SAN FRANCISCO BAY SUBTIDAL HABITAT GOALS REPORT

Appendix 1-2: Economic Valuation of San Francisco Bay Natural Resources Services

BATTELLE MEMORIAL INSTITUTE

San Francisco Bay Subtidal Habitat Goals Project: Economic Valuation of San Francisco Bay Natural Resource Services

Final Report

Battelle Memorial Institute
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Portland, OR 97204

Submitted to:
National Oceanic and Atmospheric Administration
San Francisco, CA

July 2008

Disclaimer

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Summary

The San Francisco Bay Estuary is the largest estuary on the Pacific Coast. Home to over 130 species of fish and serving as the temporary home for over one million migratory birds each year, the San Francisco Bay Estuary defines the region surrounding it, and the natural resource services it provides (e.g., commercial fishing, shipping, recreation, scenic amenities) collectively serve as the backbone for the region's economy.

This report supports the Subtidal Habitat Goals Project in San Francisco Bay. The project represents a long-term plan for protection and restoration of the subtidal habitats of the San Francisco Bay. This report was prepared because the economic benefits associated with the natural resource services offered by the Bay are not well known to the Subtidal Habitat Goals Administrative Core Group or the Subtidal Habitat Goals Work Groups.

This report effectively serves as an environmental values primer, which can be referenced when considering the linkages between the environment and economy in the San Francisco Bay Area. It can also be used to better understand the Bay's environmental values that generate economic benefits to the region. For some natural resource services, it documents the magnitude of the economic benefits, the groups that benefit from the service, the ecological issues surrounding the service, and potential tradeoffs between restoration and economic activity.

This report documents a broad range of environmental values and stratifies each according to the components that collectively comprise total economic value – i.e., direct-use value, indirect-use value, non-use value, and intrinsic value. Each value is identified in Table E-1. For each value, the table summarizes the results of the qualitative, and in some cases quantitative, assessment presented in this report.

The perspectives of selected stakeholders are also documented in this report. Stakeholders offered numerous recommendations worthy of further consideration, including:

1) Benefits from restoration activities are cross-cutting; habitat restoration enhances several natural resource services (e.g., commercial fishing, waterfowl hunting, swimming, boating)

2) One gain achieved through restoration can be offset by another environmental or economic loss

3) Any measures taken by NOAA should involve close collaboration with key stakeholders and follow an open public process

4) When considering protection goals within the context of economic impacts, it is important to understand the full range of benefits and costs, including those related to employment, output, local tax revenues, impacts on secondary industries, and multiplier effects

5) The issues being considered by the Core Group and Work Groups are complex with overarching regulations and competing interests

6) While the setting of new goals and objectives was viewed positively, some of the stakeholders argued that a good first step would be to enforce existing laws and regulations

7) More preservation, restoration, and protection activities are needed

8) The economic benefits from subtidal habitat restoration are not well documented and further analysis is required to inform the Core Group and Working Groups' decision-making process.

More detail regarding the stakeholder recommendations is provided in Section 1.5 of this report.

Table E- 1. Summary of Qualitative and Quantitative Assessment of Environmental Values Offered by San Francisco Bay

Environmental Value	Qualitative Assessment	Quantitative Assessment
Commercial Fishing	San Francisco Bay serves as a fishing destination, a passageway for migrating species, and a nursery for juvenile fish. Primary species reported from Bay Area ports include: Dungeness Crab, California Halibut, Chinook Salmon, Pacific Herring, Sablefish, sole, rockfish, Bay and Brine Shrimp.	The value of commercial fishery landings in the San Francisco Bay Area were $12.2 million in 2006.
Sport Fishing	Primary fish species caught by sport fisherman in the San Francisco Bay Area include: Jacksmelt, Shiner Perch, Northern Anchovy, Pacific Herring, Striped Bass, California Halibut, and Black Perch.	There were 327.5 thousand fish caught by sport fisherman in 2007 in the San Francisco Bay Estuary and Bodega Bay. Sport fishing activities were estimated to be valued at $65.5-$98.3 million in 2007.
Subsistence Fishing	Subsistence fishing in San Francisco Bay is an activity disproportionately undertaken by low-income and otherwise disadvantaged groups that rely on subsistence fishing as an important portion of their food supply.	None.
Hunting	Primary species hunted in San Francisco Bay Estuary include: ducks, geese, doves, coots, snipe, rabbits, quail, pheasants, wild pigs, and elk.	In 2006, there were 1,786 hunters of dark geese, 348 hunters of light geese, and 7,213 duck hunters in the nine county area surrounding the San Francisco Bay Estuary. The economic impact of these hunters was estimated at $3.3-$4.1 million in expenditures or $5.5-$6.7 million in output.
Recreation and Eco Tourism	Popular recreation and eco tourism activities in the San Francisco Bay Area include: boating and sailing, hiking, kayaking, windsurfing, swimming, beach use, photography, surfing, scuba diving, and bicycling.	There are 40 marinas located in the central San Francisco Bay Area with more than 11,000 boat slips. There are one million birds traveling along the Pacific Flyway that rest and feed in the Bay Area. There are 15,000 Gray Whales that migrate off the cost of California, drawing interest from whale watching tours.
Water Transportation	San Francisco is a major port for cruise ships. San Francisco Bay also supports seven commuter ferry routes connecting San Francisco to Alameda (two locations), Larkspur, Oakland, Sausalito, Tiburon, and Vallejo.	In 2006, the number of cruise ship passengers visiting San Francisco reached 262,000, with a total economic impact to the region of $48.8 million. Average daily ridership on San Francisco Bay ferries totaled 9,594 in 2006.
Mineral Extraction	Within the San Francisco Bay Estuary, sand mining activities have been concentrated in the Central Bay, Carquinez Strait, Middle Ground Shoal, and Suisun Bay Channels. Cargill operates salt production facilities in Newark and Redwood City.	Annual sand mining estimated at 2 million tons at a value of $20-$36 million. Annual salt harvests are estimated at 650,000 tons valued at an estimated $39.7 million annually.
Oyster Shell Mining	Historic oyster shell deposits are dredged from San Francisco Bay for use in cement, cattle feed, soil conditioner, and poultry grit.	Approximately 36,000 tons of oyster shell is dredged up each year and sold for $5.4 - $7.2 million.

Table E-1. Continued

Environmental Value	Qualitative Assessment	Quantitative Assessment
Shipping and Ports	The Ports of San Francisco, Oakland, Richmond, and Redwood City are all located within the San Francisco Bay Estuary.	The annual economic impact of the Port of San Francisco is estimated at $2.0 billion (output) and 15,200 jobs. The economic impact of Port of Oakland was estimated at $2 billion in personal income and consumption expenditures and 28,522 jobs. Port of Redwood City generated $6 million in revenue during fiscal year 2007. No estimate of the economic impact of the Port of Richmond.
Wastewater Assimilation	San Francisco Bay serves as a waste sink to industrial, municipal, and agricultural discharges of effluent.	There are 46 publicly owned wastewater treatment plants and 65 industrial points discharging 40,000 tons of waste containing at least 65 different types of contaminants each year. Each day, San Francisco Bay receives more than 800 million gallons of municipal wastewater containing 60 tons of nitrogen.
Residential and Industrial Water Supply	San Francisco Bay water is used in once-through cooling systems at three Bay Area power plants: Contra Costa, Pittsburg, and Potrero. The four largest water supply agencies in the San Francisco Bay Area are jointly exploring the feasibility of developing regional desalination plants.	Three power plants with a combined generation capacity of 3,031 megawatts draw 1.7 billion gallons of San Francisco Bay water daily. The desalination plants being explored by San Francisco Bay Area water suppliers could deliver 120 million gallons per day to San Francisco Bay Area residents.
Scientific Research	Scientific research in the Bay benefits the local economy through the generation of high-paying research positions and innovations that permeate the region's technology-based economy. Research programs highlighted in this report include the Regional Monitoring Program, the Interagency Ecological Program, the CALFED Bay-Delta Program, the San Francisco Bay National Estuarine Research Reserve and the U.S. Geological Survey Continuous Monitoring Program.	None.
Education	For San Francisco Bay, education values are those associated with nature observance and the conduct of science by students, teachers, stakeholders, and the general public. Education programs noted in this report include those offered through the San Francisco Bay National Estuarine Research Reserve, the Aquarium of the Bay, the Headlands Institute, Save the Bay, and the U.S. Fish and Wildlife Service.	None.

Table E-1. Continued

Environmental Value	Qualitative Assessment	Quantitative Assessment
Amenity Values	Amenity values are experienced through the sights and sounds of the Bay and though they are not directly quantifiable, housing prices and tourism expenditures are indicative of the amenity value of the Bay.	San Francisco drew nearly 16 million visitors in 2006. These visitors spent $7.8 billion, supporting 68,652 jobs and generating $1.83 billion in income. Housing prices in the San Francisco-Oakland-Freemont Metropolitan Area ranked second among the most expensive metro areas in the United States with a median home price of $736,800. The price of bayside property in San Francisco carries a roughly 20 percent premium.
Indirect Use Values	Indirect use values include the biological support, nutrient cycling, climate regulation, flood protection, water quality maintenance, biodiversity and genetic maintenance, and sediment transport benefits.	Climate regulation benefits the Napa Valley wine industry. The total economic impact of the Napa Valley wine industry was estimated at $9.5 billion annually.
Non Use and Intrinsic Values	Non-use values include the option, bequest, and stewardship motives and are tied to our interest in preserving a natural resource either for our own potential future use or the use of others.	None.

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1.1 Introduction

The Subtidal Habitat Goals Project in San Francisco Bay represents a long-term plan for the protection and restoration of the subtidal habitats of the San Francisco Bay. The primary product of the Subtidal Habitat Goals Project is a document that provides recommendations and goals for use, protection, restoration, and research to improve subtidal habitat management in San Francisco Bay. Resource managers will be able to use this document to make informed decisions, and researchers will be able to prioritize activities and pursue funding for subtidal projects.

The economic benefits associated with subtidal habitats, however, are not well known to the Subtidal Habitat Goals Administrative Core Group (Core Group) or the Subtidal Habitat Goals Work Groups (Work Groups). Thus, understanding the economics associated with protecting resources represents an important piece of information for managers who are responsible for implementing protection and management measures. The ability to share a common knowledge of the expected economic changes, both good and bad, that may result from management decisions will enhance the goals development process. An understanding of which interests are likely to be affected by these changes will also broaden the knowledge base during the selection and implementation of protection goals.

Before an economic assessment of protection and restoration goals associated with subtidal habitat can be completed, this first report has been prepared to inform the Core Group and Work Groups as they consider alternative policies and programs. It effectively serves as an environmental values primer, which can be referenced when considering the linkages between the environment and economy in the San Francisco Bay Area. This document can be used to better understand the Bay's environmental values that generate economic benefits to the region. For some natural resource services, this report also documents the magnitude of the economic benefits, the groups that benefit from the service, the ecological issues surrounding the service, and potential tradeoffs between restoration and economic activity.

To date, more detailed analysis of the economic benefits tied to subtidal habitat in San Francisco Bay has not been prepared. Once protection and restoration goals have been defined, more detailed economic assessments can be proposed and completed.

This report is divided into 10 sections, with the first being this introduction. The second section is a brief note on the linkage between the environment and economy. The third section documents the geographic area considered within this report. The fourth section presents the study methodology. The fifth section documents input gathered during the stakeholder interviews. The sixth section identifies the natural resource services or environmental values provided by San Francisco Bay. The seventh section examines the direct use values or services offered by the Bay in more detail. The eighth section examines indirect use values or services of the Bay. The ninth section examines the non-use and intrinsic values offered by the Bay. The tenth, and final, section presents study conclusions and recommendations for further research.

1.2 The Environment and Economy

The environment and economy of any region are directly linked. The environment supplies raw materials and energy required to produce goods consumed by human populations, while the output of the production and consumption process generates waste that is either recycled or dumped back into the environment. The link between environment and economy represents a circular, closed system. As environmental inputs cycle through the economy and are used to produce goods and services, the environmental and economic systems work together to generate positive utility or satisfaction to consumers.

The San Francisco Bay defines the region surrounding it, and the natural resource services it provides (e.g., commercial fishing, shipping, recreation, scenic amenities) form a backbone for the region's economy. There are a number of natural resource services provided by the San Francisco Bay that are directly consumed by human populations or used as an input into a production process (e.g., commercial fishing, sport fishing, hunting, sand mining, and salt production). These services, however, capture only a small share of the overall value provided by the Bay to the region's economy. From the impact of the aesthetic value of the Bay to shipping and port activity at the Ports of San Francisco, Oakland, Richmond or Redwood City, the Bay is an economic driver.

1.3 Study Area

The environmental values highlighted within this report are those found in the entire San Francisco Bay Estuary (Figure 1). North of San Francisco Bay, the combined waters of the Sacramento and San Joaquin Rivers flow south into Suisun Bay. The waters then flow through the Carquinez Strait into the San Pablo Bay and Central and South San Francisco Bays. The San Francisco Bay Estuary is the largest estuary on the Pacific Coast. The estuary is home to over 130 species of fish and serves as a temporary home for over one million birds each year, while they rest and feed during migratory trips along the Pacific Flyway. The San Francisco Bay Area is home to more than 6.9 million people (U.S. Census Bureau 2006). Local human populations in the San Francisco Bay Area are spread throughout this densely populated region. The largest population centers in the Bay Area are located in San Jose (916,220), San Francisco (744,041), and Oakland (377,259).

Figure 1. San Francisco Bay Subtidal Habitat Goals Study Area

1.4 Methodology

The study team relied on data and other information acquired through interviews with stakeholders, analysis of public sources of local natural resource and economic data, and through the review of literature identified and collected for this study. In April through July of 2008, members of the research team interviewed a number of key stakeholders. National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC) staff provided an initial list of stakeholder contacts. CSC staff developed this list through internet searches and input gathered from CSC West Coast staff and members of the Core Group. This list was later refined by the research team based on stakeholder input (Appendix A).

The objectives and scope of the interview process were clearly defined, as were the topics covered during the interviews. Participants were asked to discuss:

a) natural resource services provided by the San Francisco Bay
b) the link between ecological conditions in San Francisco Bay and local economic benefits
c) local industries and other stakeholders reliant on the Bay
d) classes of economic benefits derived from the Bay
e) sources of data that could be used to quantitatively examine the identified benefits
f) sources of literature that could be used to qualitatively examine the economic benefits tied to the Bay
g) ecological threats to these natural resource services
h) thoughts concerning potential restoration activities.

Follow-up telephone contacts and information transfers completed the data collection process.

Table 1 lists the stakeholders interviewed for this report. It identifies the environmental value discussed during the interview and the organization each interviewee represents. In some cases, the interviews were abbreviated or focused on a sub-set of the topics outlined in the preceding paragraph. As shown, the stakeholders contacted for this report include both public and private employees, as well as volunteers.

Table 1. Interviewed Stakeholders

Environmental Value	Contact	Organization
Commercial Fishing	Zeke Grader	Pacific Coast Federation of Fisherman's Association
Sport Fishing	Roger Thomas	Golden Gate Fisherman's Association
Hunting	Larry Wyckoff	California Department of Fish and Game
Recreation	Ray Murray	National Park Service, Pacific West Region
Sand Mining	Brenda Goeden	San Francisco Bay Conservation and Development Commission (BCDC)
Sand Mining	Chris Lind	Jerico Products, Inc.
Boating and Sailing	Ann Buehl	Coastal Conservancy
Wildlife Viewing	Barbara Salzman	Marin Audubon Society
Water Transport	John Sindzinski	San Francisco Bay Area Water Emergency Transportation Authority
Shipping and Ports	Tina Olsen	Port of San Francisco
Salt Harvesting	Steve Ritchie	South Bay Salt Pond Restoration Project
Education	Sylvie Lee	California Coastal Commission

For certain environmental values where there were no local studies to cite, the research team extrapolated results from other relevant studies to define the economic value of the natural resource service to the region. For instance, the findings a report that focused on angler expenditures in the State of California was combined with San Francisco Bay Area sport fishing data to estimate the economic impact of sport fishing on the Bay Area economy. While not ideal, this approach enabled the research team to report a reasonable economic impact estimate.

It is important to note that the timeline and scope associated with this project did not allow for a more detailed and statistically valid extrapolation procedure. Since environmental and economic conditions in one location differ from those found in another, applying results of studies conducted in one location or situation to another can be less than ideal. Thus, this report cites studies conducted in California and uses sensitivity analysis to present a range of estimated impacts. Further, in the final section of this report, which outlines next research steps, we recommend applying the benefit transfer method and meta analysis to generate more precise estimates. In applying quantitative methods to the problem of comparing and combining results from relevant individual studies into a single statistical analysis, meta analysis would allow the research team to analyze findings from previous studies statistically and elicit from them the weight of the evidence with greater accuracy and precision.

1.5 Summary of Interviews

The stakeholders interviewed for this study are viewed as subject matter experts in the natural resource service areas listed in Table 2 by both NOAA CSC staff and the research team. Thus, the interviews were viewed as a key component of the methodology detailed in Section 1.4. The input received from the experts, along with the literature and data they pointed the research team towards, were used extensively in framing the analysis presented in this report.

Because the information gathered from the stakeholders is presented throughout this report, this section focuses only on the main themes and major points expressed by the stakeholders. The scope and objectives of the interviews were presented in the preceding section, and the interview guide or protocol is presented in Appendix B.

The stakeholders were very supportive of the San Francisco Bay Subtidal Habitat Goals Project. Views differed, however, on the activities each expert would recommend be undertaken to enhance the positive economic effects of the natural resources services offered by the Bay. With that noted, stakeholders offered numerous recommendations the Core Group and Work Groups should consider:

1) Benefits from restoration activities are cross-cutting. For example, restoring habitat for protected species enhances both boating and wildlife viewing experiences. Further, oyster reef restoration would improve water quality and enhance the recreational experience for boaters and swimmers. Enhancing local fisheries would generate economic benefits to commercial and sport fisherman but would also grow local bird populations to the benefit of hunters and eco tourists.

2) One gain achieved through restoration can be offset by another environmental or economic loss. For example, curtailing sand mining activities would marginally reduce the environmental effects of sediment suspension and entrainment but would result in more sand being exported from British Columbia. Thus, the local gain would be at least partially offset by the environmental impacts associated with diesel fuel consumption and mining activities in Canada.

3) Any measures taken by NOAA should involve close collaboration with key stakeholders and follow an open public process. Without buy-in from local stakeholders and the public, the implementation of protection programs will be more difficult and the results not as effective. To the extent the public can participate, it will enhance acceptance and develop a sense of stewardship. Further, by bringing a broad group of interests to the table, it ensures that results aren't biased towards some predetermined outcome.

4) When considering protection goals within the context of economic impacts, it is important to understand the full range of benefits and costs, including those related to employment, output, local tax revenues, impacts on secondary industries, and multiplier effects.

5) The issues being considered by the Core Group and Work Groups are complex, with overarching regulations and competing interests. For example, sand mining is regulated by the Army Corps of Engineers, California State Lands Commission, Regional Water Quality Board, and the BCDC. Further, sand and oyster shell mining activities are tied to multi-year leases executed between private companies and public agencies. Thus, there are limits to what can be explored when setting subtidal habitat goals, and these limitations should be considered during the goal-setting process.

6) While the setting of new goals and objectives was viewed positively, some of the stakeholders argued that a good first step would be to enforce existing laws and regulations. For example, one stakeholder argued that the Clean Water Act was frequently violated without consequence.

7) More preservation, restoration, and protection activities are needed. Effective management activities highlighted by stakeholders included the South Bay Salt Pond Restoration Project, hatcheries managed by the California Department of Fish and Game (CDFG), and wetlands managed by the CDFG and Suisun Resource Conservation District (SRCD).

8) The economic benefits from subtidal habitat restoration are not well documented, and further analysis is required to inform the Core Group and Working Groups' decision-making process. Potential next research steps are highlighted in the final section of this report.

Based on stakeholder input, the research team was able to narrow the focus of the literature search and data collection efforts. Stakeholders were also helpful in extracting data and interpreting relevant research findings.

2.1 Environmental Valuation of San Francisco Bay

Table 2 documents and categorizes environmental values attributed to San Francisco Bay. These values were developed using a three-step approach. First, the research team noted the values identified in an annotated bibliography recently prepared for NOAA (Battelle 2007). Second, the research team consulted public databases, websites dedicated to local environmental conditions in San Francisco, and additional published and unpublished literature. Following this preliminary research, a draft table of environmental values was presented to NOAA CSC staff members, who shared it with members of the Core Group. After responding to comments provided by NOAA and members of the Core Group, the table was shared with stakeholders and modified based on their comments.

The typology of environmental values identified in Table 2 demonstrates the components of total economic value. Total economic value is presented in the following equation:

Total economic value = direct-use value + indirect-use value + non-use value + intrinsic value

When determining the total economic value of the San Francisco Bay, each of these components should be considered. The environmental values identified for San Francisco Bay through this research effort are examined in greater detail in the pages following Table 2.

Table 2. San Francisco Bay Environmental Values

(a) Direct use values – goods and services directly consumed by users

- Commercial fishing
  - Pacific Herring
  - Salmon
  - Dungeness Crab
  - California Halibut
  - Rockfish
  - Brine and Grass Shrimp
  - Sole (San Francisco Bay acts as a nursery)
  - Sablefish (San Francisco Bay acts as a nursery)
  - Starry Flounder (San Francisco Bay acts as a nursery)
  - Crawfish
- Sport fishing
- Subsistence fishing
- Hunting
  - Ducks
  - Geese
- Recreation (boating and sailing, hiking, kayaking, windsurfing, swimming, beach use, photography, surfing, scuba diving, bicycling, running)
- Eco tourism (wildlife viewing)
- Water transportation (ferry system, cruise lines)
- Mineral extraction (production of salt, sand mining)
- Mining of oyster shells
- Shipping and ports
- Wastewater assimilation (industrial and municipal sewage, urban and agricultural runoff)
- Residential and industrial water supply
- Scientific research
- Amenity values
- Education

(b) Indirect use values – indirect benefits arising from ecological and aquatic systems

- Biological support – links to other species and habitats (e.g., migratory birds, marine mammals)
- Nutrient cycling
- Climate regulation
- Flood protection
- Water quality maintenance
- Biodiversity and genetic maintenance
- Sediment transport

(c) Non-use values

- Option value (future knowledge and future economic uses)
- Existence value (cultural, aesthetic, spiritual)
- Bequest (stewardship, heritage, legacy)

(d) Intrinsic value – organisms have a worth of their own regardless of usefulness to humans

2.2 Direct Use Values

Direct use values, as identified within Table 2, are the goods and services produced by the Bay that are consumed directly by users. These values can include those that produce physical products (e.g., fish, ducks), as well as those that generate utility or value to humankind (e.g., sunsets on the Bay or scientific research). Each direct use value highlighted in Table 2 is examined in more detail within the remainder of this section of the report.

Commercial Fishing. San Francisco Bay serves local commercial fisherman in a multidimensional capacity as a fishing destination, a passageway for migrating species, and a nursery for juvenile fish. Primary fish species caught by commercial fisherman in San Francisco Bay include Pacific Herring, Chinook Salmon, and California Halibut. Sole (Petrale, Dover and English) and Sablefish use the Bay in a nursery capacity and are generally caught by commercial fisherman out at sea. Dungeness Crab, Bay and Brine Shrimp, and crawfish are also harvested in the San Francisco Bay Estuary.

Table 3 presents the value of landings in the San Francisco Bay Area and the entire State of California for 2000 and 2006. All values are presented in 2006 dollars. The value of landings in the San Francisco Area has remained fairly stable in the past 7 years in nominal terms, but declined by roughly 18.6 percent in real terms to $12.2 million in 2006. The value of fish landings peaked in the Bay area in 2004 at $19.8 million, before falling back to 2006 levels (California Department of Fish and Game 2007a). The San Francisco Bay data presented in Table 3 includes fish landings reported for the Ports of San Francisco, Princeton-Half Moon, Sausalito, Alviso, Richmond, Berkeley, Alameda, Vallejo, Petaluma, China Camp, Oakland, South San Francisco, Rodeo, and San Rafael. The decline in the value of the catch in the San Francisco Bay Area is consistent with statewide declines over the same time period (18.3 percent).

Although the value of commercial landings in the San Francisco Bay Area has remained reasonably consistent, a rapid increase in the value of Dungeness Crab landings has masked a steep decline in the value of fish landings for nearly all species, including an 89.4 percent and 83.5 percent decline in the value of landings for Chinook Salmon and Pacific Herring, respectively (California Department of Fish and Game 2007a). In the San Francisco Bay Area, commercial fishing has also shifted towards California Halibut while statewide, California Halibut landing values have declined in real terms. Some of the shift towards California Halibut and Dungeness Crab has undoubtedly resulted due to the declines in other species, particularly the Chinook Salmon.

Table 3. Value of Landings, San Francisco Bay Area and California (2000, 2006)

	2000		2006		Percent Change	
Species	**SF Bay**	**California**	**SF Bay**	**California**	**SF Bay**	**California**
Dungeness Crab	$2,436,933	$16,066,706	$7,525,106	$44,868,658	208.8%	179.3%
California Halibut	$871,898	$2,858,872	$1,226,040	$2,712,829	40.6%	-5.1%
Chinook Salmon	$4,763,023	$12,021,370	$503,496	$5,255,417	-89.4%	-56.3%
Pacific Herring	$2,519,404	$2,672,092	$416,239	$427,219	-83.5%	-84.0%
Sablefish	$632,770	$6,150,819	$347,636	$4,890,167	-45.1%	-20.5%
Sole	$706,956	$5,251,809	$389,363	$3,549,989	-45.0%	-32.4%
Rockfish	$900,248	$4,737,569	$202,212	$1,973,898	-77.5%	-58.3%
Bay and Brine Shrimp	$319,281	$320,698	$74,344	$169,537	-76.7%	-47.1%
All Other Species	$1,785,384	$109,414,863	$1,472,003	$66,425,628	-17.6%	-39.3%
Total	$14,935,898	$159,494,797	$12,156,439	$130,273,342	-18.6%	-18.3%

Source: California Department of Fish and Game (2007)

It is important to note that much of the landings reported from Bay Area ports are caught offshore. As noted previously, however, the Bay does serve as a nursery for many of the species caught out at sea.

The commercial fishing fleet supports a range of secondary and ancillary industries, including fish packing and shipping, fish supply industries (bait shops, fuel docks, gear stores), piers, marinas, local restaurants, and tourism. Fisherman's Wharf and Pier 39 serve as the home of San Francisco's commercial fishing fleet. Pier 39 is also San Francisco's top tourist attraction, hosting an estimated 10.5 million visitors annually. Pier 39 is home to 110 shops and 11 full-service restaurants (Fisherman's Wharf Merchants Association 2008).

There are tradeoffs between water quality and water diversion in the San Francisco Bay Estuary. That is, hydrology issues relating to the pumping of fresh water away from the estuary to locations to the south impact fresh water flows and salt water intrusion. These issues, as well as those tied to agricultural runoff, wastewater assimilation, residential and industrial water supply, and mineral extraction, all take a toll on local fish populations and consequently, commercial, sport, and subsistence fishing interests. Tradeoffs between these natural resource services are inevitable and should be considered when defining subtidal habitat goals.

Sport Fishing. The economic value of sport fishing to a region is roughly equivalent to the willingness to pay on the part of fishermen for the experience of landing fish. Angler expenditures in California in 2006 were estimated to top $2.4 billion, resulting in $1.3 billion in income and 43,130 in jobs. Of those expenditures, $1.1 billion were associated with equipment, $0.4 billion with food and lodging, and $0.3 billion with transportation (Alkire 2008).

In a 1996 study of fishing activities in the Sacramento-San Joaquin Delta Region, total expenditures associated with fishing trips to the Delta were estimated at $392 million, with $186.0 million of those expenditures taking place in the Delta. The average fishing trip included 2.9 people with anglers spending $111 within the Delta and $123 outside it (Goldman et al. 1998).

Table 4 shows the impacts of fishing activities in the Sacramento-San Joaquin Delta in 1995. The impacts of the initial expenditures are magnified by multiplier effects. Regional economic impact analysis divides economic impacts into three categories that collectively comprise the full range of economic effects: direct, indirect, and induced effects. This framework can be better understood through an illustration. As it relates to fishing trips, the direct effects would be tied to expenditures by anglers on food and beverage, hotel and accommodations, and other purchases. The secondary effects are tied to subsequent rounds of spending and include both indirect and induced effects. In our example, this could include the changes in sales, income, and employment of businesses supplying goods and services to sport fishing industries. These are considered indirect effects. Induced effects are those tied to household spending of the income earned in the sport fishing industry and other linked industries.

When total effects (direct, indirect, and induced) are considered, expenditures by anglers in the Sacramento-San Joaquin Delta were found to generate an estimated $336.1 million in output and $137.8 million in income, and support 6,152 local jobs (Goldman et al. 1998).[1]

Table 4. Impacts of Fishing Activities in the Sacramento-San Joaquin Delta Region, 1995

Expenditure Category	Expenditure in the Delta ($millions)	Impacts on the Delta Region ($Millions)			
		Output	Income	Value Added	Number of Jobs
Overnight lodging, including campgrounds	$50.4	$94.2	$38.0	$57.3	1,572
Food and drinks at cafes or snack stands	$49.8	$89.9	$32.5	$48.3	1,838
Supplies, gas, repairs, parking, gifts	$52.0	$92.3	$40.1	$61.9	1,342
Recreation: equipment, bought/rented, fees	$33.8	$59.7	$27.2	$41.8	1,400
Total	$186.0	$336.1	$137.8	$209.4	6,152

Source: Goldman et al. (1998)

Because sport fishing is a leisure activity with value determined according to an angler's willingness to pay for a fishing experience, the value placed on each fish caught generally exceeds its market value. Based on the findings of a small number of studies conducted in California, one recent report (Alkire 2008) estimated that the total economic impact of expanded sport fish catches due to protection and restoration efforts would equal $200-$300 per fish (2006 dollars). It is important to note that the studies summarized in Alkire (2008) focused on the economic impacts associated with anglers targeting salmon and steelhead.

CDFG estimates that 327.5 thousand fish were caught by sport fisherman in 2007 in the San Francisco Bay Estuary and Bodega Bay.[2] Using the Alkire (2008) estimate of value placed on fish catches, sport fishing in the San Francisco Bay Area would have been valued at $65.5-$98.3 million in 2007. It is important to note that the CDFG data include fish caught in Bodega Bay and certain species (e.g., smelt, Northern Anchovy) that might be caught for bait. With that noted, even if the value per fish was reduced to $100, the total economic impact of sport fishing in the San Francisco Bay Area would still total $32.8 million annually.

[1] Output is the dollar value of goods sold. Income is the money earned from the sale of goods, including wage and salary income, profits, and rents. Value added represents the sum of total income and indirect business tax revenue. The value added measure avoids the double counting of intermediate sales. Thus, it captures only the value added to final products by the region.

[2] http://www.recfin.org/forms/est2004.html

Subsistence Fishing. Subsistence activities are the customary and traditional uses of wild resources, including local fisheries, for food, clothing, fuel, and trade. Subsistence fishing in San Francisco Bay is an activity disproportionately undertaken by low-income and otherwise disadvantaged groups (e.g., immigrant and native populations) that rely on subsistence fishing as an important portion of their food supply.

In a survey of a Laotian community located along the eastside of San Francisco Bay, in West Contra Costa County, Chiang (1998) calculated mean seafood consumption rates of 18 g/day. Of those surveyed, 87 percent reported consuming seafood at lease once each month. Chiang also reported that while only 50 percent of the surveyed community purchased fish at large markets, more than 54 percent consumed fish caught by themselves, family members, or friends (Chiang 1998).

Because of high levels of mercury, PCBs and other chemicals in San Francisco Bay sport fish, the California Office of Environmental Health Hazard Assessment has issued an advisory that recommends limiting consumption for men and women beyond childbearing age to two meals per month (meal is defined as 8 ounces). Other restrictions also apply. Based on the findings of Chiang (1998), who found that consumption rates in the surveyed community were as high as 100-450 g/day, the presence of these toxins in fish poses a significant health hazard to subsistence fisherman.

Hunting. The San Francisco Bay Area is a popular destination for waterfowl hunters who target migratory duck and goose populations. There are also opportunities to hunt larger game, such as wild pigs and elk on Grizzly Island. Other species hunted near San Francisco Bay include doves, coots, snipe, rabbits, quail, and pheasants. Hunting is allowed on state and federal lands in the Bay Area, including those in the Nappa-Sonoma Marshes Wildlife Area, Grizzly Island Wildlife Area, Don Edwards National Wildlife Refuge, Petaluma March Wildlife Area, and San Pablo Bay Wildlife Area.

The Suisun Marsh Area is also a popular destination for hunters. Suisun March encompasses 116,000 acres, including 52,000 acres of managed wetlands. It is home to 221 bird species, 45 animal species, and more than 40 fish species. The Suisun Marsh is also a resting and feeding ground for thousands of birds migrating along the Pacific Flyway. It offers public waterfowl hunting and is home to 158 private duck clubs (California Department of Water Resources 2008).

In 2006, there were 1,786 dark goose hunters, 348 light goose hunters, and 7,213 duck hunters in the nine county area (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma) surrounding the San Francisco Bay Estuary (California Department of Fish and Game 2007b). The total number of days spent hunting waterfowl in the nine-county area totaled 105,184 in 2006.

The research team was unable to identify any studies of the economic impact of hunting in the San Francisco Bay Area. The economic impact of waterfowl hunting in California, however, has been studied. In 2001, there were 102,000 waterfowl hunters in the State of California, and these hunters spent approximately $86.5 million on trip and equipment-related expenses. The national average expenditure per waterfowl hunter was $541. The economic impact of waterfowl hunting in California in 2001 was $143.7 million in output and $45.0 million in income. In total, industries supporting waterfowl hunters in California generated 1,303 jobs, $8.4 million in state tax revenue and $12.5 million in federal revenue (U.S. Fish and Wildlife Service 2005).

Extrapolating the results of the statewide analysis to the San Francisco Bay Area hunting total yields an estimated economic impact to the nine-county area of $3.3-$4.1 million in expenditures and $5.5-$6.7 million in output. The range reflects the uncertainty surrounding the estimate, with the range established at plus or minus 10 percentage points around the point estimate. Note that the expenditures reflect the total amount spent by hunters residing in those counties. Some of these expenditures certainly took place outside of the nine-county area, though most equipment-related expenditures likely took place within it. With that noted, this estimate would not include expenditures by hunters residing outside the nine-county area who travel to San Francisco Bay marshes to hunt.

The economic benefits of hunting are complex and cross-cutting in that many of the restoration actions that benefit hunters would also benefit eco tourists, boaters, and fisherman. For example, water quality maintenance goals would enhance local fisheries and bird populations that prey on fish. Whether the goal is viewing wildlife or hunting it, improving subtidal habitat would enhance the value hunters and eco tourists place on these activities. The value associated with both hunting and eco tourism is largely dependent on species abundance and diversity.

Recreation and Eco Tourism. Recreational value is captured in both direct expenditures and the value placed on recreational experiences by individuals. San Francisco Bay offers numerous recreational opportunities in the form of boating and sailing, hiking, kayaking, windsurfing, swimming, beach use, photography, surfing, scuba diving, and bicycling.

Boating and sailing are extremely popular recreational activities in San Francisco, with 40 marinas located in the central San Francisco Bay Area, holding more than 11,000 boat slips. Boating and sailing in San Francisco Bay supports numerous industries, including boat brokers, boat dealers, small boat rentals, charters, boat builders, equipment and gear shops, maintenance and repair services, yacht clubs, sailing schools, boat yards, marinas, fuel docks, and restaurants.

Human powered boats (e.g., kayaks, dragon boats, and canoes) are also popular in San Francisco. To accommodate the needs of these boaters, a vision for a San Francisco Bay Area Water Trail was born. The trail will ultimately be a network of launch and landing sites around the Bay that will enable continuous, single- and multi-day trips on the Bay. The benefits of the Bay Area Water Trail will include improved facilities located near boat launch sites, development of more launch sites, and more access to accommodations along the Bay shoreline.

There are a number of other recreational activities enjoyed in San Francisco. Windsurfing, for example, is popular in many locations in the Bay, including the Berkeley Marina, Alameda, Crissy Field, and Coyote Point. There are also hundreds of hiking trails located around the Bay.

Eco tourists from around the US descend on San Francisco to take advantage of bird watching, whale watching, and other wildlife viewing opportunities. San Francisco is located along the Pacific Flyway, the major North-South corridor for migrating birds on the Pacific Coast. More than one million migrating birds stop to feed and rest at San Francisco Bay annually, which affords bird watchers many viewing opportunities.

Popular bird watching areas near San Francisco Bay include the Golden Gate National Recreation Area, Golden Gate Park, Don Edwards San Francisco Bay National Wildlife Refuge, Pillar Point, Crissy Field Marsh, Las Gallinas Salt Ponds, Arrowhead Marsh, East Shore State Park, Lake Merritt, and the Palo Alto Baylands Nature Preserve. At these locations, bird watchers can view Osprey, Northern Harrier, Red-tailed Hawks, Golden Eagles, Peregrine Falcons, Western Scrub-Jays, Chestnut-backed Chickadees, Great and Snowy Egrets, Common Moorhen, Black-necked Stilt, American Avocet, sandpipers, terns, pelicans, and herons.

The annual migration of Gray Whales from Arctic feeding grounds to Baja California also draws visitors to San Francisco. Approximately 15,000 Gray Whales migrate off the California Coast annually. Humpback Whales are also popular targets for whale watching cruises.

Bird watching is an extremely popular activity in California. In 2005, 2.58 million individuals dedicated 65.76 million days to bird watching in California. Other wildlife viewing engaged 2.55 million individuals for 38.58 million days (Pendleton 2006). Pendleton (2006) reviews literature estimating expenditures on trips made for wildlife viewing and concludes that average per day expenditures vary significantly based on the target species and location. The cost for whale watching trips ranged from $30 to $70 per person. Non-market values associated with rare or interesting species can also be significant. Pendleton (2006) reported that non-market values for wildlife viewing trips in Alaska were estimated at $143 to $229 per person per trip, while wildlife viewing in the Florida Keys generated non-market benefits of $108 per person per trip.

Water Transportation. San Francisco is a major port for cruise ships traveling up and down the Pacific Coast. In 1985, 102,000 passengers on cruise ships visited San Francisco. Following a period of decline, where the number of passengers dipped to below 33,000 in 1991, the number of passengers passing through the Port of San Francisco grew steadily to roughly 62,000 in 2002 before soaring to 262,000 by 2006 (Bay Area Economics 2008). The total economic impact of expenditures by passengers and crew, as measured by output, is an estimated $31.2 million annually in San Francisco and $48.8 million regionally. The cruise industry supports 302 jobs in San Francisco and 346 regionally (Bay Area Economics 2008).

In addition to the cruise industry, San Francisco Bay supports seven commuter ferry routes connecting San Francisco to Alameda (two locations), Larkspur, Oakland, Sausalito, Tiburon and Vallejo. Average daily ferry ridership in San Francisco is presented in Table 5. As shown, ridership declined between 2000 and 2002 but rose by 14.6 percent between 2002 and 2006.

Table 5. San Francisco Bay Area Average Daily Ferry Ridership

Year	Alameda Oakland	Sausalito	Larkspur	Vallejo Baylink	Harbor Bay	Tiburon	Total
2000	1,432	1,247	4,106	2,116	337	627	9,865
2001	1,447	1,026	3,652	1,900	365	537	8,927
2002	1,246	902	3,615	1,866	315	428	8,372
2003	1,119	950	3,384	1,709	310	395	7,868
2004	1,199	1,131	3,633	1,825	217	444	8,448
2005	1,126	1,199	3,695	1,916	334	429	8,699
2006	1,266	1,433	3,878	2,104	370	543	9,594
					% Change 2000-2006		-2.8%
					% Change 2003-2006		21.9%

Source: Bay Area Economics (2008).

Mineral Extraction (Salt Harvesting and Sand Mining). The San Francisco Bay Area is located in a mineral-rich region, where ever since the first discovery of gold at Sutter's Mill in Coloma, California, mining operations have flourished. Today, mining operations continue in the Bay Area. Figure 2 identifies mines and mineral producers by commodity operating in the San Francisco Bay Area in 1997-1998. Minerals mined in the San Francisco Bay Area, as highlighted in Figure 2, include stone/rock, sand/gravel, specialty sand, silica, decomposed granite, fill, salt, limestone, shale, and clay. Minerals mined in the Bay include sand and salt.

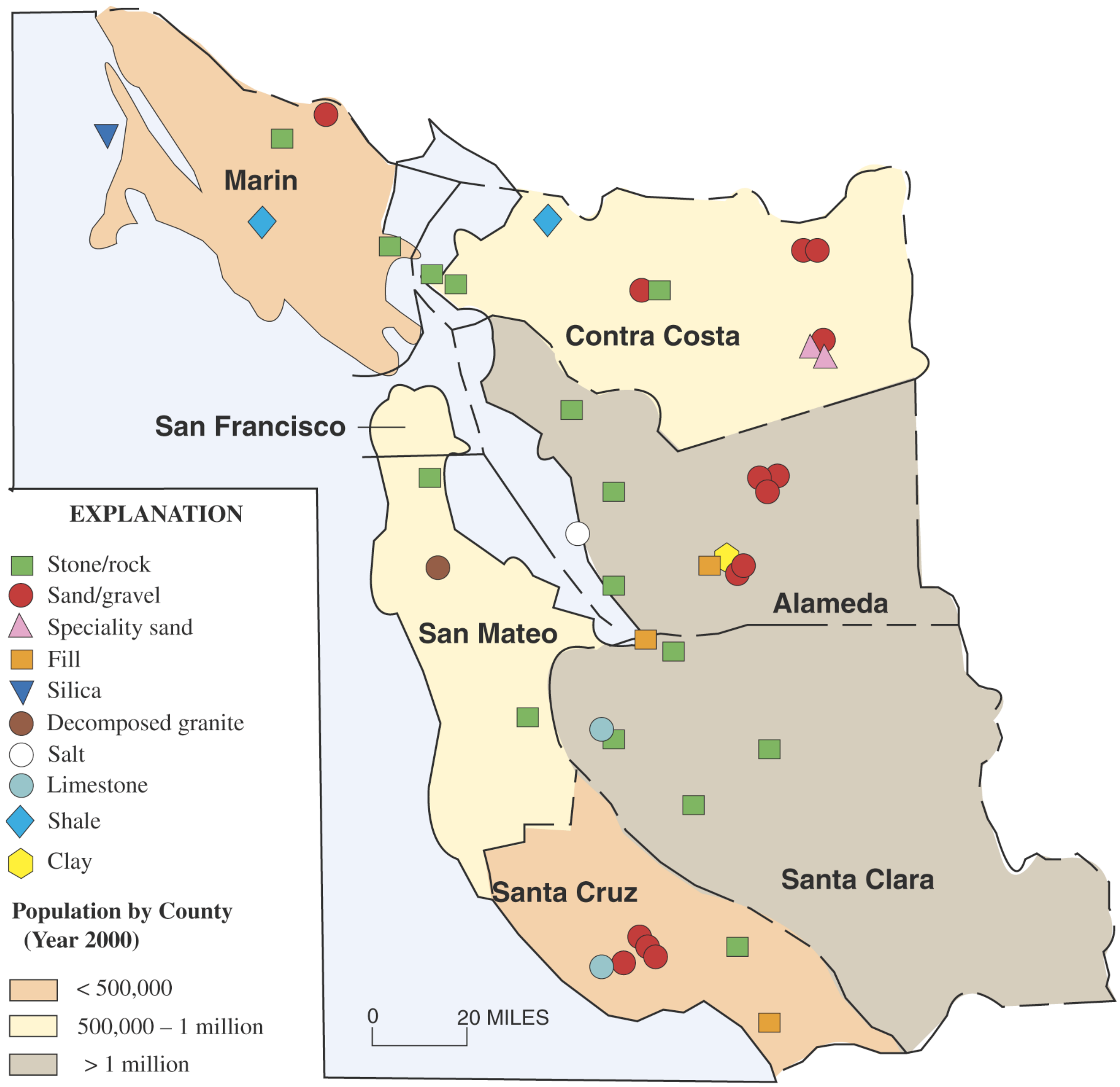

Figure 2. The Mines and Mineral Resource Producers in Seven Bay Area Counties (1997-1998) and the Commodities Produced (Source: Galloway, Weather and Frank 2001).

An average American uses over 1 million pounds of industrial minerals during their lifetime. Industrial minerals include limestone, clays, cement, dimension stone, and aggregates. Uses for these industrial minerals include roof shingles, ceiling and walls, home foundations, appliances, bricks, concrete, computers, telephones, and construction sand and gravels. In 2006, the market value of minerals extracted in California totaled $4.6 billion, with an estimated $1.5 billion generated through sand and gravel operations. In 2006, there were 800 active mines producing non-fuel minerals, which collectively employed 10,300 individuals (Kohler 2007).

Sand Mining. Sand, stone, and gravel are essential to the local construction industry and as expanding housing and commercial developments have competed for land with local quarries, sand extraction has moved offshore. Sand mined in the San Francisco Bay Area is used to support local commercial construction activities, including those related to the construction of commercial buildings, construction of freeway systems, and the reconstruction of bay bridges. Within the San Francisco Bay Estuary, sand mining activities are concentrated in the Central Bay, Carquinez Strait, Middle Ground Shoal, and Suisun Bay Channels. There are three companies that until recently, held sand mining leases in the estuary: Hanson Aggregates, CEMEX (formerly RMC), and Jerico Products / Morris Tug and Barge (Jerico).

Production limits are set in the permits issued by the California State Lands Commission, U.S. Army Corps of Engineers and BCDC. For the Central Bay, production limits are set at approximately 1.5 million cubic yards annually. Within the Carquinez Straits, production limits are 50,000 cubic yards per year. Production limits in Suisun Bay are set at 1 million cubic yards annually. From March 2002 to February 2003, sand mining activities were monitored as part of an evaluation of the effects of sand mining on aquatic habitat and fish populations. The investigation monitored roughly 1.5 million cubic yards of sand or 1.9 million tons being mined during 862 mining events (Hanson et al. 2004).

In an interview conducted in support of this study, Chris Lind of Jerico estimated annual sand mining production in the estuary at around 2.0 million tons per year, a value well within the permitted limits.[3] Further, he noted that at an average sale price of $10-$18 per ton, annual revenue from sand mining activities in the San Francisco Bay Estuary totaled roughly $20-$36 million.[4] It is important to note that this value may decline in the future because CEMEX, which bought out RMC, has ended its sand mining operations in San Francisco Bay. CEMEX was permitted to extract roughly 400,000 cubic yards of sand annually.

Hanson et al. (2004) evaluated the potential environmental effects associated with sand mining in San Francisco Bay focusing on:

- the direct impacts of suspended sediment concentrations and turbidity, entrainment in the suction head, and physical disturbances of benthic organizations during sand mining activities; and

- the indirect impacts of the depletion of bottom sediments resulting in increased water depths and changes in the composition of the substrate.

The findings of the report suggest that the environmental impacts associated with sand mining are highly localized, short in duration, small in magnitude, and occur intermittently. The study concluded that sand mining activities did not have a significant environmental effect on subtidal habitat quality or habitat function within the Bay-Delta Estuary (Hanson et al. 2004).

When considering the tradeoffs between subtidal habitat protection and the economic benefits of sand mining, it is also important to note that in the absence of local sand mining activities, sand would need to be transported from areas outside the region (e.g., British Columbia) at greater cost to the local construction industry.[5] Moving the source of sand for local construction industries would also come at its own price that would include greater cost to local construction industries and environmental impacts associated with quarrying and transport over long distances.

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[3] The weight of sand is estimated at 2,500 pounds per cubic yard. Permits allow 2.55 million cubic yards or roughly 3.2 million tons of sand to be extracted each year in San Francisco Bay.
[4] Interview with Chris Lind of Jerico Products, Inc. July 11, 2008.
[5] The price of sand imported from British Columbia was estimated at $20-$25 per ton by Mr. Chris Lind of Jerico Products, Inc.

Salt Harvesting. In 2006, the U.S. was the top salt producer in the world, with production topping 44.3 million metric tons. Salt is valuable in a wide variety of household, industrial, and commercial applications, including: manufacture of chlorine, coproduct sodium hydroxide and synthetic soda ash; application on roads during extreme weather conditions; additive to feed sold to farmers and ranchers; food preservation and flavor enhancement; and industrial applications in the oil and gas industries, textiles and dyeing, metal processing, pulp and paper, tanning and leather treatment, and rubber manufacturing.

The first commercial salt operation in San Francisco Bay was launched by Captain John Johnson in 1854. Cargill entered the market in 1979, when it bought out the Leslie Salt Company, and is currently the only salt producer operating in San Francisco Bay. At its peak, Cargill salt pond operations produced 1.3 million tons of salt on an annual basis, with three plants operating in Napa, Redwood City, and Newark.

In recent years, salt production locally has been scaled back to 650,000 tons annually, with the Redwood City plant recently being targeted for closure. Local salt production is harvested using the solar method. At a price of $61.08 per ton for solar salt, local salt production would generate roughly $39.7 million annually. It is important to note that the average price per ton of solar salt was generated using weighted average prices for salt sold nationally, as estimated by the U.S. Geological Survey (U.S. Geological Survey 2008a).[6] Local salt prices are proprietary and were not provided by Cargill and were not determined by the research team.

In recent years, harvesting techniques have rendered salt operations less land-intensive, and this enhanced efficiency, combined with scaled back operations, have allowed Cargill to donate or sell 16,500 acres of land to state and federal governments for wildlife protection (EDAW et al. 2007). As noted previously, salt is required for a large number of commercial, industrial, and household uses. To the extent that the demand for salt continues to grow in the Bay Area, scaling back salt production locally would result in more salt being transported to the region from other salt production centers (e.g., Salt Lake City).

Oyster Shell Mining. Historic oyster shell deposits are dredged from San Francisco Bay for use in cement, cattle feed, soil conditioner, and poultry grit. Morris Tug and Barge holds a lease with the California State Lands Commission to dredge up to 80,000 yards of historic oyster shell deposits annually using a tug and barge on 1,560 acres in south San Francisco Bay, San Mateo and Alameda counties. Morris Tug and Barge uses a hydraulic dredge that is inserted 12 to 36 inches beneath the Bay floor. The shell material is washed and transported to Petaluma or Collinsville, where it is offloaded and processed for sale. Historic oyster shell deposits in the Bay are estimated to exceed 60 million tons. Thus, extraction levels called for in the most recent 10-year lease agreement total less than one-tenth of 1 percent of total deposits.

Approximately 36,000 tons of oyster shell is dredged each year in San Francisco Bay by Morris Tug and Barge. Prior to sale, the oyster shell is sold to Jerico Products, Inc. where it is thoroughly cleaned, dried, crushed, screened to a preferred size and stored. At an average price of $150-$200 per ton, the sale of oyster shells dredged from San Francisco Bay generates approximately $5.4 - $7.2 million in revenue annually.[7]

Oyster shells are a local source of lime, a mineral necessary for cement production. The other primary source of lime, limestone, is most closely located to the south in Santa Clara, Santa Cruz, and San Benito

[6] Price per ton was calculated by dividing the total value of all solar salt sold in the United States by the quantity sold, as presented in Table 3 of U.S. Geological Survey 2008a. That value was then adjusted from a price per metric ton ($67.33) to a price per ton ($61.08).
[7] Interview with Chris Lind of Jerico Products, Inc. July 24, 2008.

counties. It is extremely expensive to transport cement over large distances. Thus, the presence of a local source of lime in the form of oyster shells is an important component to the booming local construction industry and the Bay Area economy.

While negotiating the most recent lease agreement, concerns were expressed by NOAA Fisheries, BCDC, CDFG, and the San Francisco Bay Regional Water Quality Board. The concerns centered on a number of issues, including:

- the need to clarify the water depth at which mining is conducted
- the use of water jets to break up the substrate
- the need for additional information regarding sediment suspended during mining operations
- the need for bathymetric and benthic surveys
- the potential entrainment of endangered species and larval fish
- effects on native oyster populations
- benthic disturbance and recovery.

In response to these concerns, Morris Tug and Barge clarified that suction heads for oyster mining were positioned 1 to 3 feet beneath the Bay floor (the dredging depth was previously thought to be 6 inches beneath the Bay floor), and agreed to conduct a bathymetric survey every five years.

Shipping and Ports. The Ports of San Francisco, Oakland, Richmond, and Redwood City are all located within the San Francisco Bay Estuary. The Ports of the San Francisco Bay serve as a key gateway to eastern markets, destinations for cruise lines, and terminals for water transportation between communities located on the Bay.

In an economic study recently completed for the Port of San Francisco by Bay Area Economics, the total direct, indirect, and induced economic effects of the port were estimated at $1.7 billion. The study found that the port supported 13,500 jobs just in the City of San Francisco. When expanded to the Northern California region, the total economic impact expanded to $2.0 billion and 15,200 jobs. The annual revenue generated by port activities to the City of San Francisco through sales, parking, stadium admissions, possessory interest taxes, business taxes, utility user taxes, retail and non-retail sales and use taxes, and transient occupancy taxes were estimated at $25 million annually (Bay Area Economics 2008). The port also serves as an important destination for cruise lines and terminal site for commuter ferries.

The Port of Oakland serves as a nationally significant hub for international cargo transportation and distribution. The port holds 10 container terminals and is served by 2 intermodal rail facilities. In 2007, container throughput at the Port of Oakland totaled 2.4 million 20-foot equivalent units (TEUs). The port handled 99 percent of the containers traversing through Northern California. In 2005, the port generated $2 billion in personal income and consumption expenditures and 28,522 local jobs. Port activities also generated $208 million in state and local taxes (Martin Associates 2006).

The Port of Richmond is located on 32 miles of shoreline along on the northeastern shores of San Francisco Bay. The port includes five city-owned and ten privately-owned terminals. These terminals handle bulk liquid, dry bulk materials, metals, break-bulk cargoes, and automobiles. No estimates of the economic impact of the Port of Richmond were obtained by the research team.

The Port of Redwood City is located at the southwestern reaches of San Francisco Bay. In the most recent fiscal year ending June 30, 1997, the port handled 1.44 metric tons of cargo largely consisting of imported bulk commodities (e.g., cement, bauxite, gypsum) for the local construction industry and

exports of recycled metals. Marine port operations generated $6 million in that timeframe (Trans Systems 2008).
Wastewater Assimilation. In San Francisco, the Bay adds value to the local economy by serving as a waste sink. In San Francisco, toxic contaminants from industrial, commercial and agricultural activities are dumped into the Bay for assimilation. To the extent the waste exceeds the assimilative capacity of the natural environment, damage will occur. Such is the case in San Francisco Bay, where 46 publicly owned wastewater treatment plants and 65 industrial points discharge 40,000 tons containing at least 65 different types of contaminants each year. These contaminants are in some cases toxic to plants and animals, and impose health risks to humans. On a daily basis, San Francisco Bay receives more than 800 million gallons of municipal wastewater, containing 60 tons of nitrogen (U.S. Geological Survey 2008b).

The research team was unable to identify any studies documenting the economic impacts of wastewater assimilation for San Francisco Bay.

Residential and Industrial Water Supply. San Francisco Bay water is used to supply once-through cooling systems at three Bay Area power plants: Contra Costa (natural gas), Pittsburg (natural gas), and Potrero (natural gas and distillate). Once-through cooling technology draws water into the plant and runs it one time only past condenser units before discharging the water back into the Bay. These three power plants are permitted to intake a combined 1.6 billion gallons of water daily. The Pittsburg Power Plant is the largest plant located on the Bay, and is permitted to intake nearly 1.1 billion gallons of water daily. The Contra Costa Power Plant's maximum permitted intake volume is 341 million gallons per day, and the Potrero Power Plant is permitted to intake 226 million gallons per day. Together, these three power plants have a generation capacity of more than 3,031 megawatts (Moss Landing Marine Laboratories 2008).

Power plants that use once-through cooling systems do not pollute directly, but do have negative environmental impacts because of their intake systems entraining larval fish and invertebrates, and output systems displacing polluted sediment when discharging water back into the Bay. Once-through cooling systems also impinge marine life by trapping them in the intake flow and crushing them against screens. Finally, there are thermal effects caused by the discharge of heated water into waterways at the conclusion of the cooling cycle.

Desalination is the process by which salts are removed from ocean or otherwise salty waters to produce fresh drinking water. Desalination has been used extensively around the world but has not been widely applied in the U.S. because of its cost relative to the alternatives and the environmental impacts associated with the disposal of brine, a waste product of the desalination process. As a result of technological advancements in the desalination process, the four largest water supply agencies in the San Francisco Bay Area (East Bay Municipal Utility District, San Francisco Public Utilities Commission, Contra Costa Water District, and the San Clara Valley Water District), are jointly exploring the feasibility of developing regional desalination plants that could deliver 120 million gallons per day to San Francisco Bay Area residents.

Scientific Research. Scientific research in the Bay benefits the local economy through the generation of high-paying research positions and the innovation and breakthroughs that permeate one of the most dynamic and technology-oriented regional economies in the U.S. The complex San Francisco Bay Estuary is one of the most studied ecosystems in the world. The 1993 Comprehensive Conservation and Management Plan (CCMP) noted that there were over 70 monitoring programs identified in the estuary, and many of those monitoring programs continue today.

The Regional Monitoring Program, which was created in 1992 by the San Francisco Regional Water Quality Control Board, continues to monitor the effects of wastewater, urban runoff, and dredging discharges on contaminant concentrations in water, sediments, and fish and shellfish tissue in San Francisco Bay.

The Interagency Ecological Program involves the collaboration of 10 member agencies (California Department of Water Resources, California Department of Fish and Game, California State Water Resources Control Board, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Geological Survey, Army Corps of Engineers, National Marine Fisheries Service, Environmental Protection Agency, and the San Francisco Estuary Institute). These agencies work together to study the ecology of San Francisco Bay and examine the effects of the State Water Project and Federal Central Valley Project on the Bay's physical, biological, and chemical conditions.

The CALFED Bay-Delta Program represents collaboration between 25 state and federal agencies. The objective of the program is to improve the biological health of San Francisco Bay through the funding of research designed to aid policymakers' understanding of the complex ecological issues that persist in San Francisco Bay.

The U.S. Geological Survey (USGS) Continuous Monitoring Program has studied and monitored Bay temperature, salinity, water level, and suspended-solids concentrations at sites throughout the San Francisco Bay Estuary since 1989.

Amenity Values. Amenity values are experienced when tourists and local citizens watch the sun set on San Francisco Bay or when they walk along the Bay on a foggy fall morning. Amenity values are experienced through the sights and sounds of the Bay and although they are not directly quantifiable, housing prices and tourism expenditures are indicative of the amenity value of the Bay.

San Francisco Bay is an enormous tourism destination, with the Golden Gate Bridge, Pier 39, Alcatraz Island, local ferries, and Fisherman's Wharf drawing nearly 16 million visitors to San Francisco in 2006. While in San Francisco, these visitors spent $7.8 billion, supporting 68,652 local jobs and generating $1.83 billion in income. On an average day in San Francisco, visitors spend $21.26 million. Annually, visitor spending generates $473 million in taxes to the City of San Francisco.

Housing prices are also indicative of the local amenities offered by a community. While economic and topographic conditions also play a part in determining local housing prices, San Francisco consistently ranks among the most expensive cities in the U.S. In 2007, the San Francisco-Oakland-Freemont, California Metropolitan Area ranked second among the most expensive metro areas in the United States, with a median home price of $736,800. Furthermore, in a study conducted by Kirshner and Moore (1989), the price of bayside property in San Francisco was roughly 20 percent higher than other properties with otherwise similar characteristics.

Education. For San Francisco Bay, education values are those associated with nature observance and the conduct of science by students, teachers, stakeholders, and the general public. Similar to the value of scientific research, education value is more general and is tied to its ability to inform local populations. These values are not well defined, but are significant, as reflected through the many local education programs run at the Bay, including those offered through the San Francisco Bay National Estuarine Research Reserve, the Aquarium of the Bay, the Headlands Institute, Save the Bay, and the environmental education programs of the U.S. Fish and Wildlife Service.

The San Francisco Bay National Estuarine Research Reserve (NERR) serves as an important laboratory for scientists who use the stable environment to support long-term research studies and monitoring activities. The reserve is also used as a reference site for comparative studies. There are a number of research projects underway at the reserve covering a broad array of topics, including those related to eelgrass restoration; habitat mapping and change; technologies used to monitor nutrients and nutrient loading; channel geomorphology; and invasive species impacts.

Because San Francisco Bay offers the opportunity to monitor and examine natural systems, it presents numerous research options for students attending local universities (Stanford, University of California Berkeley, University of San Francisco, St. Mary's College, Santa Clara University, San Francisco State University) in numerous fields of study, including earth sciences, biological sciences, environmental sciences, physical sciences, and social sciences.

2.3 Indirect Use Values

Indirect use values represent the indirect benefits of aquatic and ecological systems from which humankind derives economic value or satisfaction. These values include the biological support, nutrient cycling, climate regulation, flood protection, water quality maintenance, biodiversity and genetic maintenance, and sediment transport benefits tied to marine environments.

Biological support values are tied to links with other species and habitat, such as the one million birds that rest and feed in San Francisco Bay during migratory trips along the Pacific Flyway and the 15,000 Gray Whales that migrate between Arctic feeding grounds and breeding grounds located off Baja California. The biological support found at San Francisco Bay sustains migrating wildlife to the economic benefit of bird watchers, whale watching tours, eco tourists, and hunters up and down the Pacific Coast.

San Francisco Bay serves a climate regulation function as the cool currents of the Pacific Ocean strongly influence the San Francisco Bay Area climate. The Bay Area is characterized by mild, consistent temperatures throughout the year (average high temperatures ranging from 56ϒ in January to 70ϒ in September and average low temperatures ranging from 46ϒ in February to 56ϒ in October), negligible snowfall, and limited rainfall in May through September (Weatherbase 2008). The mild climate supports local wine growers and prevents freezing temperatures that can destroy food crops. The climate also benefits local populations, improving local quality of life and significantly enhancing property values.

The climate regulation benefits of the Bay are evident when considering the case of the Napa Valley wine industry. Napa Valley is located to the north of San Francisco and is far enough inland to escape most of the fog coming of the Bay and Pacific Ocean yet benefits greatly from the cooling effects of the fog and winds that do make their way north to Napa Valley. The Napa Valley economy is heavily reliant on the local wine industry. The total economic impact of the Napa Valley wine industry was recently estimated at $9.5 billion annually. In 2005, the Napa Valley wine industry accounted for only 4 percent of California's wine production by volume but represented 21 percent of the total economic impact of the statewide wine industry (MKF Research 2005).

The wetland areas and adjacent floodplains located near San Francisco serve to store water during storms and form natural floodways that enable water to transport easily downstream. These flood protection benefits serve to lower flood peaks and protect the local population and property from damage experienced during storms.

Other indirect use values include the water quality maintenance, nutrient cycling (removal of excess nutrients and chemical contaminants), biodiversity and genetic maintenance benefits of San Francisco Bay.

The research team was unable to locate any studies focusing on the water quality, nutrient cycling, or genetic maintenance benefits of San Francisco Bay but did identify a report that examined the findings of

12 studies published in peer-reviewed journals focusing on the economic value associated with water quality benefits of coastal wetlands. Mean and median water quality benefits for coastal wetlands in the reviewed studies were estimated at $323.05 and $178.64 per acre per year, respectively. The study also found that benefits varied greatly due to the assimilative capacity of the wetland area under consideration and that coastal wetlands are undervalued by society because their benefits are largely unrecognized in the marketplace (Kazmierczak 2001).

2.4 Non-Use and Intrinsic Values

Non-use values include the option, bequest, and stewardship motives. These values are tied to our interest in preserving a natural resource either for our own potential future use or the use of others, including future generations and other forms of life. Existence values include the option value, existence value and bequest value. The option value is derived from the ability to take a future trip and enjoy the benefits of a natural resource. That is, even if a person had no plans of visiting San Francisco Bay, the Bay still has value inasmuch as that person would want to reserve the option of visiting it one day in the future. The bequest value is the satisfaction gained by endowing a natural resource on future generations. The intrinsic values that individuals place on the environment reflects the view that natural organisms and environmental habitat is valuable regardless of the values placed on it by humans.

The annotated bibliography prepared by Battelle previously for NOAA in support of the San Francisco Subtidal Habitat Goals Project documents a number of studies that stress the significance of non-use and non-market benefits. The annotated bibliography concludes that the high value attached to non-use benefits suggests that environmental values are multidimensional and more complex than most experts and policymakers recognize (Battelle 2007).

3.1 Conclusions and Recommendations for Further Research

The San Francisco Bay Area economy is inextricably linked to the natural resource services (e.g., commercial fishing, shipping, recreation, scenic amenities) provided by the Bay. These services include those that confer direct value to consumers: commercial fishing, sport fishing, subsistence fishing, hunting, recreation, eco tourism, water transportation, mineral extraction, shipping and ports, wastewater assimilation, residential and industrial water supply, scientific research, amenity value, and education. There are also a number of indirect use values arising from the ecological and aquatic systems of the San Francisco Bay: biological support, nutrient cycling, climate regulation, flood protection, water quality maintenance, biodiversity and genetic maintenance, and sediment transport. There is also an intrinsic value that society places on the Bay. Each of these value sets are examined in this report.

This report documents the economic impact of shipping and ports, sport fishing, hunting, cruise ships, and amenity values on the San Francisco Bay Area. It presents estimates of revenue generated through commercial fishing, sand mining, oyster shell mining, and salt harvesting activities. It defines the activity associated with water transport, wastewater assimilation, and residential and industrial water supply but does not produce estimates of their economic impact. It also performs a qualitative assessment of the economics tied to subsistence fishing, recreation and eco tourism, scientific research, education, and indirect and intrinsic values. For recreation, eco tourism, and some indirect values, the magnitude of economic impacts are explored using studies performed outside the San Francisco Bay Area.

The perspectives of the stakeholders were also documented in this report. Stakeholders offered numerous recommendations worthy of further consideration, including:

1) Benefits from restoration activities are cross-cutting

2) One gain achieved through restoration can be offset by another environmental or economic loss

3) Any measures taken by NOAA should involve close collaboration with key stakeholders and follow an open public process

4) When considering protection goals within the context of economic impacts, it is important to understand the full range of benefits and costs, including those related to employment, output, local tax revenues, impacts on secondary industries, and multiplier effects

5) The issues being considered by the Core Group and Work Groups are complex with overarching regulations and competing interests

6) While the setting of new goals and objectives was viewed positively, some of the stakeholders argued that a good first step would be to enforce existing laws and regulations.

7) More preservation, restoration, and protection activities are needed

8) The economic benefits from subtidal habitat restoration are not well documented and further analysis is required to inform the Core Group and Working Groups' decision-making process.

More detail regarding the stakeholder recommendations is provided in Section 1.5 of this report.

The research team concurs with the 8th stakeholder recommendation. Once the Core Group and Work Groups have defined subtidal habitat protection and management measures, there are a number of additional research steps we recommend NOAA take to better understand the economic implications of the measures. We recommend this research program follow a two-phase approach.

In the first phase of the research work plan, we recommend the research team construct a set of tables that consider all direct, indirect, non-use, and intrinsic values that are likely to result from each protection and management measure developed under the San Francisco Subtidal Habitat Goals project and study. The examination should include a qualitative analysis of the economic impacts of protection and management measures, and should identify stakeholders that will likely benefit or be harmed by protection and management measures.

Under the first phase of the work plan, the research team should also document methods with potential application for assessing the economic benefits associated with each protection and management alternative. Each method should be examined in terms of its relevance for valuing the identified economic impacts. For each economic impact, data required to support potential valuation methods should be documented.

Once the research team has completed its preliminary analysis of the economic benefits applied to each management and preservation measure, the research team should examine the type and relative magnitude of economic impacts associated with the protection and management measures developed as a part of the San Francisco Bay Subtidal Habitat Goals Project and Study. For each measure, the research team should examine the impacts on the local economy within the nine-county region surrounding San Francisco Bay, consisting of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma counties.

The scope of the benefits considered should include both direct, indirect, non-use, and intrinsic values, as defined in Phase I of the work plan. The research team should consider the distributional impacts of the measures, and examine the impacts over a short- (5 to 10 years) and long-term (50 years) planning horizon. In performing this analysis, the research team should assess when benefits would be expected to first accrue and how the stream of benefits would be expected to change over time.

Within the framework noted above, the research team could employ a number of accepted environmental valuation techniques to measure the economic impacts of the management and protection measures. Environmental economists have developed a number of market and non-market-based techniques to value the environment. Some of these techniques, such as the contingent valuation and travel cost methods, require extensive surveys. Others, such as the hedonic pricing method, require analysis of large property value databases. There are a number of techniques, however, that do not require extensive data sets yet could be employed to generate reasonable economic impact estimates. The methods we recommend for the Phase II analysis include: the factor of production approach, defensive expenditures approach, benefit transfer method, meta analysis, and qualitative assessments based on available data and expert opinion.

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Appendix A – Stakeholder Contact List

Table A- 1 Stakeholder Contact List

Environmental Value	Contact	Organization
Commercial Fishing	Zeke Grader	Pacific Coast Federation of Fisherman's Association
Sport Fishing	Roger Thomas	Golden Gate Fisherman's Association
Hunting	Larry Wyckoff	California Department of Fish and Game
Recreation	Ray Murray	National Park Service, Pacific West Region
Boating and Sailing	Ann Buehl	California Coastal Conservancy
Wildlife Viewing	Barbara Salzman	Marin Audubon Society
Water Transport	John Sindzinski	San Francisco Bay Area Water Emergency Transportation Authority
Shipping and Ports	Tina Olsen	Port of San Francisco
Salt Harvesting	Steve Ritchie	South Bay Salt Pond Restoration Project
Sand Mining	Brenda Goeden	San Francisco Bay Conservation and Development Commission (BCDC)
Sand Mining	Chris Lind	Jerico Products, Inc.
Scientific Research	Drew Talley	San Francisco Bay National Estuarine Research Reserve
Education	Sara Ferner	San Francisco Bay National Estuarine Research Reserve
Education	Sandi Potter	San Francisco Bay Regional Water Board
Education	Athena Honore	Save the Bay
Education	Miha Aida	Headlands Institute
Education	Sylvie Lee	California Coastal Commission
General Economics	Phil King	San Francisco State University
Biological Support	Jamie Kooser	San Francisco Bay National Estuarine Research Reserve
Bequest	Amy Hutzel	California Coastal Conservancy

Appendix B - Subtidal Habitat Goals Project - Interview Protocol

National Oceanic and Atmospheric Administration

May 19, 2008

The Subtidal Goals Project in San Francisco Bay represents a long-term plan for protection and restoration of the subtidal habitats of the San Francisco Bay. The primary product of the Subtidal Goals Project will be a document that provides recommendations and goals for use, protection, restoration, and research to improve subtidal habitat management in San Francisco Bay. Resource managers will be able to use this document to make informed decisions and researchers will be able to prioritize activities and pursue funding for subtidal projects.

The economic benefits associated with subtidal habitats, however, are not well known to the Subtidal Goals Administrative Core Group or the Subtidal Goals work groups. Thus, understanding the economics associated with protecting resources represents an important piece of information for managers who are responsible for implementing protection and management measures. The ability to share a common knowledge of the expected economic changes, both good and bad, that may result from management decisions and which interests will be affected by these changes will support the selection and implementation of appropriate protection goals. The National Oceanic and Atmospheric Administration (NOAA) has contracted with Battelle to address the economic components of the subtidal habitat of San Francisco Bay that will in turn support the overall Subtidal Habitat Goals Project.

To support this project, Battelle will be conducting interviews with a number of stakeholders. The objectives and scope of the interviews include:

a) natural resource services provided by the San Francisco Bay
b) the link between ecological conditions in San Francisco Bay and local economic benefits
c) local industries and other stakeholders reliant on the Bay
d) classes of economic benefits derived from the Bay
e) sources of data that could be used to quantitatively examine the identified benefits
f) sources of literature that could be used to qualitatively examine the economic benefits tied to the Bay
g) ecological threats to these natural resource services
h) thoughts concerning potential preservation or restoration activities.

Table 1 lists the stakeholders targeted for interview. An original list of stakeholders was provided by NOAA Coastal Service Center (CSC) staff, and that list was refined based on stakeholder input. It identifies the environmental value to be discussed during the interview and the organization each potential interviewee represents. A member of the research team will be contacting these stakeholders for interviews. This protocol will be used to guide the interview. Once the interviews are completed, follow-up telephone contacts and information transfers will complete the data collection process.

Table B- 1 Stakeholder Contact List

Environmental Value	Contact	Organization
Commercial Fishing	Zeke Grader	Pacific Coast Federation of Fisherman's Association
Sport Fishing	Roger Thomas	Golden Gate Fisherman's Association
Hunting	Larry Wyckoff	California Department of Fish and Game
Recreation	Ray Murray	National Park Service, Pacific West Region
Boating and Sailing	Ann Buehl	California Coastal Conservancy
Wildlife Viewing	Barbara Salzman	Marin Audubon Society
Water Transport	John Sindzinski	San Francisco Bay Area Water Emergency Transportation Authority
Shipping and Ports	Tina Olsen	Port of San Francisco
Salt Harvesting	Steve Ritchie	South Bay Salt Pond Restoration Project
Sand Mining	Brenda Goeden	San Francisco Bay Conservation and Development Commission (BCDC)
Sand Mining	Chris Lind	Jerico Products, Inc.
Scientific Research	Drew Talley	San Francisco Bay National Estuarine Research Reserve
Education	Sara Ferner	San Francisco Bay National Estuarine Research Reserve
Education	Sandi Potter	San Francisco Bay Regional Water Board
Education	Athena Honore	Save the Bay
Education	Miha Aida	Headlands Institute
Education	Sylvie Lee	California Coastal Commission
General Economics	Phil King	San Francisco State University
Biological Support	Jamie Kooser	San Francisco Bay National Estuarine Research Reserve
Bequest	Amy Hutzel	California Coastal Conservancy

[BACKGROUND INFORMATION]

Name of Respondent	
Date Survey was Completed	
Employer of Respondent	
Respondent Address	
Job Title of Respondent	
Phone Number(s) of Respondent	

[QUESTIONS RELATING TO ENVIRONMENTAL VALUES OF SAN FRANCISCO BAY]

1. The table on the following page presents a list of the environmental values of the San Francisco Bay that generate economic benefits to society. Please review this table and modify it, removing values that you do not believe should be on the list, adding values not presently on the list, and adding comments that you think are relevant to the list.

2. Please discuss what you consider to be the direct economic impacts of [the value or activity the respondent is expert in]. Direct economic impacts could include the total value of sales, output, tax contributions, jobs, or a more general overview of how the activity benefits the San Francisco Bay Area economy. Please provide data or literature concerning the economic impacts of the value in question.

3. Please list the ancillary services or secondary industries that indirectly benefit from those supporting the [value or activity that you are expert in]? In addition to listing the industries, please discuss the manner in which they support the activity or primary industry that is the focus on this interview. Please provide data sources and literature to document these connections and activity.

4. What sort of protection, restoration, preservation, or other related activity would you recommend be undertaken in order to enhance the positive economic effects of the [value or activity that you are expert in]?

5. Do you have any other comments you would like to provide at this time about the economic valuation of the Bay, or any questions?

6. In our final report, could we include your name in a list of experts interviewed for this study?

Table B- 2 San Francisco Bay Environmental Values

(a) Direct use values – goods and services directly consumed by users

- Commercial fishing
  - Pacific Herring
  - Salmon
  - Dungeness Crab
  - California Halibut
  - Rockfish
  - Grass Shrimp
  - English Sole (San Francisco Bay acts as a nursery)
  - Starry Flounder (San Francisco Bay acts as a nursery)
  - Crawfish
- Sport fishing
- Subsistence fishing
- Hunting
  - Ducks
  - Geese
- Recreation (boating and sailing, hiking, kayaking, windsurfing, swimming, beach use, photography, surfing, scuba diving)
- Eco Tourism (wildlife viewing)
- Water transportation (ferry system, cruise lines)
- Aquaculture (oyster farming)
- Shipping and ports
- Production of salt, magnesium and magnesium compounds and bromine
- Mining oyster shells for cement and soil conditioner
- Sand mining
- Wastewater assimilation (industrial and municipal sewage, urban and agricultural runoff)
- Industrial water use – once through cooling
- Residential and industrial water supply
- Scientific research
- Amenity values
- Education

(b) Indirect use values – indirect benefits arising from ecological and aquatic systems

- Biological support – links to other species and habitats (e.g., migratory birds, marine mammals)
- Nutrient cycling
- Climate regulation
- Flood protection
- Water quality maintenance
- Biodiversity and genetic maintenance
- Sediment transport

(c) Non-use values

- Option value (future knowledge and future economic uses)
- Existence value (cultural, aesthetic, spiritual)
- Bequest (stewardship, heritage, legacy)

(d) Intrinsic value – organisms have a worth of their own regardless of usefulness to humans

Thank you for taking time to address these questions. If you have any additional comments, questions or information you would like to share with the research team, please contact Mr. Patrick Balducci at the phone numbers and addresses listed below.

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Economic Support for the San Francisco Subtidal Habitat Goals Project: Annotated Bibliography

Prepared for

The Coastal Services Center
National Oceanic and Atmospheric Administration

September 17, 2007

Prepared by

Battelle
The Business *of* Innovation

Table of Contents

1.0 INTRODUCTION

The Subtidal Goals Project in San Francisco Bay represents a long-term plan for protection and restoration of the subtidal habitats of the San Francisco Bay. The economic benefits associated with subtidal habitations, however, are not well known to the Subtidal Goals Administrative Core Group or the Subtidal Goals work groups. Thus, the goal of this report is to identify, summarize, and examine literature relating to the economic benefits associated with subtidal habitats. This literature will inform the working groups supporting the Subtidal Goals Project by the extent and economic methods used to value the environmental goals and projects under consideration.

2.0 SUMMARY OF INTERVIEWS

In order to better understand the ecological benefits associated with subtidal habitat restoration, including the potential benefits to San Francisco Bay, the research team attempted to contact members of the following groups:

- Science Working Committee
- Restoration Working Committee Members
- Resource Management Working Committee Members
- Other Interested Stakeholders

Input from these groups assisted the research team in defining potential actions and associated ecological benefits. This report represents one step in an iterative process. Through the working group members' evaluation of this draft report and response to a planned presentation, more input and guidance are anticipated from these groups. This input will assist the research team in shaping the final annotated bibliography.

The consensus among the working committee members contacted for this study was that although there had been several studies published that deal with the benefits of wetlands, estuaries and other aquatic environments, there were few studies that focused entirely on the benefits of subtidal habitat restoration. Thus, the working committee members recommended that the research team adopt an indirect analytical approach to constructing the annotated bibliography. A review of literature conducted for this project led the research team to the same conclusion. Thus, the annotated bibliography focuses on articles covering the benefits of specific marine habitat restoration efforts (e.g., oyster reef restoration, eelgrass bed restoration) and the economics underpinning environmental valuation of aquatic ecosystems, including estuaries, wetlands and other marine environments.

The working committee members interviewed by the research team concluded that subtidal habitat restoration would be vital to establishing habitat for native aquatic mammals (including harbor seals), invertebrates (including oysters), birds, and fish species in historic decline. The focus of the input dealt with restoration concepts and the ecological benefits of proposed subtidal habitat restoration actions. More specifically, members pointed to a number of concepts and outcomes associated with subtidal habitat restoration, including:

- Restoring eelgrass beds to provide nurseries for herring and other fish;
- Restoring mudflat and sandy habitat that could provide refuge for Dungeness crab;
- Restoring or constructing native oyster beds in order to provide habitat for juvenile fishes and spawning herring;
- Restoring rocky reefs that could provide habitat for rockfish;
- Restoring benthic areas that have been trawled in order to enhance fish (particularly halibut) populations;
- Restoring seagrass beds and oyster reefs in order to enhance benthic biodiversity and water quality;
- Restoring subtidal habitat in order to promote algae growth, which could increase primary productivity and enhance habitat for aquatic mammals, invertebrates, and fishes; and
- Restoring eelgrass, rocky and soft bottom in order to provide foraging habitat to harbor seals.

Working committee members also noted that the benefits of habitat restoration extend beyond direct benefits tied to enhanced catch rates and natural resource outputs. For example, sediment stabilization from eelgrass beds and other restoration efforts could enhance fishing and kayaking opportunities and provide better viewing for naturalists, thus enhancing the recreational and amenity value of San Francisco Bay to local residents and eco tourists. Further, oyster reefs could also enhance eco tourism by enhancing water quality and improving habitat for fish. Based on this input, the research team considered a broad range of literature focusing on both direct and indirect benefits of aquatic ecosystems.

3.0 SUMMARY OF REVIEWED LITERATURE

The literature review conducted for this project and documented in the annotated references section of this report explored the benefits outlined by the working committee members and others identified and in many cases quantified in the literature. The remainder of this section of the annotated bibliography presents a scheme for categorizing environmental benefits, documents relevant studies falling within each benefits category, and documents economic methods used to value the environmental benefits falling within each category.

The literature suggests that historically, environmental resources have been undervalued because many of the ecological services they provide (e.g., climate regulation, water filtration, amenity values) are not bought and sold in a market (Barbier 1997). In recent years, however, economists have developed methods to evaluate a broader set of environmental values. The total economic value of a natural resource is now considered to be the sum of its direct-use value, indirect-use value, non-use value and its intrinsic value.

Table 1 presents a categorization of environmental values considered within the literature reviewed for this report. These are the economic values of marine environments that could be enhanced through subtidal habitat restoration. Direct use values would include the goods and services that are directly consumed by users. Within the context of subtidal habitat restoration, direct use values could include enhanced fish catches, oyster harvests and eco tourism resulting from oyster reef restoration and other restoration projects. Indirect use values are the indirect benefits resulting from enhancements to ecological systems. These values include the food web, climate regulation and global life support benefits tied to marine environments. Non-use values include the option, bequest, and stewardship motives. These values are tied to our interest in preserving a natural resource either for our own potential future use or the use of others, including future generations and other forms of life. The intrinsic values that individuals place on the environment reflects the view that natural organisms and environmental habitat is valuable regardless of the values placed on it by humans.

The direct benefits of aquatic habitat restoration are well documented in the literature. The research reviewed for this report examined the direct use values, as well as indirect use, non-use, and intrinsic values of aquatic ecosystems. The direct use values reviewed in the literature were mainly tied to the fishery and recreational impacts of restoration actions.

Anderson (1989) examined the impacts of seagrass restoration to the Virginia hard-shell blue crab industry. Anderson found that seagrass beds served as a principle habitat for blue crabs and that through restoration efforts, the net economic benefit to the hard-shell blue crab industry would total $1.8 million per year, with an additional $2.4 million accruing to U.S. consumers. This study employed the factor of production approach, which measures the value of a resource based on its role as an input into the production of goods.

Patterson and Whitfield (2000) and Perkins-Visser et al. (1996) examined the benefits of seagrasses tied to their ability to serve as nurseries for juvenile fish and crab species. Patterson and Whitfield found that eelgrass beds offered refuge to juvenile fishes from predation by piscivorous fishes and that this protection enhanced fish populations. Even in the absence of predators, Perkins-Visser et al. (1996) found that enclosed blue crabs attained a significantly larger carapace volume and higher rates of survival in enclosures with seagrass beds relative to those without them. Hovel (2005) examines the complications with transplanted eelgrass beds in San Diego Bay, where no beds lasted more than six months after transplant but also documented the potential effects of eelgrass on epifaunal diversity and fish recruitment. Food web and other benefits of seagrass were explored in Opaluch et al. (1999), Stewardship Centre for British Columbia (2005) and Wilbur (2004-2005).

Table 1. Categories of Marine Environmental Values

(a) Direct use values – goods and services directly consumed by users
- Sport and commercial fishing
- Oyster and crab harvesting
- Mineral extraction
- Seaweed extraction
- Medicinal
- Recreation (beach use, swimming, boating) and eco tourism (wildlife viewing, hiking)
- Waste assimilation
- Scientific research
- Treatment of human and industrial wastes
- Education
- Amenity values
- Underwater photography

(b) Indirect use values – indirect benefits arising from ecological systems
- Biological support – links to other species and habitats
- Nutrient cycling
- Physical protection – coastal defense function
- Climate regulation
- Erosion protection and stabilization
- Water quality maintenance
- Biodiversity and genetic maintenance
- Global life support – functions that aid in supporting life on Earth

(c) Non-use values
- Option value (future knowledge and future economic uses)
- Existence value (cultural, aesthetic, spiritual)
- Bequest (stewardship, heritage, legacy)

(d) Intrinsic value – organisms have a worth of their own regardless of usefulness to humans

The benefits of oyster reef restoration are well documented. Brumbaugh et al. (2006) examines benefits tied to water quality, habitat for benthic species, and sediment stabilization accruing due to restoration of shellfish populations. It also examines how to optimize site selection for restoration efforts. One restoration effort in Chesapeake Bay was examined in terms of its ability to enhance value to sport fisherman who travel to the bay to take advantage of increased catch rates resulting from the water filtration function of oysters (Hicks 2004). The study used a random utility model (RUM) to determine that sites with relatively high concentrations of oyster bottom did correlate with higher catch rates and that higher catch rates correlated with increased numbers of anglers and a willingness to pay for enhanced catches. Using data collected through surveys distributed to recreational users, RUMs are econometric models that can be used to attribute a willingness to pay for a resource to an area based on its characteristics (e.g., location, accessibility, amenity value, water quality, presence and diversity of fish or bird species). Posey et al. (2004) also found that oyster reefs served as primary fish habitat providing a structural refuge for small fish and invertebrates, enhanced water quality through filtration, and enriched the local sediment enhancing growth of submerged vegetation.

Henderson and O'Neil (2003), Breitburg et al. (2000), Ulanowicz (1992) and Soniat (2004) explored a full range of benefits accruing through oyster reef restoration. Henderson and O'Neil (2003) found that the environmental services of oyster reefs netted positive rates of return to the oyster industry within 5 to 14 years but that the secondary impacts on fish and crab harvests, recreational fishing (valued at $2.3 million in Chesapeake Bay), eco tourism, boating ($8 million in Chesapeake Bay), beach use and swimming (valued at $7.20 to $23.29 per person for a 1 percent reduction in oil and bacteria), erosion protection and stabilization and other benefits tied to oyster reef restoration far exceeded the direct benefits to the oyster industry. Qiu (2003) found that some of these same benefits could be realized through the development of artificial reefs. Qiu examined the ability of artificial reefs to develop epibiotic communities (e.g., barnacles, green mussels, and tunicates) in Hong Kong. Qiu found that the construction material (e.g., wood, steel, concrete) had little impact on the characteristics of the climax community. Thus, the design of artificial reefs should focus more on other physical and economic aspects, such as durability, flow dynamics, stability, cost, and effects on the ambient environment.

There have been several studies that have placed a value on the recreational (including sport fishing) and amenity values of wetland, estuaries and other marine environments. Kazmierczak (2001a) reported that the private economic gains from wetland conversion had been historically overvalued and that the non-market benefits, including impact on land values and amenity values, had been undervalued when making decision to fill or preserve wetland areas. Kazmierczak (2001b) reviews 12 studies exploring the economic link between wetland restoration and hunting and fishing opportunities. The studies referenced in Kazmierczak used a wide range of methods, including the travel cost method, contingent valuation method, net factor income method, and hedonic pricing method. The results of these studies suggest that the values that humans place on fishing and hunting in wetlands is highly variable (ranging between $83.99 to $616.46 per respondent) and dependent upon numerous factors, including: the target species, geographic location, type of hunting activity, and the environmental valuation measurement technique.

The travel cost method documented in Kazmierczak (2001b) models the recreational value of a site based on the economic costs incurred by travelers in order to access the site (e.g., time and travel expenses). The travel cost method relates the cost and number of trips taken by visitors to demographic and socioeconomic factors, including age, location of home, race and income levels. Sample data collected through surveys are then blown up to the population to estimate the total valuation. The travel costs are considered an indication of a traveler's willingness to pay for the benefits enjoyed at the site. The travel cost method is also used in Leeworthy (1997) and Farber (1988).

The contingent valuation (CV) method reviewed in Kazmierczak (2001b) measures the non-market benefits of a site based on preferences stated through surveys, questionnaires, and interviews. The CV method can be used to measure multiple non-market benefits (e.g., recreational, bequest and existence values). When using the CV method, an examiner constructs scenarios designed to simulate markets where environmental resources can be traded at a cost. For example, one scenario might measure an individual's willingness to pay for enhancements to local marine environments through an increase in the local property tax while another may consider an individual's willingness to accept monetary compensation to offset damage to a local marine environment. The CV method is perhaps the most flexible and widely used environmental valuation technique; however, the shortcomings of CV are also well documented, including its inability to properly set budget constraints, its inability to set the size of the market studied and the warm glow effect that individuals face when making value judgments about the environment (Arrow 1993). The CV method was used as the basis of valuing environmental resources in Kazmierczak (2001b), Farber (1998), Opaluch et al. (1999), Shorney (2004) and Thibodeau (1981).

Shorney (2004) explored the economic contribution of sea angling at four locations in England – Wymouth, Whitby, Hastings, and Anglessey. Shorney assessed the consumer surplus enjoyed by sea anglers, as measured through surveys distributed to households. Environmental valuation is often determined based on measures of consumer surplus. Consumer surplus is calculated as the difference between what consumers are willing to pay for a good or service and what they actually pay. Thus, if a hunter pays $200 for a hunting trip but was willing to pay $300, the $100 difference is considered consumer surplus and is an additional benefit to the hunter. Shorney found that the annual consumer surplus of those surveyed varied based on whether fishing took place on shore (£381 or $753 annually per angler) or in personal watercraft (£886 or $1,752 annually per angler). The survey also found that anglers were willing to pay more for larger species and also for greater diversity of catch. The annual aggregate angler consumer surplus was measured at £594 million ($1.2 billion), which translated into 18,889 jobs, £71 million in suppliers' income.

Leeworthy (1997) estimated the non-market economic values of tourism at the Florida Keys by using the travel cost method. The weighted average cost of travel to the Florida Keys was estimated by all summer and non-summer travelers at $740 and $561, respectively. The total annual value placed on trips to the Florida Keys by tourists was estimated at $1.2 billion. Opaluch et al. (1999) also used the travel cost method in examining the swimming, boating, fishing and bird watching values of the Peconic Estuary System. The findings of the travel cost survey demonstrated that recreational users of the estuary valued fishing at $22.4 million, viewing birds and wildlife at $49.3 million, boating at $18.1 million, and swimming at $12.1 million. These values represent annual benefits presented in 1995 dollars. Opaluch also used a property valuation or hedonic pricing model to examine the impact of proximity to open space and other environmental attributes on property values. Hedonic pricing uses surrogate markets, often the housing market, to measure the impact of environmental conditions on property values. Air, noise and sound pollution impact housing prices negatively while open spaces and scenic vistas enhance value. The results of Opaluch et al. (1999) suggest that parcels of land near open spaces were, on average, 12.83 percent more valuable than parcels with otherwise similar characteristics.

There are other direct and indirect environmental services referenced in the literature, including water transport, treatment of human wastes, treatment of industrial wastes, and future goods and services (Fischer et al. 1986). Beaumont (2006) examined the impacts of marine environments on ecosystem regulation, flood and storm protection, cultural services and climate regulation. Grigalunas and

Opaluch (2002) examine the significance of non-market benefits tied to the bequest and existence motives.

4.0 ANNOTATED REFERENCES

The annotated references presented in this section are stratified according to three categories: reports that address ecological issues relevant to aquatic habitat restoration, reports that present theory and methods for valuing environmental resources, and reports that use environmental valuation methods to estimate the value of natural resources.

4.1 Ecological Benefits of Restoration

Anderson, E. A. 1989. Economic Benefits of Habitat Restoration: Seagrass and the Virginia Hard-Shell Blue Crab Fishery. *North American Journal of Fisheries Management NAJMDP* Vol 9(2): 140-149.

Since the early 1960s, water pollution has caused the disappearance of much of the seagrass (predominantly eelgrass Zostera marina) and other submerged aquatic vegetation in Chesapeake Bay. Seagrass beds appear to serve as preferred habitat for the blue crab Callinectes sapidus during early stages of its life, and there is a statistically significant relationship between the abundance of submerged aquatic vegetation and catch per unit of effort in the Virginia hard-shell blue crab fishery. Virginia seagrass beds might be partially or fully restored through a combination of pollution abatement and replanting. A simple simulation model with minimal data requirements to generate rough estimates of some of the economic benefits that would accrue from seagrass restoration was developed. The estimated net economic benefit to Virginia hard-shell blue crab fishermen of full seagrass restoration is about $1.8 million per year, and additional annual benefits of about $2.4 million should accrue to United States hard-shell blue crab consumers. This study demonstrates the value in both ecological and economic terms of seagrass beds in terms of providing habitat for hard-shell blue crab.

The value of seagrasses as habitat for crab and other marine species is relevant to preservation and restoration efforts in San Francisco Bay. Further, this article demonstrates the direct link between seagrass restoration and crab recovery and illustrates methods for restoring seagrass beds. The estimates presented in this report, however, are not directly applicable to San Francisco Bay and are based on restoration of seagrass beds to their historic levels without a commensurate estimate of the cost of pollution abatement and replanting.

Breitburg, D.L., L.D. Coen, M.W. Luckenbach, R. Mann, M. Posey and J. Wesson. 2000. Oyster reef restoration: Convergence of harvest and conservation strategies. *Journal of Shellfish Research* 19: 371-378.

This article serves as a detailed guide for supporting a sustainable harvest of oysters that meets both fishery and conservation needs. It describes the detrimental effects harvesting oysters has on oyster reef habitat and recommends ways to manage the reef system in order to compensate for this damage. The act of harvesting oysters destroys reef substrate, thereby decreasing the area of available settlement ground for oyster recruits and preventing growth of the reef. Removing oysters also reduces the reef's vertical relief and structural complexity, which harms oyster recruitment, survival, and growth rates, decreases niche habitat for other reef inhabitants, and reduces the ability of reefs to provide a buffer to shorelines from wave energy. In addition, harvesting decreases oyster density, which should remain high to maximize fertilization success and provide oyster shell for recruits to settle on. In order to compensate for the harm caused to reefs by harvesting, the authors recommend creating refuge reefs nearby harvested reefs. The refuge reefs maintain the ecological benefits of unharvested sites while providing larvae to colonize the harvested sites. While the largest, healthiest oysters are removed from the stock in the harvested sites, the refuge reefs maintain their hardiest individuals, which remain to contribute to a stronger, more resistant gene pool within both the harvested and unharvested sites. Hence, creating refuge reefs benefits both fishery and conservation goals.

The article also describes the considerations that must be made when selecting sites for oyster reef restoration or construction. Sites would optimally be located in waters where high phytoplankton biomass is likely to occur, such as nutrient loaded areas. There, oysters will have access to a dense food source and can maximize local water clarity. Reefs located near salt marshes help to reduce soil erosion by dissipating wave energy. Furthermore, reefs constructed in areas where little structured habitat is present can serve as "migration corridors" for species traveling from and between structured habitats.

This article is instructive for the San Francisco Bay Subtidal Habitat goals project because it provides a practical guide to conceptualizing oyster reef restoration and fishery management. While it does not address concerns specific to projects in San Francisco Bay, it does supply general justification and instruction for current and future restoration projects while specifying methods of creating a sustainable harvest in the future.

Brown, L.R. 2003b. Will tidal wetland restoration enhance populations of native fishes? In: *San Francisco Estuary and Watershed Science*, ed. L.R. Brown, 1 (1) (2).

This author examines the history of the tidal wetlands in San Francisco Bay and the Sacramento – San Joaquin Delta, noting that as tidal wetlands have been lost (80 percent of San Francisco Bay and 95 percent of the Sacramento – San Joaquin Delta) during the past 150 years, the losses have coincided with significant declines in the native fish populations. The author does not correlate the decline in tidal wetlands with declining native fishes but does examine the possibility through a review of relevant data sources and literature.

The report documents the benefits of wetland areas to fishes, including providing cover for smaller organisms from larger predators and service as nurseries for young fish. Also, vegetation in wetland areas provides important food resources for invertebrate species that serve as a food source for fish. The author notes that since vegetative wetland areas also attract large predatory fish, it is unclear whether the expansion of wetland areas would, indeed, enhance native fish populations.

The literature reviewed for this study concludes that some native fishes would be likely to benefit from restored tidal wetlands but not all types of fishes would be expected to benefit, and the author is not sure how significant the benefits would be. The author also identifies several uncertainties regarding these conclusions resulting from: the absence of large areas of tidal wetlands with the characteristics viewed as desirable, the view that Egeria densa would invade restored areas and the types of native and non-native species it would be expected to support would not be desirable, and the lack of direct evidence concerning the predation impacts of wetland restoration.

Brumbaugh, R.D., M.W. Beck, L.D. Coen, L. Craig, and P. Hicks. 2006. *A practitioner's guide to the design and monitoring of shellfish restoration projects*. The Nature Conservancy and National Oceanic and Atmospheric Administration.

This guide describes the causes of decline in shellfish populations and the benefits of shellfish restoration, suggests approaches to managing restoration, and provides case studies of current restoration projects. Shellfish populations have declined worldwide largely due to over harvesting, declining estuary extent and health, and the introduction of shellfish diseases and parasites. The guide describes the enhanced water quality, additional habitat for benthic species, and sediment stabilization that is expected to accrue from restoring shellfish populations. It advises that local tidal current patterns will affect the optimal site selection for shellfish restoration because the tides heavily influence larval recruitment. In addition, different shellfish species prefer different types of settlement substrate, so it is important to match the restored substrate to the targeted shellfish species.

This guide provides justification and practical guidance for restoring oyster reefs within the San Francisco Bay. Unfortunately, none of the case studies used included San Francisco Bay, but the underlying approach presented remains applicable.

Castel, J., P-J. Labourg, V. Escaravage, I. Auby and M.E. Garcia. 1989. Influence of seagrass beds and oyster parks on the abundance and biomass patterns of meio- and macrobenthos in tidal flats. *Estuarine, Coastal and Shelf Science* 28: 71-85.

This study measured the density and biomass of meiofauna and macrofauna in bare sandbanks, mud flats occupied by the seagrass *Zostera noltii*, and oyster reefs to compare faunal abundance with sediment structure and levels of seagrass debris and benthic chlorophyll in Archachon Bay, on the coast of France. The ratio between macrofaunal and meifaunal biomass was also calculated for the three examined habitats. The results suggest that nitrogen-rich oyster feces supply nutrients that support meiofauna populations but also lead to anoxic conditions that drive down macrofauna populations. In comparison, macrofauna biomass far exceeded meiofuana biomass in sandbanks, because of oxygen availability for macrofauna and the relative scarcity of bionutrients present in the sandbanks for meiofauna as compared to the oyster reefs. Of the three habitat types surveyed, meiofaunal and macrofaunal abundance were both maximized in the seagrass beds. The seagrass beds provided refuge and greater food resources for the macrofauna and decaying seagrass blades acted as a significant food source for meiofuana.

This study is relevant to planning efforts for the San Francisco Bay because it describes factors that support or decrease macrofaunal and meiofaunal abundance. Restoration projects attempting to increase the overall abundance of macrofaunal or meiofaunal species might consider focusing on restoring eelgrass beds instead of oyster reefs. The results must be interpreted with caution, however, because while the majority of macrofaunal species may be better supported by eelgrass beds than by oyster reefs, it would be imprudent to assume that an individual species would show the same preference. In addition, the water parameters, tidal patterns, and species present differ between Arcachon Bay and San Francisco Bay.

Edyvane, K. S. 1999. Coastal and marine wetlands in Gulf St. Vincent, South Australia: Understanding their loss and degradation. *Wetlands Ecology and Management* 7(1-2): 83-104.

Despite the vastness of South Australia's coastline, approximately 95 percent of the state's population of 1.4 million is on the Adelaide metropolitan coast of Gulf St. Vincent. The concentration of human activity around this shallow, sheltered gulf ecosystem has led to conflict and competition over the use of marine and coastal resources. The gulf supports extensive areas of ecologically significant subtidal and tidal coastal wetlands, comprising seagrass meadows, mangroves and salt marshes, with nine wetlands having recognized national importance. The wetlands support economic activities such as commercial and recreational fishing, tourism and aquaculture, and to a lesser extent, mineral and petroleum exploration and shipping.

These environments and activities are threatened by the effects of land-based urbanization, coastal development, storm water runoff effluent and industrial discharges, and the resultant decline in water quality and food-chain contamination. Marine activities can also have adverse effects (i.e., dredging, sea-dumping, over fishing, fishing methods, oil spills, anti-foulants, ballast water introductions), including the developing aquaculture industry. The continued loss and degradation of marine and coastal wetlands in the gulf is exacerbated by inadequate protection measures, lack of integrated management structures and policies, and conflict between competing user groups. Strong policies and integrated decision making based on sound information is required for the equitable and sustainable use of these wetlands. Gulf-level management of multiple-uses would limit the cumulative impacts of human use and coastal development. There is a particular need to protect areas with high conservation value and for future research and marine conservation to focus on the coastal nearshore ecosystem. High priorities are coastal and biodiversity inventories, understanding of ecological processes, linkages between coastal and offshore habitats, and coastal spatial mapping and information systems.

The authors of this article reviewed the status of marine wetlands in the Gulf of St Vincent (seagrasses, mangroves, and salt marshes) and the causes and effects of degradation (chemical, physical, biological and fisheries). This article is relevant to the San Francisco Bay Subtidal Habitat Goals project because it details the cause and effect relationship between pollution, coastal development, dredging and other human activities and declining natural resource outputs. Further, it defines restoration solutions, including integrated coastal and marine management, research, and monitoring. Impacts can be inferred from the causes and effects of degradation to the ecosystem, but the article did not assess the benefits of remediation actions.

Healy, T., S. Stephens, et al. 2002. Port redesign and planned beach re-nourishment in a high wave energy sandy-muddy coastal environment, Port Gisborne, New Zealand. *Geomorphology [Geomorphology]*. Vol. 48: 1-3.

Redesign of Port Gisborne for the 21st century has encompassed a broad interdisciplinary approach. This procedure has taken into account the operational requirements of the port, effects of dredging and construction upon the benthic fauna, and wave activity within the port confines after the proposed development. Added amenity value of the development to the local community is an important ancillary redesign consideration. Initially, a major research project into the environmental impacts of the developments has been undertaken. The project, which commenced in 1996 and is still continuing, involves an iterative approach integrating the initial design and development options with the operational feasibility, construction constraints, environmental constraints, social acceptability, and economic practicality of the port; all of these require in-depth assessment to obtain the necessary planning and development approvals. This requires close liaison between the professional environmental research scientists, port management, port operation staff (pilots), construction engineers, planners, and the community interest groups.

Numerical modeling of the hydrodynamics of Poverty Bay, simulating waves and current effects on the various initial design options, and calibrated against data from a substantial field program, has been a fundamental tool. It was applied experimentally to determine the best option for the port layout, as well as to assess sedimentation impacts. Modeling results indicated a significant increase in maintenance dredging expected as a result of deepening the navigation approach channel. Because this may have an impact on the nearby sandy beach by inducing erosion, the best option for disposal of the sandy dredged material was determined to be disposal in the surf zone for subtidal beach profile re-nourishment. Textural analysis of the sediments trapped in the navigation channel demonstrated that they were suitable for this purpose.

This report is useful to the San Francisco Bay Subtidal Habitat Goals project in that it demonstrates methods for examining the economic benefits and costs associated with a project with aquatic environmental impacts.

Hovel, K.A., T.W. Anderson. February 3, 2005. Evaluating eelgrass restoration: effects of habitat structure on fish recruitment and epifaunal diversity in San Diego Bay. San Diego, CA: San Diego Unified Port District.

This study examined the effects of eelgrass (*Zostera marina* L.) habitat structure and location on epifaunal diversity and fish recruitment in San Diego Bay, California. Over a period of two years, researchers monitored the success with which transplanted eelgrass beds served as habitat for epifauana and the effects upon donor beds of harvesting eelgrass patches. The results indicated that the location of the transplanted eelgrass bed within the San Diego Bay had a greater impact on the density and type of epifaunal resident species than did the structure (e.g., shoot density, patch spacing and patch size) of the bed. Furthermore, epifuanal diversity and density within donor eelgrass patches that were part of large, contiguous beds did not decline until approximately 50 percent of the patch was harvested. These results may provide guidance to eelgrass restoration projects within San Francisco Bay. However, the transplanted beds in this study did not survive beyond a period of six months at any site, and therefore caution must be used when determining the applicability of the results.

Josselyn, M.N. and J.A. West. 1985. The distribution and temporal dynamics of the estuarine macroalgal community of San Francisco Bay. *Hydrobiologia* 129: 139-152.

This report documents the findings of a long-term study of intertidal macroalgae within San Francisco Bay. The report identifies numerous ecological benefits associated with macroalgae, including biomass accumulation, nutrient sinks, consumption by herbivores, and serving as an organic substrate within the food web. Collections of macroalgae were taken at nine sites in San Francisco Bay from 1978 to 1983. Four sites were identified for more detailed measurement during the 1981 to 1983 time period. At each site, macroalgae growth was taken and site physical characteristics were also measured, including temperature, salinity, and a light coefficient.
The study identified 162 species of macroalgae in San Francisco Bay but registered a significant decline in the number of species resulting from decreasing salinity and a lack of hard substrata in the upsteam direction. The authors note the presence of seasonal variations in macroalgal abundance resulting from changes in salinity, temperature, and light availability at the bottom. These findings suggest the decline in a significant foundational element supporting the aquatic ecosystem and document some of the potential sources of strain being placed on macroalgae in San Francisco Bay. The study also examines factors that may be involved in the occurrence of macroalgal nuisance blooms. The study, however, is dated and does not fully document the underlying causes for continued decline in salinity and issues related to water temperature. Further, the study does not consider the ecological or economic impacts of the decline in the conditions that support macroalgae.

This study is relevant to subtidal restoration efforts in San Francisco Bay in that it identifies and documents the specific ecological benefits of macroalgae to the Bay and examines the how water quality, temperature and light impact macroalgae growth.

Massachusetts Institute of Technology Sea Grant College Program. 2006. *Why is eelgrass important?* Cambridge, MA: Massachusetts Institute of Technology.

This article details the importance of eelgrass as food for detritivores, as a habitat for many marine species (including important prey for waterfowl), and as a sediment anchor that helps protect shorelines from erosion. A sidebar lists some historical human uses of eelgrass, which range from compost and roofing to medicine and cigars, and the article ends by listing the many commercial fisheries that depend on eelgrass beds. The key strength of this non-technical summary as it related to San Francisco Bay is that it stresses and characterizes the importance of eelgrass to commercial fisheries, industrial processing, shoreline protection, and the marine food web.

Nichols, F.H., J. Cloern, S. Luoma, D. Peterson. 1986. The modification of an estuary. *Science* 231: 567-573.

This article, published in 1986, describes the history of factors that have altered the physical, chemical, and biological features of San Francisco Bay and its tributaries. Some of the first commercial fisheries in the Bay, such as those in salmon and sturgeon, crashed in the early 20th century from water quality decline, over fishing, and essential habitat modification or elimination. In addition, the offshore Dungeness crab (*Cancer magister*) fishery saw decline mid-century from pollution, increased ocean temperatures, and predation of crabs by hatchery-reared salmon. The water chemistry of the Bay has been altered by reduced freshwater inflow caused by the diversion of tributary water for industrial, agricultural, and residential usage. As a result, nontidal currents driven by differences in salinity between South and Central Bay have decreased and the mean residence time in the Bay of water contaminated by agricultural and industrial wastes has increased. Such wastes are known to cause a decline in health among local birds and benthic invertebrates and evidence suggests that trace metals cause significant physiological stress in oysters.

While the article contained no recent information, it described the factors that historically caused detrimental changes to San Francisco Bay and which, if present today, likely harm the Bay as well. Current and future restoration projects might tie species- or habitat-specific goals to the mitigation of variables that have historically been harmful to those species or habitats.

Patterson, A.W. and A.K. Whitfield. 2000. Do shallow-water habitats function as refuge for juvenile fishes? *Estuarine and coastal shelf science* 51: 359-364.

This study examined the role of shallow estuarine habitats as refuge for juvenile fish from piscivorous fish predation. It discussed the dominance of young of the year marine transient species in the fish community within North American and southern African salt marsh creeks and evidence that piscivorous fish are largely absent from these areas. Researchers used gill nets to determine the presence of piscivorous fish in a southern African salt marsh intertidal creek and the adjoining bay, eelgrass beds, and main channel. Results showed a significant relationship between depth and the number of piscivorous fish caught, with the majority of piscivorous fish caught in the channel, few in the eelgrass beds and bay, and none caught in the creek.

This study provides evidence that eelgrass beds and bay habitat offer refuge to the young of marine fish species from predation by piscivorous fishes. The refuge may serve to support fish populations, which are an important resource both economically and environmentally in San Francisco Bay. Therefore, protecting and restoring subtidal habitat in the bay may boost fish populations in the long-run. However, the results of the study should be interpreted with some caution because of the differences in fish species and water chemistry between bay habitats in southern Africa and San Francisco Bay (although the study did not find a correlation between the distribution of piscivorous fish and water temperature, turbidity, and salinity). Furthermore, the study did not examine avian predation of young fishes, which is likely greater in shallow subtidal habitats than in deeper waters. In addition, while there are numerous studies to support the hypothesis that shallow water habitats serve as refuge for young fishes, there also exist studies that suggest differently.

Qiu, J. W., V. Thiyagarajan, et al. 2003. Development of a marine subtidal epibiotic community in Hong Kong: Implications for deployment of artificial reefs. *Biofouling* 19(1): 37-46.

A 2-year study was conducted in Hong Kong to examine the effects of substratum, season and length of submersion on the development of a subtidal epibiotic community using four types of settlement panels (concrete, steel, wood, and tyre). The season and length of submersion had a strong influence on the total biomass and on community structure while the type of substratum had very little impact on the total biomass or the structure of the epibiotic community. The season of submersion determined the species composition of the newly submerged surfaces. In the spring and summer, tubeworms were the most abundant. In the autumn and winter, barnacles and tunicates dominated. Community succession was not obvious in the first year of submersion as it was intermingled with strong seasonal settlement, growth and death of barnacles and tunicates. In the second year of submersion, green mussels and tunicates settled and grew to occupy most of the panel surfaces, forming an assemblage that was characteristic of climax communities in the local subtidal waters. The results suggest that the type of construction material has limited impact on the development of epibiotic communities on artificial reefs deployed in Hong Kong; the season of submersion may affect community structure in the early successional stage, but not the characteristics of the climax communities. This study indicates that the type of substratum should not be of concern when deploying artificial reefs in the subtidal waters in this region. The design of artificial reefs should focus more on other physical and economical aspects such as durability, flow dynamics, stability, cost, and effects on the ambient environment.

San Francisco Bay Area Wetlands Ecosystem Goals Project. 2000. *Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish and wildlife*, ed. P.R. Olofson. Prepared for the San Francisco Bay Regional Water Quality Control Board. Oakland, CA.

This report represents the scientific backbone of a 4-year project intended to establish goals for future management of the baylands and adjacent habitat in the area of the San Francisco Bay-Delta Estuary, downstream of the Sacramento – San-Joaquin Delta. The report represents the work of more than 50 scientists who donated their time to: generate a list of key species in the San Francisco Bay Area; compile information regarding habitats, migration patters, and interactions with other plant and animal species; and construct plant and animal species "profiles" that could be used to facilitate more thorough and balanced recommendations for ecosystem management. Plant community profiles were categorized accordingly:

- Plants and shallow and subtidal habitat and tidal flats,
- Tidal marsh plants,
- Plants and environments of diked baylands,
- Plants of the San Francisco Bay salt ponds, and
- Plant communities ecotonal to the baylands.

The report also constructed profiles for 27 types of estuarine fish and associated invertebrates, including Dungeness crab, pacific herring, and Chinook salmon. The report profiles 15 types of invertebrates, including Franciscan brine shrimp and tiger beetles. Profiles were also constructed for 9 types of amphibians and reptiles (e.g., pacific tree frog, western pond turtle), 13 types of waterfowl and shorebirds (e.g., mallard, northern pintail), and 18 types of bayland birds (e.g., brown pelican, snowy egret, California gull, song sparrow). This report effectively documents the most significant plant and animal species to be considered when setting preservation and restoration goals related to subtidal habitat in the San Francisco Bay.

San Francisco Estuary Project & CALFED. 2005. *State of the estuary: 2005*. Oakland, CA.

This report briefly documents the evolution of the San Francisco Bay and the Delta from the early 1800s through the present, and in doing so frames the discussion of the ecological consequences associated with hydraulic mining, sedimentation, the building of dams, massive pumping of waterways, and the filling of tidal marsh by farmers and developers. It provides vital statistics that can be used to better understand the conditions present within the San Francisco Bay, including the analysis of trends in estuary conditions (e.g., freshwater flows, percent of inflow diverted) and the magnitude of native and invasive species in the San Francisco Estuary since 1980. This report effectively provides background material concerning the animal and plant species existing within the San Francisco Estuary and documents the findings of a conference where numerous stakeholders (e.g., public officials, academics, environmental organizations, public agency technical staff members) framed the discussion concerning the issues faced by planners and scientists attempting to protect and restore habitat in the San Francisco Estuary, including those relating to inadequate funding, threats to aquatic habitat in the estuary, and where best to dedicate resources.

Stewardship Centre for British Columbia. 2005. *Protecting eelgrass.* Vancouver, BC.

This pamphlet highlights some of the benefits of eelgrass, such as protecting coastline and supporting biodiversity, and explains some of the reasons for eelgrass loss. The rest of the pamphlet suggests ways in which shoreline residents and boaters can help to reduce eelgrass loss: minimize disruption to the shoreline, protect a buffer of shoreline vegetation, share or restructure docks so that they do not block sunlight to eelgrass meadows, and avoid dragging kayaks through eelgrass beds. Also provided is a summary of Canada's laws prohibiting projects that could harm fish habitats, which allow for authorization of such projects only as a last recourse and only if the resulting habitat loss can be balanced by a habitat gain elsewhere. The suggestions in this document can be useful for San Francisco Bay residents, visitors, and developers who wish to prevent their own actions from resulting in eelgrass loss, though local laws may be different from the Canadian legal constraints described.

Ulanowicz, R.E. and J.H. Tuttle. 1992. The trophic consequences of oyster stock rehabilitation in Chesapeake Bay. *Estuaries* 15: 298-306.

This study used a quasi-equilibrium, mass action model to predict the effects of increasing oyster (*Crassostrea virginica*) stocks in Chesapeake Bay on water quality, primary production, and species abundance. The model predicts that as oyster stocks increase, phytoplankton productivity, particulate organic carbon, and populations of pelagic microbes, ctenophores, and medusae will decrease. Conversely, benthic primary production, mesozooplankton density, and fish populations are predicted to increase. The researchers suggest that the increased level of water filtration that accompanies enhanced oyster populations will lead to higher water clarity and increased benthic vegetation stocks by mitigating the effects of eutrophication. Furthermore, the decrease in phytoplankton stocks due to predation by oysters should decrease gelatinous zooplankton abundance. Planktivorous fishes would thus face less competition from gelatinous zooplankton and fish stocks would increase.

This study is instructive for the San Francisco Bay Subtidal Habitat Goals project because it describes some of the likely benefits of oyster reef restoration: enhanced water clarity and increases in fish and benthic vegetation stocks. The study's findings (which are focused on the Chesapeake Bay), however, cannot be directly applied to San Francisco Bay due to differences in species present and water chemistry; specifically, the rates of eutrophication due to source inputs and the corresponding algal growth differ between the two bays. While decreased algal density may benefit the Chesapeake, the same may not be true for San Francisco Bay.

United States Environmental Protection Agency National Estuary Program. *About Estuaries.*

This article defines estuaries as coastal bodies of water where freshwater from streams and rivers mixes with oceanic saltwater. It explains the importance of estuaries, with benefits ranging from harboring wildlife, filtering out pollutants, and preventing erosion to serving as excellent locations for recreation and scientific study. Estuaries' significant economic value (especially to the fishing, tourism, and coastal recreation industries) is placed in contrast with the ways in which human activity threatens these natural resources. The report is no more than a summary and does not cite external sources; however, it does provide a clear introduction to the environmental, economic, and aesthetic value of America's estuaries, underscoring the reasons to protect and restore them. This article is relevant to the San Francisco Bay Subtidal Habitat Goals project only insomuch as it provides a general understanding of the values humans place on coastal marine environments.

Wilbur, A.R. Winter 2004-2005. Spotlight on eelgrass: A species and habitat at risk. Boston, MA: Massachusetts Office of Coastal Zone Management.

This article demonstrates eelgrass' role as a keystone species and describes current threats to habitat. The negative effects of the decline that eelgrass suffered in the 1930s are used to justify taking action to prevent a similar decline in the future. Eelgrass provides vast ecological functions as a nursery, refuge, and foraging area for many fish and invertebrates. Detached leaves sink and decompose to sustain detritus feeders, or instead accumulate on beaches, harboring insect and amphipod communities that become important prey for shorebirds. Eelgrass also produces oxygen, absorbs nutrients, and stabilizes sediment. However, this normally-resilient plant is suffering a decline caused by human activities including physical disturbance, degradation of water quality and global warming and sea level rise. Although eelgrass is being monitored by the Massachusetts Department of Environmental Protection and other groups, the article recommends that the state should follow the lead of Australia and the Chesapeake Bay by implementing a conservation plan to protect and restore eelgrass habitat.

This article's description of the major ecological functions of, and human threats to, eelgrass is general enough to apply to the San Francisco Bay as well, but the focus on Massachusetts means that it fails to describe the state of San Francisco Bay's eelgrass habitats or related conservation efforts in any meaningful detail.

Williams, P.B. and P. Faber. 2001. Salt marsh restoration experience in San Francisco Bay. *Journal of Coastal Research*, Special Issue No. 27: 203-311. Royal Palm Beach, FL.

This report provides a brief overview of the decline in salt marshes in the San Francisco Bay Estuary. Over the past 150 years, the area of salt marshes ringing the San Francisco Bay has declined by approximately 90 percent, from its original 220,000 ha, including 80,000 ha of salt marshes. Beginning in 1972, tidal marsh restoration began, initially resulting in the reclamation of some of the lost wetland areas, with approximately 2,000 ha of land reclaimed in the 28 years following the original project at Faber Tract. The San Francisco Bay Area Wetlands Ecosystem Goals Project has recommended restoring an additional 24,000 ha of tidal salt marshes.

This report examines the effectiveness of past approaches for tidal wetland restoration, concluding that restoring physical processes by encouraging rapid natural evolution of sites and other procedures is more effective than the historic practices of planting native and non-native grass species, replicating wetlands with man-made systems, and manipulating wetland areas through control gates and weirs. The authors note that the first attempts at wetland restoration were not successful due to a lack of planning and over-engineered approaches to encouraging natural processes. Numerous lessons learned were presented in this report, including:

- vegetated salt marshes can be restored if prior to breaching, appropriate site templates are designed,
- restoration science remains experimental and continues to evolve,
- restoration takes time and should be viewed in terms of restoring natural processes,
- planting is unnecessary for sites with large seed sources as is present in the San Francisco Bay Estuary, and
- cumulative benefits and impacts need to be monitored and recognized.

The lessons and experience of tidal marsh restoration efforts in the San Francisco Bay Estuary could prove useful to the San Francisco Bay Subtidal Habitat Goals Project.

4.2 Environmental Valuation Theory and Methods

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOAA Panel on Contingent Valuation.

This unpublished work provides a detailed analysis of the contingent valuation (CV) method of environmental valuation, and an extensive set of guidelines for CV survey construction, administration, and analysis. NOAA established a panel of social scientists, chaired by two Nobel laureates, to critically evaluate the validity of CV measures of nonuse values. This panel was established in order to examine the issue concerning whether CV surveys could provide valid economic measures of people's values for environmental resources.

The panel identified several problems with the use of CV in determining non-use values associated with environmental resources. One issue related to the inconsistency of CV results with rational choice. That is, consumers would be expected to respond to price and budget constraints in theoretically valid terms (i.e., price increases reduce quantity demanded); however, rational choice is not always exhibited in CV surveys. Another issue with CV surveys cited by the panel was its propensity to generate implausibly large estimates of willingness to pay. Also, respondents are not faced with realistic and certain budget constraints. Establishing the extent of the market (i.e., statewide, regional, national) was also deemed problematic. Respondents were also viewed as having a "warm glow" concerning the environmental program they were asked to evaluate, leading to an overstatement of its worth. Finally, respondents of CV surveys were found to alter their decisions based on the manner in which information was presented to them. Based on the panel's evaluation of these issues, they provided recommendations for addressing these issues, including the design of survey techniques.

This report is relevant to the San Francisco Subtidal Habitat Goals Project in that it defines the issues relating to the CV techniques, which could be used to evaluate the non-market values associated with San Francisco Bay subtidal habitat preservation, and documents methods to correct for shortcomings inherent in the CV method.

Barbier, E.B., M. Acreman, D. Knowler. 1997. *Economic Valuation of Wetlands: A Guide for Policy Makers and Planners*. Gland, Switzerland: Ramsar Convention Bureau.

This book provides guidance to policymakers and planners when conducting an economic valuation of wetland areas. The authors argue that wetlands have been historically undervalued because many of the ecological services they provide (e.g., climate regulation, water filtration, amenity values) are not bought and sold in the marketplace. The book outlines total valuation techniques used to capture the full range of environmental services provided by wetlands, including market, non-market and non-use values. The book presents a three stage approach for total valuation: 1) determining the overall objective or problem and choosing the correct economic assessment approach, 2) defining the scope of the problem or project, and 3) selecting a valuation technique and collecting data required to perform the analysis.

The book highlights several environmental valuation case studies, including the valuation of coastal wetlands in the southeastern U.S. In this case study, the authors use travel cost, contingent valuation, and direct valuation methods to quantify the economic impact of coastal wetlands in Louisiana. Environmental services provided by the coastal wetland include the commercial fishery, trapping, recreation, and storm protection. These services were valued at $2,429 per acre in present value terms (1983 dollars), with nearly 80 percent of the value being attributed to storm protection. In 2006 dollars, the value of these environmental services would be $4,907.

This book is useful within the context of the San Francisco Bay Subtidal Habitat Goals Project in that it presents a comprehensive approach to conducting the total economic valuation of wetlands and demonstrates that non-use and non-market benefits often generate a considerable amount of the total value. This lesson should be considered when assessing the economic value of environmental services in the San Francisco Bay.

Cole, R., J. Loomis, T. Feather, and D. Capan. 1996. Linkages between Environmental Outputs and Human Services. U.S. Army Corps of Engineers. Alexandria, VA.

This report identifies relevant use and nonuse values associated with environmental projects and also improves the linkages between environmental output measures and necessary inputs for socioeconomic evaluation. It answers the question: What are the possible changes in the ecosystem that may result from USACE environmental mitigation and restoration projects, and what outputs and services do these changes provide society?

This report examines ecosystem processes from the basis of material and energy flows. It also examines methods that can be used to simulate market pricing of environmental resources, including the use of simulated demand curves for recreation, simulated markets using the CV method, and replacement cost analysis. Further, it examines how ecological and economic valuation in tandem can be an effective combined approach to making public policy decisions.

This report is useful to the San Francisco Subtidal Habitat Goals Project in that it presents and examines methods for valuing environmental resources through analysis of market prices and the establishment of surrogate markets, which can be used as a proxy to estimate economic values.

Farber, S., R. Costanza, and M. Wilson. 2002. Economic and ecological concepts for valuing ecosystem service. *Ecological Impacts.* 41: 375-392.

This report examines the theory underpinning environmental valuation, including labor theory, how goods are valued, how an individual's willingness to pay for a non-market resource can be used to establish value, and the difference between the willingness to pay and willingness to accept measures. This report also examines the intersection between ecological and economic value, including the non-linearity between ecosystem impacts and economic outcomes. That is, changes to an ecosystem can sometimes be dramatic and irreversible. Thus, the marginal costs of ecosystem damage can often be significantly non-linear. The paper discusses critical thresholds or tipping points where ecological damage can have dramatic economic consequences. This paper also discusses conflicts between economic and ecological values, noting that the manner in which economists value environmental resources (i.e., aggregation of the value that humans place on the resources) does not properly address the intrinsic value of nature, the values that other species place on the environment, the importance of biodiversity, and critical thresholds and threats to irreversibility. Finally, the paper presents overviews of numerous environmental valuation methods, including the avoided cost method (the costs that society would incur in the absence of these natural resources), replacement cost method, factor income (natural resource impacts on income), the travel cost method, hedonic pricing method, and CV method.

This article is useful to the San Francisco Subtidal Habitat Goals Project in that it presents an overview of the theoretical underpinning of environmental valuation, examines issues that should be accounted for when preparing environmental valuation studies, and discusses methods used to value environmental resources.

Goodman, S., W. Seabrooke, and S. Jaffry. Considering Conservation Value in Economic Appraisals of Coastal Resources. *Journal of Environmental Planning and Management.* v41, n3:313-336.

This paper presents the findings of a contingent valuation survey designed to measure non-use values for the natural coastal environment. This was attempted through evaluating public and scientific values of conservation quality. The results suggest that public perceptions of conservation quality are multidimensional, and that it may be difficult for some individuals to express their preferences for the conservation value of natural resources in monetary terms. Additionally, public and scientific judgments differ concerning some of the physical attributes imparting conservation value. These findings have important implications for efforts to consider environmental quality in land and coastal use decisions, including those in San Francisco Bay.

Harrington, K. and T. Feather. 1996. Evaluation of Environmental Investments Procedures: Interim Overview Manual. U.S. Army Corps of Engineers. Alexandria, VA.

This report is intended to serve as a reference guide for Corps environmental planning. It is a procedures manual that synthesizes the many products of the Evaluation of Environmental Investments Research Program (EEIRP) and show how they can support environmental planning, which is conducted in accordance with the six-step planning process. It provides an overview of Corps environmental planning and identifies EEIRP products that support specific planning activities.

This report supports the San Francisco Subtidal Habitat Goals Project by serving as a reference document for environmental planners, highlighting EEIRP products that can be applied to environmental projects. The EEIRP presents a number of tools designed to assist environmental planners, demonstrates how to integrate these tools and techniques into existing environmental programs, and documents how to implement these tools and techniques in a manner that will address ecological and economic issues.

Hartwick, J. and N. Olewiler. 1998. *The Economics of Natural Resource Use: Second Edition.* Addison Wesley Longman. New York, NY.

This book provides an extensive examination of economic concepts used to analyze natural resource use (welfare economics, property rights and time preference), sustainability and natural resource scarcity, valuation of land and water, regulation of the fishery, environmental externalities and pollution, non-renewable and renewable resource analysis, dynamic fishery models and the economics of sustainability. It provides the basis for identifying and valuing the economic benefits associated with aquatic ecosystem restoration but does not directly address subtidal habitat restoration or consider the conditions present at San Francisco Bay.

Turner, R.K., Jeroen C.J.M van den Bergh, Tore Soderqvist, Aat Barendregt, Jan van der Straaten, Edward Maltby, Ekko C. van Ierland. 2000. The Values of Wetlands: Landscape and Institutional Perspectives. *Ecological Economics* 35 (2000) 7-23.

This special report highlights the causes of wetland degradation and loss (e.g., port expansion, urban and industrial sprawl, urban and industrial pollution, hydrology changes, development, gas drilling and exploration) and outlines a combined ecological and economic approach to environmental valuation of wetlands. It identifies the key stakeholders in wetland function and valuation, including direct users, direct exploiters of natural resources, agricultural producers, water abstractors, developers of human settlements close to wetlands, indirect users, nature conservation and amenity groups, and non users. It establishes a framework for conducting combined ecological and economic analyses within the context of institutional realities. It establishes a more complex multi-criteria decision analysis tool that considers both qualitative (classification of wetlands and comparison with similar sites) and quantitative tools, including input-output models, nonlinear dynamic systems models, optimization models, land use models linked to geographical information systems (GIS), and mixed models. The combined approach proposed within this paper that considers both qualitative ecological benefits, and the total valuation of a broad range of economic benefits is valuable to the case in San Francisco Bay. Further, the concepts presented within this report consider the institutional settings in which decisions are made. This report does not, however, address subtidal habitat restoration or preservation activities, and the models it discusses are presented within a theoretical framework.

4.3 Environmental Valuation Studies

Beaumont, N., Townsend, S, Mangi, M, Austen, C. 2006. *Marine Biodiversity: An Economic Valuation.* Plymouth Marine Laboratory, Plymouth UK.

This report employs a goods and services approach to valuing biodiversity in marine habitat in the United Kingdom (UK). The goods and services examined within the report include: production services, regulating service or the benefits obtained through regulation of ecosystem processes, cultural services, and supporting services that are required for production of other ecosystems. The goods and services targeted for analysis were obtained through a stakeholder workshop. The authors rely on the findings of previous research to monetize the value of the goods and services identified in the workshop. Food provision is valued at £513 million. Marine organisms as raw materials were valued at £81.5 million. Gas and climate regulation realized through carbon sequestration by phytoplankton was valued at between £420 million and £8.47 billion. Disturbance prevention through flood and storm protection offered through the wave dampening impact of biogenic structures was valued at £17 to £32 million. The bioremediation of waste generated through storage, dilution, transformation, detoxification, and burial was valued at £1,098.81 - £1,236.54 per acre, measured over 30 years and discounted at 9 percent. Education and research values were estimated at £317 million. Leisure and recreation values were estimated at £11.77 billion. Non-use values (bequest and existence) were valued at £0.5 million to £1.1 billion using the contingent valuation method. Nutrient cycling achieved through the storage, cycling, and maintenance of nutrients by marine bio organisms was viewed as nearly invaluable due to its ability to sustain marine habitat. With that noted, the nutrient cycling function was estimated using the replacement cost method at £800 billion to £2.3 trillion.

This report demonstrates the broad range of values associated with marine biodiversity. The lessons from the report regarding the value of biodiversity and the types of goods and services provided by marine habitat can be applied in San Francisco Bay. The study, however, does not represent primary research and, instead, relies on a series of reports prepared by other authors. The authors of this report did not perform a meta analysis in order to systematically compare numerous reports prepared in each category of good and service. Further, the values presented in this report cannot be applied in San Francisco Bay due to the different scale, water conditions, and animal species present in the marine habitat studied in the UK.

Farber, S. 1988. The Value of Coastal Wetlands for Recreation: An Application of Travel Cost and Contingent Valuation Methodologies. *Journal of Environmental Management.* 26:299-312.

This study reports on a survey of Louisiana coastal wetlands recreational users administered for the purpose of estimating wetlands recreational value. The primary technique was the travel cost method. The value estimates obtained using this method were of similar magnitude to those obtained using a contingent valuation question in the surveys. Depending on the time cost value used, the average capitalized value ranged from $36 to $111 per acre. This study provides an overview of the travel cost method of environmental valuation and provides an application of its use. This study is relevant to the subtidal habitat restoration goals of San Francisco Bay because it provides an assessment of the values that consumers of coastal wetlands place on recreational value and demonstrates methods for determining these values. These values, however, are not directly relevant to San Francisco Bay or to the benefits of subtidal habitat restoration. Further, the travel cost method does not fully capture the value that individuals place on environmental resources. That is, the method captures the marginal additional cost the consumer is willing to pay to travel to the location but does not capture the benefits associated with existence, bequest and other indirect values.

Fischer, A.C., M. Hannemann, J. Harte, A. Home, G. Ellis, and D. Von Hippel. October 1986. *Economic Valuation of aquatic ecosystems*. *Final report to the U.S. EPA, Cooperative Agreement No. 811847.* Berkeley, CA.

This report identifies and categorizes the direct and indirect services provided by aquatic ecosystems. The goods and services provided by aquatic ecosystems that are used as inputs in a production process include: fisheries products (e.g., fish, shellfish, crustacea, kelp, aquatic mammals), hydroelectric power, transportation, treatment of human wastes, water purification, treatment of industrial wastes, drinking water storage, and information produced through scientific research. The authors also categorize goods and services that are considered a final good, including: direct recreational use of water (e.g., boating, rafting, sailing, canoeing, swimming), recreational use of aquatic ecosystems (e.g., fishing, waterfowl hunting, collection of shellfish and crustacea), waterfront recreational activities (e.g., hiking, sunbathing, bird watching, recreational sports), amenities (e.g., scenic values, modulation of local climates, education values, psychological benefit of pristine areas), and future goods and services (e.g., preservation of genetic information and preservation of wild areas for future generations). The authors also examine valuation techniques as applied to each category of benefit. For valuing the environment as an input into the production process, such as the commercial harvesting of fish, the authors recommend examining how enhanced environmental quality could result in a shift in supply curves. When applied to fish harvests, enhanced water quality resulting in improved habitat for fish would reduce the cost of harvesting fish. For valuing the recreation and amenic values of aquatic habitats, the authors recommend employing the travel cost and hedonic pricing methods, respectively. The authors recommend using the contingent valuation method for valuing existence and bequest values.

This report is useful to valuing subtidal habitat restoration benefits in San Francisco Bay because it provides an overview of the benefits typically associated with improved environmental conditions in aquatic ecosystems, and provides a framework for categorizing and valuing the economic benefits associated with environmental enhancement. Many of the benefits outlined within the report, however, are not directly applicable to San Francisco Bay and the analysis of the valuation methods provided in the report, which was drafted more than 20 years ago, is now somewhat dated.

Grigalunas, T. and Opaluch, J. 2002. *Proposed Delaware River Channel Deepening Project: Review and Critique of Economic Analyses.* Prepared for Wetlands and Subaqueous Lands Section, Department of Natural Resources and Environmental Control.

The purpose of this report is to present a review and assessment of the numerous economic studies completed in support of the proposed Delaware River channel deepening project. The study's authors explored the concepts used by the studies, the methods employed, the data underpinning each study, the reasonableness of assumptions used, and the soundness of the conclusions drawn.

Through its analysis of previously conducted studies, this report identifies numerous marine benefits and costs associated with dredging projects, including enhanced shipping opportunities, wetland restoration and protection, use of dredged sand for beach renourishment, water quality issues, groundwater contamination, and impacts on fish and wildlife habitat.

This study stresses the importance on non-market costs of dredging associated with habitat destruction, resulting impacts on wildlife, and those impacts on eco tourism and other indirect benefits tied to existence and bequest economic values. The study notes that these benefits are often ignored or significantly understated.

The study examines the outcome of an input-output analysis associated with the dredging project's impact on the Delaware economy. This critique notes that this study provides little useful information to public policy markers in that input-output analysis includes multiplier effects associated with economic activity and does not properly capture the costs of dredging from a regional or societal perspective. Thus, the usefulness of input-output analysis is limited.

This study is useful to the San Francisco Subtidal Habitat Goals Project in that it identifies and examines the pitfalls associated with economic analyses conducted in support of marine projects. Lessons learned through this assessment include: a) limiting the reliance of public policy decisions on input-output analysis, b) consider assumptions in the economic analysis regarding markets in a non-static manner while accounting for current trends, c) do not examine impacts in a vacuum instead considering ecosystem benefits, d) completing complex economic analyses of environmental projects is extremely difficult and analysis results are not likely to receive unanimous agreement, e) historic analysis of environmental project costs suggest that these costs are almost always understated in economic analyses, and f) cost should be examined from a national (not just regional) perspective.

Henderson, J. and O'Neil J. 2003. *Economic values associated with construction of oyster reefs by the Corps of Engineers.* EMRRP Technical Notes Collection (ERDC TN-EMRRP-ER-01), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

The authors of this technical note examine a broad spectrum of benefits that accrue as a result of oyster reef restoration, and cite recent literature that quantifies the economic impacts associated with oyster reef restoration. The environmental services of oyster reefs reviewed under this study include oyster production (restoration efforts in Virginia have netted positive returns on investment in 5 to 14 years), oyster reef impacts on harvest of fish and crabs (structure and water quality improvements provided by oyster reefs enhanced fish catches such that the value of the catch exceeded the value of oyster production in North Carolina's Ocracoke Island), recreation (water quality benefits), increased recreational fishing (valued at $2.3 million in Chesapeake Bay), boating ($8 million tied to water quality benefits of oysters in Chesapeake Bay), beach use and swimming (valued at $7.20 to $23.39 per person for a 10 percent reduction in oil and bacteria), erosion protection and stabilization (reduced need to construct structural and non-structural management measures for protecting shorelines), and enhanced habitat for benthic organisms. The benefits of oyster reefs extend far beyond the commercial harvest of oysters, though the commercial harvest did net positive returns on the initial cost of establishing the oyster reefs. For San Francisco Bay, the oyster reefs may or may not generate positive returns on investment from the standpoint of the commercial oyster harvest but experience from around the U.S. suggests that the indirect benefits could easily surpass the direct harvest benefits.

Hicks, R.L. May 2004. Recreational fishing and the benefits of oyster reef restoration in Chesapeake Bay. College of William & Mary. Williamsburg, Virginia.

This study examines the value that recreational fisherman place on improved trip quality when improved catch rates are realized through the water filtration function and enhanced water quality created by oyster reefs in the Chesapeake Bay. The study relies on surveys of recreational anglers and employs a random utility model (RUM) to examine the anglers' willingness to pay for enhanced catch rates by examining the costs they incur when traveling to better fishing locations. Further, a model was developed to assess the extent to which enhanced catch could be related back to the presence of hard oyster bottom at the fishing site. Other variables used to model catch rates included the fisherman's years of experience, the log of hours fished, and historic site catch rates. The findings of the study suggest that: a) sites with relatively high concentrations of oyster bottom did correlate with higher catch rates, b) higher catch rates increase the probability that a fishing site will be chosen, and c) anglers would be willing to pay $1.32 per trip to realize the restoration benefits that result in higher catch rates modeled by the authors.

This study is instructive for the San Francisco Bay Subtidal Habitat Goals project because it outlines two indirect benefits associated with oyster reef restoration: enhanced water quality and improved fish catch rates. These benefits would be realized even if oyster harvests were not enhanced through restoration efforts. Further, the study demonstrates how these values translate into enhanced willingness to pay on the part of recreational fisherman. The study's findings (which are focused on the Chesapeake Bay fishery), however, cannot be directly applied in San Francisco Bay due to differences in water chemistry, local incomes, preferences of local recreational fisherman, presence of alternative fishing options, and the composition and quantity of fish available to anglers in the San Francisco Bay Area.

Kazmierczak, R.F. 2001a. *Economic linkages between coastal wetlands and water quality: a review of value estimates reported in the published literature. Staff paper 2001-02*. Baton Rouge, LA: Natural Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Centre.

This report documents the findings of 12 studies published in peer-reviewed journals that focus on the economic value associated with the water quality benefits of coastal wetlands. The author notes that the findings of the reviewed studies suggest that historically, private economic gains from wetland conversion have been emphasized over the largely non-market environmental services (e.g., water quality) associated with wetland habitat. The reviewed studies present a broad spectrum of estimated water quality benefits from coastal wetlands, ranging from $2.85 per acre per year to $5,763.80 per acre per year, with mean and median values of $825.04 per acre per year and $210.93 per acre per year, respectively. The large variance between the mean and median values was due to the non-normal distribution of the findings and the presence of significant outliers. Removing outliers results in a new mean and median value of $323.05 per acre per year and $178.64 per acre per year, respectively. Studies using the contingent valuation method to determine the willingness to pay for the water quality benefits offered by coastal wetlands generated per respondent benefits estimates ranging from $41.71 to $101.81, with mean and median values of $66.59 and $63.19, respectively. The wide variation in benefits estimates reflects the importance of the type of water quality service provided, geographic location, and whether the benefits were attributed to single or much larger wetland areas. The studies reviewed by the author provided a few lessons relevant to restoration efforts in San Francisco Bay. First, water quality benefits of coastal wetlands are significant but largely not considered within the marketplace and are undervalued by society. Thus, more thoughtful analysis is required to understand these benefits. Second, water quality benefits are largely tied to the assimilative capacity of the wetland area under consideration. As larger concentration of pollutants from industrial or human waste accumulates, nutrient cycling and wastewater assimilation benefits erode. Last, water quality benefits vary widely based on a number of factors outlined previously. Thus, the findings of these studies cannot be directly applied to the San Francisco Estuary.

Kazmierczak, R.F. 2001b. *Economic linkages between coastal wetlands and hunting and fishing: a review of value estimates reported in the published literature. Staff paper 2001-03*. Baton Rouge, LA: Natural Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Centre.

This report examines the findings of 12 studies linking the presence of coastal wetlands with hunting and fishing opportunities. The author selected studies using methods that value wetlands within the neoclassical framework of economics, focusing on studies that used the travel cost method, contingent valuation method, the net factor income method, and the hedonic pricing method. The results of the studies reviewed by the author suggest that results vary widely based on the type of hunting activity considered, the target species of hunting activities, geographic location, and the measurement technique. For single-target hunting (e.g., oysters), the value of wetlands across the studies ranged from $1.05 per acre per year to $663.74 per acre per year, with a mean of $113.95 per acre per year and a median of $10.03 per acre per year. When commercial and recreational hunting and fishing are combined, values increase to between $16.76 per acre per year and $1,025.03 per acre per year, respectively. Willingness to pay studies that focus on stated preferences without empirical data to support the conclusions produce a tighter range, with hunting and fishing at wetlands valued at $83.99 to $616.46 per respondent.

The findings of these studies suggest that the values that humans place on wetlands is highly variable and dependent upon numerous factors, including: the target species of hunting activities, geographic location, and the measurement technique. From the standpoint of valuing subtidal preservation and restoration benefits in San Francisco Bay, the findings of these studies suggest that commercial and recreational fishing and hunting opportunities may be highly prized, but the value placed on hunting and fishing is highly variable and it would be difficult to apply the findings of this study to San Francisco Bay without consideration of the variables driving individual estimates.

Leeworthy, V. and J. Bowker. 1997. Nonmarket Economic User Values of the Florida Keys / Key West. National Oceanic and Atmospheric Administration. Silver Spring, MD.

This report provides estimates of the nonmarket economic user values for recreating visitors to the Florida Keys/Key West that participated in natural resource-based activities. It is the fifth in a series that is being developed as part of the project entitled "Linking the Economy and Environment of the Florida Keys/Florida Bay." The overall project objectives are to 1) estimate the market and nonmarket economic values of recreation/tourism uses of the marine resources of the Florida Keys/Florida Bay ecosystem; 2) provide a practical demonstration of how market and nonmarket economic values of an ecosystem can be considered an integral component of the economy of a region when formulating sustainable development objectives and policies; and 3) foster cooperative management processes.

The study relied on the travel cost method relating the number of trips made per year and the per-trip value cost to socioeconomic factors, such as age, race and income level to estimate how tourists would respond to changes in prices associated with travel to the Florida Keys. The weighted average travel costs paid by all summer and non-summer visitors were $740 and $561, respectively. The total annual value that tourists placed on travel to the Florida Keys was estimated at $1.2 billion and the total non-market asset value of the resource, as represented by the future stream of benefits realized through trips to the Florida Keys, totaled $24.1 billion using a 5 percent discount rate and $40.2 billion when a 3 percent discount rate was applied.

This report demonstrates that in many cases, the non-market values associated with coastal habitat restoration are significant and it uses methods that could be applied in the San Francisco Bay. Further, it provides some indication of the enormity of the value that travelers place on the resource, and presents a method for valuing non-market environmental resource benefits.

Lipton, D., K. Wellman, I. Sheifer, and R. Weiher. 1995. Economic Valuation of Coastal Resources: A handbook for Coastal Resource Policymakers. NOAA Coastal Ocean Program Decision Analysis Series No. 5.

This report is the outcome of COP-sponsored environmental valuation workshops. The handbook is a blend of writings by experts in the field specifically tailored for the management community. The report provides a background on the history and legislative mandates for environmental valuation, including those relating to wetlands permitting, nonpoint source pollution control, fisheries management, and other environmental regulations.

The report outlines the theories underlying the economics of environmental valuation, including consumer and produce surplus, how society uses environmental resources as an input into production processes, nonuse values, and the manner in which humans value natural resources can be used to derived value. This report documents numerous economic tools for use in coastal management decisionmaking, including benefit-cost analysis, cost-effectiveness analysis, natural resource damage assessment, and economic impact analysis. It also documents several techniques for measuring the direct market value of natural resources (constructing demand curves and measuring consumer surplus) and the non-market values associated with natural resources (e.g., travel cost model, random utility models, hedonic pricing, contingent valuation method, benefit transfer).

This report also presents several case studies where these methods are used. The case studies in this report include: oyster restoration in Chesapeake Bay, salmon habitat restoration in Alaska, the Florida Keys National Marine Sanctuary, Coastal Barrier Island preservation in North Carolina, artificial reef program in Lake Erie, wetland restoration in Louisiana, and nonpoint source pollution in California.

This report is useful to the San Francisco Bay Subtidal Habitat Goals Project in that it provides historical context for environmental valuation in the U.S., methods for valuing natural resources, and numerous case studies documenting how to apply the most common environmental valuation techniques.

Mann, R. and M. Whittmann. March 2004. *Aquatic Pesticide Monitoring Program: Determining economic impacts of aquatic plant management in California waters*. Oakland, CA: San Francisco Estuary Institute.

This report presents a methodology for examining the economics of aquatic plant management. It presents three approaches for weighing the benefits of various aquatic plant management plans, ranging from a cost-effectiveness approach where only costs are weighed for different plans that meet a specified objective to full benefit-cost analysis. The report provides detailed steps for conducting the assessments, including specifying management alternatives, conducting feasibility tests, estimating the cost of each management alternative, describing damage costs, and arranging data into a period of analysis in order to compare costs. This report could be useful to planners considering alternative aquatic plan management alternatives in San Francisco Bay.

Opaluch, J., Grigalunas, T., Diamantides, J., Mazzotta, M., and Johnson R. 1999. Recreational and resource economic values for the Peconic Estuary System. Prepared for the Peconic Estuary Program, Suffolk County Department of Health Services.

This study deploys four methods to measure the non-market benefits of the Peconic Estuary System. The Peconic Estuary System and it natural assets (e.g., beaches, wetlands, parks, watershed lands) generate both market benefits that can be directly measured in market transactions and non-market benefits that are not directly measurable through market interactions such as those tied to property values; outdoor recreational uses; economic value of eelgrass, intertidal marshes, and sand/mud bottoms; and the desire for local residents and visitors to preserve the amenic value of the estuary.

The research team developed a property value model to examine the impact of proximity to open space and other environmental attributes on property values and found that parcels of land near open spaces were, on average, 12.83 percent more valuable per acre than similar parcels located elsewhere.

A travel cost model was used to examine individuals' willingness to pay in order to enjoy the swimming, boating, fishing, and bird watching benefits of the estuary. The travel cost model examined how much visitors pay to travel to the location. Travel cost represents the minimum value that these individuals place on each trip. The findings of the travel cost survey demonstrates that recreational users valued fishing at $22.4 million, viewing birds and wildlife at $49.3 million, boating at $18.1 million, and swimming at $12.1 million. These are annual values in 1995 dollars.

The wetland productivity values associated with eelgrass, saltmarsh and intertidal mud bottoms were valued for the habitat and food web they provide for fish, shell fish, waterfowl and birds. The research team developed a food web model to determine the impacts of these natural assets on the productivity of the local fishery and viewing values for birds. The results of the analysis estimate the per acre benefits of eelgrass at $12,400, salt marshes at $4,300, and mudflats at $786 over 25 years using a 7 percent discount rate.

A survey was administered to 968 residents and second homeowners, and the results of the survey found that the residents of the nearest population center valued the per acre benefits associated with undeveloped land at $14,000, unpolluted shellfish grounds at $30,000, salt marshes at $56,700, eelgrass at $70,000, and $74,500 for farmland, using a 25-year time horizon and 7 percent discount rate.

This study is relevant to the Subtidal Habitat Goals Project in that it examines the non-market benefits associated with marine resources similar to those found in San Francisco Bay and presents methods for estimating their values.

Perkins-Visser, E., T. G. Wolcott, and D.L. Wolcott. 1996. Nursery role of seagrass beds: Growth of juvenile blue crabs (*Callinectes sapidus* Rathbun). *Journal of Experimental Marine Biology and Ecology* 198: 155-173.

This study examined the benefits, other than protection from predation, that accrue to blue crabs (*Callinectus sapidus* Rathbun) by inhabiting seagrass beds (*Zostera marina* L.) in the lower York River, Virginia. Crab survival and growth rates were compared between crabs in enclosures within seagrass beds and those in enclosures in un-vegetated areas. Results showed that young blue crabs attained a significantly larger carapace volume and higher rates of survival in the enclosures within the beds than in un-vegetated enclosures. Because predators were excluded from all enclosures, the greater benefits obtained by crabs living within vegetated areas were independent of reduced predation. However, the precise mechanism for enhanced survival and growth rates in vegetated enclosures was not determined.

This study has relevance for the San Francisco Bay Subtidal Habitat Goals project because it documents the benefits that accrue to a crab species from the availability of seagrass habitat. However, the results cannot be directly applied to San Francisco Bay. The water parameters and species present differ between the lower York River and San Francisco Bay. In addition, the study did not determine the mechanism that enhanced survival and growth rates for blue crabs inhabiting vegetated areas, so it is unknown whether the same mechanism would be present between San Francisco Bay seagrass beds and crab species.

Posey, M.H., T.D. Alphin, H. Harwell, and B. Noller. 2004. Studies of oyster reefs in New Hanover County tidal creeks. In: *Environmental Quality of Wilmington and New Hanover County Watersheds: 2002-2003*, eds. M.A. Mallin, L.B. Cahoon, M.H. Posey, V.L. Johnson, T.D. Alphin, D.C. Parsons, and J.F. Merritt. Wilmington, NC: Center for Marine Science, University of North Carolina at Wilmington.

This study examined the structural complexity, uniformity, and oyster density of oyster reefs within tidal creeks in New Hanover County, North Carolina. The results, which discuss the specific characteristics (such as the amount of sedimentation present and the density of live oysters) of the oyster reefs in those particular tidal creeks, are not applicable to the San Francisco Bay Subtidal Habitat Goals project. However, the background of the report provides a useful summary of the existing literature regarding the role of oyster reefs as providers of refuge and foraging area, crucial habitat, and water filtration.

Oyster reefs provide a structural refuge from predation for small fish and invertebrates. Crab, fish, and shrimp species utilize the living and broken oyster shells as places to hide. Predators also benefit from the oyster reefs; fish species such as striped bass, bluefish, and weakfish use subtidal reefs as foraging sites. Transient species benefit by using subtidal oyster reefs to travel between marsh, seagrass, and other habitats. In addition, the hard substrate created by the reefs can serve as a place of attachment for sponges. Oyster reefs contain the nitrogen-rich feces of oysters and enrich the local sediment, which may enhance the growth of submerged vegetation. At the same time, oyster reefs improve water quality by removing particulate matter from the water column.

Resources Agency for California. 1995. *California's Ocean Resources: An Agenda for the Future.* Sacramento, California.

This report identifies the conservation mission of the California Ocean Resources Management Program and outlines key goals for realizing the mission. The report also estimates the economic impacts, including multiplier effects, of seven key ocean-dependent industries in California. The report examines coastal tourism, estimating that it contributes $9.9 billion annually to the state economy. The report attributes $6.0 billion annually to water transportation, ship / boat building and repair. It also identifies commercial fishing, mariculture, and kelp harvesting as key ocean-dependent industries, and attributes $554 million in annual economic activity to them. Finally, offshore oil and gas and coastal mineral production was estimated to contribute $852 million to California's economy annually. The report is important as it relates to subtidal habitat goals in San Francisco Bay because it demonstrates the magnitude of the benefits associated with ocean-dependent industries in California. This study, however, does not examine the full range of environmental services provided by coastal areas and oceans, including non-use values, and it limits its analysis to seven of the most significant industries to the exclusion of many others.

Shorney, B. 2004. Research into the economic contribution of sea angling. Commissioned by the Economics and Statistics Group of DEFRA and carried out by Drew Associates Ltd.

This report examines the economic contribution of sea angling as measured through an assessment of consumer surplus identified through surveys distributed to households, anglers, and businesses providing services to anglers in four case study locations in England – Weymouth, Whitby, Hastings, and Anglessey.

The annual consumer surplus for sea anglers was found to equal £381 per shore angler and £886 per own boat anglers. The annual aggregate consumer surplus estimate was £594 million. The survey found that anglers were willing to pay more for larger species and also for greater diversity in the catch. Spending by anglers translated into 18,889 jobs and £71 million in suppliers' income. Spending by anglers was estimated at approximately 1 percent of total income from tourism.

This study is useful to the San Francisco Bay Subtidal Habitat Goals project in that it estimates the value of sea angling, examines the factors that contribute to that value, and presents a method for estimating the consumer surplus enjoyed by sea anglers.

Soniat, T. M., C. M. Finelli, et al. 2004. Vertical structure and predator refuge mediate oyster reef development and community dynamics. *Journal of Experimental Marine Biology and Ecology* 310(2): 163-182.

The authors demonstrate in this article that in addition to their economic value, oysters supply a number of critical ecosystem services such as controlling eutrophication, recycling nutrients, and providing habitat for many invertebrates and fishes. Thus, the maintenance and restoration of oyster reefs is vital for properly functioning estuarine ecosystems. The authors hypothesized that spatially heterogeneous and refuge-rich reefs are superior habitats for oysters and associated invertebrates and fishes. If this is the case, then vertical structure and refuge should be included in the design of newly constructed oyster reefs and conserved in existing reefs.

The findings indicate the primary importance of settlement surface orientation (horizontal vs. vertical) over predation refuge when predators are absent. In contrast, two field recruitment studies indicated that the importance of surface orientation relative to predation refuge might depend on sedimentation rates. When sedimentation was low, the number of oysters and barnacles (live, dead, and total) was significantly higher on no-refuge models than on refuge models. This leads to a conclusion that although fewer oysters may settle on refuge shells, those that do have a higher rate of survival. In a year when sedimentation was high, recruitment and survival of oysters, barnacles, and bryozoans was higher on vertical models regardless of refuge. In aggregate, the results of the analysis indicate that both vertical orientation and predation refuge are critical to the early development of the oyster reef community and should be included in restoration designs.

Thibodeau, R.R. and B.D. Ostro. 1981. An economic analysis of wetland protection. *Journal of Environmental Management* 12: 19-30.

This article examines the economic benefits of wetland areas (marsh and wooded swamps) in the Charles River Basin in Massachusetts. The articles notes that historically, wetland areas have been drained and filled nearly indiscriminately as housing demands have strained the supply of land suitable for development. As the demand for housing has expanded in many areas surrounding wetlands across the U.S., development decisions were largely made without consideration of the broad range of economic benefits derived from the wetlands being drained and filled.

The study examines the benefits derived from wetland protection in the Charles River Basin through an analysis of broad categories of benefits, including: increases in land value, pollution reduction, water supply, recreation and aesthetics, preservation and research, vicarious consumption and option demand, and undiscovered benefits.

The impacts of wetland areas on land value were examined from the standpoint of both flood control and privacy values for land abutting the wetland areas. Using Corps of Engineer estimates of flood damage, the benefits associated with flood protection were estimated at $33,000 per acre of wetland in present value terms. Note that this article was published in 1981. Thus, these estimates would be significantly higher today. Using a combined survey and econometric approach for examining land value near wetland areas, the impact of wetland areas on land values was estimated at between $150 and $480 per acre.

The value of wetlands for reducing pollution and removing nutrients and biological oxygen demand from sewage were estimated based on the costs to construct and maintain water treatment plants, which was estimated at $16,960 per acre. The study also examines the value of wetlands derived from municipal wells in Massachusetts, which are typically located in or adjacent to wetlands. Using a study conducted in 1973, the average cost of obtaining well water in Atlantic States was estimated at 100,000 gallons per day at a cost of $7.44. When comparing the estimated cost of well water to that of the Metropolitan District Commissions, which cost approximately $24 per 100,000 gallons, the benefit was calculated based on the difference ($16.56 per day) between the two sources. The water supply benefit was estimated at $6,044 per year or $100,730 per acre over the study time horizon.

Recreation and aesthetic values were evaluated. These values included small game hunting, waterfowl hunting, trout fishing, warm water fishing, and nature study. The study relied on surveys distributed by the Fish and Wildlife service to determine how much hunters, birdwatchers, fishermen, and other eco tourists would be willing to pay to preserve wetland acreage. The study also computes a demand curve to determine the consumer surplus experienced by current eco tourists. The recreation and aesthetic values were estimated at $2,145 - $38,469 per acre.

Based on the findings outlined above, the benefit associated with one acre of Charles River Wetland in 1981 was estimated at $153,535 - $190,009. This estimate did not include any benefits associated with preservation and research, vicarious consumption, or undiscovered benefits. These benefits were examined qualitatively within the study.

This study is useful within the context of the San Francisco Bay Goals Project in that it documents numerous classes of environmental benefits (e.g., increases in land value, pollution reduction, water supply, recreation and aesthetics, preservation and research, vicarious consumption and option demand, and undiscovered benefits) and explores several techniques used to quantify these benefits, including contingent valuation, hedonic pricing, and construction of demand curves).

Wiley, P. August 2003. *Valuing our National Marine Sanctuaries.* Prepared for the National Oceanic and Atmospheric Administration. Silver Spring, Maryland.

This report identifies and characterizes the 13 National Marine Sanctuaries in the U.S. that collectively protect more than 18 thousand square miles of ocean and coasts. The report documents the missions of the sanctuaries, ranging from the protection of coral reef ecosystems and kelp forests to protection of the U.S.S. Monitor, which was sunk off the coast of North Carolina during the U.S. Civil War. It documents the environmental services provided by coastal areas, including:

- market values, as determined through the impact of coastal resources on sales, employment, and income;
- non-market values, including direct use, indirect use, option, and quasi-action; and
- non-use values, including bequest and existence values.

This report also examines the link between environmental quality and resource values, and provides numerous methodologies for valuing those benefits, including the travel cost method for valuing recreational values, the contingent valuation method for valuing recreation and existence values, the hedonic price method for valuing amenity and other values that impact housing and commercial development prices, benefit transfer method that uses previous studies' estimates or models from similar sites and applies them to the current site under evaluation, and the opportunity cost method that evaluates the cost of a resource through the value of its next most preferred use.

This report provides a framework for valuing marine habitat in a manner that could be applied in San Francisco Bay and outlines the benefits of establishing National Marine Sanctuaries and models that can be used to monetize the benefits of doing so.