

The benefits, structure and principles of cooperative research: A guide for the development of projects in Puget Sound supporting rockfish recovery

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Introduction

The inland marine waters of western Washington known as the Puget Sound are home to diverse ichthyofauna, including over twenty species of rockfish (Miller and Borton 1980). Rockfish (*Sebastes* spp.) are an economically and ecologically important group of marine fishes with unusually long life-spans, slow growth, and high fecundity. The group includes many deep-dwelling species that sustain internal injuries and positive buoyancy (barotrauma) after rapid decompression, resulting in high mortality rates through catch-and-release practices (Jarvis and Lowe 2008).

Due to their unique life history characteristics, rockfish are highly vulnerable to the effects of overfishing, including ghost fishing and incidental mortality due to bycatch. Following heavy exploitation in the 1970s and 1980s in Puget Sound, rockfish populations have declined and failed to recover despite increasingly restrictive management measures. As a result, in 2010 two species of rockfish in Puget Sound were listed as threatened and one species was listed as endangered under the Endangered Species Act (NMFS 2010). To assist in rockfish recovery, scientists have identified an extensive list of data needs, including: barotrauma and bycatch avoidance, habitat identification and rockfish use of habitat, ecosystem processes, fisheries management, effectiveness of habitat restoration, and rockfish stock structure. Gathering this data will be crucial to rockfish stock recovery efforts.

Coincidentally, there is a pressing need to engage local user groups, particularly the recreational fishing and diving communities, in the conservation of Puget Sound rockfish. Inclusion of these groups in the scientific process can facilitate acceptance of management measures, and will provide an opportunity to collect more and higher quality data. Additionally, cooperative projects represent a great opportunity to foster environmental stewardship and promote scientific literacy.

The purpose of this report is to serve as a review and guide for the development of cooperative research projects with recreational stakeholders that address rockfish recovery and conservation in Puget Sound. This report has three major sections: clarification of terms, identification of the benefits of cooperative research projects, and a discussion of how to design successful projects. The report concludes with a review of two projects outside of Washington State that have been chosen specifically for their applicability to the study site and species in question, and will provide examples that are feasible for Puget Sound

Definitions

Cooperative research in fisheries, as defined by the National Research Council, is any partnership between commercial and recreational fishermen, fishing industry groups, nongovernmental organizations (NGOs), Sea Grant, state resource agencies, and universities (NRC 2004). Cooperative research is actually an umbrella term that encompasses a wide range of activities and user groups. Only minimal levels of user participation are required in order for a project to qualify as *cooperative*; examples from industry include keeping log books of fishing activity or partnering with governmental agencies to provide vessel chartering (NRC 2004). At the other end of the spectrum there are the truly *collaborative* projects, which occur when:

[...] fishermen and agency personnel work together in all phases of the project, including development of the research question, design of the project, performance of research, analysis and interpretation of results, and communication and dissemination of study findings (NRC 2004).

The distinguishing characteristic along this continuum is the increasing involvement of the user group in the scientific process. Many project types will fall somewhere in between these two extremes.

Partnerships between commercial fishing interests (industry) and governmental agency scientist dominate analysis and discussion in the literature. This is likely due to a number of factors. Industry-government partnerships include some of the most well-funded and well-organized cooperative efforts in the country. The Northeast Cooperative Research Program, administered by the Northeast Fisheries Science Center (NEFSC), is a notable example that receives millions in Congressional funding each year to fund a variety of short and long-term projects. Furthermore, there are government mandates under the Magnuson-Stevens Act to engage with the industry that are absent for other scientific groups and with other participant groups. Commercial fishermen have an invested interest in the outcome of scientific management decisions, and their incentives for cooperation are easy to identify: financial benefits, since retention of part of the experimental catch is common; a desire to prove scientific estimates or scientists wrong, which occurs when there is a mismatch between management restrictions and fishers' personal observations (Stanley et al. 2000); or a general desire to be more fully included in a process that impacts their livelihood (Hartley and Robertson 2006).

As a result of this strong emphasis on industry involvement in cooperative research, a large number of examples included in this report draw from commercial fisheries. Yet despite this focus, other user groups have often been appropriate partners for cooperative research projects (NRC 2004). In many areas of the world, including Washington State, recreational activities have a significant impact on the local economy and ecosystem (Cooke and Cowx 2004; TCW Economics 2008), and in some cases extract more resources from the environment than do commercial interests (Schroeder and Love 2002). Incorporation of user groups with such levels of expertise or interaction with the environment into research projects can result in rich new insights and improvements in the state of scientific knowledge.

The use of recreational user groups for collaboration blurs the line between cooperative research and another type of research known as *citizen science*, which is defined by Wiggins and Crowston (2011) as a "form of research collaboration involving members of the public in scientific research projects to address real-world problems". The broadness of this definition highlights the lack of distinction between what constitutes a cooperative partnership versus a volunteer partnership. For instance, projects with recreational fishers are often considered a form of cooperative research (NRC 2004), whereas projects involving even highly informed recreational divers are usually classified as citizen science (Goffredo et al. 2010).

There is, however, little functional difference between a project using a commercial fisher, a recreational angler, or a diver, once the specific needs and interests of the type of participants have been addressed. These needs will be highly dependent upon the participant's level of expertise, which is really what the distinction between citizen scientist (low expertise) and collaborator (high expertise) is intended to address. Therefore, while the phrase *citizen science* will be occasionally used throughout this document for the sake of brevity, it is preferable to think of designing appropriate projects for recreational resource users in terms of

their level of expertise. Anglers can be inexperienced, whereas a local longtime diver will have a high level of knowledge about dive conditions and organisms.

Benefits of Cooperative Research

While not a new idea or practice in fisheries research, interest in cooperative research and citizen science has expanded rapidly in recent years (NRC 2004), perhaps due to recognition by the world fisheries community that the traditional model of scientific inquiry is incomplete (Baelde 2007). Cooperative research projects have four broad advantages over traditional methods. These projects can: generate a large quantity of data inexpensively; foster positive relationships between scientists and user groups; incorporate insights that are generally ignored by the scientific community; and provide an educational experience to the participating community.

Inexpensive Data

There is a significant precedent for the commercial fishing industry to be involved in data-gathering as a method for scientists to reduce research costs. For example, trawlers on the West Coast of the United States have had a long involvement in voluntary log book programs to track discards, while vessel chartering by researchers has been a common way for industry to facilitate the collection of data more cheaply (Harms and Sylvia 2000). There have been few rigorous examinations of the savings provided by these types of cooperative research projects over traditional methods. However, given that the cost of chartering a research vessel can range from \$2,500 – 5,000 USD per day, reduction in costs are likely to be significant.

Evaluation of the economic benefits of citizen science has been more common. This may be because the coordination and training of non-specialists requires more resources than does networking with people who were already engaging in a commercial activity, and therefore requires greater justification to funding partners or agencies. Some significant examples of benefit analysis include an estimate by one diving survey that the amount of data gathered by volunteers in three years would have taken a professional researcher 20 years and \$1.365 million USD to gather (Goffredo et al. 2004). In Australia, the Threatened Bird Network (TBN) estimated that volunteers contributed \$2.6 million AUD (approximately \$2.4 million USD) worth of effort toward bird conservation and recovery from 1996 – 2000 (Weston et al. 2003).

While inexpensive data collection can be a very beneficial secondary or tertiary motivation for cooperative research projects, it is unwise in most cases for this to be the sole reason for starting a cooperative research project. Coordinating with partners entails the interaction of participants and researchers, leading to changes in interpersonal relationships and perceptions (NRC 2004). These changes can either improve or degrade subsequent interactions among the partners. Researchers not interested in or prepared to address the human element of projects may inadvertently worsen relationships with participating communities.

Fostering Relationships and Improving Compliance

The relationship between resource users and scientists is famously fraught with misunderstanding and hostility. As described by Wilson (1999), the people that make up the

fisheries and fisheries management communities are by definition interested in the outcome of the fishery, take truth claims personally, and are more skeptical of others' motivations than of the inferences they draw from personal observations. Resource users tend to believe that scientists are purposely underestimating what the resource can withstand, whereas scientists may believe that resource users are overexploiting a resource out of ignorance or greed. In general, cooperative research is assumed to facilitate the development of relationships built upon mutual trust and respect as participants work together for a common goal.

Surveys with fishermen and scientists provide support that collaborative or cooperative projects can help build rapport and increase mutual understanding in fisheries science. In one study, fishermen cited mutual learning, improvements in how data were collected; and the development of relationships with other participants as the primary benefits to cooperation (Conway and Pomeroy 2006). Hartley and Robertson (2006) found that the majority of participants on both sides (fishermen and scientists) had positive feelings about the cooperative project that they had participated in and that 82-83% of all participants felt that the partnerships built would be long-lasting.

There are indications that participation in the management process (co-management) by those who are regulated improves compliance with regulations (Jentoft et al. 1998; Kaplan 2000; Kaplan and McCay 2004). The theory is that participation in the process legitimizes the regulatory regime and allows users to contribute their knowledge in meaningful ways while concurrently becoming more knowledgeable (Jentoft et al. 1998).

It has been hypothesized that a similar result will occur when user groups are involved in the scientific process (NRC 2004). Surveys from Robertson and Kennedy (2004 *in* Hartley and Robertson 2006) determined that "generating sound scientific data" and "assurance that the data generated would be used in making management decisions" were the most important incentives for cooperation by fishermen in one project. This finding appears to support the assumption that if fishermen are confident in how the data were collected and analyzed, then they will find it easier to accept and trust the management recommendations that emerged from the process (NRC 2004). This intriguing and potentially significant benefit to cooperative research needs to be investigated further in future projects.

New Insights

A further benefit to cooperative research projects can be the incorporation of new information and insights when recreational or local experts are included. Mackinson and Nøttestad (1998) assert that non-scientific knowledge is one of the richest and most overlooked sources of information and that it offers immense potential. Resource users often have a detailed understanding of the resource they use, their environment, and their use practices that may not be represented by the scientific literature or prevailing management knowledge (Neis et al. 1999). Stakeholder involvement can be especially useful for data that improve the spatial and temporal resolution of scientific estimates; an example of this is the fishers' precise knowledge about the location and timing of fish shoals (Mackinson and Nøttestad 1998; Stanley et al. 2000; Johnson and van Densen 2007).

Education

Finally, there is enormous potential for cooperative research projects to assist with a variety of educational goals. Projects with high levels of participation (e.g. collaborative-style projects) will naturally facilitate learning for user groups, provided participants share results and communicate well with one another. Collaborative-style projects also provide mutual education, as scientists learn from stakeholder groups. In a small, well-organized research project funded by the Northeast Consortium, a large number of surveyed fishermen (73%) felt that the experience had increased their understanding of the scientific method, whereas an even larger number of scientists (83%) felt that participation had improved their understanding of fishing methods (Hartley and Robertson 2006).

Projects that involve lower levels of participation require careful planning and design on the part of project developers in order to promote specific educational goals. This is especially true of citizen science projects, given that public education is generally one of the more prominent goals for these types of projects (Bonney et al. 2009). For example, one project using volunteers to monitor bird nesting habitats was found to be effective at teaching participants about bird biology but not about the scientific process. The study concluded that projects hoping to increase understanding of the scientific process should be framed in a way that will make participants particularly aware of the process as they are involved in it (Brossard et al. 2005). This general principle of designing to achieve a specific educational goal will be true of all projects.

Structuring Projects

The following steps are intended as a guide for the development of a cooperative research project and are adapted from the suggestions found in Yochum et al. (2011) and Johnson and van Densen (2007). Special emphasis has been placed upon making this structural guide relevant to cooperative research projects with recreational users, as opposed to collaborative projects (Yochum et al. 2011) or those that involve commercial interests (Johnson and van Densen 2007). Specifically, these steps are designed for projects where researchers develop the questions of interest and the research design before, rather than after, they identify and reach out to likely participant groups. A summarized version of the steps from Yochum et al. (2011) is provided for reference (Figure 1).

Step 1: Identify project goals

As with any other kind of project, the first step toward developing a cooperative research project is to identify the **goal**. The goal should ideally have three parts: the study system, the participants, and the intended purpose of the project. The intended purpose can alternatively be thought of as the primary benefit of doing a cooperative research project rather than a traditional research project. In general, the goal will be the most important step because it will direct how the project is structured and how it should be evaluated for success. For instance, the goal of a beach monitoring citizen science project could be to:

“Increase public awareness of beach conservation while gathering inexpensive data on intertidal organisms”

This goal highlights beaches as the study system, non-specialist volunteers as the participants and two purposes: education and inexpensive data collection. On the other hand, the goal of a recreational angler gear testing program could be to:

“Improve relationships between anglers and scientists; facilitate understanding of the scientific process and the need for gear compliance among anglers; and efficiently test specialized angling gear while gathering information on angler perceptions”

This goal is clearly more complex, but still has all the necessary elements. Fishing is the study system, the participants are anglers, and there are three purposes: fostering relationships, facilitating compliance, and specialized data collection that is informed by angler expertise.

Step 2: Identify the research question

The research question should follow from the goals (i.e., the study system, participants and intended outcome) and will be influenced by financial, technical, logistical and time constraints. It will be helpful at this stage to get all project leaders together in order to make sure those in charge understand what questions the research is seeking to answer, and that all assumptions are clearly stated (Johnson and van Densen 2007). Given that many projects are a mix of collaboration and cooperation (Hartley and Robertson 2006), scientists may want to consider including a small number of community “experts” in the research design process even if the project is intended to be primarily cooperative.

Step 3: Design the study

A comprehensive account of research design and sampling methods is beyond the scope of this report. However, there are some characteristics of good design in cooperative research to consider, and common missteps that should be avoided. In addition to designing standard sampling protocols and methods, project designers should decide in advance how to address the considerations that are specific to cooperative research.

First, as a general rule, cooperative research projects are a type of applied research seeking to answer questions of practical management or conservation relevance (Almany et al. 2010). The research questions should be, by definition, of interest to both researchers and community participants. Therefore, researchers owe it to non-scientist participants to ensure that sample sizes are large enough to answer the question (statistical power; Zar 2004), and that the spatial and temporal scales at which data are collected match those of the question.

Secondly, sampling protocols must take into account the skill levels of the intended participants. This means that protocols should limit to a certain extent what participants are asked to do, and include some way to verify the reliability of the data being collected (Cohn 2008). Researchers can also maximize sampling efficiency by getting stakeholder input on research questions and protocols early on in the design process (Johnson and van Densen 2007).

Finally, researchers should decide in advance how data will be shared with participants (Johnson and van Densen 2007) and design a plan to evaluate the success of the project upon its completion (e.g. Margoluis and Salafsky 1998; see also Step 8). Following all these steps will be easier if concrete examples of successful cooperative research projects with similar methodologies and goals are used as a guide. If no such example exists or if there has been

difficulty in constructing research projects of a certain type, researchers should consult the vast store of existing literature on research design theory (e.g. Creswell 2003).

Step 4: Identify individual or group participants

The type of participant has been identified already in the goal (Step 1). However, within a participant type there are a variety of sub-groups as well as specific individuals who may or may not be available and interested in cooperating. For instance, “recreational fishing community” is a diverse group of people and includes recreational anglers, private recreational fishers, charter operators, and industry support personnel like sport fishing organizations, fishing supply stores and marine representatives (Conway and Opsommer 2007).

The ability of certain groups to participate effectively depends partly upon the constraints of the project. If a long-term project is needed in an area where the majority of recreational anglers come from far away, for example, then a better choice of participant may be local charter boat operators who stay in an area year-round (Heck et al. 2011). As the list of possible participants is refined, it may be necessary to revise the goals, research questions and study design of the project. This is a reality of the collaborative process. Flexibility is a key element that will ensure a more successful project overall.

Step 5: Identify incentives for participation

Identification of the correct incentive for stakeholder participation is a key element in designing a successful cooperative research project. In many cases, a compelling incentive is already built into the project. For instance, projects seeking to refine and improve fisheries stock estimates will find willing partners in anxious recreational fishermen hoping to fend off fisheries closures. Other projects can be easily modified to include natural incentives. For divers, free air fills and an opportunity to dive in unusual locations with expert oversight can make participating in research fun and desirable.

In other cases, it may be necessary to provide financial incentives. When this occurs, it is likely because the cost to participating outweighs any benefits. A project involving local subsistence fishers in Papua New Guinea found that, because participating in research took time away from subsistence activities, researchers needed to provide adequate financial remuneration to fishers to encourage interest. Providing useful, high-end prizes (a spear gun, a wetsuit, and mask and snorkeling set) for the most successful fishers also proved to be a strong motivating factor (Almany et al. 2010).

An intimate understanding of participants and their communities will make identification of the correct incentives easier. For this reason, it is recommended that researchers either meet with or interview stakeholders ahead of time to get ideas about their interest in participation (Sine and Gaydos 2005; Heck et al. 2011). It may take some trial and error to find the correct incentives, but periodic evaluation and communication with participants will lead to an effective solution. Finally, it is always effective to be asking a research question that directly impacts the participant community. Even in cases where financial compensation is necessary, addressing questions about recreational or economic opportunity offers a secondary incentive (Almany et al. 2010).

Step 6: Reach out to participants

Once incentives have been designed and the correct participant groups have been identified, it is then time to reach out to participants through advertising and networking. One highly successful way to reach a large number of potential participants and to foster trust at an early stage is to reach out to influential community members or established groups (Almany et al. 2010; Heck et al. 2011). If a lead community member has been included in the planning process, this person or persons will be essential in fostering conversations with other potential participants. Other good choices for trusted partners are local angling or diving associations, well-respected tackle and dive shops, and non-profits. Pamphlets, flyers, websites, email lists and word-of-mouth are common and successful methods to advertise new projects (Bonney et al. 2009).

Step 7: Train volunteers

Volunteer training ensures that participants get the resources and support they need to contribute to a project with confidence (Bonney et al. 2009). Training also directly translates into scientific education, as participants learn about how scientists collect data and follow the scientific method. Finally, training is the only way to guarantee that participants are practicing good data collection methods in keeping with the design of the study.

The importance of proper training for this latter end cannot be overemphasized. Concerns about data quality have long been one of the biggest impediments to the acceptance of cooperative research by the scientific community (Cohn 2008). A considerable effort has been made to prove that cooperative research projects do have the ability to contribute meaningfully to the scientific discourse (Mumby et al. 1995; Goffredo et al. 2010; Holt et al. 2013). However, it is up to scientists to make sure that participants have all the tools and understanding to collect data accurately, and that they understand the importance of standardization and consistent data collection according to the outlined protocols (Johnson and van Densen 2007).

Step 8: Execute the study and evaluate the project's success

Monitoring and evaluation are two of the most overlooked steps in project design, yet they are essential for the long-term effectiveness and continuation of a program. Monitoring during a project allows researchers to gauge the project's effectiveness during execution, and grants participants an opportunity to ask questions and receive help. Monitoring can be as simple as a series of workshops at each step in the process (e.g. Yochum et al. 2011) or may involve a more elaborate ordering of intermediate goals that measure progress (Margoluis and Salafsky 1998).

Evaluation is the natural continuation of monitoring and can be considered the final act in a monitoring plan. Evaluation is especially important given the financial structure of science. With scarce funding, and most scientific projects receiving monies either through taxpayer dollars (government and academia) or donations (NGOs), research is increasingly being held accountable by policy makers for achieving its goals (Geuna and Martin 2003). Evaluation provides an opportunity for program designers and researchers to reflect upon and improve projects over time (Yochum et al. 2011).

The measure by which **scientific goals** are judged is often more straightforward than that for other types of goals. For instance, publication in a peer-reviewed journal is an accepted form

of validation that indicates the research has added something of value to the state of current knowledge (Bozeman et al. 2001). Other straightforward measures include size and quality of scientific database, or frequency of media exposure of results (Bonney et al. 2009). Incorporation of the data into management or conservation efforts is an even more meaningful outcome, although a project that does not enact immediate regime change is not necessarily a failure.

There are a suite of methods for evaluating **sociological goals**. Surveys are commonly used to evaluate participants' feelings about engagement in cooperative research, ranging from how the experience affected interpersonal relationships to how much the project informed participants about the management process (Conway and Pomeroy 2006; Hartley and Robertson 2006). Projects with **educational goals** often use tests to determine how successful the project was at teaching participants (Brossard et al. 2005). A range of other tools from cost-benefit analysis to in-depth interviewing are available to the researcher, depending upon the evaluation needs of the project (Geuna and Martin 2003; Bonney et al. 2009).

Step 9: Communicate results and management implications

Many user groups are motivated to participate in projects due to an interest in producing quality data that will either inform management or promote scientific understanding. Therefore, researchers are encouraged to maintain open lines of communication with participants and their communities throughout the duration of the study and after its completion. Non-scientists have demonstrated a preference for information that is user-friendly and makes sense to them; effective media include websites, emails, newsletters and articles in local newspapers (Conway and Opsommer 2007; Yochum et al. 2011). Projects with citizen scientists that use interactive websites to keep volunteers updated on data, conservation projects and resulting publications have also been popular (Silvertown 2009; Wiggins and Crowston 2011).

Communication should especially focus on the management or conservation implications of the results, depending on the audience. Hartley and Robertson (2006) found that following the end of an otherwise-successful project, fishermen regretted that the data they had collected had not been used to inform management as much as they had expected. It is the responsibility of lead researchers to ensure that cooperative research project results are used effectively and that the importance of participants' contributions is emphasized.

EXAMPLES

The California Cooperative Fisheries Research Program (CCFRP)

Description

In 2007, the State of California began implementation of 29 marine protected areas (MPAs) established by the Marine Life Protection Act (MLPA). As part of the MLPA, California is required to monitor and evaluate newly established MPAs as a tool for conservation and fisheries management. In anticipation of this mandate, researchers at California Sea Grant at Moss Landing Marine Laboratories (MLML), SLOSEA / Center for Coastal Marine Sciences at

Cal Poly San Luis Obispo; and the captains and crew of 12 fishing vessels¹ developed the California Cooperative Fisheries Research Program (CCFRP). CCFRP is a collaborative fisheries project designed to monitor fish populations at four of the new MPAs and associated environmentally similar reference sites beyond the MPAs.

Prior to implementing the project, researchers held a series of workshops with a diverse array of local stakeholders and fishermen to incorporate their expertise into the development of standardized sampling protocols. These workshops were facilitated by a neutral moderator (Wendt and Starr 2009). In later workshops, boat captains also used their knowledge to suggest appropriate sampling locations. The four MPAs chosen were the Año Nuevo State Marine Conservation Area (SMCA); and the Point Lobos, Piedras Blancas, and Point Buchon State Marine Reserves (SMRs). Within each MPA and reference site, researchers and stakeholders created and used 500 x 500 grid cells to delineate sampling sites.

Summarized briefly, the methods employed by the CCFRP involve standardized hook-and-line sampling with a variety of bait and tackle, including lingcod bars and shrimp fly lures. Anglers fished in stations arranged around the bow and the port and starboard sides of the vessel. Fish that were caught were identified to species, measured, and tagged. Participants took great care to minimize the time in between catch, processing and return to the water. They also restricted sampling to <40 m of water in order to limit fishing mortality from barotrauma. For a more detailed description of the sampling procedures for this project, see Starr et al. (2008).

Volunteer anglers were recruited to sample through fishing clubs, online fishing websites and other collaborative projects. As of 2012, 665 volunteers had contributed 21,950 volunteer hours to the CCFRP.

Reasons for Success

As a scientific research project, the CCFRP has been a success because the program was founded upon the principle that cooperative research should be as scientifically exacting as any other kind of research. As a result of the program's high scientific standards, the CCFRP has been able to achieve its goal of providing information for stock assessments and helping to evaluate the use of MPAs as a management and conservation tool.

To illustrate, the sampling protocols developed by the CCFRP rigorously accounted for environmental, temporal and spatial variability through properly constructed stratified random sampling (Wendt and Starr 2009). Environmental variability was addressed with the use of reference sites that had similar size, habitat, and oceanographic conditions to linked MPA sites. Researchers accounted for the high temporal variability in late summer months by sampling four days a month in each of three months in each area. Spatial variability was reduced by sampling in four random grid cells each day, within which vessel captains were instructed to locate three appropriate fishing locations to account for spatial variability *within* the cell (Figure 2).

Similarly, effort was standardized as much as possible. Each grid cell received the same amount of effort in terms of angler hours and each type of gear was sampled at the same time and for the same length of time. If any problems with gear occurred, a new rod was retrieved for the angler as quickly as possible. If it took longer than one minute to remedy the situation, the extra time was subtracted from the total effort (Starr et al. 2008).

¹ F/Vs *Admiral, Caroline, Fiesta, Huli Cat, New Captain Pete, Pacific Horizon, Patriot, Princess, Queen of Hearts, Rita G, Salty Lady and Tigerfish*

The CCFRP owes much of its success as a cooperative effort to its use of workshops drawing together all stakeholders at important stages of the project. Early workshops articulated program goals and research questions and established sampling protocols (Starr 2010; Yochum et al. 2010). Later workshops trained participants and scientists on how to perform their duties accurately. For example, science crew were trained on fish identification and practiced measuring, tagging and venting on dead fish at workshops before any sampling took place (Yochum et al. 2010).

The workshops further supported this program's unique mixed collaborative-cooperative design by engaging and training all types of participant groups. Although incorporating fishermen's expertise through all stages of the process was decidedly collaborative, the inclusion of hundreds of volunteer anglers who predominantly followed instructions was a cooperative process. The result was a program that engaged a wide range of community members and received all four major benefits of cooperative research projects. Volunteer anglers provided an enormous amount of inexpensive labor, while simultaneously learning more about how the scientific process works. On the other hand, expert fishermen were able to contribute their unique insights to the scientific process and improve their relationships with scientists and managers through teamwork.

The CCFRP also did an outstanding job of communicating with expert fishermen and volunteer anglers throughout the research process. For instance, at the end of a sampling day, anglers were thanked by email for their participation and updated on the number of fish that had been caught that day. At the end of the month, every volunteer angler was also mailed a flyer that provided updated information on the status of the project as well as a list of the largest fish caught of each species and the name of the angler who caught it (Starr et al. 2008). This level of recognition satisfied the principle of successful citizen science projects that volunteers need to receive feedback on their contribution as a reward for participation (Silvertown 2009). Although disagreements and misunderstandings occurred, it was found that careful explanations and transparency were usually effective at resolving conflicts (Yochum et al. 2011).

Of interest to note is that this collaborative effort may have benefitted greatly from the execution of a project several years prior. From 2003-2005, the same researchers in charge of the CCFRP led a cooperative study with commercial fishermen and the California Department of Fish and Game (CDFG) to determine the most effective sampling methods for surveying nearshore fish. The study was designed in response to a new interest in California in managing fisheries based upon fine-scale data, coupled with the recognition that very little information existed in 2003 to achieve this goal (Starr et al. 2006).

This study laid much of the preliminary groundwork for the CCFRP. It provided information upon the species of fish in nearshore California waters that would be caught with various forms of angling gear and what species would be seen by divers. As a collaborative effort, it also provided a template for managing participants' involvement and interaction. This example suggests that a pilot study may be a valuable and cost-effective tool for identifying areas of critical importance prior to the execution of a full-scale cooperative research project.

Adaptation Potential for Puget Sound

Much of the structure and design of the CCFRP could be adopted wholesale for implementation in Puget Sound. California's rocky reef ecosystems bear a striking resemblance to the rocky reefs found in Puget Sound, both in terms of species assemblages and benthic

characteristics. The CCFRP also targeted groups of fish that are found in Puget Sound, although with different species: rockfish (*Sebastes* spp.), cabezon (*Scorpaenichthys marmoratus*) and hexagrammids (Wendt and Starr 2009). Coastal California and Puget Sound have similarly active, interested, and vibrant recreational angling communities nested within dense urban areas. The legacy of fishing in both regions dates from the mid- to late-19th century (Norman et al. 2007), and exhibits similarities due to the common histories of communities on the West Coast of the United States.

Based upon these similarities, researchers in Puget Sound could adopt much of the design from the CCFRP addressing recruitment, interaction and communication with participants. The only recommended adaptation for Puget Sound is careful consideration of research partners. The CCFRP was an effort led by academic researchers, who are typically viewed by fishermen as a more neutral partner than government researchers (NRC 2004). Therefore, if state or federal agencies intend to lead a project with the recreational angling community, it may be helpful to include a university or non-governmental organization (NGO) as a partner to accelerate the trust building process.

In addition, given the current management regulations on rockfish catch in Puget Sound (e.g. fishing prohibited below 120 ft, and a zero-bag limit on rockfish retention; WDFW 2011), it would be untenable to design a scientific research plan exactly like the CCFRP. Researchers have already identified several alternative research topics in Puget Sound that would lend themselves well to a project similar to the CCFRP.

As a starting point, many unresolved questions regarding rockfish recovery and conservation are amenable to opportunistic data gathering. A variety of projects could be constructed where researchers work cooperatively with recreational anglers to target legal species. The research goal could be designed to find new techniques for bycatch and barotrauma avoidance or to identify rockfish stock structure. Researchers could teach the angling partners how to tag incidentally captured rockfish and how to take a fin clipping for genetic analysis, while anglers simultaneously test new recompression devices intended to reduce incidental mortality of rockfish.

If researchers wish to ask questions regarding the effectiveness of MPAs as the CCFRP did, then it will be necessary to obtain a special permit to target rockfish in Puget Sound. Participants in such a study would still need to fish in the shallows, however, and would not be able to gather much data about any of the listed species. This option does have the benefit of providing an easy incentive for angler participation: the opportunity to capture a restricted group of species or to fish in areas that are now off-limits, like MPAs and rockfish conservation areas (RCAs). It may also attract experienced anglers who were accustomed to targeting rockfish before the new restrictions.

Reef Check California

Description

The Reef Check Foundation is a 501(c)(3) non-profit marine environmental organization dedicated to the conservation of reef systems worldwide. Since its establishment in 1996, Reef Check has expanded its effort to more than 90 countries and territories (Dawson and Shuman 2009).

In 2005, the Reef Check Foundation launched its first *temperate* reef project along California's coast, called Reef Check California. Like the California Cooperative Fisheries Research Program, Reef Check California was developed to address data gaps surrounding the implementation of the MLPA and the Marine Life Management Act (MLMA).

The protocols used by Reef Check California were designed to match those of an earlier monitoring project as much as possible. In 2004, the California Department of Fish and Game (CDFG) administered a collaborative sampling effort of California's nearshore waters in association with various universities, private organizations and other government programs. This project, referred to as the Cooperative Research and Assessment of Nearshore Ecosystems (CRANE), was the largest and most comprehensive project of its type to date in California. Despite the project's scale, it did not receive funding for future monitoring efforts (Freiwald et al. 2013).

In recognition of the value of continuing CRANE's work, CDFG developed a sophisticated Memorandum of Understanding (MOU) with The Reef Check Foundation to establish Reef Check California. This MOU outlines that, in return for Reef Check California's provision of scientifically valid and defensible data to assist with CDFG's management goals, CDFG will provide Reef Check California with staff and vessel support for volunteer divers and their data collection efforts. CDFG will also provide technical support for the development of a user-friendly data dissemination web portal (CDFG 2007).

Reef Check California uses volunteer divers to survey and report on selected sites. The volunteer divers receive comprehensive training in identification of organisms, sampling methods and theory, techniques of research diving, and safe diving practices. Individual divers pick their site and complete a standard Reef Check California survey which includes:

- One **site description**, covering anecdotal, observational, historical or geographic information that will help correlate survey results to human influences.
- Six **core transects**, which the divers haphazardly place at least five meters from one another. These transects are 30 m long by 2 m wide. Divers must report on the following for each of the core transects:
 - *Fish transect* – 35 target species
 - *Invertebrate transect* – 30 species and 1 order (*Actiniaria* – anemones)
 - *Algae transect* – 8 species and 1 genus comprising several species. Any invasive species present are noted.
 - *Substrate Uniform Point Contact (UPC)* – Points are sampled at 1 m intervals along the tape. At each point, data are collected about reef substrate composition, organisms covering the reef (that are too numerous or crustose to count individually) and rugosity.
- Twelve additional **fish-only transects** that must be at least 5 meters from any other transect.
- One **urchin size frequency survey**, that occurs in the vicinity of a core transect.

Further information regarding Reef Check California sampling protocols can be found in Dawson and Shuman (2009).

Reasons for Success

Reef Check California was developed to respond to the same scientific needs that promoted the development of the CCFRP. However, the two projects are very different. Reef Check California would traditionally be considered a citizen science program, and as such, employs a top-down approach to research design that is appropriate for an effort engaging primarily non-expert volunteers. This means that Reef Check California's research questions, goals and sampling protocols were developed exclusively by professional researchers in a closed setting. Volunteers were brought on board once the project had already been defined.

Reef Check California is successful from a scientific perspective for several reasons. The program employs strong sampling protocols based on standardized transect methodology, ensures data quality through a series of checks, and provides comprehensive training to volunteer divers. The result is a program that produces data that is better suited to long-term monitoring and management needs than have citizen science dive projects using alternative methods (Schmitt et al. 2002).

Reef Check California protocols are based upon a rigorous standard transect sampling method that is widely accepted in the field (Brock 1982; Friedlander and DeMartini 2002; Schmitt et al. 2002). The training protocols developed by Reef Check California are also simple enough for trained volunteer divers to use. The protocols rely upon easily recognized key indicator species in a limited number of taxonomic groups (Hodgson 2001). And, while Reef Check California allows anyone to participate in a dive, study volunteers must complete all training, pass two written tests with 85% accuracy and successfully complete field methods and identification practical exercises before they can submit their data to the online database (Dawson and Shuman 2007).

In return for agreeing to modify their normal diving activities to follow specified transects and standardized data collection methods, volunteers receive detailed training in fish, invertebrate and algae identification. According to Goffredo et al. (2010), citizen scientists are often motivated to participate in projects due to their interest in and concern for nature. This indicates that thorough training in the identification of fish commonly encountered on dives may be a good incentive for volunteer divers.

Throughout, Reef Check California has been aware of the importance of the human factor in building success. Reef Check California's implicit focus upon satisfying volunteer needs has made the program succeed as a cooperative effort.

Aside from comprehensive training in identification, participants receive the chance to gain research experience and are attracted by the camaraderie associated with the volunteer community (Goffredo et al. 2010). Reef Check California has encouraged this engagement through their website, which includes an interactive data viewer that allows users to compare species abundance at different sites, look at changes over time, and select a number of pre-set overlays. The website includes a forum for divers to network and plan trips together. Reef Check California's Buddy Breathing Program has also partnered with dive shops across California to provide volunteer divers with free air fills and low-cost gear rentals, as an additional incentive for participation.

Adaptation Potential for Puget Sound

There are two primary ways that Reef Check California could be adapted for Puget Sound: through expansion of the existing Reef Check program or independent design of a similar program.

The most straightforward way to adapt this program would be for researchers to consult directly with the Reef Check Foundation about expanding the program to include a Puget Sound or Washington State chapter. Expansion of Reef Check into various local communities worldwide has often been the result of grassroots efforts. In California, Reef Check was launched with the assistance of the David and Lucile Packard Foundation's California Coastal and Marine Initiative, the CDFG, and a board of scientific advisors from universities, state and federal agencies, and NGOs that collaboratively developed the sampling protocols (Freiwald et al. 2013).

This process also occurred for the development of Reef Check Hawaii. There, the environmental NGO Save Our Seas acted as the coordinator and was supported in part by the State of Hawaii Department of Land and Natural Resources (Division of Aquatic Resources), the University of Hawaii's Marine Option Program, Sea Grant, the Sierra Club, and many local dive and community groups (Hodgson and Stepath 1998). In general, Hodgson (2001) recommends that local communities start with modest monitoring plans using the core Reef Check protocols adapted to local needs. As a project expands, it can add more detail.

There are numerous benefits to recommend this option. With direct expansion, The Reef Check Foundation is able to provide logistical support and advice based upon more than a decade of experience administering locally adapted Reef Check projects. This alternative may also relieve the burden of funding from government agencies by joining the collaborative efforts of many interested groups, as it did in California and Hawaii.

This choice also supports the development of a project that covers a wide variety of fish, algae and invertebrate species. While the focus of this document is upon the promotion of rockfish recovery efforts, it would require little effort using these methods to provide data to researchers in Puget Sound focused upon other species. Provision of these data may open the door to future collaborative efforts and data-sharing between researchers.

Alternatively, government agencies could choose to develop their own program based upon the core Reef Check California protocols without the involvement of The Reef Check Foundation. Reef Check California's protocols are preferable to other regions' protocols, given their scientific rigor and the similarities between Puget Sound and California's rocky reef ecosystems. This option has the benefit of allowing a project to be tailored specifically to rockfish and kelp habitat monitoring. A smaller, focused project could deliver results more quickly and provide an outreach opportunity to educate the public about rockfish conservation and management.

Regardless of the chosen scenario, the taxonomic list for a volunteer diving project would need to be modified to fit Puget Sound fauna. In California, target species were chosen after a thorough literature review and consultation with the REEF volunteer database. These sources helped determine what species were commonly seen in the area and what species were already being monitored by existing sampling programs (Dawson and Shuman 2009).

Finally, it is recommended that some of the transect methods be revised for Puget Sound, even if a pared down version of the project is chosen. A recent study found that while Reef Check California's fish and invertebrate transects were comparable in quality to transects completed by professional divers, physical site descriptions were not (Gillett et al. 2012). Given the number of projects currently underway to define the benthic structure of Puget Sound, it

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might make sense to drop reef substrate composition as a measurement completely. Evaluation of the quality of algae transects in comparison to professionally conducted dives still needs to be completed, especially since these data would be of primary importance to rockfish monitoring project in Puget Sound.

Figures

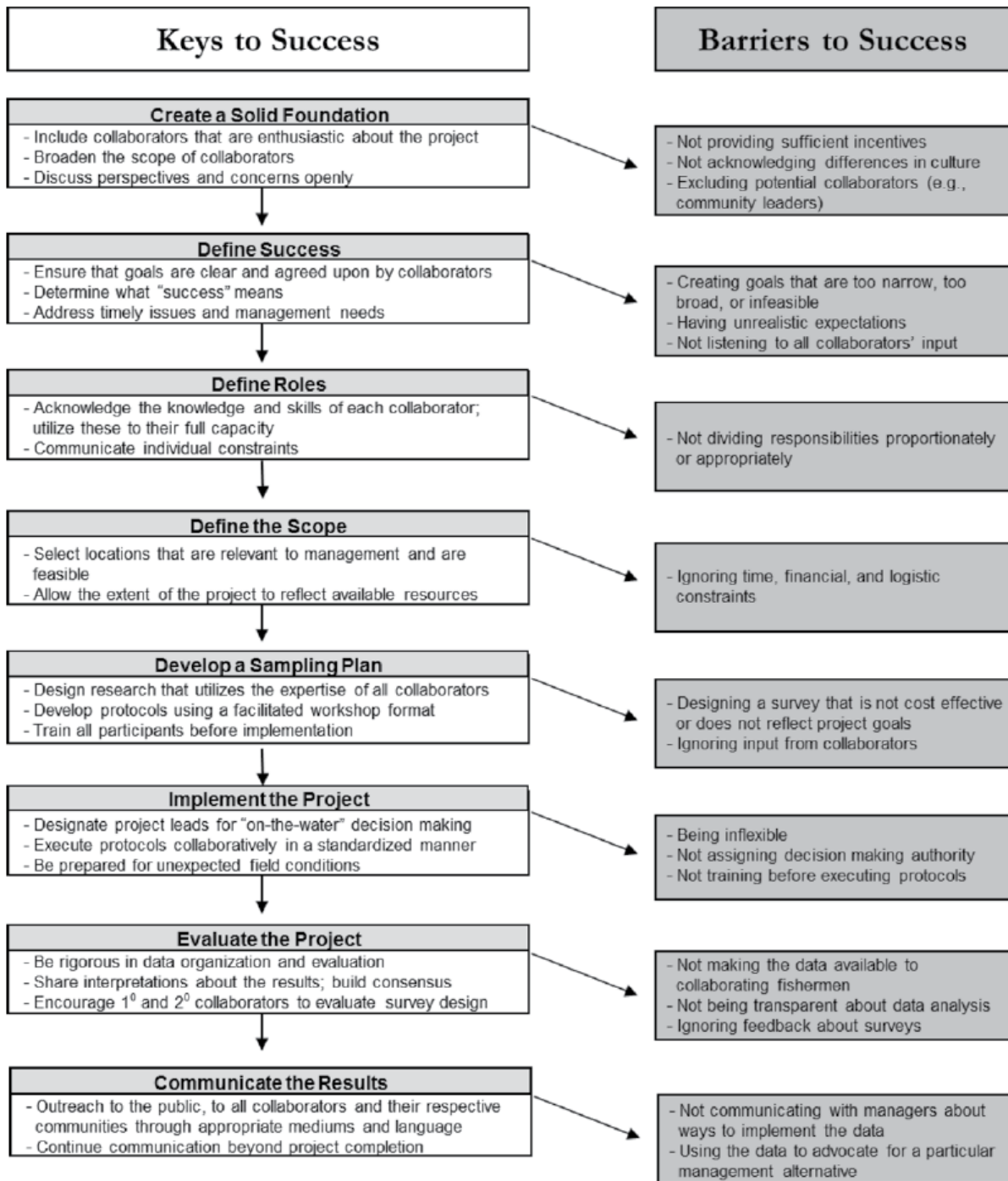


Figure 1. Eight key steps for developing and implementing collaborative fisheries research and potential barriers to success (Yochum et al. 2011)

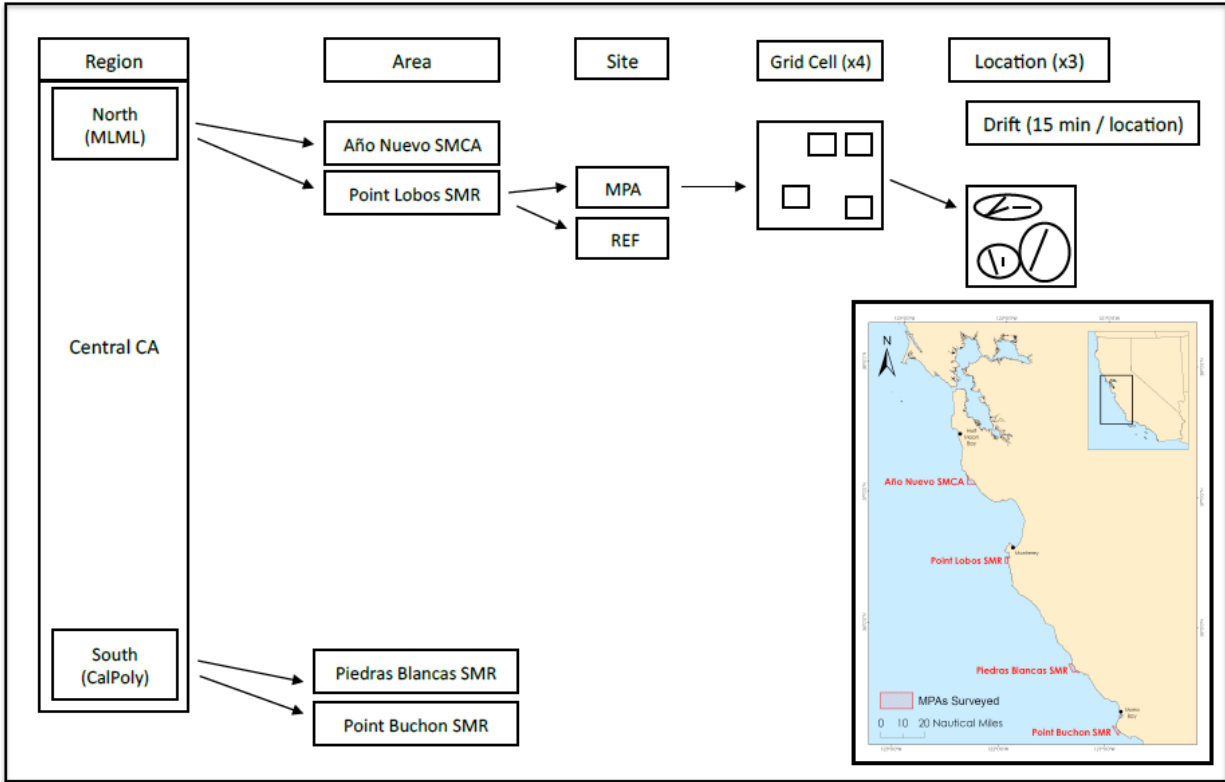


Figure 2. Diagram of CCFRP spatial terminology and sampling design (Starr 2012).

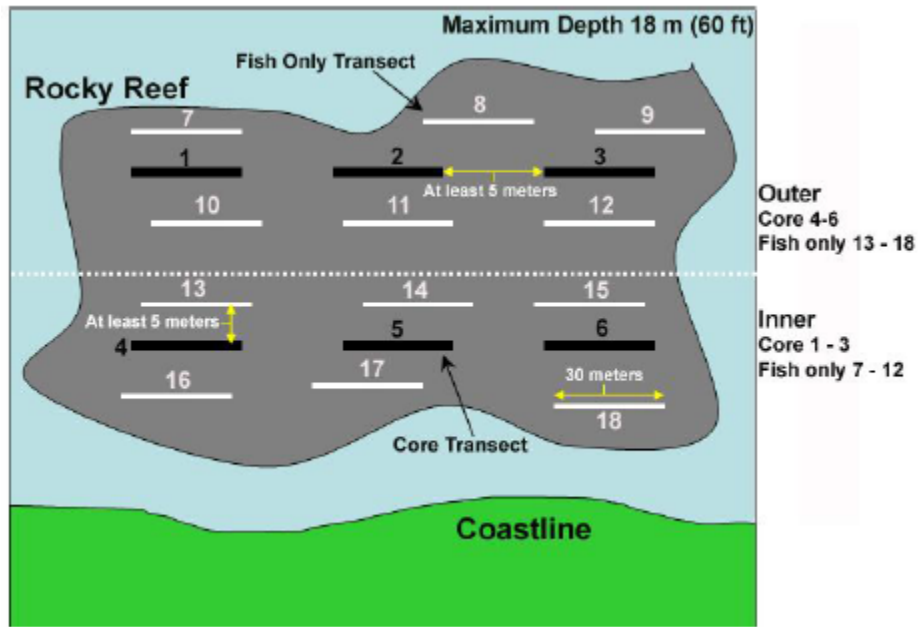


Figure 3. Hypothetical layout of transects at a Reef Check California site. Dark bolded lines indicate core transects and light lines indicate fish only transects (Dawson and Shuman 2009).

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