Benefits and organization of cooperative research for fisheries management

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Drawing on research in the northeastern USA and northwestern Europe, a description is given of how cooperative research is organized and a statement made of how involving fishers in research can contribute to better fisheries management. The focus is on improving stock assessments through the collection of better fishery-dependent and -independent data and through efforts to address bycatch through gear-selectivity studies. Direct benefits of cooperative research include increased quantity and quality of data, inclusion of fishers' knowledge in science and management, improved relevance of research to fisheries management, and reduced costs of science. Indirect benefits are the buy-in of science and management by industry and improved relationships and trust between fishers and scientists (and managers). These indirect benefits are best achieved under conditions of transparency and communication. In some cases, cooperative research also provides income to the industry and supports the maintenance of fishing infrastructure. Most important, cooperative research improves capacity-building and establishes intellectual property rights within the fishing industry, and it encourages innovative approaches to management, such as adaptive and ecosystem-based approaches. Finally, guidelines for making cooperative research more effective are outlined.

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Introduction

Many authors have explored how user participation in management decision-making (co-management) can produce legitimacy and more effective regulations (Wilson et al., 2003). Others have documented the nature and value of fishers' knowledge and advocated its use in management (Neis et al., 1999). Today, an expansion of this discussion focuses on the role of fishers in fisheries science, or what is known as cooperative research (Kaplan and McCay, 2004). By cooperative research, we mean scientific research conducted in partnership with the industry, which ranges from chartering commercial vessels for research to the full integration of fishers in all stages of research (NRC, 2004).

A lack of consensus on the status of fish stocks can significantly impair management decision-making. For example, industry distrust of scientists and the inherent uncertainty of stock assessments contributed to an over-harvest of many New England resources, because managers, reacting to strong pressure from industry, did not implement regulations that adequately reduced fishing mortality (Dobbs, 2000). Fishers tend to be sceptical about the ability of assessment scientists to forecast fish population dynamics and to provide sound management advice. Because stock assessments often rely on spatially and temporally coarse data and are inherently complex, they often do not match fishers' daily observations. When science is distrusted, management may not be viewed as legitimate, resulting in evasion of measures and potentially high cost of enforcement. Industry's buy-in of science is expected to improve the legitimacy of the whole management system.

One way to generate buy-in of science and to move towards consensus on resource status is to utilize fishers' knowledge. Fishers' knowledge is often labelled as anecdotal, and its use in science and management has been limited (Pálsson, 1998; Neis et al., 1999), in part because of its largely local, hidden, and qualitative nature, making translation into scientific knowledge difficult (Pálsson, 1998). However, the utility of fishers' knowledge has been documented extensively. For example, fishers may contribute information about stock structure by describing migration patterns, current and historical spawning grounds, juvenile habitat, and spatial patterns in morphological attributes (Hutchings, 1996; Maurstad and Sundet, 1998; Neis et al., 1999; Ames, 2004). Their experience-based knowledge also includes valuable information about schooling behaviour (Parrish, 1999), habitat preference and gear selectivity (Hall-Arber and Pederson, 1999), and effort changes in response to regulatory change (Neis and Felt, 2001). Consequently, many researchers argue for increased inclusion of fishers' knowledge (Johannes et al., 2000).

In the northeastern USA, interest in and opportunities for such programmes (e.g. the Northeast Consortium and the National Marine Fisheries Service Cooperative Research Partners Program) have reached an unprecedented level (Sissenwine, 2001; Hartley and Robertson, 2006), involving almost all important fish and shellfish species, as well as studies of habitat and

environmental conditions. In Europe, cooperative research is also emerging through the UK's Fisheries Science Partnership and the Dutch F-project.

Here we discuss three important forms of cooperative research that currently exist in the northeastern USA and north-western Europe: fishery-dependent data collection, industry-based surveys, and gear-selectivity/bycatch studies. Information for the USA is based on semi-structured interviews, observations at science and management meetings, and a review of relevant documents. Information for Europe is based on direct experience in the F-project and in the ICES/NSCFP Working Group on the Incorporation of Additional Information from the Fishing Industry into Fish Stock Assessments (ICES, 2004). We then discuss benefits to management and provide recommendations for the organization of cooperative research projects.

Three forms of cooperative research
Fishery-dependent data collection

Traditionally, fishery-dependent data collection represents the most important source of input to stock assessment. The data include landings statistics, market sampling, and logbooks or vessel-trip reports. Today, fishers are obliged to provide such data to ensure compliance with regulations and to monitor the exhaustion of quota or days-at-sea allocations. This information may also be used by scientists to assess fishery removals and to monitor stock changes. One challenge to utilizing fishery-dependent data in stock assessment is the time-lag that arises, because hardcopy logbooks must be captured on electronic data-bases and audited for error. Use of these data is problematic. First, fishers are concerned that their data may be "used against them". This can happen directly when fishers are prosecuted for violations and indirectly when data are translated into restrictions on fishing possibilities (e.g. closed areas). Fishers also view their knowledge, as documented in these logbooks, as private intellectual property and feel that sharing it with other fishers may put them at an economic and social disadvantage in future. Clearly, there are incentives for fishers not to record information accurately in their logbooks, and as a consequence, landing statistics are considered unreliable. Additionally, fishers feel that use of logbook data to measure catch per unit effort (cpue) is biased because regulations interfere with their fishing patterns.

Many cooperative efforts aim to improve the quality and quantity of fishery-dependent data used in the stock assessment process. Currently in the northeastern USA, there are two cooperative programmes in progress to improve the collection of real-time data. One consists of a pilot "study fleet" of groundfish vessels in New England, and the other is a more established programme focusing on the mid-Atlantic squid (*Illex*) fishery. In both programmes, catch data are collected electronically in real time, and fishers and their vessels are used principally as instruments (or data collectors) and research platforms. In the squid fishery, the goal is to move from real-time data collection to real-time management (Powell *et al.*, 2003), but limited industry participation remains a stumbling block. The fishery is managed through quotas, and some fishers are reluctant to share information that they fear could lead to future quota reductions or effort restrictions. As *Illex* is a short-lived species and abundance indices are highly variable, the status of the population is difficult to assess (Hendrickson and Hart, 2006). Real-time data collection, combined with a pre-season survey, should allow the fishery to adapt

to actual abundance. However, real-time management also requires institutional flexibility to allow for in-season adaptation by industry.

In the Netherlands, fishers and scientists cooperate in the F-project to obtain appropriate data on cpue, mainly for assessment purposes. A selected group of beam trawl skippers records catches of plaice (*Pleuronectes platessa*) and sole (*Solea vulgaris*) by haul, together with a high-resolution information on location and time of day. The data are converted by scientists into maps and graphs documenting patterns in resource abundance, which varies through space and time (annual, seasonal). The results are discussed in groups with the participating skippers in their own harbours. Major topics for discussion are how constraints on total allowable catch (TAC) through, for instance, individual transferable quotas influence effort allocation through space and time and how to weight the data to obtain a meaningful annual mean that can be used as an index of total resource abundance, especially of plaice. The weighting method currently agreed is illustrated in an information sheet distributed throughout the whole fleet. That information sheet also provides information on the consequences of technical creep (Rijnsdorp *et al.*, 2006) for the index of resource abundance.

In the course of the F-project, fishers benefit from discussing their own information on catch and effort with scientists and among themselves. Such capacity-building has created a feeling of shared ownership of information and a greater understanding of, and access to, scientific information. The information is now being supplemented with similar maps and graphs constructed using data from the many, obligatory EU logbooks of all skippers in the Dutch fleet. Thanks to the F-project, this trajectory was able to be organized in a more structured and official way, to facilitate dialogue between fishers, scientists, and administrators.

Two important and related issues with these types of cooperative research programmes are the need for an adequate and representative sample from the total fleet and the hesitation, or sometimes refusal, of specific groups of fishers to participate. For example, participation in the squid programme plummeted as a consequence of distrust on the part of industry. Similarly, during the F-project, the present small number of skippers participating caused poor coverage of the resource area. If cpue data from such programmes are to be used in assessments, they need to be free of bias. Therefore, utilizing key industry leaders to increase commitment is crucial. Just as important, though, scientists should communicate clearly and exactly how the data will be used.

Industry-based surveys

To avoid statistical problems associated with using fishery-dependent data, assessment scientists frequently utilize fishery-independent surveys to monitor trends in fish populations (Sissenwine *et al.*, 1983; Gunderson, 1993). Such surveys are typically carried out with research vessels deploying standardized sampling gear to provide information on relative abundance, distribution, and other biological aspects of species. However, the surveys typically receive little support from industry. The methodology of selecting haul locations in a semi-random manner means that samples may be taken in areas almost devoid of fish, a counter-intuitive methodology to a fisher. Also the gears used may be questioned, in particular, because standardization means that they may be outdated compared with the gears used by

commercial vessels. Differences of opinion on the value of fishery-independent surveys are difficult to bridge.

Nevertheless, several cooperative industry-based surveys have been initiated recently. In the northeastern USA, some target species that are not sampled well by the large-scale, multispecies federal research-vessel survey (cod, *Gadus morhua*; yellowtail flounder, *Limanda ferruginea*; scallops, *Placopecten magellanicus*; surfclams; and monkfish, *Lophius americanus*), whereas other surveys focus on specific geographic areas that are not covered well (e.g. inshore waters or offshore, deeper water). The cooperative surveys are conducted aboard industry vessels, operated by experienced fishing skippers and crew, and using random station selection, with several surveys allowing some station selection by fishers. The crews have contributed their knowledge of gear/vessel operations and gear-habitat interactions, as well as of spatial and temporal fish behaviour in some cases. These industry-based surveys are more than just charters of vessels as research platforms, because the fishers are involved in critical aspects of survey planning and implementation.

Around Iceland, the cod stock has been monitored using an industry-based survey based on a stratified sampling scheme since 1985, also known as the trawling rally. The initial strata were defined by scientists and skippers working together, and considerable effort has been devoted to ensuring standardization (Pálsson *et al.*, 1989). Identical industry vessels, each with an experienced skipper and the same scientist as his mate on-board, sample both at randomly selected stations and at fixed stations selected using the best knowledge of the skipper on resource availability. However, crews need to know that problems of interpretation arise when they tinker with the gear and change fishing behaviour during standardized surveys. They also need to understand the statistical justification for random sampling vs. targeted sampling in areas of (expected) high density. When fishers do understand the rationale behind survey strategy, they are more likely to have confidence in the process and the results. This underscores the need for effective communication.

Gear-selectivity studies

Many cooperative research efforts aim to improve the selectivity of fishing gear and to reduce or avoid the discarding of unwanted fish. Discards may result from regulations prohibiting landings of these fish (regulatory discards). For example, juvenile fish below some minimum landing size or fish caught in excess of some trip or quota limit may have to be discarded because they cannot be landed legally. Discarding is notably prevalent in multispecies or mixed fisheries. Discarded fish are generally dead, in which case they represent a biomass removal that is difficult to quantify, but critical to stock assessments. Another problem is that the bycatch of threatened species (e.g. dolphins and turtles) in fisheries targeting healthy stocks may become a reason to prohibit the latter. Normally, fishers would prefer not to catch fish that they cannot keep for sale, because culling and shovelling unwanted catch overboard takes time and interferes with other activities. Generally, discarding is regarded as a wasteful practice that should be avoided.

Discarding is a major problem in the North Sea beam trawl fishery, which targets plaice and sole. The regulations prescribe a minimum mesh size of 8 cm to avoid the catch of undersized sole, but plaice are retained in these nets from 17 cm up, whereas the minimum landing size is 27 cm. Therefore, the discard rate for plaice may be up to 50% by weight and 80% by

number (ICES, 2006). On the basis of samples from a limited number of commercial fishing trips, the percentage of discards by age group has been used to improve the plaice assessment (ICES, 2006), but because of sampling error, the accuracy of population estimates for young plaice is poor. After consultation with scientists on sampling design and data recording, the industry has started its own, more extensive sampling scheme for collecting discard data, which has a larger coverage through space and time.

Dutch beam trawl skippers and scientists have also embarked on a cooperative gear-selectivity study to evaluate the relative efficiency of various mesh sizes for catching sole graded by market category. Fishers state that the minimum mesh size (8 cm) does not match the legal minimum landing size for sole (24 cm) and that some of the marketable sole escape through the meshes. This is based on their experience with (illegal) double codends to enhance selectivity for sole. A clear understanding of how changes in mesh size would change the size composition of plaice and sole catches is urgently needed. In that project, a large part of the observation scheme is executed by fishers instructed on how to record their catches. It is generally felt that the codend-cover selectivity experiments carried out in the past used commercial vessels as research platforms, without much input from fishers and with limited feedback about the results to the participants. It is anticipated that the new project will contribute to better mutual understanding and serve as a learning process for the fishers.

Gear-selectivity studies in the northeastern USA appear to have influenced management more than any other type of cooperative research (McCay *et al.*, 2006). In some cases, fishers and scientists collaborate to test whether a specific gear configuration reduces the impact on protected species. Managers have used data from such projects that document minimum bycatch of stocks requiring protection, while targeting sustainable stocks to develop temporal and/or spatial "special access programs". One example is the exemption of the Gulf of Maine whiting (*Merluccius bilinearis*) fishery from mesh restrictions when using a Nordmore-style grate and a raised footrope (NEFMC, 2003), because this gear was demonstrated to have a negligible bycatch of protected groundfish species.

In those studies, fishers contribute the use of their vessels as research platforms, as well as lending the benefit of their experience-based knowledge. The latter is especially important in determining key logistic aspects of gear research: where and when to fish. To determine whether a specific configuration meets its objectives, the gear must be fished in commercial mode, so there must be fish present. These projects can contribute significantly to management. However, in some cases, it can take years of testing to ensure that the objectives are met under all circumstances.

Benefits for management
Direct benefits

Cooperative research improves the quality and quantity of scientific observation by enhancing spatial, temporal, and categorical resolution, typically missing from traditional data-collection programmes. By focusing on single species, industry-based surveys supplement research-vessel surveys that typically focus on multiple species over large areas. Attention to finer temporal and spatial scales of data collection is important, because managers increasingly rely on area-based management approaches, such as fishery closures and areas where gear restrictions apply.

Involving the industry in research can also improve the relevance of scientific research by ensuring that the data collected address the most pressing management problems. This is especially true for gear research. Scientists are often far removed from what is going on in the fishery and in fisheries management. As one US scientist explained, "It is easy for people like me to sit and say it would be nice to do this. It may or may not have any relevance to the industry, but the people who are out there everyday know what is going on". This is especially true in the USA, where fishers are meaningful participants in the management process.

In some cases, cooperative research can significantly reduce the monetary costs of data collection. This is important because research institutes, whether governmental or private, are typically limited by the availability of funding. Assuming that some costs can be recovered through the sale of the catch, using industry vessels may be less expensive than using research vessels, allowing more research to be done than would otherwise be possible.

Indirect benefits

Cooperative research facilitates transparency and communication between scientists and fishers. For example, many Dutch fishers were convinced that scientists relied only on surveys for their stock assessments. Discussions within the F-project allowed them to understand how important the information from the fishery is for assessment and model calibration. Ideally, in cooperative research, all participants share their findings, including the explanation of how the data have been or will be used. When fishers learn and understand how science is applied, they are more likely to trust science-based management. Effective communication builds trust, which can be expected to translate into more effective management. Incorporating fishers' information and knowledge also generates buy-in of science and management, because the results are more likely to be viewed as sensible and thus legitimate.

Involving fishers in scientific research contributes to capacity-building in the industry because the participants learn how to interpret the information they produce, which they feel is their intellectual property, and to discuss stock assessments and management advice. They also develop better understanding and appreciation for information produced through scientific research. Understanding the science used in fisheries management aids participants in the EU Regional Advisory Committees and the US Regional Fishery Management Councils.

Cooperative research facilitates interest in and opportunities for more adaptive types of management, in which catch and effort data play a more prominent role. The increasing calls for real-time approaches to management in the US squid fishery are not unique, but are also heard elsewhere, e.g. in the Falkland Islands squid fishery (Beddington *et al.*, 1989; Agnew *et al.*, 1998) and the Scotian Shelf and Bay of Fundy herring fishery (Stephenson *et al.*, 1999). In Norway, fishers who detect high concentrations of juveniles inform their management, which in turn bans the fishery in that area until the situation changes.

The improved spatial and temporal collection of data via cooperative research also facilitates an ecological approach to fisheries management. In the northeastern USA, several exciting cooperative research projects are looking at ecosystem factors such as species–stock interaction and movement patterns (Northeast Regional Cod Tagging Program), habitat (Western Georges Bank Cod Habitat Study), trophic linkages (Trophic Ecology of

Atlantic Cod), and oceanographic conditions (Environmental Monitors on Lobster Traps, EMOLT).

Finally, cooperative research may represent an alternative source of income. Indeed, much of the cooperative research carried out in New England is paid for with federal "disaster relief" funds provided by Congress with the intention of mitigating the social and economic impacts of the groundfish fishery crisis (Hartley and Robertson, 2006). Many fishers here rely on (and anticipate) cooperative research funding as part of their annual business plans. This funding helps maintain fishing communities and fishing industry infrastructure so that, when stocks have been rebuilt, vessels, fishers, processors, ice houses, etc. will remain to exploit the resource sustainably and to get the products to consumers.

Guidelines for organizing cooperative research

Our observations suggest that improving the outcomes of cooperative research requires keeping several principles in mind throughout the research effort. These guidelines are discussed subsequently in relation to different stages of research (Table 1).

Problem identification and formulation of research objectives

Fishers need to be involved in all stages of the research process, starting with problem identification. Development of the research question or hypothesis is one area where fishers' knowledge can contribute significantly to the scientific research process. It is also important to include the end-users of the research, such as scientists and managers. For example, stock assessment scientists, who will use real-time fishery-dependent data collected by fishers or data from industry-based surveys, need to be brought into the process early on to ensure that the data are collected effectively and in a manner that lends itself to their subsequent analytical use.

The research objective should follow clearly from the problem description. All assumptions should be stated clearly, and participants need to understand what questions the research seeks to answer as well as how the data will be used. This is critical to ensuring that expectations remain realistic and that surprises are avoided. Participants will be discouraged if they expect the research to translate into a specific management outcome, and the research subsequently does not support that outcome. This was seen in the F-project where the decision to lower the TAC from its level the previous year caused skippers to leave the research fleet. By guarding the neutral position of science, these expectations can be avoided.

Research approach/design specification and data collection

Fishers should contribute significantly to project planning and design. Their knowledge of appropriate timing and location is critical to cooperative research efforts. For example, in gear studies, fishers know best when and where to test a specific gear that will be used by the industry. Fishers are critical to assessing the technical feasibility of research (e.g. how many tows can be completed in XX days), and calculating the cost to the project in vessel expenses (e.g. crew, fuel, supplies). The importance of planning should not be underestimated, and ample time needs to be appropriated to this phase.

When planning, it is also critical to be clear about the roles of scientists and fishers in the project (who is going to do what, when?). Ideally, fishers should be given roles that go beyond

Table 1. Guidelines for organizing cooperative research by stage of the programme.

All stages
Involve fishers at all stages
Include those who are most likely to use the data (e.g. managers or stock assessment scientists)
Communicate to industry at large about the project
Problem identification
Reserve sufficient time to develop a clear and shared problem description
Deduce the objective clearly from the problem description
Formulate the assumptions
Articulate what meaning the results will have and how they could be used (guard the neutral position of science)
Research approach and design specification
Assess the technical feasibility and statistical power of the observation scheme
Appraise the budget (time, money)
Allocate the research effort to fishers and scientists
Write a grant proposal and submit it to appropriate funding agencies
Data collection
Cooperate with fishers on board
Instruct fishers how to collect data, emphasizing consistency and the standardization of techniques
Make fishers confident that their task is done properly
Data processing/analysis
Review data for quality control purposes (e.g. auditing and peer review)
Provide the crew directly with the raw data obtained during a fishing trip
Allow industry participants to review preliminary results
Discuss the format for presenting the results
Communication of results
Communicate the significance of the results to the fishers involved in the project
Discuss the meaning of the outcome and the way the outcome will be communicated to the fishing industry
Communicate the objective, approach, and meaning of the outcome (distribution of leaflets, presentations at meetings, use of industry trade media)
Provide final report/data to appropriate end-users (e.g. managers, stock assessment scientists)
Assure clear demarcation between results (neutral) and the management implications (value-laden)
Co-publish the outcome of the study in partnership with those involved

using them merely to provide research platforms. Fishers, particularly in the northeastern USA, consider cooperative research to be "more than just chartering vessels" and view themselves as "equal partners" in the research effort. When fishers are not treated as equals, the project outcome is viewed with distrust. In some cases, projects are viewed as successful or unsuccessful depending on the level of cooperation, regardless of the research findings. Scientists need to assess the statistical power of the observation scheme to ensure that the results will be valid statistically for use

in science and management. It is disheartening to research participants to learn that an insufficient number of tows render their research results invalid for use in management or stock assessments.

Depending on the budget, scientists and fishers may have to sit down together to write a research grant proposal to pay for the research. The budget must be crafted carefully. One item often missing from early cooperative research budgets in the northeastern USA was funds for data analysis. Although the scientist partner typically drafts a proposal, the industry partner should review the grant to ensure that it meets its expectations and is logistically and financially feasible.

Fishers should also be involved in the collection and recording of data at sea. In cooperative research, fishers are trained in some cases to collect the data themselves. For example, fishers have learned how to record catch and effort data in real time using electronic logbooks, and fishers have been taught also how to tag fish for capture-release studies. This is part of the capacity-building associated with cooperative research. Scientists must ensure that the fishers collect the data consistently and according to specified protocols and that they understand the significance of standardization. Sometimes it is necessary to separate the scientific and fishing activities: fishers preparing their catch for market and completing legally required logbook information and the scientists "scientifically" processing the catch (measuring, weighing, etc.). Fishers should not be hindered from doing their job by scientific activities (e.g. such that might make the trip unsafe or reduce the value of the catch).

Before, during, and after a research project, the findings need to be communicated to the fishing industry at large. Such transparency contributes to the building of trust and confidence in the research. For example, tagging studies rely on fishers to report tagged fish, but if they do not value the project, they may not report these critical data. Many projects in the northeastern USA have benefited from public outreach efforts, such as posters, brochures, and internet sites.

Data processing/analysis and communication of results

Data quality controls are necessary before data can be made available for use in management. For example, US federal scientists are legally obliged to ensure data quality standards through the Data Quality Act of 2000. Data or final reports need to be peer-reviewed before their use in science and management. This can be a barrier to success, however, when cooperative research results are time-sensitive. This issue is similar to permitting; activities that go beyond normal fishing activities (such as in closed areas or with smaller mesh sizes) have to be reviewed for a permit before they can proceed.

As noted, data sharing and interpretation are often the sore spots of cooperative research. Fishers want to see the raw data, at least the data collected on board their vessels. Including their knowledge of the picture into the analysis sometimes offers insights not considered by scientists. Still, the industry partners should understand that preliminary results must be treated as such and not jump to conclusions before the final analysis. For example, premature release of data to the media following a cooperative industry-based survey in the mid-Atlantic USA eroded the trust between the partners and temporarily ended the cooperative effort (NRC, 2004, p. 28).

The scientists should discuss with their industry partners how best to format data for sharing and how best to present the analysis

to them and the rest of the industry. Moreover, scientists should make sure that data are provided to managers and other scientists in a way that facilitate their use.

The research partners should be clear about what the results mean and how they should be communicated to industry. Fishers need to understand results and share them with other fishers to generate buy-in. Scientists, therefore, need to communicate effectively so that the statistical treatments and uncertainty in the estimates are understood. Such understanding is aided by distribution of leaflets, presentations at industry fora and management meetings, and publications in fishing trade papers. Again, project results must be communicated to managers and stock assessment scientists, with a clear demarcation between results (neutral) and their management implications (value-laden).

Finally, it is necessary to give credit to all partners when the results are published or presented. Ideally, reports should be "co-authored" efforts, fishers being treated as equals. Although fishers may not care about the prestige of publishing in peer-reviewed journals, it is appropriate to offer them due recognition.

Participation and distribution of cooperative research funds

As noted, cooperative research is also, at least in the northeastern USA, a form of government assistance to the fishing industry. In such cases, it is important that the distribution of available funds is as fair as possible, providing opportunities for as many as possible to participate. This is also part of the trust-building needed in industry; if only a select group of fishers participate, broad buy-in of science may not come to pass.

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