Cultural Consensus Analysis and Environmental Anthropology: Yellowfin Tuna Fishery Management in Hawaii

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Natural resource policies in the United States are implemented with a social technology of objectivity. Accordingly, resource managers rely on scientific and quantitative analyses to satisfy constituencies distrustful of regulatory authorities. Cultural consensus analysis is a powerful method for determining whether knowledge domains are structured in ways that support a conclusion that cul-

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tural members recognize certain cultural truths not known beforehand to the investigator. The authors compare hand-line fishermen and fishery scientists in Hawaii regarding their knowledge about stock structure, fish movements, resource abundance, stock condition, and fishery interactions. Yellowfin tuna fishery results show that fishermen and scientists exhibit an overall consensus about ecological knowledge, although they disagree in some areas. Some practical advantages of consensus analysis are discussed along with the possibilities for growth in the fishery social science sector, cross-cultural applied research, and the practice of environmental anthropology.

Keywords: *traditional knowledge; natural resource anthropology*

> There are some who might argue that it is all well and good to assume that regularities exist in the physical and natural sciences but that human behavior is different and is not characterized by such regularities. . . . I think that a careful consideration of the written record will show that when researchers have looked for regularities in human behavior they have found them. The discovery and analysis of such lawful regularities in human behavior is not different, in principle, from those found in the natural sciences. One thing is certain and that is without a search no regularities will be found.
>
> —A. K. Romney (1989, 157-158)

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Environmental anthropology is pertinent to the resolution of pressing real-world problems. This article illustrates an application of cross-cultural research in the context of a natural resource subfield of environmental anthropology. A systematic study of the beliefs of fishermen and fishery scientists in Hawaii indicates the usefulness of anthropological methods such as consensus analysis in applied research and the expanding niche for fishery social science and environmental anthropology.

Cross-cultural research is inherently scientific. As such, it is based on the premise that comparisons—whether these broadly concern social, biological, or physical phenomena—are ontologically possible and epistemologically warranted by methodologies attuned to the ideal of objectivity (and whose results are discussible according to tests of reliability and validity). A defining characteristic of cross-cultural work is found in the analytical activities undertaken by researchers to consider how they might be wrong. In this risk-taking aspect of science, researchers are obliged to leave tracks of their procedures and thinking so that colleagues might confirm or challenge findings.

Were the cross-cultural paradigm otherwise, there would be no point at all to making comparisons. The disciplinary result would consist of a hodgepodge of particularistic or idiocultural ethnographies. Although these might be provocative in their own right, such relativistic and unmonitored endeavors could at best be expected to have the impact of art or at worst to be indistinguishable from mystical postmodern products. Artists and postmodernists do not engage in cross-cultural comparisons because it is not interesting to them to imagine how they might arrive at incorrect conclusions. Put simply, a commitment to imagination and speculation replaces a dedication to demonstration.

Without standards for reaching comparative conclusions, communication about presumed cultural differences (or similarities) becomes impossible. Science is the only explanatory metalanguage available for cleanly establishing how multiple worldviews are (in)consistent with one another. It will not, however, fuel any argument that there are—strictly speaking—multiple realities.

In a recent article looking at the place of anthropology in cross-cultural research, Roy D'Andrade (2000) points out that whereas single culture ethnographies rarely incorporate statistics, comparative analyses have different requirements:

> One cannot do cross-cultural research if one does not know any statistics. And without statistical methods, there is no systematic way to compare ethnographies, which leaves anthropology without a strong method to generalize beyond the individual case. Even more incapacitating than not being able to do cross-cultural research, without some knowledge of statistics such findings cannot even be understood. (p. 225)

D'Andrade (2000) is confident that social scientists can be recruited to address cross-cultural issues, but he fears that cultural anthropologists will be displaced by sociologists and social psychologists. In making this point, D'Andrade notes that mainline anthropology has for nearly 20 years endorsed an agenda of cultural critique while categorically denouncing an agenda of science. In particular, faculty influenced by antiestablishment and other political attitudes generated by the Vietnam War have stifled scientific anthropology and now promote epistemological relativism while engaging in moral advocacy. Sadly, as D'Andrade notes, the cultural anthropology student pool appears destined to suffer even more from "numerical illiteracy."

D'Andrade's (2000) report of the decline of science in cultural anthropology suggests that blame falls on self-righteous faculty displaying "expertise" only for the benefit of one another in an isolated academic community. Although D'Andrade laments the general situation, he is not entirely pessimistic about the future. Thus, he observes that the "huge enterprise of nature science has become annoyed with epistemological relativism," that cultural studies are "becoming an academic joke," and that "a new generation of undergraduates are not nearly as moralistic in their orientation as their teachers" (D'Andrade, 2000, pp. 229-230).

D'Andrade's account suggests that the specialty of cross-cultural anthropology is endangered because it lacks the support of mainline anthropology professors. But academic fields are also responsive to real-world markets. In this regard, the historical research of Theodore Porter (1995) shows that quantification is of double import in Western society. On one hand, quantification is a scientific technology that facilitates the pursuit of truth. On the other hand, quantification is a "social technology" employed by government agencies with management authority over people and nature. It is Porter's thesis that quantification in regulatory analyses is especially convincing to the public and special interest audiences (Porter, 1995). In particular, quantification is a social signal of objectivity that mediates against the distrust of distanced authorities shown by affected parties of policies and observers.[1]

Speaking of social and economic quantification in government and business arenas, Porter (1995) employs distinctions made by Megill (1991) between claims of objectivity with universal standing ("absolute objectivity"), claims that appeal to the authority and consensus of specialist or expert communities ("disciplinary objectivity"), and claims that appeal to a reliance on procedure ("mechanical objectivity").[2] In reviewing cases having to do with accounting, insurance, cost-benefit analysis, and civil engineering, Porter (1995) concludes,

> the transition from expert judgment to explicit decision criteria did not grow out of the attempts of powerful insiders to make better decisions, but rather emerged as a strategy of impersonality in response to their exposure to pressures from outside. (p. xi)

These findings lead Porter (1995) to postulate that bureaucratic policy making in democratic systems is likely to be characterized by tensions between a technology of disciplinary objectivity driven by a community of experts and a technology of mechanical objectivity that relies on rules of quantification and statistical inference.

> Disciplinary objectivity is made conspicuous by its absence. Where a consensus of experts is hard to reach, or where it does not satisfy outsiders, mechanical objectivity comes into its own. Mechanical objectivity . . . has a powerful appeal to the wider public. It implies personal restraint. It means following the rules. Rules are a check on subjectivity: They should make it impossible for personal biases or preferences to affect the outcome of an investigation. Following rules may or may not be a good strategy for seeking truth. But it is a poor rhetorician who dwells on the difference. Better to speak grandly of a rigorous method, enforced by disciplinary peers, canceling the biases of the knower and leading ineluctably to valid conclusions. (p. 4)

The work of Porter (1995) leads one to reflect on D'Andrade's article with a guarded optimism. Porter reminds us that applications of science are demanded by managers and regulators because they are satisfying to policy constituencies. Despite the antiscientific agenda of mainline cultural anthropologists, there would seem to be hope for sustained anthropological cross-cultural research if pockets of scientific anthropologists could establish working relationships with policy makers.

ENVIRONMENTAL AND NATURAL RESOURCE ANTHROPOLOGY

This section outlines the development of a niche for applied environmental anthropology in the context of the federal management of natural resource systems in the United States. It would not be incorrect to suggest that this opportunity emerged in a way that resembles Porter's (1995) observations on the roles of science and quantification in the fields of insurance, medicine, and engineering. By Porter's template, management and bureaucratic entities are spurred to adopt social technologies of (e.g., absolute, disciplinary, and mechanical) objectivity by constituencies whose activities are subject to regulation.

During the past several decades, two fields—conservation biology and environmental anthropology—have expanded and to a degree cross-fertilized to address real-world problems concerning ecologically, biologically, socially, and economically appropriate relationships involving people and place. Many researchers in these fields examine conditions of scarcity and diversity and regard "sustainable development" as a reasonable overarching ideal. Widespread environmentalism (as, e.g., reflected in the agendas of nongovernmental organizations and special interest groups) has fostered the idea that Western societies have a moral obligation to marshal scientific expertise to examine and resolve an assortment of environmental problems.

In the 1980s, conservation biology crystallized as a "mission-oriented crisis discipline" with roots in the academic fields and professions associated with forestry and fisheries and wildlife management (Soulé, 1986). Soulé (1986) has called conservation biology the "biology of scarcity" (p. 10) because it focuses on ecosystems, habitats, species, and populations that must contend with some kind of "artificial [i.e., anthropogenic] limitation." Conservation biology has become increasingly multidisciplinary, and today, social scientists (e.g., cultural anthropologists, sociologists, and economists) and scholars with backgrounds in the humanities (e.g., philosophy, history) are being encouraged to remark on the human norms and values, behaviors, and knowledge that shape relationships between humankind and the remainder of the natural world.

Concurrent with the rise of conservation biology, the field of environmental anthropology has emerged to respond to problems of scarcity in a way that is intertwined with that of conservation biology. Townsend (2000) notes that environmental anthropology has origins in the cultural ecology work of Julian Steward in the 1940s and 1950s and in ethnoecology. The field is also indebted to cultural anthropologists who pioneered in ecological anthropology, human ecology, ethnoscience and folk biology, and cognitive anthropology (see Bennett, 1975; Berlin, Breedlove, & Raven, 1973; Bricker, 1977; D'Andrade, 1995; Hardesty, 1977; Hunn, 1976; Kempton, Boster, & Hartley, 1995; Netting, 1977; Romney & D'Andrade, 1964; Tyler, 1969; Vayda & McCay, 1975) as well as to many development anthropologists active in the period since the end of World War II. In recent years—and due in part to the growth of conservation biology—environmental anthropology has expanded its purview in academe and in application to address environmental topics not only in face-to-face societies but also in complex and industrialized societies.

In most institutions of higher education, environmental anthropology (as with applied anthropology) has no special status and is regarded as one of many topical dimensions that cultural, biological, linguistic, and other branches of anthropology have in common. In a few anthropology departments, it is more sharply defined as an area of concentration. At Rutgers University (in New Brunswick), environmental anthropology is a special graduate program. A graduate program in ecological and environmental anthropology has been developed in the University of Georgia. A third example is found at the University of Washington where an environmental anthropology graduate program complements others in anthropology with biocultural, sociocultural, and archaeological orientations.

Applied environmental anthropology, like conservation biology, takes many forms. One variant within the field discussed here addresses D'Andrade's (2000) concerns with a scientific and quantitative cross-cultural research agenda. Burton, Schoepfle, and Miller (1986) have broadly identified natural resource anthropology as a promising field for the investigation of environmental topics where public policy goals concern increases in economic productivity, ecological quality, equity, and the conservation of heterogeneous cultural systems. These authors see a potential for natural resource anthropology to integrate concepts, theories, and methods from anthropological subfields of cultural ecology, economic anthropology, and cognitive anthropology. In an observation about the public demand for objectivity that fits with those later made by Porter (1995), Burton et al. (1986) note that "any applied science must offer a corpus of scientific knowledge and methods for the purpose of achieving some set of consumer goals" (p. 261). Burton and coauthors encourage students to prepare for careers in natural resource anthropology by obtaining training in complementary data collection methodologies standard in the social sciences (e.g., participant observation, interviewing, sampling, and survey research). Burton et al. (1986) stress that a familiarity with techniques of multivariate statistical analysis is essential for those who would advance natural resource anthropology in a multidisciplinary environment.

MARINE FISHERIES

The application of environmental anthropology of central interest in this article concerns the federal management of marine fisheries in the United States. Fisheries—along with national forests and parks—are examples of what Miller, Gale, and Brown (1986; see also Miller & Gale, 1986) have termed *natural resource management systems* and as such consist of four interlocking elements: (a) natural resources, (b) management bureaucracies, (c) profit-seeking industries, and (d) diverse publics.[3]

Marine fisheries with nutritional, economic, and social significance are conducted in waters 3-200 nautical miles offshore in the U.S. Exclusive Economic Zone and are managed in accordance with the Magnuson-Stevens Fishery Conservation and Management Act of 1976 and as amended by the Sustainable Fisheries Act of 1996, the Marine Mammal Protection Act (1972), and the Endangered Species Act (1973). The principal executive agency in the management of fisheries is the National Marine Fisheries Service (NMFS) housed within the National Oceanic Atmospheric Administration in the Department of Commerce. Under the Magnuson-Stevens Act, fishery management plans (FMPs) are first developed by eight quasi-federal regional fishery management councils and then submitted through NMFS to the Secretary of Commerce for final approval. The councils work closely with Regional Offices and Fishery Science Centers of NMFS and are further assisted by scientific and statistical committees and advisory panels composed of fishing industry and other experts (see Barber, 1987; Gale & Miller, 1985; Kelly, 1978; Knight, 1978; Miller & Broches, 1993; Miller & Van Maanen, 1983; Wallace, Hosking, & Szedlmayer, 1994).

The leadership within NMFS is of the strong opinion that multidisciplinary science is vital for the responsible management of fisheries. The head of NMFS, Assistant Administrator for Fisheries William Hogarth (2002) has stressed that "science for public policy choices must be based on science that is responsive, relevant, respected, and reliable." In elaboration, acting director of the NMFS Office of Sustainable Fisheries Bruce Morehead (2001) has emphasized the role for social science as follows:

> Precise scientific economic and social information needs to be incorporated into assessments so that managers will be able to determine how, when, where, by whom, and for what the maximum allowable harvest is to occur. The foundation for effective management is sound, applicable scientific information.

FMPs prepared by the councils for important species specify the "optimum yield" for each fishery. Optimum yield is determined to be the maximum sustainable yield from the fishery reduced by any relevant economic, social, or ecological factor. Optimum yield takes the human dimensions of a fishery into account in expressing the amount of fish that "will provide the greatest overall benefit to the nation, particularly, with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems" (Magnuson-Stevens Fishery Conservation and Management Act of 1976 [MSFCMA; and as amended], Sec. 3[28]; Kelly, 1978; Miller & Broches, 1993).

In addition to describing the fishery (by addressing such features as the number of vessels involved, the kinds of gear used, costs and revenues, and the nature of foreign fishing and Indian fishing rights), an FMP must contain a "fishery impact statement" specifying the effects of regulations on participants in the fisheries and fishing communities (MSFCMA, Sec. 303[9]).

Fishery management under provisions of the Magnuson-Stevens Act relies heavily on the display of scientific and quantitative expertise. The act makes it clear that social science research regarding social, cultural, and economic phenomena is required for implementation of the law. Furthermore, FMPs must be consistent with 10 national standards for fishery conservation and management. Several of these standards are linked to social science research (MSFCMA, Sec. 301[a]). It is important that social science is also mandated by the National Environmental Policy Act (1969), the Regulatory Flexibility Act of 1980 and as amended by the Small Business Regulatory Enforcement Fairness Act of 1996, and other environmentally relevant legislation (see Barber, 1987; Knight, 1978; Miller, 1987; Miller & Broches, 1993).

Collectively, these statutes provide a legal underpinning for social factor analyses, social impact assessments, social survey research, economic impact assessments and analyses, community impact assessments and profiles, and ethnographies among other applied social science products (see National Marine Fisheries Service, 1998, 2001).

EXPERT KNOWLDEGE OF THE YELLOWFIN TUNA FISHERY

In elementary terms, a fishery may be defined as a system in which humankind is linked (e.g., via subsistence, commercial, and recreational activity) with life forms we call fish. Fishery management is defined as the activity of executive decision making by an authority (e.g., an element of bureaucracy or traditional government) on the behalf of its constituency (e.g., citizens in a state or nation, members of a society or culture) and in accordance with a prevailing legal or cultural mandate (e.g., a federal, state, or local statute or a tradition). In contemporary societies that have rationalized oversight of natural resource systems (by, e.g., the creation of regulatory bureaucracies and the use of scientific expertise), fishery management is commonly attuned to the goal of fishery conservation. Fishery development is an example of an appropriate management goal when a fishery would seem to be able to tolerate growth (e.g., in the quantity of fish harvested or in the quantity of fishermen involved) without a sustainability risk (see, e.g., Miller et al., 1986; Miller & Francis, 1989; Miller & Johnson, 1989).

Fishery problems refer to fishery conditions (e.g., the status of fish stocks, the status of a human community) that are judged as unacceptable by fishery managers and their constituencies. It follows that fishery problems are social problems. When in the eyes of managers, a fishery problem warrants the systematic observation of fishery processes, a window of opportunity opens for applied fishery science. When the problem concerns the behavior, cognitions, and affect of people involved in a fishery, natural resource anthropology (as a form of environmental anthropology and, more generally, applied social science) finds a niche.

CONSENSUS ANALYSIS

Consensus analysis has its origins in the confluence of mathematical anthropology and psychometrics (see, e.g., Batchelder & Romney, 1988; Romney, Batchelder, & Weller, 1987; Romney, Weller, & Batchelder, 1986). As Romney, Boyd, Moore, Batchelder, & Brazil (1996) point out in a recent special inaugural article by members of the National Academy of Sciences that appeared in the *Proceedings of the National Academy of Sciences*, "Cultural consensus analysis consists of a family of formally derived mathematical models that simultaneously provide an estimate of the cultural competence or knowledge of each informant and an estimate of the correct answer to each question asked" (pp. 4700-4701).

In its most specific meaning, cultural consensus analysis refers to formal mathematical models developed by A. K. Romney and his associates. Cultural consensus is related to a host of affiliated data collection techniques (including, e.g., pile sort, triad, paired comparison, and other judged similarity tasks that have become standard in cognitive anthropology) and quantitative methods (e.g., multidimensional scaling, hierarchical clustering, quadratic assignment procedure) that are somewhat more well known in the social sciences. For an overview of the linkages of these data collection and quantitative algorithms, see Weller (1998). For integrated personal computer software concerning the transformation and analysis of these types of data, see Borgatti (1996).

U.S. FISHERY MANAGEMENT IN THE PACIFIC

Pelagic fisheries in the Exclusive Economic Zone off the shores of the Hawaiian islands and the Territory of Guam fall under the jurisdiction of the Western Pacific Fishery Management Council. In the implementation of the Magnuson-Stevens Fishery Conservation and Management Act of 1976, the council annually develops a fishery management plan for an array of pelagic fishes including tunas (ahi), billfish (marlin), sharks, and wahoo (ono). In the course of the policy-making process, the council addresses two coupled fishery management decisions. The first of these—the conservation decision—refers to the quantity of fish that can be harvested on a sustainable basis. The second—the allocation decision—concerns the way in which access to harvestable fish should be distributed across fishing constituencies.

The canonical fishery management question for the scientific study of the human side of the fisheries equation may be phrased in the following way: What is the value (or significance, importance, or meaning) of fishing (a) to people who fish and (b) to other members of society?

In using this overarching question to shape research agendas, the vast majority of fishery social science studies have consisted of analyses provided to managers that are pertinent to the aforementioned allocation question. Almost by definition, fishery social science entails the direct collection of data from elements of the fishing industry. In particular, the economists and cultural anthropologists who have talked with fishermen have asked two kinds of questions: "What are your characteristics?" and "What do you want?"

Studies oriented to the first question concerning "characteristics" have generated economic and ethnic profiles of industries, measurements of fishermen's dependence on fishing and their patterns of fishing and career mobility, and specifications of the human relationships created and sustained through fishing. Studies oriented to the second question about what fishermen "want" have generated understandings of preferred regulations and policies and some appreciation of how fishermen might respond to changes in regulatory regimes.

The fishery social science research described in this article is oriented to the conservation question faced by managers rather than to the allocation question that has so dominated fishery social science. Specifically, the purpose of our research was to study the fishery knowledge of fishermen and other pelagic experts. Thus, the research design posed a third kind of question to fishermen (and to other experts). This question has an entirely different form from those typically employed in allocation studies: "What do you know?"

CULTURAL ANALYSIS

Specific Fishery Problem

In the context of federal fisheries management in the United States, it has become all too common for conflicts to emerge about the status of stocks between fishermen, on one hand, and government fisheries scientists on the other. To a degree, this is to be expected. Scientists trained in the scientific method root their findings in theory and in sampling and quantitative analytical procedures. In contrast, the conclusions of fishermen about the condition of fisheries are based in personal experience on the water. This is a study of the yellowfin tuna fishery conducted off the shores of the island of Hawaii and managed by the Western Pacific Fishery Management Council established by the Magnuson-Stevens Act.

We sought to formally compare the “professional knowledge” of Hawaii hand-line fishermen with the “scientific knowledge” of fishery scientists in Hawaii. The professional knowledge of fishermen is a variant on what in the anthropological literature has been variously termed *local knowledge* and *traditional knowledge*. It should be noted that the scientific knowledge of the fishery scientists also is a kind of local or traditional knowledge, although the tradition stems from the Enlightenment. The research concentrated on the target species of yellowfin tuna (*Thunnus albacares*).

Respondent and Question Samples

At the study site, researchers worked with members of the local community and with others professionally familiar with local fishing practices to identify expert fishermen (and, at one site, fishery scientists) likely to have expert knowledge regarding the status of pelagic fisheries of management and research interest.

The fishermen respondents in the study were drawn from the population of hand-line fishermen on the “big island” of Hawaii who specialized in tuna fisheries. The scientist respondents in the study consisted of fishery scientists (primarily fishery biologists) in federal and state fishery agencies (e.g., the National Marine Fisheries Service; the Division of Aquatic Resources Department of Land and Natural Resources, State of Hawaii; universities; and the private sector). Whereas only some of these scientists specialize intensively on the Hawaii tuna fisheries, all were familiar with the fishery science conducted to assist the Western Pacific Fishery Management Council in regulating pelagic fisheries in Hawaii. The fishermen and scientists in the study constituted a convenience sample of respondents known to the investigators.

The research team developed a list of research questions based on conversations with fishermen, scientists and other experts and a review of the scientific and management literature. Questions were selected that would elicit input about fisheries resource knowledge pertinent to Western Pacific Fishery Management Council management of pelagic fisheries. The question sample consisted of yellowfin tuna fishery propositions, addressing such issues as stock structure, fish movements, resource abundance, stock condition, and fishery interactions.

Elicitation of Fishery Knowledge Data

In face-to-face interviews, the research team elicited "yes" and "no" answers to the 21 fishery knowledge questions. Typically, the researchers systematically queried respondents (one at a time) about whether they each believed a series of pelagic propositions to be true or false. In communicating these instructions, the research team provided synonyms for *believe* that included *tend to believe*, *agree*, *yes, true*, and *correct*. This strategy was designed to help respondents understand that the study was focused on contemporary pelagic fishery knowledge rather than on absolute truth. Many of the questions were provocative with a potential for stimulating the experts to volunteer additional insights beyond one-word responses. This supplementary information was written down in field notes. Generally, interviews were completed in a 1-hour period.

Analytical Sequence

The research team began analysis with yellowfin consensus data that represented 35 fishermen and 23 scientists, and 21 questions. This database was reduced in size as rows and columns were dropped from the analysis if (a) a respondent failed to answer 90% of the questions or (b) a fishery knowledge proposition was not answered by 90% of the respondents. This yielded a response matrix with 31 rows (for respondents consisting of 24 fishermen and 7 fishery scientists) and 20 columns (for fishery propositions).

Consensus analysis of this response matrix supports the conclusion that the 31 respondents as a group share a single cultural knowledge base. In those small number of cases in which response matrix cells were found to contain missing data, these cells were filled with randomly generated 1s and 0s. We also examined inter-respondent agreement with multidimensional scaling analysis and other complementary analyses facilitated by *ANTHROPAC 4.92* computer software (Borgatti, 1996).

For the matches method (Romney et al., 1986) of measuring agreement among respondents, the ratio of the first eigenvalue to the second is 3.64. The mean competence score is .60 (SD = .15, range = .25 to .87). Consensus analysis results based on the covariance method (Batchelder & Romney, 1988) showed a somewhat more marginal fit to the consensus model (eigenvalue ratio = 2.70, mean competence = .47), although the estimated answer keys for both methods are identical except for one question. There is a high proportion of "true" responses in the matrix and a high proportion (.75 to .80) of estimated answers classified as true for both methods. Therefore, we used the results from the matches method in our subsequent analysis and interpretation, given the covariance method's sensitivity to the underlying proportion of true answers.

Although there is an overall consensus among the fishermen and scientists, these two groups of respondents have distinctly different response patterns. Fishermen respondents (n = 24) have higher competencies on the yellowfin questions (M = .63, SD = .13) than do the scientist respondents (n = 7, M competence = .49, SD = .16; point biserial r = .42, p < .05). This result suggests that fishermen know the culturally correct answers to the yellowfin questions better than do the scientists.

However, further analysis showed that it is more accurate to say that fishermen and scientists display agreement on most questions but differ sharply on a few. The agreement matrix that indicates the proportion of matches (corrected for guessing) between each pair of respondents was submitted to nonmetric multidimensional scaling to represent graphically the similarity of respondents in terms of their response patterns. The first two dimensions of the multidimensional scaling solution (stress = 0.16, iterations = 29) are shown in Figure 1. In the figure, the numbers plotted represent individual respondents. Numbers followed by an F indicate fishermen respondents, and numbers followed by an S indicate scientist respondents. Although there is some overlap between the

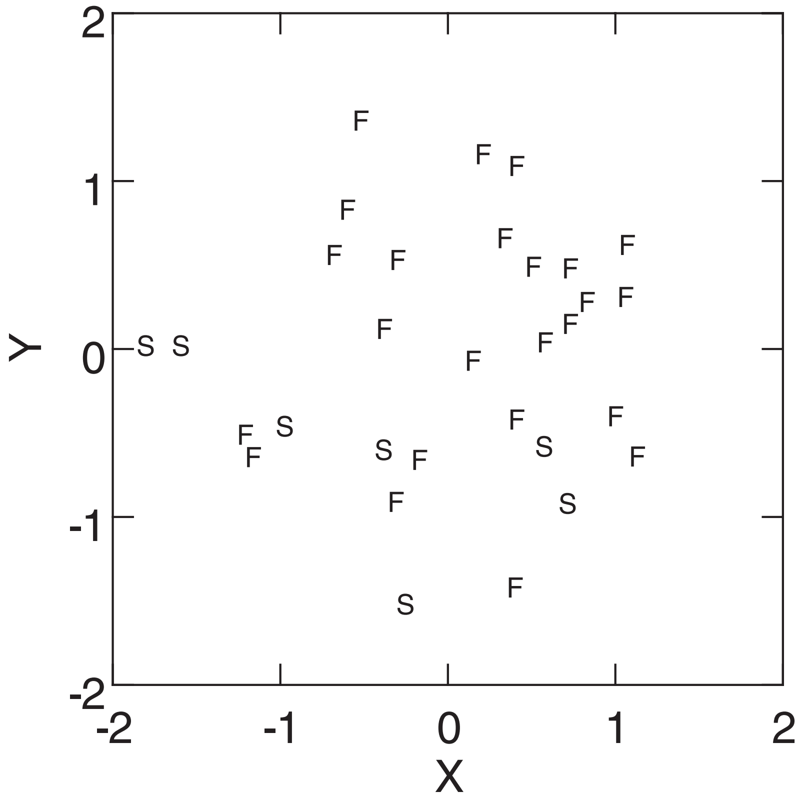

Figure 1: Nonmetric Multidimensional Scaling of Yellowfin Tuna Fishermen (F) and Scientists (S) (Hand-line, Hawaii)
NOTE: Stress in two dimensions is 0.163.

two groups reflecting the overall similarity of their responses, the scientists do distinctly cluster in the bottom and left parts of the plot. This suggests that scientists responded similarly to each other and differently from the fishermen on at least some of the questions.

To test these impressions, we compared the agreement matrix with a hypothesis or structure matrix that embodied the hypothesis that fishermen agreed with each other (all fisherman-fisherman pairs represented by cell values of 1), scientists agreed with each other (all scientist-scientist pairs represented by cell values of 1), and fishermen did not agree with scientists (all fisherman-scientist pairs represented by cell values of 0). We compared these matrices with the quadratic assignment procedure (Hubert & Schultz, 1976). Quadratic assignment procedure involves correlating the observed agreement matrix with this binary hypothesis matrix and estimating the probability that the observed correlation would arise by chance. For our analyses, we computed probability values by performing a Monte Carlo randomization test in which the hypothesis matrix was correlated with each of 10,000 randomly permuted versions of the agreement matrix. The probability value indicates the proportion of these 10,000 comparisons in which the correlation was as large or larger than that observed with the original observed agreement matrix.

The quadratic assignment procedure results indicate that there was a modest difference between fishermen's and scientists' response patterns. The observed correlation between the hypothesis matrix and agreement matrix is .25 (Monte Carlo $p < .005$). The mean proportion of matches (corrected for guessing) for fisherman-fisherman respondent pairs is .40, .37 for scientist-scientist respondent pairs, and .29 for fisherman-scientist respondent pairs. These results can be interpreted as evidence for mild subcultural response patterns in which fishermen agree with each other moderately and scientists agree with each other moderately but the two groups agree with each other somewhat less.

To describe the difference in responses for the two respondent groups, we submitted the responses to consensus analysis separately for fishermen and scientists. The 24 fishermen display a clear consensus for these questions. The eigenvalue ratio is 4.31, and the mean competence score is .63 (*SD* = .15, range = .34 to .89) for the matches method of consensus analysis. The covariance method also indicates consensus, and the estimated answer keys for the two methods are identical with each other (with each proposition, except one, classified at greater than the 0.99 level of confidence) as well as with the estimated answer key based on the matches method when responses for fishermen and scientists were analyzed together.

The 7 scientists also show consensus in their responses to the yellowfin tuna questions. The eigenvalue ratio for these respondents alone is 2.13, which suggests only a marginal fit to the consensus model. However, the mean competence is .61 (*SD* = .17, range = .41 to .93), indicating a clear signal of agreement. The covariance method also indicates consensus, and the estimated answer keys for the two methods are identical (with all but three propositions classified at greater than the 0.95 level of confidence).

Examination of the estimated answer keys for the fishermen and scientists shows that the two respondent groups have the same answers for 16 of the 20 questions. The information in Table 1 displays the consensus-derived answer key (for the combined sample of scientists and fishermen) for yellowfin propositions. The 4 questions in which the estimated answers differ pertain to the location of yellowfin tuna (Question 3) and issues of sustainability (Questions 14, 18, and 19). For the three sustainability questions in which the fishermen and scientists differ, each group's estimated answer is estimated to be correct at a probability greater than .99. For these latter questions, fishermen viewed the abundance of yellowfin tuna in Hawaii as being sensitive to heavy fishing in Hawaii, whereas scientists disagreed.

Significance

We have reported on the ways in which fishermen and scientists understand the condition of the yellowfin tuna fishery in Hawaii. Our findings confirm that whereas both expert groups share a single cultural code, the groups differ about the answers to some questions concerning the location of yellowfin tuna and the sustainability of the fishery. Our work supports the notion that there is a social problem market for consensus analysis in the federal management of U.S. marine fisheries. Results of the study discussed earlier are likely to be useful to three audiences composed of fishery managers, scientists, and fishermen. Yellowfin fishery managers stand to be informed about the contemporary state of pelagic fisheries as evaluated by the expert communities of hand-line fishermen and scientists and should therefore be in an enhanced position to make conservation decisions. Fishery scientists stand to benefit not only from a summary of scientific consensus but also from an introduction to the local knowledge of fishermen concerning fish ecology and behavior. Hand-line fishermen in Hawaii stand to learn how their views of the pelagic fisheries match with those of the scientific community. Finally, the institution of fishery management stands to be strengthened for the incorporation of fishermen in the production of pelagic knowledge.

TABLE 1
Consensus Findings for Yellowfin Tuna Fishery Knowledge (Hand-Line Fishermen and Scientists, Hawaii)

Proposition	True	False
Yellowfin caught in Hawaii are a mix of resident and migratory fish.	26	5
Yellowfin tuna are caught in Hawaii mostly in the summer because they migrate to other areas in the winter.	31	0
Most of the yellowfin tuna catch in Hawaii is concentrated around the 1000-fathom contour. (True for fishermen and false for scientists)	18	13
The abundance of yellowfin tuna in Hawaii depends on how much fishing occurs in and around the 200-mile zone.	9	22
The abundance of tuna in Hawaii depends on the availability of food (prey) in Hawaii waters.	31	0
The cycles of high and low tuna abundance in Hawaii depend on variations in ocean temperature and currents.	31	0
Variation in tuna (marlin) abundance in Hawaii depends on variation in fish abundance ocean wide (outside of Hawaii).	27	4
Yellowfin tuna catch is strongly affected by the full moon.	25	6
FADs divert tuna away from natural ahi koa.	25	6
The overall abundance of tuna around Hawaii is the same with or without FADs.	25	6
Tuna abundance around natural ahi koa has declined because of overfishing.	16	15
The yellowfin tuna resource in Hawaii is being overfished (present yields are not sustainable).	11	20
The yellowfin tuna resource in Central and Western Pacific is being overfished (present yields are not sustainable). (True for fishermen and false for scientists)	21	10
The yellowfin tuna caught in Hawaii are getting smaller.	23	8
The yellowfin tuna resource in Hawaii is not as abundant as 10 years ago.	25	6
Heavy fishing by existing Hawaii boats alone could deplete tuna abundance in Hawaii.	7	24
Heavy fishing of small tuna at seamounts, weather buoys, and FADs will cause a decline in the future abundance of large tuna in Hawaii. (True for fishermen and false for scientists)	20	11
Heavy fishing of large tuna and large marlins in Hawaii will cause a decline in the future abundance of these fish in Hawaii. (True for fishermen and false for scientists)	20	11
Heavy fishing in any one area can cause localized depletion (long-term).	10	21

NOTE: FAD = fish aggregation device. For the combined responses of fishermen and scientists, each proposition has been classified as either true or false at greater than the 0.999 level of statistical confidence in the right-hand columns. Results for fishermen and scientists analyzed separately appear in brackets.

DISCUSSION

The consensus research covered in this article illustrates a scientific and quantitative approach available to environmental anthropologists for comparing fishery knowledge of fishermen and scientists concerned with the federal management of fisheries in the United States. The yellowfin study in Hawaii was undertaken to answer questions fishery managers had that they judged to be pertinent to responsible resource management and development. The fishery managers desired unambiguous biological and ecological answers (if these existed) to questions concerning the status of pelagic and sport fisheries marked by fishery (i.e., social) problems.

Our research agenda and methodology also was evaluated as interesting by the respondents. Fishermen, for example, were pleased that the research explored the features of their professional knowledge rather than their regulatory preferences or their collective behavioral or motivational profiles. Consensus analysis was able to reveal what no single informant could know—that is, culturally correct answer keys with statistical confidence limits. Fishery scientists who participated as respondents in the yellowfin study were equally intrigued by the method and its potential for displaying scientific consensus.

We also think that consensus analysis can be a tool of great value to researchers in addressing a few of the problems of data collection and analysis. Several important logistic advantages of the consensus approach became apparent to us in the course of our work. First, respondents do enjoy communicating the knowledge they possess and they appreciate its relevance to the design of policy. Second, data collection tasks that yield data suitable to consensus analysis tend to take relatively little time to administer. Third, the small respondent sample size needed for consensus analysis is a major advantage of the method over social survey research as conventionally undertaken, although care still must be taken in drawing culturally representative samples of informants. Finally, the availability of consensus software for the personal computer allows for almost immediate analysis of data. The kinds of social science hypotheses, insights, speculations, and findings that in the past could be achieved only after prolonged fieldwork can now be generated in the first weeks and months of activity.

FISHERY SOCIAL SCIENCE

To better judge the significance of consensus analysis for future applications in environmental anthropology, it is useful to consider the recent record of human dimensions research in marine fisheries management. In the first few years after the passage of the Magnuson-Stevens Fishery Conservation and Management Act in 1976, social scientists were routinely appointed to scientific and statistical committees that provided advice to the regional fishery management councils created by the Magnuson-Stevens Act (Miller, 1987). Unfortunately, rather little social, cultural, and economic research was supported by the councils or funded by the NMFS. As Maiolo, Johnson, and Griffith (1992) note, “Some of the early results, namely the implementation of FMPs, created a gloom among some social scientists that nothing had really changed” (p. 392).

Regulatory demand for social science improved gradually from the late 1970s onward as councils sought to justify policies scientifically that allocated access to fish to competing constituencies of fishermen. In the early 1990s, Maiolo et al. (1992) wrote that “social science is beginning to have an impact on fisheries management” (p. 392).

Despite this optimism, however, social science expertise has yet to be institutionally integrated within NMFS. NMFS lags far behind other executive agencies such as the U.S. Forest Service and the National Park Service in support of applied social science. In 2000, NMFS employed 37 persons (34 economists and 3 anthropologists) to attend to fishery social science. This compared poorly with the 583 persons within the agency who collected, processed, and engaged in research for stock assessments (Ocean Studies Board, 2000).

In recognition of this inadequacy—and also in direct response to substantial increases in the number of lawsuits by coalitions of fishermen, environmental organizations, and other special interest groups challenging NMFS and council fishery management policies—NMFS developed plans to recruit 95 new social scientists (Ocean Studies Board, 2000).

LOOKING AHEAD

In the introduction to this article, we alluded to an institutional phenomenon noticed by Theodore Porter in which bureaucracies and industries in Western society increasingly have been seen to use social technologies of quantification and science to inform and legitimate public policies. We suggested that the several applications of consensus analysis discussed in the body of the article illustrate a powerful quantitative method for the study of high-concordance codes in the context of marine fisheries management.

We cannot say with any certainty that consensus analysis will thrive and be diffused as a scientific innovation within fishery management circles, but we do see the method as having many of the features that would make this possible. With respect to Megill's (1991) taxonomy of objectivity discussed by Porter (1995), consensus analysis can be seen to support concerns for disinterested and fair judgment in several ways.

The mathematical foundation of cultural consensus analysis supports a contention that the method is attuned to absolute objectivity. The rise of consensus analysis in the field of cognitive anthropology and its applications to the resolution of social problems in medical anthropology and now natural resource and environmental anthropology supports a claim that the method reflects disciplinary objectivity. Finally—and to the degree consensus analysis is institutionalized as a standard procedure by regulatory entities—the method satisfies constituencies for its mechanical objectivity.

We began this article by acknowledging along with D'Andrade (2000) that quantitative abilities are requisite for comparative research. If the "sad story" that D'Andrade describes is played out further, mainstream cultural anthropologists will continue to ignore opportunities to teach quantitative skills, and their students will cease to be competitive with others in related disciplines who insist on cross-cultural research of scientific quality.

If there is hope on the horizon, we see it in the influence of A. K. Romney. In our view, consensus analysis as developed by Romney and his colleagues and students transmits the message that researchers in natural resource anthropology, environmental anthropology, and cultural anthropology in general can scientifically seek regularities in knowledge and beliefs that contribute to systemic culture patterns.

Notes

1. Porter (1992) notes that "objectivity" has different, if overlapping, meanings for scientists and the general public. For scientists, objectivity has epistemological significance concerning truth and the correspondence of contemporary knowledge with reality. For many nonscientists, objectivity (e.g., in the opinion of a judge or parent) presumes disinterested analysis and is found in judgments seen to be just or fair.

2. Porter's "mechanical objectivity" is equivalent to Megill's (1991) "procedural objectivity."

3. This four-component framework is adjustable to fit to prevailing cultural, social, and institutional realities. For example, "profit-seeking industries" can be expanded to encompass recreational, sport, and subsistence fishing as well as commercial fishing. Similarly, "management bureaucracies" can refer also to non-Western (e.g., tribal) authorities and "diverse publics" might include nonfishing ethnic and cultural groups studied by ethnographers.

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