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Boundary spaces, objects and activities in mixed-actor knowledge production: making fishery management plans in collaboration

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Abstract

This paper investigates knowledge production in collaborations where the actors have different knowledge and interests. Building on boundary object theory, a conceptual framework is developed to analyse knowledge exchange in two stakeholder-led collaborations to make fishery management plans. The framework introduces *boundary spaces* to conceptualise the dynamic interaction between objects and activities. Within boundary spaces, actors can share, transfer and translate their knowledge, and common understanding can emerge. The collaborations analysed aimed to produce management plans for the *Nephrops* (*Nephrops norvegicus*) fishery in the North Sea and the boarfish (*Capros aper*) fishery in the Northeast Atlantic. Several boundary spaces were identified in each collaboration. During the production phase, the emerging management plans took on multiple representations as boundary objects that facilitated knowledge exchange. Activities were essential, as these created entry points for different actors to become part of the boundary spaces where they could contribute to knowledge production. Fishing industry representatives in the North Sea Advisory Council and the Pelagic Advisory Council played key roles in initiating and coordinating activities. The case studies demonstrate that Advisory Councils take on pro-active roles in initiatives that aim to expand the knowledge base for European fisheries management. Direct engagement was instrumental to create ownership of the problem addressed in the various collaborative settings that emerged during the management plan initiatives.

Keywords: Knowledge production, Knowledge exchange, Boundaries, Boundary objects, Participation, Stakeholders, Fishery management, Fisheries, Advisory Councils, Cooperative research

Introduction

A key challenge in environmental management is how different kinds of knowledge can be integrated into products that are useful for managers (Roux et al. 2006; Fazey et al. 2013; Raymond et al. 2010). European fishery management under the Common Fisheries Policy (CFP) has a legacy of being informed by science that focuses exclusively on biological aspects of fisheries (Hegland 2006). Critical inquiries have highlighted, however, that knowledge contributions from a broad range of natural and social science disciplines as well as from stakeholders are needed to embrace the complexity of fishery management (Degnbol et al. 2006; Symes and Hoefnagel 2010; Garcia and Charles 2008;

Hawkins 2005; Schwach et al. 2007). CFP decision-making should, in accordance with good governance principles, be based on best available scientific advice and broad stakeholder involvement (EU 2013). The two principles can be combined by involvement of stakeholders in research, here referred to as 'the scientific route' to knowledge integration. This scientific route was highlighted in the European Commission's Green Paper, which discussed how the CFP could be improved through reforms. Addressing the knowledge base for the CFP, the Green Paper asked: "How can we better promote stakeholder involvement in research projects, and incorporate stakeholder knowledge in research-based advice?" (European Commission 2009:20–21).

Stakeholders can also contribute to the knowledge base of the CFP by submitting their recommendations to the European Commission through the Advisory Councils, here referred to as 'the stakeholder route' to knowledge integration. Established as Regional Advisory Councils (RACs) as part of the 2002 CFP reform, and as Advisory Councils following the 2013 reform[1] (Council 2002, 2004; EU 2013), these are heterogeneous stakeholder forums with 60 % representation from the fishing industry and fishermen's organisations and 40 % representation from other interest groups, including non-governmental organisations (NGOs). The Advisory Councils' role is to provide the European Commission and European Union (EU) member states with advice on issues related to fishery management. Linke et al. (2011) draw attention to challenges associated with incorporating the stakeholder knowledge provided by the Advisory Councils into management and policymaking as these bodies are typically consulted during the final stages of a governance process. Active involvement in earlier stages where knowledge is generated would be better aligned with the original motivation for the establishment of Advisory Councils, i.e. to "enable the Common Fisheries Policy to benefit from the knowledge and experience of the fishermen concerned and of other stakeholders and to take into account the diverse conditions throughout Community waters" (Council 2002:4).

Some Advisory Councils have moved beyond a reactive consultation role by taking initiatives to make long-term management plans. Such plans, also commonly referred to as multiannual plans, are used as tools by the EU bureaucracy to achieve the objectives of the CFP (EU 2013; European Commission 2014). Stakeholder-driven initiatives to make such plans is a recent phenomenon in the EU. The first plan produced by an Advisory Council was a proposal regarding the western stock of Atlantic Horse mackerel (*Trachurus trachurus*) presented by the Pelagic Advisory Council (PELAC) in 2007 (PRAC 2007; Hegland and Wilson 2009). In 2012, the PELAC followed up with a plan for boarfish (*Capros aper*) in the Northeast Atlantic (PRAC 2012a). A third Advisory Council plan was presented by the North Sea Advisory Council (NSAC) in 2015 as their advice concerning management of *Nephrops* (*Nephrops norvegicus*) in the North Sea (NSAC 2015).

Advisory Council initiatives to produce management plans open up for integration of various forms of knowledge into the EU fishery management knowledge base via the stakeholder route. Knowledge exchange processes in such stakeholder-driven settings are largely unexplored. Knowledge exchange research on stakeholder engagement typically focuses on science-driven collaborations and the scientific route to knowledge integration (Fazey et al. 2013, 2014). However, the Advisory Council initiatives are mixed-actor collaborations that are not conducted as formal research projects. Insights

about best practices from experiences with science-driven participatory research (Mackinson et al. 2011; Reed et al. 2014; Hegger et al. 2012) are thus not directly applicable.

In this paper, we apply and develop boundary object theory to investigate knowledge exchange processes in stakeholder-led initiatives to make management plans for EU fishery management. Building on previous research on boundary processes (Star and Griesemer 1989; Star 2010; Carlile 2002, 2004; Nicolini et al. 2012) described in the next section, we ask: How do *boundary objects*, supported by *boundary activities*, create *boundary spaces* that facilitate knowledge exchange in stakeholder-led collaborations to make management plans? We address this question by analysing the initiatives to make long-term management plans for *Nephrops* and for boarfish, mentioned above. The two cases represent unique and recent examples of how stakeholders, who represent the fishing industry's interests, engage in activities with other stakeholders and with scientists in collaborations to produce tools for EU fishery management. The two cases complement each other by illustrating collaborations in different fisheries and stakeholder groups; the *Nephrops* case provide insights into an established demersal fishery and a collaborative process in the NSAC, while the Boarfish case is set within the context of a new pelagic fishery and illustrates collaborations co-ordinated by interests in the PELAC. Our analysis focuses on the interplay between objects and activities, and on activities as entry points for various actors, with the aim of advancing understanding of knowledge production in stakeholder-led settings. The paper contributes to boundary object theory by presenting a theoretical understanding of knowledge exchange in stakeholder-led collaborations. In addition, the findings help fishery stakeholders, scientist and mangers understand the mechanisms and dynamics of developing long-term management plans in collaborative settings.

The next section introduces boundary object theory and the conceptual framework developed to analyse boundary processes and knowledge exchange. This is followed by a description of the methods used to collect and analyse empirical material for the two case studies. The *Nephrops* and Boarfish cases are then presented and discussed, and in the final section conclusions are drawn.

Theory on boundary processes in mixed-actor collaborations

The metaphor of boundaries is applicable when analysing the dynamics between actors in collaborative knowledge production processes. Reflecting on the usefulness of boundary concepts in social science research, Lamont and Molnar (2002:169) comment that "[i]f the notion of boundaries has become one of our most fertile thinking tools, it is in part because it captures a fundamental social process, that of relationality". Seminal contributions are Gieryn's concept of boundary work (Gieryn 1983) and Star and Griesemer's concept of boundary objects (Star and Griesemer 1989). The two concepts represent different interpretations of boundaries as a metaphor. While Gieryn's boundary work addresses demarcations, in particular between science and non-science and between scientific disciplines, Star and Griesemer's boundary objects address convergence, as in creating a common understanding between actors who wish to collaborate. As Riesch (2010:455) puts it: "The groups that Star and Griesemer are concerned with here are not rivals that, as in Gieryn's schema need to protect their interest against outsiders, but rather different groups that may have different values,

norms and aims, but nevertheless need to work together". Star and Griesemer were interested in how collaborations between diverse groups of actors involved in scientific work can succeed. They describe boundary objects as

> *"objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. They may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation"* (Star and Griesemer 1989:393).

A clarification of Star and Griesemer's use of the words *boundaries* and *objects* in this context is appropriate. Susan Star explains: "Often, boundary implies something like edge or periphery, as in the boundary of a state or a tumour. Here, however, it is used to mean a shared space, where exactly that sense of here and there are confounded" (Star 2010:602–603). An *object*, in Star's understanding, is "something people … act toward and with. Its materiality derives from action, not from a sense of prefabricated stuff or "thing"-ness" (*ibid*:603).

According to Carlile (2002), objects can perform as boundary objects in mixed-actor knowledge exchanges if they have certain characteristics: 1) they establish a shared syntax or language for individuals to represent their knowledge; 2) they provide concrete means for individuals to specify and learn about their differences and dependencies across a given boundary; and 3) they facilitate a process where individuals can jointly transform their knowledge. Carlile (2004) draws attention to that knowledge-sharing becomes increasingly challenging and complex if the actors in the collaboration have high stakes and if there is novelty involved. Boundary objects with characteristics tailored to the complexity and challenge at hand is therefore needed. Nicolini et al. (2012) highlight that boundary object theory is only one of several possibly useful lenses when seeking to understand the dynamics of mixed-actor collaborations. By using multiple theoretical approaches; theory on boundary objects, epistemic objects, cultural historical activity theory, and objects as infrastructure, they shed light on not only *how*, but also *why* and *when* objects may play a role in cross-disciplinary collaborations. They propose that objects can have several functions: 1) motivate collaboration; 2) facilitate work across different types of boundaries; and 3) provide infrastructure. This clarifies that a boundary object works for a reason; someone makes efforts that triggers activities which enable an object to perform as a boundary object in a particular setting and context. *Activities* thus become important when understanding the role of boundary objects in collaborations. We propose that the interplay between activities and boundary objects create 'boundary spaces' within which actors can share, transfer and translate their knowledge into joint knowledge. Without such activities, here referred to as 'boundary activities', the materiality of objects referred to by Star (2010) will not emerge.

These insights on boundary processes discussed above inspired us to develop a conceptual framework for analysing knowledge exchange in stakeholder-led, mixed-actor collaborations.

The framework (Fig. 1) addresses the dynamic interplay between objects, activities and actors. A boundary here refers to an abstract, shared space between collaborating actors with different knowledge. This 'boundary space' is where tacit knowledge becomes explicit and where actors are confronted with, and learn about, each other's interests and perspectives. Actors can be individuals or groups. In collaboration, they want to produce new knowledge, based on their own individual knowledge and interests. Objects become boundary objects when they play a role in connecting these actors and help establish a shared understanding between them. Objects can be both abstract and tangible. We introduce the concept of 'boundary activities' as activities that are instrumental in making objects function as boundary objects. Examples of boundary activities are face-to-face meetings, phone calls, workshops, field work, study visits, presentations, and decisions to initiate projects. These activities create entry points for actors to participate in a collaboration. They create ways to focus efforts around a certain shared idea, concept or product that can potentially be a boundary object. Activities are thus instrumental in making objects function as boundary objects in a specific context. Boundary activities and boundary objects are intrinsically interrelated in the sense that the objects trigger activities while the activities, in return, support the objects.

Methods

Knowledge exchange processes were investigated in two case studies of stakeholder-led collaborations; the *Nephrops* case and the Boarfish case. The cases represent two out of three to us known examples where long-term management plans have been presented by Advisory Councils. A third collaboration to make a plan for western horse mackerel has previously been analysed from a participatory modelling perspective by Hegland and Wilson (2009). The collaborations studied here were recent or still ongoing, which made it possible to follow the developments in, or close to, real time. Qualitative empirical material was collected from documents, through semi-structured interviews, and from observations. The use of multiple methods gave opportunities for triangulation, i.e. to check and validate findings by combining evidence from multiple sources (Yin 2009). The principal investigator participated as observer in eight NSAC meetings

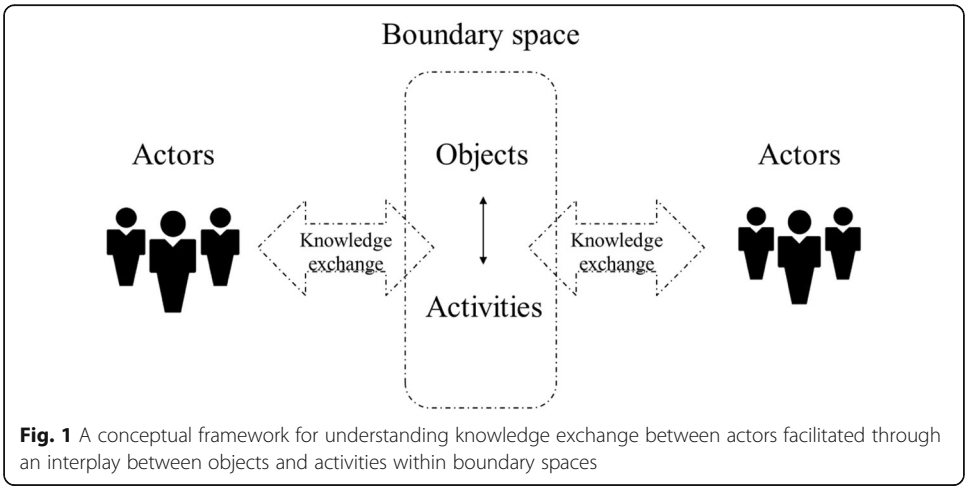

Fig. 1 A conceptual framework for understanding knowledge exchange between actors facilitated through an interplay between objects and activities within boundary spaces

in 2012 and 2013, and in six PELAC meetings in 2014. Documents studied included minutes from NSAC meetings 2006–2015 and PELAC meetings 2006–2015. Other documents consulted were International Council for the Exploration of the Sea (ICES) Advice and Working Group (WG) reports related to *Nephrops* and boarfish, CFP-related documents from the European Commission, and newsletters from fishermen's organisations. The documents were particularly useful to gain an overall understanding of the various actors' involvement with management plans, establish timelines, and identify potential informants for interviews. Semi-structured interviews ($n = 37$) were conducted between May 2012 and November 2014 with fishing industry stakeholders, including Advisory Council members and staff ($n = 17$), scientists who had been involved in *Nephrops* or boarfish research or in the making of management plans ($n = 14$), and civil servants in the European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE) ($n = 6$). The interviews were conducted face-to-face, and via telephone or Skype, and were - with a few exceptions - recorded and transcribed.

Documents, interview transcripts and observer notes were assembled, labelled and structured using ATLAS.ti qualitative analysis software. The software aided retrieval and analysis of information from the combined pool of documents. Detailed narratives of the processes of making the *Nephrops* and boarfish management plans were created. The narratives described initiatives taken, actors involved in activities, and tangible output produced by the collaborations. Key informants were asked to review drafts of these narratives to help identify any errors and omissions. The narratives were used to analyse the role of objects, activities and actors with the conceptual framework presented in Fig. 1 as a lens. Ideas and interpretations were tested and developed in dialogue between the co-authors in an iterative process through which the conceptual framework evolved.

Nephrops case

Background

Nephrops are crustaceans that live in burrows in soft sediment. In the North Sea, they are primarily caught by demersal (bottom) trawling within nine areas, called functional units. The functional units are considered to have separate stocks (ICES 2013). A catch quota (Total Allowable Catch, TAC) is currently set for all of the North Sea. ICES advises, however, that management of *Nephrops* should be at the functional unit level "to ensure that catch opportunities and effort are compatible and in line with the scale of the resources in each of the stocks defined by the functional units" (ICES 2013:2). How management at the functional unit level can best be arranged has been subject to debate between stakeholders, managers and scientists for several years. In 2006, the NSAC Demersal Working Group conceived the idea of producing a long-term management plan for *Nephrops* in the North Sea. The NSAC Executive Committee (ExCom) set work in motion, and in 2015 their proposal could be presented to the European Commission. Here, the dynamic interplay between objects, activities and actors is analysed to illuminate the knowledge exchange process from idea to proposal. An overview is presented in Table 1.

Table 1 Boundary spaces and knowledge exchange in the *Nephrops* long-term management plan process

Boundary spaces at stages in the collaboration	Object	Actors	Activities	Knowledge exchange
Evolution of idea to make a long-term management plan	Long-term management plan as a template	NSAC members	NSAC Demersal Working Group meetings (long term); ExCom decision.	NSAC members develop common interest in taking ownership of a stakeholder-driven, holistic management plan process
Production of draft plans	Long-term management plan as drafts	NSAC members and external experts in the *Nephrops* Focus Group	*Nephrops* Focus Group meetings (ad-hoc, long term)	Focus group members learn about each other's concerns and priorities; invited experts contribute with scientific knowledge
Port visits	Long-term management plan idea and process as a PowerPoint presentation	*Nephrops* Focus Group members, scientists and fishermen	Meetings in fishing ports to discuss management plan ideas and progress (one time)	Presentations and responses; difficult to reach common understanding in "one-off" settings
Functional unit plans	Fishing plan for the Farne Deeps	Farne Deeps Focus Group members	Farne Deeps Focus Group meetings; scientific study. (ad-hoc, short term)	Deliberations to identify functional unit-specific management options; scientific study provides analysis and alternatives
Long-term management plan proposal	Long-term management plan as a NSAC proposal	NSAC ExCom members	NSAC ExCom decision	NSAC-owned plan holds stakeholder produced knowledge

The idea of a plan

At the initial stage of the management plan process, the members of the NSAC Demersal Working Group played key roles. Several of them were at the time actively engaged in workshops and conferences where potential benefits of more holistic approaches to fishery management were discussed between stakeholders, scientists and managers (Pope et al. 2006; RACs 2008; ICES 2009). They were inspired by these discussions, and eager to take ownership of a knowledge production process in which stakeholder input would be as important as contributions from scientists and managers. A template for a long-term management plan that would encompass biological, ecological, economic, social and institutional perspectives on fishery management (NSRAC-DWG 2006) became the "scaffolding" around a management plan production process. The NSAC ExCom took action by deciding to establish a *Nephrops* Focus Group as a subset of the Demersal Working Group to bring the hands-on work with the plan forward. With this decision, a new set of actors became involved and another boundary space emerged.

Production of draft plans

The *Nephrops* Focus Group consisted of NSAC members with strong interests in the *Nephrops* fishery. Their main activity was meetings; 16 *Nephrops* Focus Group meetings were held between May 2007 and September 2015. Face-to-face interaction over several years allowed the participants to learn from each other about perspectives and priorities within different segments of the fishing fleet. Group members with NGO affiliations brought forward conservation issues including discards, bycatch of vulnerable species, and impact of bottom trawling on the seabed. An activity which further shaped knowledge production within the *Nephrops* Focus Group was to invite scientists. This expansion in terms of actors involved gave opportunities for the *Nephrops* Focus Group members to gain new insights about *Nephrops* biology, recruitment mechanisms, stock assessments, and scientific advice provided by ICES. The scientists contributed with texts on fishery science-specific issues, such as reference points, for inclusion in the long-term management plan. Updated versions of the emerging plan were made available as tangible representations of how the work progressed. As such, the drafts provided a medium for making the participants' tacit knowledge explicit. Furthermore, they served in a boundary object capacity as "containers" for *Nephrops*-related information assembled and ideas discussed by the *Nephrops* Focus Group.

Port visits

Additional activities were initiated in 2010 to involve more actors in the management plan development process. A press release was sent out to invite fishermen to attend meetings:

> *"In a ground-breaking initiative that could set a precedent for other stocks, the North Sea Regional Council [sic] is to hold a series of meetings with fishermen and other stakeholders in the main nephrops ports. Chairman of the North Sea RAC …, said: 'We have been working on a long-term management plan for nephrops in the North Sea for two years. Now it is time to share our work with those in the fishery to test whether we have got things right and to see whether we have missed anything. Long-term*

management plans are the future and it is therefore extremely important that everyone involved in the nephrops fishery contributes to its development […].” (NFFO 2010).

The port meetings created entry points for active *Nephrops* fishermen to contribute with their knowledge. In these meetings, PowerPoint slides presented by *Nephrops* Focus Group members set the stage by explaining the rationale behind the NSAC management plan initiative, present progress to date, and share ideas for ways forward. The responses from the fishermen signalled that there were strong and diverging interests and views between different operators and fleet segments. In this boundary space, lack of a shared language between the actors was a barrier to knowledge exchange. While the *Nephrops* Focus Group members and the scientists present were familiar with the scientific and bureaucratic jargon associated with stock assessments and management plans, this was not the case for the other participants. A one-off opportunity for face-to-face interaction, supported by the PowerPoint presentation, was insufficient for common understanding to develop. The feedback from the fishermen did, however, clarify to the NSAC that an overall plan for *Nephrops* management in the North Sea needed to take various local conditions and concerns into account. The next step was therefore to initiate more activities, this time with a local or regional focus.

Functional unit management

Based on feedback from the fishermen in the port meetings, and scientific advice from ICES that management of *Nephrops* should be at the functional unit level rather than on the overall North Sea level, the *Nephrops* Focus Group proceeded with the idea to make separate “fishing plans” for functional units. Initiatives to make functional unit fishing plans brought new actors into the overall process. Scientists were engaged to help draft a fishing plan for the Farne Deeps, the functional unit where management measures were most urgent. The scientists interviewed *Nephrops* fishermen and explored which objectives and management options that might be suitable for this particular area (Bailey et al. 2012). The response from fishermen to the scientists’ enquiries to participate in the study was low, but for the fishermen who chose to engage, the initiative provided entry points for contributing with their knowledge and concerns. A quote from the Farne Deeps study highlights differences in interests and perspectives between the local fishermen and the more distant operators:

“There was a stark difference of opinion between fishers registered at ports in North East England and those from elsewhere. The main concern of those registered at ports close to the grounds was that the twin rig gears preferred by many visiting skippers were damaging the seabed and taking too much from the fishery. … There was a strong call from many of the local fleet to ban twin rigging on the Farne Deeps Nephrops grounds. In contrast, those using twin rig gear were of the opinion that claims of seabed damage were unfounded and that bottom contact by heavy weights used by twin rig gear was minimal if it was set up correctly.” (Bailey et al. 2012:ii).

The *Nephrops* Focus Group established a Farne Deeps sub-group to discuss possible alternatives to reduce fishing pressure. This initiative reduced the number of actors involved in this boundary space to only a few individuals. After considering effort

controls, gear restrictions, spatial measures, and "of which no more than x tonnes" quota-restricting clauses, the Farne Deeps sub-group found the quota-restricting clauses most promising (NSRAC-NFG 2012). However, this conclusion triggered questions from industry stakeholders about who would then be eligible to take the functional unit-specific quota in the Farne Deeps (NSAC-NFG 2014). Exploratory calculations on how such a clause would be materialised in the form of quota allocations to fishermen under the existing management regime highlighted problems related to creating winners and losers. Diverging views on appropriate management measures in the Farne Deeps among fishing industry representatives, who wished to protect the business interests of their constituencies, could not be resolved by arranging yet more Farne Deeps sub-group or *Nephrops* Focus Group meetings. The NSAC finally settled for including a provisional fishing plan for the Farne Deeps as an annex to the overall management plan for the North Sea *Nephrops* fishery. The annex highlighted the "…of which no more than …" provision as a potentially good solution for the Farne Deeps, while also drawing attention to possible consequences of imposing such quota-restricting measures:

> *"… all parties accept that in the event of a significant reduction in Nephrops fishing opportunities for operators in the Farne Deeps fishery, quota availability would become a serious issue for locally based vessels dependent on this single fishery. The administrations involved would need to work with the POs (producer organisations) to find the best outcome for those who have a record of fishing in the area and to safeguard the interests of the locally based fleet for the duration of any required quota reductions."* (NSAC 2015:38).

The challenges encountered when trying to reach consensus on management measures for the Farne Deeps functional unit clarified how far such a constellation of actors as the Farne Deeps sub-group, the *Nephrops* Focus Group, and ultimately the NSAC, could take a collaborative mixed-actor knowledge production process before encountering politically sensitive issues and handing it over to managers for further work and decision-making (Stange et al. 2015).

A *Nephrops* long-term management plan proposal

In February 2015, nine years after the decision to make a management plan was taken by the NSAC ExCom, a 43-page long document *A Long Term Management Plan for North Sea Nephrops* was submitted to DG MARE as NSAC's advice (NSAC 2015). A provisional fishing plan for the Farne Deeps was included in an annex. Another annex, written by scientists, proposed a new reference point for identifying precautionary levels of *Nephrops* stocks. Actors involved at this stage were the NSAC's ExCom as the formal owner and producer of the plan. Introductory statements explained the plan's somewhat unusual length and format:

> *"Because this is the first plan that has been prepared in this way, with the full involvement of stakeholders, the plan is rather longer [sic] and more detailed than a conventional Management Plan. The plan includes information on how the management conclusions were reached, and how the plan has progressively evolved. Later versions are expected to be more concise."* (NSAC 2015:3).

With this, the NSAC communicated that it had been as important the them to develop a plan with ideas and elements that the fishermen could support as to deliver a product that would fit smoothly into the existing management framework.

Nephrops case summary

Producing a long-term management plan for the *Nephrops* fishery became a lengthy learning-by-doing exercise for the NSAC. The process was open and transparent. Stakeholders, scientists and managers with an interest in *Nephrops* science and management were invited to contribute to the hands-on knowledge production process by engaging in the *Nephrops* Focus Group. Several boundary spaces emerged within which actors could exchange knowledge. Draft versions of the long-term management plan served as objects through which this exchange took place. Boundary activities were manifested in the form of numerous group meetings, port visits and an interview study. These activities provided entry points for participation in the knowledge production process; however, direct engagement by active fishermen and managers was limited. It seemed an overly ambitious undertaking to produce a long-term management plan with a holistic approach to management based on broad input from stakeholders with different knowledge and interests. Still, a tangible output was produced and delivered through the stakeholder route. The proposal for a long-term management plan presented to DG MARE represents a milestone for the NSAC as stakeholder contributors to the knowledge base for EU fishery management.

Boarfish case

Background

Boarfish is a small pelagic species that is being caught in increasing amounts on the shelf edge south and west of Ireland. Some consider it a nuisance by-catch species, while others target it as a resource for the fishmeal industry. In 2013, boarfish was added to the list of stocks handled by the PELAC (EU 2013:Annex III). In the PELAC, a majority of the boarfish fishermen's interests is represented through Killybegs Fishermen's Organisation (KFO) and Danish Pelagic Producers Organisation (DPPO). Development of a long-term management plan for the boarfish fishery in the Northeast Atlantic was part of collaborations in 2010–2012 between KFO, DPPO and fishery scientists (Stange 2016). Here, knowledge exchange processes during these collaborations are described with focus on the interplay between objects, activities and actors. An overview of the boundary spaces that emerged is shown in Table 2.

Science-industry collaborations

In 2010, representatives for the fishermen saw a need for the industry to contribute to expand scientific knowledge about boarfish, as explained by the KFO Chief Executive in a newsletter editorial:

> *"The KFO has embarked on a scientific study of boarfish with the contracting of (name) to carry the necessary scientific work. Very little is known about boarfish and in light of development of the fishery by the RSW (refrigerated seawater) pelagic vessels, the KFO considered it was necessary to have the relevant biological information. Such information is central to devising rational management*

Table 2 Boundary spaces and knowledge exchange in the Boarfish long-term management plan process

Boundary spaces at stages in the collaboration	Object	Actors	Activities	Knowledge exchange
Science-industry research initiatives	Problematic knowledge gaps in a rapidly developing fishery	Fishermen's organisation representatives (KFO and DPPO); Scientists (Marine Institute and DTU-Aqua); Boarfish fishermen	Mobilisation of funding for scientific studies; sampling program, acoustic survey, age and maturity studies	New scientific knowledge produced; fishermen develop understanding about the role of scientific data in stock assessment and management
Interim plan proposal development	Interim plan proposal as idea	Fishermen's organisation representatives (KFO and DPPO); Scientist (Marine Institute)	Deliberations (one-on-one)	Common interest identified
Long-term management plan proposal development	Long-term management plan as idea	Fishermen's organisation representatives (KFO and DPPO); Scientist (Marine Institute); PELAC WG II members	Deliberations (one-on-one); PELAC WG II presentation	Common ground established, facilitated by industry representatives
Long-term management plan proposal	Long-term management plan as proposal	PELAC ExCom members	PELAC ExCom decision	PELAC owned plan holds stakeholder produced knowledge

arrangements that will ensure the long term sustainable future for this fishery. This is a new developing fishery, which has the potential to become a significant economic Irish fishery. Investment in the science at an early stage is paramount to that development." (KFO 2010:4).

Funding for scientific studies on boarfish was made available through contributions from fishermen who had boarfish quotas, as well as from the land-based processing industry. Co-ordination and deliberations within the producer organisations were essential to mobilise the funding. An interviewee explained:

"If the members (of the producer organisation) believe that this is the right thing to do, there is never an issue with money. If they don't believe in it, you will never get beyond that first talk." (Interview, Industry representative).

The funding from the industry enabled fishery scientists at the Marine Institute in Ireland and at the Danish Technical University DTU-Aqua to quickly initiate studies on maturity and age verification of boarfish (Farrell et al. 2012; Hussy et al. 2012). Funding also made it possible to arrange annual acoustic surveys to generate abundance data (O'Donnell et al. 2011) and to investigate boarfish-specific acoustic signals (Fässler et al. 2013). The scientific studies provided opportunities for the fishermen to be directly involved in the research undertaken, not only as financers, but also as suppliers of boarfish samples. These activities created entry points for the fishermen to engage in a boundary space where a shared understanding about scientific components to support management of the new boarfish fishery could evolve. Results that emerged from the scientific studies were regularly communicated back to the fishermen in KFO meetings and newsletters, along with explanations of how scientific knowledge on boarfish life history and abundance fit into the contexts of stock assessment, scientific advice, and management decisions. The scientists also published their findings in scientific journals, and brought their new insights on boarfish to the ICES' Working Group for Widely Distributed Stocks (WGWIDE) where it was used to underpin stock assessments and scientific advice (ICES 2012). The scientific studies facilitated knowledge exchange between industry actors and scientists around elements that were relevant for decision-making on boarfish quota and management.

An interim management plan

In parallel with the science-industry collaborations, a first interim management plan for boarfish was developed in 2010 as an Irish-Danish initiative. The initiative was triggered by a mesh size regulation that temporarily closed the boarfish fishery. At the time, industry representatives, scientists and managers were assembled to discuss other pelagic stocks, and they took the opportunity to engage in informal one-on-one discussions around the urgent boarfish situation. A scientist and a representative for a producer organisation, who could draw on experiences from previous collaborations around management plans, developed an interim boarfish management plan proposal within a time frame of only a few weeks. An interviewee explained the role of the scientists in this kind of setting:

"My role was to act as a technical advisor to the industry. That doesn't mean that I, or the institute where I work, endorsed those plans. We provided a technical service. We tried to develop something that represented their value system. It was clear to the industry that if they wanted to get a plan accepted, it had to have my value system in it. But ultimately, it is their plan. … By the time the boarfish plan came along, we had experiences with other plans that had failed because they weren't precautionary. So that learning curve had already been established and we didn't need to go through that phase again." (Interview, Scientist).

The key actors who were involved in this boundary space had a history of working together. Among previous collaborations was the development of a management plan for horse mackerel (Hegland and Wilson 2009; Clarke et al. 2007). The boarfish interim plan proposal was a 2-page document which emphasised the need for taking a precautionary approach, given the very limited knowledge about this species. A specific TAC-setting rule was proposed, and this element made the plan directly applicable as a tool for managers. The proposal also included measures to avoid by-catch of unwanted species. The interim plan filled a role as a boundary object by facilitating a transformation of thinking for the industry actors from short-term gains to longer term strategies (Stange 2016). To the fishermen, the interim plan implied a dramatic reduction of catch opportunities, at least in the short term. However, it also served as a stimulus to collaborate with scientists. Filling scientific knowledge gaps was urgent to avoid closure of the fishery and could possibly lead to better catch opportunities in the longer term. The interim plan also served as a medium through which the Irish and Danish industry actors could signal their commitment to sustainable management of the rapidly expanding boarfish fishery.

A long-term management plan proposal

In 2012, Irish and Danish industry representatives wished to follow up the interim plan initiative with a proper long-term management plan for boarfish that could be endorsed by the PELAC and used as a tool by DG MARE. At this stage, boarfish was not yet among the species formally handled by the PELAC. There was, however, an understanding between the PELAC and the European Commission that boarfish would be added to the PELAC list of species with the 2013 reform of the CFP. With the inclusion of the PELAC as actor, the boundary space widened and the process became more formal and structured. However, the development work was done outside the PELAC by the same key actors who had been involved in the interim plan process. With only a small number of people involved, one-on-one communication co-ordinated by the producer organisation representatives was efficient for bringing the process forward. The long-term management plan for boarfish was introduced to the PELAC's WG II in July 2012 in the form of a PowerPoint presentation (Clarke 2012). The meeting minutes reflect how the design of the plan could be interpreted as linking level of knowledge with more and less restrictive quota-setting mechanisms:

"… the more information is available the more generous the TAC can be set whereas the less information is available the higher the uncertainty becomes and therefore the more restricted the TAC would have to be." (PRAC 2012b:12).

The design of the plan thus created incentives for continued collaboration between the scientists and the industry to further expand the scientific knowledge base for boarfish management. The few members of the PELAC WG II who had high stakes in the boarfish fishery had been involved during the drafting phase of the plan, and were already familiar with its content when it was presented to the PELAC. Other PELAC members had little interest in the boarfish fishery. With a few edits, including a change of ownership in the preamble from KFO and DFFO to the PELAC, the plan was brought forward for endorsement by the PELAC ExCom (PRAC 2012b).

The PELAC submitted their *Draft management plan for Boarfish, Caperos aper* as their recommendation to DG MARE in August 2012 (PRAC 2012a). This recommendation was a 5-page long document designed to meet the managers' needs when making decisions about TAC in a new fishery with a small, but growing, scientific knowledge base. Put forward through the formal channel established for delivering stakeholder advice to the EU fisheries management system, i.e. through an AC, the boarfish plan got a "wrapping" as stakeholder produced knowledge. In this boundary space the PELAC ExCom members were the main actors, while the scientists were no longer involved.

Boarfish case summary

The analysis highlights that the mixed-actor collaborative process that led towards a long-term management plan proposal for the boarfish fishery in the Northeast Atlantic had two distinct components; one was the production of boarfish-specific scientific knowledge, and another was the making of a long-term management plan that could be proposed through the PELAC as their stakeholder advice to the European Commission. In between, an interim plan helped draw stakeholders', managers' and scientists' attention to the implications of the lack of knowledge on which to build management decisions, and the urgency in building a knowledge base to support this new fishery. Through all stages, representatives for the fishermen co-ordinated initiatives and activities that provided entry points for participation and engagement by various actors. The initial stages were fairly closed and involved only a few, well informed individuals who trusted each other and could work efficiently together. The setting changed from the point when the PELAC took ownership of the long-term management plan. Additional actors then entered the boundary space, and the producer organisation representatives followed up on boarfish matters in roles as PELAC members. The widening of context did not trigger any controversies. This indicates that interests were aligned, or that contested issues had been worked through in the preparation phase, during which activities were co-ordinated by PELAC members in roles as representatives of producer organisations.

Conclusions

This paper has described and analysed how proposals for long-term management plans for the *Nephrops* fishery in the North Sea and the boarfish fishery in the Northeast Atlantic evolved through collaborations in which fishing industry representatives in the NSAC and PELAC played key roles. The paper contributes to boundary object theory by presenting a theoretical understanding of knowledge exchange in stakeholder-led collaborations. In addition, the findings help fisheries stakeholders, scientist and

mangers understand the mechanisms and dynamics of developing long-term management plans in collaborative settings. The *Nephrops* case involved a large number of actors who needed to understand each other and establish ways of working together. The Boarfish case involved only a few actors, and several of them had experiences from previous collaborations. The conceptual framework added dimensions to traditional boundary object theory that were helpful for understanding knowledge exchange in both settings. The analysis focused on the interplay between objects and activities at the boundary between actors, and on how this interplay created spaces for knowledge exchange.

In both cases, management plans were boundary objects in a capacity of motivating the collaborations. Additional boundary objects with different capacities emerged during the course of the collaborations. For example; a management plan template provided "scaffolding" to guide the work with the *Nephrops* plan on from idea to action. In this capacity, the template served as a translational device between actors who needed to develop a common understanding of what a long-term management plan should contain. A more complex boundary process was illustrated in the Boarfish case, where an interim management plan was instrumental in transforming boarfish fishermen's priorities from short-term gains to longer-term precautionary harvesting strategies.

The conceptual framework highlighted the importance of activities as entry point for actors' engagement. In the *Nephrops* case, *Nephrops* Focus Group meetings were key activities. These meetings provided a forum for knowledge-sharing between stakeholders and scientists as well as between different stakeholder interests. Over time, a common understanding evolved around key issues and challenges. Initiatives to address specific problems triggered new activities, which brought different sets of actors into the collaboration. In the Boarfish case, scientific studies created entry points for direct engagement by fishermen in roles as sample providers and financers. These activities created leverage for fruitful knowledge exchange, and a common understanding around the need for management measures for the new boarfish fishery developed.

Analysing the collaborations as a progression of boundary spaces was useful for pinpointing challenges encountered and strategies chosen to address them. For example; when contested issues are encountered, opening up another boundary space with new actors and objects can be a strategy for bringing the process forward. This was illustrated in the *Nephrops* case when diverging views triggered the need for another boundary space where a tailored functional unit management solution could be elaborated. In the Boarfish case, the creation of a small boundary space with only a few well informed individuals was an efficient way of getting an interim plan produced quickly. These examples demonstrate that multiple boundary spaces evolve during a collaborative knowledge production process, and that inclusion of new actors and exclusion of others are elements in such processes.

The stakeholder-led collaborations analysed were characterised by *ad hoc* ways of working. Individuals with a strong interest in the issues took initiatives to get collaborative processes started. They used their networks to get others involved, and took on roles as facilitators. These individuals also acted in roles as representatives of fishermen, and were thus not without stakes themselves. In the Boarfish case, the absence of formalities seemed to make the collaborations efficient. As long as there was agreement within and between the producer organisations where the interests of a majority of the boarfish fishermen were represented, decisions could be made quickly and new

activities were initiated on short notice. The *Nephrops* process encountered a number of more complex problems which required significant time and efforts to identify ways forward. The approach to problem-solving practiced by the *Nephrops* Focus Group made the development of a long-term management plan for *Nephrops* an inclusive "bottom-up" process, in line with the NSAC's original intensions.

The *Nephrops* and boarfish long-term management plan proposals were submitted as Advisory Council recommendations to the European Commission. This route represents a formally established channel for stakeholder input, and the tangible outcome from the mixed-actor collaborations in the form of management plan proposals could thus be recognised as stakeholder knowledge contributions to the EU fishery management knowledge base. The Boarfish case illustrated that a dual strategy was used by the pelagic industry actors. Their engagement as funders of scientific studies on boarfish resulted in knowledge contributions through the scientific route as well, e.g. in the form of scientific publications and data to underpin ICES stock assessments.

The management plan proposals illustrate Advisory Councils' ability and willingness to take on pro-active roles as producers of knowledge for EU fishery management. The plans produced were different in terms of their form and content. The *Nephrops* plan was long and descriptive, while the Boarfish plan was short with focus on harvest control strategies. It is beyond the scope of this study to evaluate the utility of the two proposals for EU fishery management. It is notable, however, that managers were literally absent from the boundary spaces during the production of the plans. Including managers in the knowledge exchange process would increase possibilities for producing plans that take managers' current priorities and needs into account. This could, however, make the process more complex and time-consuming.

Endnotes

[1]The name change was introduced during the period studied. In this paper, these groups are generally referred to as Advisory Councils, while Regional Advisory Councils (RACs) is used when referring to documents published by these groups prior to the name change.

Abbreviations

CFP: Common Fisheries Policy; DG MARE: European Commission's Directorate-General for Maritime Affairs and Fisheries; DPPO: Danish Pelagic Producers Organisation; DWG: (NSRAC and NSAC) Demersal Working Group; EU: European Union; ExCom: Executive committee; ICES: International Council for the Exploration of the Sea; KFO: Killybegs Fishermen's Organisation; NFFO: National Federation of Fishermen's Organisation; NFG: (NSRAC and NSAC) *Nephrops* Focus Group; NGO: Non-governmental organisation; NSAC: The North Sea Advisory Council; NSRAC: The North Sea Regional Advisory Council; PELAC: Pelagic Advisory Council; PRAC: Pelagic Regional Advisory Council; RAC: Regional Advisory Council; TAC: Total allowable catch; WG: Working group; WGWIDE: (ICES) Working Group on Widely Distributed Stocks

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Availability of data and materials

Copies of interview guides, recordings, transcripts and observer notes have been deposited in accordance with the Data Management Policy of the Environmental Policy Group, Wageningen University, version March 2014.

Authors' contributions
KS collected the empirical material, analysed data, and wrote most of the manuscript under the supervision of JvL and JvT. All authors contributed to development of the conceptual framework and interpretation of results. All authors read, edited and approved the final manuscript.

Competing interests
The authors declare no competing interests.

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