Fishery Management, Monitoring Systems, and Data Layering in Data-Poor Environments

ABSTRACT

Using the example of California's MPA monitoring program, we demonstrate how multiple, independently-derived, data sets can be assembled and analyzed, within low-information environments, to identify use areas, gear, seasonal, and social conflicts, and re-concentration of effort, resulting from past and present regulatory and fishery management actions. The paper examines, in particular, two methodological approaches intended to resolving both the issue of data inadequacies and data abundance (in the form of GIS data layering and analysis), and the issue of informant selection and reliability (through careful, replicable, informant network analysis). The results represent the basic requirements of a robust system for tracking changes over time in response to MPA constraints, and for "adaptive management" to a multitude of complex and overlapping regulatory controls on fisherman behavior.

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INTRODUCTION

The California Marine Life Protection Act (MLPA; Stats.1999, Chapter 10.5), referred to herein as the "Act,"[1] requires that the preferred alternative for each protected area address at least one of the two principal goals of the law.[2] These two goals are defined in California Fish and Game Code Subsection 2857(b), as follows: (1) "protection of habitat by ***prohibiting potentially damaging fishing practices*** or other activities that upset the natural ecological functions of the area," and (2) "enhancement of a particular species or group of species, by ***prohibiting or restricting fishing for that species*** or group within the MPA boundary."

The desired intent of these goals – to protect biological diversity and enhance depleted fisheries – gives rise to the prescribed management objectives for all of the prospective MPAs in the State of California. The Act, stripped of its manifest good intentions, is directed almost exclusively to address the behavior of a particular group of stakeholders – commercial fishermen (and, to a lesser extent, extractive recreational fishermen) – by "prohibiting potentially damaging fishing practices" and/or "prohibiting or restricting fishing" for particular species or groups of species. A deeper reading of the specifics of the MLPA makes clear that the intent of the law is primarily to manage the spatial distribution of commercial fishing effort and deployment of associated fishing gear.

Indeed, it is important to recognize this fundamental fact. The MLPA is not about *directly* managing species abundance, ecosystem status, biodiversity, or the condition of habitat. Rather, it is about *indirectly effecting improvement* in those factors by managing the behavior of commercial fishermen considered by many to be the principal cause or contributing factor of decline in abundance of certain fish species in the region. It should be noted, however, that the extent to which fishing has contributed to such decline is clearly not a settled question - factors such as coastal pollution, oceanic regime shifts, and other environmental factors are also implicated though not clearly understood.

GOALS AND OBJECTIVES OF THE IAI STUDY EFFORT

This paper is centered primarily on work undertaken by Impact Assessment, Inc. to develop a comprehensive baseline socioeconomic data base on which to base future measurement of the human effects and implications of implementing the MLPA along the California coast. The study, entitled ***Socioeconomic Baseline Data Collection, Resource Use Mapping, and Rapid Social Appraisal*** was designed to document historic (baseline) and contemporary commercial and recreational use of the marine environment along the Central Coast and for

[1] We include, for purposes of this paper, consideration of the regulatory and enforcement objectives of the Marine Life Management Act of 1998 (MLMA; Stats. 1998, Chapter 1052), as well as the Marine Managed Areas Improvement Act of 2000 (MMAIA; Stats. 2000, Chapter 385), and the California Ocean Protection Act of 2004 (COPA; Stats. 2004, Chapter 719) which delineates responsibilities to be assumed by the respective state agencies.

[2] While subsection 2853(b) actually sets out six objectives, objectives 3-6 are all subordinate to and directly dependent on the first two objectives: "(1) to protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems and (2) to help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.

assessing how such use patterns have and will change following establishment of the new network of 29 MPAs. The overarching goal of the project was to generate descriptive assessment in a form that that would be of maximal practical utility to marine resource managers, decision makers, and persons undertaking future ecological research and monitoring of MPAs across the region.

The study was designed to contribute to the "adaptive management" intent of the MLPA. By establishing a baseline understanding of historic trends and contemporary conditions for specific variables, it will now be possible to compare and evaluate change in those variables from an initial state. This will enable resource managers to better understand the human and biological implications of the MPAs and thus improve the likelihood of achieving desired outcomes. Without an *adequate* initial baseline, all subsequent management options will be distorted by the question of which elements of change are outcomes of the MPA implementation process, and which result from trends and processes underway at the time the MPAs were first initiated. *Development of a valid and effective human use baseline is vital for all initial and future management purposes.*

As such, the IAI study advances the data collection and analytical objectives of the MLPA Master Plan. It also directly addresses the socioeconomic assessment objectives of the Central Coast MPA Baseline Data Collection Project, and indirectly supports the biological assessment objectives of the MLPA study plan.

The administrative context of Central Coast MPA Baseline Data Collection Project required collection and compilation of data within a 15-month period. Given the need for development of a comprehensive baseline data base within that limited timeframe, it was essential that the research approach be both time- and resource-efficient. The research design thus involved satisfaction of the following technical objectives which sequentially build on each other to achieve the goals of the project:

(1) Conduct preliminary fieldwork throughout the Central Coastal region immediately before and following formal establishment of the new network of MPAs, thereby enabling documentation of initial social-behavioral response to the new regulatory regime and to inform development of a valid, timely, and effective approach to human dimensions MPA research in the region;

(2) Develop a detailed technical approach and field plan to enable baseline documentation of historic and contemporary patterns of fishing and other use of resources in and adjacent to the areas that are now MPAs;

(3) Establish strong rapport and trusted confidence with public officials, resource user group representatives, and others with interests in the process and outcome of the new network of MPAs;

(4) Systematically identify social networks of commercial and recreational fishing experts and other user group experts; undertake collaborative interaction with such persons to develop a thorough understanding of spatial and temporal (diachronic) aspects of resource use patterns within and adjacent to the new MPAs throughout the study region;

(5) Use spatial and ethnographic data to document, describe, and explain trends and variability in consumptive and non-consumptive use of the marine environment prior to and following establishment of the new protected areas;

(6) Use standard ethnographic and archival research methods to gather the data necessary to conduct basic and preliminary analysis of fleet- and community-level socioeconomic implications of the new system of MPAs; and

(7) Report and present study findings in a manner that is useful to resource managers and others involved in the MPA process in California; generate recommendations for: (a) effective, ethical, and collaborative interaction with fishery participants, and (b) a cost effective methodology through which to follow and analyze long-term social and economic sequelae of the MPA implementation process in the State of California.

IMPLICATIONS AND WIDER APPLICATIONS

The present study benefits from, and is an outgrowth of, a long series of fisheries social science research studies undertaken by IAI over the last 30 years. A representative sample of our work is provided as an appendix to this paper for those interested in the deliberative evolution of our approach and methods. The intent of this section is to crystallize the benefits of our experience into a core set of recommendations for the collection and analysis of fisheries-relevant social, economic, sociodemographic, and sociocultural data. It should be noted that, with few exceptions, the work performed by IAI since the late 1970s was conducted on behalf of federal or state government agencies, for clearly defined management purposes. Thus, the process of securing the work, preparing the research designs, field plans, and data collection methods invariably involved close collaboration with lead agency personnel, approval of all methods, with a clear objective of transparency, reliability, and replicability. Unlike many academic pursuits in the social science, each of the studies undertaken by IAI involved rigid time and cost constraints inherent to government contracting. These constraints have invariably required careful planning, prudent management, and efficient and reliable research methods. The last of these requirements is the focus of this paper.

DATA COLLECTION IN DATA-POOR ENVIRONMENTS

In practical terms, the vast majority of studies undertaken by IAI on behalf of local, state, federal and international agencies derive from agency perspectives that there is insufficient secondary source information for making sound management decisions.[1] Focusing only on fisheries resdearch, the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) has undertaken many studies over the years to address a broad spectrum of management questions involving the behavior of fishermen, the organization of fishing “communities,” or the industrial components (sectors) of “fisheries” (i.e., harvesting, processing, marketing, sales, etc.). The agency sometimes requires detailed studies in support

[1] There is, of course, a background environment within which all of these studies have been undertaken – the NEPA process establishes thresholds and explicit requirements within which all agencies have operated for the last 40 years.

of specific regulatory actions such as implementation of harvest regulations and,limited entry programs, or establishment of marine monuments and conservation districts

In each case, the underlying understanding is that insufficient secondary information exists "at the level of detail required" to confidently reach a balanced regulatory action. This relates directly to the concept of data-poor environments and to questions about what is meant by "data-poor environments"? The "straw-man" argument, of course, is that every regulatory action under consideration exists, by definition, in a "data-poor" environment. To a certain extent, this is inherently the case. If there were abundant or sufficient information on which to base a resource management decision, such a decision would likely have been made at an administrative level without further research or analysis. In practice, detailed scientific investigation and analysis tends to be called for only when the action in question is sufficiently large, novel, narrowly targeted, or uncertain in its effect.

For purposes of discussion, we consider a hypothetical extreme – a situation in which dramatic decline in a biological resource is being observed, but in the absence of information about the larger ecosystem in which the resource is situated and in the absence of data regarding fishing-related pressure on that resource. How might we approach such an extreme situation? Because reliable archival information does not exist in this case, and because our expertise as social scientists relates to human dimensions of marine fisheries, our first instinct would be to work directly with fishery participants to document fishing operations and resource use patterns in the area of concern.

Assuming that the fishery participants are telling the truth, and there are many ways to establish reliability, it becomes clear that an active fishery does exist in the area. In this abstract case, a small fleet has been exerting pressure on the resource in question with a specific type of gear in a specific area over past eight months. The fishery participants concur with the biologists that the resource is not as abundant as in years past. Although some managers retain uncertainty about the full range of factors affecting the resource, there is a tendency to quickly regulate the fishery since fishing is the only factor that can be directly and immediately linked to the resource.

In this simplistic model, the present activity of the fishermen represents the "base case." and thus our participant-based description is merely a "synchronic" documentation of activity. This is a poor indicator of the real association between fishing and the status of the resource since it involves only one data point. The more important questions would address trends over time since understanding of these is sorely needed to adequately assess the relative effect of any given fishing-related event or process on the resource in question. Such questions would therefore necessarily include, at a minimum: (1) "how has this type and extent of fishing activity contributed to change in the status of the resource over time" – i.e., diachronically?, (2) to what extent have harvest levels increased or decreased over recent years and why, and (3) what technological adaptations have been employed to respond to changes in the commercial, regulatory, or physical environment?

While these kinds of questions would result in data that begin to relate the complete picture rather than the idiosyncractic case, it now also becomes clear that the information itself is very complex. One year a fishermen catches immense quantities of one species in the area of concern, the next year another, the next almost no fish. One year he catches fish well offshore and outside of the zone of concern, the next year he harvests fully within the zone of concern. Decisions to fish in certain areas for certain species and with certain gear each relate, in turn, to a variety of factors such as reports about area viability from other fishers, market value of various species, operational economics, macro-economics, and so on. Without adequate understanding of such inter-annual variation in fishing activity, management decisions could fail to account for factors that have alternately little or everything to do with fishing.

Likewise, over the previous decade, many regulatory actions may have been implemented to limit: entry into a given fishery, the types of gear that may be used, the areas that may or may not be fished, the kinds and sizes of fish that may be pursued, and so on. Based on analysis of fishing trends under such conditions, it quickly becomes apparent that the behavior of persons in the harvest sector has long been conditioned by factors related to governance of fishing activity.

As this example indicates, it is imprudent to examine the effects of any given source of contemporary change in marine fisheries without considering the history of environmental challenges, regulatory constraints, and social and economic conditions within which fishermen have operated. Indeed, as has been so well-established in the sociological literature on resource use, contemporary human actions are invariably conditioned by historic constraints and initiatives. Humans can be consulted to discuss such constraints and initiatives and their responses to them.

Thus, there are, at least, two sources of critically important information available even in the most primitive of fisheries data environments. These are: (1) representatives of the agencies that govern marine fisheries, and (2) the fishery participants themselves. Although interaction with both of these sources requires outlay of time and resources beyond which would be needed to compile existing archival data, each is a valid and important source of information concerning the past sequence of changes out of which present conditions have evolved.

This example provides us with the basic requirements of a framework for understanding at the status of marine fisheries in coastal communities throughout the U.S. In most cases, the current conditions in any fishery of the United States derive from the interaction of: (1) global, regional, or local environmental changes (the differences between these three are of profound importance); (2) past regulatory actions or inactions; and (3) the behavior of fishery participants in response to environmental challenges, fishing regulations, economic constraints and opportunities, and other limiting and enabling factors.

Past IAI projects have almost invariably involved consideration of all three of the above elements with a central component of our methods involving consultation with fishery participants and managers, along with various methods of observation. Our specific role has focused primarily on descriptive analysis of the last two components: the regulatory environment and the ongoing and event-specific reaction of fishery participants to that environment. Again, such analysis has almost invariably been conducted in direct response to agency needs for information and under conditions of limited time and resources. Design and use of efficient research methods have been critical to these missions.

We turn now to two key issues that are of critical importance under “data-poor” conditions – sample selection, and data integration. Sampling or sample selection is critical in terms of the validity and reliability of the primary source data collected. Data integration is critical since primary source data can serve to cross-validate and/or provide contextual support for findings deriving from archival sources, and vice-versa. Although our example illustrated the desirability of working with fishery participants and other knowledgeable persons to better understand long-term patterns of change in the absence of archival data, such data is in fact very often available.

THE CRITICAL UTILITY OF GEOGRAPHIC INFORMATION SYSTEMS

As noted above, the MLPA requires the California Department of Fish and Game (CDFG) to establish an "adaptive management" strategy that is capable of responding in a timely manner to changes associated with implementation of the law [§2852 (a)]. The MLPA *Adaptive Management, Monitoring, and Evaluation Framework* (AM&MEF) establishes the monitoring objectives and impact variables for the state's MPA adaptive management program (March 7, 2006). The AM&MEF defines the structure and processes to be employed and the data requirements for monitoring and evaluating the efficacy of the program. Central to this requirement is documentation of baseline biophysical and socioeconomic conditions against which the progress and/or effectiveness of the MLPA process may be measured and evaluated.

The California Marine Life Protection Act Initiative, *A Policy Framework for Baseline Data Collection* (December 1, 2006) was established by a blue-ribbon panel of experts. The initiative resulted in recommendations for: (a) an "overarching" and "integrated" data collection structure, (b) criteria for selection of key variables, (c) identification of cross-cutting research themes, (d) establishment of monitoring via interrelated biological and social variables, and (e) due consideration of the temporal and spatial dimensions of monitoring and impact assessment.

We firmly believe, and have advocated since 1993, that the Geographic Information System (GIS) approach offers the greatest potential for achieving the information needs of regulatory agencies intent on analytically integrating social, economic, environmental, political, and other variables. No other tool offers the potential to integrate spatial information within a single platform and to analyze the relationship between layers (or data sets) to understand how the social phenonmena they represent interact in concert (or competition). The ability of GIS to represent and convey complex social-spatial analysis in a clear and self-explanatory manner is a profoundly important characteristic of the technology. In sum, GIS has led to significant advances in analysis of human -environmental interactions, and its real potential is only now being recognized.

Stepping back, as indicated in our extreme example of a fishery without any descriptive secondary source data, fishermen are fully capable of recollecting the places, areas, catches and periods of past fishing behavior – and, having been heavily reliant on maps and mapping technology in the conduct of their industry, can easily reconstruct or map those past behaviors, by species, by harvest levels, and sometimes even by cost and distance. They typically are able to recall and depict why certain fishing areas were selected over others, and to describe and spatially document the role of season, species, markets, and regulatory constraints in their decision-making matrix. Such information, if collected from a sufficient sample of seasoned and/or highly-knowledgeable fishery participants to address a sufficient historical period will, in combination with even a minimum of biological knowledge, will yield a nearly three-dimensional time-series understanding of the history of the fisheries in question. This information can then be depicted in a spatial format, with a range of iterations possible, including depiction of fishing activity by season, by species, by fleet, and so forth. A GIS can also be used to document other uses of the marine environment (such as recreational diving, kayaking, sailing, surfing, wind-surfing, etc.), and the resulting layers can be analytically related to each other to document/analyze existing patterns of interaction and to predict spatial parameters of potential future interface between user groups and/or between those groups and components of the marine ecosystem such as certain habitats or fish populations.

These kinds of data and analyses, in turn, provide the information necessary to effectively monitor resource use patterns associated with (or not associated with) a given regulatory action or other source or vector of change. Such information can ultimately aid in the identification of unintended adverse human-to-human and/or human-to-environment interactions. For instance, GIS analysis can serve to identify and define areas where fishing and other resource use activities are likely to become more highly concentrated, thereby threatening to reverse or undermine the intended objective of the regulatory action. Such analysis is, in fact, a required and intended objective of the "adaptive management" regime under the MLPA. GIS analysis is ideal. When developed and used in a timely manner, it can provide managers with the ability to intervene at the earliest possible moment to tailor or adjust a given regulatory approach to minimize adverse, and magnify beneficial effects of the newly-implemented regulations.

VALIDITY, RELIABILITY, AND SAMPLING

Assuming we all agree about the value of GIS technology for purposes of assembling, maintaining, integrating, and analyzing primary and secondary data for purposes of effective fisheries management, what practical procedures can or should be employed to ensure that the highest quality and most useful primary source data are collected and integrated into the system? This question is central to the utility and efficiency of a fisheries monitoring system.

With sufficient forethought and planning, virtually any relevant information can be compiled and assembled in a manner that will render it useful in a GIS monitoring system. But careful consideration must be given to the quality, validity, and reliability of the data to be used.

In the end, consideration about data validity and reliability dictate the type and manner of primary source data that should collected and how its quality should be determined for use in an "adaptive management" environment. In short, we seek highly relevant information that approximates the truth about historic and contemporary use of the marine environment and as regards related issues and factors. In a perfect world, we would attain perfectly valid and reliable information. We would ask every fisherman, and other user of the marine environment, every possible relevant question, and do so while connected to a "lie detector" system. Alternately, we would directly observe how each person has actually used the marine environment over the course of time. Given the impossibility of these solutions, how do we ensure that data are used in our spatial analyses are valid and reliable? The answer is similar to that of biophysical scientists who cannot track the life histories of each fish or each population of fish, or examine in full detail each environmental factor impinging on those individuals or populations. In all cases, some mechanism is use to *approximate* the true nature of those phenomena.

In the social sciences, the key to maximizing validity and reliability of interview data is to: (a) draw from a large randomized sample and infer the truth about some phenomenon from a component of the sampling frame, or (b) use a purposive sampling approach to interview or observe persons who are highly likely to know and report the truth about a specific phenomenon of interest.

Short surveys, widely distributed, are capable of generating specific, statistically reliable, answers to basic demographic or resource use characteristics. This information is of very limited use, however, in understanding patterns of change, or in understanding the underlying reasons for decisions taken or anticipated. It is also difficult to ensure validity of responses. That is, it is difficult to know whether survey questions are getting at the right issues and whether the responses "fit" the intended nature of the questions.

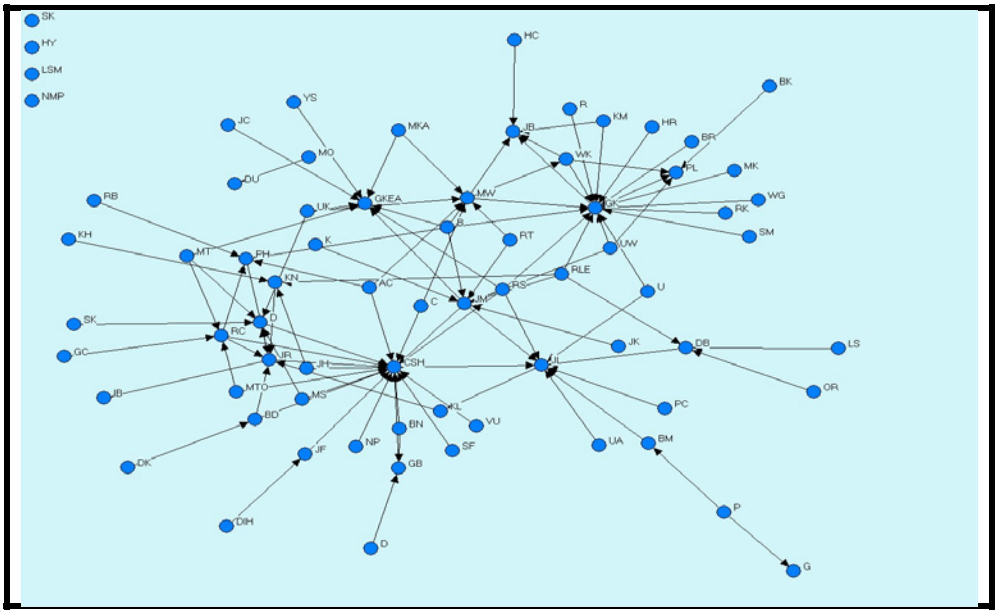
In order to generate a valid and robust understanding of relevant behaviors and perspectives, purposive sampling, in-depth interviews with selected respondents, and careful elaboration of the "ethnographic context" can significantly enhance validity of responses. Such an approach can also provide for the level of detail required to interpret, anticipate, or appropriately intervene to achieve a particular management outcome.

Unfortunately, almost all fisheries (with some exceptions, such as certain tightly-controlled Alaska limited entry fisheries and certain highly-specialized fisheries elsewhere) tend to be composed of a wide range of fishermen who participate at widely varying levels of intensity. In California, for example, out of 100 fishermen in a particular fishery, sometimes as few as 10 percent of the fishermen harvest 90 percent of the total catch. For this reason, and because these patterns seem to be fairly persistent across years, it is more important for management purposes to understand the behavior of the 10 percent than the remaining 90 percent (although it is a good practice to have a clear idea how the pattern evolved and how persistent it is). But narrowing the number of "key informants" to 10 percent of the entire population of commercial fishermen, for example, would still represent an insurmountable problem for purposes of collecting intensive one-on-one interviews. The population must be narrowed even further if we are to generate detailed results of high reliability. How can this best be accomplished?

IAI has applied social network theory and methods in a variety of contexts to generate valid, reliable, and cost-effective information and analyses based on the input of relatively small but highly informed sample of resource users. Readers are referred to Hanneman and Riddle (2005) for a thorough discussion of the approach. In short, social network methods and related statistical analyses can serve to to identify core groups of persons who are highly knowledgeable of fishery-ecosystem interactions, patterns of resource use, and other relevant phenomenon.

We include graphics from recent fisheries research on the Big Island (Figure 1) and from a project completed in Alaska in 2004 (Figure 2). These are provided to illustrate the results of social network sampling and its rationale for sampling and interview purposes among populations of fishery participants. In both cases, social structural attributes of popular commercial fisheries are depicted. In both cases, arrows depict incoming and outgoing nominations for peer participation in the respective research projects as based on perceived social status and general involvement in the fisheries in question. While the requirements of the studies called for selection of persons with extensive achieved status and knowledge, the methodology is also highly effective for identifying groups of people who simply cooperate or interact to a specific end (such as executing a certain kind of fishing).

The graphics are based on a binary matrix of social relations wherein cells in the matrix are entered with value one (1) where row participant *i* nominates column participants *j*, and no value (zero) is entered where nomination does not occur. In technical terms, this constitutes an adjacency matrix that is asymmetric with directed ties (the ties travel from the source row to the receiver column). Such a matrix reveals whether there is a path or social tie from one fishery participant to another. A value of one represents the presence of a path, a zero the lack of a path. This simple method serves as a means for organizing and analyzing data about many relationships, and for identifying relationships across multiple groups of actors. The nature of the relationships being assessed can vary based on needed information, and their validity and associated social context should be assessed and described via sustained fieldwork.



<u>Figure 1: Network of Fishery Participants in Hawaii</u>

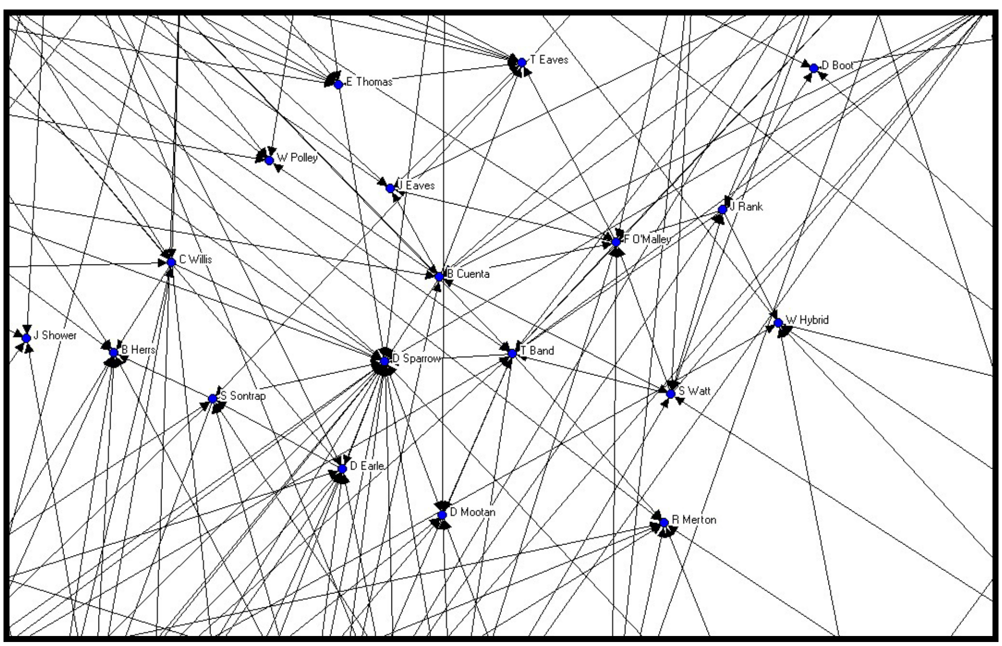


Figure 2: Core Group of Seasoned Veteran Fishers in Alaska

The second graphic depicts a core network of 17 participants derived from an initial network of 149 fishermen (as developed naturally via the question "can you recommend three persons you consider most highly knowledgeable of this fishery?"). Of note, most of the core group revealed close and ongoing interaction in the fishery in question but few shared residence in a distinct community of residence in what was a very rural study area. We were ultimately able to assess variation in social relations, fishing operations, and associated experiences based on geographic factors. It was found that regional geography rather than community or municipality of residence was most significant in explaining patterns of social relationships between core participants.

Once core groups of participants in each of the fisheries in question are similarly identified, it is possible to conduct a series of in-depth interviews to aid in interpretation of existing fisheries data, and to enable description of the social, economic, and cultural contexts within which the fisheries and fishery-ecosystem interactions occur. As fishing effort and production varies across seasons and over time, informants can be asked to discuss seasonal and longer-term trends and patterns in their harvest and distribution activities, including recent trends in effort and with respect to species, pieces, and pounds landed and kept, shared, sold, and so forth.

DATA INTEGRATION AND REPRESENTATION

The final product of the careful selection of research participants, and collection of in-depth, one-on-one, primary source interview data regarding past and present fishing practices, beliefs, expectations, and values into a carefully populated GIS data system yields a product of immediate value both to the process of documenting impacts, as well as in service of the "adaptive management" objectives of all of the agencies involved. Such a system will ideally enable valid and reliable depiction of past and present regulatory boundaries, fishing restrictions, and operational constraints, with the similarly constructed history and operational characteristics of other fisheries, recreational activities, and other "at-sea" use patterns

The following graphic is an example of the ability of such a system to identify emergent zones of fishery interface following from historic regulatory and environmental changes, and recent establishment of the new system of MPAs along the Central California Coast. The graphic is based on the input of a core group of knowledgeable fishery participants who reside in the study region.

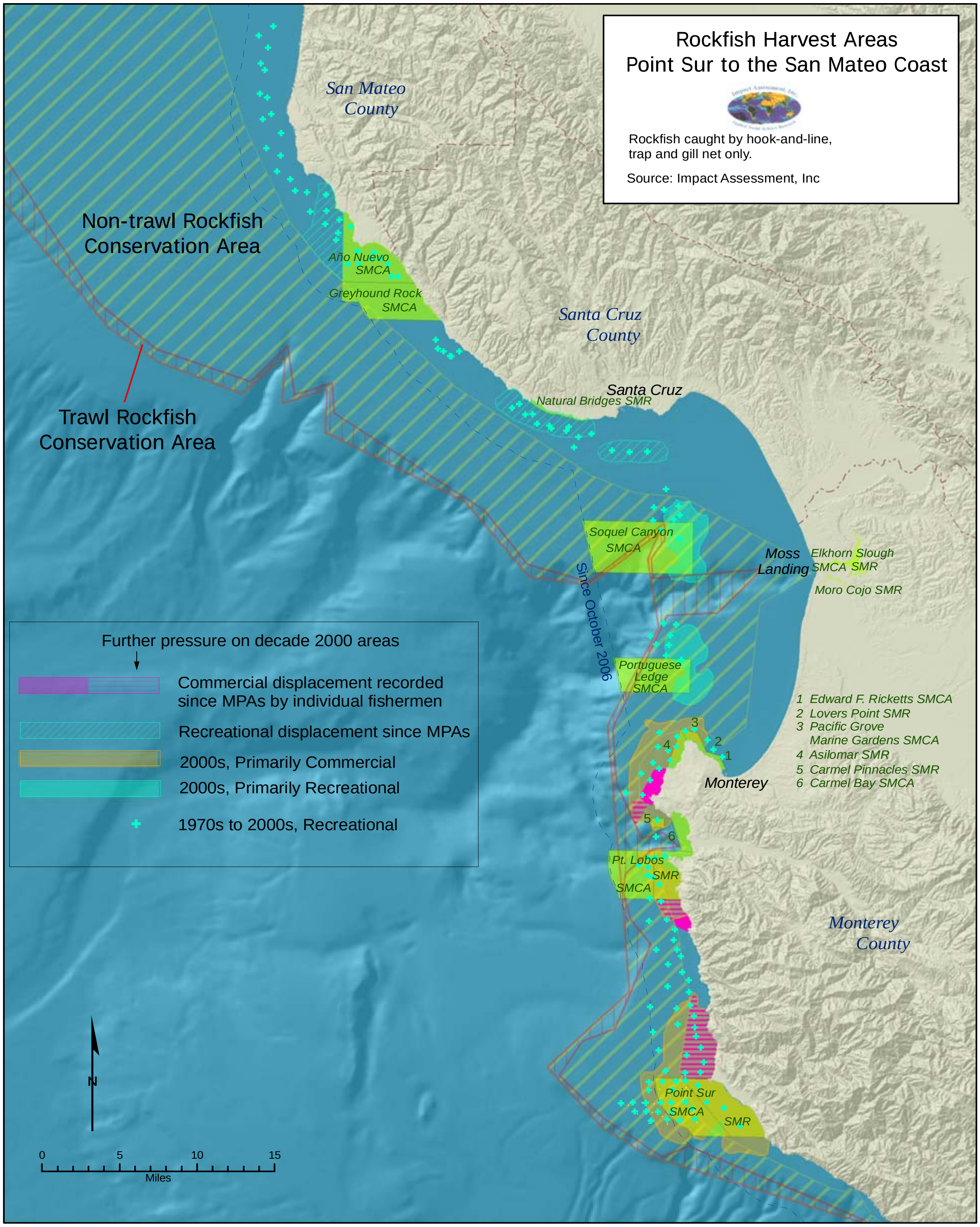


Figure 3 Identified Fishery Interface Areas in Central California

CONCLUSION

When ultimately combined with an equally robust biophysical environmental database, the resulting GIS will be capable of generating a wide range of products of direct relevance to the management process. For example, it will be capable of generating maps of emergent interface and high concentration fishing zones that will alert agency representatives to potential future areas of biological stress, thereby enabling appropriate management responses that would accommodate both biological and socioeconomic considerations. The ability to simplify and integrate such a diverse and complex set of variables into a coherent analytic framework offers the promise of improved and, possibly one day, real-time adaptive management in California and throughout the coastal zone of the United States.

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