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Institutional and ethical dimensions of resilience in fishing systems: Perspectives from co-managed fisheries in the Pacific Northwest

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ABSTRACT

Resilience defines the ability of a system to retain control of function and structure despite changing conditions. In human-natural systems this is related to the capabilities of social institutions. This paper presents insights into institutional and ethical dimensions of resilience, focusing on case studies in the Pacific Northwest that involve cooperative management of Pacific salmon by tribal, state and federal governments. Several characteristics enhance resilience, including institutional nesting and linkages, responsiveness, flexibility, adaptive capacity, opportunities for cross-cutting cleavages, collaborative problem definition, routinization of conflict, knowledge generation, dissemination and feedback loops, and ethical underpinnings that enlarge the boundaries of community.

1. Introduction

Vulnerability and resilience constitute different ends of a continuum marking a system's capacity or ability to cope with, resist and recover from adverse effects, to retain structural and functional integrity in the face of change, and to resist collapse [1,2]. Humans are often, but not always, implicated in generating or exacerbating these adverse effects. However, whatever their origin, humans have long engaged in developing collective responses to these challenges. Aside from physical characteristics, the vulnerability or capacity for resilience of coupled human-natural systems is also related to the existence and capabilities of social institutions, their ability to stimulate and channel information, communication and action. Functioning institutional arrangements, therefore, are vital, both before and after perturbations (ranging from minor changes to large-scale catastrophic events) occur, to mitigate impacts, speed recovery and restoration.

Policymakers utilize both science and values in their decision-making, for it is only in relation to a set of values or ethical framework, whether implied or explicit, that knowledge or scientific "facts" have meaning for developing public policy and guiding the activities of institutions [3]. Institutions represent a nexus of knowledge and ethics. The institutional and ethical dimensions of resilience are critically important to ensure the ethical functioning of society, so that coordinated actions might alleviate or mitigate human suffering.

Ecologists have applied the concepts of vulnerability and resilience to the functioning of ecosystems. More recently, there have been efforts by researchers to apply these concepts to the social institutions that have been created to mediate our relations with the natural world [4–6]. Examining vulnerability and resilience in terms of institutions can aid coastal resource managers in understanding the characteristics that contribute to their ability or inability to cope with adverse effects and perturbations. Along this line, both the ethical frameworks that guide institutional action and the knowledge producing, using and disseminating functions of institutions, appear to be among the critical variables conveying institutional resilience.

This paper presents some insights into the institutional and ethical dimensions of resilience in coupled human-natural systems, focusing on institutional attributes and interactions that enhance resilience in changeable and dynamic systems in coastal and marine areas. Specifically, it explores the role of institutions and environmental ethics in conveying resilience within the context of several case studies from the Pacific Northwest that involve the management of Pacific salmon (Oncorhynchus spp.).

As the empirical basis of this analysis, this paper draws upon an on-going examination of several cooperative management institutions. Specifically, the results presented are based on the author's experiences as a fisheries management biologist in

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Washington as well as focused, on-going research. This included over 200 semi-structured interviews, participant observation of hundreds of management meetings (both in-person and teleconference) of a variety of local, state, regional, national and international management arenas, subsistence, commercial and ceremonial fishing practices, and a review of relevant management documents.

2. A framework for envisioning resilience

Both vulnerability and resilience have biophysical, social and institutional components. The biophysical component is defined by the natural and physical environment, and includes attributes such as the carrying capacity, geographic location, size and both internal and external linkages associated with the ecosystem, species life histories and bottlenecks. The social component encompasses the social, cultural, political and economic context. Pertinent aspects may include the income, assets, the size and diversity of the economic base, the number and tightness of linkages to global markets and various social networks of the human population [7]. Finally, institutional components of vulnerability and resilience can be thought of as a subset of social aspects. Here our attention is focused on the nature of management and regulatory regimes.

The social component of resilience can be conceived of in terms of capital. Human capital encompasses the characteristics of the human population such as their education, skills and cultural attributes. Social capital refers to the social and political environment that humans create and includes the various connections among individuals, social networks and norms of reciprocity and trust that arise from these connections and networks [8]. Finally, institutional capital, which can be thought of as a subset of social capital, refers to the character and density of institutions available to a given community [9].

The attributes associated with vulnerability and resilience differ at different temporal, spatial and organizational scales within systems from individual animals to populations to entire systems. At the individual organismal level, resilience can be defined as the amount of change, disturbance or sub-optimal conditions that can be buffered by the organism itself, for example, through fat or starch storage [10].

At the population or species level, resilience can be defined in terms of genetic diversity or geographic range. Pacific salmon have a variety of traits that decrease vulnerability. These include the habit of straying, which refers to the ability to exploit new or changing conditions. Straying allows new species to fill unused niches or new niches that have developed as a result of environmental change. The salmon's high genetic diversity, large number of spatially and temporally discrete populations provide redundancy and thus conveys resilience in the face of environmental change.

Resilience at the habitat or ecosystem level can be defined in terms of species diversity, the diversity of trophic levels within a system, which minimize waste during cycling, and the existence of linkages to other systems [1]. Resilience at the landscape level can be characterized in terms of habitat diversity. Resilience in coupled human-natural systems is evidenced by the ability to learn, adapt and self-organize [1]. Systems with the capacity to evolve can survive almost any change by changing themselves [11]. Overall, systems that exhibit flexibility, variability, redundancy, adaptability and foresight tend to be resilient. The ability to evolve, to change direction and take timely corrective actions is predicated on some amount of foresight, which in turn is facilitated in systems that continually monitor or probe their external environment. Here one sees the confluence of ethics, in this case a precautionary approach, and the knowledge generating capacity of the system, in conveying resilience.

3. Institutional dimensions of resilience

Humans have organized collectively, developing institutions, to assess and respond to anthropogenic and naturally induced changes in ecosystems. To understand the operation and articulation of this collective organization, it is necessary to broaden the focus on inquiry to examine the "environment" that institutions are embedded within. In the case of natural resource management institutions, the institutional environment includes social, institutional and biophysical dimensions. The social dimension reflects the broader societal context. The institutional dimension reflects the institution's relationship to other institutions with which it interacts, overlaps, competes or co-exists. The biophysical dimension reflects its intersection with the abiotic and biotic components of ecosystems.

In order to survive, organizations either adapt to their environment or reconfigure it to suit their needs [12]. The environment may exert significant pressures on organizations and they in turn may adapt, altering to fill new or changing niches. For example, the relationship of the major companies such as DuPont that produced ozone-depleting chemicals (e.g., chlorofluorocarbons (CFCs)) to the Montreal Protocol, the international law governing their use, provides a good example of this type of organization–environment interaction.

Alternatively, organizations may actively work to make their environment more favorable. An example of this type of interaction occurred during the 2004 controversy over the US Environmental Protection Agency's mercury regulations. The New York Times reported "[c]oal and utility groups lobbied intensively to help shape [EPA mercury] regulations, which will cost billions of dollars" [13]. Similar processes occur in fisheries management regimes in which stakeholder organizations work to create more favorable external environments. It should be noted that this latter type of interaction does not necessarily lead to enhanced system resilience or improved outcomes from the point of view of resource conservation.

Social institutions and ecological systems have different "sizes" or dimensions that can be defined spatially, temporally and functionally. To enhance effectiveness, that is to be successful in creating resilient outcomes and to survive, institutions should have a good "fit" with their environment. Fit, in this sense, refers to the way in which the dimensional characteristics of institutions match their environment [14]. Resilience is enhanced when there is a good match between institutional characteristics (i.e., social, geographical and functional scope) and the natural context of ecological systems. On the other hand a poor fit can detract from a system's resilience.

The governance of many large river systems in North America, such as the Connecticut and Columbia, in which the rivers themselves act as boundaries between separate political and management jurisdictions provide useful examples of coupled system with poor fit [15]. In these cases, effective management of riverine and riparian habitats and resources is problematic without some linkage among the various management institutions on these rivers. Ideally, rivers should be managed as whole systems, not as halves or quarters. Improving fit in these situations entails creating institutions that bridge different political jurisdictions, thereby matching the ecosystem they are attempting to manage. In these types of situations, fit can be enhanced by creating new institutions with more appropriate jurisdictional authority or by altering jurisdictional boundaries to match both ecological boundaries and the range of human behaviors.

In addition, fit can be enhanced by producing and integrating knowledge from a variety of different sources at different spatial and temporal scales [16].

The space that institutions operate within may overlap or intersect with that of other institutions. Interactions between different institutions can influence or redirect institutional activities and cause outcomes to be altered, enhanced or impeded. Interplay refers to those interactions that occur among or between institutions [14]. Interplay can occur at the same or different levels of social organization and can impact the effectiveness and resilience of institutional activities and outcomes both positively and negatively.

Resource management institutions have tended to utilize a specific ethical framework or set of values along with scientific knowledge in their management work. In the US, these regimes have been wedded to the progressive conservation ethic of Gifford Pinchot, trying to maximize resource use or enjoyment for the most people over the longest period of time. However, for centuries prior to contact, Northwest Tribal Nations managed salmon fisheries by controlling access, establishing property rights to harvest areas and use rights to the fish within these areas [17].

Before contact, indigenous Native American groups had acquired an extensive knowledge of plants and animals and their ecological relationships gathered over relatively small geographic areas for long time periods, termed traditional ecological knowledge (TEK). They combined this with a worldview or ethic that placed humans in nature, not apart, and had long time horizons, often conceived in terms of seven generations. Further, Northwest and Alaskan tribes had prohibitions against wastage that limited harvests, prescribed reciprocal social obligations and established appropriate behaviors. This combination of TEK and tribal ethics gave rise to effective traditional management systems suited to the area.

Co-management institutions are institutional hybrids, merging state and tribal management institutions. They bring resource users, local communities as well as other stakeholders directly into the management process and allow individuals and groups with different perspectives, knowledge systems, understandings of the world, values and ethical frames to come together and share responsibility for managing resources. There is a great diversity in the structure of these institutions. They can be more or less formal and establish different arrangements for the sharing of authority, responsibility and decision-making power.

4. Empirical evidence from case studies of co-management

In the Pacific Northwest a number of cooperative management institutions have emerged in the past few decades that have focused on the management of salmon as well as other fisheries resources. The empirical evidence presented is derived from a set of interrelated co-management regimes operating in the states of Washington, Oregon and California that formally involve federal, tribal and state governments.

The origin of these co-management regimes is based in the aboriginal rights and treaties that were negotiated by the government of the United States in their quest to open the lands of the Pacific Northwest for white settlement. The Northwest Indian tribes signed these treaties in the mid-1800s, reserving their right to fish in common with all citizens if the territory in their usual and accustomed fishing areas [18]. Non-Indian fishermen had greater access to capital and licenses and thus were able to outcompete tribal fishermen. In-river and near-shore tribal fisheries were often closed by state management agencies due to concerns over the conservation of the run after large offshore non-Indian fisheries had completed their harvests. Since the 1890s, Northwest tribes have used the courts to adjudicate their treaty rights.

4.1. Columbia River

In the Columbia River, the pivotal court case that led to the development of cooperative management is the Sohappy vs. Smith case, also known as the Belloni decision or US vs. Oregon, which was decided in 1969. Four Columbia River tribes, the Yakima, Umatilla, Nez Perce and Warm Springs, intervened in the case. The court ordered that these tribes were entitled to a "fair share of the fish produced by the Columbia River system" and encouraged the tribes and state to pursue "a cooperative approach" to fisheries management (911–12) [19]. As a result cooperative salmon management eventually developed and is now implemented by the states of Oregon and Washington and the Columbia River tribes.

4.2. Puget Sound, WA

In 1974, the US vs. Washington or Boldt decision was handed down and in 1979 the US Supreme Court upheld most of its findings. This decision recognized the rights of 20 tribes of western Washington to harvest up to 50% of the harvestable salmon run. The ruling further gave these tribes the authority to manage their on and off-reservation fisheries, provided that the tribes met several qualifications, including possessing trained fishery scientists and managers. The Boldt decision set up the framework for the cooperative management between the state of Washington and the tribes of Puget Sound and the Washington coast [17,20]. Each tribe has a co-management relationship with the state in which the two parties coordinate individual fisheries. The Puget Sound Salmon Management Plan outlines the responsibilities of the tribal and state co-managers in this co-management institution. System-wide coordination is also needed, so there is also a regional co-management relationship within Puget Sound, encompassing Puget Sound tribes and the federal and state governments. On occasion, there is also need for coordination among all the various co-managers in western Washington, encompassing the 20 tribes, state and federal governments.

4.3. Washington coast

The Hoh, Quileute and Quinault tribes situated on the Washington coast were party to the US vs. Washington case. Additionally, these coastal tribes initiated litigation in the seminal Hoh vs. Baldrige case. A ruling was issued in Hoh vs. Baldrige in 1981, mandating that the 50% allocation should occur on a stock-by-stock basis rather than on an aggregated run. This decision led to the adoption of "weak stock" management policy, in which wild stocks deemed at risk of not achieving their escapement goals, that have "conservation problems", are considered "driver" stocks. Escapement objectives for driver stocks are negotiated between the state and tribal co-managers to balance legal requirements with the conservation needs of the stock. Fisheries that impact these stocks are "shaped" to avoid impacts on these driver stocks through combinations of time, area and gear restrictions. As in Puget Sound, each coastal tribe has a co-management relationship with the state. Similarly, there is also need to have coast-wide coordination, so a regional co-management relationship exists among the state of Washington and the coastal tribes.

4.4. Klamath River

Although treaties were negotiated with the California tribes on the Klamath River in 1851, the US Senate refused to ratify them because of opposition from the California delegation [21]. As a result of this legal history, the character of the fisheries of the Yurok, Hoopa Valley (or Hupa) and Karok Tribes on the Klamath and the emerging co-management institution have a different history and character. The critical case on the Klamath River, Mattz vs. Arnett, was initiated in 1969. After a series of appeals, the Court acknowledged the rights of Indians to fish on tribal reservations free of state intervention. In 1985, the Pacific Fishery Management Council (PFMC) brought together a group of Klamath River stakeholders, including tribal representatives, to develop a long-range agreement to manage Klamath River salmon stocks [22]. This led to the formation of the Klamath River Salmon Management Group (KRSMG) [23]. The KRSMG meets several times a year to negotiate mutually acceptable management and allocation strategies. The agreements that emerge from this group are passed on to the PFMC for incorporation into the yearly salmon fishing plans.

4.5. North of Falcon

Because of the court-ordered allocation requirements an institutional means of linking ocean fisheries, under federal (PFMC) control, with coastal and in-river fisheries was needed. The North of Falcon institution (NOF) was created in the mid-1980s to provide this institutional connection. NOF encompasses fisheries north of Cape Falcon, on the northern coast of Oregon, to the US–Canada border. It provides a forum for representatives of state and tribal management agencies, various industry and environmental organizations, tribal, non-tribal, commercial, recreational and charterboat fishermen along with other interested stakeholders from the region to come together to design fishing plans for inshore fisheries in conjunction with ocean fishing levels. NOF meetings encompass a series of smaller breakout caucuses involving subsets of the stakeholders from Puget Sound, the Washington coast and Columbia River. At these smaller meetings state and tribal representatives discuss a variety of management concerns, establish interim escapement goals for weak stocks, develop stock specific fishing plans and court-reviewed Memoranda of Understandings (MOU) for critical salmon stocks.

5. Co-management and institutional resilience

5.1. Problem definition

Complex problem definitions are more likely to facilitate nuanced and resilient management plans and regulations. The formation of this set of nested co-management institutions on the Pacific Coast has allowed a greater number and diversity of stakeholders to come to the table. This in turn has allowed management problems to be defined with a greater degree of complexity than if defined by one agency or commission alone. Stakeholders enrich problem definition processes and this facilitates the development of more refined and robust management responses [4,20].

5.2. Institutional responsiveness, flexibility and adaptation

Resilient management needs to be responsive, flexible and adaptive. There is a need for management structures that are responsive to feedbacks from the environment, to various changes and cycles, and are able to react appropriately. There is a need to shift from control to responsiveness and adaptation [1].

These co-management regimes are quite flexible in practice. New initiatives and programs have been created to address the various issues that have emerged in the years since their formation [24]. What started with a fairly singular focus on harvest management has evolved to encompass a broad suite of environmental issues such as culvert placement and maintenance, water quality and quantity, logging best practices and growth management of urban areas, to name only a few. As a former manager from the Washington Department of Fish and Wildlife commented,

> There is now more focus on rebuilding fisheries rather than on allocation. In 1983 we spent two-thirds of our time on allocation. That was not responsible management. We counted fish to allocate them…Now we're worried about impacts on rivers, the impacts of El Niño, future status, how hatcheries are working.

This has allowed managers to be more responsive to new and changing signals in the environment, to develop appropriate responses and to adapt institutionally to changing conditions. On the Columbia River, the Northwest Power Planning Council has explicitly adopted an adaptive management approach [25].

5.3. Cross-cutting cleavages

Cross-cutting cleavages describe issues that provide an opportunity for competitors or opponents to become allies in support or opposition of a different issue [26]. In this way, cross-cutting cleavages provide a basis for alliances or coalitions to form across social and political divisions and allow social conflicts to be bounded to some degree. The crafting of the 1982 UN Law of the Sea Convention has been identified as an example whose success is at least in part attributable to the existence of cross-cutting cleavages. As Magraw and Nickel wrote in their 1990 assessment,

> It is widely believed that the reason agreement was possible on so many critical and divisive issues—including such vital national security issues as the right of transit by military vessels through narrow straits—was precisely that there were so many of them and they cut so many ways and so differently that voting blocs could not and did not materialize. Allies on one issue were opponents on another and creative statesmanship and negotiating, rather than chaos, resulted (150) [27]

The co-management institutions of the Pacific Northwest have broad jurisdictional scopes and a diversity of participants, with 20 tribes in Washington, four in the Columbia River, three on the Klamath and a number of different state and federal agencies. This context provides ample opportunities for the formation of various alliances and cross-cutting cleavages [28]. As one tribal fisheries manager explained,

> Bringing other fisheries into line is mostly a matter of persuasion intertribally. There are no defined rules, but that's being litigated now. In lieu of that there's persuasion and a view of what's fair and the hidden threat that you can come back to get them in another forum…In a lot of ways, the tribal community is a small town, like the Middle East. You don't know who your ally might be week to week. You create long-term enemies at your own risk.

With expansive interests tribes are able to mobilize a wide range of cross-cutting issues. These issues provide a basis around

which cooperation can develop. This in turn helps to divert and disperse conflict in many directions. Conflicts have less chance of becoming polarized or entrenched along the same social or political divisions. It also provides a more complex social environment, which may facilitate negotiating consensus-based compromise agreements.

5.4. Conflict management

Two types of conflict have been identified: distributive and integrative [29]. Distributive conflict is zero-sum, a prisoner's dilemma in which communication is faulty and information is withheld. Integrative conflicts involve seeking an optimal solution out of a set of alternatives and are distinguished by the sharing of information.

Co-management institutions have most certainly not eradicated all conflicts. But they have stimulated and facilitated the development of processes in which conflict has become bureaucratized and thus more manageable. This routinization of conflict has relied on processes such as the court-ordered Fishery Advisory Board (FAB) process in Washington. Co-management has allowed conflicts to be resolved "more humanely," transforming them from physical to verbal confrontations [30]. The work of co-management in the Pacific Northwest revolves around a yearly cycle of meetings. Participants are in frequent contact. This helps to enlarge the "shadow of the future" and helps to keep conflicts from escalating.

Conflicts may also generate positive effects. Conflicts may expose underlying problems and value differences, thereby fostering more resilient resolutions that accommodate or at least recognize and respect differences. In many cases, knowledge-based conflicts have led to institutional changes that have ultimately enhanced the quality of information used in management and the robustness of management decisions [31].

In addition, conflicts can stimulate a reassessment of the nature of problems. For example, resource allocation conflicts, in which stakeholders compete for limited stocks, may provide motivation for an examination of the underlying causes of low run sizes, and ultimately transform the underlying problem definition.

Conflicts clarify differences and can provide the basis for social learning. They may provide the stimulus for institutional innovation and creation. Conflicts link institutions to their environment allow the "situation to speak back" [32]. In these case studies, the conflicts that were brought before the courts provided the stimulus for the formation of co-management regimes. In these ways, the existence of natural resource-based conflict may be transformed from distributive to integrative, and thereby enhance the adaptive capacity of the institution and the overall resilience of the system.

5.5. Vertical and horizontal linkages

Co-management regimes are localized endeavors, embedded within narrow spatial boundaries. Resilient management requires that local institutions have linkages to management institutions at higher spatial and organizational scales. The co-management regimes in the Pacific Northwest are nested and linked to regimes at both higher and lower levels of social organization.

Tribal representatives are "cross-cutting actors", active in management arenas at multiple scales of social organization, wearing "different hats" to represent different interests or constituents [28]. By wearing "different hats", tribal actors are able to permeate the social boundaries of different levels of social organization within a hierarchical regime, in this way linking diverse spatial and temporal scales. They also cut across different issue-specific policy subsystems within and outside of fisheries management regimes. Crossing-cutting actors carry knowledge and values across different scales of management, and this has a number of implications for allocative equity and resource conservation. With expansive interests that encompass a wide range of environmental issues, tribes are active in a number of functionally related regimes such as those focused on habitat concerns, water management, shellfish management and upland hunting. This involvement facilitates the flow of information, and the construction of an integrated knowledge.

5.6. Scientific expertise and knowledge production

As a result of the mandates of the Boldt decision, most Northwest tribes established departments of fisheries and natural resource management. Most tribes employ fisheries managers and natural resource management staff that include biologists and technicians with different areas of expertise.

Tribes are involved in the collection of management information. They are responsible for collecting a wide variety of fisheries and habitat-related data. They are also charged with enforcing regulation in tribal fisheries. Tribes conduct test fisheries to develop inseason updates of stock sizes and stream surveys to get information on spawning escapements. They collect catch data as well as coded wire tag and genetic stock information data from commercial fisheries. Tribes conduct primary research on a variety of subjects such as the impacts of logging on salmon habitats. They engage in habitat restoration activities as well as enhancement, encompassing a range of hatchery production and supplementation efforts. They are active in most management and environmental arenas.

Knowledge allows humans to make the world mutually meaningful, to understand the range of outcomes associated with human activities, transform uncertainties into risks, prepare for surprises, develop strategies to minimize or avoid negative outcomes. Learning is essential to form assessments of changing situations, to adapt to meet the emerging challenges and to be proactive rather than solely reactive in responding to environmental change. Institutions not only act upon existing knowledge, they actively engage in producing new knowledge [33]. The creation, dissemination and storage of knowledge are institutional characteristics with important implications for resilience.

Knowledge produced from a number of different sources is considered to be more reliable and robust than knowledge produced from one source alone. For example, the practice of triangulation, combining at least three sources of information to validate a conclusion, is widely accepted and promoted by many disciplines. The existence and structure of knowledge flows and feedbacks are also regarded as an important component in building more robust knowledge bases. In her 1994 analysis of the failure of the dam spanning the Teton River in 1975, Mary Schmidt distinguished between bottom-up knowledge, requiring bodily involvement, and top-down knowledge, gained through the use of various instruments. She elaborated upon bottom-up knowledge, classifying it into "a feel for the hole", relating to individual expertise or artistry acquired through intimate practice (214), "a feel for the whole", representing collective knowledge of a subject, held incompletely by individuals and assembled during gatherings of individuals, (215), and "intimate knowledge", which represents the understanding of a specific thing acquired over long time periods (221) [34].

Managing for resilience requires gathering information at different scales. This requires bottom-up and top-down knowledge, fine-grained local knowledge and information on coast-wide trends. In addition, these inputs of information need to be

integrated into a cohesive whole. For example, it is critical to know when development along a small tributary destroys spawning redds or negatively impacts juvenile survival. It is also important to know the number of salmon harvested by Alaskan and Canadian fishermen in order to have an idea of the population entering Washington waters. The co-management regimes in the Pacific Northwest have created institutional mechanisms for collecting and disseminating finer-grained knowledge about the system allowing those with top-down knowledge, knowledge of the hole and intimate knowledge to create a multi-scalar knowledge of the whole [31].

Tribal fisheries management has decentralized management throughout the Pacific Northwest. Fisheries managers are now situated along most major tributaries in the region. There are now more monetary and human resources devoted to fisheries management than before the emergence of co-management regimes. Tribal involvement in management has increased the geographic range of research as well as the collection of finer-grained knowledge. There is now more research being conducted along more rivers and within more watersheds along the Pacific coast than prior to tribal involvement. Co-management has allowed a greater number of individuals and agencies to engage in fisheries research and the production of knowledge. This in turn has provided new technical perspectives from the new set of actors, which includes tribal councils, fishermen and fisheries staff. Further, tribal managers have access to different types of knowledge, such as experiential and traditional.

The initial contentiousness surrounding co-management and lack of trust between state and tribal co-managers meant that many technical analyses were duplicated or subjected to critical review. This can be interpreted as inefficient; however, it has fostered a system of peer review, thereby facilitating critique and refinement of the information and analyses used in management. Tribal involvement in management efforts has increased the monetary and human resources directed at management. Finally, the new allocation rules necessitated better modeling capabilities, and a much finer understanding of the stock specific components. This in turn has led to the development of an array of coast-wide integrative models for understanding exploitation rates in more fisheries along the Pacific coast.

5.7. Communication, dissemination and feedback loops

The quality of communication, information flows and feedback loops is also important in influencing decision-making and behaviors. One of the common causes of system malfunction is lack of appropriate feedback loops for information [11]. For example, in fisheries, there often exists a lack of feedback between knowledge of the state of fish populations and a fishermen's decision to harvest fish. When abundance is low, fish prices are often higher, thereby creating an incentive for increased fishing pressure.

Regional co-management initiatives such as the NOF process bring tribal and state managers and wide variety of other stakeholders from the region together at frequent meetings. This has allowed those with different types of knowledge to communicate, disseminate and integrate information, so that a collective and more comprehensive knowledge of the whole can be constructed. This, in turn, leads to an improved informational foundation on which management and allocation decisions can be made.

Information moves horizontally within and between the different co-management regimes as well as vertically up to the PFMC and US–Canada Pacific Salmon Commission [35]. The PFMC acts as a mediating forum, allowing each co-management subsystem to negotiate local and regional agreements within its overarching structure. Agreements are subject to approval by the PFMC; however, if a consensus among stakeholders emerges, though tenuous, the PFMC is likely to incorporate these agreements into its fishing plans.

The relationship between the PFMC and the nested co-management institutions is mutually beneficial [35]. The PFMC infrastructure provides structured space and time, protection from the external environment and access to limited physical resources. The NOF, KRSMG and smaller breakout caucuses for Puget Sound, Washington Coast and Columbia River utilize the PFMC institutional structure to bring together technical resources, information and relevant stakeholders to negotiate and produce locally based allocation and management agreements. The PFMC provides connections among the different regional associations through which technical and policy information flow, both vertically and horizontally. The PFMC integrates local agreements into comprehensive and coordinated coastwide fishing plans for outside and inside fisheries along the Pacific coast.

Salmon management takes place in a turbulent and changeable environment [35]. Management information contains substantial uncertainties and is subject to change as it is refined and analyzed. A large group of highly diverse stakeholders with competing interests vie for pieces of the salmon allocation. There are numerous institutions whose activities impact the production of Pacific salmon and the interests of the various stakeholders. The environment is complex, generating the potential for various forms of functional and political interplay.

Institutions operating in turbulent and uncertain environments require flexibility to promote a good fit and facilitate positive forms of interplay. Collaborative institutional relationships may ameliorate this turbulence and enhancing resilience. These co-management institutions allow stakeholders to endogenize what were once external relations, to gain some control over the regulatory environment in which they operate. They allow the PFMC to formalize and coordinate the way in which stakeholders (part of the PFMC's external environment) provide input for management decisions. Co-management institutions facilitate and formalize the transfer and sharing of information as well as the crafting of consensus positions on complex allocation questions. Finally, they represent institutional spaces where shared understandings of common problems and innovative solutions to these problems can be developed and elaborated upon by stakeholders [35].

6. Ethical dimensions of resilience

Finally, resilient management requires a durable environmental ethic that promotes stewardship and sustainability. Co-management not only allowed people with different values to come together at the management table but also helped to transform and solidify new values and new identities [20]. Aldo Leopold promoted a shift to a new ethic, a "land ethic" [36]. He urged managers and hunters (or fishers) alike to think like a mountain, to enlarge and diversify their temporal and spatial scales of understanding and analysis, to create multiscalar thinking [37]. Resilient management demands extending the temporal time scale beyond the current fishing season. Longer time horizons can promote more unified visions of the future. Resilience is also enhanced by expanding the spatial scale of management to mobilize cross-cutting issues and to provide a common ground for cooperation and consensus [38].

Leopold urged his fellow tinkerers to think about the small cogs and wheels in a system, and to keep all the parts [36]. This is an inherently precautionary approach. Leopold merged his ethic

with an ecology that stressed the interrelatedness, feedbacks and complexity of human-natural systems. This has led to more complex and nuanced problem definitions and objectives in fisheries management.

Aldo Leopold helped to change the "boundaries of community", to enlarge the paradigmatic box that frames the world. Similarly, humans need to enlarge their ethical frame to encompass rivers, seas and oceans, changing what is in the box, what is valued and how it is valued. Collectively, there needs to be a redrawing of boundaries in marine and coastal communities to include the human species along with substrate, water, plankton, macrophytes, invertebrates and fish.

Coastal resource managers need to move their science and values in different directions, shifting science from a focus on natural systems in which humans and human activities are viewed as exogenous perturbations to a focus on coupled human-natural systems in which humans are endogenous actors. Managers need a more refined understanding of how humans and other living being interrelate on earth and how this relationship might be sustained for the benefit of multiple species. At the same time, humans need to infuse their social institutions with an ethics that shift from human-centered frameworks that conceive and value nature in anthropocentric terms to those that imbue the natural world with intrinsic value.

There are surely no final endpoints in this endeavor, just a process or moving towards goals and refining the means of movement. Here, institutions act as vehicles, frameworks or structures, to engage humans and human communities, as components of coupled human-natural systems, in a dynamic process. The ethical systems embedded within these institutions are, however, critically important, acting as maps or sets of directions, allowing humans to chart possibilities, evaluate consequences, set and locate goals. Reconfiguring institutions and realigning the ethical underpinnings of human's collective attempts to manage the world are not necessarily sufficient to ensure system sustainability and resilience, but nonetheless essential.

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