the probability tables where the dependencies are quantified.

All variables of the present ID have alternative states, which describe the possible changes in the state of the variable between the baseline year (2015) and the target year (2040). As the number of states affects the size of the CPTs, also this element has an impact on the complexity of a BBN. We aimed for a low number of states to keep the number of probability values to be defined moderate. The criteria used here were that the states must be *exhaustive*, but *mutually exclusive* (see Korb & Nicholson, 2011). In other words, the states of a node must cover all the conceivable states, but be defined so

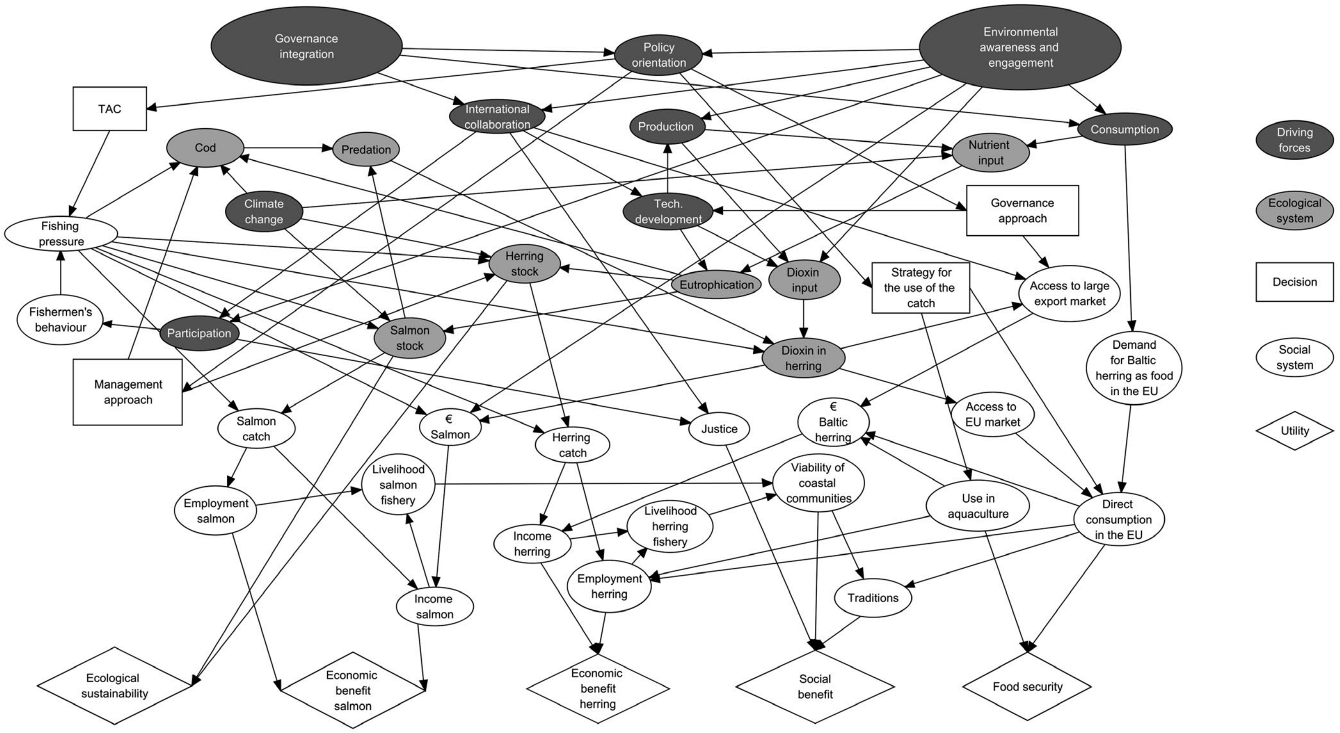

FIGURE 2 Influence diagram (ID) to analyse the sustainability of commercial Baltic herring and salmon fisheries in 2040, under uncertain societal and environmental development. The two critically uncertain driving forces relating to governance integration and environmental awareness and engagement are represented by the independent larger nodes on the top

that the variable can only be at one state at a time. In the present ID, the number of states in the context nodes is between two and four.

The causalities between the variables were quantified based on the authors' expert understanding and the collected materials for the ESS. In practice, the variables, arrows between them and the probability distributions were originally produced by the first author of the paper and then reviewed by the other authors, discussed and revised accordingly. Lastly, the validity of the model to describe the intended functioning of the system was evaluated by running the model with divergent settings, studying the posterior probabilities and ensuring the logic (see Pitchforth & Mengersen, 2013). Detailed description of the variables and the CPTs with their background assumptions and references are provided in the Supplementary Material (A1-A4).

The two critically uncertain drivers (governance integration and environmental awareness and engagement) are represented by two random variables that can be either set to certain states or handled as uncertain with equal probabilities (i.e. both possible states have probability of 0.5). To analyse how these critical drivers affect the other drivers, the ecological and social system as well as utilities, they were "observed" by setting them to a known state. This procedure generated the four possible combinations produced by the ESS matrix logics, while the other variables of the ID were left uncertain, their alternative states being weighed according to their realization probabilities in each case. In the model, climate change is treated as an external driver (i.e. its expected impact on the system and the related uncertainty is the same across the ESS) as it cannot be solved in the Baltic Sea region or at the EU level alone. The result is four probabilistic scenarios for the Baltic herring and salmon fisheries system (S1: "*Increasing societal stratification*", S2: "*Transformation to sustainability*", S3: "*Transformation to protectionism*" and S4: "*Business-as-usual*") where the uncertainties inherent to the four ESS are taken into account.

The diamond-shaped utility nodes correspond to the fundamental management objectives of the EU CFP (i.e. the ends that the decision-makers value in EU fisheries management) (Gregory et al., 2012) and are used to assess changes in Baltic herring and salmon fisheries in 2040. Utilities were assigned independently for each management objective according to a rough estimation whether the utility was assumed to increase or decrease in relation to the base year (2015). For each utility, we used an index scaled from −2/−1 to 2, zero representing the business-as-usual state. For example, the ecological sustainability utility was determined by changes in the state of the Baltic herring and salmon stocks. Increase in the abundance of Baltic herring and salmon were both given a value of 1, whereas no change in the state was 0 and decrease in the state −1. Thus, the total ecological sustainability utility options in the ID were determined by nine combinations of the states of the two stocks. The rationale behind the impact of the parent nodes to the utility nodes are presented in Supplementary material A.5. The economic utility of the two fisheries are treated as separate entities in order to avoid comparison between the relative economic importance of the two species. In the analysis, the focus is on the utility changes across the four contrasting futures (probabilistic scenarios S1–S4) and not on trade-offs between the utilities.

In addition to the abovementioned, we analysed the impact of different management objectives on the total expected utility of the management decisions under the four ESS. In other words, we were interested in whether the inclusion or exclusion of an objective affects the expected utility of the decisions in relation to other decisions. This was done first by comparing the expected utilities of management decisions when one (ecological), two (ecological and economic), three (ecological, economic and social) or four (ecological, economic, social and food security) utilities were included in the assessment. This order of objectives (ecological, economic, social and food security) corresponds to their historical order of appearance in fisheries policies (Atkinson, 1988; Pihlajamäki et al., 2018). Second, we assessed the expected utilities when one of the objectives was missing from the assessment at a time and compared these utilities to a situation when all the objectives were included. The state of the decisions was determined by the probabilistic scenarios.

The expected utility is the weighted average over the utility function, where the weighting is based on the probabilities of alternative outcomes of the variables on which the utility is dependent. Thus, very different probability distributions of the variables linked to the utility may result in the same expected utility. We analysed the uncertainties inherent to the utilities by converting each utility node into a random node, which exhibited same utility function as the original utility node. The mean of the random node corresponded to the expected utility (calculated with the utility node), whereas the dispersion around the mean (expressed as standard deviation) reflected the variation and uncertainty related to each utility.

3 | RESULTS

3.1 | Sectoral utilities under the four ESS

The results of the assessment show how changes in the surrounding societal and environmental conditions affect the sectoral fisheries utilities by 2040 (Figure 3). The assessed utility for each management objective across the four future states was the highest in the "*Transformation to sustainability*" scenario (S2) and the lowest in the "*Transformation to protectionism*" scenario (S3). However, the difference in total utility between the two scenarios, where the key uncertainties form the opposite combinations (i.e. "*Increasing societal stratification*" scenario (S1) and "*Business-as-usual*" scenario (S4)) was small. These reflect the rationale of the contrasting storylines. Food security and economic herring utilities increased in all scenarios, whereas economic salmon and ecological sustainability utilities increased in S2 but decreased in all the other scenarios. Social utility increased in S1, S2 and S4, but decreased in S3. The explanations for these results are provided below together with more detailed description of the main changes in the fisheries system under the four scenarios. The posterior probability distributions of the variables in the alternative states in each of the four scenarios are shown in Supplementary Material B.

3.1.1 | Ecological utility: Ensuring biological sustainability of fish populations

Ecological sustainability, which was calculated based on the assessed changes in the abundance of both Baltic herring and salmon, was most likely to increase in S2 and to decrease in all the other scenarios. The probability that the abundance of herring increases was the highest in S2 (P("*increases*") = 0.42), but in the other scenarios it most likely decreases (S1 P("*decreases*") = 0.57; S3 P("*decreases*") = 0.87; S4 P("*decreases*") = 0.60). As for salmon, the abundance was also most likely to increase in S2 (P("*increases*") = 0.57) and to decrease in S3 (P("*decreases*") = 0.58), but in S1 and S4 the change in the salmon abundance between the three assessed states (increases, current level, decreases) was more uncertain. These reflect assessed changes in fishing pressure (below or above the MSY) and in the marine ecosystem in terms of eutrophication status and climate change. In addition, management approach (single-species vs. EBFM) affected the assessed change in the abundance of herring. The assessment showed that fishing pressure was most likely to be below the level that provides maximum sustainable yield (MSY) in S2 (P("*below MSY*") = 0.6) and above it (overfishing) in the other scenarios. This in turn was driven by changes in the TAC, that is, whether fishing level is set according to scientific advice, and fishers' commitment to it. Based on the results, the TAC was likely to be set according to the scientific advice in S2 (P("*TAC = advice*") = 0.9) and above it in S3 (P("*TAC > advice*") = 0.9) and S4 (P("*TAC > advice*") = 0.6), while in S1 the decision was fully uncertain. As for fishers' commitment to the TAC, which was driven by whether and how the fishers are included in the decision-making processes (see Table 1), the results show that the fishers were slightly more likely to be committed than not to policy in S1, S2 and S4, but in S3 the commitment was low due to exclusive decision-making process (S1 P("*high commitment*") = 0.55; S2 P("*high commitment*") = 0.6; S4 P("*high commitment*") = 0.52; S3 P("*low commitment*") = 0.74). The probability that climate change has significant impact on the Baltic Sea ecosystem was the same in all scenarios (P("*significant impact*") = 0.8), but the state of Baltic Sea eutrophication was assessed to improve in S2 and S4 due to changes in nutrient input and technological development. While climate change and eutrophication were assumed to deteriorate the environmental conditions for Baltic herring reproduction and growth, the former was assumed to have a positive impact on salmon abundance (see Supplementary Material A).

3.1.2 | Economic salmon utility: Maximizing economic benefit of salmon fishery

The expected economic utility of commercial salmon fishery increased in S2 and decreased in all the other scenarios. The decrease

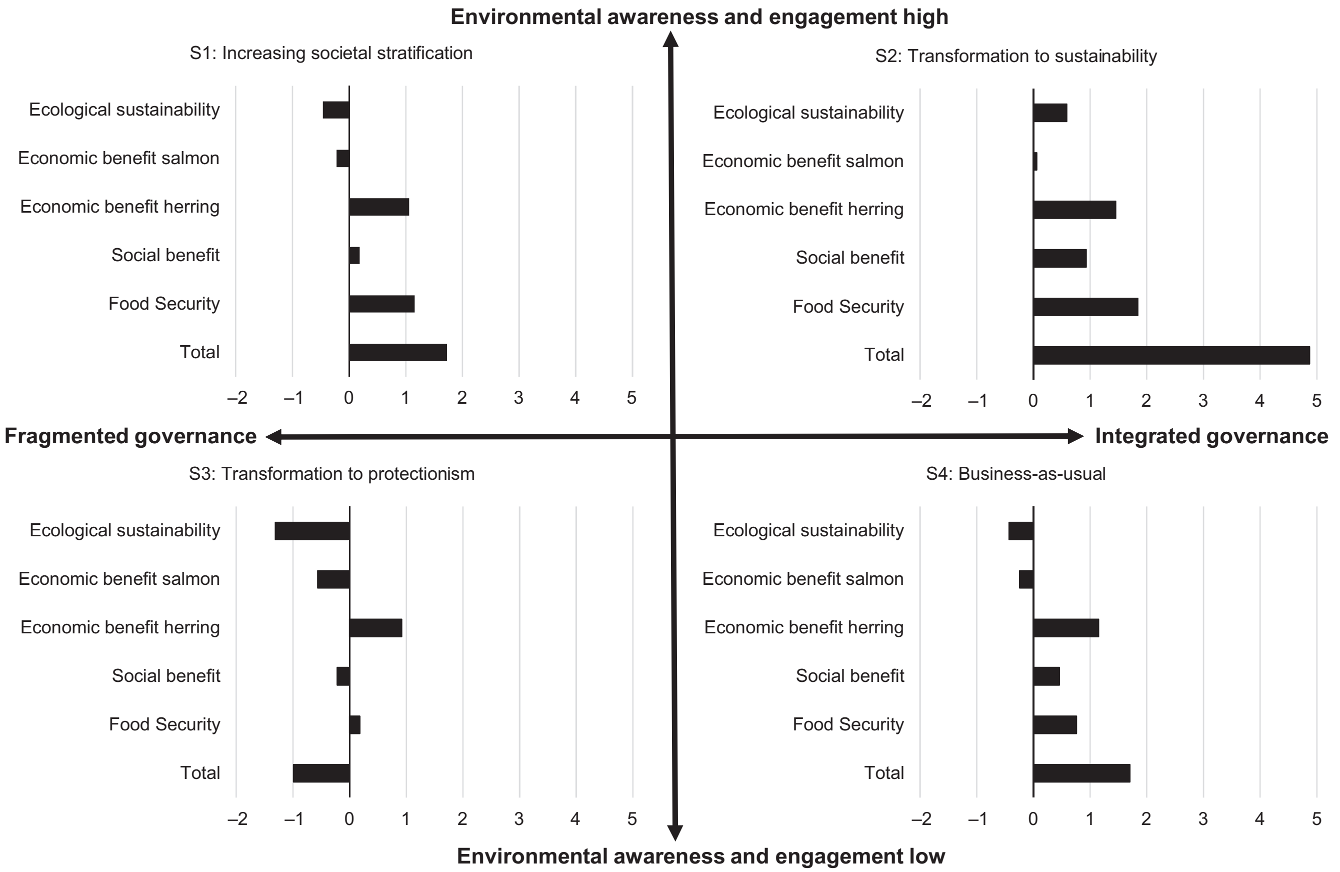

FIGURE 3 The impacts of the two critically uncertain driving forces to the sectoral fisheries utilities in 2040. X-axis of the bar diagrams describes the expected change in the utilities with respect to the current state (zero-level), when the two variables are set to their corresponding states and the rest of the variables in the influence diagram handled as uncertain. The utilities range from −0.46 to 1.16 in S1, 0.06 to 1.84 in S2, −1.31 to 0.18 in S3 and −0.43 to 1.15 in S4

was the largest in S3 due to assessed changes in employment and income. The probability that employment in the salmon fishery decreases was the highest in S3 (P(”*decreases*”) = 0.47) and the lowest in S2 (P(”*decreases*”) = 0.41). This reflects assessed changes in catch volumes, which were most likely to to stay close to current levels or to decrease in all the scenarios due to assessed changes in fish abundance and fishing pressure. The probability that fish abundance increases was the highest in S2 (P(”*increases*”) = 0.57), but in this scenario, increase in the catch volume was limited by fishing pressure, which was more likely to be moderate than high, i.e. within the MSY level rather than above it. The probability of increased income in the salmon fishery was the highest in S2 (P(“*increases*”) = 0.49) and the lowest in S3 (P(“*increases*”) = 0.22). In addition to catch size, income depended on changes in the value of the fish, which was determined by changes in the detected dioxin levels, sustainability of the fishery and environmental awareness and engagement. The value of salmon was most likely to increase in S2 and S1 (P(“*increases*”) = 0.52 and P(“*increases*”) = 0.34, respectively), whereas in the other two scenarios the probability that there is no change in the value was high (S3 P(“*no change*”) = 0.96 and S4 P(“*no change*”) = 0.89).

3.1.3 | Economic herring utility: Maximizing economic benefit of herring fishery

Economic utility of Baltic herring fishery increased across all four scenarios owing to the assessed increases in employment and income. The probability of increased employment was the highest in S2 (P(“*increases*”) = 0.83) and the lowest in S3 (P(“*increases*”) = 0.73). The assessed increase in employment was mainly caused by the assessed increase in the use of the herring catch for human consumption and/or as feed in aquaculture instead of fur animal feed, which was assumed to create jobs in the fishing sector. These changes in the catch use were driven by changes in the demand for Baltic herring food products, the access to large export markets and the selected strategy for catch use governance. The access to large export markets was most probable in S2 and S4 (S2 P(“*access*”) = 0.94; S4 P(“*access*”) = 0.85) due to strong international collaboration. In contrast, S1 and S3 were less likely to have access to large export markets due to weak international collaboration. The use of Baltic herring in aquaculture was likely to increas in all the scenarios, but the probability that the demand for herring as food increases was only high in S1 and S2 (see 3.1.5). These changes in catch use also affected the value of herring catch and thereby income. Based on the assessment, income was likely to increase in all scenarios. Employment and income were also affected by the assessed changes in herring catch, but the assessed changes were more uncertain due to uncertainties related to changes in fish abundance and fishing pressure (see 3.1.1).

3.1.4 | Social utility: Maximizing social benefits of Baltic herring and salmon fisheries

Social utility increased in all the other scenarios except for S3. The small decrease in S3 was caused mainly by the assessed change in fishers' sense of justice (P(*"decreases"*) = 0.76), which reflected the weakening international collaboration and exclusivity of the decision-making processes in S3. In comparison, the fishers' sense of justice was more likely to increase or stay at the current level in the other scenarios, being the highest in S2 (P(*"increases"*) = 0.9). Social utility was also affected by the assessed changes in the viability of coastal communities and traditions, the changes in which were more uncertain than those related to fishers' sense of justice. However, in all the scenarios, a positive change was slightly more probable than a negative one. Even in S3, the viability of coastal communities was more likely to be ensured (S3 P(*"ensured"*)=0.51) and traditions strengthened (S3 P(*"strengthens"*) = 0.51) than not. Viability of coastal communities was influenced by the livelihoods related to Baltic herring and salmon fisheries, which in turn were determined by changes in income and employment. While the herring fishery-related livelihood was unlikely to decrease – even in S3, the probability for decreased livelihood was very low (P(*"decreases"*) = 0.1) – the salmon fishery-related livelihood was most likely to decrease in all the scenarios. The difference between the two was mainly due to the assessed changes in the use of Baltic herring catch. The assessed positive changes in traditions (S1 P(*"strengthens"*) = 0.55; S2 P(*"strengthens"*) = 0.65; S3 P(*"strengthens"*) = 0.51; S4 P(*"strengthens"*) = 0.54) were driven by assessed changes in the viability of coastal communities and the use of Baltic herring for direct human consumption.

3.1.5 | Food utility: Maximizing fisheries contribution to fish food availability

The contribution of Baltic herring fishery to food security increased in all four scenarios. The assessed increase was the highest in S2 and S1, due to increases in both the direct consumption of Baltic herring in the EU and the use of herring as fish feed in aquaculture. The probability that the direct consumption of herring in the EU increases was high in S1 (P(*"increases"*) = 0.59) and S2 (P(*"increases"*) = 0.94), but low in S3 (P(*"increases"*) = 0.14) and S4 (P(*"increases"*) = 0.31). However, the use of Baltic herring in aquaculture was likely to increase in all the scenarios. The change in the use of Baltic herring as food directly or indirectly was driven by changes in the demand for herring food products, the access to the EU fish market and the strategy for catch use governance. The demand was in turn driven by changes in consumption patterns, that is, whether a transition to sustainable and environmentally friendly food production and consumption takes place. Based on the assessment, the probability that demand for herring food products increases was high in S1 and S2, but low in S3 and S4 (S1 P(*"increases"*) = 0.59; S2 P(*"increases"*) = 0.8; S3 P(*"increases"*) = 0.1; S4 P(*"increases"*) = 0.18). The access to EU market depended on changes in the dioxin levels in fish, which currently exceed the maximum allowable level in some areas of the Baltic Sea, and was driven by changes in technological development, production and/or environmental awareness and engagement. Based on the assessment, the access was most likely in S2 (P(*"yes"*) = 0.74) and S4 (P(*"yes"*) = 0.55) and least likely in S3 (P(*"yes"*) = 0.28). As for the strategy, the assessment suggest that in S2 the strategy focuses on both increasing human consumption of Baltic herring as well as its usein aquaculture (P(*"human consumption and aquaculture"*) = 1), whereas in S4 the strategy is most likely to focus on aquaculture alone (P(*"aquaculture"*) = 0.9). In contrast, in S3 the probability that there is no strategy, is the highest (P(*"no strategy"*) = 0.7).

3.2 | Decision analysis in the light of multiple management objectives

Increasing the number of utility nodes (i.e. management objectives) to be considered in parallel does not seem to have an effect on the most important decision: the decision to set the TAC according to the scientific advice produces the highest expected utility in all cases across the four scenarios (Supplementary material C: Table 1). This is also the most important decision if one of the following: "economic utility of herring," "social utility" or "food security" utility is removed from the assessment (Supplementary material C: Table 2). However, this is not the case if the "ecological utility" node is removed. In such cases throughout the four scenarios, decisions to implement EBM and/or a strategy for the use of catch produce the highest total utility. If "economic utility of salmon" is removed from the assessment, in S2 and S3 the decision to set the TAC according to the scientific advice also produces the highest expected utility, whereas in S1 and S4 a strategy for the use of the catch produces the highest expected utility.

Compared to a situation where all the utility nodes are included in the assessment, the expected total utility decreases the most if food security or economic utility of herring is removed from the ID, implying that their contribution potential to the total utility is greater than the economic utility of salmon, ecological utility or social utility in this assessment. Regarding the decision relating to governance approach, the difference between the two alternatives (reactive or proactive) is small in general.

3.3 | Uncertainty behind the expected utilities

The uncertainty inherent to the utilities across the four scenario storylines, described here by standard deviation (*SD*) of the utility variable, is shown in Figure 4 (for the full probability distributions for different utilities, see Supplementary material D). The social utility is generally more uncertain; that is, it has higher SDs, than the other utilities in all four scenarios. The probability distribution of the social utility is wide and bimodal; that is, it has two peaks (see figures in Supplementary material D). This is explained by the wide distribution of the one of the parent nodes, "Viability of coastal communities". The variable has only two states (both producing their own peak in "Social utility"), which have very similar probability to become realized across all four scenarios. Uncertainty is lowest with food security, yet there are clear differences between the scenarios, "*Transformation to sustainability*" exhibiting the lowest uncertainty for food security.

In general, it seems that the utilities related to social benefit and economic benefit of salmon exhibit more or less equal uncertainty across different scenarios, whereas there are more distinct differences between scenarios when food security, economic benefit of herring and ecological sustainability are considered. From the perspective of ecological sustainability, the outcome of S3 is clearly less uncertain than the outcomes of the other scenarios. Whereas for economic benefit of herring, as well as food security, S2 produces the least uncertain outcome.

4 | DISCUSSION

4.1 | Future sustainability of Baltic herring and salmon fisheries

We combined a qualitative scenario study with quantitative BBN modelling to explore the long-term sustainability of Baltic salmon and herring fisheries. A BBN was utilized for translating four contrasting storylines into a systemic causal representation that enables quantitative comparison of the alternative futures in terms of likely trends in relevant sectoral utilities. The empirical aim of the paper was to explore how the underlying societal conditions, and especially uncertainties relating to human behaviour and the way we govern the common resources, affect the Baltic herring and salmon fisheries in the long-term. The results demonstrate how both integrated governance and environmentally friendly human behaviour are needed to maximize the utilities relating to ecological, economic, social and food security objectives. The results also demonstrate that the future sustainability of the fisheries does not only depend on marine ecosystem dynamics, but also on the wider societal context of the fisheries.

Based on the results, Baltic herring fishery is more resilient towards the changes in societal driving forces than Baltic salmon fishery. This can be, at least partly, explained by the current differences in the state of these fisheries. Baltic herring fisheries are recovering from the collapse in the late 1980s and are an important source of employment within the fisheries sector (ICES, 2016b). In contrast, the commercial salmon fisheries are currently at their lowest in terms of catch volumes and employment (ICES, 2016c). Another explanation is the inclusion of food security-related objective in the assessment. Following the universal call to prioritize the use of wild captured fish as food (FAO, 1995) and the trend towards increasing fishmeal and oil production in the Baltic Sea region, the viability of herring fisheries is likely to increase despite the changes in the surrounding societal conditions. Fisheries governance could, of course, fail to materialize this potential, for example, by continuing to fish to feed fur animals, instead of proactively changing the current catch use trend towards aquaculture and human consumption. In comparison, Baltic salmon does not have similar potential as the catch is already used wholly as food.

The inclusion of the food security-related objective and variables in the assessment of forage species such as Baltic herring is also important from the perspective of economic and social objectives. This largely explains the increase in the economic herring utility across the scenarios. The results show that in the scenario "*Transformation to sustainability*" (S2), the food security utility is the highest due to

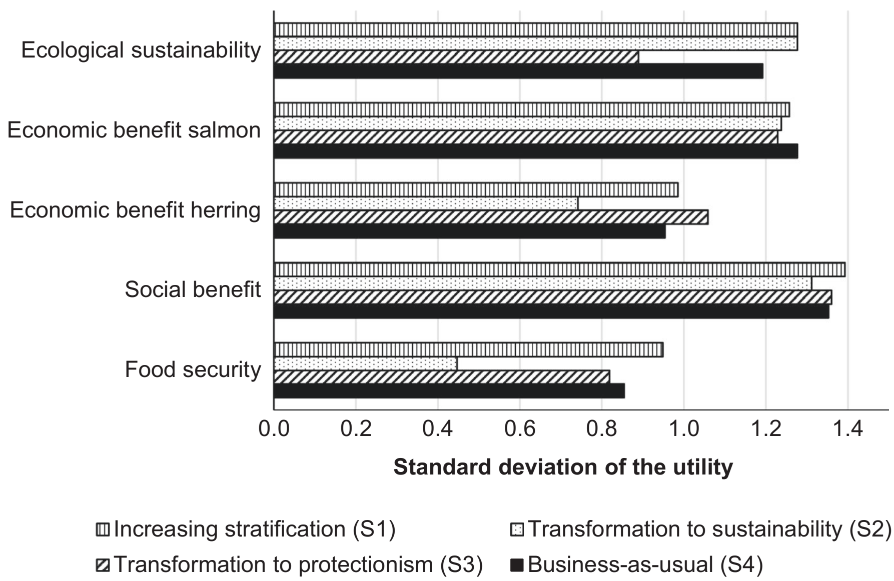

FIGURE 4 The standard deviation (*SD*) reflecting the inherent uncertainty of different utilities across the four scenarios

the combined effect of proactive catch use governance and changes in consumer demand. These findings support previous research that calls for thorough inclusion of the food security aspects in fisheries governance (McClanahan, Allison, & Cinner, 2015; Thurstan & Roberts, 2014).

As for the decision analysis from the perspective of integrating multiple objectives in the assessment, the results show that as long as the ecological objective is included in the assessment, the decision to set a TAC according to the scientific advice remains the most important decision in terms of expected total utility. This finding demonstrates the significance of the short-term trade-off between ecological and the other objectives for fisheries management and questions the tendency of European Commission to set the TAC for some species above the scientific advice (European Council, 2018; ICES, 2018), especially since the negative consequences of systematic overfishing are well known (Aps et al., 2007; Möllmann et al., 2008). The results also highlight the impact of the underlying societal conditions to the fisheries and their governance. For example, in the "*Transformation to protectionism*" scenario (S3), due to the multiple negative changes in the societal driving forces, even the optimal decisions cannot change the development to a positive direction. However, they could help minimizing the decrease in the utilities.

4.2 | Benefits and applicability of the approach

The presented approach allowed us to create a systems model to represent alternative plausible future scenarios, by synthesizing information gathered from literature and in an expert workshop. A novelty of our approach is that we could quantitatively compare the alternative scenario paths in the social-ecological system (SES) of fisheries management, evaluating their likely effects to different sectoral utilities. This enabled us to explore what kind of decisions are the most plausible in each scenario and how these decisions would materialize into ecological, economic, social and food security-related utilities. The model also allowed us to estimate the amount of uncertainty related to the outcomes of each scenario, in terms of the analysed utilities.

The benefits of the presented approach are many. First, while the ESS facilitate examining fisheries in a wider societal context over a long time period, the BBN enriches the ESS by, for example, visualizing the causal relationships underlying the SES, accounting for the related uncertainties, quantifying the utilities of the decisions plausible in the different scenarios, thereby making different choices comparable and making the underlying assumptions more transparent. The model structuring phase also increases understanding on both the direct and indirect causal links between societal driving forces, the fisheries system and the management objectives. Second, by quantifying the ESS and describing them as a BBN ID, one can examine which scenarios are the "best" in terms of normative objectives. It, thus, broadens the examination of the ESS, which traditionally, unlike normative scenarios, do not include desirable targets. Given that in this paper, we have used the matrix logic approach to build contrasting scenarios following widely used alternative trends, it is not surprising that the outcome of S2 and S3 are clearly the best and the worst, respectively. However, the underlying ESS can also be changed to ones where the outcome is less certain in advance. Third, the approach helps to include both ecological and social uncertainties in the assessment, which is important as fisheries are first and foremost social-ecological systems. Usually, quantitative environmental assessments consider only ecological and sometimes also economic features, while the social issues remain fuzzier. The BBN, as applied here, was able to incorporate factors from various scientific domains, and even quantify the utilities rising from the interactions between the factors. Fourth, although the estimation of the dependencies in the presented model was relatively coarse, the probabilistic inference allowed us to analyse, through the complex and "noisy" system, the likely impacts of the future scenarios on the variables of societal interest and the magnitude of uncertainties related to each of them.

Although the present paper has focused on Baltic herring and salmon fisheries, the presented approach could be applied, not just to other fisheries and in other areas, but also to any other SES. Given that the societal conditions for fisheries governance and management may vary between sea areas, applying the presented approach in other sea areas would highlight the regional specificities, but also the similarities across the regions, both of which are important for gaining a better understanding of the threats and possibilities for the future sustainability of world's fisheries. Although the presented ID model, which is attached as Supplementary Material (E, F, G), is not applicable for other areas and fisheries directly, it can be either developed further by e.g. updating the probabilities based on new information or alternative assumption concerning the SES, or some applicable pieces of it (e.g., structures or probabilities) copied and used in another context. However, the unique specificities of each system need to be considered when corresponding models are constructed. General guidelines for the application of the approach presented in this article are provided in Box 1.

4.3 | Communicating uncertainties

Uncertainties are inherent in both future scenarios and in any modelling effort. Scientists need to be cognizant about underlying uncertainties regarding complex environmental problems and their assessment by purposeful learning processes to find suitable coping strategies (Van der Sluijs, 2005). BBN is designed for modelling uncertainty and therefore a well-suited approach for quantifying and analysing the ESS. The ID presented in this study is a simplified description (Bailer-Jones, 2009) of the two Baltic Sea fisheries systems that are interlinked via ecological and biological processes (the prey–predator relationship and its impacts to the biomagnification of dioxins). The model represents one possible way of portraying the complex dynamics of the fisheries in their societal contexts. Typical to any future scenario, this scenario synthesis is based on a multitude of assumptions. However, the intention of the model

Box 1 Guidelines for the application of the approach

1. **Framing the system.** The first step is to create a holistic understanding of the environmental and societal characteristics of the fishery, including the related governance framework, management plan and sustainability targets (i.e. the societal and ecological long-term objectives), based on interdisciplinary knowledge, which in addition to the analysts' prior understanding on the system, can be derived via, for example, scientific literature, policies, statistical databases and expert discussions. Methods such as back-casting (Robinson, 2003), value-focused thinking (Gregory et al., 2012) and DPSIR approach (e.g. Smeets & Weterings, 1999) may be useful for identifying key variables and interlinkages between them and also for drawing a graphical representation of the system (i.e. pathways to reach a certain target), which can be later converted into a BBN (Step 3). In fisheries, the meta-analysis of key biological dependencies (e.g. S/R relationship) may also be useful, even when the modelling focuses on a single fishery. Consider questions such as "What kind of causal paths facilitate or prevent achieving the objectives?", "Do the paths share some common key variables or are some of them interlinked?" and "Which variables are affected by the current or planned policy actions?"
2. **Key uncertainties and exploratory scenario storylines (ESS).** In this step, the task is to define the key uncertainties and other societal and environmental driving forces that may have a role in the development of the fishery in the future by affecting, for example, the use and management of the fish stocks (Wade, 2012). Some fisheries may have environmental impacts and some environmental factors may impact the fishery. Take an advantage of available ESS studies and scenario archetypes (Harrison et al., 2019) and/or organize a participatory workshop. Drawing from literature and expert views, describe qualitatively the assumed (direct or indirect) impacts of the key uncertainties and driving forces on different parts of the fishery and ultimately at reaching management objectives. Add the key uncertainties and driving forces as additional factors into the causal description of the current system (Step 1).
3. **Constructing a graphical BBN.** The third step is to convert the causal representation of the system into a graphical BBN using suitable software such as Hugin, Netica or GeNIe. Changes to the conceptual model (Step 2) are often needed at this point. Note that a system can be represented with several alternative combinations of variables and links. Model building is always about making trade-offs between the complexity, relevancy and accuracy of the model. For an expert elicited BBN to be populated manually, it is recommendable to consider carefully the relevancy of each link. Simple model structures keep the size of the individual probability tables moderate and are, for an expert, easier to fill in a logical manner. Excessive complexity also weakens the understandability of the model behaviour, hampering the interpretation of its output. At this step, ask "What kind of data and information is available regarding the fishery?" as this may affect the conditional dependencies that can be estimated. It is advisable to familiarize oneself with the practical guidelines for constructing BBN(e.g. Chen and Pollino (2012) and Korb and Nicholson (2011)).
4. **Defining the counterfactual states.** The fourth step is to define the states for all nodes in the BBN. Each node in the network has a set of mutually exclusive states. It is recommendable to keep the number of states (possible outcomes of a variable) reasonable. This will both decrease the number of probability distributions to be defined and ease the interpretation of the final model. However, the node states represent the counterfactual futures, and together the states should cover the whole conceivable range of relevant options. Only one of these options can materialize. We do not know which one it will be, but the probability distributions encoded in a BBN contain estimates of the likelihood of each state to realize. Consider "What kind of outcomes (states) are of interest to the end-users of the obtained knowledge?" For example, in fisheries, the probability of fishing pressure being below or above of the maximum sustainable yield can be identified as a relevant outcome for policy discussions.
5. **Populating the probability tables.** The fifth step is to assign probability distributions for the nodes (variables) in the network. Nodes without incoming links (e.g. the key uncertainties) have a single probability distribution describing the probabilities the variable being in a certain state. Variables with one or more incoming links have a conditional probability table (CPT), which contains a set of conditional probability distributions – one for each combination of the states of the parent variables. The values of each separate probability distribution sum up to one. The shape of the distribution represents the state of knowledge: probability mass that is equally distributed among the states represents maximal uncertainty, whereas probability mass concentrated in one state represents full certainty. The probabilities can be based on any type of quantitative or qualitative data (experimental, monitoring, modelled, expert elicitation etc). In this study, they were based on the analysts' research-informed degrees of belief, originating from heterogeneous sources (see O'Hagan et al., 2006 for the elicitation of experts' knowledge).
6. **Model evaluation.** The final step before the BBN is used for the analysis is the evaluation of the model's behaviour and its capability to represent the analysts' thinking about the system logically. It is important to test the model as comprehensively as possible and obtain an understanding of why the model behaves as it does. This understanding, created by learning between variables and leading to a more comprehensive view about the behaviour of a complex and uncertain system, is one of the key outcomes of a modelling exercise. This can be done, for example, by locking some nodes to "observed" states and studying how the rest of the

Box 1 (Continued)

model reacts. Also, a so-called extreme conditions test can be applied, where locking some node(s) to its extreme state should – based on deductive reasoning – decrease the uncertainties in some other parts of the model (see Pitchforth & Mengersen, 2013). Other evaluation methods can be found, for example, from Chen and Pollino (2012). In the case of surprising results, try to track their origin and check the input knowledge. Some unexpected results that at first sight feel illogical, may after a thorough examination, prove to be correct conclusions.

actually is to be a representation of these assumptions, embedded in the qualitative storylines. By adding the probability tables and the logic behind them as supplementary material, we attempt to make these assumptions transparent. We acknowledge that some of the assumptions are different from those made in previous studies. For example, Merkens, Reinmann, Hinkel, and Vafeidis (2016) assumed that a future where transition from meat intensive to low-meat diets has taken place is characterised by a low demand for fish products as well. On the contrary, we assume that decreased demand for meat products results from increased environmental awareness and engagement, which indicates higher demand for locally and sustainably produced products such as herring.

The uncertainty varies across sectoral utilities and scenarios. None of the scenarios (S1–S4) produce consistently the highest or lowest uncertainty with respect to all five utilities. Hence, in general, we cannot conclude that any individual scenario exhibits more uncertainty than the others do.

When it comes to the expected changes in utilities, the social utility is the most uncertain and the food security the most robust one across all the four scenarios. The social variables (fishers' behaviour, viability of coastal communities, livelihoods, etc.) were the most uncertain part of the ID due to natural contingency of human behaviour, but also due to knowledge gaps. For example, although environmental social science research suggests that fishers' commitment to policy would increase if they were thoroughly engaged into decision-making processes (Haapasaari et al., 2007), it remains uncertain whether a shift to a more participatory governance would actually yield improved commitment. In contrast, the robustness of food security across the scenarios is mainly due to the underlying assumption that the use of Baltic herring as food, either directly or indirectly through aquaculture, will increase. This increase is assumed likely due to both, the current substantial potential for increasing the contribution of Baltic herring to food security (ICES, 2016b), and the need for more sustainable food systems (Nordic Council of Ministers, 2012; UN, 2015). Further, the uncertainty related to the expected change in social utility varies only a little across different scenarios, as does the economic utility of salmon fisheries.

For food security and economic utility of the herring fisheries, uncertainty is clearly the lowest in the scenario "*Transformation to sustainability*" (S2), whereas for the change in ecological utility, "*Transformation to protectionism*" (S3) exhibits the lowest uncertainty. This reflects reasonably the polarity of the scenarios: transformation to sustainability shifts the probable change in the food security and herring fisheries towards the high increase end of the range, whereas transformation to protectionism has the opposite effect for ecological sustainability, the probabilities being the highest for the decreasing trends to materialize.

High uncertainty associated with utilities has implications that are important to bear in mind. For instance, although in S2 the ecological sustainability is expected to increase (expected change in the utility = 0.59), the probability that the change is actually negative is 23%, and the probability that there is no change or the change is negative, is as high as 42%. The result highlights the importance of explicit handling of uncertainty behind divergent impact assessments and policy analyses, for which BBN offer a convenient way.

4.4 | Future research needs

This paper presents a model for long-term assessment of a SES, assuming that the relevant variables and their interlinkages, as well as the probabilistic dependencies remain the same over the whole assessment period. Further research could develop the existing ID to include temporal dynamics by adding separate but connected networks for shorter time periods (i.e. "time-slices", see for example, Johnson & Mengersen, 2012). In addition to the abovementioned evolution of the system, time-slicing would enable the inclusion of divergent feedback mechanisms. For example, one relevant feedback mechanism with the need for shorter assessment periods would probably be the dynamics between the fishing pressure and the development of the stock sizes (i.e. the maximum sustainable yield principle). Without an assessment of the feedback mechanism, the long-term impact of overfishing may be misleading.

5 | CONCLUSIONS

The analysis of a probabilistic scenario synthesis presented in this paper highlights that fisheries and their governance are embedded in a complex social-economic-ecological system. We have provided ideas on how to prepare for and plan the future, by presenting a causal expert model that translates alternative storyline narratives to a set of key variables and plausible assumptions about their interdependencies. For fisheries science, there is a clear need to strengthen interdisciplinary collaboration to represent the future.

For fisheries governance, this implies the importance of a holistic perspective in strategic long-term planning.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

To support transparency, the ID model, the original data and all the results are available as Supplementary material.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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