Basins and Coasts
Volume 2 Issue 2 May 2008

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IMCAFS INTEGRATED MANAGEMENT OF COASTAL AND FRESHWATER SYSTEMS

Economic valuation of ecosystem services: A new impetus for shellfish restoration?

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Introduction

What is an oyster worth? In restaurants along the Gulf of Mexico coast, where most of the U.S. oyster catch is landed these days, a dozen oysters will cost patrons somewhere around US$10. In New York City, one might expect to pay as much as three times that amount for specialty oysters that have been grown in the burgeoning aquaculture industry along the east coast of the U.S. But what is the value of an *UNHARVESTED* oyster, or an entire reef of oysters for that matter? Scientists, managers, restoration practitioners and conservationists are beginning to grapple with this question because it is increasingly apparent that native shellfish play a critical role in ensuring the long-term health of coastal bays and estuaries.

Bivalve shellfish like oysters have been described in the scientific literature as ‘ecosystem engineers’ – organisms that physically, biologically or chemically modify the environment around them in ways that influence the health of other organisms (Jones et al. 1994). Other ecosystems, such as coral reefs and mangroves, have been recognized for providing such ‘engineering’ services, prompting greater protection for them and management with multiple ecosystem services in mind (Day 2002, Gilbert and Jansson 1998). Oyster reefs could also be managed in ways that consider the value of these systems to surrounding coastal areas. Although there is increasing recognition that shellfish provide multiple ecosystem services, management for objectives beyond harvest has not yet become widespread (Table 1).

The role of temperate oyster reefs as habitat for other species was described beginning in the 19th century and, as more studies were conducted, their role as ‘essential fish habitat’ has been suggested in the literature (Coen et al. 1999). More recently, the stabilizing influence of intertidal reefs on adjacent shorelines has been noted in the scientific literature (Meyer et al. 1997, Piazza et al. 2005). As suspension feeders, shellfish like oysters exert a controlling influence on ambient water quality, enhance denitrification (reviewed by Newell 2004) and may, at sufficiently high densities, suppress harmful algal blooms (Cerato et al. 2004) and stimulate the growth of seagrasses (Newell and Koch 2004). Field measurements by Grizzle et al. (2006) reveal a considerable fraction of suspended particulate matter (seston) is removed - up to 62% at some sites in their study—from waters overlying dense shellfish assemblages. In addition, shellfish reefs play an important role in tourism and recreation. Shellfish reefs can create habitat for fish, allowing recreational fisher use and can improve adjacent beach water quality, resulting in more desirable areas for tourists to visit (Freeman 1995, Lipton 2004).

Given this array of ecosystem services, it

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Table 1: Comparison of ecosystem services provided by three 'ecosystem engineers', Coral Reefs, Mangroves and Shellfish Reefs. The categories of services are based on those defined by the Millennium Ecosystem Assessment (2005).

CATEGORY OF SERVICE	Coral Reefs	Mangroves	Shellfish
Regulating	Protection of beaches and coastlines from storm surges and waves	Protection of beach and coastlines from storm surges, waves and floods	Protection of coastlines from storm surges and waves
	unknown	Water quality maintenance	Water quality maintenance
	Reduction of beach erosion	Reduction of beach erosion	Reduction of marsh shoreline erosion
	unknown	Climate Regulation through CO_2 uptake	unknown
	Formation of beaches and islands	Stabilization of land by trapping sediments	Stabilization of submerged land by trapping sediments
Provisioning	Subsistence and commercial fisheries	Subsistence and commercial fisheries	Subsistence and commercial fisheries
	Fish and invertebrates for the ornamental aquarium trade	Aquaculture	Aquaculture
	Pharmaceutical products	Fuelwood	
	Building materials	Building materials	Fertilizer and building materials (lime)
	Jewelry and other decoration	Traditional Medicines	Jewelry and other decoration (shells)
Cultural	Tourism and recreation	Tourism and recreation	Tourism and recreation
	Spiritual and esthetic appreciation	Spiritual-sacred sites	Symbolic of coastal heritage
Supporting	Cycling of nutrients	Cycling of nutrients	Cycling of nutrients
	Nursery habitats	Nursery habitats	Nursery habitats

seems logical that efforts to restore and manage native shellfish populations specifically with ecosystem services in mind should increase (Coen et al. 2007). However, for this increase to occur and be sustained over time, two things are needed. First, a concerted effort is necessary to measure and document these services in the field. Second, economic returns on the investment in restoration must be better quantified and should account for the full range of services. Most efforts to restore shellfish in the past have been focused on increasing or maintaining landings, with mixed results (NRC 2004). Restoration projects should also include enhanced quantitative monitoring of the larger populations and coastal systems in which they are embedded.

Why focus on ecosystem services?

The Millennium Ecosystem Assessment (2005) organized ecosystem services into four broad categories that are relevant to shellfish restoration: 'provisioning' (e.g., fisheries), 'regulating' (e.g., erosion control), 'supporting' (e.g., nutrient cycling), and 'culturally significant' (e.g., tourism) services. Ecosystem services in each of these categories are frequently invoked as a desired outcome of shellfish habitat restoration, with the 'provisioning' service of fisheries production being the predominant management objective until very recently. However, many restoration projects have been implemented on an ad-hoc basis, often with limited or no effort to set *a priori* measurable objectives based on these services. In the absence of other kinds of monitoring data, the default measure of project success tends to be subsequent harvest levels, often with disappointing results (NRC 2004). This is caused, in part, by a mismatch between the scale of restoration and anticipated outcomes—even relatively small restoration projects can be costly (e.g., > US $100,000 per acre for restored oyster reef; USACE 2005) relative to the value of oyster landings measured on the same area (Grabowski and Peterson 2007).

Although fisheries production is a legitimate ecosystem service ('provisioning') to derive from shellfish restoration efforts, shellfish provide additional services that are meaningful, measurable and potentially of greater economic value. The benefit to cost ratio of oyster reefs for shoreline protection is likely quite high, particularly when the value of nutrient removal and fish production are included on an areal basis, however, efforts to place economic valuations on these services are just beginning. Newell et al. (2005) estimated the annual value of nitrogen removal by oyster reefs in the Choptank River, Maryland, at $314,836 or $181/ha/year. Peterson et al. (2003) estimated fish production from 10 m^2 of restored oyster reef sanctuaries in the southeastern U.S. at 2.6 kg/year (2600 kg/ha/year). For fish of commercial significance, this enhanced production by the reefs equates to $3,700/ha/year and, over a 50 year time span, the fish productivity would exceed the anticipated value of directed oyster harvest from the same area by more than 34% (Grabowski and Peterson 2007). Including the value of denitrification along with the enhanced fish productivity further increases the annual value of services provided by a restored oyster reef. Although there are many assumptions that must be satisfied when scaling upward from these estimates, it is clear that there is great potential economic value in restoring and managing reefs in the southeastern U.S. for ecosystem services other than direct shellfish harvest. Balancing tradeoffs between various services will be essential, as not all services may be available simultaneously from a given reef. Harvesting oysters from reefs, for example, may significantly diminish their ability to support fish and other organisms, leading to lower returns for the ecosystem service of fish production (Grabowski and Peterson 2007). Understanding these trade-offs would enable managers to manage different areas for a particular ecosystem service or set of services.

Monitoring for ecosystem services

To help advance the field of restoration and increase the focus on ecosystem services, The Nature Conservancy and partners have developed a nationwide network of shellfish restoration sites where quantitative approaches are used to monitor ecosystem services and outcomes associated with restoration projects. To date, approximately 3 dozen shellfish restoration projects have been funded through various programs, including a national partnership between The Nature Conservancy and the National Oceanic and Atmospheric Association's (NOAA) Community-based Restoration Program, that monitor an array of species and project metrics (Table 2). The intent of this network of projects is to develop and share new tools for monitoring, compare results at different locations and geographic scales and to advance the restoration of shellfish for ecosystem services at larger scales. Thayer et al. (2005) provide a comprehensive overview of science-based monitoring approaches for marine ecosystems, including oyster reefs and habitats that support other bivalves such as mussels.

Table 2. Ecosystem services metrics used at various ongoing shellfish restoration sites. Target species include: bay scallop *Argopecten irradians* (*Ai*), eastern oyster *Crassostrea virginica* (*Cv*), hard clam *Mercenaria mercenaria* (*Mm*), blue mussel *Mytilus edulis* (*Me*), and Olympia oyster *Ostrea conchaphila* (*Oc*). Key metrics for assessing ecological function of oyster reefs were identified at a workshop convened in South Carolina in 2004, and methods for monitoring projects are outlined on the following website: http://www.oyster-restoration.org.

STATE	WATER BODY	TARGET SPECIES	POPULATION PARAMETERS	SHORELINE PROTECTION	WATER QUALITY	HABITAT/ BIODIV.
CA	San Francisco Bay; Humboldt Bay	*Oc*	✓			✓
FL	Indian River Lagoon	*Cv, Mm*	✓	✓		✓
LA	Grand Isle	*Cv*	✓	✓		✓
MS	Biloxi Bay, Grand Bay	*Cv*	✓	✓		✓
NH	Great Bay	*Cv, Me*	✓		✓	✓
NY	Peconic Bay, Great South Bay	*Ai, Mm, Cv*	✓			✓
NC	Pamlico Sound	*Cv*	✓	✓		✓
OR	Netarts Bay	*Oc*	✓			✓
SC	ACE Basin	*Cv*	✓	✓	✓	✓
TX	Copano Bay, GICW	*Cv*	✓	✓	✓	✓
VA	Chesapeake Bay, Eastern Shore Lagoons	*Cv*	✓	✓		✓
WA	Puget Sound	*Oc*	✓			✓

The long-term challenges

A major challenge with restoration is ensuring both long-term stewardship of the site and, related to this, a commitment to long-term monitoring. Many funding sources for restoration are short term (e.g., 2-3 years). In addition, there are sometimes barriers (programmatic or philosophical) to devoting a significant fraction of restoration budgets to monitoring. These issues conflict with the desire by most agencies and restoration practitioners to pursue an adaptive management approach for sites, whereby data inform decisions about remedial action that may be needed over time (Walters 1986). Longer-term funding commitments or strategic partnerships that leverage resources would facilitate monitoring over necessary timescales and, we believe, would result in more sustainable benefits from restoration.

Protection of restoration sites from adverse impacts (e.g., direct or indirect) is also desirable. Many, but not all, shellfish restoration projects occur on submerged or intertidal lands that are held in public trust. Regulatory or statutory frameworks for ensuring long-term protection of these public areas are increasingly common, such as designation of restored oyster reefs as spawner sanctuaries in states like New York,

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Virginia and North Carolina (http://www.ncfisheries.net/shellfish/sanctuary1.htm).

Restoration of shellfish on submerged or intertidal lands that are privately leased or owned in fee simple title is also increasingly common and shows great promise as a tool for long-term protection of restoration sites (Beck et al. 2004). In Virginia, for example, intertidal oyster reefs restored on property owned by The Nature Conservancy (TNC) are clearly posted and monitored frequently; despite some incidences of unauthorized harvest, the sites have among the highest abundances of oysters in the region and are designed to complement sanctuaries on public lands located nearby. In New York, TNC's private investment in restoration and monitoring of a 13,000 acre parcel of submerged land in Great South Bay has helped to catalyze a coalition of local, state and federal agencies and other stakeholders (Bluepoints Bottomlands Council) who are developing a comprehensive restoration plan for the entire estuary (http://www.nature.org/wherewework/northamerica/states/newyork/press/press1616.html).

Shellfish reefs: A new frontier for payment for ecosystem service schemes?

As scientists more clearly describe and quantify the various ecosystem services associated with oyster reefs and other shellfish ecosystems, a logical question is: toward what end? Restoration practitioners and others believe these services have intrinsic value and have initiated small-scale restoration projects around the U.S. However, perhaps assigning more explicitly an economic, and not just intrinsic, value would help make a compelling case for more restoration activities, or restoration at larger scales. The valuation of a full array of services would enable environmental and fisheries managers to better understand tradeoffs inherent in areas managed for harvest versus other uses.

Perhaps just as important is the need to develop markets in which the services can be traded. For example, Newell et al. (2005) postulated that over a ten year period the removal of nitrogen by oyster reefs in the Choptank River, Maryland, was more valuable than the dockside value of those same oysters. Given the public and private funds being invested in reducing nitrogen pollution from land-based sources, this information has some relevance to managers. We postulate that if a well-designed and regulated market existed for trading the nitrogen removed by the oysters, it might have the effect of spurring further investments in restoration of oyster reefs and in land-based investments in pollution abatement. With markets for a broad array of services and robust monitoring methods for documenting the delivery of those services, one can imagine shellfish farmers cultivating plots of oysters or clams specifically for nitrogen removal and fish habitat.

Conclusions & Reccomendations

A shift in emphasis toward ecosystem services is occurring with shellfish restoration projects across the U.S. Projects are beginning to be more extensively monitored, which is consistent with recommendations of the U.S. Oceans Commission (2004):

"One of the most significant obstacles to conservation and restoration efforts is the lack of adequate knowledge about the structure and functioning of coastal habitats and the relative effectiveness of restoration techniques. Furthermore, many individual efforts do not benefit from the knowledge and positive experiences that do exist. Enhanced support for ecosystem restoration science and applied research on effective restoration techniques is needed, as is support for programs that educate practitioners on how to implement these techniques." (p.176)

To facilitate this shift and improve project outcomes overall, a Practitioners' Guide to Shellfish Restoration has been published that describes the services mentioned here in greater detail, as well as some 'better practices' for the design and implementation of projects (Brumbaugh et al. 2006). In addition, we offer some general recommendations for improving the design of shellfish restoration projects for a broader array of ecosystem services.

- Projects should include an experimental design for rigorous testing of site-specific hypotheses, using metrics that also enable comparisons across project sites.
- New and innovative monitoring approaches are needed to understand the relationship between restored shellfish ecosystem services and overall condition of coastal systems.
- Greater dissemination of results would improve the ability to set restoration objectives and design future projects. Publishing results in scientific literature, as well as providing information to central repositories such as the National Estuarine Restoration Inventory (https://neri.noaa.gov/) should be a high priority for all restoration practitioners.
- Changes in public policy are needed to more explicitly encourage restoration for outcomes other than harvest. For example, many states discourage or prohibit restoration of shellfish in closed or restricted waters regardless of whether they are conducive to restoration for ecosystem services other than harvest (e.g., Brumbaugh et al. 2000).
- Valuation of 'regulating' and 'supporting' ecosystem services associated with oyster reefs and other shellfish populations would help to increase understanding of the tradeoffs between projects at larger scales.

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