

Developing a landscape scale framework to guide conservation planning for cays within the U.S. Caribbean: A preliminary strategy

A Case Study from the Structured Decision Making Workshop

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Decision Problem

This report outlines a structured decision-making process using the PrOACT (Problem, Objectives, Actions and Alternative scenarios, Consequences, and Trade-offs) approach to both frame the decision context/problem and to develop a framework that will lead to the best multi-partner solution.

Partners within the Caribbean Landscape Conservation Cooperative community have recently identified a shared interest in the ecological conservation of the small islands (cays) surrounding the main islands of Puerto Rico, Culebra, Vieques, St. John, St. Thomas, and St. Croix. Here we define a “cay system” to include any cay, island, or islet and the surrounding marine zone (Bush et al. 2014). Cays within the US Caribbean provide many ecological, cultural, historical, recreational, and economic resources. The resources cays provide are influenced by human activities, as well as by changing climate conditions such as sea level rise, increased intensity and frequency of storms, increasing temperature, and ocean acidification. *The region currently lacks a coordinated, values-based conservation framework that integrates the values and*

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objectives of all the stakeholders in the management of the resources. A comprehensive approach is needed to best preserve a *network of cays* capable of supporting shared landscape-scale objectives. The current management at the individual cay level leads to inefficiencies in the allocation of resources and, presumably, a slow deterioration of those resources that frequently depend on a network of cays (e.g. species metapopulation structure). Cays fall under the ownership and jurisdiction of many different entities including private, territorial, and federal each of which have their own priorities and capacities for the management of individual cays. There are also multiple decision-makers, as well as stakeholders who currently affect the resources and management decisions at the individual cay level. The structured decision-making process is intended to help us identify commonalities among these different goals and approaches, to provide a guide to the management actions and resource allocations of multiple decision makers and stakeholder interests.



Here we define (working definition to be refined) a ‘cay system’ as the terrestrial lands and adjacent marine areas (e.g. reefs, sand flats, and seagrass beds) out to a clear transition to the deeper pelagic habitats and/or a clear separation from other such cay systems. This transition will be defined uniquely for each system and an important early step will be defining the individual systems throughout the region by the Cay Conservation Action Team for approval by the CLCC Steering Committee.

Our primary goal is to determine the best approach for optimizing the allocation of resources and actions towards the management of a network of cays that sustainably support the shared landscape-scale objectives of the CLCC. Specifically, we seek to conserve cultural, historic, recreational, and ecological resources associated with cays systems in Puerto Rico and the U.S. Virgin Islands (USVI) over the next 10-15 years (operational timeframe), with a longer term (e.g. 2060) conceptual horizon.

Several key invited partners could not attend this effort; hence *this report represents an initial draft strategy that will be refined through a process of continued engagement and consultation with stakeholders and partners. This endeavor is not intended to be prescriptive, but instead should provide a framework for management options.* Final approval of suggested courses of action will depend on the CLCC Steering Committee.

Background

Legal, regulatory, and political context

Many of our CLCC Steering Committee members represent regional conservation organizations and agencies with regulatory authority. The SDM process will help guide their management actions and resource allocations related to cay systems. Possible management actions include: approval/denial of permits (for actions such as extractive use, construction of structures, development projects, etc.), land acquisition, long-term easement contracts, habitat restoration, and initiatives to conserve the cultural and ecological value of cays for future generations balanced with societal demands for continued use of these resources. The outcomes to be measured will be determined during the process, but could include population viability of protected and managed species, habitat quality, and sustained cultural value. Key uncertainties include human use pressure and effects of climate change, as well as political will and available funding to implement recommended management actions.

While some cay systems in Puerto Rico and USVI are legally protected, enforcement is often limited. Other cays are private property and under pressure for recreational and residential development. A few cays in Puerto Rico and USVI are federally-owned and managed as wildlife refuges or national parks/monuments. Other cays are owned by the Territorial or Commonwealth government and managed as wildlife sanctuaries or part of larger natural reserves. Whether cays are publically or privately owned, construction of structures for recreational, residential, or commercial purposes is regulated by local, Commonwealth or Territorial, and federal agencies. Federal, Commonwealth, and Territorial natural resources agencies also have regulatory authorities to protect terrestrial and marine resources associated with cays, including fish assemblages and their habitat, migratory birds, seabirds, and threatened and endangered species and their habitat.

Ecological and cultural context

Climate change is already having an effect on some cays, as some low-lying coralline and mangrove cays have already become partially or completely submerged with rising sea level, such as one in the area of Guayanilla, Puerto Rico, which was monitored by the U.S. Fish and Wildlife Service from 1991 until it's submergence in 2004. Five species of seabirds and shorebirds that used the cay for breeding were affected and, in some cases, breeding populations are no longer present in Puerto Rico. In addition to their importance for migratory and resident seabirds, cay systems also provide habitat for many endemic, threatened, and endangered plant and reptile species, and they also provide important habitat for juvenile and adult marine species of commercial and ecological importance, including queen conch, Caribbean spiny lobster, groupers, and snappers.

The maritime heritage of the U.S. Caribbean dates back to the settlement of islands by waves of indigenous Amerindians from the Yucatan and South America. During the 1400's Spain, the Netherlands, Britain, France, the Knights of Malta, Denmark, and the United States had dominion over different islands, and many artifacts, historic structures, and landscape changes

associated with those histories are remnant on cays, such as Buck Island Reef National Monument in St. Croix managed by the National Park Service (one of about 50 cays in USVI alone). Beyond the historic and cultural values, cays and islets are important today for recreational opportunities and recreational, commercial, and subsistence fishing.

Decision Structure

Development of Fundamental Objectives

After defining and clarifying the problem (i.e. the region currently lacks a coordinated, multi-stakeholder, values-based conservation framework that integrates the values and objectives of all stakeholders), the next step of the PrOACT approach is to identify fundamental objectives. Fundamental objectives (or goals) are often considered the “values” or the “why” behind the problem and proposed actions. It is our intent that the fundamental objectives serve as an umbrella under which most agencies, organizations, and stakeholders can find a niche within the cays conservation framework. To determine fundamental objectives, the group brainstormed objectives and management actions that were a focus and/or a priority for group members and their organizations. The brainstorming generated a mix of activities and concerns, e.g. invasive species eradication, recovery of federally-listed species and support for species of particular concern, and balancing of conservation with human use. From these ideas, we identified 6 broad categories that became the basis of our fundamental objectives.

Next, in an effort to make this as broadly applicable to the widest range of stakeholders as possible, we conducted a thorough actor analysis. We listed all the federal, Commonwealth, Territorial, and local government agencies, NGOs, and business sectors (e.g. hotels, equipment rental services, guides, etc.) that we could think of that have some level of interest in cays and/or the resources associated with them, and then listed what each most valued from cays. From this extensive list, we defined an initial set of 8 fundamental objectives for the management of cays within the U.S. Caribbean as:

- Increase economic benefits to Puerto Rico & US Virgin Islands
- Maintain ecological Integrity (Marine/Terrestrial)
- Recover and support species of interest and threatened and endangered species
- Support cultural & traditional resource use
- Protect and preserve historic landmarks & structures
- Enhance tourism and recreational experiences
- Ensure public health and safety
- Minimize operational costs

Sub-objectives (which also could be considered crudely defined means objectives) represented more detailed objectives whose outcomes, although not of fundamental importance to the decision makers, directly influence the realization/attainment of fundamental objectives. A total of 28 means/sub-objectives were developed across the 8 fundamental objectives (Appendix 1). This process provided valuable feedback and insights that were used to later refine and reduce our initial fundamental objectives from eight to five:

- Maximize Economic benefits to PR & USVI

- Minimize Operational costs (but we noted that higher costs could reflect stronger commitment to desired outcomes)
- Maximize Ecological integrity (structure and function)
- Maximize Preservation of Cultural/Traditional Resources
- Maximize Tourism/Recreational Opportunities

The group then brainstormed a total of 62 prescribed actions that would help to achieve the fundamental objectives (Appendix 2). These were then grouped into 7 action categories or themes:

- Habitat (13 actions)
- Wildlife populations (4 actions)
- Fisheries (4 actions)
- Economic activity (6 actions)
- Human dimensions (25 actions)
- Human dimensions – Hazards (7 actions)
- Monitoring (3 actions)

We then developed a series of strategies (suites of specific actions) for 3 proposed alternatives (in addition to the status quo): (1) ecological integrity, (2) cultural/historical, and (3) ‘balanced’, which was an attempt to make everyone happy (all are described in greater detail below). To complete the PrOACT cycle, we then formally evaluated the consequences (C) and trade-offs (T), with respect to our fundamental objectives, associated with each of these alternatives. Preliminary means objectives and some measurable attributes and units of measurement were identified for each of these fundamental objectives (Table 1).

Table 1. Initial fundamental objectives and measurable attributes identified during the first round of rapid prototyping (here rapid prototyping simply means a complete quick run-through of the entire PrOACT cycle to get to a final solution). These objectives and especially the measurable attributes will be refined through subsequent stakeholder engagement. This table serves as a draft framework that requires refinement based on available data and finer-scale development of objectives.

Objective	Measurable attribute	Units	Direction
Economic benefits to PR & USVI	Percent contribution to economic activity	%	Up
Marine Ecological integrity (structure and function)	Percent of cays with high integrity	0-20, 20-40, 40-60, 60-80, 80-100	Up
Terrestrial Ecological integrity (structure and function)	Percent of cays with high integrity	0-20, 20-40, 40-60, 60-80, 80-100	Up
Recovery of species of interest (T&E's, other)	% species > min. popn size	0-100	Up
Cultural/Traditional Use	General Satisfaction (public and concessioners)	1 to 5	Up
Historical Structures and Landmarks	% of landmarks with high integrity	0-20, 20-40, 40-60, 60-80, 80-100	Up
Tourism/Recreational Experiences	General Satisfaction (public and concessioners)	1 to 5	Up
Public Health & Safety	Risk to public health & saftey	0-1	down
Operational costs	Cost of implementation	dollars	Down

Alternative strategies developed during the first rapid prototyping segment

Alternative 1: Status Quo

This alternative consists of the maintenance of current management actions and plans for cays in Puerto Rico and USVI by each of their owners (federal, private, Territorial, Commonwealth) with limited collaboration.

Alternative 2: Enhancement of cultural and traditional resource use opportunities and enjoyment at cays in Puerto Rico and USVI

This alternative consists of a strategy to enhance opportunities for cultural and traditional resource uses on cays in Puerto Rico and USVI through an increase in outreach and education activities that include information on traditional practices, and culture and events promoting traditional and cultural resources; increased protection for cultural resources; construction of low impact facilities that improve access to cays; improvement of public safety in the form of increased enforcement, emergency services plan, and enhanced water quality; and protection of aesthetics. Additionally, monitoring would be used to identify cultural and traditional resources, as well as to track changes in opportunities, use, and visitor satisfaction.

Alternative 3: Enhancement of the ecological integrity of the marine and terrestrial ecosystems of cays in Puerto Rico and US Virgin Islands

This alternative consists of a strategy to enhance the ecological integrity, defined as structure and function, of the marine and terrestrial ecosystems of the cays through habitat restoration (where needed); visitor management (to include designating use areas, managing fires, pets, etc., installation and management of moorings, emergency response, pollution management); and improved enforcement of fishing and other environmental protection regulations. Additionally, monitoring would be used to identify ecological resources, as well as to track the effectiveness of enhancement (protection / enhancement) and visitor management efforts and measure changes in the condition of terrestrial and marine ecological resources.

Alternative 4: Balancing the use of cultural, traditional, historic, and ecological resources across cays in Puerto Rico and US Virgin Islands to make everyone smile

This alternative consists of a strategy to balance resource use by local people and tourists while managing for the enhancement of the ecological integrity, defined as improved condition in terms of structure and function, of the marine and terrestrial ecosystems of the cays. This will be accomplished through the management of erosion on cays and the main islands of Puerto Rico and USVI; the limiting of human access to cays during certain times (such as sea bird nesting season) or to certain sensitive areas on cays (for example, where there are endemic plants); installation of moorings and designation of anchorage areas; eradication of terrestrial invasive species and management of marine invasive species; an increase in the number of concessionaires operating tours and other services; improved enforcement of environmental regulations; sponsorship of the establishment of outdoor classrooms; development and dissemination of education materials, collection and dissemination of oral histories; the designation of use areas; the creation of a certification program for tour operators; the

development of hiking trails and creation of wildlife viewing opportunities; and improved trash removal. Additionally, monitoring would be used to inventory biodiversity and conduct vulnerability and viability assessments for species of concern, as well as to evaluate the effectiveness of actions under this strategy.

Consequences

To examine the consequences of each alternative, an Objective and Performance Measures Table was developed to include the objectives, units and desired direction of change (Table 1). This table also details the measurement used to score each alternative against the initial 8 fundamental objectives. We identified measurable attributes and units of measurement for each of these fundamental objectives (Table 1). We rated the current status of each of our objectives based on their indicator values, e.g. under current management, we estimated the percent of cays with high terrestrial ecological integrity between 3 and 30 percent. This formed the basis of our Status Quo alternative for developing the consequence table. As a group we examined the status quo scenario and developed the Consequences Table to provide the framework for assessing tradeoffs associated with each alternative set of actions (Table 2). As part of the development process to create the Consequences Table, expert elicitation was used to predict the consequences of each strategy (relative to the status quo) independently for each fundamental objective (Appendix 3). For example, if we felt that a particular action would increase the ecological integrity of the cays, we assigned the value that we felt the implementation of such a strategy would achieve. Because attributes were in different units they were normalized for comparison. Using the normalized scores we then calculated a Utility score for each of the 4 identified alternatives (i.e., Status quo, Ecological Integrity, Cultural and Traditional Use and Balanced Design). The Utility scores provided a quantifiable basis for ranking the alternative management strategies, with higher Utility scores representing better ranking alternative strategies .

Table 2. Consequences table to assess alternatives: status quo, cultural and historical, ecological integrity, and the balanced design. Note that the definition, unit of measurement, and desired direction following management activity are listed in Table 1 for each of the 8 fundamental objectives.

Objectives	Goal	Status quo	Cultural and Historical	Ecological Integrity	Balanced Design
Economic benefits to PR & USVI	Max	3	9	8	12
Marine Ecological integrity (structure and function)	Max	24	29	59	37
Terrestrial Ecological integrity (structure and function)	Max	30	34	64	41
Recovery of species of interest (T&E's, other)	Max	9	8	35	16
Cultural/Traditional Use	Max	3	4	3	4
Historical Structures and Landmarks	Max	20	36	20	26
Tourism/Recreational Experiences	Max	3	4	3	4
Public Health & Safety	Min	2	1	1	2
Operational costs	Min	2	3	6	5

Decision Analysis/Trade-offs

Predictive analysis

Using the values in the completed Consequence Table (Table 3) for each of the 4 alternative strategies (Baseline, Cultural/Historical, Ecological, and Balanced), we evaluated how well each strategy met our fundamental objectives. Two of the strategies, Cultural/Historical and Ecological, were fairly equally favored at this level of analysis.

We refined our evaluation by individually ranking the Fundamental Objectives according to our values. To do this, we each scored the objectives according to how important each individual felt this action would meet our overall goals, which resulted in a differential weighting of each objective. By adjusting the weights, the model shifted how each strategy would meet our objectives, thereby demonstrating how stakeholder values can influence the final decision outcome.

Since the 2 strategies (Cultural/Historical and Ecological) did not show much differentiation in the model, we went back and re-evaluated them to develop a 5th strategy that incorporated both Cultural/Historical and Ecological strategies and further focused efforts on the recommended actions. The next step was to add in the attribute measures and compare with Status Quo and the other alternatives to see if this fifth strategy is, in fact, the preferred.

New alternative strategy developed after reevaluation

Upon completion of the PrOACT process, including the evaluation of each alternative against the status quo and comparison to weighted scores based on the fundamental objectives, it was decided that an additional alternative combining alternatives 2 and 3 was needed. This was decided because the promotion and protection of cultural and traditional resource use opportunities and the enhancement of ecological integrity, which were also components of two of our fundamental objectives, consistently had the highest scores.

Alternative 5: Enhancement of cultural and traditional resource use opportunities and protection and enhancement of ecological integrity for the marine and terrestrial system of cays in PR and USVI

This consists of the creation of an education and outreach program highlighting ecological, cultural, and traditional resources; habitat protection and restoration to support ecological and cultural resources; the creation and implementation of visitor management measures; increased enforcement of protective regulations; and the creation and implementation of pollution management strategies. Additionally, an increase in system understanding / knowledge would be achieved through monitoring responses to management measures on the part of both visitors and ecological resources, compiling existing data regarding resources on cays and visitor use, and independent research (e.g. studies of effects of climate change on cays that could improve our understanding of impacts at larger spatial scales; ecosystem responses to invasive mammal removals that would shed light on keystone species roles and biogeologic relationships).

Final Fundamental Objectives

Completion of the first iteration of the PrOACT cycle, or rapid prototyping then led us to revisit and refine our proposed fundamental objectives. Each group member provided suggestions for revision, which allowed us to further refine our fundamental objectives into 4 core-values that represented **our final draft fundamental objectives**:

Fundamental Objective 1. Enhance the structure and function of the marine and terrestrial ecosystem of the cays to maximize native and endemic biodiversity

Fundamental Objective 2. Conserve and enhance the cultural and historical resources associated with cays

Fundamental Objective 3. Increase/maximize public satisfaction in coastal communities

Fundamental Objective 4. Maximize available resources (\$, time, coordination etc.) for cay conservation

Uncertainty

Our framework incorporates uncertainty in 5 main areas: (1) linguistic differences or absence of a common language; (2) selection of the best units for measuring attributes; (3) data sources and confidence in the data; (4) selection of alternative strategies; and (5) level of implementation of actions. Two additional uncertainties are also influencing the framework: (1) lack of sufficient knowledge about the cay systems; and (2) environmental variability and stochasticity, especially for stressors like disturbances and climate change.

Throughout the process we repeatedly noticed that we were operating without a common language. At times the team would be discussing different things using the same terminology. These linguistic differences may have influenced the selection of fundamental objectives, means objectives, the actions, and the alternative strategies.

The decision to rely on science, data collection, or expert elicitation is an uncertainty that can be an impediment to making a good decision if the information source is questionable. Our team process at NCTC was to use the expertise in the room to come up with educated guesses for each means objective metric. Because of the heavy bias towards ecological expertise in our NCTC team, the amount of uncertainty is less for the initial *marine and terrestrial ecological integrity* fundamental objective than for the other fundamental objectives.

Another uncertainty our team faced was in the selection of the alternative strategies themselves. For the purposes of the NCTC training and moving through the first rapid prototype, the list of

actions the team brainstormed by fundamental objective were placed into broader themes with action elements and those with the greatest overlap were selected to focus the alternative analysis. This process did not necessarily reflect the range of all possible alternatives towards the creation of our framework.

One of our largest uncertainties involved the probability of alternative action implementation. Taking into consideration the spatial scope and multi-actor nature of the decision problem, the consequences of each suite of actions is dependent on the feasibility and quality of implementation. Additionally, agencies and organizations experience policy and leadership changes. These realities, as well as the variability in political willingness and other institutional impediments to collaboration, may affect the level of implementation of the alternatives presented in the framework.

To capture this, the original tradeoff analysis was re-analyzed integrating the possibility that certain alternative actions would or would not be implemented. The end result of this analysis demonstrated that the level of implementation definitely has a strong impact and cannot be ignored. At this stage in the process we need not dig deeper into this, but as we solicit more expert input and narrow in on the final set of actions we will need to redo this analysis with more robust estimated probabilities of implementation and strongly consider the outcomes in the decision context.

Discussion

Value of decision structuring

The SDM process was particularly valuable for our team because of the complexity of our problem. The SDM approach provided a valuable framework for exploring multiple objectives and integrating several values.

Historical management of the cays in the USVI focused on sea bird conservation. In Puerto Rico, cays that are within existing reserve boundaries receive some level of management but are not the focus of management actions directed at issues specific to cays. More recently Coastal Zone Management Programs in Puerto Rico and USVI, Areas of Particular Concern (APCs) have been established and management actions drafted that include the cays within APC boundaries. We will need to crosswalk those and other existing plans (e.g. the State Wildlife Action Plans, individual species recovery plans, watershed management plans for coral reef conservation priority areas, etc.). Much of the information required to effectively manage cays is either lacking or dispersed among various stakeholders, for example knowledge about their importance for human uses and their biodiversity. The ProACT process, and in particular the rapid prototyping approach, allowed us to overcome those hurdles and move through the entire decision cycle to provide confidence that once we consolidate the data, the process will be effective and we can build on what was drafted at the workshop.

Further development

Development beyond the initial workshop is needed to make our conservation strategy for cays in the U.S. Caribbean a reality. Our first step will include updating the CLCC Steering

Committee during an upcoming monthly call (March/April 2015). We will use this update as (1) a ‘reality check’ on the direction and content of the present prototype, (2) an opportunity to identify additional experts / policy-makers (specifically experts that can better inform cultural resource components of this framework) with whom we should consult during this early phase of the project, (3) present the steps and timeline for project completion, (4) discuss the products, and (5) remind the Steering Committee of how this project serves as a starting point and example for the upcoming Southeast Climate Science Center sponsored SDM workshop with the Steering Committee. Once we confirm that we are on the right path and/or make necessary adjustments, we will elicit additional technical expertise to fine-tune means objectives and establish meaningful (i.e. clear spatially-explicit connection to resources of interest) metrics, locate suitable data, list additional actions to further develop decision alternatives, and identify information gaps. After objective and metric fine-tuning and consolidation of supporting data layers we will sponsor workshops for targeted stakeholders (i.e. subject matter experts) to (1) refine the document and process, (2) consolidate additional supporting data layers, (3) identify additional actions, and (4) explore additional alternative management scenarios. Throughout the process we will upload available supporting data to the CLCC data portal (el CAMPO), create supporting maps and synthetic layers, and identify information / data gaps. As necessary, we will hold additional workshops focused on alternative analysis and uncertainty modeling. A more specific step-by-step timeframe will be established with the CLCC Steering Committee. The final framework, document, support layers, and decision tool (el CAMPO) for the cays conservation framework needs to be completed by May 2016 in advance of the Large Landscape Conservation workshop to be held in October 2016. The Southeast Association of Fish and Wildlife Agencies (SEAFWA) expects to roll-out the Southeast Conservation Adaptation Strategy at this workshop, including a Caribbean component that will highlight the cays framework. Once the products are complete we will host a workshop as part of efforts to disseminate and communicate with Puerto Rico and USVI stakeholders regarding the results of our efforts toward the cays conservation framework.

Literature Cited

Bush et al. 2014. *Potential Future Land Loss of Small Islands of Puerto Rico and the United States Virgin Islands*. FINAL REPORT for Project #: R-111-1-10 to University of Puerto Rico Sea Grant College Program Mayaguez, Puerto Rico.

Appendix 1. Fundamental objectives (numbered 1-8) and sub-objectives associated with each fundamental objective. The identification of sub-objectives enabled subsequent refining and combining of the initial 8 fundamental objectives into a more concise and comprehensive set of five fundamental objectives.

- 1) Economic benefits to PR & USVI
 - Fisheries (yield)
 - Tourism
 - Real estate
 - Weddings
 - Maintain ecological services to (storm mitigation, fish production)
- 2) Marine & Terrestrial Ecological Integrity (structure and function)
 - Seabirds
 - Invasive species
 - Sea grass
 - Coral reef fish assemblages
 - Seabirds
 - Lizards
 - Native plant community
 - Invasive species
- 3) Recovery of Species of Interest (T&E's, etc)
 - Invasive species
 - Terrestrial habitat
 - Marine habitat
- 4) Cultural/Traditional Resource Use
 - Traditional resources (egg poaching, goat foraging, camping activities, fishing)
 - Maintaining cultural communities' identities and practices
- 5) Historical landmarks/structures
 - Historic structures (lighthouses)
 - Archaeological (pre-european, slave, dutch, etc)
 - Preservation of indicators of past long-term land and sea use (mining)
- 6) Tourism/Recreational Satisfaction
 - Hiking, Wildlife viewing, Partying, Overnight charters
 - Fishing, diving, swimming, kayaking, paddle boarding
- 7) Public Health and Safety
 - Water quality
- 8) Operational costs
 - Minimize loss of infrastructure due to hazard events
 - Maximize efficiency of resource allocation
 - Minimize costs
 - Minimize time

Appendix 2. List of possible management activities (Action Elements) that could be implemented as part of any Alternative Management Strategy (i.e., a management Portfolio representing a collection of Actions). Each Action Element below was placed under one of seven general themes (this was done purely for convenience) to keep track of general categories of actions. Ultimately, the Team used this list of possible actions to develop and define the components of each of the 5 general Alternative Strategies (Status quo, Cultural/Traditional Resources, Marine and Terrestrial Ecology, Balanced, and Combined Ecological and Cultural/Traditional Resource Use. Each of the 5 Alternative Strategies is described in detail in the text body.

Themes	→	Habitat	Populations	Fishing	Economic activity	Human use	Hazards	Monitoring
Action elements	↓	Improve fish habitat	Eradicate and control invasives	Change fishing regs to ...	Residential and commercial development	Implement public outreach and education plan	Expand BVI emergency management to USVI	Inventory skinks, specifically, or biodiversity, in general
		Replant native vegetation	Translocation of	Change access to technology	Increase moorings	Improve enforcement	Identify hurricane (hazard events) safe zones for Cays visitors	Vulnerability/viability assessments for species of concern
		Managing erosion	Eradicate rats and goats	Fishing associations	Invest in green/natural infrastructure (e.g., mangrove for shoreline protection)	Limit public access to...	Spill response plan	Inventory/investigation/survey for historic resources
		Seagrass re-establishment	Enforce of take prohibition	Increase fishing tournaments	Head tax for accessing Cay	Sponsor establishment of outdoor classrooms	Rescue services	
		Build artificial reef		Provide incentives to comm. Fishers	Increase # of concessioners	Install composting toilets	Water quality/seafood warnings and awareness (signage)	
		Limit access during sensitive time periods/sites				Issue permits for traditional uses	Enforcement of prohibitions of bilge pump outs	
		Install moorings and anchorage areas to prevent anchoring in sensitive areas				Collect and disseminating oral histories	Unexploded ordinance management	
		Purchase islets				Designating use areas (i.e., zoning)		
		Establish conservation easments				Establish or supporting visitor center / museum		
		Terrestrial habitat restoration				Install signage for public education		
		Corral habitat restoration				Historical societies		
		Remove invasive vegetation				Social media		
		Protect and restore nesting beaches (turtles and roseatte terns)				Outreach/awareness of historical resources		
						Restoration of historical resources		
						Registry of historical resources		
						Develop action plan for each historical site		
						Certification program for tour operators		
						Hiking trails		
						Wildlife viewing (e.g., bird blinds)		
						Increase and training for interpretive rangers		
						Develop guides/interpretive media		
						Low-impact facilities to improve access		
						Improve trash removal		
						Increase concessioners for eco-tourism (e.g., kayaking and biking)		
						Marketing eco-tourism (e.g., discount packages)		

Appendix 3. Consequence Table expert elicitation results. Each of the 7 workshop participants (Stakeholders) predicted the consequences of each of the 4 alternative management strategies (Status Quo, Cultural, Ecological, and Balanced) independently with respect to each of the 8 fundamental objectives. The units of measurement and possible range of values for each fundamental objective are listed in parentheses. The mean response (i.e., averaged across all 7 participants) of each Fundamental Objective/Alternative Strategy combination were used to populate corresponding cells in Table 2.

**Economic Benefits to PR & USVI
(% contribution to economic activity; range = 0-100)**

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	5	7	3	3
2	1	4	3.5	5
3	n/a	10	20	40
4	8	10	3	7
5	3	30	20	20
6	2	2	4	4
7	1	1	5	3
Mean	3	9	8	12
stdev	2.56	9.87	7.98	13.88

Marine Ecological Integrity (% of cays with high integrity; range = 0-100)

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	30	30	70	30
2	50	30	50	40
3	10	30	50	50
4	30	30	50	40
5	30	45	75	60
6	10	10	60	20
7	10	25	60	20
Mean	24	29	59	37
Stdev	15.12	10.29	10.18	14.96

Terrestrial Ecological Integrity (% of cays with high integrity; range = 0-100)

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	50	50	90	50
2	50	30	50	40
3	30	30	50	50
4	10	30	60	40
5	30	45	75	60
6	30	30	60	30
7	10	25	60	20
Mean	30	34.28571429	63.57142857	41
Stdev	16.33	9.32	14.35	13.45

**Recovery of Species of Interest
(% of species > minimum population size; range = 0-100)**

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	n/a	6	25	15
2	n/a	5	20	10
3	20	10	25	50
4	0	10	20	10
5	10	15	25	20
6	10	5	50	5
7	5	8	80	5
Mean	9.00	8.43	35.00	16.43
Stdev	7.42	3.60	22.36	15.74

Cultural/Traditional Use (General satisfaction; range = 1-5)

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	3	5	3	4
2	3	4	3	4
3	3	4	4	5
4	3	4.5	3	4
5	2	4.5	3	4
6	3	4	3	4
7	2	4	2	4
Mean	3	4.29	3	4
Stdev	0.49	0.39	0.58	0.50

**Historical Structures/Landmarks
(% of landmarks with high integrity; range = 0-100)**

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	10	30	20	30
2	50	50	20	20
3	n/a	50	40	50
4	n/a	50	20	20
5	10	30	15	20
6	25	10	20	20
7	2.5	30	5	20
Mean	20	36	20	26
Stdev	18.91	15.12	10.41	11.34

Tourism/Recreational Experiences (General satisfaction; range = 1-5)

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	3	5	4.5	5
2	4	4	3	4
3	3	4	4	5
4	4	4	3	4
5	2	4.999	2.5	4
6	2	3.5	3	4
7	2	3.5	3	4
Mean	3	4	3.29	4
Stdev	0.90	0.63	0.70	0.49

**Public Health & Safety
(Risk to public health and safety; range = 0 [no risk]to 2 [high risk])**

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1	2	1	1	2
2	n/a	1	2	2
3	1	1	1	1
4	n/a	1	1	1
5	2	1	1	2
6	2	1	2	2
7	2	1	2	2
Mean	1.80	1.00	1.43	2
Stdev	0.45	0.00	0.53	0.49

Operational Costs (Millions of dollars)

Stakeholder	Status Quo	Cultural	Ecological	Balanced
1		4.2	3.2	4
2		3.2	6	4
3		n/a	n/a	n/a
4	2.2	3.2	7.2	4
5		2.5	10	8
6		4	6	6
7		3.2	4	6
Mean	2.2	3.38	6.07	5
Stdev	0.00	0.62	2.42	1.54