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To shape or to be shaped: engaging stakeholders in fishery management advice

Paz Sampedro[1*], Raúl Prellezo[2], Dorleta García[2], José María Da-Rocha[3], Santiago Cerviño[4], Julia Torralba[3], Julia Touza[5], Javier García-Cutrín[3] and María José Gutiérrez[6]

[1]Instituto Español de Oceanografía, Centro Oceanográfico de A Coruña, Paseo Marítimo Alcalde Francisco Vázquez 10, 15001 A Coruña, Spain

[2]Azti-Tecnalia, Txatxarramendi Ugartea z/g, 48395 Sukarrieta, Spain

[3]University of Vigo, Campus Universitario Lagoas-Marcosende, 36310 Vigo, Spain

[4]Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, Cabo Estai-Canido, 36200 Vigo, Spain

[5]University of York, Wentworth Way, Heslington, YO105NG York, UK

[6]University of the Basque Country, Avda Lehendakari Aguirre 83, 48015 Bilbao, Spain

*Corresponding author: tel: +34 981 218253; fax: +34 981 229077; e-mail: paz.sampedro@co.ieo.es

Abstract

The purpose of this paper is to assess the effectiveness of the collaboration between stakeholders and scientists in the construction of a bio-economic model to simulate management strategies for the fisheries in Iberian Atlantic waters. For three years, different stakeholders were involved in a model development study, participating in meetings, surveys and workshops. Participatory modelling involved the definition of objectives and priorities of stakeholders, a qualitative evaluation and validation of the model for use by decision-makers, and an iterative process with the fishing sector to interpret results and introduce new scenarios for numerical simulation. The results showed that the objectives of the participating stakeholders differed. Incorporating objectives into the design of the model and prioritising

them was a challenging task. We showed that the parameterization of the model and the analysis of the scenarios results could be improved by the fishers' input: e.g. ray and skate stocks were explicitly included in the model; and the behaviour of fleet dynamics proved much more complex than assumed in any traditional modelling approach. Overall, this study demonstrated that stakeholder engagement through dialogue and many interactions was beneficial for both, scientists and the fishing industry. The researchers obtained a final refined model and the fishing industry benefited for participating in a process, which enables them to influence decisions that may affect them directly (to shape) whereas non-participatory processes lead to management strategies being imposed on stakeholders (to be shaped).

Introduction

There is increasing consensus among scientists that the future of fishery policy research depends on an interdisciplinary approach combining biological, economic and social sciences, and that more attention should be paid to stakeholder involvement (Symes, 2012; Phillipson and Symes, 2013; Aanesen et al., 2014). This has led to a growing trend of engaging stakeholders in fishery research and fishery management systems worldwide. The participative process of stakeholders can take many different forms, from the use of fishers' knowledge in fishery planning (Neis et al., 1999; Johannes and Neis, 2007; Johnson and van Densen, 2007) to co-management experiences (Berkes, 2003; Wilson et al., 2003). In most cases, this literature shows that cooperation between scientists and stakeholders has resulted in greater legitimacy and more effective regulations.

In Europe, stakeholder participation in the fishery management has been encouraged at regional and local levels by a network of Regional Advisory Councils (now known as Advisory Councils) and Fisheries Local Action Groups (Linke and Bruckmeier, 2015; Phillipson and Symes, 2015). The European Commission has funded projects such as JAKFISH (Judgement And Knowledge in Fisheries Including Stakeholders (Röckmann et al., 2012)), MEFEPO (Making the

European Fisheries Ecosystem Plan Operational, http://www.liv.ac.uk/mefepo/) and GAP2 (Bridging the Gap between Science, Stakeholders and Policy Makers, http://www.gap2.eu/) that followed a participatory process in research into fishery governance. Other initiatives, such as the development of a long-term management plan for western horse mackerel have emerged from the fishing industry itself (Hegland and Wilson, 2009).

Earlier experiences in participatory research in fishery management were carried out in Atlantic Iberian waters (AIw), focused on the management of the coastal resources of the Spanish region of Galicia. For example, Molares and Freire (2003) assesses a co-management system for the exploitation of barnacle (*Pollicipes pollicipes*), based on territorial user rights set with the participation of fishers' associations. Similarly, a long term management plan for fleets targeting octopus (*Octopus vulgaris*) was outlined using fishers' traditional ecological knowledge (García-Galdo, 2014; Pita et al., 2016). In addition, the GEPETO project (http://gepetoproject.eu/) consisted of collaborative research with the aim of developing a management plan for the Iberian mixed fisheries.

This study is framed in the Western Waters case study of the MYFISH project (Maximising Yield of Fisheries while Balancing Ecosystem, Economic and Social Concerns, http://www.myfishproject.eu/). The MYFISH project was specifically designed to foster stakeholder collaboration. However, it did not contain a pre-defined plan for following up stakeholder engagement in each case study, and participatory process in AIw was adapted as new needs and opportunities for collaboration were identified. Our research addresses the need to engage multiple stakeholders related directly and indirectly to fisheries (fishing sector, policy makers, scientists and environmental Non-Governmental Organisations (NGOs)), but focuses on the potential key role of the industry in fishery research. Berghöfer et al. (2008), Hartley and Robertson (2009), and Dreyer and Renn (2011) provide illustrative examples of participatory research involving fishers and scientists. A common feature of these examples is recognition of the extraordinary potential for integrating knowledge held by fishers and scientists. Fishers' knowledge is recognised as a valuable source of information for helping scientists to define research objectives and facilitating understanding of expected outcomes, thus increasing the relevance of scientific research to the management process (Johnson and van Densen, 2007; Squires and Renn, 2011).

With this aim in mind, bio-economic models are effective tools for assessing different management strategies. Such models enable fishery dynamics to be analysed and trade-offs between environmental, social and economic goals to be identified. Stakeholders were engaged through a participatory modelling process, in which the modelling techniques and participatory procedures are combined (Voinov and Bousquet, 2010; Dreyer and Renn, 2011; Röckmann et al., 2012).

The new legal framework created by the latest reform of the Common Fisheries Policy (CFP) (EC, 2013) involves significant actions such as the implementation of the landing obligation (LO) and the exploitation of all stocks at their maximum sustainable yield (MSY). The bio-economic model used in this paper assesses the effects of these regulatory measures in a mixed fishery context, as is the case of AIw, in order to help decision-makers to draw up a multiannual management plan for the area. Multiannual plans are considered as the principal instruments of CFP (EC, 2012) and they should be designed to achieve sustainability objectives and preserve marine biological resources (Prellezo and Curtin, 2015). The expected final deliverable of this study is a management recommendation in which the main stakeholder concerns are taken into account.

Material and methods

The study area was the Atlantic Iberian waters comprising ICES divisions 8.c and 9.a and work focused on the Spanish demersal fleet operating in the fishing ground called Cantábrico-Noroeste (Figure 1). A detailed description of the fisheries studied and stakeholders involved in the case study can be found in Supplementary material.

Stakeholder engagement

The stakeholder engagement process defined in the MYFISH project started in 2012, taking advantage of the momentum created by the reform of the CFP. Even though the final CFP regulations had not yet been approved at that time, the drafts were put in place (EC, 2011). One of the key measures was the explicit adoption of the MSY objective in agreement with the stated goal of the World Summit on Sustainable Development to “maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015” (UN, 2002).

The stakeholders involved and their level of participation varied at different stages of the study (see Supplementary material). The project was designed around two main phases: defining stakeholder objectives and modelling management scenarios. From April 2012 to June 2015 a number of participatory workshops, meetings and surveys were conducted. Table 1 summarises the engagement activities, the stakeholders involved and the goals for each phase of the study.

Defining stakeholder objectives

The first workshop was held in April 2012 with the main aim of identifying objectives for the MYFISH project and ranking options by case studies (Table 1). Participants were invited from partners and organisations working with the MYFISH project, including NGOs, fishing industry associations, management organisations, and scientists. The workshop consisted of two parts. In the first part all participants involved in different case studies under the MYFISH project drew up a generic list of potential objectives. In the second part this generic list was ranked in groups set by case study area. This process to elicit stakeholder preferences included a open group survey (survey 1) using the methodology described by Leach et al. (2014). The profile of participants in survey 1 is shown in Table 2. The participants were asked to rate individually the importance of each option, the vote was not secret and all participants had the opportunity to speak. There was uncertainty related to three aspects: 1) does the necessary information exist?; 2) how informative is it in relation to the objective?; and 3) is it likely that management measures will result in meeting the objective?. This uncertainty was recorded and quantified using a four scale rating (from very low to high). The rating and uncertainty for each option were combined into a single index using a matrix method (Holt et al., 2014). Because of the small number of participants within each type of stakeholder, it was not possible to calculate an index by stakeholder type.

Moreover, a regional (Galicia) and sectoral (fishing industry) focused meeting was arranged for the members of FREMSS. This was followed by semi-structured interviews with stakeholders, survey 2, to gather information about their preferences regarding alternative management objectives and practices. Fieldwork was undertaken mainly in Galician ports between January and March 2014 and the profiles of the respondents to survey 2 are shown in Table 2. All participants were informed of the purpose of the questionnaire. The introductory part of the questionnaire included a set of questions related to their professional activity and experience in the sector (e.g. target species, vessel size, fishing methods). Specifically, the topics assessed were their interest in participating in the design of management plans, their opinion on what the main goal in managing fisheries was and what kind of research they thought could improve their fishing possibilities. The respondents were also asked to rank three alternative management scenarios (Figure 2): (i) sustaining the number of vessels in operation; (ii) allowing for greater flexibility in total allowable catch (TAC); and (iii) maintaining stability of catches. The ranking was restricted to three management alternatives given that it has been shown in the literature that stakeholders may not be able to prioritise if they are asked to rank too many options (e.g. Chapman and Staelin, 1982; Touza et al., 2014).

These management scenarios were simulated using a bio-economic optimisation model based on Da-Rocha et al. (2012) by assuming a sustained level of fishing effort, a reduction of TAC when stock is low to enhance future catches and stable catches around a given level (taken to be 70%) for the three scenarios, respectively. Figure 2 shows the resulting changes in the level of catches over a five-year period under these management scenarios as shown in the questionnaire.

Modelling management scenarios

In phase two we requested the participation of a broad range of regional stakeholders, first via e-mail or by telephone and then at information meetings in order to further develop and evaluate the scenarios, model parameterization and input data. This phase was divided into two parts: the model was analysed and validated at two meetings with the South Western Waters Advisory Council (SWWAC) and then there was an iterative process with strong involvement of the regional fishing sector.

<u>Analysis and validation of the model</u>

Before management scenarios are analysed stakeholders need to understand the process designed to achieve particular results or to perform an impact assessment (Leach, 2006). We therefore presented the data, the conditioning and the model with no results. The number of presentations that could be delivered was, of necessity, limited, so this presentation was delivered only to the SWWAC in October 2013, when most major stakeholders were present. The meeting consisted of a short presentation provided by the scientist, followed by an open group consultation about the suitability of the proposal. The group, as a whole, agreed that the capabilities of the model were evident and some feedback was received; stakeholders also expressed their interest in seeing the results of the model.

The first set of results derived from the bio-economic model was presented to the SWWAC in June 2014 (see Table 1). Scientists presented seven possible management scenarios, based on the results of the previous phase with the engagement of regional stakeholders, which combined the Harvest Control Rule (HCR) using multi-stock and single-stock approaches to MSY, with and without LO and with different fleet dynamics (see section Bio-economic model below).

The comparison of different management scenarios was facilitated by the use of Decision Support Tables (DSTs) created for the Iberian waters demersal fisheries (see Supplementary material, Table s1). DSTs are user-friendly guides that provide a structured process in which assumptions, model parameters and predicted outcomes can be reviewed. DSTs have been shown to be key tools to help fisheries stakeholders make decisions on how much fish can be caught considering economic, ecosystem and social indicators (Table 3). Two DSTs were presented to the stakeholders, one with the medians of the indicators and the other with the coefficients of variation.

Iterative process: stakeholders-scientists

Three meetings with regional stakeholders were held with the objective of adapting the parameterization of the model and creating alternative scenarios that met the priorities at regional scale. Stakeholders acted as a group at all these meetings, enabling information to be exchanged and giving all participants the opportunity to speak. We recognise that there is a wide range of formal techniques for eliciting information from stakeholders (Burgman, 2005; Martin et al., 2012; Burgman et al., 2014). However, we opted to follow a group elicitation method involving group discussion in order to facilitate the interchange of information and thus generate the maximum utility from the meeting. This method can lead to biases, especially if some participants assert dominance over the group opinions (Martin et al., 2012). When this issue was identified it was minimized by the meeting leader by directly asking other participants about the question under discussion.

During the first meeting, 37 management scenarios and their results in terms of ecological and economic indicators were presented to stakeholders, and an open group discussion was then held. Participants expressed their opinion about the parameterization of the model and some of them proposed alternative scenarios. A second meeting was held to present and assess the results of the management scenarios suggested by stakeholders in the previous meeting. Scenarios with free-quotas for horse mackerel, mackerel and blue whiting for demersal fleets were assessed by the participants. A final meeting was held in June 2015 to gather information about their perceptions regarding the results of new scenarios proposed by the European Commission on their Impact Assessment of a Multiannual Management Plan for the Iberian Waters (STECF, 2015). The management scenarios assessed included one with the strict application of the LO (to all stocks subject to quota since 2018 and without exceptions (such as survivability, de minimis, etc)) and six scenarios created by combining fleet dynamics (traditional or profit maximisation) with values of F_{MSY} (fishing mortality consistent with achieving MSY) and the lower and upper limits of F_{MSY} ranges (fishing mortalities leading to no less than 95% of MSY). After presentation of the background of each scenario and their results, stakeholders had the opportunity to discuss the effects of the implementation of F_{MSY} ranges for their fisheries.

Bio-economic model

The Bio-Economic Impact Assessment of Management strategies using the FLR (Fisheries Library in R) (FLBEIA) modelling framework (Jardim et al., 2013; García et al., 2016), which follows a management strategy evaluation approach (Punt et al., 2014), was used to build the bio-economic model for the AIw fisheries. FLBEIA (Bio-Economic Impact Assessment using FLR) is a simulation toolbox implemented as an R library (www.r-project.org) that uses FLR libraries (http://www.flr-project.org/). This bio-economic model can incorporate many stocks and fleets in a dynamic, stochastic environment. A detailed description of the model developed in this study is presented in García et al. (2016). The stock dynamics, fishing fleet dynamics and HCR were specifically modelled using the functions available (García et al., 2016). Thus, the population dynamics of the eight main stocks with analytical assessment (hake, megrim, four-spot megrim, white anglerfish, mackerel, southern horse mackerel, western horse mackerel, and blue whiting) were explicitly included in the model. Fleet dynamics were modelled considering effort allocation, using two different approaches. In the traditional approach, the effort share over métiers is constant (the average effort in the preceding three years) and the total effort is based on the quota of the stocks caught by each fleet. In the profit maximisation approach, the total fishing effort and its distribution over métiers are based on maximising the profits of the fleet. The HCR was defined in two ways. One formulation applies the single-stock reference points (singleRP) related to MSY: the fishing mortality target (F_{MSY}) and two spawning stock biomass reference points ($B_{trigger}$ and B_{lim}) defined in the ICES framework for advice. The second uses the multi-stock reference points (multiRP) as a management rule. These multiRP are those that maximise the Net Present Value (the difference between the present value of cash inflows and the cash outflows) (NPV) of the entire fishing activity. These were estimated using the bio-economic optimisation model developed by Da-Rocha et al. (2012).

The scenarios used to simulate different management strategies were defined by combining the options available for fleet dynamics (traditional or profit maximisation), HCR (singleRP or multiRP) and the implementation (or not) of LO. For modelling purposes, the fisheries were classified into seven fleets: four Spanish fleets (trawlers, gillnetters, longliners and purse seiners) and three Portuguese fleets (trawlers, polyvalent (artisanal multi-gear fleet) and purse seiners). These fleets, in turn, were divided into métiers created by grouping trips with the same gear, mesh size and target species. The data used to formulate the model were compiled from several sources. Catch and fishing effort by fleet and métier were collected by the research institutes in Spain (IEO) and Portugal (IPMA) during the GEPETO project. Stock-population dynamics data were derived from ICES assessment reports (ICES, 2013a, b, c), average prices per stock were obtained from the regional government of Galicia (www.pescadegalicia.com), and fishing fleet cost data from the STECF (2014).

Results

Defining stakeholder objectives

The MSY as a legal requirement was of special relevance to the AIw fisheries. Three of the eight stocks considered did not meet the MSY objective (Table 4). The fishing mortality (F) of hake was particularly high (one of the main economically relevant stocks in this fishery); the actual F value was twice as high as the target F (Fmax as F_{MSY} proxy). However, bringing the fisheries up to an MSY level requires some sacrifices from the fishing sector, at least in the short term.

During the workshop and survey 1, participants discussed their preferences related to MSY. The most strongly preferred MSY variants as management objectives were (in this order): "Maximise yield in value of key commercial species", "Maximise yield in value", "Maximise inclusive governance", and "Maximise willingness to invest in the future fisheries" (Table 5). The results demonstrate firstly that the stakeholders were interested in a yield maximisation process but not in the final result of their activity as a general objective. That is, they expected fishery management objectives to provide increased catches (preferably in value). However, they considered cost management to be a private decision dependent on their own strategies as commercial companies. Secondly, the MSY variant "Maximise inclusive governance" was ranked third highest, below only two variants related to maximum economic yield, showing that participation in fishery governance is a priority for stakeholders. This coincides with the findings of other authors who view participation as the main vehicle for increasing the governability of fisheries (Bavinck et al., 2013). There is no practical mechanism for including/measuring "inclusive governance" in a bio-economic model. However, planning this study as a participatory modelling approach can help to build an inclusive governance system. Finally, stakeholders and, in particular, fishers showed themselves willing to invest in the fishery.

The outcome of the meeting with FREMSS showed that the regional fishing sector was mainly concerned about the need to sustain the number of vessels currently in operation, allow for greater flexibility in annual TACs to quickly respond to variations in fish abundance, and maintain stability in catches, which could allow for stability in incomes.

The results of survey 2 indicate that three quarters of the respondents were willing to participate in the design of management strategies. The most highly regarded management goal when designing fishing opportunities was "having the highest possible TACs" (37%), followed by "ensuring a minimum economic return for each vessel" (27%). Fisher's exact test showed that the number of respondents supporting those objectives varied significantly across different stakeholder types: those willing (compared to those not willing) to participate in management design (p-value<0.05), those that use trawlnets (compared to those that use other gears) (p-value <0.05), and those involved in hake, anglerfish and/or megrim mixed fisheries (compared to those involved in other fisheries) (p-value<0.1). These preferences concerning the stability of catches were investigated when respondents were asked to rank actions over a specific five-year period (Figure 2). Moreover, in contrast with their previous support to the objective of having the highest possible quotas, respondents showed strong preferences for having stability in annual catches. More than 80% of them ranked "to maintain the fishing effort" as the least preference action if it meant that catches would decrease over time (scenario I, Figure 2). Thus, in agreement with some of the needs highlighted in the previous meeting with FREMSS, 50% of those interviewed ranked management measures that maintain stability of catches (scenario III, Figure 2) as their most preferred option.

Modelling management scenarios

<u>Analysis and validation of bio-economic model</u>

The first analysis and validation of the model were conducted through two meetings with SWWAC. A key output from these meetings was the need for more time to perfectly understand a multi-species, multi-fleet bio-economic model. On several occasions, participants expressed the view that "The change from the current single-species management to a multi-species management is a complex issue. We would need more time to assimilate the change and search out the implications and interactions". It is important to take into account that for most participants this was the first time that they had seen a model with multiple objectives (ecological and socio-economic) applied to a mixed fishery. DSTs were found to be useful tools for presenting scenarios and identifying interactions between fleets and between ecological and socio-economic concerns (see Supplementary material, Table s1). There was consensus that the model and indicators were very useful in the case study and might be employed in other management areas.

The SWWAC were particularly interested in the MSY variants presented and the alternative paths (progressive implementation) for reaching MSY. Participants expressed their concern about the economic and social costs of the implementation of LO; they requested an assessment using the model. SWWAC proposed maximising the number of employees while maintaining the quality of employment. The only social indicator that was included in the model was employment. The intrinsic limitations of quantitative bio-economic models for including qualitative variables, prevented other social concerns (such as safety and quality of work) from being modelled.

These two meetings confirmed to us that the proposed model was valid for simulating management strategies for the AIw fisheries and revealed the importance of efficient communication between scientists and stakeholders.

Iterative interaction

In this process DSTs (Supplementary material, Table s1) were employed to facilitate discussion of a range of management scenarios in terms of their ability to generate a specific economic or ecological goal. There was clear consensus among stakeholders that management options must be compatible with the sustainability of stocks. The open group discussions held helped stakeholders to share valuable information about fishing activity, but also about social and economic issues. In some cases, these new insights affected model assumptions and parameterization. The artisanal fisheries representative pointed out the impact of some bycatch species subject to TAC: “Skates and rays are not target species for our vessels. These stocks are not explicitly included in the model, they are only considered in the “Other stocks” group. However, under the LO, these bycatch species will be a limiting factor due to their low quota, and vessels will have to stop fishing”. The economic issues discussed also included the effect of the global fish market on model predictions. A stakeholder stated this concern: “Average prices by species, used in the model to estimate future revenues, will be impacted by the global fish market. The global market dynamics should be taken into account in revenue projection calculations”.

In the regional context, the stakeholders expressed a preference for a less constrained fishery system. They revealed that the economic viability of trawlers and gillnetters fleets strongly depended on catches of pelagic species. Representatives of the trawler fleet indicated on several occasions that “Horse mackerel and mackerel catches are essential to the economic viability of the trawler fleet”. Catches of these stocks are limited by the quotas agreed in the context of the principle of relative stability; the quota share of these fleet segments is low (around 5% of allowable catches for mackerel stock and 9% of TAC for western stock of horse mackerel). This stakeholder input led to new scenarios with free-quota for mackerel and horse mackerel stocks being simulated. In addition, the significance of the principle of relative stability to the economic viability of these fisheries was discussed. The comparison of scenarios (multiRP and multiRP-LO) with quota constraint and those with free-quotas for mackerel and horse mackerel (Table 6) revealed that trawlers and hookers could increase their NPV by up to 55% and 10%, respectively, in a free-quota situation. On the other hand, a free-quota situation for mackerel and horse-mackerel would not lead to an increase in the NPV of gillnetters.

The results of this interaction with stakeholders also showed that the two options for modelling fleet dynamics (the traditional and maximum-profit approaches) should be considered as just extreme cases of the possible parameterization of fleet dynamics. This is because stakeholders argued that fleet dynamics are much more complex and diverse, and can be influenced by multiple factors.

Quantitative added value

This section presents the results of the quantitative analysis of two objectives prioritised by stakeholders. The first objective considers the summed value of landings of key (or all) commercial species and the second, involves maximising willingness to invest in future fisheries.

The first objective was simulated by comparing the singleRP and multiRP approaches. The results varied significatively depending on the scenario, but in the simplest case (without LO and assuming that fleet behaviour followed the traditional approach), the NPV of the fishery increased from 415 million euros to 531 million (approximately a 28% increase).

The second objective was included in the simulations by using an equilibrium model (Da-Rocha et al., 2016) that took into account stakeholders' preferences for stable exploitation trajectories; this smoother approach increased the NPV from 531 to 589 million euros (11%).

Overall, the increase in the NPV of the fishery, considering stakeholder preferences, might be as high as 50%. However, this value is unlikely to be reached in practice: these were the results obtained for the overall fishery and not for the fleets. In that sense, the main (and probably the most useful) quantitative result is the possibility of not only qualifying but also quantifying the trade-offs that stakeholders currently have to make depending on their management decisions. We show here that these trade-offs can be obtained by comparing the results for the different fleets or the different dimensions of sustainability.

A snapshot of the DST (Table 7) shows that in scenarios in which the artisanal fleet (understood here as all fleets except trawlers) is protected and multiRP are used the economic efficiency of trawlers decreases. This suggests that the trawler subsector is not likely to accept proposals protecting artisanal fisheries (this was not explicitly mentioned at the meeting). This trade-off can be seen when the institutional dimension is considered. Table 8 presents a second snapshot of the DST and illustrates that none of the scenarios with multiRP reaches the F_{MSY} objective for hake, at least, when artisanal activity is not protected.

Furthermore, different trade-offs arise when other indicators are considered, such as the discard indicator (Table 8); under the scenarios protecting artisanal fleets, they end up with a higher overall level of discards.

Qualitative added value of the stakeholder engagement process

Our results show that the insights and proposals of stakeholders enhanced the scientific value of the case study. Figure 3 illustrates the phases of the participatory modelling process and the benefits obtained in each phase. Knowledge-sharing between regional actors improved the parameterization of the bio-economic model, which enabled us to investigate the socio-economic and ecological effects of alternative scenarios. This will better inform decisions on prioritisation of management measures.

The quantitative analysis of different results obtained by using the information/preferences supplied by stakeholders should serve to demonstrate the importance of engaging them in the development of multiannual management plans.

Other improvements in the model emerged at meetings between scientists and stakeholders, such as the introduction of the population dynamics of all stocks subject to TACs and a better identification of the métiers. These were of irrefutable value in the research study.

Discussion and conclusions

Collaboration between stakeholders and scientists is not conflict-free (Gutiérrez et al., 2011). Different stakeholders have different objectives and face different constraints, which make it harder to reach consensus on a single objective for fishery management. Perceptions may vary depending on the type of stakeholder (e.g. fishing industry, administration and environmental

NGOs) and even among those involved in the fishing industry; they may vary across Member States or depending on the degree of industrialisation of fleets. Scientific knowledge has the ability to influence stakeholders' beliefs and decisions, and a wider acceptance in the research community of the precautionary approach and uncertainty in the analysis often also help to promote alternative views on the part of stakeholders (Sethi et al., 2010). Stakeholder engagement in a research study is not a straightforward process, and the actors and steps involved often depend on the context or the requirements of the decision-making process (Mackinson et al., 2011).

The participatory process for Atlantic Iberian waters engaged stakeholders in the early stages, allowing for a better understanding and analysis of stakeholder objectives in the modelling process. Such early involvement of stakeholders has been pointed out as an essential element of any participatory process, since it allows room to change ideas and knowledge, enables regional priorities to be met and confers legitimacy (Reed et al., 2006; Berghöfer et al., 2008; Reed, 2008). Various groups of stakeholders (on different geographical scales, with various perspectives and uses of the sea) were engaged in the process here, but the regional fishing industry played a key, active role in our study. Fishers and their representative organisations are considered as key stakeholders in fishery research (Mackinson et al., 2011) because they are directly affected by management decisions and have experiential knowledge about fishing activity and socio-economic aspects of the fisheries studied.

However, we would like to highlight several problems that we faced in this process:

- Stakeholder preferences on main management objectives can differ significatively depending on who is consulted. In addition, it is difficult to avoid short-term issues such as, for example, changes in the elected representatives of stakeholders.

- The process is never fully completed; time and money constraints in the research project can lead to changes in the process of defining who has to be consulted and by whom.

In the case of AIw, regionalization was interpreted as prescribed by the CFP basic Regulation, first on a multi-Member State level, but interacting with the relevant Advisory Council (AC) for the region. We found that, as anticipated by Hilborn (2007), the objectives of the different parties comprising the AC also differ. The regional-level analysis (note that Galicia is Europe's most important fishing region in terms of contribution to regional Gross Domestic Product (IGE, 2015)) also showed conflicting objectives, but it helped to clarify how fleets differ in their objectives. For example, at regional level the Galician Federation of Fishers' Associations (the main organisation representing the artisanal fleet of Galicia) expressed a clear preference for keeping employment at the maximum viable level. This is not a new finding: Mardle et al. (2004) found that employment was one of the main objectives in small-scale fisheries.

However, even though their objectives were different at a micro level, when we transferred them to a more general scenario we found some common ground. For example, our surveys demonstrated that all stakeholders agreed that maximising the value of catches and guaranteeing some stability in catches needed to be prioritised. Furthermore, we concluded that stakeholders were not interested in the cost of effort as an objective of public fishery management, as fishing firms perceived that they could only influence their own costs. Put simply, this means that fishers require the highest sustainable output in a stable environment, and then they will decide how to manage the cost side by quantifying and qualifying the effort exhorted. However, this attitude can be also affected by the economic cycle in which stakeholder engagement takes place. The most substantial costs, such as fuel costs, followed a decreasing trend over the period in which the study was conducted.

In this research we tried to avoid any kind of prescriptive message in terms of fishery management objectives. However, consistently with previous literature, we were able to illustrate and quantify the trade-offs between different potential objectives and/or trade-offs, within the same objective between different stakeholders, fleets or types of fleet (see, e.g., Mardle and Pascoe, 2002). The main point when exploring trade-offs is that as long as the main settings (model conditioning and assumptions) are the same, the results are comparable.

One important conclusion of stakeholder participation in research has been to provide or improve the knowledge needed for management. In our case, parameterization of the bio-economic model benefited from the information supplied by different stakeholders and inputs from stakeholders improved the scenario development and interpretation of results. For example some species that are not, in general, of any great economic importance, such as mackerel and horse mackerel, were considered as key stocks by some stakeholders. Moreover, stakeholders also drew our attention to other species (such as rays and sharks) that had not been scientifically assessed but might limit fishing activities. These species, placed in the "others" group, are important because of the constraints that they impose on fishers. This could be particularly relevant under the new landing obligation regulation, as they might act as "choke" species. The exhaustion of their quotas would trigger the closure of the fishery and leave tonnes of quotas of economically more important stocks uncaught. The combination of fishing sector knowledge and scientific information helped to further our understanding of fishery dynamics and to investigate model assumptions. This clear benefit of the participatory process is consistent with those emphasised in environmental management studies (Reed, 2008; Raymond et al., 2010).

Moreover, the model considers two possible extreme tactical fleet behaviours: the traditional approach (inertial behaviour), where the share of the effort among métiers is constant, and maximum-profit behaviour, where the share of the effort among métiers is determined by optimising the profits. Fishers showed scientists that there was still some room for refinement as neither of these behaviours is observed in real life in its pure form.

Another relevant message drawn from this interaction experience is related to how the results of any model should be presented (Röckmann et al., 2012). The manner in which the DSTs and plots (see in García et al., 2016) present the data is not immediately obvious: the participants required time to assimilate the information. Likewise, the results are harder to interpret in a multi-stock, multi-fleet approach than in the classical single-stock situation. Stakeholders will probably need more time to make the transition to this different approach. To allow for this, the material should be sent in advance. Stakeholders are aware of the uncertainty of the results; however, they did not appear to be interested in a detailed analysis of that uncertainty.

We would like to highlight that stakeholder engagement benefits both stakeholders themselves and scientists. This is true even when the scientific results are not as expected by stakeholders. From our perception, the participatory modelling process is a way forward in creating transparent procedures in fisheries management. Moreover, the desire expressed by the regional stakeholders to continue using the bio-economic model for presenting alternative management options to be assessed by the SWWAC indicates a good understanding of the management process and the transparency of the whole process.

The process explained here delivered another important result: the need of set up a framework for interaction with a system of feedback. However, it must be noted that such feedback requires assessment and reflection on whether the needs defined are being met. Unfortunately, time constraints prevented us from conducting an evaluation of stakeholder perceptions of the engagement process. Such an evaluation would have enabled us to assess the effectiveness of engagement procedures in achieving project goals and to identify opportunities for future improvements.

The contribution of stakeholders must make a real difference to the rigour of scientific advice and meet the needs dictated by specific fishery situations. The value of that contribution must be recognised by high-level policy makers. Otherwise, such efforts will continue to be undermined by a lack of trust in the use of science in decision-making.

Supplementary data

The following supplementary material is available at ICESJMS online: a description of the fisheries studied and the stakeholders involved in the case study and an example of the DSTs used to report results to stakeholders.

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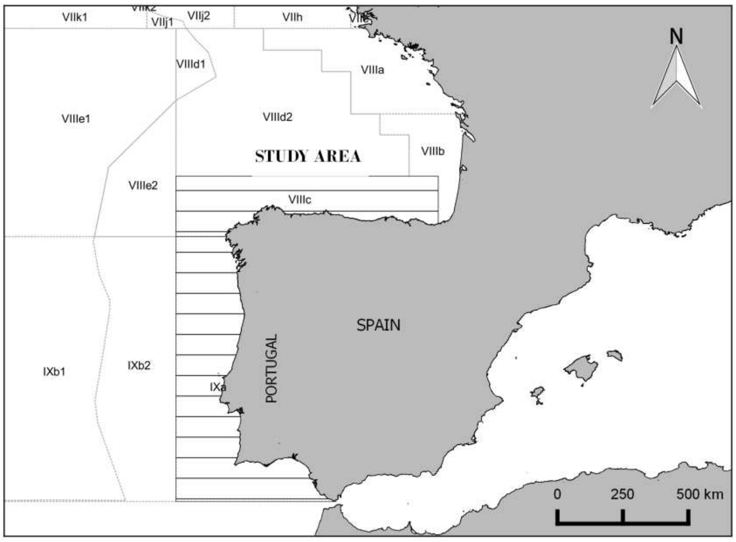

Figure 1. Map of the study area.

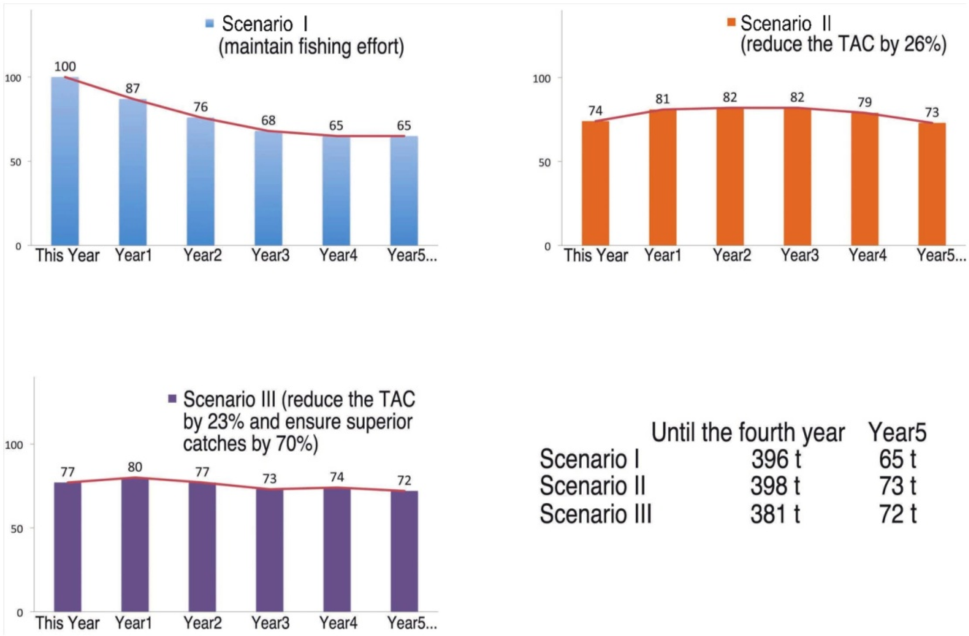

Figure 2. Management scenarios included in the questionnaire to stakeholders in regional fishing industry. The following objectives are represented: to maintain fishing effort (scenario I); to reduce TACs when stock is low to increase future catches (scenario II), and to sustain captures stable above a certain level (scenario III).

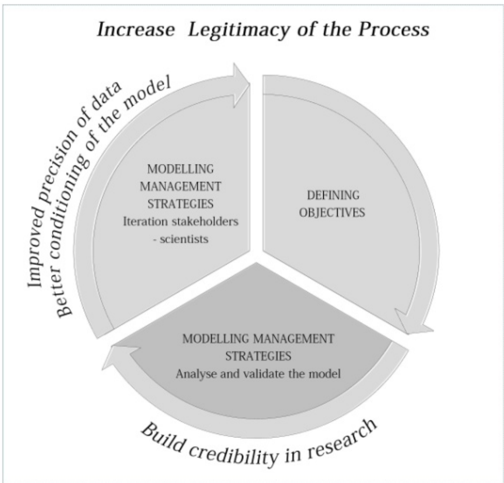

Figure 3. Diagram of the stakeholder engagement phases and main qualitative results of the participatory process to develop a bio-economic model for Cantábrico-Noroeste fisheries.

Table 1. Route of stakeholders' engagement in the model development of the AIw case study.

Phase	Action (participants)	Stakeholders involved	Goals	Place Date
Defining stakeholder objectives	Workshop (n=64) & Survey 1 (n=12)	Administration Scientists Fishing sector NGOs	Identify objectives and priorities	Vigo (Spain) 04/2012
	Meeting (n=6)	FREMSS	Identify priorities for fisheries management	A Coruña (Spain) 11/2013
	Survey 2 (n=52)	Fishers Ship owners Fleet managers	Identify preferences and define scenarios	Various ports 01-04/2014
Modelling management scenarios	Meeting (n=17)	SWWAC	Evaluate the acceptance of the model	Saint Jean de Luz (France) 09/2013
	Meeting (n=17)	SWWAC	Present first results	Paris (France) 06/2014
	Meeting (n=11)	FREMSS Galician Fishers' Association LONXANET	Analyse and evaluate the model	A Coruña 12/2014
	Meeting (n=11)	FREMSS Galician Fishers' Association LONXANET	Present first result Receive feedback on data input, model assumptions, and scenarios	A Coruña 12/2014
	Meeting (n=10)	FREMSS ACERGA	Present results of the scenarios proposed by stakeholders Discuss how to move forward: new joint projects and participation in the elaboration of a Multiannual Management Plan	A Coruña 03/2015
	Meeting (n=6)	FREMSS	Present results of scenarios simulated for Impact Assessment of Multiannual Management Plan (STECF, 2015)	A Coruña 06/2015
	Survey (n=1)	FREMSS	Identify preferred scenarios	A Coruña 06/2015

Table 2. Profile of the participants in survey 1 and survey 2 to define stakeholder objectives.

Survey 1 (n = 12)	% participants
Regional specific knowledge	75
Pan-regional knowledge	17
Management	8
Ecosystem scientists	17
Fisheries scientists	25
Socio-economic scientists	42
Fishing sector	17
NGO	0
Men	75
Women	25

Survey 2 (n = 52)	% respondents
Ship owners	52
Fishers	42
Fleet managers	6
Age < 40 years	37
> 40 years	63
Men	94
Women	6
Small fishing firm	67
Medium fishing firm	33
Main target species: hake, anglerfish and megrim	63
other species	37
Fishing method: Trawlnets	50
Hooks	27
Artisanal gears	23

Table 3. Indicators presented in Decision Support Tables.

Field	Indicator
Overall sustainability	Biological: max(p(SSB<Bref))
	Economic: min (NPV) (million €)
	Economic: % variation in total catch
	Social: % variation in number of vessels
	Ecological: % variation in discards
	Ecological: % variation in landings and discards ratio
	Ecological: max (dist. from virgin age distribution)
Biological and ecological outcomes by stock (hake, anglerfish, megrims, horse mackerel)	p(SSB<Bpa)
	Distance to F_{MSY}
	Distance to virgin age distribution
	Landings and discards
	Annual variability in catch
Results by fleet (trawlers, gillnetters, hookers, purse seiners)	NPV (million €)
	Profits per vessel (million €)
	Effort
	% change in wages
	Number of vessels

Table 4. Exploitation status in 2012 in contrast to the objectives defined for the main stocks of AIw case study.

Stock	**F in 2012**	**F_{MSY} (as defined by ICES)**
hake	0.57	0.24
white anglerfish	0.17	0.19
megrim	0.18	0.17
four-spot megrim	0.09	0.18
southern horse mackerel	0.07	0.11
western horse mackerel	0.19	0.13
mackerel	0.19	0.25
blue whiting	0.10	0.30

Table 5. List of MSY variants and ranking considered as acceptable and feasible in the region studied. In bold those ranked as preferable by the participants of workshop and survey 1.

Variant	Ranking	Variant	Ranking
Maximise yield in value of key commercial species	**1**	Maximise yield in tonnes	-
Maximise yield in value	**2**	Maximise Social Yield (utility, future, institutional value from a social, cultural, governance, ecological perspective)	-
Maximise inclusive governance	**3**	Maximise Gross Value Added over the entire value chain	-
Maximise willingness to invest in the future fisheries	**4**	Maximise catch in tonnes	-
Optimize number of fishing units	5	Maximise employment on viable fishing units	-
Minimise risk of falling outside constraints (boundaries beyond which management is considered unsustainable)	6	Maximise present yield for human consumption	-
Maximise Net Present Value	7	Maximise fishing community viability	-
Maximise Gross Value Added	8	Maximise health benefit/CO2	-
Maximise resource rent	9	Maximise useful knowledge	-
Maximise yield in tonnes of key commercial species	10	Maximise community biomass	-
Maximise fisher welfare/happiness	-	Maximise stability in biomass, landings or catches	-
Maximise consumer welfare/happiness	-	Maximise resilience	-

Table 6. A snapshot of the Decision Support Tables presented to stakeholders. The Net Present Value by fleet for different management scenarios with and without free-quota for mackerel and horse mackerel is indicated. Scenarios, showed in the table, are based on the combination of the options for the Harvest Control Rule using multi-stock (MultiRP) approach of MSY, with and without the landing obligation (LO), and traditional quota or free-quota for mackerel and horse mackerel (FQ).

Scenario		MultiRP	MultiRP/FQ	MultiRP/LO	MultiRP/LO/FQ
Net Present Value	Trawlers	407	631	307	477
(million euros in 10 years)	Gilnetters	207	207	150	144
	Hookers	134	144	158	167

Table 7. A snapshot of the Decision Support Tables presented to stakeholders. The Net Present Value by fleet for different management scenarios is indicated. Scenarios showed in the table, apart from *status quo* scenario, are based on the combination of the options for the Harvest Control Rule using multi-stock (MultiRP) and single-stock (SingleRP) approaches of MSY, with and without the landing obligation (LO), and with Artisanal effort constant or not.

Net Present Value (million euros in 10 years)	**Scenario**								
Fleet	status quo	SingleRP	MultiRP	SingleRP/ LO	MultiRP/ LO	constant	constant	Artisanal constant	
Trawlers	447	359	409	364	413	369	407	367	406
Gillnetters	196	101	125	107	131	170	170	174	174
Hookers	169	79	99	84	104	136	142	139	146

Table 8. A snapshot of the Decision Support Tables presented to stakeholders. Distance to F_{MSY} and discards for the southern hake stock in different management scenarios. Scenarios showed in the table, apart from *status quo* scenario, are based on the combination of the options for the Harvest Control Rule using multi-stock (MultiRP) and single-stock (SingleRP) approaches of MSY, with and without the landing obligation (LO) and with Artisanal effort constant or not.

Hake (all fleets)	**Scenario**								
	status quo	SingleRP	MultiRP	SingleRP/LO	MultiRP/LO	constant	constant	constant	constant
Distance to F_{MSY}	-36%	0.2%	-5%	-5%	-12%	59%	30%	35%	7%
Discards (t)	1040	1122	1356	480	666	4295	3711	3381	2672