ECONOMIC VALUATION OF ECOSYSTEM SERVICES IN BAHAMIAN MARINE PROTECTED AREAS

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Stanford University
people ➔

environment
ECOSYSTEM SERVICES
benefits nature provides to people
people
environment
The Natural Capital Project • Economic Valuation of Bahamian MPAs • December, 2017
This work

1. Reviews past studies of economic value of marine ecosystems, species, and MPAs

2. Makes the economic case and build awareness and support for MPA declaration by quantifying the economic value of ecosystem services within the existing MPA network

3. Explores management issues and quantifies ecosystem services at the island-scale for 5 regions with MPAs with varying management regimes
SUMMARY OF ECONOMIC HABITAT VALUES IN EXISTING STUDIES

- Coral reefs: $44,500–$1.35 million km²/yr
  (fisheries, coastal protection, tourism, non-use etc.)
- Mangroves & wetlands: $850,000–$1.2 million km²/yr
  (fisheries, coastal protection, tourism, water quality etc.)
- Tidal Creeks: $35,000–$1.75 million km²/yr
  (coastal protection, fisheries, carbon sequestration)
- Seagrass: $500–$150,000 km²/yr
  (fisheries, coastal protection, tourism)

VALUE OF ECOSYSTEM SERVICES EXPLORED IN PREVIOUS STUDIES

- Fisheries: $124.5 million an. in lobster and reef fish export value
  - 33,100 tons/yr in subsistence catch, 4,000 fishing vessels, 9,300 directly employed

- Tourism: $402 million from stop-over visitor (2007)
  - $150 million in aggregated econ. impact from rec fishing; $115 shark-related
  - 300 fishing guides nationally, 500 nature-based tourism employees on Andros

- Coastal Protection: $3.9 billion km²/yr in coastal protection by habitats
  - > 50% of Andros coastline protected by habitats
  - > $33,000 in avoided cost to government from erosion control on Great Abaco

Production function models
changes in ecosystems →
changes in ecosystem services →
changes in benefits to people

InVEST
integrated valuation of ecosystem services and tradeoffs
Free & open source
ECONOMIC VALUATION OF ECOSYSTEM SERVICES IN BAHAMIAN MPAs

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A. General framework for an ecosystem services assessment

<table>
<thead>
<tr>
<th>Action</th>
<th>Change in ecosystem structure and function</th>
<th>Change in ecosystem services</th>
<th>Change in societal benefit</th>
</tr>
</thead>
</table>

Production function

B. Ecosystem services assessment for coastal protection services provided by habitats

- Mangrove restoration
- Change in mangrove extent and hydrodynamic conditions
- Avoided erosion and flooding of public or private land
- Avoided damage costs
- People protected

Arkema et al. 2017
2. QUANTIFY THE ECONOMIC VALUE OF FOUR ECOSYSTEM SERVICES IN THE EXISTING NETWORK OF MPAS

- Nursery habitat for spiny lobster fishery
- Coastal protection
- Tourism
- Carbon storage & sequestration
**VALUING NURSERY HABITAT FOR LOBSTER**

**Inputs**
- Mangrove distribution
- Seagrass distribution
- Shelf
- Stock assessment parameters

**Outputs**
- Catch of spiny lobster
- Revenue from catch
- Value of habitats for contribution to catch and revenue
Amount of nursery habitats in MPAs for lobster fishery

*MPAs with less than 0.3% of their region's mangrove and seagrass are left out of this table.
Nursery habitats in MPAs' contribute **6.01 million pounds** to the annual lobster catch, generating **$22.52 million** in revenue per year.
2. QUANTIFY THE ECONOMIC VALUE OF FOUR ECOSYSTEM SERVICES WITHIN THE EXISTING NETWORK OF MPAS

- Nursery habitat for spiny lobster fishery
- Coastal protection
- Tourism
- Carbon storage & sequestration
Inputs

- Ministry of Tourism visitor surveys (# visitors—cruise and stopover, length of stay, $/stay)
- Industry job surveys
- Spatial distribution of visitors

Outputs

- Visitor nights per area
- Visitor expenditure
- Number of jobs

Wood et al 2013 Scientific Reports
TOURISM

Approach to valuation

~383,000 visitor-days are spent annually at sites within the MPA network.
ECONOMIC VALUE of TOURISM IN MPAS

~$67.6 million in expenditures are associated with annual visits to sites within MPAs
2. **QUANTIFY THE ECONOMIC VALUE OF FOUR ECOSYSTEM SERVICES WITHIN THE EXISTING NETWORK OF MPAS**

Nursery habitat for spiny lobster fishery

Coastal protection

Tourism

Carbon storage & sequestration
COASTAL PROTECTION

**Inputs**
- Geomorphology
- Habitats
- Wind exposure
- Wave exposure
- Storm surge (continental shelf)
- Relief
- Sea level rise
- Census data (population, income)

**Outputs**
- Exposure
- Reduction in exposure attributable to habitat
- People protected
- Income protected

$
Coastal habitats in MPAs reduce exposure to **39,000 people** and **$806 million** in annual income.

<table>
<thead>
<tr>
<th>Island group</th>
<th>Current MPAs</th>
<th>Reduction in exposure ($ millions annual income)</th>
<th>Reduction in exposure (# of people)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abaco</td>
<td>Abaco NP – Black Sound Cay NP – No Name Cay MR – Fowl Cays NP – Tilloo Cay Reserve – Pelican Cays Land And Sea Park – Cross Harbour NP – Marls of Abaco NP – East Abaco Creeks (The Bight) – East Abaco Creeks (Snake Cays) – East Abaco Creeks (Cherokee) – South Abaco Blue Holes NP</td>
<td>$32.32</td>
<td>3,630</td>
</tr>
<tr>
<td>Acklins/Crooked</td>
<td>Bight of Acklins NP</td>
<td>$0.00</td>
<td>0</td>
</tr>
<tr>
<td>Berry Islands</td>
<td>South Berry Islands MR</td>
<td>$1.92</td>
<td>238</td>
</tr>
<tr>
<td>Exuma</td>
<td>Exuma Cays Land &amp; Sea Park – Exuma (Jewish Cay) MR – Moriah Harbour Cay NP</td>
<td>$15.89</td>
<td>1,482</td>
</tr>
<tr>
<td>Grand Bahama</td>
<td>Northshore/The Gap NP – East Grand Bahama NP – Peterson Cay NP – Lucayen NP</td>
<td>$16.63</td>
<td>1,027</td>
</tr>
<tr>
<td>Inagua</td>
<td>Union Creek Reserve – Little Inagua NP</td>
<td>$0.00</td>
<td>0</td>
</tr>
<tr>
<td>New Providence</td>
<td>Bonefish Pond NP – Southwest New Providence MMA</td>
<td>$717.53</td>
<td>30,416</td>
</tr>
<tr>
<td>San Salvador</td>
<td>West Coast Dive Site – Greens Bay NP – Graham’s Harbour – Pigeon Creek &amp; Snow Bay NP</td>
<td>$15.76</td>
<td>1,403</td>
</tr>
<tr>
<td><strong>totals</strong></td>
<td></td>
<td><strong>$806.45</strong></td>
<td><strong>38,978</strong></td>
</tr>
</tbody>
</table>
2. Quantify the Economic Value of Four Ecosystem Services Within the Existing Network of MPAs

- Nursery habitat for spiny lobster fishery
- Coastal protection
- Tourism
- Carbon storage & sequestration
BLUE CARBON MODEL

**Inputs**
- Mangrove distribution
- Seagrass distribution
- Biomass
- Litter
- Soil
- Rates of decay
- Social value

**Outputs**
- Carbon storage
- Carbon accumulation
- Carbon emissions
- Net sequestration
- Net present value
CARBON STORAGE BY MPA

Westside National Park
Marls of Abaco National Park
Northshore / The Gap National Park
East Grand Bahama National Park
Exuma Cays Land & Sea Park
Bight of Acklins National Park
South Abaco Blue Holes National Park
Joulter Cays National Park
Cross Harbour National Park
South Berry Islands Marine Reserve
Exuma (Jewfish Cay) Marine Reserve
Southwest New Providence Marine Managed Area
East Abaco Creeks - Cherokee Union Creek Reserve
Little Inagua National Park
East Abaco Creeks - The Bight
Southeast Bahamas Marine Managed Area
Hogsty Reef Protected Area
Moriah Harbour Cay National Park
Andros Northern Marine Park
Pigeon Creek & Snow Bay National Park
East Abaco Creeks - Snake Cays
Graham’s Harbour
Andros Southern Marine Park
Pelican Cays Land And Sea Park
West Coast Dive Site
Conception Island National Park
Stonefish Pond National Park
No Name Cay Marine Reserve
Crab Cay Marine Reserve
Walker’s Cay National Park
Green Cay Marine Park
Fowl Cays National Park
Lucayan National Park
Green Bay National Park
Abaco National Park
Peterson Cay National Park
Tilloo Cay Reserve
Black Sound Cay National Park

404 million tons of CO₂ equivalent stored in mangroves and seagrasses within Marine Protected Areas
Value of avoided emissions by MPA

$5 billion in avoided damages from emissions (at $12.58/ton market price)
<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Values provided ecosystems within the existing MPA network</th>
<th>Factors that influence spatial variation in ecosystem service (not comprehensive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tourism</td>
<td>383,000 visitor-days and $67.6 million in expenditures annually</td>
<td>Island differences in visitation, expenditure, habitat extent, access, infrastructure</td>
</tr>
<tr>
<td>Coastal protection</td>
<td>Reduced exposure to 39,000 people and $806 million in income annually</td>
<td>Habitat type and quality, coastal elevation, shoreline type, surge potential, wave characteristics, sea-level rise, proximity of habitats in MPA to coastal population</td>
</tr>
<tr>
<td>Nursery habitat for spiny lobster</td>
<td>6 million lbs. and $23.5 million in revenue from the lobster fishery is attributable to nursery habitat annually</td>
<td>Habitat type and extent, larval recruitment to nursery habitat, proximity of nursery habitat to shallow shelf habitat for adults</td>
</tr>
<tr>
<td>Carbon storage for climate mitigation</td>
<td>400 million tons of CO₂ stored and $5 billion in avoided damages from emissions globally</td>
<td>Relative abundance of mangroves and seagrass, carbon stored in soil and aboveground biomass (based on climate).</td>
</tr>
</tbody>
</table>
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EXUMA

Entire coastline protected

$130 million in avoided damages due to emissions by storing 10.7 million tons of carbon

$6.6 million in visitor expenditure from 23,000 visitor-days (annually)

$1 million in export value from 240,000 lbs of catch (annually)
BIMINI

- 3,000 people and $31.2 million in annual income protected
- $3.3 million in visitor expenditure from 19,500 visitor-days (annually)
- $46.2 million in avoided damages due to emissions, 3.5 million tons of carbon stored
- $300,000 in export value from 76,505 lbs. of catch (annually)

**Economic Valuation of Bahamian MPAs**

**December, 2017**
**ANDROS**
CURRENT RISK ASSESSMENT

- Mangrove
- Beach
- Seagrass
- Coral

Current

- Low Risk
- Moderate Risk
- High Risk
ANDROS
ALTERNATIVE FUTURE SCENARIOS & ASSOCIATED RISK

The Natural Capital Project • Economic Valuation of Bahamian MPAs • December, 2017
ANDROS RESULTS

• Nursery habitats within Andros’s MPAs contribute 3.5 million lbs. in lobster catch and $14.5 million in export value
  – The Master Plan (sustainable prosperity scenario) could increase export value to $21. million

• Andros’ MPAs support $113 million in visitor expenditure
  – The Master Plan would increase expenditure to $170 million

• Coastal habitats such as mangrove and coppice forests, coral reefs and seagrass reduce the risk to 50% of the islands’ population, protecting $2.4 million in income
  – The Master Plan would protect 60% of the islands’ population

• Carbon storing mangrove and seagrass in Andros West Side National Park are worth $6 billion in avoided damages from emissions.
  – These assets could increase by 3% under the Master Plan
SOUTHWEST MARINE MANAGED AREA
MAPPING HUMAN USES

- Development & dredging
- Oil leakage & zone of influence
- Tourism
- Lionfish and Casuarina
- Fishing
- Marine Transportation
SOUTHWEST MARINE MANAGED AREA
RISK ASSESSMENT APPROACH

A) Beach
B) Coral reef
C) Seagrass

D) Mangrove
E) Coppice
F) Pine

Low Risk  Moderate Risk  High Risk
SOUTHWEST MARINE MANAGED AREA
PROPOSED CORAL RESTORATION
SOUTHWEST MARINE MANAGED AREA

Risk from current activities reduce the export value attributable to nursery habitat by 50%, $127,000

$14 million in visitor expenditure from currently, could increase by 14% with lower risk
6% of people at greater risk from storms as a result of risk to habitats. Habitats could protect 30,000 people.

Under current risk, habitats store ½ as much carbon, worth $16 million.
All 11,000 people protected by coastal habitats, $130 million in protected income

$58.5 million in visitor expenditure (annually)

$1.5 billion in avoided damages due to emissions, 120 million tons of carbon stored

$5.7 million in export value from 1.5 million lbs. of catch (annually)
ISLAND-SCALE EVALUATION

- In-depth analysis of specific MPAs shows value of ecosystem services in these areas
  - E.g. Bimini and Exuma Cays Land and Sea Park

- Including human activities in a risk assessment highlights the potential gains of effective management
  - E.g. Andros and Southwest Marine Managed Area

- An ecosystem services approach can be used to explore locations for future MPAs
  - E.g. Eleuthera
The economic benefits are large, and vary between locations

Effective management is needed to maintain and grow the economic value

- 4 of 40 MPAs have finalized management plans (as of Nov, 2017) and 15 have draft plans

Designated marine protected areas of The Bahamas
management plan status: finalized (x) drafted (*)

- 4 of 40 MPAs have finalized management plans (as of Nov, 2017) and 15 have draft plans

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IMPLICATIONS OF FINDINGS FOR MPA POLICY, PLANNING, AND MANAGEMENT

- The economic benefits are large, and vary between locations.
- Effective management is needed to maintain and grow the economic value.
  - 4 of 40 MPAs have finalized management plans (as of Nov, 2017) and 15 have draft plans.
IMPLICATIONS OF FINDINGS FOR MPA POLICY, PLANNING, AND MANAGEMENT

• MPA planning and management should be part of comprehensive efforts
  – E.g. National Development Planning (Vision 20140) & Integrated Coastal Zone Management
• MPA contribute to the Sustainable Development Goals (and other international commitments)
• An ecosystem services approach can help evaluation possible sites for future protection under the 20-by-20 challenge
• Iteration between ecosystem service valuation and stakeholder engagement can ensure local support and the future sustainability of MPAs
QUESTIONS?

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We reviewed the existing literature to glean useful information and to give context for our analysis

Approach:

• We focused on existing studies of economic value (variety of metrics) of species, habitats, and marine protected areas in The Bahamas

• We searched the peer-reviewed literature, reports and citations within, and studies by local experts

• Values did not need to be monetary, but they did need to include demand from people for the services
ECONOMIC VALUE OF HABITATS (PER UNIT AREA)

NUMBER OF VALUATION STUDIES BY ECOSYSTEMS AND SERVICES

~ 23 Bahamian-specific reports with service values ($, jobs etc.)

- Beach/Sand
- Mangrove/Wetland
- Coral
- Seagrass
- Flats/Estuary/Tidal Creek
- Open Ocean/Deep Water
- Forest
- Sharks
- Fisheries
- Tourism/Recreation
- Coastal Protection
- Carbon and climate mitigation
- Cultural and aesthetic
- Biodiversity

Others: raw materials, water supply and quality, research, non-use, pest control, waste treatment, and entertainment
PREVIOUS ECONOMIC VALUATION STUDIES

• 23 Bahamas-specific valuation studies
• Mangroves, coral, seagrass, and tidal flats the most commonly valued
  • Benefits-transfer approaches are the most common
  • Up to $1.2 – $1.75 million per km$^2$, depending on the habitat
• Fisheries and tourism the most commonly studied
  – $125 million in export value for fisheries, > $400 million in visitor expenditure
• Opportunities for new work
  – Focus on coastal protection benefits of habitats from storms
  – Spatially-explicit approaches
  – Specific contribution of MPAs
ECONOMIC VALUE OF FISHERIES

- Lobster
  - $64.5 million annually in export value from 2,301 tons/yr (2000-2009)
  - Reconstructed catch was 4.5x greater, 10,500 tons/yr

- Reef fish
  - $60 million annually in export value

- Subsistence fishery
  - 33,100 tons/yr supporting food security for thousands of Bahamians

- Employment
  - 4,000 Bahamian fishing vessels
  - 9,300 directly employed in the fishing industry
  - 1,300 active lobster fisherman

ECONOMIC VALUE OF TOURISM

- $402 million annually from stopover visitors (2007)
  - 4.5 million visitors annually contributing 60% to the national economy (2007)
- $50 million in annual expenditure related to sharks with aggregated economic impact of $115 million
- $75 million in annual expenditure from guided and non-guided fishing with aggregated economic impact more than $150 million
- Employment figures are limited
  - > 500 employees in nature-based tourism on Andros (2010)
  - > 300 fishing guides nationally (2010)

ECONOMIC VALUE OF COASTAL PROTECTION

- Habitats in The Bahamas provide an estimated $3.9 billion km$^2$/yr in coastal protection and $120 million in erosion control

- Exuma
  - $8.5 million km$^2$/yr in disturbance regulation

- Andros
  - $6.8 million km$^2$/yr in disturbance regulation
  - 95 km of shoreline and 50% of the coastal population protected by natural habitats

- Great Abaco
  - $1,137 in avoided costs for communities from disturbance protection
  - $1,348 in avoided costs for government from disturbance protection
  - $33,423 in avoided costs for government from erosion protection

VALUE OF LOBSTER CATCH ATTRIBUTABLE TO MANGROVES AND SEAGRASS IN MPAs

2014
- 4,763,00 lbs. of lobster tails exported
- $53,777,000 (~86% of exports by value)

- Age-structured matrix model
- Beverton-Holt recruitment
- Habitat dependent survivorship
TOURISM

APPROACH TO TRACK PEOPLE

empirical user days (%)

photo user days (%)

flickr photos

Wood et al 2013
Scientific Reports
TOURISM
EXTENSIVE SURVEY DATA

Ministry of Tourism 2015 Statistics:
- 9,943,549 total visitor nights
~383,000 visitor-days are spent annually at sites within the MPA network.
COASTAL PROTECTION APPROACH

Grid coast ➔ Input data ➔ Variable ranks ➔ Hazard index

- Geomorphology
- Habitats
- Relief
- Wind exposure
- Wave exposure
- Surge potential

Arkema et al. Nature Climate Change 2013
COASTAL PROTECTION
DATA INPUTS

- Storm surge
- Sandy Beach
- Rocky Coast
- Geomorphology
- Habitats
- Wind exposure
- Wave exposure
- Relief
- Social & Economic metrics
- Sea level rise

COASTAL PROTECTION
DATA INPUTS

- Storm surge
- Sandy Beach
- Rocky Coast
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CARBON STORAGE/SEQ PROVIDED BY MANGROVES AND SEAGRASS IN MPAS

**CARBON SEQUESTRATION AND STORAGE**

Carbon dioxide ($CO_2$)

- Sequestered by coastal vegetation
- Incorporated into biomass, litter and soils
- Soil carbon can make up 50-99% of total carbon

**CARBON SOURCE**

Carbon dioxide ($CO_2$)

- Destruction of coastal habitats leads to release in stored carbon
- Rate of release depends on disturbance type
CARBON-STORING HABITATS

MPAs

- Westside National Park
- Northshore / The Gap National Park
- Marls of Abaco National Park
- Exuma Cays Land & Sea Park
- East Grand Bahama National Park
- Bight of Acklins National Park
- Joulter Cays National Park
- South Abaco Blue Holes National Park
- South Berry Islands Marine Reserve
- Southwest New Providence Marine Managed Area
- Jewfish Cay Marine Reserve
- Cross Harbour National Park
- Southeast Bahamas Marine Managed Area
- Hogsty Reef Protected Area

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mangrove

seagrass

habitat area (sq km)
Exuma Cays Land & Sea Park

- Mangrove
- Seagrass
- Coral Reef
• Nursery habitats within Andros’s MPAs contribute **3.5 million lbs.** in catch and **$14.5 million in export value**

• The Master Plan (sustainable prosperity scenario) could increase this to **$21. million**
• Andros’ MPAs support $113 million in visitor expenditure

• The Master Plan (Sustainable Prosperity scenario) would expenditure to $170 million
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- **Coastal habitats** such as mangrove and coppice forests, coral reefs and seagrass **reduce the risk to 50% of the islands’ population, protecting $2.4 million in income**

- The Master Plan (Sustainable Prosperity scenario) would protect 60% of the islands’ population
ANDROS CARBON STORAGE

- Carbon storing mangrove and seagrass in Andros West Side National Park are worth **$6 billion in avoided damages** from emissions.

- These assets could increase by 3% under the Master Plan (Sustainable Development Plan)
SOUTHWEST MARINE MANAGED AREA

Southwest New Providence Marine Managed Area

Mangrove  Seagrass  Coral Reef

East DelMar, DEBCC, NOAA, CDF, and other contributors
Distribution of mangroves and seagrass among shelf areas