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THE HUMAN ACTOR IN ECOLOGICAL-ECONOMIC MODELS

Political ecology and ecological resilience: An integration of human and ecological dynamics

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Abstract

The biosphere is increasingly dominated by human action. Consequently, ecology must incorporate human behavior. Political ecology, as long as it includes ecology, is a powerful framework for integrating natural and social dynamics. In this paper I present a resilience-oriented approach to political ecology that integrates system dynamics, scale, and cross-scale interactions in both human and natural systems. This approach suggests that understanding the coupled dynamics of human-ecological systems allows the assessment of when systems are most vulnerable and most open to transformation. I use this framework to examine the political ecology of salmon in the Columbia River Basin.

Keywords: Salmon; Columbia river; Resilience; Cross-scale; Scale; Complex adaptive systems

1. Introduction

The Earth's biosphere provides the ecological services that underpin human life. However, as scope and intensity of human domination over the biosphere have expanded, basic attributes of the biosphere such as the physical movement of materials, numbers and distribution of species, and the terrestrial landscape are being primarily controlled by people (Vitousek et al., 1997). Most ecosystems studied by ecologists have and continue to experience significant anthropogenic changes. To understand these ecosystems, ecologists need to better understand the behavior of their dominant species — humans. Similarly, social scientists should recognize that ecological change alters human behavior (Dove, 1992).

In this paper I present a new approach to political ecology. Political ecology, like ecological economics, is a trans-disciplinary attempt to integrate natural and social sciences approaches to understanding the relationship between human and ecological systems. I define political ecology

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as an approach that combines the concerns of ecology and political economy to represent an ever-changing dynamic tension between ecological and human change, and between diverse groups within society at scales from the local individual to the Earth as a whole. I critique the lack of ecology in most current political ecology before elaborating my approach. I advocate using the concepts of resilience, the adaptive cycle, and cross-scale interactions to understand human-ecological dynamics. I illustrate this approach by applying it to the political ecology of salmon in the Columbia River Basin.

2. Political ecology

Political ecology began as a framework to understand the complex interrelations between local people, national and global political economies, and ecosystems (Blaikie and Brookfield, 1987; Schmink and Wood, 1987). The concept has been adapted in a variety of ways, such as Third-World political ecology (Bryant, 1992) or feminist political ecology (Rocheleau et al., 1996). Most current political ecology tends to overlook ecological dynamics and focus upon the structure of human systems (Rocheleau et al., 1996; Gale, 1998; M'Gonigle, 1999). Rather than being called political ecology, these approaches could better be described as the political economy of natural resources, for they do not consider ecosystems to be active agents. Rather they represent nature as a passive object that is transformed by human actors. They present narratives rather than tests of hypotheses, and ignore ecological complexity. For example, in their widely praised book 'Misreading the African Landscape', Fairhead and Leach (1996) criticize simplistic environmentalist depictions of anthropogenic forest degradation. They convincingly show that some local people do manage to increase rather than decrease wooded areas, but they fail to distinguish between different types of forest. They equate fast growing tree species, including non-native species, with far more diverse old-growth forest (Naughton-Treves, 1997).

Political ecology should incorporate the diversity and dynamics of life. The ecological services and resources that are available at a given time and place determines the alternatives that are available to people. This set of alternatives shapes the politics, economics, and management of these ecosystems. However, these constraints are fluid because ecosystems are dynamic and variable. Climate changes, species migrate, populations fluctuate, rivers change their course, and diseases evolve. Ecological change, whether independent of, influenced by, or controlled by human action, alters the types of conflict over ecological resources and services that can occur. Political ecology research that does not address these ecological dynamics may be political, but it is not ecology. Similarly, while politics cannot ignore ecology, ecological approaches need to consider political dynamics in their explanations of human action.

Natural scientists often prefer to ignore the politics of human societies. While this attitude is by no means universal, it does tend to appear in the policy recommendations of natural scientists. They frequently ignore important determinants of human behavior, such as the political forces that influence what and how people learn, the political dimensions of what events are or are not considered crises, and what things are and are not considered to be property. Such blind spots may cause scientists to provide advice or formulate policy that is either spectacularly inadequate, or open to disastrous misuse (Ludwig et al., 1993; Gunderson, 1999).

Human and natural systems have important differences. Humans, individually or in groups, can anticipate and prepare for the future to a much greater degree than ecological systems can (Brock, 1997). These views of the future are based on mental models of varying complexity and completeness. People have developed elaborate ways of exchanging, influencing and updating these models. This creates complicated dynamics based upon access to information, ability to organize, and power. However, the behavior of ecological systems is based upon the past. Ecological dynamics are the product of the mutual reinforcement of many interacting structures and processes rather than design. Similarly, the behavior of biota emerges from the successes of past evolutionary experimentation. This fundamental difference between human and ecological behavior means that understanding the role of people in ecological systems requires not only understanding how people have acted in the past, but also what they think about the future.

Economists generally expect that people's 'rational expectations' will stabilize the behavior of economic systems. The theory of rational expectations proposes that people plan for the future based upon what they think will change in the world and how other people will respond to those changes. If a person's behavior is based upon his or her expectation of what will happen, and this expectation is based upon a person's prediction of the behaviors of other people, then when the world is well understood, these expectations will cause individual behaviors to rapidly converge. However, when the world is poorly understood many possible behaviors become equally likely, which makes it difficult to predict people's behaviors. Consequently, when the world is unknown and difficult to understand people's ability to form 'rational expectations' will actually destabilize system dynamics, making it extremely difficult to predict how a human-ecological system will change in the future (Brock and Hommes, 1997).

Ecological economics has focussed on integrating ecology and economics. However, the inability of economic theory to predict human behavior in novel, poorly understood situations suggests that it has severe shortcomings in explaining human behavior in many human–ecological interactions. Other social sciences that focus on power, the capacity of an actor to purposefully effect the behavior of another actor, appear to have much to offer the field of ecological economics (Gale, 1998).

3. Political ecology — a resilience approach

I define political ecology as combining the concerns of ecology and political economy that together represent an ever-changing dynamic tension between ecological and human change, and between diverse groups within society at scales from the local individual to the Earth as a whole. This approach to political ecology derives from my participation in two research collaborations: the Resilience Network and the Resilience Alliance (http://www.resalliance.org/). The Resilience Network focuses upon the role of diversity, conflict, and cross-scale interactions in the structure and dynamics of coupled social-ecological systems (Berkes and Folke, 1998; Gunderson et al., 1995a; Holling and Sanderson, 1996; Gunderson et al., in preparation1996). These efforts have produced a set of case studies and integrated models of human-nature systems, which include rich empirical descriptions and analyses of resource management by local people (Berkes and Folke, 1998; Colding and Folke, 1997), and the dynamics of regional ecosystems (Gunderson et al., 1995a; Pastor et al., 1998). In addition, a number of conceptual models have been used to explore system behavior (Ludwig et al., 1997; Peterson et al., 1998). Researchers have used complex adaptive systems approaches (Hartvigsen et al., 1998; Levin et al., 1998) to develop an integrated set of socio-economic ecological models (Carpenter et al., 1999a,b; Janssen and Carpenter, 1999). The Resilience Alliance uses the concepts of resilience, the adaptive cycle, scale, and cross-scale dynamics to describe systems dynamics. Below, I introduce these concepts and then apply them to analyze the political ecology of salmon in the Columbia River Basin.

3.1. Resilience

Ecological resilience is the amount of change or disruption that will cause an ecosystem to switch from being maintained by one set of mutually reinforcing processes and structures to an alternative set of processes and structures (Holling, 1973). For example, what fire regime will convert a tropical forest to a grassland? Ecologists also use an alternate definition of resilience (Pimm, 1984). Differences between these definitions of resilience are discussed elsewhere (Holling, 1996; Peterson et al., 1998).

Ecological resilience can be represented using a model of a ball on a surface. The ball represents the state of the system and the surface represents the forces acting to change that state. Pits in this surface represent stable states — states in which the system is organized into a set of mutually reinforcing structures and processes. The slope of the landscape represents the strength of the forces moving the system in a direction. Disturbances, which reorganize a system, move a ball across the landscape's surface. Ecological resilience of a state corresponds to the width of a stability pit. This width represents the amount of change that a system would have to experience before it moves from one set of mutually reinforcing processes, a pit, to another (Fig. 1). Ecological resilience allows ecologists and managers to focus upon the likelihood of transitions among different sets of organizing processes and structures, rather than the internal dynamics of specific ecological organizations.

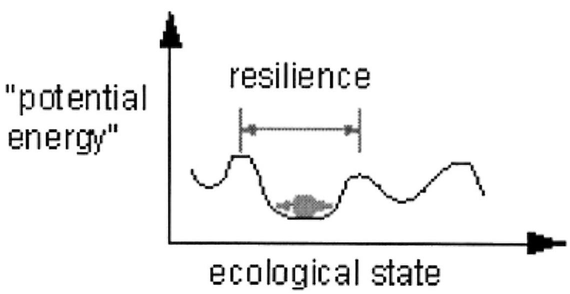

Fig. 1. The ecological resilience of a system can be illustrated by a ball on a surface. This surface represents the forces acting upon a system in any given state. Pits in this surface represent stable states — states in which the system is organized into a set of mutually reinforcing structures and processes. The slope of the landscape represents the strength of the forces moving the system in a direction. Disturbances reorganize the system moving the ball across the landscape's surface. Ecological resilience is a measure of the disturbance required to shift a system from being organized around one set of mutually reinforcing structures and processes to another. On a surface, the ecological resilience of a state corresponds to the width of a stability pit. This represents the amount of change that a system would have to experience before the system's state is moved from one set of mutually reinforcing processes to another.

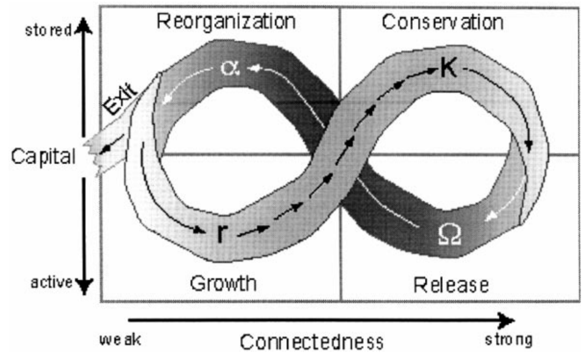

Fig. 2. The dynamics of a system as it is dominated by each of the four ecological processes: rapid growth (r), conservation (K), release (Ω), and reorganization (α). The arrows indicate the speed of the cycle. The short, closely spaced arrows indicate a slow and predictable change, while the long arrows indicate rapid and less predictable change. The cycle reflects systemic change in the amount of accumulated capital (nutrients, resources) stored by the dominant structuring process in each phase, and the degree of connectedness within the system. The exit from the cycle at the left of the figure indicates the time at which a systemic reorganization into a less or more productive and organized system is most likely to occur. Adapted from Gunderson et al. (1995b).

3.2. Adaptive cycle

Holling (1986) has presented a general model of systemic change that proposes that the internal dynamics of systems cycle through four phases: rapid growth, conservation, collapse, and re-organization. The adaptive cycle is meant to be a tool for thought. It focuses attention upon processes of destruction and reorganization, which are often neglected in favor of growth and conservation. Including these processes provides a more complete view of system dynamics that links together system organization, resilience and dynamics.

Holling first applied this model to ecological systems, and Gunderson et al. (1995a,b) extended it to human-ecological systems, based upon the argument that the continual production of novelty by human–nature interactions destabilizes human forward looking behavior. The model proposes that as weakly connected processes interact, some processes reinforce one another, rapidly building structure, or organization. This organization channels and constrains interactions within the system. However, the system becomes dependent upon structure and constraint for its persistence, leaving it vulnerable to either internal fluctuations or external disruption. Eventually, the system collapses, allowing the remaining disorganized structures and processes to reorganize (Fig. 2). As the organization of a system changes over time its resilience expands and contracts (Fig. 3).

The exploitation or 'r' phase of the adaptive cycle describes a system that is engaged in a process of growth, resource accumulation and storage. The system's components are weakly connected to one another, its internal state is weakly regulated, and the system is resilient. During this period actors can grow rapidly, as they utilize disorganized resources. The actors that thrive are those that develop interrelationships that reduce the impacts of external variation, and reinforce their own expansion. Examples of such processes are the vegetative control of microclimate in ecosystems, and bureaucratic rationalization in human organizations. These processes of organization increase a system's efficiency at the cost of its flexibility, decreasing its resilience.

As a system becomes more organized, the competitive advantage shifts from actors that are able to grow rapidly despite environmental variation (i.e. r-selected species in ecosystems) to those that can effectively manage and benefit from intense competitive and facilitative interactions with other actors (i.e. K-selected species). Actors whose persistence is not supported by the other actors are displaced from the system, reducing its diversity. Increased system connectivity and efficient resource leaves few opportunities available for new actors to enter the system. In ecology, an example of such a system is an old-growth forest. A social example is a large corporation, such as Microsoft, that dominates its markets. The future dynamics of a system in this state appear to be gradual, constrained, and predictable, but a system's in-

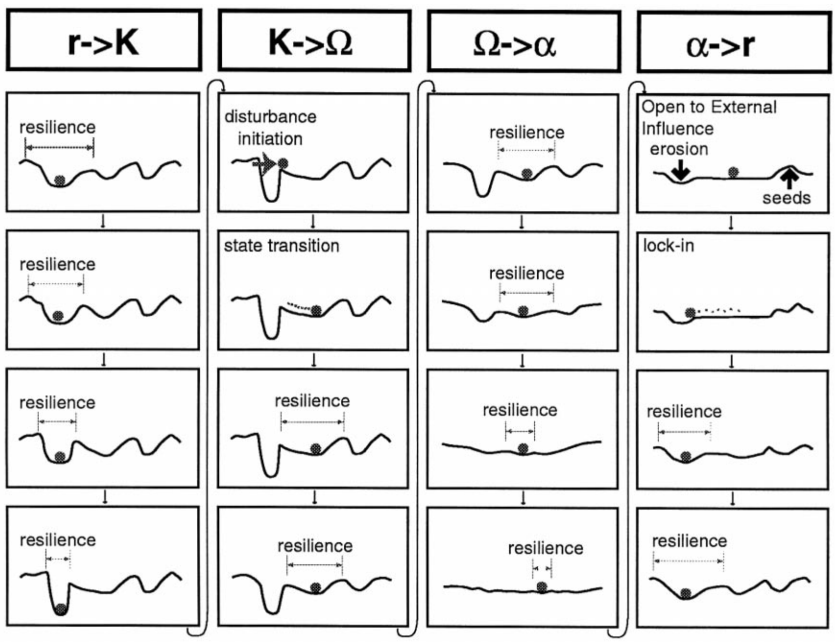

Fig. 3. As a system progresses through the adaptive cycle its resilience expands and contracts as the system changes and reorganizes. Resilience shrinks as the cycle moves from r to K, where the system becomes more brittle. Until the system flips to a very resilient disturbance state, this state quickly changes the configuration of the system, abolishing constraining forces, leaving the system open to external influence (Ω to α). During this phase the system has little resilience and can be easily reorganized by small inputs. However, as the system reorganizes systematic controls begin to reemerge, producing a resilient set of ecological organizations.

creasing dependence upon the persistence of its existing structure leaves it increasingly vulnerable to any process or instability that releases its organized capital. Such a system is increasingly stable, but over a decreasing range of conditions. This reduces the resilience of the system.

A disturbance that exceeds a system's resilience breaks apart the web of mutually reinforcing interactions that maintain the system. At this point the system flips abruptly into a transitory disturbance state that rapidly disperses the system's accumulated capital and connections until the disturbance has altered the system to such an extent that the disturbance exhausts itself. The disorganization and release of accumulated resources is represented by Ω, or release, phase of the adaptive cycle. This phase is analogous to what Schumpeter (1964) termed creative destruction. Disturbance processes such as fire, insect outbreaks, floods, ungulate grazing, and disease outbreaks disrupt ecosystems. Social disturbance processes may include financial panics (Lewis, 1999), banking crises (Chandler, 1977), revolutions (Goldstone, 1991), or pollution events (Erikson, 1994).

Following a period of destruction, a system's boundaries and internal connections are tenuous. This state is represented by α, or reorganization, phase in the adaptive cycle. Such a loosely defined system can easily lose or gain resources and actors. During this period a system can easily be reorganized by small inputs. This is the time when exotic species of plants and animals can invade and dominate an ecosystem, or when a group of outsiders can take over an organization. It is the time when chance events can shape the future organization of the system. The new system that emerges from these interactions may replicate a previous system organization or it may be something entirely new. The lack of systemic connection and control makes it difficult to predict what type of organization will form. For example, consider the radically different structure of Eastern European countries following the collapse of the Soviet Union, or the succession movements that followed the resignation of Suharto in Indonesia.

The adaptive cycle can temporarily break down due to either the loss of ecological capital or the creation of a very robust ecological organization. In the first case, the removal or destruction of ecological resources eliminates the possibility that an ecosystem will reorganize. This could occur when an event, such as an intense forest fire, destroys a site's soil, removing the ecological substrate of the old ecosystem. While life still persists at such a site at the fine scale, local ecological dynamics have been derailed. In the second case, an ecosystem that manages to organize into a very robust ecological organization may be able to survive disturbance, environmental variation, and prevent species turnover. However, such a system is probably only possible in situations where it experiences a limited amount of environmental variation; it is isolated from species or other ecological impacts from neighboring ecosystems, and the interactions of its biotic and abiotic processes strongly reinforce each another. Because no ecosystem is completely isolated from other ecosystems, the ecosystems will eventually escape from these traps. Systems stuck in poverty will be enriched by the arrival of organisms or materials from surrounding systems, while stable systems will eventually be disrupted by changes at a larger scale that exceed their capacity to cope.

The adaptive cycle shows two very different stages. One, from r to K, is the slow, incremental phase of growth and accumulation. This alternation between accumulating organized resources and experimenting with alternate organizations generates novelty and tests diversity. This alternation may result from a necessary tension between invention, novelty and change and efficiency, conservation, and stability. It appears that neither of these processes is stable alone. Efficiency undercuts its own ability to persist by reducing the ability of a system to respond to change, and successful innovations grow while unsuccessful innovations vanish.

3.3. Scale

Ecological organization emerges from the interaction of structures and processes operating at different scales. I define scale as the resolution and extent of the spatial and temporal frequencies of these structures and processes (Peterson et al., 1998). A system exists within an environmental context and is composed of sub-systems. It interacts across scales with its environment and subsystems, all of which can be described by the adaptive cycle. The sensitivity of a system to changes in its sub-systems or its environment depends upon its internal state. Similarly, the degree of impact that the transformation of a system has upon its environment or its sub-systems depends upon the state of those systems.

I propose that there are four ways that change propagates through dynamic hierarchies. First, change at a higher level alters a lower level due to the constraints that it places upon it. For example, offshore fishing for salmon reduces the number of salmon returning to spawn in watersheds along a coast. Second, reorganization at a higher level can trigger reorganization at a lower level. The construction of Grand Coulee dam in the Columbia River illustrates this type of cross-scale change. The dam made it impossible for salmon to travel above or below the dam, extinguishing the migrating salmon populations upstream of the dam. Third, small-scale disturbance can trigger a larger scale collapse if the larger system is in a brittle stage in its adaptive cycle. The introduction of opossum shrimp (*Mysis relicta*) into lakes in the Columbia River Basin provides an example of a small event triggering large scale reorganization. The shrimp has caused the reorganization of the lake and surrounding ecosystems, as salmon populations and the species feeding upon them have declined and been replaced by bottom feeding fish (Spencer et al., 1991). Fourth, following the collapse of a system, small-scale and surrounding large-scale systems provide the components and constraints out of which a system reorganizes. An example of this type of cross-scale change is provided by the 1934 destruction of Sunbeam dam on the Salmon River. This dam had cut salmon off from their spawning beds, but following its removal salmon from neighboring watersheds recolonized the restored river, establishing new populations (Wilkinson, 1992).

I have defined a political ecology that focuses upon the dynamic connections between human and natural processes across a range of scales, and I propose that a key aspect of this connection is how the resilience of different systems changes. Below, I illustrate the utility of these concepts by using them to analyze the the poltical ecology of salmon in the Columbia River Basin of western North America.

4. An example: salmon in the Columbia River basin

The Columbia River is the fourth largest river in North America. It flows almost 2000 km from its source in the Canadian Rockies, through desert, arid valleys, farmland and forest to the Pacific Ocean. The river passes through what are now seven US states, two Canadian provinces, and many Indian reservations. When Europeans arrived in the 18th century, between 10 and 16 million salmon returned annually to the Columbia River Basin, where they were the chief sustenance of the approximately 100 000 people whose ancestors had been living in the basin for millennia (NRC, 1996). In the century and a half following the start of the colonization of the Columbia River Basin, the area's population increased to 9 million. During the same time, the number of returning salmon dropped below 1 million and more than 25% of the region's salmon populations have become extinct (Nehlsen et al., 1991). Salmon is economically and socially important, and its decline has amplified conflict over how people live within and use the Columbia River Basin.

Salmon populations in the Columbia have been impacted by three major classes of human action: dams, fishing, and land-use change (Table 1). These actions have impacted salmon at a number of points in their life cycles. Most salmon hatch in freshwater, grow in freshwater streams and lakes, migrate to the ocean to grow and mature, and return to freshwater to reproduce. Before the recent anthropogenic modification of the Columbia River Basin, mature salmon would return from the Pacific up to 1.5 m in length and 50 kg in weight. Salmon swam up the rivers, leaping up through rapids and waterfalls. Some salmon would stop in the lower reaches of the river, while others moved hundreds of kilometers upstream in the Columbia's tributaries. People and animals

Table 1
Human activities have greatly affected salmon populations in the Columbia River Basin[a]

Activity	Agents	Impact	Benefit	Regulatory agencies
Dams	Electric utilities, industry, agriculture	Eliminates habitat, barrier to returning fish, barrier to departing fish, slows river flow for departing fish	Hydropower, flood control, barge transport, irrigation	Northwest Power Planning Council, Bonneville Power Administration, Army Corps of Engineers, Bureau of Reclamation, Federal Energy Regulatory Commission, and as of 1994, state environmental agencies under Clean Water Act.
Fishing	Tribal fisheries, non-tribal fisheries, international fisheries, sport fishers	Reduces number of returning reproductive fish, artificial selection	Food	Fish and Wildlife Service, National Marine Fisheries Service, tribal and state agencies
Land-use change	Ranchers, logging companies, farmers, developers	Elicitation and degradation of spawning areas, reduces woody debris, increased frequency of disturbance	Agriculture, logging, suburban development	Bureau of Land Management, Forest Service, Dept. of Agriculture, and Dept. of Transportation

[a] This table outlines the agents responsible for these activities, their impacts on the salmon, direct benefits gained from these activities and some of the agencies responsible for regulating these activities (Lee, 1993; NRC, 1996).

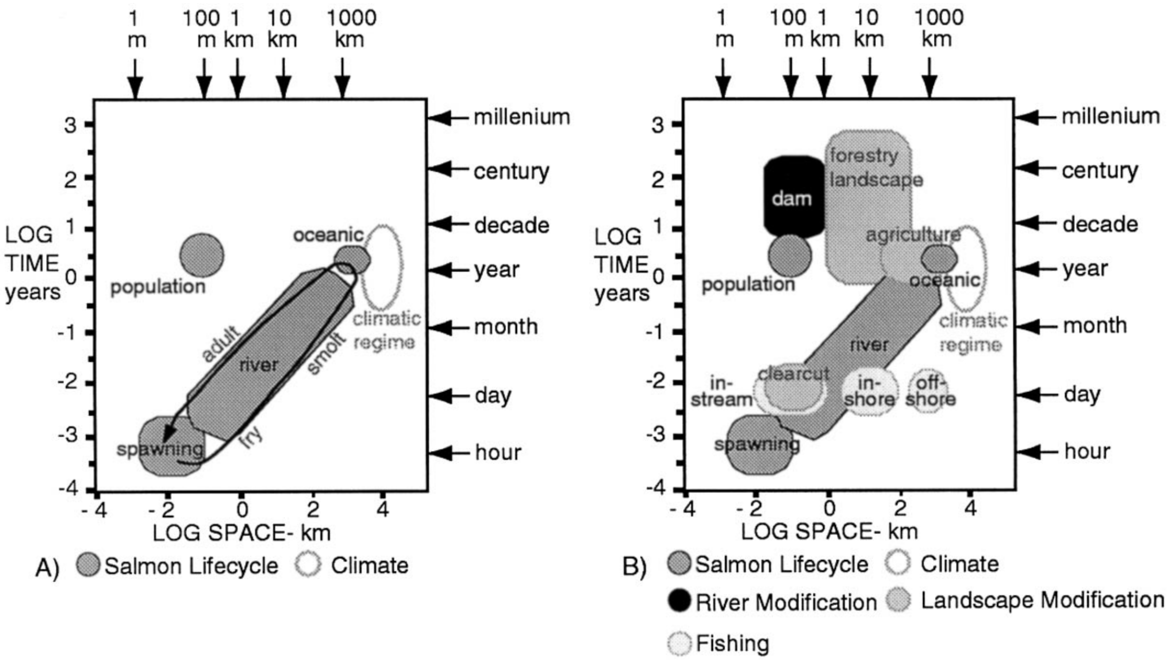

Fig. 4. A comparison of scales of (A) the salmon life cycle (Groot and Margolis, 1991) and atmospheric processes (Clark, 1985) to (B) anthropogenic environmental modifications of the Columbia River Basin (NRC, 1996).

caught some salmon, but others managed to return to the clear fast flowing water above the gravel beds in which they were born. Female salmon dug nests for their eggs in the gravel. Competing males would rush to fertilize the eggs as they sank to the gravel, where the female would bury them beneath more gravel. After this burst of fecundity the adult salmon died. The young salmon fry that emerged foraged over ever increasing areas of a pool, and then river, until they migrated to the sea. Some of the salmon remained in the river for a few months, while other species remained for over a year before swimming downstream. In the Pacific Ocean, salmon foraged over thousands of kilometers before returning to spawn in the same stream bed where they were born. The number of years of growth required to reach maturity varied among salmon species, between the sexes, and among individuals (Groot and Margolis, 1991).

The wide-ranging life cycle of the salmon and its great diversity means that different human actions, in different places, impact salmon at different times in their lives. The relationships between human action and salmon can be clarified by plotting the spatial and temporal scales at which these processes occur. This reveals the scales at which processes strongly interact (Fig. 4).

The scales of processes that affect salmon vary across their life cycle (Fig. 4A). Young salmon depend upon local stream chemistry, temperature, substrate and food availability. Mature salmon depend upon patterns of ocean circulation, prey availability, and temperature for growth and survival. Due to the ability of salmon to return to their birthplace to reproduce, salmon populations are very localized, possessing the same spatial scale as their spawning areas, but one that is resolved at a generational rather than yearly temporal scale. Consequently, salmon population dynamics reflect both broad scale climatic regime variation in the north Pacific (Beamish et al., 1999), and local changes in their spawning beds (Torgersen et al., 1999).

Human action changes salmon habitat both at broad and small scales (Fig. 4B). Dams interrupt movement between the river and the sea, altering the entire watershed, and reducing the ability of salmon to inhabit the area above the dam. Land-use impacts salmon at both broad and local scales. Logging adjacent to a particular reach of river can eliminate spawning habitat, while the overall amount of logging in a watershed determines stream quality by modifying water temperature, turbidity, and the volume of woody debris. Similarly, the impact of fishing on salmon populations depends upon how it is conducted. The impact of offshore fishing is evenly distributed across the set of populations that are present, while in-stream fishing impacts specific populations. For example, offshore fishing cannot avoid impacting endangered populations of salmon if those are mixed in with other salmon. These cross-scale connections between human action and ecological dynamics determine both the human and ecological impacts of people's decisions.

4.1. Institutional dynamics

Dam operation, fishing and land-use change are the three main human actions that impact salmon populations in the Columbia River Basin. These actions are mediated through a complex set of institutions. These institutions are not static, rather they change in response to internal and external dynamics. These shifts in management institutions can be represented using the adaptive cycle (Fig. 5).

4.1.1. Dams

Dam building has fundamentally altered the ecology of the Columbia River Basin (Fig. 5A). Dams impede or even block the salmon's migration to and from the ocean. They also flood potential spawning areas, and change the temperature, speed, and other characteristics of the river. Dam building began soon after European colonization, but it was not until the 1930s that large dams were constructed. In the 1970s dam building drew to a halt because there were few potential sites remaining and public support for dam building had declined (NRC, 1996). From the 1970s onward, the management of the dams became more complex as river regulators attempted to balance power generation and salmon conservation (Lee, 1993). This balancing act appears to have failed (Volkman and McConnaha, 1993), and by the late 1990s the previously unmentioned

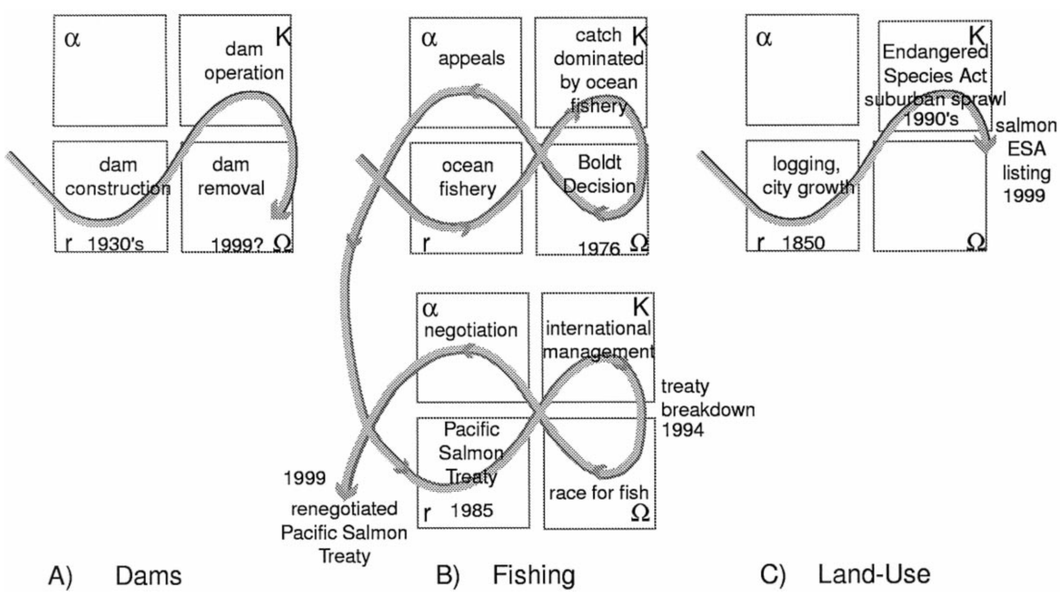

Fig. 5. Management institutions in the Columbia River Basin have been transformed at different rates (NRC, 1996). (A) Dams have changed more slowly than (B) fishing rights. While (C) land-use policy has changed the least.

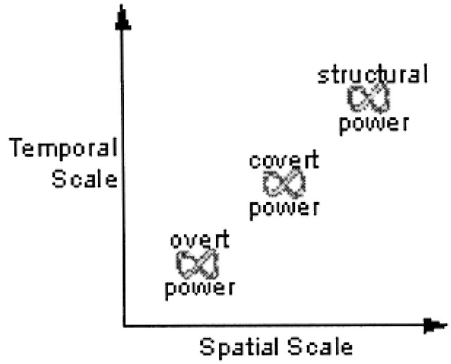

Fig. 6. Power can also be visualized as changing at different temporal and spatial scales. I argue that Lukes' (1973) three dimensions of power can be thought of as operating at three different scales and that power will follow an adaptive cycle.

idea of removing dams was raised, and then met with increasing acceptance (NRC, 1996; Kenworthy, 1997; Verhovek 2000).

4.1.2. Fishing rights

The changing interpretations of treaties between the USA and native peoples and between the USA and Canada radically changed the scale and sets of rights associated with salmon (Fig. 5B). In 1969 a number of natives sued the state of Washington over their fishing rights, and in 1973 Judge Boldt ruled that native treaties with the federal government entitled them to half of the total salmon catch. This decision transformed the declining salmon fishing industry, which at that time was dominated by non-Indians engaged commercial fishing and sport fishing (Cohen, 1986; Lee, 1993).

Salmon do not recognize international borders, but fishing boats do. Salmon from both the USA and Canada spend the majority of their lives in the North Pacific Ocean before migrating southward along the coast of North America. This situation led to conflict between Canada and the USA over how much fish each country's fishers should be allowed to take. In 1985 the Pacific Salmon treaty divided rights to these fish among the two countries, but the agreement broke down in the early 1990s as salmon populations declined. This breakdown lead to rampant overfishing, as fishermen from both countries attempted to catch as many fish as possible before they were caught elsewhere (NRC, 1996). This situation exacerbated conflict between Canada and the USA, until in 1999 the Canadian fisheries minister unilaterally began closing British Columbia's salmon fisheries. This act was followed by closures in Washington State and further Canadian closures. In this drastically transformed situation the Pacific Salmon Treaty was renegotiated to place greater emphasis upon salmon conservation than on the allocation of fishing rights (Anderson, 1999).

4.1.3. Land-use change

The anthropogenic transformation of the landscape through agriculture, road building, logging, housing development, mining, dams and flood control structures has altered the ecological structure and dynamics of watersheds in the Columbia River Basin (Fig. 5C). This development began with the first settlement in the area, but accelerated as European colonization greatly expanded the numbers and activities of people at the close of the 19th century. Today, at the end of the 20th century, this expansion has begun to run up against a number of limits: no more dams are being constructed, the area logged is declining, land-use change is more tightly regulated (NRC, 1996). The US government has protected several salmon populations under the Endangered Species Act, which has increased the pressure to reform and restructure present land-use practices.

The shifts in management institutions are illustrated using the adaptive cycle (Fig. 5). The comparison of dams, fisheries and land-use change reveals that the institutional relationship between fisheries and salmon has undergone more rapid institutional change than dam operation or land-use change. Fisheries management became more complex within the Columbia River Basin, by the inclusion of tribal management, and expanded its range through increased international salmon management.

4.2. Power

Ecological dynamics operate across a variety of scales and so does political power. Lukes (1973) defined three dimensions of political power: overt, covert, and structural. I view these three dimensions of power as defining three scales at which power operates (Fig. 6).

Overt power is the direct wielding of power through force, incentives, or intimidation to influence people's decisions. Overt power operates in the here and now because it requires mobilized people, by necessity, it occurs over brief periods at specific locations. For example, fisheries police arrest Indians 'illegally' fishing (Egan, 1990).

Covert power removes the opportunity for people to behave in specifc ways by controlling what type of decisions can be made. Covert power requires the manipulation of institutions, and this manipulation will usually occur over slower and larger institutional scales. Covert power operates by controlling whether issues are discussed or addressed by an institution. For example, the dam building agencies ignored native treaty rights and destroyed native fishing areas (Cohen, 1986).

Structual power is the slowest and broadest scale type of power. Structural power is the ability of the institutions of a society to restrict the set of issues about which people think they can make decisions. Structural power involves manipulating culture, which is slow to change, and likely operates over a broader area than an individual institution. Because it determines what concepts are even considered, and therefore requires a group that is relatively insulated from external ideas. An example of structural power is how the removal of dams from the Columbia river was not considered seriously or even discussed until quite recently (Kenworthy, 1997; Verhovek, 2000).

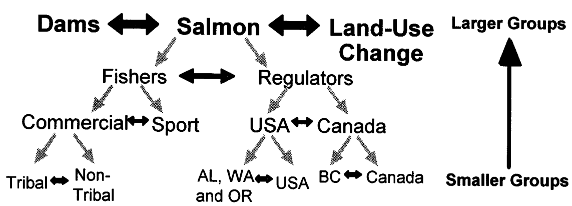

Fig. 7. A hierarchical political taxonomy of groups engaged in salmon-related conflicts within the Columbia River Basin. AK, WA, and OR represent the states of Alaska, Washington and Oregon in the USA. BC represents the province of British Columbia in Canada.

4.3. Cross-scale heterogeneity

It is important to note that the dynamics discussed above at the scale of the entire Columbia are also occurring within the various groups I identified. Groups are usually quite heterogeneous because the individuals and organizations that comprise them have different interests, values, and power. While group members may be able to agree upon one issue, they will likely disagree on another issue. Consequently, conflict within and among groups can be viewed as an interacting hierarchical structure. Arguments over salmon unite loggers, fishers and environmentalists against hydropower utilities, as well as pitting native fishers against offshore fishermen and environmental groups. However, within all these groups there are also internal tensions. An example of these nested conflicts is portrayed in Fig. 7. For example, salmon advocates can be divided into those who use the resource and those who regulate it. Fishers are internally divided into commercial and sport fishers, and commercial fishers can be further divided into tribal and non-tribal fishers — particularly since these two groups have different fishing strategies, social organization, legal rights and fishing histories. Similarly, regulators are divided between two countries and within those countries between officials at the federal level as well as the provincial and state. This figure is just one of many hierarchical taxonomic distinctions that can be drawn between groups. Often political change occurs as groups or coalitions split their sub-groups reform to create a new arrangement of hierarchies of conflict, in a fashion similar to the large-scale institutional changes in fisheries or dam management.

In this example I have illustrated how considering the scale, the adaptive cycle, and cross-scale dynamics can be used to explain and understand a complex socio-ecological issue. Analyzing the comparative scale of human and ecological processes allows one to identify scale mismatches between human and ecological processes, as well as potential scales at which new institutions could be formed. The adaptive cycle focuses attention on destructive and reorganizing processes, as well as organizing and conservative processes. This attention may alert people to institutional change, as well as suggesting when opportunities for institutional change are likely to arise. Finally, the study of cross-scale interactions may identify systems that are vulnerable to change at other scales, as well as opportunities for the formation of novel coalitions.

5. Conclusions

Humans now dominate the functioning of most ecosystems, and human action occurs at a number of scales. Ecologists need to incorporate the behavior of humans, Earth's keystone species, into their thinking; however, this is quite difficult. Similarly, social scientists need to be aware that nature is not an inert entity that is only squabbled and over and rearranged by people. Ecological processes and the structures they maintain, create and destroy are dynamic. Political ecology should spring from the intersections of the social and the ecological. In this paper I have presented some of the concepts and frameworks that members of the Resilience Network have used to approach this integration. It is my attempt to put ecology back into political ecology. This approach may help assess when these systems are vulnerable to both natural and human disturbances. Furthermore, it offers the potential of identifying when political, ecological or economic intervention may be most successful in reorganizing the relationships between people and nature into a more sustainable form.

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