Estimating the benefits from restoring coastal ecosystems: A case study of Biscayne Bay, Florida

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United States' natural ecosystems have been invaded by approximately 5,000 exotic plant species which compete with 17,000 native plant species for space and resources. The total cost including damages and control expenditures of invasive plants in natural systems has been estimated to be $159.5 million (Pimentel, 2002). In Florida, establishment of exotic plants in natural ecosystems has jeopardized the viability of many listed threatened and endangered species. State response has been public funding for controlling invasive plants in natural areas to the tune of $32 million per year. This study examines the value of restoring ecosystems damaged by exotic plants through a case study of Biscayne Bay Florida. Since 1987, more than $11 million has been spent on exotic plant removal and coastal habitat restoration in Biscayne Bay. Results show the net gain from restoring coastal ecosystems in Biscayne Bay Florida to be from $37 million to $41 million with an internal rate of return between 10% and 11%.

1 Cost of invasive plants in the U.S.

United States' natural ecosystems have been invaded by approximately 5,000 exotic plant species which compete with 17,000 native plant species for space and resources. Many of the invaders were brought to the U.S. to be grown for food, feed, fiber, and ornamental purposes. While most non-indigenous species are unable to survive in the wild, some possess characteristics that enable them able to grow and reproduce rapidly unchecked by natural enemies and out compete native plants for space, sunlight, and nutrients. Often growing in monocultures, invasive plants diminish biodiversity, alter habitat, and eliminate natural food sources for native birds, reptiles, and mammals. In February 1999, former President Bill Clinton signed an executive order allocating $28 million to combat invasive species (Pimentel, 2000).

Invasive plants are responsible for $25 billion in damages to U.S. to food and horticultural crops and $10 million in losses to natural ecosystems each year (Pimentel, 2002). The U.S. food and horticulture industries each spend upwards of $9.5 billion controlling invasive plants. To control just a few of the plants (Purple loosestrife, Melaleuca, and invasive aquatics) invading natural systems, expenditures top $104 million each year. The total cost including damages and control expenditures of invasive plants in the agriculture and horticulture sectors is $34.5 billion. The total cost including damages and control expenditures of invasive plants in natural systems is at least $159.5 million (Pimentel, 2002).

In Florida, exotic plants are common and numerous. In the past century, over 1,300 exotic plant species have become established in the State; 124 species are destructive to natural areas and have been classified by the Florida Exotic Plant Pest Council as Category I and Category II invasive species[1,2] (FLEPPC, 2006). Because of their habitat destroying proclivity, invasive plants jeopardize the viability of many listed endangered species in Florida.

Private expenditure in Florida for controlling invasive plants in the agriculture and forest industries is $265 million per year (Lee, 2005). State expenditure for prevention and control of invasive plants is $103 million per year (FLDEP 2006). Public funding to control invasive plants in natural areas is $32 million per year, $6.3 million for upland invasive plants and $25.7 million for freshwater aquatic invasive plants (FLDEP, 2004).

In Biscayne Bay, Florida, federal, state and local agencies have joined forces to restore coastal upland habitats through the removal of exotic vegetation and the planting of native vegetation. In addition, historically altered wetlands are being restored through the removal of exotic vegetation and fill. Since year 2000, more than $11 million has been spent on coastal habitat restoration efforts in Biscayne Bay, Florida as shown in Table 1.

2 Restoring coastal ecosystems in Biscayne Bay: a case study

Biscayne Bay, Fla., is a 428-square-mile (1,109-square-kilometer) subtropical estuarine ecosystem which formed 3,000 to 5,000 years ago when sea level rose and flooded the natural limestone depression that is now south Florida. The bay supports a diverse flora and fauna and serves as a nursery for coral reef and marine ecosystems (USGS, 2006). The unique environment

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[1] In upland ecosystems the ten "worst" invasive plants identified by the FL DEP are Melaleuca, Brazillian pepper, Lygodium spp., Chinese tallow, Australian pine, Cogon grass, Ardesia spp., Chinaberry, Air Potato, and Ligustrum (FLDEP, 2004)

[2]The listed Category I invasive plants are believed to have been originally introduced for the following reasons: ornamental purposes 47%- 69%, agriculture 21%, and accidental 6% (Fox, et. al. 2003). It is worth noting that the horticulture industry brought to Florida an estimated 25,000 plant species from other countries (Pimentel, 2000) however only a very small percentage of those have successfully invaded natural areas.

of Biscayne Bay is home to 31 animal species which have been listed as endangered, threatened or "of special concern". Seven species listed as endangered by both the State and Federal governments are as follows: American crocodile, Atlantic green turtle, Atlantic hawksbill turtle, Cape Sable seaside sparrow, Wood stork, Florida panther, and West Indian manatee (Cantillo, et al. 2000).

Throughout the last century, rapid population growth, urbanization, and development of the Miami-Dade County area have altered the Bay environment.[3] Extensive dredging in the early 1900's reshaped the Bay and created navigation channels - notably the Atlantic Intra-coastal Waterway (ICW). Remnants of ICW construction are a series of large spoil-fill islands which have become popular recreational sites. Unstable shorelines, human activity, and overgrowth of exotic vegetation contribute to island erosion and Biscayne Bay turbidity (Wanless, et al., 1984 and Milano, 2000). Documented incidents of exotic vegetation (Australian pine) contributing to coastal erosion around the world are highlighted in Box 1. In other areas of Biscayne Bay, invasive plants have overtaken native habitats and altered coastal wetlands. Plants such as Australian pine (*Casuarina equisetifolia)* and Brazillian pepper (*Schinus terebinthifolius*) are among the worst for choking out native plants and destroying the habitat of native animals (SFWMD, 2006).

[3] A compendium describing the natural and anthropogenic events that have altered the appearance and functioning of Biscayne Bay during past century can be found in Cantillo, et al. (2000).

Box 1. Australian pine: evidence of erosion and habitat alteration

Australian pine as its name suggests is native to Australia as well as the South Pacific Islands and Southeast Asia. Trees grow 5 to 10 feet per year and can reach a maximum height of 150 feet. With their towering height and thick shallow roots, Australian pines tip over in high winds. Gordon (1998) cites evidence that outside its native environment, Australian pine contributes to shoreline erosion at least in part by crowding out native vegetation which possesses the deep root structures that are more conducive to sandy beach environs harsh wind and wave conditions.

In Mauritius, an island nation located on the south east coast of Africa and east of Madagascar, Australian pines were intentionally introduced as a coastal plantation species. In the early 1960s's the island was hit by a severe cyclone. Despite devastation elsewhere, the majority of the planted Australian pine trees remained standing. That same season a second storm blew through. Almost every single tree was toppled. The few trees that remained standing were dead (Sauer, 1962).

In India, Australian pines were planted along a coastal dune belt on Sagar Island in the early 1990's as a vegetative windbreak and source of timber. By 1995, storm surges knocked down the trees and destroyed the entire dune belt. Alternative vegetation has been planted to reestablish the dune (Bandyopadhyay, 1997).

Australian pine was introduced to Andros Island in the Bahamas. The diverse native vegetation which included more than 60 plant species was quickly replaced by a pine monoculture. During high tides and high winds, the shallow, thick rooted trees of Australian pine interfered with sea turtle nesting on the beach. As the trees took over, the coastline became increasingly unstable eventually forcing residents from their homes (Earth Watch Institute, 2005). On San Salvador Island in the Bahamas, Australian pine was introduced in the late 1920's and became established during the 1950's and 1960's in conjunction with the installation U.S. military bases. Because of their ability to destabilize dunes, Australian pine is considered a "clear and present danger" in the Bahamas (Rogers 2005).

Australian pine was introduced to Florida in 1898. Trees were planted extensively as windbreaks along canals, around agricultural fields, beside roadways, and to provide shade near homes. The trees naturalized and spread across the southern region of the State and along both coasts. Across the state, Australian pine can be found on over 300,000 acres (Doren and Ferriter, 2001). On public land Australian pine is under maintenance control on 3,457 acres (FL DEP, 2004). Cultivation and sale of the plant is now banned in Florida.

Removal of Australian pine from Dry Tortugas National Park in Florida began in 1989. With ten years of effort and a cost of about $20,000 per year, the invasive tree is believed eradicated from Dry Tortugas National Park (Doren and Ferriter, 2001)**.**

Along a 2-1/2 mile stretch of beach in John U. Lloyds State Park, approximately 36,000 cubic yards of sand was being lost away each year due in part to the demise of native vegetation and extensive growth of Australian pine. As part of a larger beach management effort, $300,000 was allocated to remove Australian pine and restore native plants.

In Miami-Dade County, a series of coastal wetlands restorations in Biscayne Bay begun more than two decades ago continues today. Uninhibited growth of exotic vegetation, loss of bird and marine habitats, and eroding shorelines prompted a major effort (Milano, 1999). The Biscayne Bay Restoration and Enhancement Program coordinate activities such as removal of exotic vegetation, excavation of emplaced spoil fill, planting of native vegetation, stabilization of eroding shorelines and long-term success monitoring. In addition, a significant component of the program is the restoration and reestablishment of natural ecosystems to create suitable and stable habitats for native birds, fish, and mammals (Milano 2000).

To preserve and protect the natural setting, Biscayne National Monument was established in 1968 for the “education, inspiration, recreation and enjoyment of present and future generations a rare combination of terrestrial, marine, and amphibious life in a tropical setting of great natural beauty” according to Public Law 90–606. The monument was enlarged in 1980 and designated Biscayne National Park, which is recognized as the largest marine park in the National Park System (USGS, 2006).

Between 1987 and 2000, $11 million has been spent to implement ecosystem restoration and enhancement in Biscayne Bay. As of 2000, ten large scale (exceeding one hectare in size) wetland restoration projects and twelve island restoration projects have been completed. The projects were funded by Miami-Dade County Department of Environmental Resources Management (DERM) in conjunction with State and Federal partners.[4]

An important component in all of the projects was removal of exotic vegetation. The dominant invasive plants removed were Australian pine (*Casuarina equisetifolia*), Brazillian pepper (*Schinus terebinthifolius*), Burma reed (*Neyraudia reynaudiana*), Inkberry (*Scaevola taccad*a), and Seaside mahoe (*Thespesia populne*a). Native vegetation was replanted at most sites to recreate one or more of the following types of coastal communities: coastal strand and maritime hammock; mangrove wetland and freshwater wetland; and dune.

On most of the island projects, lime rock boulders and filter fabric were installed to stabilize eroding shorelines. A stretch of mature red mangroves along the Oleta River State Park was also reinforced with natural lime rock boulders to reduce erosion and protect the mangroves. Additional activities included creating a high salt marsh, re-creating a historical riverbed, building numerous osprey nesting platforms, installing boat docking facilities on two islands, and planting native species on a university campus.

Detail on the 22 restoration projects appears in Table 1.

[4] Funding partners include; Florida Department of Environmental Protection, FDEP; South Florida Water Management District, SFWMD; Biscayne Bay Environmental Enhancement Trust Fund, BBEETF; Miami-Dade Seaport Department; and Florida Inland Navigation District, FIND.

Table 1: Biscayne Bay Restoration and Enhancement Projects.

		Remove		Construct		Restore					
No.	Project	Invasive plants	Dredge spoils	Shore stable	Tidal connect	Coastal	Mangrove	Dune	Dune	Date	Total cost
		acs	*cu yds*	*lf*	*no.*	*acs*	*acs*	*acs*	*lf*		
1	Bear Cut Preserve	21.5	41,600	0	3	0.0	10.0	0.0		1996	$800,000
2	Bill Baggs Cape FL State Park	85.0	630,000	0	2	0.0	85.0	0.0		1999	$2,800,000
3	Biscayne Bay Vista Campus	2.0	10,000	0	1	0.0	0.0	0.0	0	1995	$140,000
4	North Virginia Key Dune	7.0	23,000	0	2	0.0	4.0	2.0		1999	$320,000
5	National Bulk Carrier Site	140.0	0	0	0	0.0	0.0	0.0		1994	$300,000
6	Oleta River State Park - Phase I	13.0	55,000	0	1	0.0	13.0	0.0		1990	$300,000
7	- Phase II	45.0	58,000	0	2	0.0	28.5	0.0		1999	$1,500,000
8	- Mangrove stabilization	0.0	0	1,900	1	0.0	0.0	0.0		1990	$430,000
9	Highland Oaks Wetlands	8.2	0	0	0	0.0	14.2	0.0		1999	$260,000
10	Chicken Key Bird Rookery	7.0	33,000	0	1	0.0	3.7	0.0	1,200	1994	$600,000
11	Dinner Key Island	4.0	0	500	0	4.0	0.0	0.0		2000	$275,000
12	Flagler Monument Island	4.5	0	900	0	4.0	0.0	0.0	750	1994	$220,000
13	Teachers Island	3.7	0	320	0	0.0	0.0	3.7	0	2000	$140,000
14	Morningside Island	4.0	0	500	0	0.0	0.2	4.0		1997	$290,000
15	Mangrove Islands	2.8	0	0	0	0.0	2.8	0.0		1996	$5,000
16	Legion Island	7.0	0	500	0	5.0	0.0	0.0		2000	$150,000
17	Pelican Island	5.0	0	1,200	0	4.5	14.0	0.0	150	1992	$300,000
18	Quayside Island	5.0	0	2,000	0	4.5	0.3	0.0	360	1993	$590,000
19	Helkers Island	4.0	0	880	0	4.0	0.8	0.0	480	1993	$300,000
20	Crescent Islands	2.0	0	800	0	0.4	0.5	0.0	600	1992	$200,000
21	Little Sandspur Island	1.0	0	620	0	0.0	0.5	1.0	220	1999	$170,000
22	Sand Spur Island	15.0	0	3,002	0	14.0	2.5	2.1	0	1993	$531,000

3 Description of Biscayne Bay restoration costs

3.1 Wetland project costs

Clearing infested acreage and removing invasive plants cost up to $15,000 per acre. Excavation of fill cost an average of $5 per cubic yard of material removed. For each project, 10% of the total budget went to “mobilization” costs. Expenditures for habitat restoration activities ranged from $0 to $2,800,000 per project. Additional information about Biscayne Bay wetland project costs can be found in Table 2 as projects numbered 1 through 10.

3.2 Island project costs

Removing invasive plants cost an average of $7,100 per acre cleared. No excavation activities were reported for the island projects. For each project, 10% of the total budget was spent on “mobilization” costs. Expenditures for habitat restoration activities ranged from $5,000 to $590,000 per project. Additional information on Biscayne Bay island project costs can be found in Table 2 as projects numbered 11 through 22.

3.3 Total Cost

Total expenditures for Biscayne Bay restoration projects as reported through year 2000 is $10,621,000. Inflating values using the Turner building cost index (Turner Corp., 2006) and the consumer price index (U.S. Department of Labor, 2006) yields the present value of total expenditures in 2006 dollars of $16,187,682.[5]

[5] Expenditures in years 1995 through 2000 were inflated with the Turner building cost index. Expenditures in years 1990 through 1994 were inflated using the CPI because Turner values were not available for those years.

Table 2: Estimated allocation of total project costs by category.

	SITE	Date	Remove: Invasive plants	Remove: Fill	Mobilization	Restoration and Other	Total cost	Year 2006 PV Total Cost
	Unit cost 1-10		*$4,900 per ac*	*$5.525 per cu yd*	*10%*			
1	Bear Cut Preserve	1996	$105,350	$229,840	$80,000	$384,810	$800,000	$1,199,238
2	Bill Baggs Cape FL State Park	1999	$391,000	$1,921,500	$280,000	$207,500	$2,800,000	$3,865,965
3	Bay Vista Campus	1995	$9,800	$55,250	$14,000	$60,950	$140,000	$218,178
4	Virginia Key Dune	1999	$34,300	$127,075	$32,000	$126,625	$320,000	$441,825
5	National Bulk Carrier Site	1994	$270,000	$0	$30,000	$0	$300,000	$479,878
6	Oleta River State Park - Phase I	1990	$59,800	$167,750	$30,000	$42,450	$300,000	$578,676
7	- Phase II	1999	$220,500	$320,450	$150,000	$809,050	$1,500,000	$2,071,053
8	- Mangrove	1990	$0	$0	$43,000	$387,000	$430,000	$829,436
9	Highland Oaks Wetlands	1999	$40,180	$0	$26,000	$193,820	$260,000	$358,982
10	Chicken Key Bird Rookery	1994	$34,300	$182,325	$60,000	$323,375	$600,000	$959,756
	Unit cost 11-22		*$7,100 per ac*	*none*	*10%*			
11	Dinner Key Island	2000	$28,400	$0	$27,500	$219,100	$275,000	$363,739
12	Flagler Monument Island	1994	$31,950	$0	$22,000	$166,050	$220,000	$351,911
13	Teachers Island	2000	$26,270	$0	$14,000	$99,730	$140,000	$185,176
14	Morningside Island	1997	$28,400	$0	$29,000	$232,600	$290,000	$415,719
15	Mangrove Islands	1996	$2,500	$0	$500	$2,000	$5,000	$7,495
16	Legion Island	2000	$49,700	$0	$15,000	$85,300	$150,000	$198,403
17	Pelican Island	1992	$35,500	$0	$30,000	$234,500	$300,000	$545,266
18	Quayside Island	1993	$35,500	$0	$59,000	$495,500	$590,000	$1,045,788
19	Helkers Island	1993	$28,400	$0	$30,000	$241,600	$300,000	$531,757
20	Crescent Islands	1992	$14,200	$0	$20,000	$165,800	$200,000	$363,510
21	Little Sandspur Island	1999	$7,100	$0	$17,000	$145,900	$170,000	$234,719
22	Sand Spur Island	1993	$106,500	$0	$53,100	$371,400	$531,000	$941,209
	Total Cost		$1,589,650	$3,004,190	$1,062,100	$4,965,060	$10,621,000	$16,187,682
	% Total Cost		15.0%	28.3%	10.0%	46.7%	100.0%	

4 Assessing the benefits from restoring Biscayne Bay

4.1 Environmental valuation methods

Methods such as hedonic price, travel cost, and random utility models use information from market traded goods to infer environmental values indirectly. Property value method and marginal productivity method are other means of utilizing available market data to indirectly ascertain environmental service values. The contingent valuation method obtains values directly by querying subjects regarding their willingness to pay for environmental services. The benefits transfer method draws on findings from previous valuation studies in one locale to make inferences about the environmental values in another locale. Benefits transfer is the method applied in this study. For more explanation about valuing coastal environmental resources, the reader is referred to Letson and Milon (2002).

4.2 Coastal ecosystem values from previous studies

The value of Florida saltwater marshland was estimated by Bell (2002). Bell applied the property value method and the marginal productivity value method. Based on historic costs of acquiring wetlands, Bell assessed Florida wetland values at $2,879 per acre. Based on the contribution to commercial and recreational fisheries, Bell arrived at $3,337 per acre as the value of Florida salt water marshes.

Milon (2002) estimated the value of the Indian River Lagoon a coastal estuary located in South Florida. Milon applied the property value method, marginal productivity method, contingent valuation method, and the travel cost method. Based on property values, human uses (including fishing, swimming, boating, nature watching, water sports, and hunting), passive uses, and commercial shell fishing, Milon estimated an ecosystem value of $724 million per year. Unlike the Indian River Lagoon, the restored areas in Biscayne Bay do not include residential properties, so we subtracted the $33 million in property values leaving a total of $691 million. The Indian River Lagoon covers an area of 2,000 square miles or 1.28 million acres. With this information we arrived at a unit value of coastal estuary of $540 per acre in 1995 dollars.

Costanza, et al. (1997) compiled findings from a myriad of studies to provide a reference on the values for a wide range of ecosystem types and the services they provide. This approach would be best classified as benefits transfer. The team of authors categorized 11 aggregate ecosystem types and defined 17 classes of services. Among the aggregate ecosystems types were coastal estuaries and coastal wetlands (categorized as tidal marsh and mangroves). Among their 17 service classes we chose three: “recreation”, “food production”, and “cultural” to capture direct human use values and allocated the remainder to indirect human use values and non-use values. With this aggregation, the coastal estuary ecosystem value to direct human use is $377 per acre and the value to indirect human use and non-use is $8,863 per acre in 1994 dollars. Coastal wetland ecosystem value to direct human use is $459 per acre and the value to indirect human use and non-use is $3,584 per acre in 1994 dollars.

Benefit values from Bell (2002), Milon (2002), and Costanza, et al. (1997) are shown in Table 3. Selected values from Table 3 (shown in green) were used in the benefit transfer analysis for Biscayne Bay and are displayed in Table 4.

Table 3: Value of coastal ecosystem services from previous studies.

	Site	Value	Year	2006[b]	Source
Coastal wetlands [a]		*$/acre*		*$/acre*	
All ecosystem services	Global	$4,043	1994	$5,763	Costanza, et al. (1997)
Ecosystem services excluding direct human uses	Global	$3,518	1994	$5,016	Costanza, et al. (1997)
Commercial and recreational fisheries	Florida	$3,337	1998	$4,227	Bell (2002)
Wetland acquisition cost	Florida	$2,879	1998	$3,647	Bell (2002)
Direct human uses [c]	Global	$524	1994	$747	Costanza, et al. (1997)
Coastal Estuaries		*$/acre*		*$/acre*	
All ecosystem services	Global	$9,240	1994	$13,174	Costanza, et al. (1997)
Ecosystem services excluding direct human uses	Global	$8,853	1994	$12,622	Costanza, et al. (1997)
Direct human uses [d]	Florida	$540	1995	$748	Milon (2002)
Direct human uses [c]	Global	$387	1994	$552	Costanza, et al. (1997)
Disturbance regulation [e]	Global	$229	1994	$326[f]	Costanza, et al. (1997)

[a] Coastal wetlands includes saltwater march, tidal marsh, and mangroves.
[b] An interest rate of 3% was used to inflate benefit values.
[c] Direct human uses include recreation, food, and cultural uses.
[d] Direct human uses includes fishing, swimming, boating, nature watching, water sports, hunting, passive uses, and commercial shell fishing.
[e] Disturbance regulation implies habitat protection from storms and other aspects of environmental variability primarily from vegetation structure.
[f] Value in 2006 dollars converts to $.122 per linear foot and $642 per linear mile assuming a linear foot and a linear mile are ½ acre wide, average width of restored areas equal to 104 ft or .0198 mile.

Table 4: Value of coastal ecosystem services applied to Biscayne Bay restoration

Ecosystem services	Shore	Coastal	Dune	Mangrove
Indirect human use and non-use	$326	$12,622	$5,016	$5,016
Direct human use	0	$748	$747	$747
All services	$326	$13,370	$5,763	$5,763
Description	*Construction activities to stabilize shoreline and reduce erosion*	*Restore native vegetation to create and enhance coastal strand and maritime hammock ecosystem*	*Restore native vegetation to create and enhance dune ecosystem*	*Restore native vegetation to create and enhance mangrove and fresh wetland ecosystem*

5 Applying benefits transfer to Biscayne Bay restoration

Where u_i is the value per acre from indirect and non-use service values from ecosystem i (where i = shoreline, coastal, dune and mangrove) and E_i is the size of each ecosystem of type i in acres restored under project j, then the indirect and non-use ecosystem service values (U_j) from project j is defined:

(1) $$U_j = \sum_{i=1}^{4} u_i E_{ij} .$$

Where v_i is the value per acre from direct human use service values from ecosystem i, then the direct human use value (V_j) from project j is defined:

(2) $$V_j = \sum_{i=1}^{4} v_i E_{ij} .$$

The wetlands projects (numbered 1 through 10) restore areas with human uses that include fishing, kayaking, bird watching, and snorkeling. The indirect human use values yields the following benefit estimate (b_I)

(3) $$b_I = \sum_{j=1}^{10} U_i .$$

The combined direct and indirect human use values for wetlands projects 1 through 10, yields the benefit estimate (b_{II})

(4) $$b_{II} = \sum_{j=1}^{10} (U_j + V_j) .$$

Island projects (numbered 11 through 22) restored areas that are popular recreation sites. The benefits from both direct and indirect human use values are given by (b_{III})

(5) $$b_{III} = \sum_{j=11}^{22} (U_j + V_j) .$$

The "base" estimate of the ecosystem service benefit value from projects 1 through 22 sums the values b_I and b_{III} in eqns (3) and (5)

(6a) $$A = b_I + b_{III} .$$

The "upper end" estimate of ecosystem service benefit value from projects 1 through 22 sums the values b_{II} and b_{III} in eqns (4) and (5)

(6b) $$A = b_{II} + b_{III} .$$

Per acre ecosystem service values (u_i and v_i) are given in Table 4. The sizes of the restored ecosystems (E_i) are displayed in Table 1. Using these values and eqns (1) through (6b) ecosystem benefits were estimated and appear as a worksheet in Table 5.

Table 5: Ecosystem services benefits worksheet summary

		Ecosystem services		
		Indirect use and non-use values	Direct human use values	All values
		$/year	$/year	$/year
1	Bear Cut Preserve	$50,158	$7,471	$57,629
2	Bill Baggs Cape FL State Park	$426,343	$63,504	$489,847
3	Bay Vista Campus	$0	$0	$0
4	Virginia Key Dune	$30,095	$4,483	$34,577
5	National Bulk Carrier Site	$0	$0	$0
6	Oleta River State Park - Phase I	$65,205	$9,712	$74,918
7	- Phase II	$142,950	$21,292	$164,243
8	- Mangrove	$1,486	$0	$1,486
9	Highland Oaks Wetlands	$71,224	$10,609	$81,833
10	Chicken Key Bird Rookery	$32,978	$4,912	$37,890
	Subtotal 1-10	b_I $820,440	$121,983	b_{II} $942,422
11	Dinner Key Island	$50,880	$2,990	$53,870
12	Flagler Monument Island	$60,205	$4,332	$64,538
13	Teachers Island	$18,809	$2,764	$21,573
14	Morningside Island	$21,457	$3,138	$24,595
15	Mangrove Islands	$14,044	$2,092	$16,136
16	Legion Island	$63,503	$3,738	$67,240
17	Pelican Island	$129,763	$14,092	$143,854
18	Quayside Island	$64,396	$4,262	$68,658
19	Helkers Island	$60,807	$4,424	$65,232
20	Crescent Islands	$14,761	$1,709	$16,470
21	Little Sandspur Island	$10,652	$1,514	$12,167
22	Sand Spur Island	$202,133	$13,902	$216,035
	Subtotal 11-22	$711,411	$58,957	b_{III} $770,368

Estimated annual benefit

Base estimate: $A = b_I + b_{III}$ = $1,590,808

Upper estimate: $A = b_{II} + b_{III}$ = $1,712,790

6 Net benefits from the Biscayne Bay restoration projects

The annual benefit from Biscayne Bay restoration projects (eqns 6a and 6b) is estimated to be from $1,590,808 to $1,712,790. The total benefit (TB) can be calculated as follows. Where A is the annual benefit and r is the annual interest rate, the present value of the ecosystem services benefit stream in perpetuity is

(7) $TB = \frac{A}{r}$.

At an annual interest rate of r = .03, total benefit from Biscayne Bay restoration projects (eqn 7) is estimated to be from $53,026,929 to $57,093,016.

Present value of net benefits (NB) is defined to be total benefit (TB) minus total cost (TC):

(8) $NB = TB - TC$.

The present value of the total cost of the restoration projects completed between 1990 and 2000 is $16,187,682. The present value of net benefits (eqn 8) from Biscayne Bay restoration projects is between $36,839,247 and $40,905,334.

Another indicator of the net gain from public expenditure is the internal rate of return (IRR) which is computed as follows:

(9) $IRR = \frac{A}{TC}$.

For the 22 restoration projects, the internal rate of return (eqn 9) is estimated to be between 0.0983 and 0.1058 or between 10% and 11%.

7 Summary

Invasive plants in natural areas are notorious for their ability to change ecosystems. In Florida coastal areas, invasive species have replaced native plants, dislodged native animals, and radically altered hydrologic processes such as tidal flows, dune replacement, and shoreline erosion rates. This study applied the benefits transfer method to assess the value of restoring damaged ecosystems in Biscayne Bay Florida. Results indicate the present value of a perpetual stream of ecosystem service benefits from the restoration projects is estimated to be between $53 million and $57 million. The cost of the projects was $16 million in 2006 dollars. Thus the net benefit from the restoration projects is estimated to be **$37 million** to **$41 million**. The internal rate of return from restoration expenditures is **10%** to **11%**.

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