Management of Black-footed Albatross in the Face of Climate Change

A Case Study from the Structured Decision Making Workshop
February 28-March 4, 2011
Hawai'i Volcanoes National Park, Hawaii USA

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Decision Problem

Global climate change scenarios predict an increase in air and ocean temperatures, storm intensity, storm surge and inundation of low-lying coastal areas and small islands. Projections of changing oceanographic conditions and inundation are at levels that could affect seabird populations including those of the black-footed albatross (*Phoebastria nigripes*; BFAL). The resilience of BFAL populations in the face of more frequent extreme weather events and nesting habitat loss is therefore a critical issue for wildlife managers. Colony establishment behavior and dispersal biology are poorly understood for BFAL. Despite this uncertainty, management decisions to safeguard BFAL breeding populations in the face of climate change are needed. BFAL breeding range is very limited (about 28 km^2 for breeding versus over 37 million km^2 for foraging), and approximately 96% of the world's BFAL population breeds in the Northwestern Hawaiian Islands (NWHI). Limited breeding range correlates with strong natal philopatry; more than 99% of NWHI BFAL breeders are expected to return to the island of their birth when they reach breeding age. Management options to prevent the degradation and loss of breeding habitat given projections of global sea-level rise (SLR) may therefore be severely constrained in the predominantly low-lying NWHI. It is currently unknown whether BFAL will adapt and establish new colonies on higher ground in the higher main Hawaiian Islands, which are currently plagued with mammalian predators. Additionally, the extent to which BFAL breeding success may be negatively affected by increasing bird density within low-lying colonies as space becomes more limited due to sea-level rise is unknown. In addition to loss of breeding range due to SLR, other climate-related changes to ocean conditions and prey abundance and distribution may adversely affect BFAL foraging. Moreover, BFAL will likely continue to be affected by current threats such as mortality from long-line and gillnet fisheries, and reduced

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reproductive output due to plastic marine debris and chemical contaminants, as well as threats from introduced mammalian predators in the main Hawaiian Islands or accidental introductions at existing colonies.

Disclaimer: This exercise for Structured Decision Making (Management of Black-footed Albatross in the Face of Climate Change) was for training purposes and to identify research needs only, and did not represent a formal analysis of the species' listing or conservation status. We used data for the exercise regarding possible threats to BFAL in the NWHI, however, the locations, actions, and agencies proposed during exercises were selected for illustrative purposes only and do not represent endorsement as U.S. Fish and Wildlife Service policy. Our goal was to explore the Structured Decision Making framework with a specific natural resource challenge as a tool for future management decisions. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Background

Legal, regulatory, and political context

BFAL have a U.S. federal status as a "bird of conservation concern" under the Fish and Wildlife Conservation Act of 1980, as amended; a Hawaii State status of "threatened"; and are listed as "vulnerable" by the International Union for Conservation of Nature (IUCN). Because the NWHI encompass both State and Federal land, they are managed through the State of Hawaii Department of Land and Natural Resources (DLNR), U.S. Department of Interior, Fish and Wildlife Services (USFWS) and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). In addition, the recently (2006) designated Papahānaumokuākea Marine National Monument serves as an overall management structure within which efforts of the other agencies are coordinated. Papahānaumokuākea Marine National Monument management responsibilities are delineated in U.S. Presidential Proclamation 8031 (with authority derived from the Antiquities Act, 34 Stat. 225, 16 U.S.C. 431), while USFWS wildlife managers are also required to manage the National Wildlife Refuge lands and waters under the statutory authority of the National Wildlife Refuge System Administration Act of 1966 as amended (16 U.S.C. 668dd-668ee); the National Wildlife Refuge System Improvement Act (Public Law 105-57, October 9 1997). The USFWS administers the Migratory Bird Treaty Act and the Endangered Species Act of 1973 (7 U.S.C. § 136, 16 U.S.C. § 1531 et seq.) as well. Specific choices about risk-mitigation actions, especially possible colony establishment within the Main Hawaiian Islands, will also be influenced by NOAA/NMFS, Hawaii DLNR/Division of Forestry and Wildlife, Hawaiian and conservation organizations, and other interested groups. Possible establishment of additional colonies on islands off the coast of Mexico, where BFAL have been documented as prospecting for nest sites during the breeding season, would necessitate international collaboration with the Mexican government and conservation organizations of Mexico.

Ecological context

Black-footed albatross spend most of their lives at sea, returning to land only to choose mates, incubate, and feed their young (Rice and Kenyon 1962). Their persistence is therefore tightly coupled to breeding habitat, much less than 1% of the total area of the North Pacific. Like other species in the order Procellariformes or "tube-nosed" seabirds, BFAL forage over thousands of square miles of open ocean in pursuit of sparsely distributed food resources that breeding birds bring back to the colony to feed their single offspring (Hyrenbach et al. 2002, Kappes et al. 2010). Their life history traits reflect the trade-offs in their foraging and breeding ecology. These traits include long life expectancy, delayed reproductive maturation, long-term pair bonding, colonial nesting, and obligate biparental care of offspring. Fecundity is low, with pairs laying a maximum of a single egg per year (Rice and Kenyon 1962b). Pairs do not breed every year and do not re-nest following nest failure (Rice and Kenyon 1962a). During the approximately nine week incubation period (Rice and Kenyon 1962b), both parents take turns incubating for 2-3 weeks at a time while the other parent departs to forage on trips that sometimes exceed 1,000 miles (Fernández et al. 2001). Parental care of chicks extends approximately five months after eggs hatch (Rice and Kenyon 1962b).

Approximately 60,000 pairs of BFAL breed in the NWHI (Naughton et al. 2007); the world population, including pre- and non-breeding individuals, is estimated at approximately 300,000 total birds (Cousins and Cooper 2000). The largest colonies are on Midway Atoll (maximum elevation 11.0 m, mean elevation < 2.5 m [Krause et al. 2012]) and Laysan Island (maximum elevation of 10.7 m, mean elevation 4.3 m [Krause et al. 2012]), which collectively provide nesting habitat for roughly 43,000 breeding pairs or approximately 70% of the global population (Naughton et al. 2007). Other BFAL colonies occupy islands of Kure Atoll, Pearl and Hermes Atoll, Lisianski Island, and French Frigate Shoals (Naughton et al. 2007), all of which are low-lying (maximum elevation of 7.6 m [Krause et al. 2012]). Necker and Nihoa islands, the only relatively high elevation islands of the NWHI, have 112 pairs and a single pair of breeding BFAL, respectively (USFWS unpub. data 2010). There are 25 pairs on Lehua, a small high elevation island off of Kauai in the Main Hawaiian Islands (USFWS unpub. data 2010). There are approximately 2,000 breeding pairs of BFAL in Japan (Arata et al. 2009), Japanese colonies were not included in our decision process.

Decision Structure

In this workshop our goal was to help identify the best sequence of long-term actions to protect BFAL against climate change threats and support the goals set out in the Conservation Action Plan for albatrosses, the USFWS Seabird Conservation Plan, and Papahānaumokuākea Marine National Monument mandates (Naughton et al. 2007, PMNM 2008, USFWS 2005).

Our working objective was to maximize the probability of persistence of BFAL over 100 years. We recognize that multiple factors affect species persistence. However, for the purposes of this workshop, we chose to focus on the fundamental objective of maximizing reproduction of BFAL at the nesting colonies.

Problem Statement: Rapid or global climate change could cause reduced black-footed albatross (BFAL) reproductive success and population persistence through loss of nesting habitat and contraction of breeding distribution.

We sought to develop the best sequence of management actions to address the threats of:

- passive sea-level rise (habitat loss) (IPCC 2007)
- frequent storm surges (loss of chicks and eggs) (IPCC 2007)
- changes in ocean chemistry and water temperature (IPCC 2007)

- inhibition of reef growth by acidification slowing calcification that may diminish natural maintenance and replenishment of islands

We recognized that climate change related alterations in ocean and weather conditions could affect BFAL reproductive performance through changes in temperature and wind regimes, increased thermal stress for chicks, and shifts in the location and type of prey available (Kappes et al. 2010, Oswald and Arnold 2012). The scope of our problem statement was limited to addressing threats specifically related to diminishing nesting habitat and breeding range, we did not address other potential threats to BFAL persistence related to rapid climate change.

Objectives

Fundamental Objective: Maximize successful reproduction of BFAL.

1st Prototype Means Objectives (measureable attributes):

1. Maximize range of breeding colonies safe from predation and passive sea-level rise impacts (distance between farthest east and west colony)
2. Maintain a maximum number of distinct breeding colonies (number of breeding colonies)
3. Maintain current nesting habitat and breeding range (number of colonies in the NWHI)
4. Maximize the total area of safe breeding habitat (total available nesting habitat)
5. Minimize the distance from breeding colonies to foraging areas (linear distance to foraging grounds)

We identified that maximizing breeding colony distribution, area, and the number of breeding colonies as essential for the long-term persistence of BFAL, due to the potential climate change impacts from storm surges, SLR and other effects. For example, with only a few large colonies on low islands a single severe storm or natural disaster could cause a substantial loss to the entire breeding population. These first three objectives could be reached not only within the current range of the species but also by establishing new colonies on higher islands through social attraction or translocation of young. Protection of current nesting areas was deemed important for two reasons: 1) strong natal philopatry by BFAL and 2) the value of these existing colonies as sources of young birds and future breeders (i.e., recruits) for many more years. Distance to foraging areas was determined as an important characteristic impacting reproductive success. Based on studies of breeding BFAL in the NWHI, two areas were identified as primary foraging areas for breeding BFAL: 1) the North Pacific Transition Domain (a region between the subarctic and subtropical frontal zones) and 2) continental shelf break and slope waters (Hyrenbach et al. 2002, Kappes et al. 2010, BirdLife International 2011).

As we worked through Structured Decision Making rapid prototyping processes (referred to as the steps of PrOACT [Problem, Objectives, Actions, Consequences, Trade-offs]; Hammond et al. 1999), we distilled these five objectives into three. The first three objectives were amalgamated into an index (using Simpson's Diversity Index) to describe colony distribution among three different regions: NWHI, Main Hawaiian Islands and east-central Pacific (includes islands off of Southern California and Baja, Mexico). Instead of maximizing breeding habitat, we decided a better index to use would be the number of breeding pairs because some islands considered for establishment of new colonies may be large in size, but the maximum number of breeders possible on an island of a given size (i.e., carrying capacity) may not be reached within our timeframe of consideration (100 years or sooner). Our goal was to reduce the risk that catastrophic events, such as severe storms or tsunamis, would remove a significant proportion of the Hawaiian BFAL breeding population. Last, we used population growth rate as index for our final objective of minimizing the distance of colonies to foraging areas. Because long foraging distance to feed chicks may result in lower reproductive success and slower population growth, we applied a distance penalty at potential (new) colonies. In our predictions of the number of breeding pairs at a translocation site after 100 years translocations sites within 100 km of foraging areas were allowed to grow at a rate of 6% annually; remaining translocation colonies, all over 1000 km from foraging areas, were allowed to grow at 3%. We assumed that the number of breeding pairs at existing colonies would not change and that these colonies occur within a reasonable distance to foraging areas.

2nd Prototype Means Objectives (measureable attribute):

1. Maximize number of distinct breeding colonies (number of islands with colonies)
2. Maximize evenness of breeding colonies distributed across three regions (Simpson's Diversity Index)
3. Maximize number of breeding pairs at the end of 100 years (count of breeding pairs)

1st and 2nd Prototype Alternative Actions

We identified and evaluated actions that fell into two broad categories:

1) *in situ* management of existing colonies; and
2) potential establishment of new colonies

Possible *in situ* actions included habitat restoration, dissuasion of birds from nesting in portions of islands vulnerable to wave overwash and storm surge, shoreline protection such as seawalls and groins and acquisition or creation of floating islands to be placed in the vicinity of existing colonies. Actions to establish new breeding colonies included translocation to higher elevation islands, acquisition or creation of floating islands, social attraction to higher elevation islands and predator control at higher elevation islands. Next, as part of our 1st prototype, we developed an array of six action portfolios that we evaluated and compared using consequence tables. One portfolio was a 'Current Management' alternative that assumed management would remain unchanged; the other five portfolios were individually developed by each team member.

Following assessment of these portfolios and refinement of our objectives, we went through a second round of portfolio development, individuals modified their portfolios and collectively the group identified two new portfolios: 1) 'Realistic' portfolio representing actions believed to be effective at meeting our fundamental objective and cost efficient, and 2) 'Idealistic' portfolio representing what we believed would be most effective for maximizing BFAL persistence including actions that we considered feasible without considering cost. Actions included in the 'Realistic' and 'Idealistic' portfolios are presented in Tables 1 and 2.

Predictive models

Establishment of new colonies

For each proposed new colony we only explored the translocation of chicks. For this exercise, we assumed 100 chicks would be translocated over five years, 100% would survive translocation and 50% would survive to fledge. For islands broadly characterized as close to foraging grounds we assumed an annual population growth rate of 6% (rate assumed reasonable based on the minimum calculated annual growth rate of 6.5% for Short-tailed Albatross at Torishima, Japan where the species is recovering from near extinction [H. Hasegawa unpub. data in USFWS 2008]). For islands more distant from foraging grounds (>1000 km) we assumed a lower growth rate of 3%. We also assumed that returning chicks paired up with other chicks returning to the natal island (i.e., assumed no immigration), and we assumed age of first breeding was 10 years. We used an observed adult survivorship rate value for BFAL in the NWHI from 1963-1982 (0.92; Kendall in Arata et al. 2009). After 100 years, this resulted in 2,500 breeding pairs on colonies close to foraging grounds and 187 breeding pairs on colonies far away. Social attraction and recruitment of breeders from existing colonies was not considered (but see, *Further development required*).

<u>Climate change scenarios</u>

To address uncertainty regarding future climate change and SLR, we evaluated three potential scenarios presented by the Intergovernmental Panel on Climate Change (IPCC 2007) and assigned hypothetical habitat loss values for the low-lying NWHI. Additionally, we considered a scenario of no climate change caused SLR and a scenario of extreme SLR that would inundate all low-lying NWHI. All scenarios reflected hypothetical conditions at the end of 100 years.

Scenarios Evaluated:

1. No climate change effects (current environmental conditions).
2. Low: +0.3 m SLR (IPCC model: B1), assumed 10% nesting habitat loss at low-lying islands.
3. Medium: +1.0 m SLR (IPCC model: A1B1), assumed 25% nesting habitat loss at low-lying islands.
4. Large: +2.0 m SLR (IPCC model: A1F1), assumed 50% nesting habitat loss at low-lying islands.
5. Worst Case: Complete loss of all 6 low-lying atolls and islands in the NWHI (equivalent to approx. +11.0 m SLR).

Decision Analysis

We used the Simple Multi-Attribute Rating Technique (SMART) approach (Runge et al. 2011) to combine our three Means Objectives (or measurable attributes) into a single objective and evaluate the effectiveness of action portfolios. In the first step of the SMART process we assessed the eight portfolios, under each of the five hypothetical climate change scenarios, by creating a consequence matrix (three examples shown in Tables 3–5) and plotting the predicted change in the value of each objective (Figures 1–3). We then normalized scores (scale of 0–1) so that attributes on different scales could be compared and combined (Tables 3–5). Based on the group's assessment of the relative importance of each Means Objective in reaching the overall objective (maximizing reproductive success) we assigned a relative weight to each objective using "swing weights" (Runge et al. 2011). As a group we weighted maximizing the number of distinct breeding colonies and the distribution of colonies across three regions (Simpson's index) equally (0.44), followed by maximizing the numbers of breeding pairs (0.11) (Tables 3–5). We did not include cost in the weighted portfolio scores, but rather, this was considered separately by plotting portfolio scores as a function of cost and drawing 'efficiency frontiers' (Runge et al. 2011; Figures 4–6). The modified portfolios produced during the 2nd prototype (those presented in this report) provided improvement in meeting the conservation objectives compared to those developed during the 1st prototype.

Uncertainty

Primary sources of uncertainty:

- Environmental
  - What will be the actual magnitude of SLR and other effects of climate change after 100 years?
  - How much habitat will be lost due to passive SLR (inundation of nesting habitat) and periodic (e.g. storm surge and overwash) habitat impacts of climate change?
- Biological
  - Behavioral plasticity of BFAL: Will adult breeders or subadult recruits relocate to new colonies or within existing colonies if nesting habitat is lost? What proportion of the population will move to islands other than their natal islands to nest? How long will it take BFAL to begin nesting at a new site after being displaced from their former nesting site?
  - What is the potential carrying capacity of islands and what is the maximum possible nesting density as island area decreases?
  - How many colonies are needed to maximize persistence? How large do the colonies need to be?
  - Are there any concerns regarding gene flow between colonies that should be considered in establishment of new colonies?
- Management
  - What is the likelihood the actions will be successful?
  - Will there be cooperation with other agencies, individuals, and nations to establish new colonies?
  - Will funding to implement actions be available?

Key assumptions:

- In comparing action portfolios, we assumed actions were successful.
- We assumed a direct proportional relationship between loss of nesting habitat and number of breeding pairs. In other words, we assumed that a 50% nesting habitat loss would equal a 50% decrease in breeding pairs.

Discussion

Value of decision structuring

There was consensus within the working group that the Structured Decision Making framework allowed a large and complex management problem to be approached in a focused and systematic manner that would allow for more efficient and effective decision making. Using this framework we refined our objectives to reflect the most biologically relevant attributes. The decision process was transparent and minimized personal biases by requiring participants to quantify potential biological benefits and costs of each action (e.g, number of breeding albatrosses gained or lost, cost). The structured process allowed us to effectively consider biological and economical aspects of BFAL conservation actions independently and then together using an 'efficiency frontier'.

Prototyping process

All team members were aware of the broad range of threats that could affect the persistence of this species through time and from the outset we were interested in concentrating on a problem that was manageable to address in a one-week workshop. Prototyping compelled us to define the spatial and temporal scale of our problem and define tightly focused objectives. At times we became side-tracked with discussions of threats and alternative actions that were not closely tied to our problem statement. Reference to our problem statement and objectives allowed the group to quickly refocus discussions. The rapid prototyping process required that some of the complexity, details and uncertainties be disregarded or minimized in order to get through the entire process one time during the first half of the workshop. By going through the entire process once and then revisiting all steps we were able to gain insight into which components of the decision problem could be simplified and those that necessitated research beyond what was possible in a week's time. Making it through the PrOACT cycle the first time without getting too held up by some of the very complex details of our problem was invaluable in allowing us to identify the details that were most important to making relevant management decisions.

Further development required

The rapid prototyping process was completed with limited data and many simplifying assumptions that contributed to uncertainty in the model outcomes and decision process. Reducing the uncertainty of many of the model inputs is necessary in informing management decisions. Specifically, to better understand the variability in the potential conservation value of newly established BFAL colonies, the simplistic models of population growth that were developed during rapid prototyping should be refined to include demographic variability. Additionally, growth models that predict colony size over time after multiple scenarios of translocation effort and immigration could be developed to evaluate specific translocation strategies for their feasibility, time frame, and conservation value. Variable rates of immigration could be incorporated in models of their population growth at new colonies as a method to explore how the population may grow as birds are displaced from colonies in the NWHI. To reduce the uncertainty in how management actions may perform in achieving short- and long-term conservation targets, the time-scale of population growth of scenarios should be made clear.

Additional reduction of uncertainty can be achieved through more exhaustive literature searches than we were able to accomplish in the limited time window of the workshop or by acquiring more accurate pricing of action alternatives. Uncertainty associated with where BFAL will go if their nesting habitat is eliminated may require new research initiatives. Finally, although our small working group allowed us to work together effectively to address or incorporate differing points of view in our models, further development would require input from additional managers, stakeholders and researchers.

Recommendations

Our SDM working group was tasked to consider the value of applying an SDM framework for developing options to manage BFAL in the face of climate change and to better understand the tools that are available for aiding complex decision making. Recent severe weather events (Jan and Feb 2011) that resulted in significant losses of BFAL nests in the NWHI have highlighted the need to consider management actions to address rapid climate change scenarios. We recommend that the decision process and the prototype tools developed during this workshop be utilized and further developed when management strategies for BFAL or other seabirds in the NWHI are considered in the future. We found that using the analytical and quantitative tools available for weighting objectives, evaluating consequences and quantifying tradeoffs were very useful in clarifying differences among sets of actions (i.e., portfolios), effectively making the decision process more transparent and less likely to be influenced by personal biases.

We recognize that it is often times difficult to get all stakeholders in a management problem to come together and for individuals to be able to spend time addressing a single issue or portion of an issue. All members of our group, however, felt that the SDM process is a valuable tool in making efficient management decisions and that the time and effort expended in going through the process when faced with complex problems would increase efficiency in the end and provide transparency that is necessary when dealing with multiple stakeholders.

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Acknowledgements

Support for the workshop was provided by the USGS Pacific Island Ecosystems Research Center, the National Climate Change and Wildlife Science Center (3206DU9.4.15), USFWS National Conservation Training Center, and USGS Patuxent Wildlife Research Center. We thank J. Adkins and J. Hatfield for reviews of this report.

Tables

Table 1. Idealistic Action Portfolio.

Idealistic
Dissuade birds from nesting in areas of Midway Atoll that are vulnerable to wave overwash and storm surge
Intra-island social attraction to move nesting to locations at Midway that are not vulnerable to wave overwash and storm surge
Shoreline protection (e.g., seawalls, groins or barrier reefs) at Midway
Beach replenishment (placement of under-water dredged sand on island) at Midway Atoll
Maintain/supplement/create beach barricades/berms at Laysan Island
Create nesting habitat on floating island/barge in harbor at Midway Atoll
Translocation to available higher islands (over 5 years): 3 Mexican Islands, 2 Californian Islands, 3 Main Hawaiian Island sites
Social attraction at higher islands: 3 Mexican Islands, 2 Californian Islands, 3 Main Hawaiian Island sites
Non-native predator eradication at new colony: 1 Main Hawaiian Island site
Land Acquisition: 1 Main Hawaiian Island site

Table 2. Realistic Action Portfolio.

Realistic
Dissuade birds from nesting in areas of Midway Atoll that are vulnerable to wave overwash and storm surge
Beach replenishment (placement of under-water dredged sand on island) at Midway Atoll
Maintain/supplement/create beach barricades/berms at Laysan Island
Translocation to available higher islands (over 5 years): 3 Mexican Islands, 2 Californian Islands, 3 Main Hawaiian Island sites
Social attraction at higher islands: 3 Mexican Islands, 2 Californian Islands, 3 Main Hawaiian Island sites

Table 3. Consequences table under a no climate change scenario.

CONSEQUENCE MATRIX		Alternatives		
Objectives		Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies		9	13	17
Maximize colony distribution among regions (Simpson's Index)		0.20	0.54	0.64
Maximize number of breeding pairs		58280	63652	73524
Minimize additional cost (dollars [millions])		0.00	11.45	86.20
NORMALIZED SCORES (scale 0-1)		**Alternatives**		
Objectives		Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies		0.00	0.50	1.00
Maximize colony distribution among regions (Simpson's Index)		0.00	0.79	1.00
Maximize number of breeding pairs		0.00	0.35	1.00
Minimize additional cost (dollars [millions])		1.00	0.87	0.00
WEIGHTED SCORES (Normalized scores * Swing weights)		**Alternatives**		
Objectives	Swing Weight	Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies	0.44	0.00	0.22	0.44
Maximize colony distribution among regions (Simpson's Index)	0.44	0.00	0.35	0.44
Maximize number of breeding pairs	0.11	0.00	0.04	0.11
Minimize additional cost (dollars [millions])	0.00	0.00	0.00	0.00
Total Score		0.00	0.61	1.00

Table 4. Consequences table under a large climate change scenario.

CONSEQUENCE MATRIX		Alternatives		
Objectives		Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies		6	10	14
Maximize colony distribution among regions (Simpson's Index)		0.28	0.78	0.77
Maximize number of breeding pairs		22934	32611	42483
Minimize additional cost (dollars [millions])		0.00	11.45	86.20
NORMALIZED SCORES (scale 0-1)		Alternatives		
Objectives		Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies		0.00	0.50	1.00
Maximize colony distribution among regions (Simpson's Index)		0.00	0.77	0.77
Maximize number of breeding pairs		0.00	0.50	1.00
Minimize additional cost (dollars [millions])		1.00	0.87	0.00
WEIGHTED SCORES (Normalized scores * Swing weights)		Alternatives		
Objectives	Swing Weight	Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies	0.44	0.00	0.22	0.44
Maximize colony distribution among regions (Simpson's Index)	0.44	0.00	0.34	0.34
Maximize number of breeding pairs	0.11	0.00	0.06	0.11
Minimize additional cost (dollars [millions])	0.00	0.00	0.00	0.00
Total Score		0.00	0.62	0.90

Table 5. Consequences table under a worst case scenario.

CONSEQUENCE MATRIX		Alternatives		
Objectives		Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies		3	7	11
Maximize colony distribution among regions (Simpson's Index)		0.44	0.90	0.84
Maximize number of breeding pairs		138	5510	15382
Minimize additional cost (dollars [millions])		0.00	11.45	86.20
NORMALIZED SCORES (scale 0-1)		Alternatives		
Objectives		Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies		0.00	0.50	1.00
Maximize colony distribution among regions (Simpson's Index)		0.00	0.96	0.84
Maximize number of breeding pairs		0.00	0.35	1.00
Minimize additional cost (dollars [millions])		1.00	0.87	0.00
WEIGHTED SCORES (Normalized scores * Swing weights)		Alternatives		
Objectives	Swing Weight	Current Management	Realistic	Idealistic
Means Objective: Maximize reproductive success				
Maximize number of breeding colonies	0.44	0.00	0.22	0.44
Maximize colony distribution among regions (Simpson's Index)	0.44	0.00	0.43	0.37
Maximize number of breeding pairs	0.11	0.00	0.04	0.11
Minimize additional cost (dollars [millions])	0.00	0.00	0.00	0.00
Total Score		0.00	0.69	0.93

Figures

Figure 1. Consequences of three action portfolios on the number of extant colonies after 100 years under five hypothetical climate change scenarios. Action portfolios presented are a suite of potential management actions for black-footed albatross that represent: 1) current management actions, 2) 'realistic' actions that would improve successful reproduction and are cost efficient, and 3) 'idealistic' actions that would improve successful reproduction without considering cost.

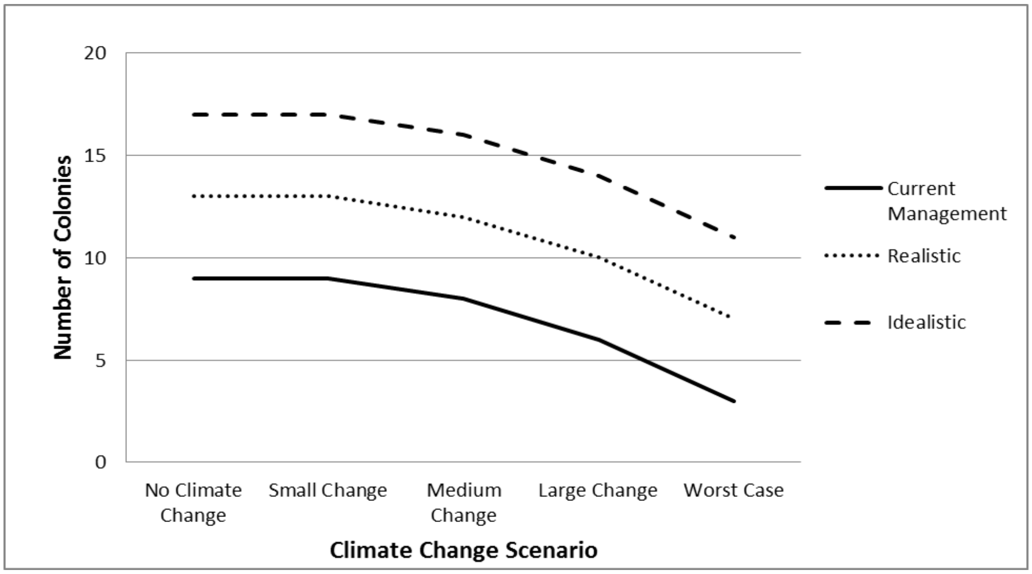

Figure 2. Consequences of three action portfolios on the distribution of colonies (Simpson's Index) after 100 years under five hypothetical climate change scenarios. Action portfolios presented are a suite of potential management actions for black-footed albatross that represent: 1) current management actions, 2) 'realistic' actions that would improve successful reproduction and are cost efficient, and 3) 'idealistic' actions that would improve successful reproduction without considering cost.

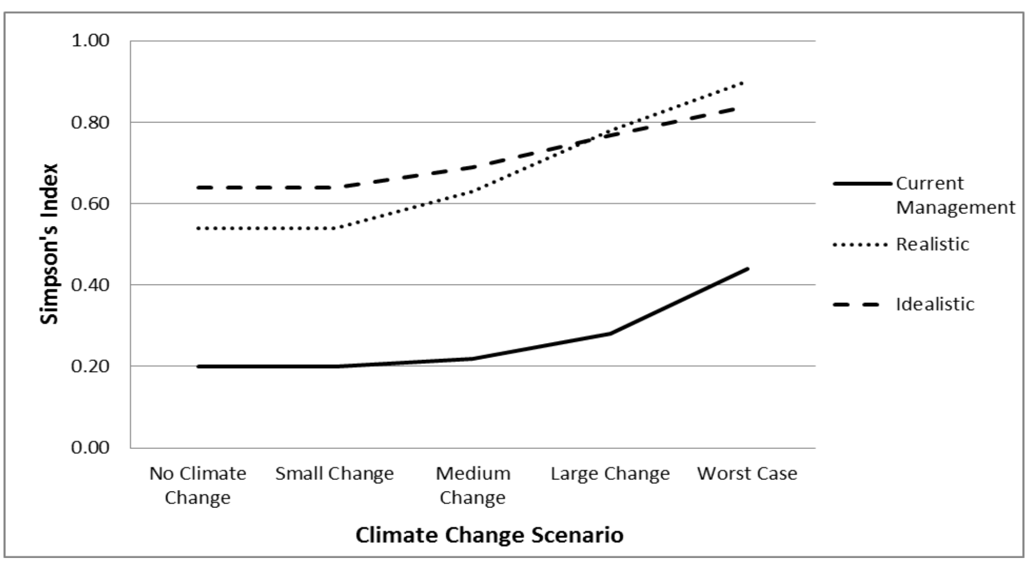

Figure 3. Consequences of three action portfolios on population predictions after 100 years under five hypothetical climate change scenarios. Action portfolios presented are a suite of potential management actions for black-footed albatross that represent: 1) current management actions, 2) 'realistic' actions that would improve successful reproduction and are cost efficient, and 3) 'idealistic' actions that would improve successful reproduction without considering cost.

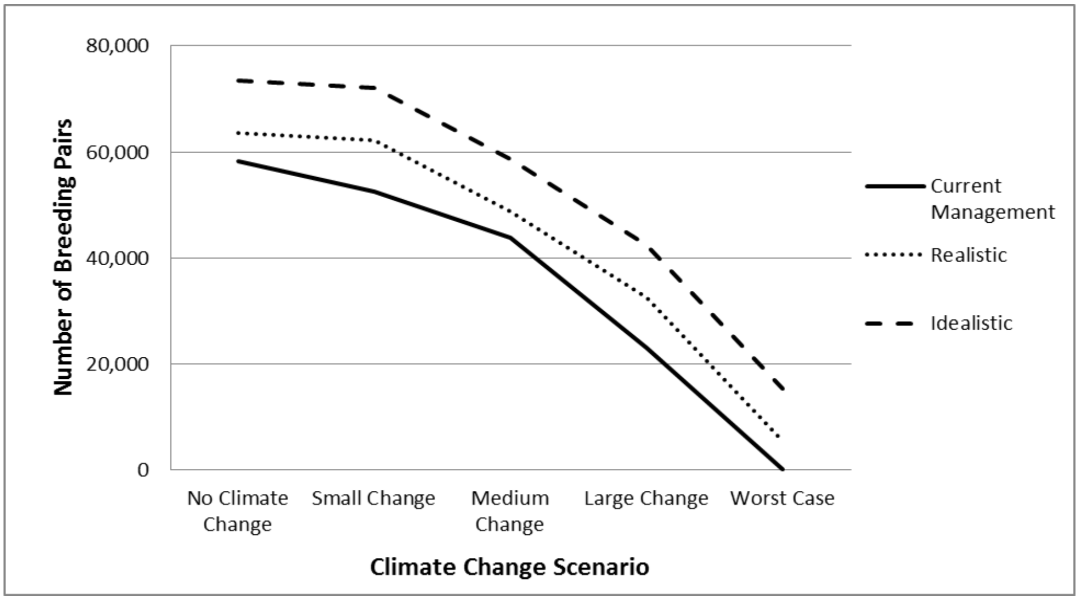

Figure 4. Benefit (weighted score) of action portfolios as a function of cost under the hypothetical climate change scenario of no change.

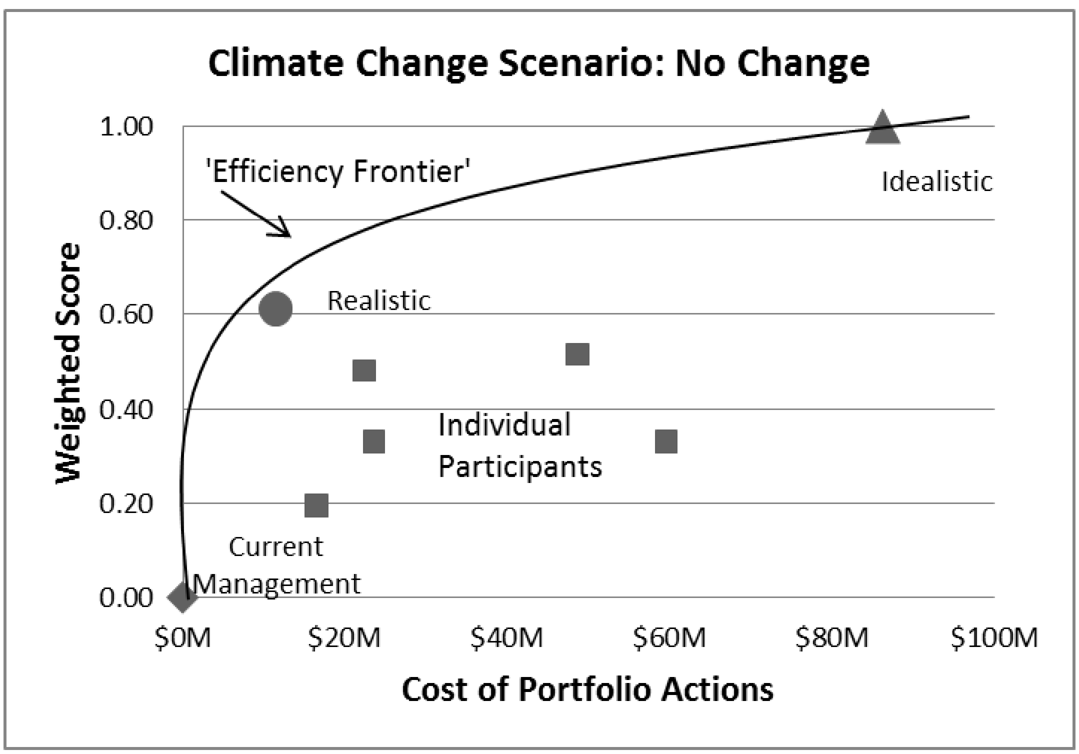

Figure 5. Benefit (weighted score) of action portfolios as a function of cost under the hypothetical large climate change scenario.

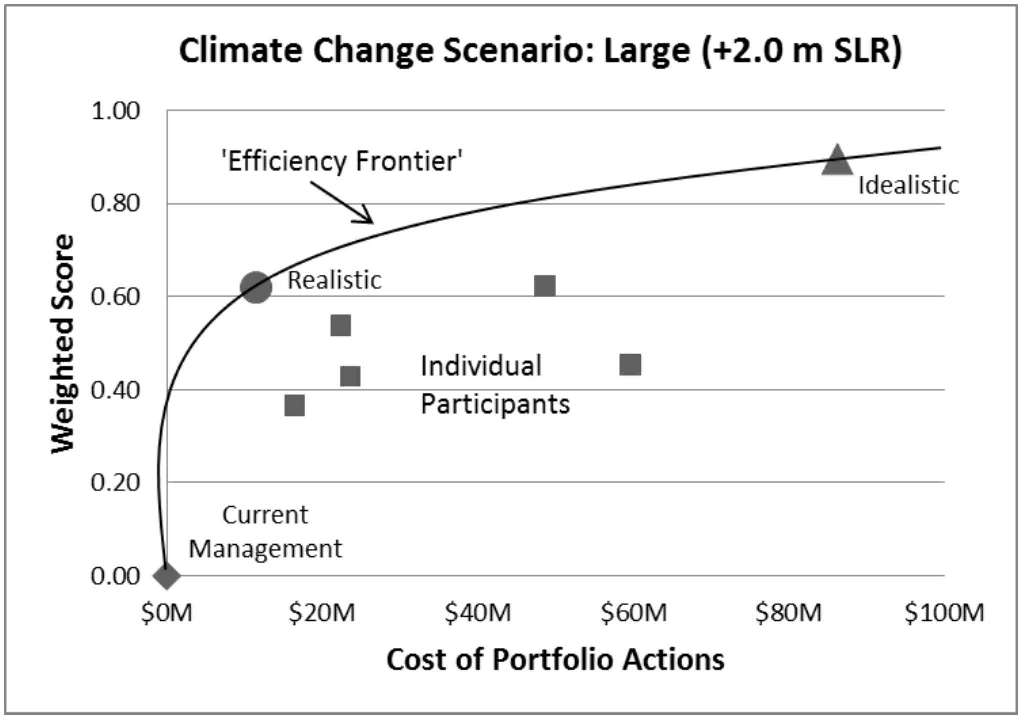

Figure 6. Benefit (weighted score) of action portfolios as a function of cost under the hypothetical climate change scenario of all low-lying islands in the NWHI being inundated.