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Research article

Fishing for ecosystem services

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ABSTRACT

Ecosystems are commonly exploited and manipulated to maximize certain human benefits. Such changes can degrade systems, leading to cascading negative effects that may be initially undetected, yet ultimately result in a reduction, or complete loss, of certain valuable ecosystem services. Ecosystem-based management is intended to maintain ecosystem quality and minimize the risk of irreversible change to natural assemblages of species and to ecosystem processes while obtaining and maintaining long-term socioeconomic benefits. We discuss policy decisions in fishery management related to commonly manipulated environments with a focus on influences to ecosystem services. By focusing on broader scales, managing for ecosystem services, and taking a more proactive approach, we expect sustainable, quality fisheries that are resilient to future disturbances. To that end, we contend that: (1) management always involves tradeoffs; (2) explicit management of fisheries for ecosystem services could facilitate a transition from reactive to proactive management; and (3) adaptive co-management is a process that could enhance management for ecosystem services. We propose adaptive co-management with an ecosystem service framework where actions are implemented within ecosystem boundaries, rather than political boundaries, through strong interjurisdictional relationships.

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1. Introduction

Fishing and hunting connect aquatic and terrestrial ecosystems with human society (Lubchenco, 1998; Bright and Porter, 2001; Liu et al., 2007). Humans have harvested fish for at least 42,000 years (O'Connor et al., 2011) and wildlife for at least 500,000 years (Wilkins et al., 2012). However, there has been a steady increase in industrial and recreational development of fishing and hunting, especially during the last half of the 20th Century (Arlinghaus et al., 2002; Cooke and Cowx, 2004; Swartz et al., 2010; Anticamara et al., 2011), that commonly manipulates ecosystems to maximize certain human benefits. These manipulations, such as overfishing and introduction of exotic game species, may provide short-term benefits to humans, but can also degrade systems, leading to cascading negative effects that may be initially undetected, yet ultimately result in a reduction, or complete loss, of certain valuable ecosystem services (e.g., Sweeney et al., 2004; Benayas et al., 2009; Biggs et al., 2009). Therefore, it is critical to understand that fisheries and wildlife management actions simultaneously enhance some ecological services and diminish others.

The resulting tradeoffs from management actions are seldom discussed (but see Rodriguez et al., 2006) during the objective-development and implementation stages of management. Ironically, reduction of some ecological services from management in favor of enhancing others has long been recognized, and many have called for ecosystem-based approaches, including governance of resilience in fisheries and wildlife management (e.g., Grumbine, 1994; Folke et al., 2004; Pikitch et al., 2004; Pope et al., 2014), with an emphasis on sustainability to properly manage such

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resources (Becker and Ostrom, 1995; Dietz et al., 2003; Rammel et al., 2007). Ecosystem-based management is intended to maintain ecosystem quality and minimize the risk of irreversible change to natural assemblages of species and to ecosystem processes while obtaining and maintaining long-term socioeconomic benefits (Tallis et al., 2008). We believe that an unambiguous understanding of the desired and undesired outcomes of actions on ecosystem services when specifying management objectives is a further progression of ecosystem-based management. Though important, managing for ecosystem dynamics alone cannot guarantee successful management of complex, multi-stakeholder systems like commercial and recreational fisheries.

There is a need for wise management of natural resources that is predicated on sound science (Lubchenco, 1998). Much of the management, and hence the science to support it, for recreational fishing and hunting in North America is achieved at the state or provincial level, rather than the national level (Mahoney, 2009; Ballweber and Schramm, 2010). We contend this decentralized level of management often leads to a focus on lower, rather than higher, levels of biological organization. That is, a focus on populations of game animals rather than a focus on ecosystems that contain game animals. Instead, some approaches that provide insights for ecosystem-based management including meta-analyses (Benayas et al., 2009), large (interstate and interprovincial) spatial studies (Lehodey et al., 2008), adaptive management (Allen et al., 2011), and adaptive co-management (Armitage et al., 2007, 2009), or some combination of these could be used. It is important for scientists to complete research focused at the ecosystem level to provide managers a better understanding of the potential intended and unintended consequences of management actions on ecosystem services.

Adaptive management, while actively managing for ecosystem services, maintains open channels of communications between all stakeholders involved. Adaptive co-management takes this one step further, eliciting input from multiple stakeholders and agencies that may span across state and provincial lines and even to non-regulatory groups who are invested in the potential outcomes (Armitage et al., 2009; Plummer, 2009). By involving these essential groups in the management planning stages, adaptive co-management seeks to avoid many of the issues that frequently befall reactionary management techniques.

Westman (1977) discussed the concept of ecosystem services and proposed that quantification of the benefits provided by an ecosystem would facilitate informed decision-making for management of the ecosystem. Westman (1977) termed these benefits as “nature's services; ” Ehrlich and Ehrlich (1981) further refined this term to “ecosystem services.” There are several definitions of ecosystem services, but a commonly referenced definition is “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life” (Daily, 1997). The Millennium Ecosystem Assessment (MEA, 2005) used four categories to classify ecosystem services: cultural services, provisioning services, regulating services, and supporting services. Cultural, provisioning, and regulating services directly affect humans, whereas supporting services are necessary for the production of the other services. Cultural services are nonmaterial benefits that are obtained from ecosystems, including recreation, religion, aesthetics, and others. Provisioning services are products obtained from ecosystems, including food, fresh water, fuel, and others. Regulating services are the benefits obtained from regulation of ecosystem processes, including water regulation, disease regulation, climate, and others.

Fisheries management techniques, though not often specifically couched in these terms, currently use ecosystem service frameworks in a disjointed capacity that fails to account for the breadth of ecosystem patterns and processes. Management practices have a tendency to focus on population dynamics of single species as opposed to a focus on population dynamics of multiple species as interconnected parts of an ecosystem (Pitcher, 2001; Pikitch et al., 2004) that produce emergent properties of community dynamics. This leads to a focus on socially valuable fish rather than ecologically important species and functional groups (Cooke et al., 2005; Adams and Schmetterling, 2007). This narrow focus can have compounding influences on ecological regimes that are difficult to predict. When management outcomes are realized, new management actions may become necessary to deal with unanticipated, deleterious effects. This reactive management style potentially creates negative feedback loops between the social and ecological components of fisheries.

Inland recreational fisheries are unique examples of tradeoffs in ecosystem services among multiple users (Arlinghaus et al., 2002). These multi-use systems generate competition between opposing policy decisions. Often, policy decisions lead to ecosystem-wide manipulations that drastically alter ecosystem patterns and processes (Arlinghaus et al., 2002) with the intent for positive, institutional gain in well-being. This essay discusses policy decisions in fisheries management related to commonly manipulated environments with a focus on influences to ecosystem services, specifically ecosystem service tradeoffs associated with three case studies of inland fisheries management: (1) dam construction and impoundments; (2) river and stream rehabilitations; and (3) fish-stock enhancement. Within inland fisheries, most management objectives are aimed at sustainable use of natural resources, rehabilitation of negatively impacted systems, and modification of systems to better suit the needs of stakeholders (Arlinghaus et al., 2002; Cowx et al., 2010). We acknowledge the ecosystem services listed and examples presented herein do not comprehensively cover the full breadth of ecosystem services provided by aquatic systems for fisheries management or any other service. Rather, we use examples to illustrate possible trade-offs in decisions as a context to suggest alternate strategies that better anticipate and directly manage resources within an ecosystem service framework.

2. Dam construction and impoundments

Man-made dams provide numerous benefits including flood control, water reserves for cities and farms, production of hydroelectric power, and transportation. In exchange, dams alter the timing and variability of water and sediment flow, and physically block fish migration routes (Baxter, 1977; Bunn and Arthington, 2002). During the last 100 years, rivers within North America were rapidly dammed in favor of civil development, with little consideration given to long-term tradeoffs among ecosystem services. Many dams built in the rapid industrialization following World War II are approaching the end of their functional lifespan (Poff and Hart, 2002), and managers are faced with four choices: create new infrastructure, maintain and retrofit current infrastructure, remove decaying infrastructure, or leave dilapidated infrastructure in place. Increasingly, fisheries biologists recognize the effects of lentic habitat created by dams on native lotic species, causing many biologists to call for dam removal as a preferred management action (Table 1; Blumm et al., 1998; Hart and Poff, 2002). However, growing human populations are increasing the demand for provisionary and cultural services produced by dams. When assessing the construction, management, or removal of dams, managers could assess benefits and costs over the long term (>50 years) to elucidate effective management actions focused on ecosystem services (Table 1). Though the effects dams have on the environment vary considerably (e.g., Poff and Hart, 2002), assessing the tradeoffs in ecosystem services provides an intuitive and