National Fish and Wildlife Foundation
Pacific Seabird Program
Conservation Impact Assessment

Final Report

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National Fish and Wildlife Foundation

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by

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EXECUTIVE SUMMARY: Pacific Seabird Program (PSP) Conservation Impact Assessment

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The final report is available as of September 2021
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Background and Purpose

Seabirds are amongst the most threatened animal groups with 29% listed as threatened by the International Union for the Conservation of Nature's Red List of Threatened Species (IUCN Red List). The goal of the Pacific Seabird Program is to enhance the viability of 12 focal Pacific seabird species by increasing population size through improved survival and reproduction. Species were selected due to their protection under the U.S. Migratory Bird Treaty or Endangered Species Acts, listing as Vulnerable (VU), Endangered (EN) or Critically Endangered (CR) by the International Union for the Conservation of Nature's [IUCN] Red List of Threatened Species, or expert opinion of conservation need. Funded conservation and recovery actions included eradicating invasive species, fencing that prevents key invasive mammals from damaging nest sites, starting new seabird colonies by translocating eggs or chicks from existing colonies, attracting birds to new colonies or enhancing existing colonies using sound and other social stimuli, colony habitat restoration, reducing unintended catch in commercial fisheries, and forage science to inform fisheries management. Projects were located in Alaska, Hawaii, California, Mexico, or Chile.

PSP Program Highlights (2011 – 2020)

- $43 Million to 181 grants from 53 organizations
- $52 Million leveraged in matching funds

PSP Focal Species

- Aleutian Tern
- Ashy Storm Petrel
- Black-footed Albatross
- Guadalupe Murrelet
- Hawaiian Petrel
- Kittlitz's Murrelet
- Laysan Albatross
- Newell's Shearwater
- Pink-footed Shearwater
- Red-legged Kittiwake
- Scripps's Murrelet
- Townsend's Shearwater

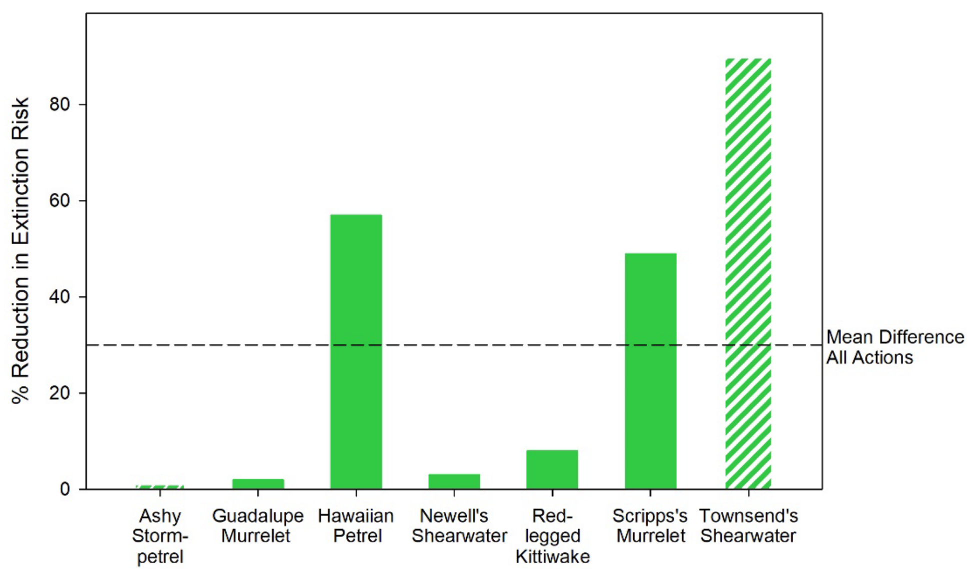
The National Fish and Wildlife Foundation (NFWF) commissioned this conservation impact assessment to understand the impact of the Pacific Seabird Program on its 12 focal species and seabird conservation over the 10-year life of the Program. This assessment examines impacts on the focal species, other seabirds, and non-seabird species located in PSP project areas, and broader impacts on NFWF grantees and the field of seabird conservation.

Summary of Impact Assessment Findings (2011-2020)

- **9 successful invasive species eradications** reduced or eliminated invasive species threats to 9 populations of 7 focal seabird species and 65 populations of 45 non-focal seabird species across over 81,000 acres of seabird breeding habitat.
- **10 predator and/or ungulate proof fencing projects** protect 2,953 acres of breeding habitat for 13 populations of 5 focal seabird species.

- **7 seabird translocations** totaling 519 eggs or chicks from six focal seabird species were successful with a 97% post translocation fledging success rate.
- **10 social attraction projects** led to the establishment of successful nesting of three populations of three focal seabird species.
- **8 habitat restoration projects** covering 1744 acres resulted in increased reproductive success of five populations of four focal seabird species.
- **5 fisheries bycatch reduction projects** documented reductions in seabird bycatch of three focal seabird species across five fisheries.

These actions helped achieve the intended goal of the Pacific Seabird Program to increase focal seabird population sizes through improved survival and reproduction. Specifically, the projects increased reproductive success for Black-footed Albatross, Hawaiian Petrel, Laysan Albatross, Newell's Shearwater, Pink-footed Shearwater, and Scripps's Murrelet. As shown in the graph below, this resulted in an average 30% reduction in predicted seabird extinction risk for seven focal seabird species. Pink-footed Shearwater, Black-footed Albatross, and Laysan Albatross are not at risk of extinction. Differences in reduction in extinction risk are due to multiple factors including the number of individuals, number of breeding islands, conservation actions (e.g. eradication, translocation, restoration) and their effects of vital rates (reproduction and survival). NFWF actions for Ashy Storm-petrel and Townsend's Shearwater (green-slashed bars) are not yet completed.

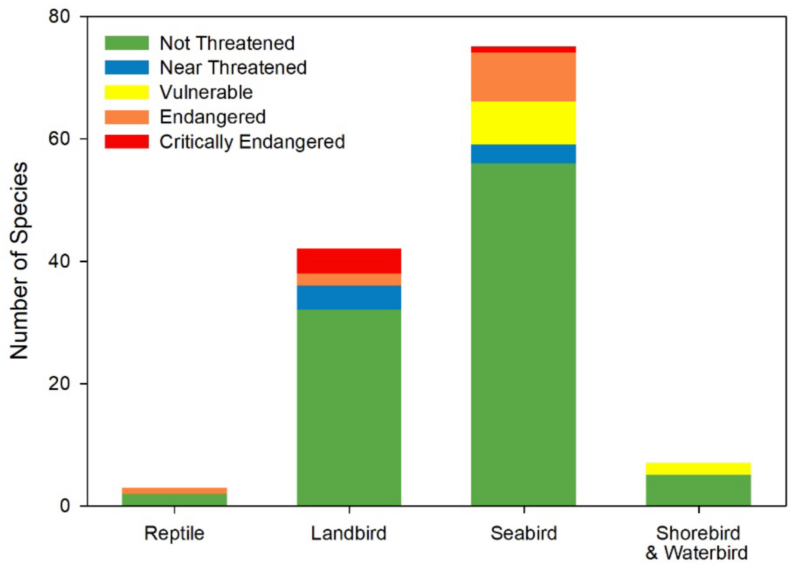


Ancillary Benefits

Biodiversity benefits beyond NFWF's investment in focal seabird species include benefits to:

- 16 non-focal threatened seabirds and 60 non-threatened seabirds. Predicted extinction risk of 5 of these threatened species will decrease by an average of 13%.

- Nine threatened and 43 non-threatened vertebrate species (land birds, reptiles, and shorebirds/waterfowl) breeding on 12 islands will also benefit from NFWF actions (22 of these species are single island endemics).



Broader Impacts, Long-term Sustainability, and Planning

Sixteen NFWF grantees or partner organizations can independently plan, permit, and implement seabird conservation intervention projects. NFWF also funded multiple community educational outreach programs and grantees published over 400 peer-reviewed manuscripts, technical reports, and presentations. Seabird-focused extramural funding and NFWF leveraging has significantly increased with the David and Lucile Packard Foundation investing over $3.44 million annually in seabird conservation and co-funding NFWF projects. Most projects are executed with government manager partners, assuring long-term conservation gains, but NFWF-funded projects would benefit from a requirement to develop specific long-term sustainability plans.

Suggestions for future seabird conservation include:

- Expanding the list of priority seabirds across a broader range of species and geographic scope to increase the impact of NFWF’s seabird program and recover threatened seabird populations.
- Using the population viability analysis tool in project selection and planning to facilitate quantitative analysis of the relative benefit and cost of potential conservation actions.
- Supporting emerging technologies and technique improvement such as drones, new toxicants, CRISPR/gene drive, and new translocation techniques will provide new opportunities for more impactful and cost-effective programs.
- Development of a conservation effort aimed at effective seabird impact assessment, mitigation actions, and revised compensatory mitigation regulatory frameworks to facilitate national efforts for sustainable offshore wind energy development.

Introduction

The National Fish and Wildlife Foundation (NFWF) commissioned this conservation impact assessment to understand the impact that the Pacific Seabird Program has had on its focal species and seabird conservation more broadly over the life of the Program. This assessment answers the following questions:

1) **Intended Impacts**: To what extent has the Pacific Seabird Program enhanced the viability of its focal species through threat reduction and improvements in survival and reproduction, as outlined in the goals and strategies of the Phase I and Phase II Business Plans?
2) **Ancillary Benefits and Unintended Consequences**: How has the Program impacted other seabirds and endemic island species (birds and other taxa)?
3) **Broader Impacts and Advances**: How has the Program increased organizational capacity and partnerships for seabird conservation? How much funding is currently dedicated to seabird conservation nationally (and globally) and what role is NFWF's funding playing? What has the conservation community learned about the effectiveness of strategies to reduce threats to seabirds and advance survival and population outcomes?
4) **Long-term Sustainability**: What steps have been taken to ensure that the Program's outcomes endure? Are there risks to the long-term sustainability of outcomes and, if so, how can they be addressed? To what extent are local communities engaged in a way that supports long-term sustainability? Have those communities also benefitted from this engagement and, if so, how?
5) **Planning**: What are the emerging threats, nascent opportunities and/or technologies for seabird conservation that NFWF could play a role in supporting? How can NFWF better align with other funders and conservation efforts to scale-up the collective impact of this work? What potential additional seabird species should NFWF consider in the Pacific and is there sufficient information and organizational capacity to plan and implement conservation actions for them?

All grants awarded since 2011 are included in the scope of this impact assessment. To determine NFWF's programmatic impact we used information provided in grantee reports, by NFWF staff, and from NFWF grantee interviews to enumerate the accomplishments and challenges of NFWF's Pacific Seabird Program (PSP). To contextualize these impacts in terms of extinction risk mitigation, we used a purpose-built seabird metapopulation viability analysis (Seabird mPVA) tool which uses data from the Threatened Island Biodiversity (TIB) database (TIB Partners 2016) and seabird demographic database developed by the program report authors at the University of California Santa Cruz (model details in Appendix 3).

Background

Seabirds are amongst the most threatened taxonomic group with 29% listed as threatened on the IUCN Red List. The Foundation's Pacific Seabird Program funded 181 grants to 53 organizations totaling almost $43 million from 2011 – 2020 with the goal of enhancing the viability of a selected suite of 12 focal seabird species by increasing population size through improved survival and reproduction. Funding primarily focused on four focal geographies (Figures 1 and 2): Alaskan Islands, Hawaiian Islands, California Current, and Chilean Islands. The 12 focal seabirds were selected based upon anthropogenic threats and protection under the Migratory Bird Treaty Act, U.S. Endangered Species Act, or being listed as Vulnerable (VU), Endangered (EN) or Critically Endangered (CR) under the International Union for the

Conservation of Nature's [IUCN] Red List of Threatened Species. Focal species include: Aleutian Tern, Ashy Storm-petrel, Black-footed Albatross, Guadalupe Murrelet, Hawaiian Petrel, Kittlitz's Murrelet, Laysan Albatross, Newell's Shearwater, Pink-footed Shearwater, Red-legged Kittiwake, Scripps's Murrelet, Townsend's Shearwater. A range of conservation interventions/strategies were applied to protect their breeding populations including: invasive species eradication, predator and/or ungulate proof fencing, translocation, social attraction, habitat restoration, bycatch mitigation, and forage science to inform fisheries management. Here we report on direct measurable results of these NFWF-funded interventions including potential extinction risk mitigation. In addition, we report on NFWF-funded development of new tools, capacity building, and educational outreach projects that fill information gaps and benefit both these focal species and the efforts of the seabird conservation community more broadly.

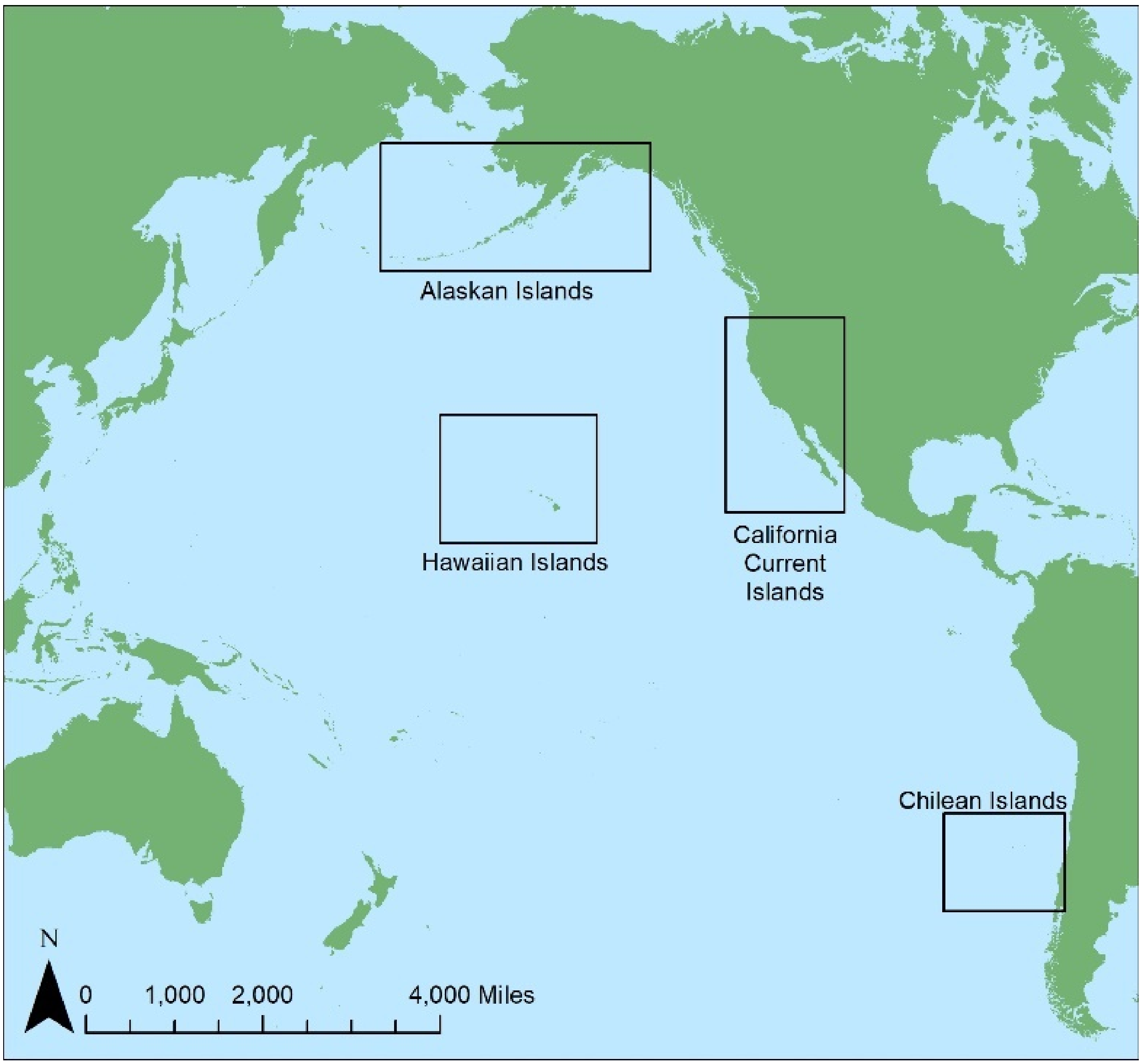


Figure 1. NFWF's Pacific Seabird Program four focal geographic regions.

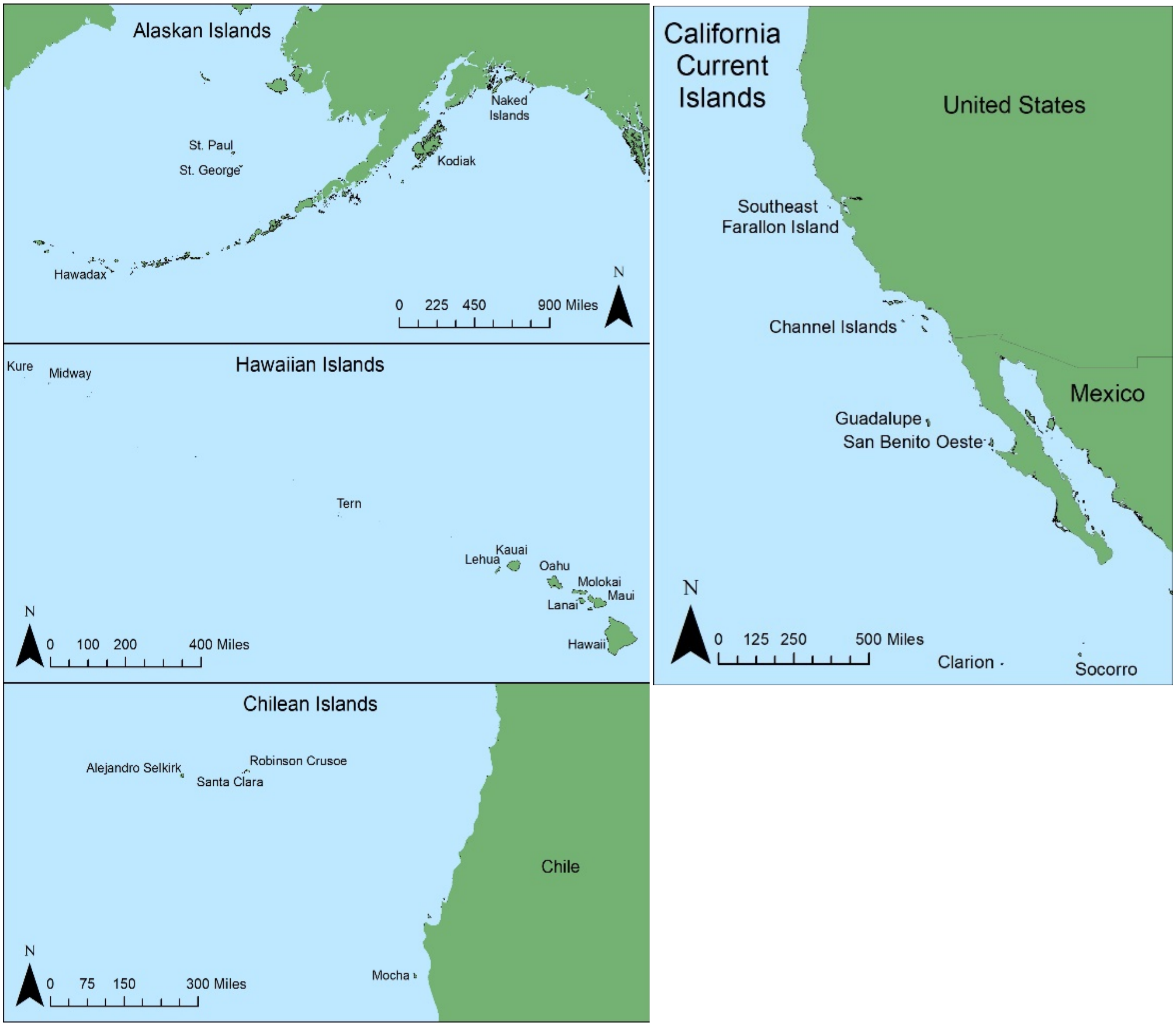


Figure 2. Alaskan Islands: Aleutian Tern, Kittlitz's Murrelet, Red-legged Kittiwake. California Current: Ashy Storm-petrel, Black-footed Albatross, Guadalupe Murrelet, Laysan Albatross, Scripps's Murrelet, Townsend's Shearwater. Hawaiian Islands: Black-footed Albatross, Hawaiian Petrel, Laysan Albatross, Newell's Shearwater. Chilean Islands: Pink-footed Shearwater.

Main Findings

Intended Impacts

NFWF-funded projects in 2011 - 2020 included:

- 9 successful invasive species eradications
- 10 predator and/or ungulate proof fencing projects
- 7 population translocations

- 10 social attraction projects
- 8 habitat restoration projects
- 5 fisheries bycatch reduction projects

These actions increased reproductive success for Black-footed Albatross, Hawaiian Petrel, Laysan Albatross, Newell's Shearwater, Pink-footed Shearwater, and Scripps's Murrelet. Collectively, this resulted in an average of 30% reduction in predicted seabird extinction risk for seven focal seabird species. Townsend's Shearwater extinction risk was reduced by 90%. In addition, based upon the Seabird mPVA model outputs, Pink-footed Shearwater, Black-footed Albatross, and Laysan Albatross are not at risk of extinction in 100 years. Model outputs predict that NFWF actions result in an 11% population abundance increase in 100 years instead of a 33% decrease for Laysan Albatross.

1. Invasive species eradications: Fifteen eradication efforts were initiated on 14 islands. Eleven were successful (with two reinvaded after the initial eradication was successful). The nine successfully completed eradications protected nine populations (seven species) of focal seabird species, 65 populations of 45 non-focal seabird species, and over 81,000 acres of seabird breeding habitat. NFWF grantees and their partners eliminated or mitigated all significant invasive species threats from three sites – Lehua (Hawaii), San Benito Oeste (Mexico), and Kure Atoll (Hawaii). In addition, six pending eradication projects will be completed within the next several years.
2. Fencing projects: NFWF grantees completed 10 predator and/or ungulate-proof fencing projects on seven islands which now protect 2,953 acres of breeding habitat for 12 focal seabird populations. In addition, five pending fencing projects will be completed within the upcoming two years.
3. Population translocations: NFWF grantees successfully translocated 519 eggs or chicks from six seabird species with an average fledging success rate of 97%. Translocation populations included: Laysan Albatross, Hawaiian Petrel, Newell's Shearwater, Bonin Petrel, Tristram's Storm-petrel, Black-footed Albatross. As of the 2021 breeding season, Hawaiian Petrel, Laysan Albatross, Bonin Petrel, and Tristram's Storm-petrel are successfully breeding on the translocated islands.
4. Social attraction projects: Social attraction efforts (sound systems, decoys, artificial burrows) led to successful nesting (since 2017) of Laysan Albatross at the James Campbell National Wildlife Refuge on Oahu; Guadalupe Murrelet nesting in artificial burrows on Guadalupe Island, Mexico; and Townsend's Shearwaters nesting in artificial burrows (since 2019) on Socorro Island, Mexico.
5. Habitat restoration: NFWF funded habitat restoration projects on eight islands to remove invasive plant species that prohibited or interfered with seabird nesting and to establish native plant species that facilitate seabird nesting. Two projects in the Hawaiian Islands, on Midway and Kure Atolls are removing *Verbesina encelioides* (a landscape altering plant) to improve nesting habitat for Black-footed and Laysan Albatrosses. Enhanced nesting due to habitat restoration efforts, coupled with predator-proof fencing on Guadalupe and Kauai islands led to a predicted change in the long-term trajectory of Laysan Albatross from a 33% decrease to an 11% increase over 100 years.

Ancillary Benefits and Unintended Consequences

- Biodiversity benefits beyond NFWF's investment in focal seabird species include benefits to 16 non-focal threatened seabirds (Vulnerable (VU), Endangered (EN) or Critically Endangered (CR) under the International Union for the Conservation of Nature's [IUCN] Red List of Threatened Species) and 60 non-threatened seabirds. The Seabird mPVA predicts that the quasi-extinction risk for five of the 16 non-focal threatened seabirds will decrease by an average of 13%.
- In addition to seabirds, nine threatened and 43 non-threatened vertebrate species (land birds, reptiles, and shorebirds/waterfowl) breeding on 12 islands will also benefit from NFWF funded actions. Of these, 21 are single island endemic species (11 on Socorro Island, six on Guadalupe Island, two on Alejandro Selkirk, and two on Gough Island). We did not quantify benefits, which likely occurred, to endemic invertebrate and plant species, including highly threatened species.

Broader Impacts and Advances

Sixteen NFWF grantees or partner organizations can independently plan, permit, and implement seabird conservation intervention projects including eradications, fence planning/construction, habitat restoration, and translocation or social attraction. NFWF has funded multiple community educational outreach programs focused on the economic benefits, public heath, and community awareness for the conservation of seabirds in all four focal geographic areas (Alaska, Hawaii, Chile, and the California Current). To help inform conservation and to aid with management decisions, grantees published 101 peer-reviewed manuscripts, wrote 56 technical reports, and gave 261 presentations based upon their NFWF funded projects. In addition, the pool of seabird-focused extramural funding has increased. For example, the David and Lucile Packard Foundation Marine Bird Program has increased significantly from its inception and currently invests over $3.44 million annually on marine birds and co-funds multiple NFWF-funded projects.

Long-term Sustainability

Many NFWF-funded seabird conservation projects require ongoing sustained actions to secure their conservation outcomes. These long-term sustainability needs will require funding beyond NFWF. Going forward, NFWF-funded projects would benefit from a requirement to develop a plan for the long-term sustainability of conservation gains. This plan should include monitoring, finance, and maintenance plans.

Islands where invasive species have been removed need robust biosecurity plans to avoid reinvasion (e.g. Guadalupe Island). Fortunately, most eradication projects are executed with the involvement of government land managers charged with island management in their planning and execution to ensure that they will be responsible for maintaining conservation gains in the long term. For example, Grupo de Ecologia y Conservacion de Islas developed a comprehensive biosecurity plan for Guadalupe Island to keep the island free of invasive species, especially rats. On Maui, Haleakala National Park developed a Predator Control Management Plan to protect Hawaiian Petrels within the park.

Fencing projects need sustained attention to ensure that they remain intact (e.g. Hawaiian and Chilean Islands). Pacific Rim Conservation, who have built the majority of predator proof fences in Hawaii, has funding commitments to maintain their fencing from government land managers and is committed to continuing to monitor their fences.

Projects with overlapping seabird/human community sites will require continued outreach and education with these communities to ensure project sustainability (e.g. Hawaiian and Chilean Islands).

Planning

The NFWF-funded seabird metapopulation viability (Seabird mPVA) tool for predicting population trajectories has been used to identify a suite of potential opportunities to protect threatened seabirds from extinction and the ability to generate improved return on investment (ROI) predictions for potential project proposals. Preliminary analyses suggest that expanding the list of priority seabirds across a broader geographic scope of focal species can increase the impact of NFWF's seabird program. Additional focal species could include Galapagos Penguin, Rapa Shearwater. Invasive species eradication and or population translocation would decrease the mean quasi-extinction risk by 53 – 71% for these species. As the threatened status (ESA and IUCN), population sizes, and the type and intensity of threats change, this list should be dynamic to assure that the most threatened or declining species remain the focus of the program.

A cost-benefit analysis of the relative cost of developing and implementing island invasive species biosecurity plans vs. island eradications will also aid in efficiently investing conservation support. While bioinvasions will likely threaten new or restored islands, new and emerging technologies such as drones, new toxicants, CRISPR and gene drive will also provide opportunities to accomplish larger and more complex island eradications. Strategies to combine island eradications with translocations should be developed, particularly for species that have been extirpated from breeding islands or restoration of current breeding sites is not feasible (e.g. large, human populated islands). Concerted effort to align conservation strategies and co-fund projects with other philanthropic (e.g. Packard Foundation) and government managers (e.g. USFWS, IUCN) can create new opportunities. For example, Re:Wild and partners recently developed a vision and roadmap for protecting marine biodiversity across seven Latin American countries, including a focus on islands, several of which include seabird species at risk of extinction over the next 100 years – the initial project investment for this effort is $43M over 10-years. Projects that align seabird benefit with human sustainability outcomes may present expanded funding opportunities in the future. Emerging offshore wind energy development is likely problematic for seabirds and efforts to estimate and mitigate the impacts of the development of this essential energy source to seabirds should be supported.

Intended Impacts

To what extent has the Pacific Seabird Program enhanced the viability of its focal species through threat reduction and improvements in survival and reproduction, as outlines in the goals and strategies of the Phase I and Phase II Business Plans?

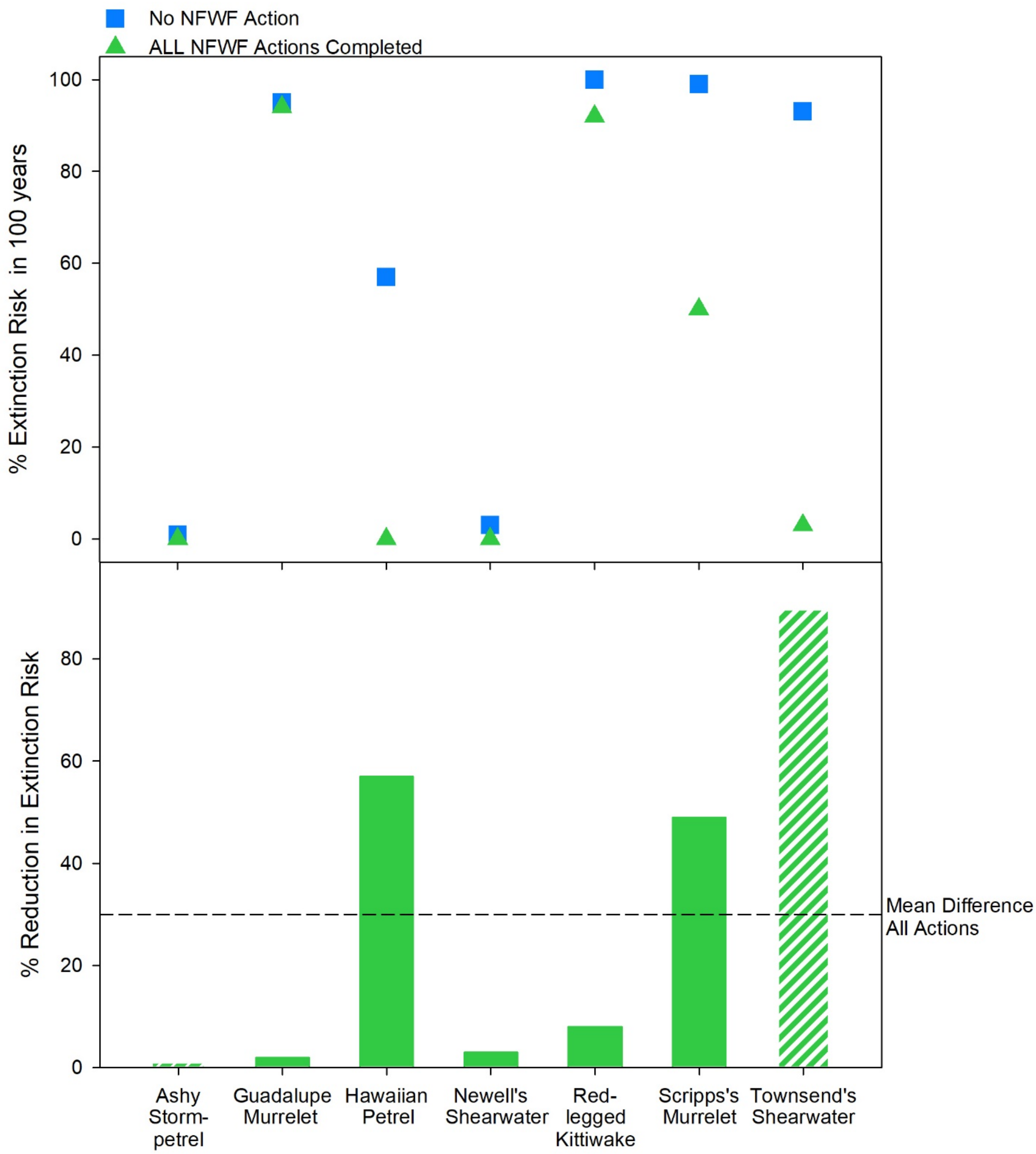
Impact of NFWF funded projects on seabird population viability

Of the 12 NFWF focal seabird species, 10 are included in this population viability analysis. The Seabird mPVA tool is principally focused on scenario planning/impact and risk assessment for IUCN RedList Vulnerable and above species. Two species were excluded from the analysis because they were either IUCN RedListed as Vulnerable after data collection was completed (Aleutian Tern) or were recently down-listed to Near Threatened (Kittlitz's Murrelet). For each of the 10 focal seabirds included, we used the Seabird mPVA to model their extinction risk prior to any NFWF funded actions (see Appendix 4 for model details). We then incorporated outcomes from NFWF funded actions, such as an increase in fledging success or an increase in the number of breeding pairs, into the Seabird mPVA. We used quasi-extinction risk (the relative likelihood that model-projected abundance would drop below a quasi-extinction threshold, the point at which abundance is so low that true extinction risk becomes unacceptably high, within a 100-year period) as our metric of extinction risk resulting from NFWF funded actions. We assumed that all NFWF funded actions were completed (ex. invasive species eradications), however for several species some eradications are projected to be completed in the next few years (Table 1). Based upon the Seabird mPVA model outputs, Pink-footed Shearwater, Black-footed Albatross, and Laysan Albatross are not at risk of extinction in 100 years. The median risk of extinction for the remaining seven species is 93% over the next 100 years (range from 1-100%) in the absence of conservation interventions. The extinction risk in 100 years pre-intervention vs. post-intervention for these seven species decreased by an average of 30% (1-90%) due to NFWF funded interventions (Figure 3; see focal species Impact Assessments in Appendix 1).

Table 1. NFWF focal seabird species with pre- and post-NFWF action(s) extinction risk in 100 years.
*Species with conservation actions to be completed within the next few years

Focal Species	**IUCN Status**	**Island(s)**	**Extinction Risk – Pre NFWF Action**	**Extinction Risk – All NFWF Actions Completed**	**% Decrease in Extinction Risk**
Aleutian Tern	VU	Alaska	Not in mPVA	NA	NA
Ashy Storm-petrel*	EN	California Current	1%	0%	1%
Black-footed Albatross*	NT	Hawaiian Islands	0%	0%	0%
Guadalupe Murrelet*	EN	Mexican Islands	95%	94%	1%
Hawaiian Petrel*	EN	Hawaiian Islands	57%	0%	57%
Kittlitz's Murrelet	NT	Alaska	Not in mPVA	NA	NA
Laysan Albatross*	NT	Hawaiian Islands	0%	0%	0%
Newell's Shearwater*	CR	Hawaiian Islands	3%	0%	3%
Pink-footed Shearwater*	VU	Juan Fernandez	0%	0%	0%
Red-legged Kittiwake	VU	St. Paul, Pribilofs	100%	92%	8%
Scripps's Murrelet*	VU	California Current	99%	50%	49%
Townsend's Shearwater*	CR	Socorro Island	93%	3%	90%

Figure 3. Percent extinction risk in 100 years based upon Seabird mPVA model results for no NFWF action (blue square), and all NFWF actions completed (green triangle). Percent reduction in extinction risk in 100 years is shown below in green bars for all NFWF actions completed (green bar). NFWF actions for Ashy Storm-petrel and Townsend's Shearwater (green-slashed bars) are not yet completed.



Impacts of NFWF funded projects by project type

Invasive Species Eradication

Invasive vertebrate species on seabird breeding islands are known to have both direct (predation) and indirect (habitat destruction) negative impacts on seabirds. To protect breeding seabirds from the effects of invasive species, NFWF funded multiple eradication projects to remove invasive vertebrate species from seabird breeding islands. Invasive plant eradications are covered below in the Habitat Restoration section. Fifteen eradication efforts were initiated on 14 islands (Appendix 2, Table 1). Eleven were successful (with two reinvaded several years after the initial eradication was successful by a different rodent species) and four are in progress. In addition, one invasive species eradication will be implemented in 2021 (Gough Island) and one in 2022 (Midway Atoll). Four additional eradications are in various stages of design and planning.

The nine successfully completed eradications protected nine populations (seven species) of focal seabird species, 71 populations of 44 non-focal seabird species, and over 81,000 acres of seabird breeding habitat. The four in progress eradications will bring the total area protected to 188,636 acres for 12 focal seabird populations. Island acreage is counted only once even if there are multiple invasive species eradications on that island. All significant threats have been eliminated or mitigated from three sites – Lehua Island, San Benito Oeste, and Kure Atoll. Eradication efforts increased reproductive success for the two focal species on Kure Atoll, Black-footed Albatross and Laysan Albatross (Appendix 1 – Impact Assessments).

Fencing

To protect focal seabird species from the direct effects of invasive species in their breeding habitats on islands where whole island eradication is not feasible (due to island size, robust human populations, or high predator loads), NFWF grantees completed 10 predator and/or ungulate proof fencing projects on seven islands which now protect 2,953 acres of breeding habitat for 12 focal seabird populations (Table 2). Another five fencing projects are in various stages of planning and implementation which will bring the total protected area to 3,330 acres for 21 focal seabird populations (Appendix 2, Table 2).

The fencing on Guadalupe Island has allowed the Guadalupe Murrelet population to expand from 40 burrows in 2016 to 195 in 2019 (387% increase). Laysan Albatrosses also increased from 286 nests in 2018 to 319 nests in 2019 (11% increase) (Appendix 1 – Impact Assessments). On Robinson Crusoe Island, the cattle proof fence at the Piedra Agujereada colony is in the process of being upgraded to a mammal proof fence.

Population Translocation

To combat the effects of invasive species and sea level rise on breeding islands, NFWF funded four major population translocation projects: Laysan Albatross eggs from the Pacific Missile Range Facility on Kauai to the James Campbell National Wildlife Refuge on Oahu; Hawaiian Petrel and Newell's Shearwater chicks from unprotected areas on Kauai to the Nihoku restoration site at the Kilauea Point National Wildlife Refuge on Kauai; Black-footed Albatross, Tristram's Storm-petrel, and Bonin Petrel chicks from Midway or Tern Atolls to the James Campbell National Wildlife Refuge on Oahu; and Black-footed Albatross eggs and chicks from Midway or Tern Atoll, Hawaii to Guadalupe Island, Mexico – the first cross-border translocation (Appendix 2, Table 3). Overall, 519 eggs or chicks from seven seabird species were successfully translocated with an average fledging success rate of 97%.

The first translocated Laysan Albatross chick from the 2015 cohort returned to the James Campbell National Wildlife Refuge on Oahu in 2018 confirming that translocation is a successful method for Laysan Albatross conservation. In addition, translocated Black-footed Albatross, Bonin Petrel, and Tristram's Storm-petrel have also returned the James Campbell National Wildlife Refuge on Oahu as adults, and translocated Bonin Petrels and Tristram's storm-petrels are now nesting. At the Nihoku restoration site at the Kilauea Point National Wildlife Refuge on Kauai, Hawaiian Petrel and Newell's Shearwater have returned and Hawaiian Petrel initiated nesting in 2021.

Social Attraction

Grantees attracted seabirds to potential breeding sites by deploying seabird decoys, creating artificial nests, and broadcasting recordings of seabird calls. These projects are relatively low cost, although it can often take years for seabirds to respond by nesting. Projects were initiated on 13 islands with plans for one more island in 2021 (Appendix 2, Table 4).

Laysan Albatross nested at the James Campbell National Wildlife Refuge on Oahu for the first time in 2017, Guadalupe Murrelet nested in artificial burrows on Guadalupe Island, Mexico, and Townsend's Shearwaters nested in artificial nesting burrows on Socorro Island, Mexico for the first time in 2019 (Appendix 1 – Impact Assessments).

Habitat Restoration

NFWF funded several habitat restoration projects to remove invasive plant species that prohibited or interfered with seabird nesting and to establish native plant species that facilitate seabird nesting (Appendix 2, Table 5). The largest project (1,453 acres), is an ongoing project to remove *Verbesina encelioides* (golden crownbeard, native to the United States mainland) from Midway Atoll and a second *Verbesina* removal is in progress at Kure Atoll. On Kure Atoll, *Verbesina* cover decreased from 21.86% in 2012 to 0% in 2020, bare ground decreased from 22.8% in 2012 to 1.59% in 2020, while native plant cover increased from 8.41% in 2012 to 64.98% in 2020. In 2011 *Verbesina* covered 78% of Midway Atoll, by 2015 it had been reduced to <1% and has remained at this level (Figure 4). This has led to an increase in the number of breeding Black-footed Albatross and Laysan Albatross on Kure Atoll. On Santa Barbara Island, Scripps's Murrelet is now nesting in the 8.3-acre restoration area (Appendix 1 – Impact Assessments).

Figure 4. Midway Atoll in 2011 (left) with *Verbesina encelioides*, and in 2014 (right) post *Verbesina* removal.

Bycatch Reduction

NFWF funded projects that either worked to ban harmful fishing practices or modify fishing gear or techniques in order to reduce seabird bycatch in fisheries. Five fisheries documented reductions in seabird bycatch (Appendix 2, Table 6). In the Russian large-scale driftnet fishery, a fishing ban was implemented. While in the Alaskan longline groundfish fishery the West Coast longline fishery, the Chilean purse seine fishery, and the Peruvian drift net fishery seabird bycatch reduction technologies were implemented (Table 6). Current projects include an analysis of seabird bycatch in Alaska gillnet fisheries, as well as a gear modification project in the Hawaii Tuna Longline Fishery to produce a new weighted hook that will improve sink rates which reduces bait exposure duration and thus reduces the catch risk of Black-footed and Laysan Albatrosses.

Fishery Closure:

Russian Far East Fisheries: The Russian large-scale driftnet fishery implemented a driftnet fishing ban for all vessels in the Russian EEZ (exclusive economic zone), resulting in an estimated reduction of seabird bycatch of approximately 100,000 seabirds per year. In addition, grantee engagement with the Russian Longline Fishing Association led them to require all of their member vessels (70% of total Russian Far East longline fleet) to use seabird gear avoidance streamers (Figure 5). Observers working on other, non-member long-line vessels have documented that gear avoidance streamer use has expanded to most of the Russian Far East longline fleet.

Figure 5. Paired (left) and single (right) seabird avoidance streamers onboard Russian longline vessels

Gear Technology Development and Implementation:

West Coast Fisheries: Grantee engagement led the Pacific Fisheries Management Council to require the use of paired fishing gear avoidance streamer lines on vessels greater than 55ft. In addition, longline gear is required to be set at night to avoid seabird entanglement. Fishery observer data indicate that night setting of longline gear has resulted in seabird bycatch rates an order of magnitude lower compared to previous fishing practices.

Alaskan Fisheries: Grantees distributed 182 free streamer lines to Alaskan longline fishermen in 10 longline fishing ports in Alaska. A retrospective analysis of all available fisheries observer data for Alaskan longline groundfish fisheries found that the bycatch rates of albatrosses and non-albatross species dropped dramatically from highs in the mid to late 1990s with the voluntary adoption of streamer lines.

Hawaiian Fisheries: Trials of a relatively new bycatch reduction tool, seabird curtains (Figure 6), showed that they were effective at avoiding seabird captures during haul back of longlines, they were commercially viable, practical to use, and had minimal interference with gear operations. Fishing captains indicated they intend to continue to use the seabird curtain.

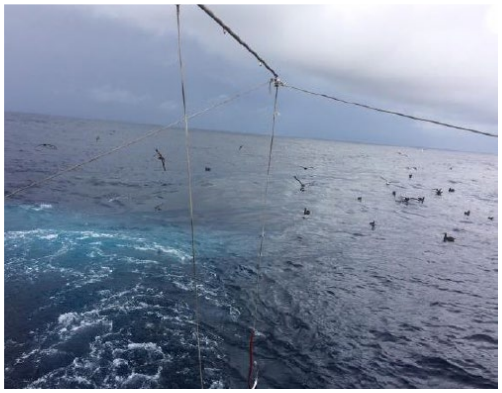


Figure 6. Seabird curtain deployed behind a Hawaii longline fishing vessel.

Chilean Purse Seine Fishery: The Chilean purse seine fishery adopted a modified purse seine net design (lower hanging ratio, small mesh panel, reduced length of buoy line) which is now a Best Practice measure for this gear type in the Agreement on the Conservation of Albatrosses and Petrels (ACAP) Seabird Bycatch Working Group. The design reduces seabird bycatch by 98% with no negative effect on catch rate of the target species. The modified net design has been shared with fishery stakeholders through collaboration with the national artisanal fishery association and presented as a regulatory consideration under the Chilean National Plan of Action – Seabirds.

Peruvian Drift Net Fishery: Net illumination was tested as a potential seabird bycatch mitigation measure. In trials only two seabirds were caught in illuminated net sets compared to 21 in control net sets. Statistical models predict this represents a potential 67% reduction in the seabird bycatch on illuminated nets, but an additional 80 trials would be necessary to generate sufficient power to statistically compare bycatch differences between net types.

Land Acquisition

In 2011, NFWF funded a 182-acre land purchase of Middleton Island in the north-central Gulf of Alaska, a seabird breeding island. While no focal seabirds breed on the island, the acquisition will protect seven species of breeding seabird (Black-legged Kittiwake, Common Murre, Glaucous-winged Gull, Pelagic Cormorant, Rhinoceros Auklet, Thick-billed Murre, and Tufted Puffin), one waterfowl (Canada Goose) and one shorebird (Black Oystercatcher).

Monitoring

Monitoring projects were funded to inform conservation management, provide evidence-based feedback on project efficacy, or determine species response to interventions. NFWF-funded monitoring programs occurred on 73 islands throughout the Pacific (Appendix 2, Table 7) and consisted of either standard monitoring techniques (measures population abundance, reproductive success or other vital rates; 28 islands), acoustic monitoring (27 islands), or both (17 islands).

Two monitoring projects, one for Aleutian Tern, the other for Ashy Storm-petrel, are directly informing conservation decisions. Aleutian Tern colony monitoring methods that have been developed will be used in an Alaska-wide Aleutian Tern colony survey framework to estimate abundance and population trends (this will be the first coordinated statewide survey for Aleutian terns using standardized methods). In 2016, California Institute of Environmental Studies (CIES) worked with key stakeholders to develop a Conservation Action Plan for Ashy Storm-petrels incorporating NFWF-funded monitoring methods. NFWF-funded acoustic monitoring research conducted by Conservation Metrics, Inc. is being integrated into seabird conservation planning for both Aleutian Tern and Ashy Storm-petrel. This same integration occurs for a variety of other NFWF focal seabird species including Hawaiian Petrel, Newell's Shearwater, Scripps's Murrelet, and Townsend's Shearwater.

New Tools

In addition to innovative fishing gear and acoustic monitoring of seabird colonies, grantees developed and applied new tools (42 total) to help inform seabird conservation planning and/or project implementation. In particular, NFWF co-funded (with the David and Lucile Packard Foundation) an online seabird metapopulation viability analysis (Seabird mPVA) tool that can be used to estimate the extinction probability of threatened seabirds and NFWF focal seabird species under different conservation intervention scenarios (https://nhydra.shinyapps.io/mPVA1/). This tool is now integrated into conservation planning for the Packard Foundation and has been used by American Bird Conservancy for seabird conservation planning. This tool is used in this report to estimate the impact of NFWF funded projects on seabird population viability of NFWF-funded actions (Tables 1 & 2).

Other newly developed tools include population genomics tools for a genetics study on Kittlitz's Murrelets, thermal drones to detect Hawaiian Petrel and Newell's Shearwater burrows (Oahu), drones to photograph Aleutian Tern colonies (Alaska), and remote sensing tools to map native vs. non-native vegetation on seabird islands (Lanai) and to monitor seabird nesting from space (albatross nests).

Ancillary Benefits and Unintended Consequences

How has the Program impacted other seabirds and endemic island species (birds and other taxa)?

Biodiversity benefits beyond NFWF's investment in focal seabird species include sixteen non-focal threatened seabird species on nine islands that are expected to benefit from NFWF funded interventions (Table 2; Figure 7). The Seabird mPVA predicts that the quasi-extinction risk for five of the 16 non-focal threatened seabirds will decrease by an average of 13%. In addition, 60 non-threatened seabirds breeding on 21 islands as well as eight threatened and 43 non-threatened vertebrate species (land birds, reptiles, and shorebirds/waterfowl) breeding on 11 islands will also benefit (Appendix 2, Table 8; Figure 7). Of these, 22 are single island endemic species: 11 on Socorro Island, six on Guadalupe Island, two on Alejandro Selkirk, two on Gough Island, and one on Robinson Crusoe.

Table 2. Sixteen non-focal threatened seabird species are expected to benefit from NFWF funded actions. Status quo extinction risk and extinction risk post-NFWF action(s) are included.

Non-Focal Threatened Species	IUCN Status	Island	Extinction Risk Pre-NFWF Action	Extinction Risk All NFWF Actions Completed
Ainley's Storm-petrel	VU	Guadalupe	3%	0
Atlantic Petrel	EN	Gough	0	0
Atlantic Yellow-nosed Albatross	EN	Gough	0	0
Black-legged Kittiwake	VU	St. George, Middleton	Not in mPVA	NA
Craveri's Murrelet	VU	San Benito Oeste	54%	30%
Juan Fernandez Petrel	VU	Alejandro Selkirk	0	0
Leach's Storm-petrel	VU	San Benito Oeste	Not in mPVA	NA
MacGillivray's Prion	EN	Gough	0	0
Marbled Murrelet	EN	Naked	0	0
Masatierra Petrel	VU	Robinson Crusoe	0	0
Northern Rockhopper Penguin	EN	Gough	35%	18%
Short-tailed Albatross	EN	Kure Atoll	0	0
Sooty Albatross	EN	Gough	0	0
Stejneger's Petrel	VU	Alejandro Selkirk	0	0
Townsend's Storm-petrel	EN	Guadalupe	75%	70%
Tristan Albatross	CR	Gough	16%	0

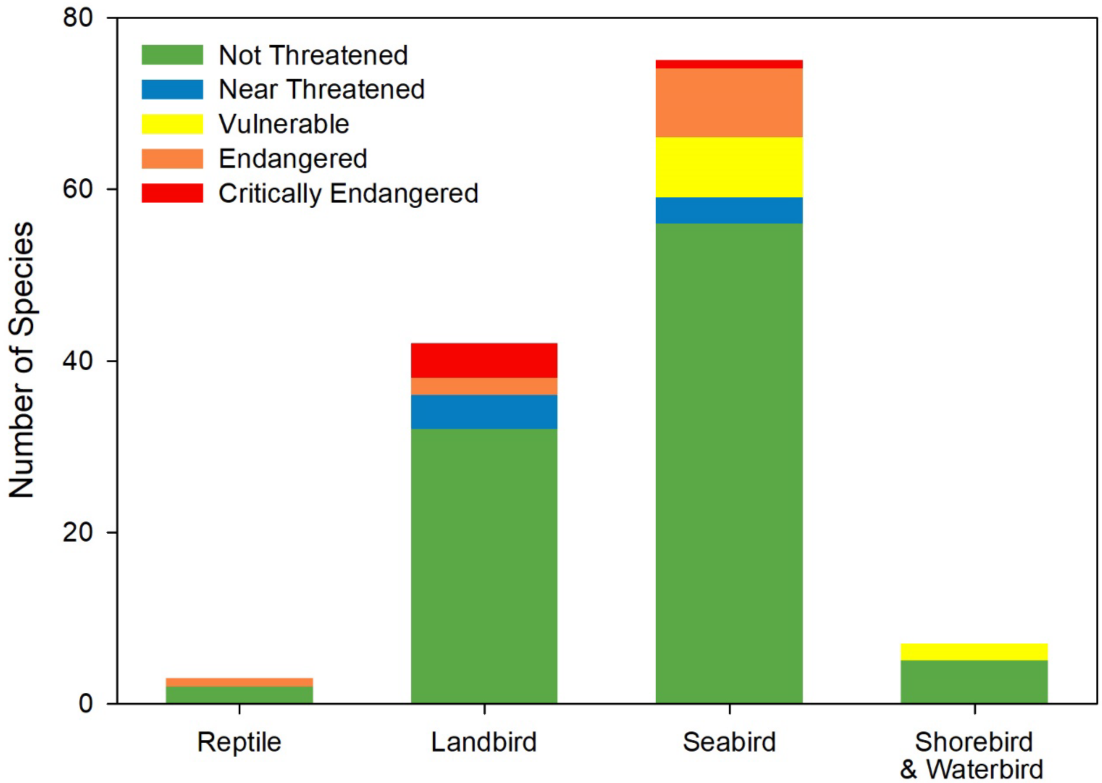


Figure 7. 127 non-focal vertebrate species from 197 populations are expected to benefit from NFWF funded actions (eradications completed or in progress (includes Gough), translocation, social attraction, fencing, habitat restoration).

Broader Impacts and Advances

How has the Program increased organizational capacity and partnerships for seabird conservation? How much funding is currently dedicated to seabird conservation nationally (and globally) and what role is NFWF's funding playing? What has the conservation community learned about the effectiveness of strategies to reduce threats to seabirds and advance survival and population outcomes?

Organizational Capacity

Sixteen NFWF grantees or partner organizations can independently plan, permit, and implement a seabird conservation intervention project (including eradications, fence planning/construction, habitat restoration, translocation or social attraction project) (Table 3). This capacity was facilitated by NFWF's support for increased staffing and administrative structure, training, partnership development, and equipment.

Table 3. NFWF Grantees or Partners that can independently plan, permit, and implement a seabird conservation project.

NFWF Grantee or Partner
USFWS Alaska Maritime National Wildlife Refuge
American Bird Conservancy

Grupo de Ecologia y Conservacion de Islas
Haleakala National Park
Hallux Ecosystem Restoration LLC
Hawaii Division of Forestry and Wildlife, Hawaii Department of Land and Natural Resources
Hawaii Division of Forestry and Wildlife
Hawaii Volcanos National Park
Island Conservation
National Park Service, Channel Islands
Northern Research Technical Assistance Center, Inc. dba NORTAC
Oikonos Ecosystem Knowledge
Pacific Rim Conservation
Parks Canada – Gwaii Haanas National Park Reserve
Pulama Lanai
Royal Society for the Protection of Birds

Many of these organizations have also grown significantly during the NFWF Seabird Program timeframe in budget, staff, or number of projects implemented per year, in part due to NFWF funding. In addition, the pool of seabird-focused extramural funding has increased. For example, the David and Lucile Packard Foundation Marine Bird Program has increased significantly from its inception and currently co-funds many NFWF-funded projects.

Community Outreach

A critical component of all conservation projects is the support and commitment of the local community and stakeholders. Without support, complicated and expensive conservation interventions can be delayed or cancelled, important biosecurity needed to avoid invasive species introductions can be ignored, and the long-term sustainability of conservation interventions can be jeopardized. Thus, in addition to conservation actions, NFWF has funded community educational outreach programs on seabird islands focused upon economic benefits, public health, and community awareness for the protection of seabirds. Examples include:

Chile: Mocha Island Outreach

> In an effort directed at enhancing community support and involvement in current and future Pink-footed Shearwater conservation projects, the American Bird Conservancy and Oikonos co-sponsored the “Copa Fardela” or “Shearwater Cup” soccer tournament and festival in collaboration with the Chilean Ministry of Environment and the National Forest Corporation, starting in 2012 on Mocha. Participation in the festival has grown from around 150 residents to upwards of 500 of the ~700 island residents. The goal of the festival is to have Mocha residents spend two days together cooking, playing, painting, and talking about Pink-footed Shearwaters and Mocha’s unique ecosystem (Figure 8). In addition to the soccer tournament, the festival now includes an opening lunch prepared by a professional chef and local residents, other games and races, a serigraphy workshop, painting booth, intertidal walk, and guided breeding colony visits for residents to see shearwaters through infra-red burrow cameras. The “Copa Fardela” will continue in the future to create stronger bonds with the islanders and to keep educating them on the conservation of the Pink-footed Shearwater. In addition,

Mocha community members act as volunteer wardens to protect the Pink-footed Shearwater breeding colonies.

Figure 8. The 2017 “Copa Fardela” on Mocha

California Current: Guadalupe Island Community Outreach

To facilitate stewardship of seabirds and other native species by the local island community and potential support for a cat eradication program on Guadalupe Island, Grupo de Ecologia y Conservacion de Islas (GECI) conducted an environmental education program designed for personnel of the Mexican Navy, the fishing community and their families. This included an “Environmental Culture Week” targeting school children and their parents. Children created a play and a song dedicated to the island and its species to raise awareness about their conservation and protection. In 2019, when increased rainfall led to an increase in the house mouse population, GECI produced an audiovisual capsule to explain the relationship between vegetation, rodents, and cats, to assure residents the increase in mice was not the result of the cat eradication project.

Alaska: St. George Island Local School Curriculum

The Pribilof Islands (St. George and St. Paul) are home to approximately 2 million breeding seabirds and the introduction of invasive mammal species would have severe ecological and economic consequences to the seabirds and local residents. To educate the community about the potential for introductions and their consequences, grantees developed integrated cross-curricula for children in the Pribilof School district. These topics were also the focus of the local programs and events: Seabird Camp and Bering Sea Days. The Invasive Species and Seabird curriculum and classroom activities are available online at the Seabird Youth Network website.

Hawaii: James Campbell NWR Translocation Project Outreach Program

> The translocation of birds from the NW Hawaiian Islands to the James Campbell National Wildlife Refuge on Oahu has become a flagship project for the Refuge system in Hawaii. Pacific Rim Conservation hired a dedicated outreach coordinator in 2018 to facilitate stakeholder and partner visits as well as K-12 school groups visiting the James Campbell National Wildlife Refuge to learn about native Hawaiian birds and why chicks were translocated, how they are cared for at the Refuge by the animal care team, and the overarching goal of creating a self-sustaining seabird colony safe from sea level rise. Ultimately, these efforts will also increase local support for future translocation projects in the Hawaiian Islands.

Scientific Outreach

Grantees published 101 peer-reviewed manuscripts, prepared an additional 13 manuscripts for publication, wrote 56 technical reports, and gave 261 presentations based upon their NFWF funded projects (see Appendix 4 for publication details). Many of these manuscripts and reports are used to inform conservation and to aid with management decisions. For example, the numerous manuscripts and reports published by the Farallon Institute on forage fish (northern anchovy and others) in the California Current System were used by conservation and policy organizations to influence and shape forage management decisions, including the protection of forage fish species under the Pacific Fisheries Management Council's Unmanaged Forage Fish Protection Initiative. To the extent that threatened seabird populations are constrained by prey availability, this protection may provide long-term benefits and potentially mitigate potential changes in prey availability driven by climate change.

Long-term Sustainability

What steps have been taken to ensure that the Program's outcomes endure? Are there risks to the long-term sustainability of outcomes and, if so, how can they be addressed? To what extent are local communities engaged in a way that supports long-term sustainability? Have those communities also benefitted from this engagement and, if so, how?

Multiple project types have long-term sustainability needs, including eradication, habitat restoration, fencing, and bycatch. In addition, projects with a high degree of overlap between target seabird conservation efforts and human inhabitants require significant community support to secure the long-term gains of interventions (see Community Outreach above). Islands where invasive species have been removed need robust biosecurity plans to avoid reinvasion, while fencing projects will require long-term support for the maintenance of established fences. Fortunately, most projects are executed with the involvement of government land managers charged with island management in their planning and execution to ensure that they will be responsible for maintaining conservation gains in the long term.

In many instances, isolation and lack of human visitation can ensure biosecurity for seabird islands. However, many NFWF funded projects occurred on islands where biosecurity measures will be necessary to prevent reinvasion or there is a long-term maintenance requirement (e.g. fencing). Grupo de Ecologia y Conservacion de Islas developed a comprehensive biosecurity plan for Guadalupe Island to keep the island free of invasive species, especially rats, to ensure that local island residents and military who consistently travel to mainland Mexico do not inadvertently transport invasive species. On Maui, Haleakala National Park developed a Predator Control Management Plan to protect Hawaiian Petrels within the park. Predator Control Management Plans are another useful strategy to keep areas free of invasive species in the long term. Pacific Rim Conservation, who have built the majority of predator proof fences in Hawaii, has funding commitments to maintain their fencing from government land managers and is committed to continuing to monitor their fences. However, long-term commitment and funding for biosecurity and fence maintenance is necessary to secure conservation gains.

Regular meetings and contact with island residents will be necessary to ensure biosecurity and integrity of seabird colonies. Projects with overlapping seabird/human community sites such as those on the Juan Fernandez Islands in Chile and Pribilof Islands in Alaska will require continued outreach and education with these communities for project sustainability. Practitioner trainings or workshops that either support island restoration actions or promote seabird bycatch reduction technologies are often key to the sustainability of projects. Overall, grantees hosted 43 trainings or workshops.

Economic cost modeling may provide insight on the tradeoffs between "spill" abatement and re-eradicating reinvaded islands. Likewise, an economic model to project the long-term maintenance cost of expanded fencing to better understand long-term constraints may be informative. At some point it may become more cost effective to focus on eradications and/or translocations on smaller, more remote islands where the long-term costs of fencing and human complications can be eliminated or reduced. Finally, including sea level rise due to anthropogenic climate change in population viability models may point to different long-term conservation options, particularly for seabirds nesting on low-lying islands and atolls. For most seabird islands an invasive species "spill" plan is useful if it can be rapidly implemented to eradicate new invasions.

Planning

What are the emerging threats, nascent opportunities and/or technologies for seabird conservation that NFWF could play a role in supporting? How can NFWF better align with other funders and conservation efforts to scale-up the collective impact of this work? What potential additional seabird species should NFWF consider in the Pacific and is there sufficient information and organizational capacity to plan and implement conservation actions for them?

Seabirds are dependent on, and contribute to, healthy ocean and coastal systems. In turn, they can play important ecosystem roles as top predators. Seabirds consume the equivalent fish biomass of global marine fisheries, but have vulnerable life histories (long-lived with low reproductive rates) and are vulnerable to invasive species, habitat destruction, sea level rise, and fisheries bycatch. Seabirds are among the most threatened animals on Earth, with 29 percent of seabird species listed as threatened by the IUCN Red List. Seabirds continue to be subject to significant anthropogenic threats, and future program/project planning may benefit from considering opportunities across a number of key areas:

1. Broadening the scope of seabird species to be considered for NFWF conservation support. Seabirds generally have broad foraging and, in many cases, breeding ranges and many seabirds that are ecologically important, severely threatened, or specially protected forage or breed in non-US controlled locations. Geographically broadening to consider species that occur in the central, western, and southern Pacific should be considered and could include the Rapa Shearwater. Invasive species eradication or population translocation of Rapa Shearwater would decrease their mean quasi-extinction risk by 53 – 71%.
2. Model-driven analysis of species-specific potential conservation actions to mitigate extinction risk, including estimated costs that will:

   a. Identify and prioritize at-risk species
   b. Model potential intervention scenarios and their outcomes
   c. Provide an estimate of potential extinction mitigation as a function of estimated investment (modeled return on investment)
   d. Identify conservation scenarios where multiple interventions can be efficiently applied (e.g. coupling invasive species eradications with translocations)
   e. Quantitatively examine potential for ESA downlisting across NFWF seabird species of interest
3. Landscape analysis of the seabird conservation sector to examine potential opportunities to promote emerging technologies/partners/techniques to benefit seabird conservation should be undertaken including:
   a. Invasive eradication – e.g. CRISPR/Gene Drive, drones
   b. Active translocation – e.g. new social attraction technologies
   c. Passive establishment – e.g. taxonomic patterns in passive establishment of new colonies
   d. Bycatch mitigation – e.g. emerging fishing technologies, collaborations with Regional Fisheries Management Organizations, sustainable fisheries market labeling
   e. Population and mortality monitoring – e.g. autonomous video and acoustic monitoring, autonomous fisheries monitoring
4. Model-driven economic analysis of the most cost-effective means to ensure long-term success of NFWF interventions
   a. A cost/benefit analysis of the relative cost of developing and implementing a biosecurity and monitoring program vs. monitoring and bioinvasion "spill" eradications.
5. Seabird conservation community capacity analysis to determine:
   a. Opportunities for new NGO partnerships and involvement.
   b. Opportunities for funding leverage and program alignment across government agencies, conservation foundations, and international sustainability funding.
   c. Opportunities to synergize across programs (e.g. island invasive species eradication to benefit terrestrial species) within NFWF and across other Foundations.
   d. Opportunities to leverage funding directed at global Sustainability Development Goals (see https://ccal.ucsc.edu/wp-content/uploads/2020/08/deWit_2020_b.pdf).
6. Identifying emerging seabird threats
   a. Framework for assessing and mitigating the impact of emerging offshore wind energy development on Pacific seabirds. The US Bureau of Ocean Energy Management has announced areas for potential wind energy leases off the US West Coast. With the emergence of floating turbine technology, it is likely that new wind energy developments will have significant overlap with sensitive seabird species. There is a need to develop a feasible framework to assess impact, take, and mitigation of seabird impacts. This should be done in collaboration with developed national and international seabird wind energy projects, government officials, stakeholders, and industry.
   b. Climate change impact modeling. Expand the use of population viability analysis tools to include climate change impacts, particularly sea level rise impacts to breeding colonies.

Appendix 1. Focal Species Impact Assessments

Aleutian Tern

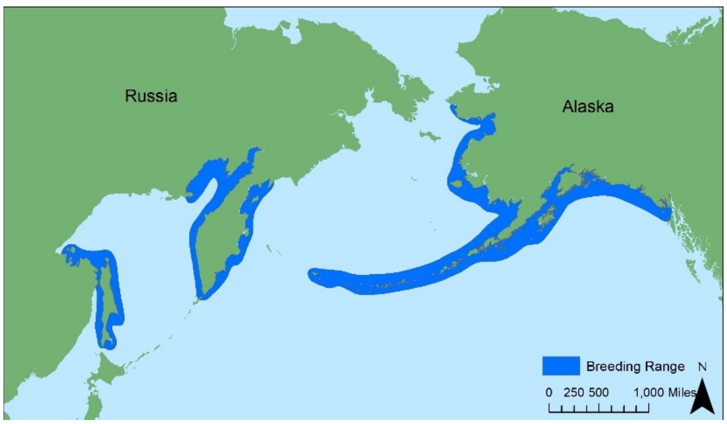
IUCN Vulnerable

Current Status & Threats

IUCN Vulnerable due to ≥ 30% population size reduction. Aleutian Tern has undergone a very rapid population decline at its Alaskan breeding colonies. Trends in Russia are less clear, but it is likely that overall the species is undergoing rapid declines over three generations, and was therefore uplisted to Vulnerable from Least Concern in 2017. Precise drivers of declines are unclear but likely include habitat modification, predation, egg harvesting, and human disturbance.

Breeding Locations

Breeds in the north Pacific Ocean on the coasts of Sakhalin and Kamchatka, Russia, on the Bering and Pacific Coasts of Alaska, and on the Aleutian Islands.



Number of mature individuals: 31,000[i]

NFWF Business Plan Goals & Accomplishments

2016 – 2021 Goals	Progress	Details
Develop a Conservation Action Plan	Not Yet Achieved	Grantees held two Aleutian Tern Conservation Planning Meetings in 2018 and 2019 and tested recommended monitoring methods at 16 colonies

Significance of Accomplishments

A Conservation Action Plan for Aleutian Tern will outline and test appropriate monitoring methods toward providing the first robust abundance estimates of Aleutian Terns in Alaska which will fill critical information gaps for this species. A pilot survey is being implemented in 2021, utilizing a draft monitoring framework developed from previous methodological awards. A first statewide survey is likely in 2023, with capstone funding requested for this key step toward Aleutian Tern conservation planning in 2021. The Aleutian Tern is not included in the Seabird mPVA because it was not listed as Vulnerable on the IUCN Red List until 2017 and therefore is not included in the Threatened Island Biodiversity Database, thus we cannot report on long-term accomplishments.

Funding/Project Details
4 Years (January 2018 – December 2021)
7 NFWF Funded Projects to 3 Grantees:

$604,600 – NFWF
$853,244 – Match

$1,457,844 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Produce statewide monitoring framework

Evaluate advances in colony monitoring methodology
- Acoustic Monitoring
- Unmanned Aerial Vehicles (UAVs or drones)
- Ground-based photo counts
- Aerial survey counts
    - Camera traps
    - Growth rates

Continue pilot assessment of automated cameras to monitor individual nest productivity and disturbance
- Remote Cameras

New tagging technology
- Solar-powered satellite telemetry tags (PTT)

Expand tissue collection
- Contaminant exposure, diet composition, and population genetic structure

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[i]IUCN Red List of Threatened Species 2020.

Ashy Storm-petrel
IUCN Endangered

Current Status & Threats
IUCN Endangered due to a ≥ 50% population size reduction over 3 generations. Studies suggest that the Ashy Storm-petrel's small population may be declining very rapidly over three generations (48 years) owing to a variety of threats including invasive species.

Number of mature individuals: 3,500 – 6,700[i]

Breeding Islands
United States: Southeast Farallon (60%), Prince (12%), Santa Barbara (9%), Sutil (6%), Santa Cruz (3%), Castle Rock (2%), Scorpion Rock (1%). < 1% on each of the following islands/rocks: San Clemente, Sppit Rock, Willows Anchorage Rocks, Franklin Smith Rock, Hurricane Point Rock, Bird Rock, Casket Rock, Benchmark Rocks, Kriby Cove Rock, Seal Cove South Rock, Castle Rocks, Middle Anacapa, West End, Ship Rock, Shag Rock, East Anacapa, Diablo Rocks, West Anacapa.
Mexico: <1% on Coronados Middle Rock, Todos Santos Sur, Todos Santos Norte.

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Reduce owl predation by 90%	Not Achieved	No projects funded to achieve this goal – no longer a primary focus for funding
Increase number of chicks produced per pair 4%	Not Yet Achieved	Southeast Farallon Islands mouse eradication to reduce predation of chicks delayed until the Final Environmental Impact Statement is approved. Grantees are working towards approval in 2021.

2016 – 2021 Goals	Progress	Details
Complete four conservation actions	Accomplished	Developed Conservation Action Plan for ASSP, formed ASSP Conservation Working Group, produced 45 artificial nests for the Channel Islands, social attraction efforts on Todos Santos, Mexico

Additional Accomplishments

Monitoring in Mendocino County found several breeding sites and breeding had not been reported in the area since 1926.

Significance of Accomplishments

The Southeast Farallon Islands mouse eradication was initially delayed, but is now back on track working its way through the permitting process. Once completed, the Seabird mPVA model predicts a decrease in quasi-extinction risk[ii] in 100 years to 0%. The Conservation Working Group produced a Monitoring Implementation Plan that sets a path for the successful execution of the Range-Wide Monitoring Plan. Initiation of the first 5-year range-wide monitoring cycle will begin in 2021, providing key data on Ashy Storm-petrels throughout their range.

Funding/Project Details

11 Years (August 2011 – January 2022)
14 NFWF Funded Projects to 8 Grantees:

$1,165,264 – NFWF
$1,469,249 – Match

$2,634,514 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Eradication

- House Mouse eradication from Southeast Farallon Island

Monitoring

- Acoustic and standard monitoring throughout breeding range

Social Attraction

- Artificial burrows

Future Prognosis due to project outcomes

Demographic changes due to all NFWF actions completed: mouse eradication from Southeast Farallon Islands.

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	1%	73% decrease
All NFWF Actions Completed	0%	42% decrease

Figure 1. Quasi-Extinction Risk. With no NFWF conservation actions, the quasi-extinction risk for Ashy Storm-petrels in 100 years is 1% (blue line). When all NFWF actions are completed and incorporated into the mPVA model, extinction risk decreases to 0% in 100 years (green line). Confidence intervals are shown as dotted lines.

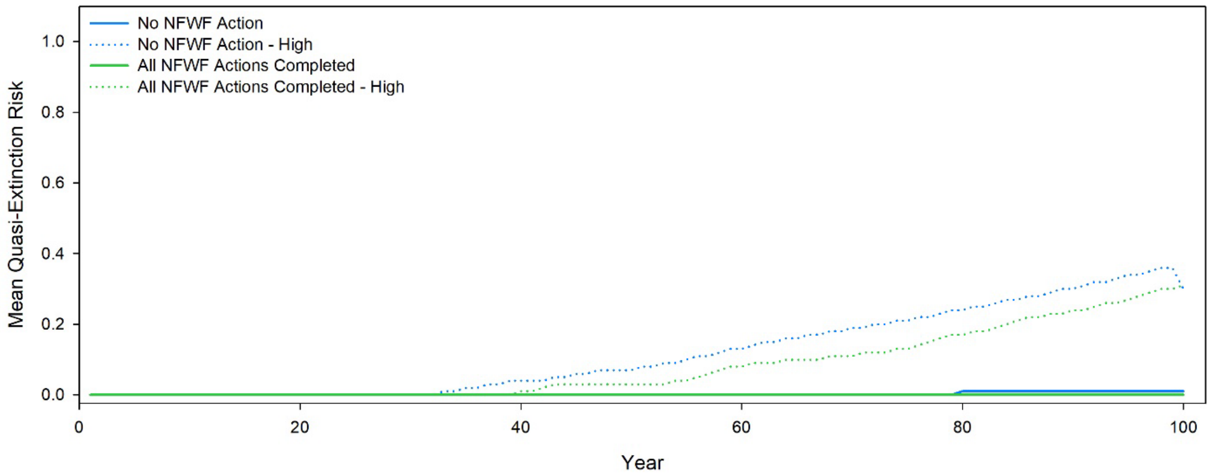
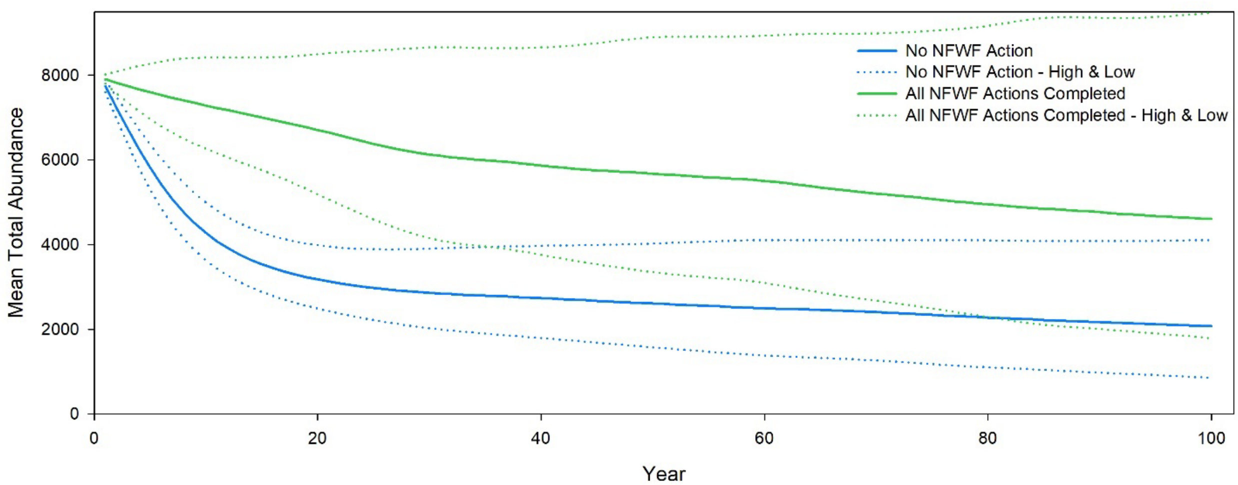


Figure 2. Mean Total Abundance. Under "status quo" conditions, the modeled mean total abundance of Ashy Storm-petrels in 100 years decreases by 73% (blue line). When all NFWF actions are completed incorporated into the mPVA model, modeled mean total abundance decreases by 42% in 100 years (green line). Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Black-footed Albatross

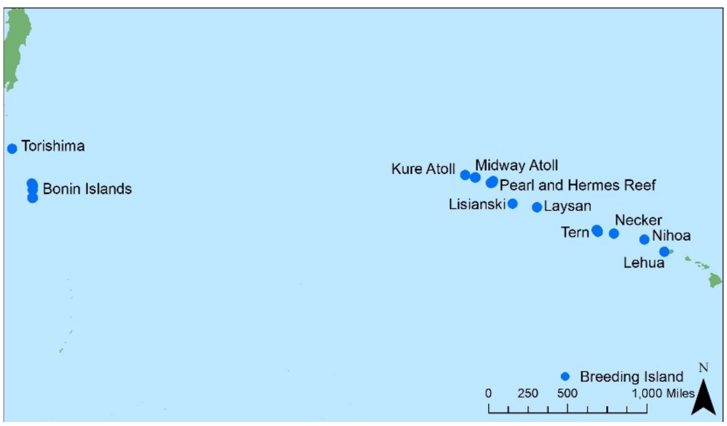
IUCN Near Threatened

Current Status & Threats

IUCN Near Threatened due to < 30% population size reduction over three generations. An analysis of recent data suggests that Black-footed Albatross's population is not undergoing rapid declines, as once thought, and is either stable or increasing. However, modelling of the likely effects of mortality caused by longline fishing fleets, combined with potential losses to breeding colonies from sea-level rise and storm surges, suggests it is appropriate to precautionarily predict a moderately rapid population decline over the next three generations (66 years).

Breeding Islands

United States: Midway Atoll (39%), Laysan Island (31%), Pearl and Hermes Reef (10%), French Frigate Shoals – Tern (7%), Kure Atoll (4%), Lisianski (3%), Necker (< 1%), Lehua (<1%), Niahoa (<1%).
Japan: Torishima (3%), Bonin Islands (3%), Ryukyu Islands (<1%).



Number of mature individuals: 139,800[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Increase reproductive success from 0.24 to 0.48 chicks per pair	Accomplished	Reproductive success increased to 0.52 chicks/pair

2016 – 2021 Goals	Progress	Details
Establish two new populations	Accomplished	46 Black-footed Albatross chicks successfully translocated and fledged at the James Campbell NWR on Oahu. Translocation of 12 chicks and 21 eggs to Guadalupe Island took place in February 2021 with 27 chicks fledging by June 2021
Increase average number of breeding pairs: • USFWS: 21,800 to 30,500	Not Yet Achieved	Number will likely increase when Midway Atoll mouse eradication is completed in 2021-22

• DLNR/Kure: 2,400 to 2,900	Accomplished	3,439 nests in December 2019

Additional Accomplishments
Tagged 18 Black-footed Albatrosses from Kure Atoll with GPS tags and determined 98% overlap with longline fisheries. Kure Atoll has been released from the most significant damage caused by mature *Verbesina encelioides* since 2014 allowing for an increase in the number of breeding pairs on the atoll. Satellite imagery can accurately predict ground-based colony counts when accounting for species, platform, and vegetation cover which will assist with future colony counts. The West Coast Sablefish fishery, the Alaskan Demersal Longline fisheries, and the Hawaii Swordfish Longline fishery implemented gear modifications (streamer lines or seabird curtains) to reduce Black-footed Albatross bycatch.

Significance of Accomplishments
Black-footed Albatross populations are currently considered stable or increasing. The *Verbesina* eradication on Kure Atoll and the mouse eradication on Midway Atoll will allow for the population to further increase. Given the high spatial overlap with longline fisheries, details on bycatch mortality are needed, especially for western pacific fleets. Establishing new populations on Oahu and Guadalupe Island (using translocation and social attraction) is key given the potential for breeding colony loss due to climate change (sea level rise and storm surges) in the Northwest Hawaiian Islands. The Seabird mPVA model predicts that the abundance of Black-footed Albatrosses will continue to increase (at a slightly lower rate post actions, likely due to variability within the model) and the quasi-extinction risk will remain at zero[ii].

Funding/Project Details
10 Years (May 2011 – January 2021)
21 NFWF Funding Projects (17 grants shared with Laysan Albatross) to 11 Grantees:

$9,467,065 – NFWF
$13,958,152 – Match

$23,425,217 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Eradication
- Mouse eradication on Midway Atoll

Translocation
- Chicks from Midway Atoll to James Campbell NWR on Oahu
- Chicks and eggs from Midway Atoll to Guadalupe Island, Mexico

Fencing
- 16-acre predator proof fence at James Campbell NWR, Oahu

Monitoring
- Plastic Ingestion on Tern Island
- Remote sensing to determine nesting population

Restoration
- *Verbesina* eradication from Midway Atoll (1,261+ acres) and Kure Atoll (188 acres)
- Convert runway substrate to nesting habitat on Kure Atoll
- Native plant propagation and outplanting on Midway Atoll and Kure Atoll

Social Attraction

- Decoys and sound system at James Campbell NWR, Oahu and Guadalupe Island, Mexico

Bycatch

- Gear technology modification in West Coast Sablefish Fishery, Alaskan Demersal Longline Fisheries, Hawaii Longline Swordfish Fishery

Future Prognosis due to project outcomes

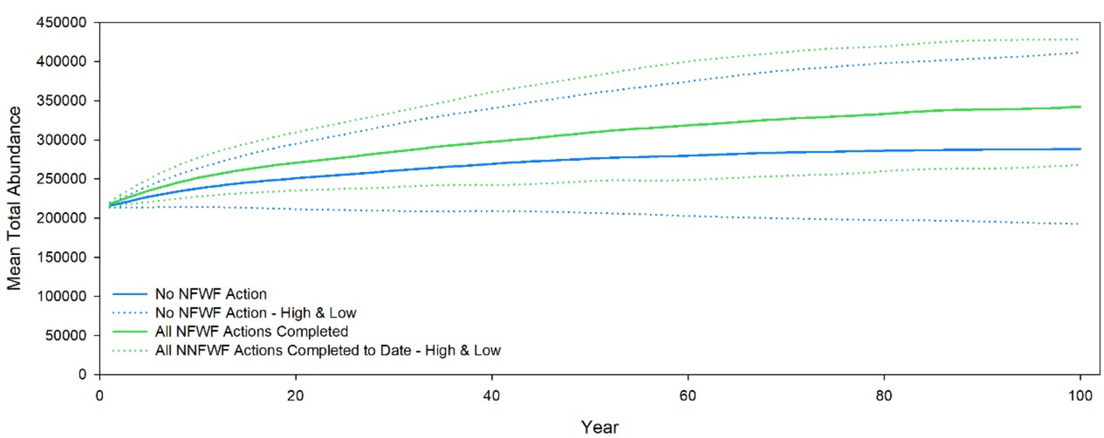
Demographic changes due to all NFWF actions completed: house mouse eradication from Midway Atoll, and 2,080 additional birds on Kure Atoll, translocation of 49 birds to Oahu, translocation of 27 birds to Guadalupe.

	Extinction Risk in 100 years*	Population Abundance in 100 years
No NFWF Actions	0%	34% increase+
All NFWF Actions Completed	0%	57% increase

*Not graphed since all values are 0

+Black-footed Albatross populations are currently increasing according to the IUCN RedList of Threatened Species and as such the Seabird mPVA model predicts an increase in population abundance

Figure 1. Mean Total Abundance. With no NFWF conservation actions, the modeled mean total abundance of Black-footed Albatrosses in 100 years increases by 34% (blue line). When all NFWF actions are incorporated into the mPVA model, mean total abundance increases by 57% in 100 years. Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2020.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Guadalupe Murrelet (formerly Xantus's Murrelet)

IUCN Endangered

Xantus's Murrelet was split into two species in July 2012 (Scripps's Murrelet and Guadalupe Murrelet) based on DNA evidence, lack of inter-breeding on islands where the two species co-occur, and morphological differences.

Current Status & Threats

IUCN Endangered due to < 500km^2 area of occupancy, ≤ 5 breeding locations, and continuing decline. Guadalupe Murrelet occupies a very small range when breeding, nesting on only a very few islands and islets, and is inferred to be experiencing on-going decline owing mainly to the impacts of invasive mammalian predators.

Breeding Islands

Mexico: Afuera (29%), Negro (29%), Gargoyle (29%), Guadalupe (11%), San Benito Medio (<1%), San Benito Oeste (<1%), San Benito Este (<1%), San Pedro Martir (<1%).

Number of mature individuals: 5,000[i]

NFWF Business Plan Goals & Accomplishments

2016 – 2021 Goals	Progress	Details
Establish one new population	Accomplished	Guadalupe Murrelet are now breeding on Guadalupe Island in an area protected by a predator proof fence after years of extirpation. 195 Guadalupe Murrelet pairs bred on Guadalupe Island in 2019, eight of which were breeding in artificial burrows

Significance of Accomplishments

The building of the predator-proof fence on Guadalupe Island created an area where Guadalupe Murrelets are thriving. Once the cat eradication is completed on Guadalupe Island the Guadalupe Murrelet population will likely expand beyond the fenced area throughout the island. This expansion should allow for an IUCN Red List down-listing from Endangered to Vulnerable. However, according to the Seabird mPVA, the Guadalupe Murrelet population will continue to have a high quasi-extinction risk[ii] and declining population over 100 years likely due to low survival values in the model. Conservation actions aimed at increasing survival for juveniles and sub-adults would make the decline less severe over time.

Funding/Project Details
10 Years (January 2013 – January 2023)
6 NFWF Funded Projects (all also addressed needs for Laysan Albatross) to 1 Grantee (Grupo de Ecologia y Conservacion de Islas, A.C.):

$4,230,000 – NFWF
$5,860,000 – Match

$10,090,000 – Total Funding (includes Laysan Albatross) *may be an underestimate due to the likelihood of additional funding sources

Fencing
- Predator proof fence creates a peninsula of 153 acres free of feral cats

Eradication
- Domestic Cat on Guadalupe Island: control ongoing since 2011. Eradication efforts initiated in 2017 and significantly increased in 2018 and 2019, but cats still remain.

Monitoring
- Colony monitoring

Social Attraction
- Artificial burrows

Future Prognosis due to project outcomes
Demographic changes due to NFWF actions to date: New meta-population of 400 individuals added to Guadalupe Island (invasive species free).

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	95%	99% decrease
All NFWF Actions Completed	94%	99% decrease

While NFWF conservation actions allowed for the expansion of the Guadalupe Murrelet population onto Guadalupe Island, the effect on quasi-extinction risk or population abundance across 100 years was minimal. This is likely due to the actions having little to no effect on low survival rates of juveniles and sub-adults, which is likely driving the extinction risk and population decline.

Figure 1. Quasi-Extinction Risk. With no NFWF conservation actions, the quasi-extinction risk for Guadalupe Murrelets in 100 years is 95% (blue line). When all completed NFWF actions are incorporated into the mPVA model, extinction risk decreases to 94% (green line). Confidence intervals are shown as dotted lines.

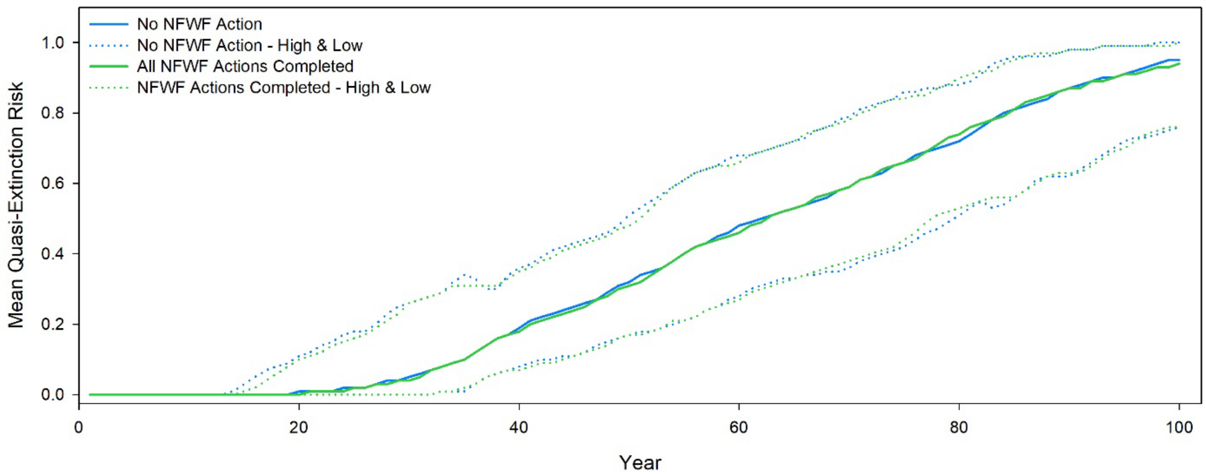
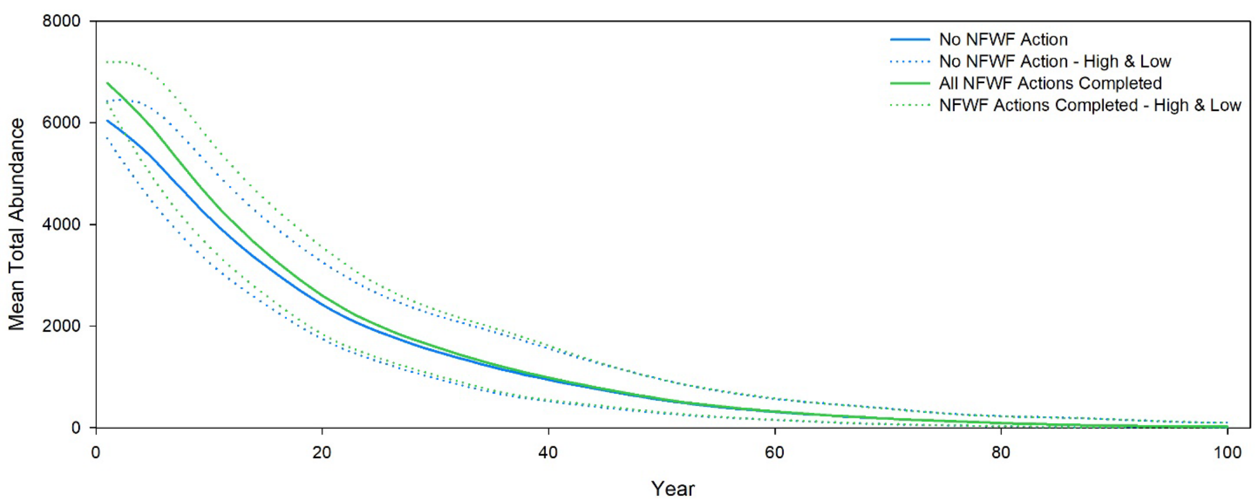


Figure 2. Mean Total Abundance. With no NFWF conservation actions, the modeled mean total abundance of Guadalupe Murrelets in 100 years decreases by 99% (blue line). When all completed NFWF actions are incorporated into the mPVA model, mean total abundance continues to decreases by 99% in 100 years (green line). Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

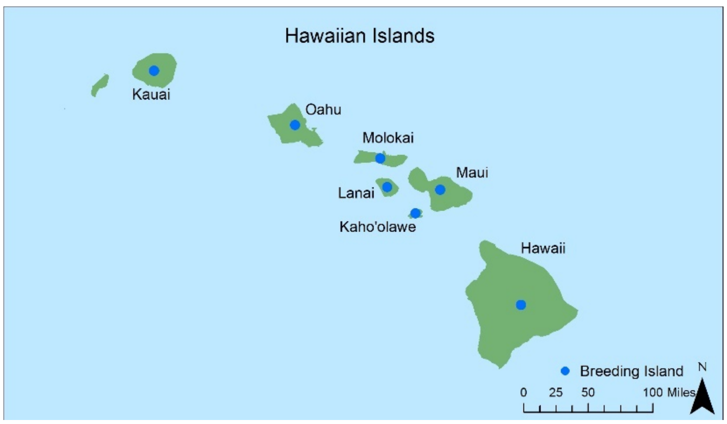
Hawaiian Petrel

IUCN Endangered
ESA Endangered
Hawaii Endangered

Current Status & Threats
IUCN Endangered due to ≥ 50% population size reduction over three generations (59 years). Hawaiian Petrel has a very small breeding range, known from five islands in the main Hawaiian Islands, and the future of at least two are in jeopardy (Mauna Loa, Hawaii and West Maui) due to invasive predators including cats, rodents, and mongoose. Radar surveys show that the species is declining rapidly on at least one of the other islands where it breeds (Kauai), and declines are probable on other islands too.

Number of Mature Individuals: 7,500 – 16,600[i]

Breeding Islands
United States: Kauai (44%), Maui (28%), Lanai (22%), Hawaii (6%), Kaho'olawe (<1%), Molokai (<1%), Oahu (unknown).



NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Protect two breeding colonies	Accomplished	Two predator proof fences constructed on Hawaii and Kauai protect 651 acres
Develop translocation techniques	Accomplished	Technique established and first translocation conducted in 2015
Increase the number of chicks produced per pair by 10%	Accomplished	Prior to the cat-proof fence on Hawaii, fledging success was 52%, in 2017 fledging success increased to 77%

2016 – 2021 Goals	Progress	Details
Increase the number of chicks produced per pair from 0.35 to 0.6	Accomplished	Monitoring of fledging success indicates an increase in 2016 to 76% on Kauai. On Lanai, reproductive success rose to an overall average of 78.4%
Establish three new populations	Partially Achieved	110 Hawaiian Petrel chicks successfully translocated and 106 fledged (96%) from a

		predator proof fence area on Kauai. Five Hawaiian Petrels have returned as adults. Other translocation sites include Lehua and additional predator proof fence areas on Kauai, however COVID-19 delayed fence construction and next steps on Lehua. Conservation actions will resume when it is safe to do so.

Additional Accomplishments
Ungulate proof fence constructed which protects 2,115 acres on Maui from trampling by ungulates. The invasive Strawberry Guava (*Psidium cattleianum*) controlled on 61.63 acres on Lanai providing additional breeding habitat for Hawaiian Petrels. Comprehensive Hawaiian Petrel monitoring plan produced for Lanai to help guide monitoring efforts and improve estimates of reproductive success. On Oahu, acoustic monitoring detected Hawaiian Petrels, which is significant since breeding is not confirmed there. Habitat suitability model produced to identify sites across the main Hawaiian Islands where Hawaiian Petrel colonies are likely to occur.

Significance of Accomplishments
According to the Seabird mPVA model, these accomplishments indicate a decrease in quasi-extinction risk[ii], from 57% in 100 years down to 0%. This decrease is due to predator control and fencing which resulted in a 49% increase in fledging success on Kauai. Developing translocation techniques and successfully completing translocations of Hawaiian Petrel chicks to the Nihoku Restoration site at Kilauea Point National Wildlife Refuge is major conservation gain. Five of the originally translocated chicks returned to the site to prospect in 2020, with nesting occurring in 2021 making the Nihoku Restoration site one of three predator-free breeding sites for these birds. This fence and others in the planning building phases should result in a stabilization and eventual increase the population of Hawaiian Petrels. Continued efforts to protect sub-colonies on Kauai will only further enhance the Hawaiian Petrel population.

Funding/Project Details
9.5 Years (November 2012 – February 2022)
34 NFWF Funded Projects (26 shared with Newell's Shearwater; 1 shared with Newell's Shearwater and Laysan Albatross) to 14 Grantees:

$6,647,334 – NFWF
$7,634,052 – Match

$14,281,386 – Total Funding (also addressed needs for Newell's Shearwater) *may be an underestimate due to the likelihood of additional funding sources

Fencing

- Predator proof fencing installed in Volcanos National Park, Hawaii (644 acres) and at Kilauea Point National Wildlife Refuge, Kauai (7 acres).
- Ungulate fencing installed in Haleakala National Park, Maui
- Funding for additional fencing projects on Kauai, Lanai, and Hawaii

Eradication

- Predators eradication within fenced area on Kauai
- Funding for additional predator control on Kauai

Translocation

- Translocation of Hawaiian Petrel chicks to area within predator proof fence on Kauai.

Standard & Acoustic Monitoring

- Monitoring work on six Hawaiian Islands: Lanai, Maui, Kauai, Oahu, Molokai, Hawaii
    - Lanai – predator control, standard and acoustic monitoring, vegetation mapping
    - Maui – vegetation analysis, nest monitoring, predator monitoring
    - Kauai – Predator control and standard monitoring
    - Oahu – Acoustic and standard monitoring
    - Molokai – Acoustic monitoring
    - Hawaii – Acoustic monitoring

Social Attraction

- Sound system on Kauai at the Nihoku Restoration site at Kilauea Point National Wildlife Refuge
- Social attraction (sound systems & nest boxes) to start in Pohakea, Kauai and on Lehua in 2021

Habitat Restoration

- Removal of Strawberry Guava from 61 acres on Lanai
- Removal of non-native weeds from 15+ acres on Lehua

Future Prognosis due to project outcomes

Demographic changes due to all NFWF actions completed: Fledging success increased to 78.4%, new meta-population of 110 birds translocated to 7-acre site on Kauai, 100 additional birds protected on Kauai in 12.9 km^2.

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	57%	99% decrease
All NFWF Actions Completed	0%	82% decrease

Figure 1. Quasi-Extinction Risk. With no NFWF conservation actions, the quasi-extinction risk for Hawaiian Petrels in 100 years is 57% (blue line). When all NFWF actions are completed extinction risk decreases to 0% in 100 years (green line). Confidence intervals are shown as dotted lines.

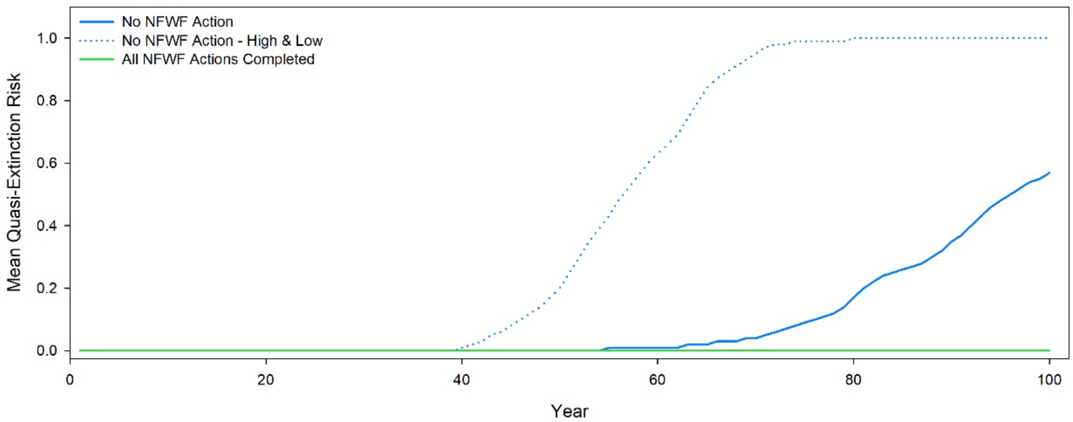
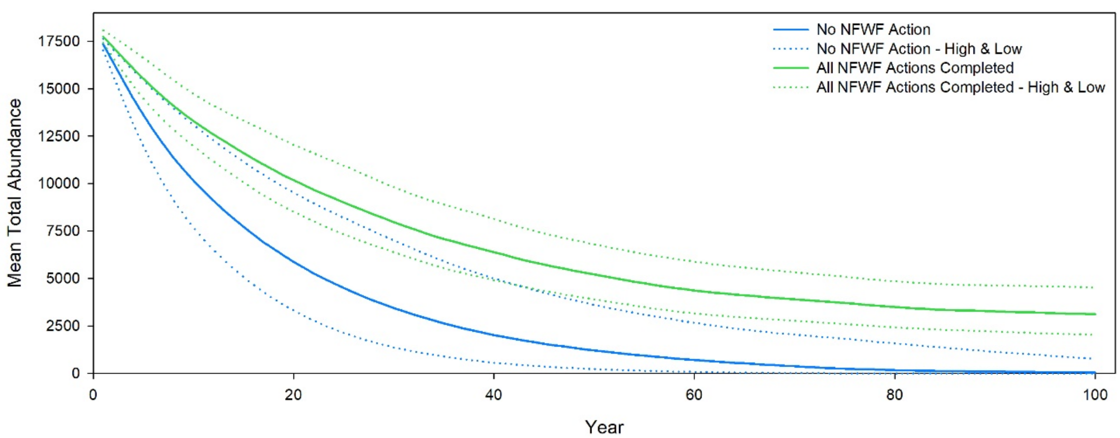


Figure 2. Mean Total Abundance. With no NFWF conservation actions, the modeled mean total abundance of Hawaiian Petrels in 100 years decreases by 99.7% (blue line). When all NFWF actions completed are incorporated into the mPVA model, mean total abundance decreases by 82% in 100 years (green line). Confidence intervals are shown as dotted lines.



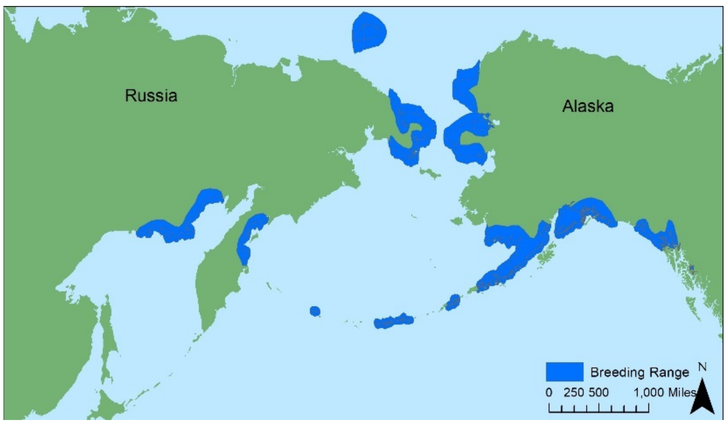
[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Kittlitz's Murrelet
IUCN Near Threatened

Current Status & Threats
IUCN Near Threatened due to < 30% population size reduction. Kittlitz's Murrelet was downlisted from Critically Endangered in 2013 because the rate of population decline that it is experiencing is suspected to be less rapid than previously thought.

Breeding Locations
United States: In Alaska, east of Cape Lisburne south to the Aleutian Islands and east to LeConte Bay. Russia: limited to the eastern Chukotskiy Peninsula in the Chukchi Sea west to Cape Schmidt and south to Anadyr Gulf, as well as Shelikov Bay in the northern Sea of Okhotsk.



Number of mature individuals: 32,000 – 55,000[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Support two to four conservation research projects	Accomplished	Two projects supported, one nest monitoring project on Kodiak Island, Alaska (2013 – 2016) and a population genetics study

Additional Accomplishments
Nest monitoring on Kodiak Island, Alaska found a variable nesting success rate (45% in 2013 to 0% in 2015) which is linked to sea surface temperatures in the Gulf of Alaska (higher temperatures correspond to low nest survival). This connection provides insights into how Kittlitz's Murrelets might react to oceanic regime shifts and how their populations might have been affected by past regime shifts. Strong population genetic structure found in Kittlitz's Murrelets which will aid management decisions.

Significance of Accomplishments
The population genetics study found that Kittlitz's Murrelets appear to compromise two genetic groups: a Western population which includes birds from the Aleutian Islands (Attu, Agattu, and Andreanof), and an Eastern population which includes birds from Kodiak Island east to Glacier Bay. However, Murrelets from both groups interbreed to some extent and thus are not separate species. Kittlitz's Murrelet is not included

in the Seabird mPVA because it is listed as Near Threatened on the IUCN Red List, thus we cannot report on long-term accomplishments.

Funding/Project Details
4 Years (December 2012 – December 2016)
4 NFWF Funded Projects to 4 Grantees:

$255,026 – NFWF
$350,773 – Match

$605,799 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Monitoring

- Nest monitoring on Kodiak Island, Alaska
    - Camera traps
    - Growth rates

Population Genetics Study

[i] IUCN Red List of Threatened Species 2018.

Laysan Albatross
IUCN Near Threatened

Current Status & Threats
IUCN Near Threatened due to < 30% population size reduction. Laysan Albatross has rebounded from declines in the late 1990s and early 2000s, perhaps because apparent changes in the breeding populations reflected large scale environmental conditions that affected the number of birds that returned to colonies to nest (instead of staying at-sea) rather than actual declines in the population. Given the difficulty of predicting long-term trends for such a long-lived species, and the number of documented threats and the uncertainty over their future effects, the species is precautionarily projected to undergo a moderately rapid population decline over three generations (84 years).

Breeding Islands
United States: Midway Atoll (73%), Laysan Island (21%), Kure Atoll (4%), Southeast (1%), <1%: Tern, Necker, Kauai, Ni'ihau, Oahu, Lehua.
Mexico: <1%: Guadalupe, Afuera, Negro, Clarion, San Benedicto; Japan: Mukojima (<1%).

Number of mature individuals: 1,600,000[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Increase reproductive success from 0.24 to 0.48 chicks/pair	Accomplished	Reproductive success increased to 0.6 chicks/pair

2016 – 2021 Goals	Progress	Details
Establish two new populations	Accomplished	51 Laysan Albatross chicks successfully translocated and 47 fledged (92%) at the James Campbell NWR on Oahu. Laysan Albatross are now nesting within the fenced area at the Nihoku Restoration Site at Kilauea Point NWR on Kauai
Increase average number of breeding pairs: • USFWS: 408,000 to 640,000	Not Yet Achieved	Number will likely increase when Midway

		Atoll mouse eradication is completed in 2021-22
• Hawaii DLNR/Kure: 20,200 to 25,900	Accomplished	42,174 nests in December 2019
• GECI/Guadalupe: 400 to 600 individuals	Accomplished	Nests are increasing on Guadalupe Island: 312 nests in 2019, up from 199 in 2016

Additional Accomplishments
Predator-proof fences constructed on Kauai, Oahu, and Guadalupe islands protect 180 acres from invasive predators. Biosecurity measures have been implemented on Guadalupe Island to keep invasive species (rats) off Guadalupe Island. Kure and Midway Atolls have been released from the most significant damage caused by mature *Verbesina encelioides* since 2014 allowing for more open ground for Laysan Albatross to breed. Grantees tagged 34 Laysan Albatrosses with GPS and 14 with geolocations tags from Guadalupe Island to investigate their distribution during the non-breeding season. Satellite imagery can accurately predict ground-based colony counts when accounting for species, platform, and vegetation cover which is helpful in providing accurate abundance estimates. Invasive rats were successfully eradicated from Lehua, Hawaii. The Russian Far East Fisheries, the Alaskan Demersal Longline fisheries, and the Hawaii Swordfish Longline fishery implemented gear modifications (streamer lines or seabird curtains) to reduce Laysan Albatross bycatch as well as a driftnet fishing ban in the Russian Far East Fisheries.

Significance of Accomplishments
The *Verbesina* eradication on Kure Atoll has already resulted in an increase in Laysan Albatross breeding pairs. Laysan Albatross breeding pairs on Guadalupe Island are increasing and will continue to do so at likely greater rates and throughout the island once the cat eradication is completed (anticipated by December 2022). The driftnet fishing ban in the Russian driftnet fishery resulted in an estimated reduction of seabird bycatch of approximately 100,000 seabirds per year (includes Laysan Albatross). Once all funded eradication and restoration efforts are complete, especially the mouse eradication on Midway Atoll, the Seabird mPVA model predicts that the abundance of Laysan Albatrosses will change from a 33% decrease to an 11% increase in 100 years and the quasi-extinction risk will remain at zero[ii].

NFWF Funding for Laysan Albatross
11 Years (September 2012 – February 2023)
30 NFWF Funding Projects (17 grants shared with Black-footed Albatross; 6 shared with Guadalupe Murrelet; 1 grant shared with Hawaiian Petrel and Newell's Shearwater) to 12 Grantees:

$14,941,403 – NFWF
$21,823,955 – Match

$36,765,358 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Funding/Project Details
Eradication
- Cat eradication on Guadalupe Island
- Mouse eradication on Midway Atoll
- Rat eradication on Lehua Island

Translocation

- Laysan Albatross eggs from Kauai to James Campbell NWR on Oahu

Fencing

- 4-acre predator proof fence at Kuaokala, Oahu
- 16-acre predator proof fence at James Campbell NWR, Oahu
- Cat-proof fence on Guadalupe Island protecting 153 acres

Monitoring

- Plastic Ingestion on Tern Island
- Reproductive success monitoring on Guadalupe Island
- Remote sensing to determine nesting population
- GPS tagging of individuals on Guadalupe Island

Habitat Restoration

- *Verbesina* eradication from Midway Atoll (1,261+ acres) and Kure Atoll (188 acres)
- Convert runway substrate to nesting habitat on Kure Atoll
- Native plant propagation and outplanting on Midway Atoll and Kure Atoll

Social Attraction

- Decoys and sound system in James Campbell NWR on Oahu and on Guadalupe Island

Bycatch

- Fishery closure in Russian Far East Fisheries
- Gear technology modification in West Coast Sablefish Fishery, Alaskan Demersal Longline Fisheries, Hawaii Longline Swordfish Fishery, and Russian Far East Fisheries

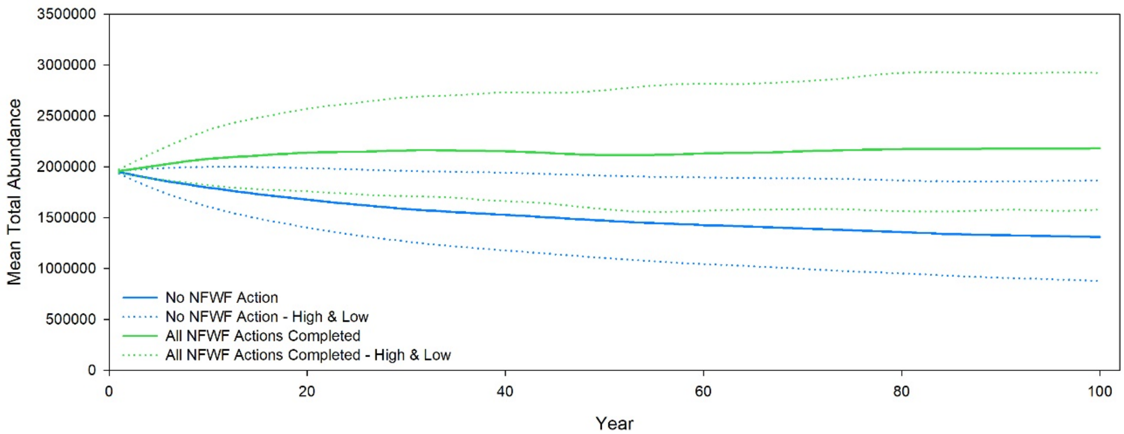
Future Prognosis due to project outcomes

Demographic changes due to all NFWF actions completed: Cat eradication on Guadalupe Island, house mouse eradication on Midway Atoll, increase in the number of birds on Kure Atoll from 78,000 to 84,000, and translocation of 47 birds to James Campbell National Wildlife Refuge, Oahu, and rat eradication on Lehua.

	Extinction Risk in 100 years*	Population Abundance in 100 years
No NFWF Actions	0%	33% decrease
All NFWF Actions Completed	0%	11% increase

*Not graphed since all values are 0

Figure 1. Mean Total Abundance. With no NFWF action, the modeled mean total abundance of Laysan Albatrosses in 100 years decreases by 33% (blue line). When all NFWF actions are completed, mean total abundance increases 11% over 100 years (green line). Confidence intervals are shown as dotted lines.



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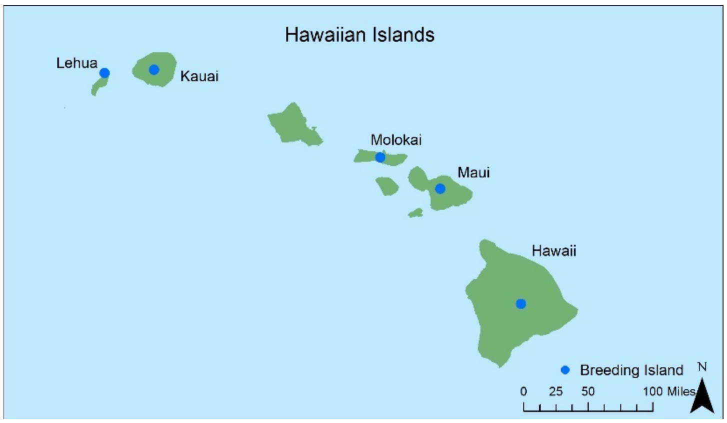
[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Newell's Shearwater
IUCN Critically Endangered
ESA Threatened
Hawaii Endangered

Current status & threats
IUCN Critically Endangered due to ≥ 80% population size reduction. Newell's Shearwater has been declining at an accelerating pace on its breeding islands, principally due to depredation by introduced predators, habitat deterioration, and hurricanes. Other impacts include power line collisions and lighting.

Breeding Islands
United States: Kauai (98%), Hawaii (2%), Maui (<1%), Molokai (unknown), Lehua (unknown).



Number of mature individuals: 10,000 – 19,999[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Protect two breeding colonies	Accomplished	A predator proof fence constructed on Kauai protects 7 acres of breeding habitat. In addition, predator control occurred at two colonies on Kauai
Develop translocation techniques	Accomplished	Technique established and first translocation conducted in 2015

2016 – 2021 Goals	Progress	Details
Increase the number of chicks produced per pair from 0.5 to 0.7	Accomplished	While the number of fledged chicks is extremely low, fledging success (number of chicks per pair) averaged 85.7% between 2016 – 2019 on Kauai
Establish two new populations	Partially Achieved	87 Newell's Shearwater chicks successfully translocated and fledged (100%) from a predator proof fence area on Kauai. Future translocation sites include Lehua and additional predator proof fence areas on Kauai; however, COVID-19 delayed fence

		construction and next steps on Lehua. These conservation actions will resume when it is safe to do so.

Additional Accomplishments
Acoustic monitoring on Oahu detected Newell's Shearwaters at five sites, indicating that breeding on Oahu is possible. This would increase the number of known breeding islands; however, breeding was not confirmed. Grantees produced a habitat suitability model which identifies sites across the main Hawaiian Islands where Newell's Shearwater colonies are likely to occur. Invasive rats were successfully eradicated from Lehua, Hawaii.

Significance of Accomplishments
According to the Seabird mPVA model, these accomplishments indicate a decrease in quasi-extinction risk[ii], from 3% in 100 years down to 0% and a decrease in total abundance of 62% in 100 years. Developing translocation techniques and successfully completing translocations of Newell's Shearwater chicks to the Nihoku Restoration site at Kilauea Point National Wildlife Refuge is major conservation gain. The original translocated chicks should begin to return to the site soon to prospect with breeding to occur several years later. While adults are visiting the Nihoku translocation site, no band recoveries have been obtained to confirm if prospecting birds are part of the translocation cohort. Once they do the Nihoku Restoration site will be one of the only predator-free breeding sites for these birds. This should result in a stabilization and eventual increase the population of Newell's Shearwater. Continued efforts to protect sub-colonies on Kauai will only further enhance the Newell's Shearwater population.

Funding/Project Details
9 Years (Nov 2012 – Dec 2021)
26 NFWF Funded Projects (25 also supported Hawaiian Petrel; 1 supported Hawaiian Petrel and Laysan Albatross) to 8 Grantees:

$4,527,075 – NFWF
$3,552,079 – Match

$8,079,154 – Total Funding (includes Hawaiian Petrel) *may be an underestimate due to the likelihood of additional funding sources

Fencing
- Predator proof fencing installed at Kilauea Point National Wildlife Refuge, Kauai
- Funding for additional fencing projects on Kauai

Eradication
- Predator eradication within fenced area on Kauai
- Funding for additional predator control on Kauai

Translocation
- Translocation of Hawaiian Petrel chicks to area within predator proof fence on Kauai

Standard & Acoustic Monitoring
- Monitoring work on six Hawaiian Islands: Lanai, Maui, Kauai, Oahu, Molokai, Hawaii

- Lanai – predator control, standard and acoustic monitoring, vegetation mapping
- Maui – vegetation analysis, nest monitoring, predator monitoring
- Kauai – Predator control and standard monitoring
- Oahu – Acoustic and standard monitoring
- Molokai – Acoustic monitoring
- Hawaii – Acoustic monitoring

Social Attraction

- Sound system on Kauai at the Nihoku Restoration site at Kilauea Point National Wildlife Refuge
- Social attraction (sound systems & nest boxes) to start in Pohakea, Kauai in 2021

Future Prognosis due to project outcomes

Demographic changes due to NFWF actions to date: Fledging success increased to 85.7% (from a baseline of 66%), a new meta-population of 87 birds translocated to 7-acre site on Kauai, and invasive rats eradicated from Lehua.

Demographic changes due to all NFWF actions completed: Fledging success increased to 85.7% (from a baseline of 66%), a new meta-population of 87 birds translocated to 7-acre site on Kauai, invasive rats eradicated from Lehua, and additional 100 birds protected on Kauai.

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	3%	97% decrease
All NFWF Actions Completed	0%	62% increase

Figure 1. Quasi-Extinction Risk. With no NFWF action, the quasi-extinction risk for Newell's Shearwater in 100 years is 3% (blue line). When all NFWF actions are incorporated into the mPVA model, extinction risk decreases to 0% in 100 years (green line). Confidence intervals are shown as dotted lines.

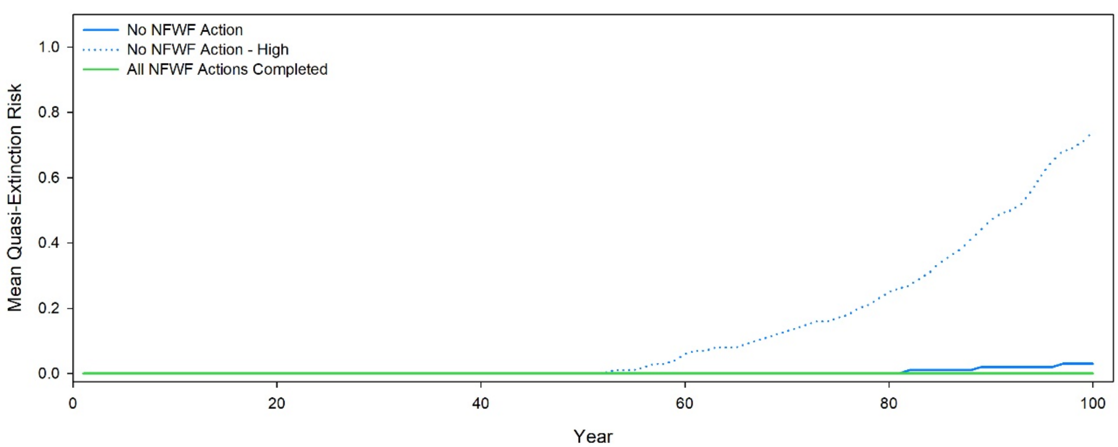
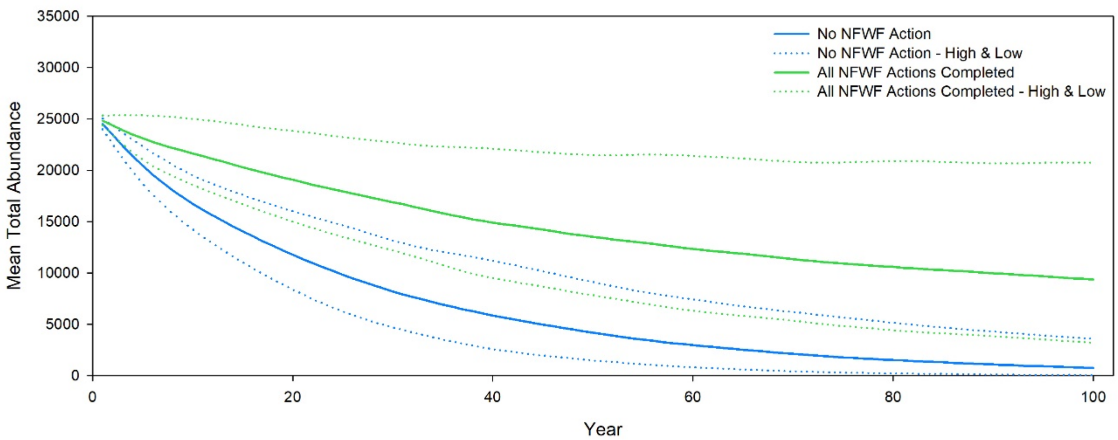


Figure 2. Mean Total Abundance. With no NFWF action, the modeled mean total abundance of Newell's Shearwaters in 100 years decreases by 96.9% (blue line). When all NFWF actions are incorporated into the mPVA model, mean total abundance decreases by 62% in 100 years (green line). Confidence intervals are shown as dotted lines.



[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Pink-footed Shearwater

IUCN Vulnerable
Chilean Threatened

Current Status & Threats

IUCN Vulnerable due to the number of breeding locations ≤ 5 with a plausible future threat that could drive the taxon to Critically Endangered or Extinct in a very short time. Pink-footed Shearwater has a very small breeding range at only three known locations, which renders it susceptible to stochastic events and human impacts. If invasive species, harvesting of chicks, bycatch in fisheries or other factors are found to be causing population declines, the species might warrant uplisting to Endangered.

Breeding Islands

Chile: Mocha (66%), Robinson Crusoe (20%), Santa Clara (14%).

Number of mature individuals: 59,146[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Increase the number of chicks produced per pair by 10%	Accomplished	In 2011, the number of chicks produced per pair was 0.63. After five years of conservation actions the average annual rate increased to 0.74
Increase adult survival by 5%	Unknown	There are no data for this goal, this metric was not measured
Increase breeding habitat by 500 acres	Not Achieved	Restoration plan on Santa Clara and Robinson Crusoe islands was not completed because water was a limiting factor

2016 – 2021 Goals	Progress	Details
Increase the average burrows occupancy from 65% to 70%	Accomplished	In 2021, the average burrow occupancy was 69%; however, the overall average burrow occupancy from 2016 – 2021 was 72%

Maintain the average number of chicks produced per pair at 0.72	Partially Achieved	In 2021, the average number of chicks produced per pair was 0.73; however, the overall average of productivity from 2016 – 2021 is 0.71

Additional Accomplishments
In an effort to reduce the number of dogs and cats that prey on seabirds, 85% of the pet population on Isla Mocha were spayed or neutered. In the long term this effort will reduce the number of dogs and cats on the island. A predator proof fence originally protected 720 breeding pairs in the Tierras Blancas colony on Robinson Crusoe (59 acres protected) from trampling by ungulates and predation by feral cats and South American coati (*Nasua nasua*). Unfortunately, the fence was destroyed by hurricane force winds in 2016. A rebuild of a second fence is almost complete protecting the Piedra Agujereada colony (7.7 acres) of approximately 2,000 pairs on Robinson Crusoe from invasive predators. In Chile, grantees collaborated with the fishing industry to modify purse seine nets and the modification was adopted as a best practice measure by ACAP (Agreement on the Conservation of Albatrosses and Petrels). This led to a 95% reduction in bycatch with the modified design. Another modified purse seine net used by fishermen on Mocha also resulted in a decrease in bycatch. On Mocha, the park warden program played a key role in deterring, limiting, and reducing illegal poaching of Pink-footed Shearwater chicks on the island. Satellite tracking of Pink-footed Shearwaters identified key foraging areas & interactions with fisheries.

Significance of Accomplishments
According to the Seabird mPVA model, these accomplishments indicate a decrease in quasi-extinction risk[ii], from 90% in 100 years down to 57%. This decrease is due to predator control and fencing which resulted in an increase in fledging success 63% to 78.5% as well as 1,000 birds saved per year due to mitigation efforts to reduce bycatch. Creating predator free areas on Robinson Crusoe Island also contributed to the decrease. Continuation and expansion of the bycatch program and fencing and eradication projects will benefit Pink-footed Shearwater populations on all breeding islands.

Funding/Project Details
10 Years (March 2011 – December 2021)
20 NFWF Funded Projects to 4 Grantees:

$7,336,750 – NFWF
$8,320,404 – Match

$15,657,154 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Fencing
- Predator/Ungulate proof fence at Tierras Blancas colony on Robinson Crusoe (59 acres)
- Repair fur seal fence on Santa Clara
- Mammal proof fence at Piedra Agujereada colony on Robinson Crusoe (7.7 acres)

Eradication
- Goat eradication on Alejandro Selkirk
- Rodent eradication on Alejandro Selkirk
- Coatimundi eradication on Robinson Crusoe

- Cat-trapping effort on Mocha

Monitoring

- Monitoring work on Mocha: burrow monitoring, cat predation, illegal chick harvest
- Pre-eradication baseline monitoring of native seabirds, flora, and fauna
- Nest occupancy and reproductive success on Mocha, Robinson Crusoe, and Santa Clara
- Population wide surveys
- Light impacts on Mocha and Robinson Crusoe

Habitat Restoration

- Native plant nursery established on Santa Clara
- Transplanting of plants, seedlings, and seeds on Mocha and Santa Clara
- Installed water catchment and irrigation system to water plants on Santa Clara

Fisheries Bycatch work

- Satellite tagging of individuals off Santa Barbara, CA and on Mocha to determine fisheries overlap
- Fishing captain surveys to determine bycatch events, composition
- Observers on small-scale gillnet fisheries and purse seine fisheries to investigate bycatch (326 monitoring trips across seven fisheries in Ecuador, Peru, and Chile)
- Mitigation trials using modified net configurations for the purse seine fishery as well as net illumination for gill net fisheries
- Trained fishery observers in seabird bycatch monitoring

Community Engagement

- Spay & Neuter program on Mocha
- Workshops to prepare for eradication on Robinson Crusoe
- Annual “Copa Fardela” or “Shearwater Cup” soccer tournament on Mocha
- Lighting in the town of San Juan Batista on Robinson Crusoe

Future Prognosis due to project outcomes

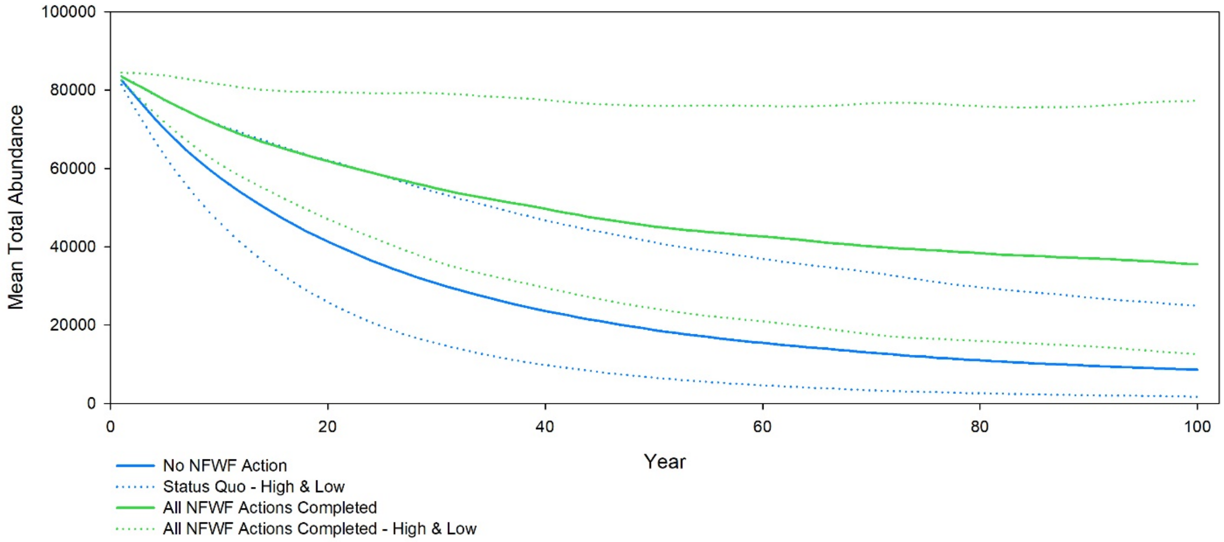
Demographic changes due to all NFWF actions completed: Fledging success increased to 78.5% from 63%, 1,000 birds saved per year via bycatch measures, 2,200 birds protected from invasive species at Piedra Agujereada colony, and coatimundi eradicated from Robinson Crusoe Island.

	Extinction Risk in 100 years*	Population Abundance in 100 years
No NFWF Actions	0%	90% decrease
All NFWF Actions Completed	0%	57% decrease

*Not graphed since all values are 0

Figure 1. Mean Total Abundance. With no NFWF action, the modeled mean total abundance of Pink-footed Shearwaters in 100 years decreases by 90% (blue line). When all NFWF actions are completed and

incorporated into the mPVA model, modeled mean total abundance decreases by 57% in 100 years (green line). Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Red-Legged Kittiwake

IUCN Vulnerable

Current Status & Threats

IUCN Vulnerable due to ≥ 30% population size reduction. Red-legged Kittiwake underwent a rapid historical decline, but there is evidence that suggests that the population has now recovered, and potentially stabilized.

Breeding Locations

United States: Pribilof Islands: St. George (66%), St. Paul (<1%), Otter (<1%); and Aleutian Islands: Unalga (4%), Buldir (2%), Amak (<1%), Bogoslof (<1%), Fire (<1%), Koniuji (<1%), Middle Rock (<1%), Outer Rock (<1%); Palaui (<1%).
Commander Islands: Toporkov (17%), Bering (9%), Mednyi (<1%), Arij Kamen (<1%).

Number of mature individuals: 100,000 – 499,999[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Decrease adult mortality by 1% or more	Not Achieved	NFWF funded project conducted surveys and created a population model

Additional Accomplishments

Supported development of a population model for Red-legged Kittiwake to assess the impact of theoretical levels of harvest on species population trajectory for St. Paul Island.

Significance of Accomplishments

Grantee model results suggest that a low-level of annual harvest of Red-legged Kittiwakes (10 – 20 birds/year) on St. Paul might be sustainable (i.e. will allow for a stable or increasing population) if natural adult survival is above 0.925. However, the Seabird mPVA does not support this conclusion, under that scenario, mean quasi-extinction risk[ii] is 96% and the total mean population at 100 years would decrease by 99.6%. While these numbers are better than the “Status Quo” scenario, when 462 birds were harvested in 1994, there are likely other factors affecting survival (invasive species, at-sea mortality) that are not fully understood. While harvest of Red-Legged Kittiwake still occurs on St. Paul, economic and social changes have led to a decline in the number of community members taking part in subsistence harvest of kittiwakes, and the result is likely a reduction in the total number of birds harvested each year.

Funding/Project Details
NFWF Funding for Red-legged Kittiwake
3 Years (October 2012 – September 2015)
1 NFWF Funded Projects to 1 Grantee:

$97,313 – NFWF
$261,840 – Match
$359,152 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Population Surveys

Population Model

Local Traditional Knowledge surveys

Education & Outreach program to accompany population modeling work

Future Prognosis due to project outcomes
The below Seabird mPVA model runs are solely for the Red-legged Kittiwake population on St. Paul Island.
No NFWF Action: Population of 2,228 (historical population) and 462 birds harvested (1994 value)
Demographic changes due to NFWF actions to date: Using current population size (1,889), 20 birds harvested, and adult survival of 92.5%

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	100%	100% decrease
All NFWF Actions Completed	96%	99.6% decrease

Figure 1. Quasi-Extinction Risk. Using the initial values from the NFWF funded project model, the quasi-extinction risk for Red-legged Kittiwake on St. Paul Island in 100 years is 100% (blue line). When using the model results from the NFWF funded project in the mPVA model, extinction risk decreases to 96% in 100 years (green line). Confidence intervals are shown as dotted lines.

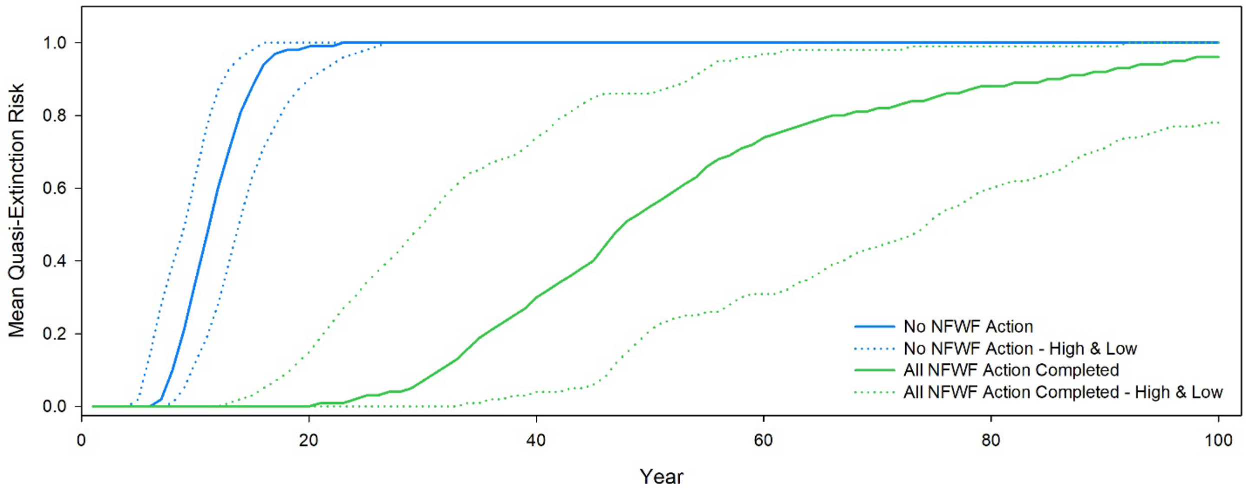
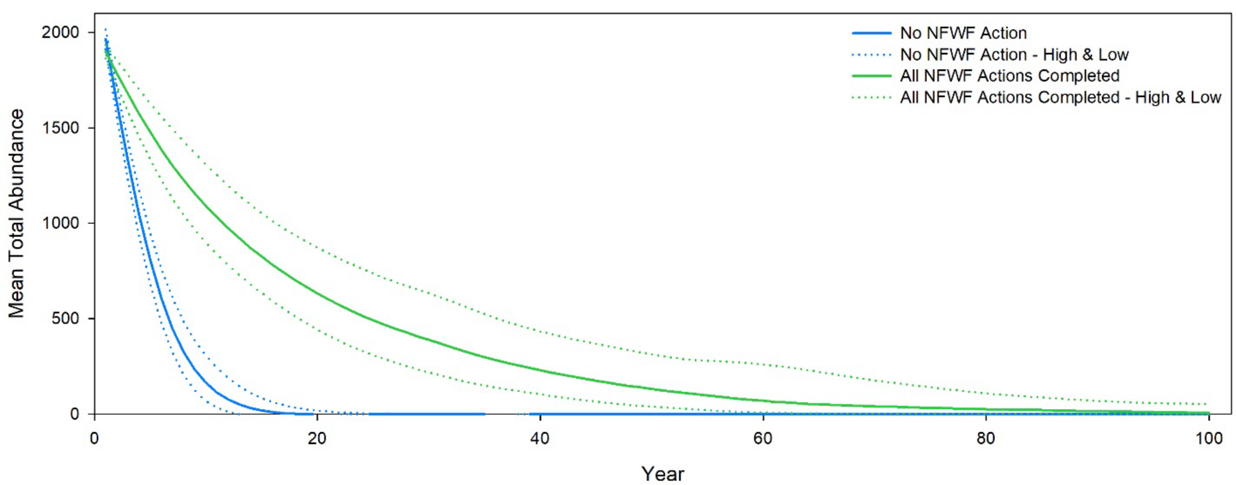


Figure 2. Mean Total Abundance. Using the initial values from the NFWF funded project model, the modeled mean total abundance of Red-legged Kittiwake on St. Paul Island in 100 years decreases by 100% (blue line). When using the model results from the NFWF funded project in the mPVA model, mean total abundance decreases by 98% in 100 years (green line). Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Scripps's Murrelet (formerly Xantus's Murrelet)
IUCN Vulnerable

Xantus's Murrelet was split into two species in July 2012 (Scripps's Murrelet and Guadalupe Murrelet) based on DNA evidence, lack of inter-breeding on islands where the two species co-occur, and morphological differences.

Current Status & Threats
IUCN Vulnerable due to < 2,000km^2 area of occupancy, ≤ 10 breeding locations, and continuing decline. Scripps's Murrelet occupies a very small range when breeding, nests on a limited number of islands and islets, and thought to be in on-going decline owing mainly to the impacts of invasive mammalian predators.

Breeding Islands
United States: Santa Barbara (13%), Santa Cruz (8%), Anacapa East (5%), Anacapa Middle (5%), Anacapa West (5%), Santa Catalina (4%), San Miguel (<1%), Prince (<1%), Shag Rock (<1%), Sutil (<1%), Willows Anchorage Rocks (<1%).
Mexico: Coronado Sur (26%), Coronado Norte (7%), Todos Santos Sur (7%), Coronados Middle (6%), San Benito Este (4%), San Benito Oeste (4%), Todos Santos Norte (2%), San Benito Medio (<1%).

Number of mature individuals: 10,000 – 19,999[i]

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Increase number of chicks produced per pair	Accomplished	Clutch success was 70% in 2014, up from 51% in 2013, and increased to 80% in 2015 on Santa Barbara Island. Hatching success on San Benito Oeste increased from 25% in 2014 to 36% in 2018

Additional Accomplishments
The number of breeding pairs of Scripps's Murrelets at Anacapa Island increased nearly 150% from 450-600 pairs pre-rat eradication to 1,100-1,450 in 2014 (post eradication) with no sign of slowing growth. On Santa Barbara Island, 8.3 acres of seabird habitat were restored and nests were found in the restoration plots in 2015. First evidence of nesting on Catalina Island since single nest was found on Bird Rock

(offshore) in 1967. Cedros Island Cactus Mouse were eradicated from Isla San Benito Oeste in 2013 making the island invasive species free.

Significance of Accomplishments
According to the Seabird mPVA model, these accomplishments indicate a decrease in quasi-extinction risk[ii], from 99% in 100 years down to 50%. This decrease is mainly due to the increase in fledging success on Santa Barbara Island. The Cedros Island Cactus Mouse eradication from San Benito Oeste will likely increase the number breeding Scripps's Murrelets, similar to the increase documented on Anacapa Island post rat eradication since both Anacapa and San Benito Oeste Islands are invasive species free.

NFWF Funding for Scripps's Murrelet
10 Years (Sept 2010 – Dec 2020)
6 NFWF Funded Projects to 5 Grantees:

$890,518 – NFWF
$1,011,311 – Match

$1,901,829 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Eradication

- Eradication of Cedros Island Cactus Mouse from San Benito Oeste

Monitoring

- Colony monitoring on Catalina, Santa Barbara, Anacapa, San Miguel, and San Benito Oeste

Habitat Restoration

- Restore 4.5 acres of seabird habitat at 5 sites and plant 5,000 plants on Santa Barbara Island

Future Prognosis due to project outcomes
Demographic changes due to all NFWF actions completed: Fledging success increased to 80% from 51%.

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	99%	99% decrease*
All NFWF Actions Completed	50%	98% decrease

While there is a large decrease in the extinction risk, the population abundance is relatively unchanged. This is due to the model's lower confidence interval value at 100 years is 151.04 individuals, indicating that on average, after 10,000 model runs, the population does not reach zero after NFWF actions.

Figure 1. Quasi-Extinction Risk. With no NFWF action, the quasi-extinction risk for Scripps's Murrelet in 100 years is 99% (blue line). When NFWF actions completed to date are incorporated into the mPVA model, extinction risk decreases to 50% in 100 years (green line). Confidence intervals are shown as dotted lines.

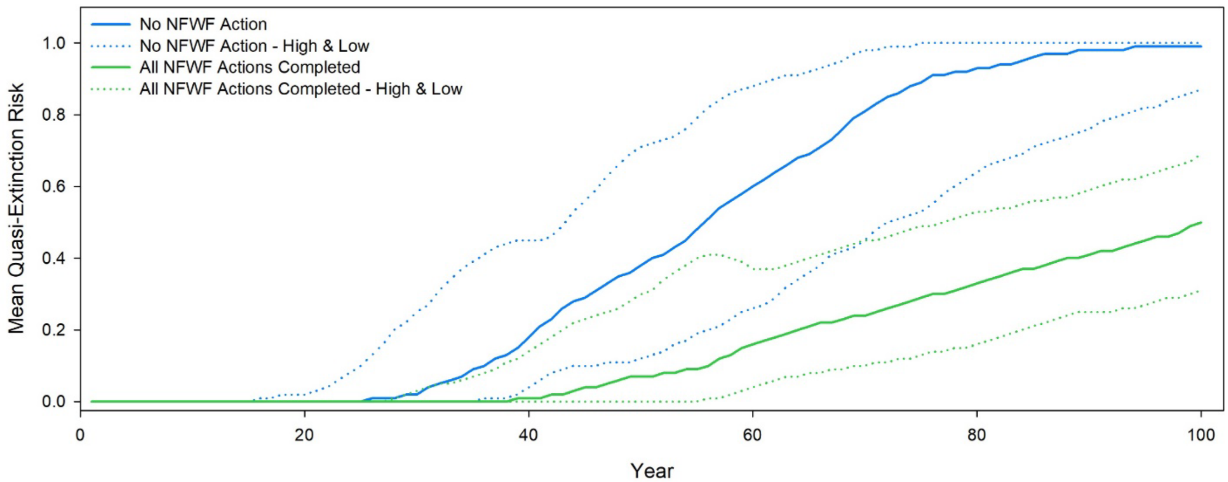
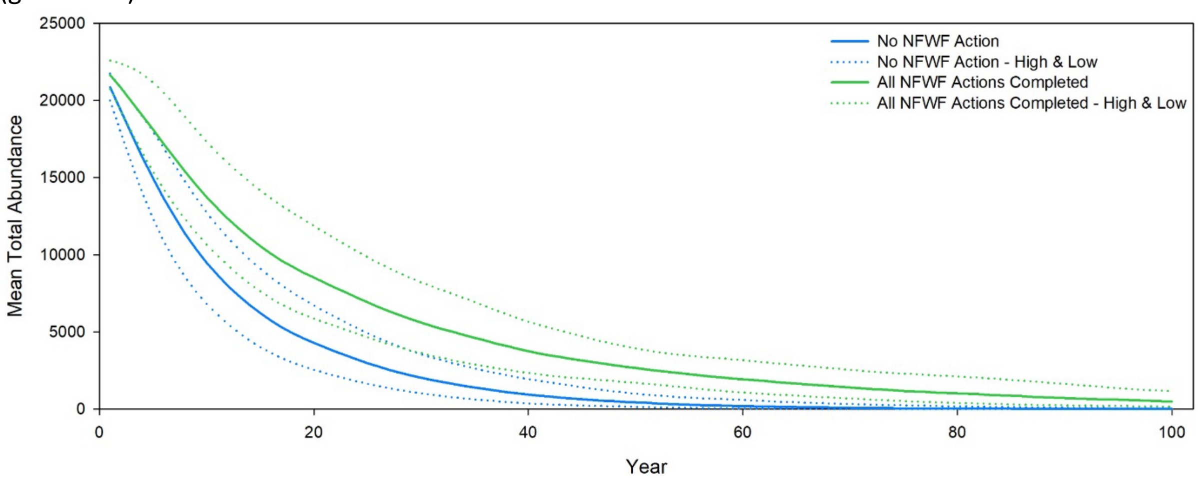


Figure 2. Mean Total Abundance. With no NFWF action, the modeled mean total abundance of Scripps's Murrelet in 100 years decreases by 99.99% (blue line). When NFWF actions completed to date are incorporated into the mPVA model, modeled mean total abundance decreases by 97.7% in 100 years (green line). Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2020.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Townsend's Shearwater
IUCN Critically Endangered

Current Status & Threats
IUCN Critically Endangered due to < $10km^2$ area of occupancy, single location, and continuing decline. Townsend's Shearwater has been extirpated from two islands, and breeding is now restricted to an extremely small area on one island, where invasive species are contributing to a population decline.

Number of mature individuals: 250 – 999[i].

Breeding Islands
Mexico: Socorro (100%), Clarion (only recently confirmed after years of extirpation, however very few burrows are present and success is low due to predation from native snakes and ravens), San Benedicto (extirpated).

NFWF Business Plan Goals & Accomplishments

2011 – 2016 Goals	Progress	Details
Reduce cat predation by 100%	Partially Achieved	Eradication is ongoing and cats are still present
Increase the number of chicks produced per pair by 25%	Not Yet Achieved	Reproductive success is very low

2016 – 2021 Goals	Progress	Details
Increase the percent of nesting area surveyed from 5 to 100%	Partially Achieved	65.6% of historical nesting area and 97% of core nesting area surveyed with acoustic receivers
Increase the number of calls detected per minute from < 2.0 to > 2.0	Not Yet Achieved	Call rates remain low: 0.24 calls per min in 2020
Increase the number of fledglings per nest from 0.2 – 0.4 to 0.5 – 0.7	Partially Achieved	Breeding success (fledglings per nest) is variable with very few nests monitored: 100% in 2016 (n=4) and 2017 (n=7); 0% in 2018 (n=5); and 50% in 2019 (n=2); 66.7% in 2020 (n=9)

Additional Accomplishments
Grantees eradicated sheep from Socorro in 2011 which increased vegetation cover lost by sheep impact by 38%. Overall vegetation cover on Socorro increased 11.6% from 2008 to 2019. Social attraction techniques are working. Since implementation in 2016, a breeding pair nested and successfully fledged a chick within an artificial burrow for the first time in 2019.

Significance of Accomplishments
The cat eradication on Socorro Island has taken much longer than initially proposed. Trapping effort doubled in 2019, but cats are still present on the island. Eradications can be more challenging as target populations decrease, with greater effort or new methods needed to complete the eradication. When the cat eradication is completed, the Seabird mPVA model predicts a decrease in quasi-extinction risk[ii] from 100% to 13%. The number of documented fledged chicks since 2016 is relatively low, between 0 and 7 (in only 7 – 27 known burrows). Completing the cat eradication is key to the survival of Townsend's Shearwater.

Funding/Project Details
11 Years (September 2010 – December 2021)
9 NFWF Funded Projects to 2 Grantees:

$2,549,122 – NFWF
$2,804,753 – Match

$5,353,875 – Total Funding *may be an underestimate due to the likelihood of additional funding sources

Eradication
- Sheep: completed in 2011
- Domestic Cat: ongoing since 2011. While eradication efforts have significantly increased, cats still remain.

Monitoring
- Colony monitoring (both standard and acoustic)
- Monitoring of native lizards, land birds, and non-native rodents

Social Attraction
- Artificial burrows

Future Prognosis due to project outcomes
Demographic changes due to all NFWF actions completed: Fledging success increased to 70% from 50% and all cats eradicated from Socorro Island.

	Extinction Risk in 100 years	Population Abundance in 100 years
No NFWF Actions	100%	100% decrease
All NFWF Actions Completed	13%	46% decrease

Figure 1. Quasi-Extinction Risk. With no NFWF action, the quasi-extinction risk for Townsend's Shearwaters in 100 years is 100% (blue line). When all NFWF actions are completed and incorporated into the mPVA model, extinction risk decreases to 13% in 100 years (green line). Confidence intervals are shown as dotted lines.

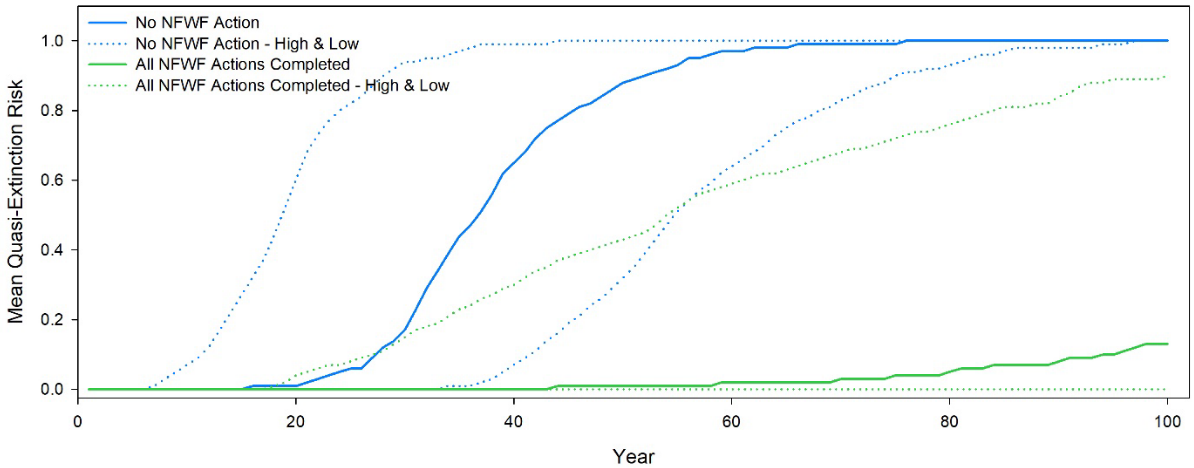
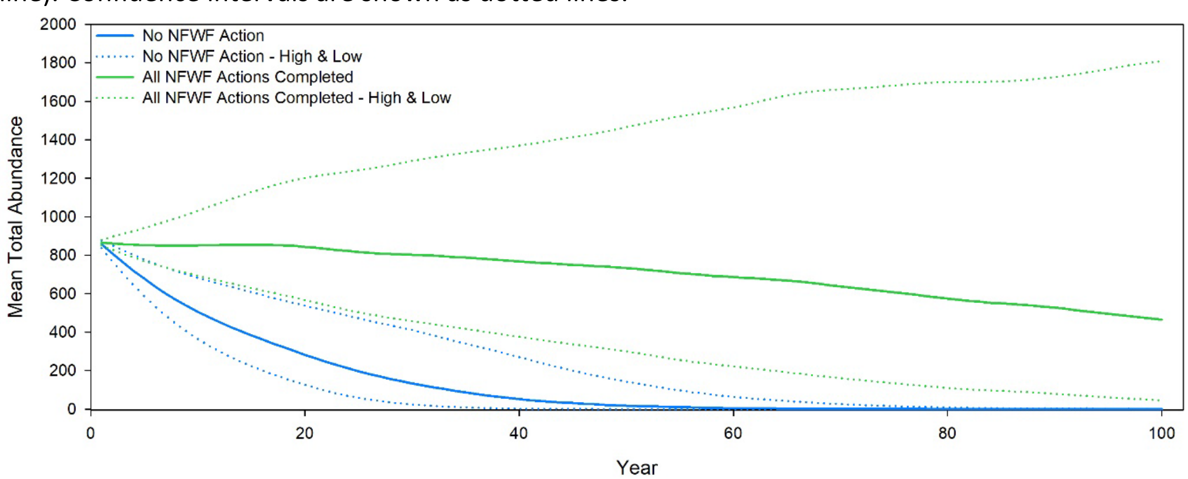


Figure 2. Mean Total Abundance. With no NFWF action, the modeled mean total abundance of Townsend's Shearwaters in 100 years decreases by 99.9% (blue line). When all NFWF actions are completed and are incorporated into the mPVA model, modeled mean total abundance decreases by 46% in 100 years (green line). Confidence intervals are shown as dotted lines.



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[i] IUCN Red List of Threatened Species 2018.

[ii] The relative likelihood that model-projected abundance would drop below a quasi-extinction threshold (the point at which abundance is so low that true extinction risk becomes unacceptably high) within a 100-year period.

Appendix 2. Assessment Tables

Table 1. NFWF funded invasive species eradication efforts.

Year Completed	Focal Geography	Island	Acres	Eradication Status	Invasive Species	Focal or Target (*) Species	Other Populations
2012	California Current	Socorro, Mexico	42,571.8	Successful	Sheep	Townsend's Shearwater	10
2013	California Current	Murchison, Haida Gwaii Canada	1,447.3	Reinvaded (Brown Rat)	Black Rat	Ancient Murrelet* Cassin's Auklet*	No Data
2013	California Current	Faraday, Haida Gwaii Canada	996.1	Reinvaded (Brown Rat)	Black Rat	Ancient Murrelet* Cassin's Auklet*	No Data
2013	California Current	San Benito Oeste, Mexico	1,351.5	Successful	Cactus Mouse	Guadalupe Murrelet Scripps's Murrelet	16
2014	Alaskan Islands	Saint George, Pribilof Islands	22,619.9	Successful	House Mouse	Red-legged Kittiwake	10
2016	Hawaiian Islands	Kure Atoll, NW Hawaiian Islands	324.2	Successful	Polynesian Rat	Black-footed Albatross Laysan Albatross	16
2017	Hawaiian Islands	Lehua, Hawaiian Islands	276.8	Successful	Polynesian Rat	Black-footed Albatross Laysan Albatross Newell's Shearwater	10
2018	Alaskan Islands	Storey, Naked Islands	1,898.1	Successful	Mink	Parakeet Auklet* Pigeon Guillemot*	2
2018	Alaskan Islands	Peak, Naked Islands	1,668.9	Successful	Mink	Parakeet Auklet* Pigeon Guillemot*	2
2018	Alaskan Islands	Naked, Naked Islands	10,266.1	Successful	Mink	Parakeet Auklet* Pigeon Guillemot*	10
2021	South Pacific	Johnston Atoll, South Pacific	732.9	Successful	Yellow Crazy Ants	Red-tailed Tropicbird*	14
	California Current	Socorro, Mexico	42,571.8	In Progress	Domestic Cat	Townsend's Shearwater	10
	California Current	Guadalupe, Mexico	64,728.1	In Progress	Domestic Cat	Guadalupe Murrelet Laysan Albatross	13
	Chilean Islands	Alejandro Selkirk, Juan Fernandez Islands	12,236.9	In Progress	Goat, Rodent, Domestic Cat	Juan Fernandez Petrel* Stejneger's Petrel*	10
	Chilean Islands	Robinson Crusoe, Juan Fernandez Islands	11,846.4	In Progress	Coatimundi	Pink-footed Shearwater	6

Year Completed	Focal Geography	Island	Acres	Eradication Status	Invasive Species	Focal or Target (*) Species	Other Populations
	South Atlantic	Gough, South Atlantic	16,520.6	2021 Implementation	House Mouse	Atlantic Petrel* Atlantic Yellow-nosed Albatross* MacGillivray's Prion* Northern Rockhopper Penguin* Sooty Albatross* Tristan Albatross*	18
	Hawaiian Islands	Midway Atoll, NW Hawaiian Islands	6.45	2022 Implementation	House Mouse	Black-footed Albatross Laysan Albatross	16
	California Current	Clarion, Mexico	29,27.9	Planning	Rabbit	Townsend's Shearwater	5
	Hawaiian Islands	Kahoolawe, Hawaiian Islands	30,415.8	Planning	Domestic Cat, Rat	Hawaiian Petrel	17
	California Current	SE Farallon Island, California	142.7	Planning	House Mouse	Ashy Storm-petrel	11
	California Current	San Miguel, Channel Islands	10,547	Feasibility Study	Black Rat	Ashy Storm-petrel Scripps's Murrelet	35

*Target species are non-NFWF focal species that were the primary focus for the eradication. Monitoring data exist to assess their response to the eradication.

Table 2. NFWF funded fencing projects protecting focal species.

Year Completed	Focal Geography	Area	Project Status	Acres	Focal Species
2014	Hawaiian Islands	Kilauea Point NWR, Kauai	Completed	7	Hawaiian Petrel Newell's Shearwater
2014	Chilean Islands	Piedra Agujereada, Robinson Crusoe	Completed – upgrade planned	11.1	Pink-footed Shearwater
2014	Chilean Islands	Refugio Colony, Santa Clara	Completed	unk	Pink-footed Shearwater
2015	California Current	Punta Sur, Guadalupe	Completed	153.2	Laysan Albatross Guadalupe Murrelet
2016	Hawaiian Islands	James Campbell NWR, Oahu	Completed	16	Laysan Albatross
2016	Hawaiian Islands	Mauna Loa, Hawaii	Completed	644	Hawaiian Petrel
2016	Chilean Islands	Tierras Blancas, Robinson Crusoe	Failed – destroyed by hurricane force winds	59	Pink-footed Shearwater
2019	Hawaiian Islands	Nu'u Haleakala National Park, Maui	Completed	2,155	Hawaiian Petrel
2020	Hawaiian Islands	Kuaokala State Forest Reserve, Oahu	Completed	4	Laysan Albatross
2021	Hawaiian Islands	Pohakea, Hono O Na Pali, Kauai	Completed	3	Hawaiian Petrel Newell's Shearwater
	Hawaiian Islands	Lanai	In Progress	85	Hawaiian Petrel
	Hawaiian Islands	Honopu State Forest Reserve, Kauai	In Progress	2.94	Hawaiian Petrel Newell's Shearwater
	Hawaiian Islands	Honopu, Na Pali Kona Forest Reserve, Kauai	In Progress	264	Hawaiian Petrel Newell's Shearwater
	Hawaiian Islands	Puu O Umi Natural Reserve Area, Hawaii	Planning	3	Hawaiian Petrel Newell's Shearwater
	Hawaiian Islands	North Bog, Hono O Na Pali, Kauai	Assessment only	21.8	Hawaiian Petrel Newell's Shearwater

Table 3. NFWF funded population translocations.

Year	Species	Source Location	Translocation Site	Number Translocated	% Successfully Fledged
2015	Hawaiian Petrel	Kauai	Nihoku, Kilauea Point NWR Kauai	10	90%
2015	Laysan Albatross	PMRF Kauai	James Campbell NWR Oahu	10	100%
2016	Hawaiian Petrel	Kauai	Nihoku, Kilauea Point NWR Kauai	20	100%
2016	Laysan Albatross	PMRF Kauai	James Campbell NWR Oahu	20	95%
2016	Newell's Shearwater	Kauai	Nihoku, Kilauea Point NWR Kauai	8	100%
2017	Hawaiian Petrel	Kauai	Nihoku, Kilauea Point NWR Kauai	20	100%
2017	Laysan Albatross	PMRF Kauai	James Campbell NWR Oahu	20	85%
2017	Newell's Shearwater	Kauai	Nihoku, Kilauea Point NWR Kauai	18	100%
2018	Black-footed Albatross	Midway/Tern	James Campbell NWR Oahu	25	88%
2018	Bonin Petrel	Midway/Tern	James Campbell NWR Oahu	53	100%
2018	Hawaiian Petrel	Kauai	Nihoku, Kilauea Point NWR Kauai	20	95%
2018	Newell's Shearwater	Kauai	Nihoku, Kilauea Point NWR Kauai	21	100%
2018	Tristram's Storm-petrel	Midway/Tern	James Campbell NWR Oahu	25	100%
2019	Hawaiian Petrel	Kauai	Nihoku, Kilauea Point NWR Kauai	20	95%
2019	Newell's Shearwater	Kauai	Nihoku, Kilauea Point NWR Kauai	20	100%
2020	Black-footed Albatross	Midway	James Campbell NWR Oahu	24	100%
2020	Bonin Petrel	Midway/Tern	James Campbell NWR Oahu	27	98%
2020	Bonin Petrel	Midway/Tern	Moku Manu	25	100%
2020	Hawaiian Petrel	Kauai	Nihoku, Kilauea Point NWR Kauai	20	100%
2020	Laysan Albatross	Midway	James Campbell NWR Oahu	1	100%
2020	Newell's Shearwater	Kauai	Nihoku, Kilauea Point NWR Kauai	20	100%
2020	Tristram's Storm-petrel	Tern	James Campbell NWR Oahu	41	81%
2020	Tristram's Storm-petrel	Tern	Kekepa	8	100%
2020	Tristram's Storm-petrel	Tern	Moku Manu	10	90%
2021	Black-footed Albatross	Midway/Tern	Guadalupe Island	27	100%

Table 4. Seabird breeding islands using social attraction techniques.

Year	Focal Geography	Island	Technique	Species to Benefit	Outcome
2015 – 2020	Hawaiian Islands	James Campbell NWR, Oahu	Decoys & Sound Systems	Laysan Albatross Black-footed Albatross Bonin Petrel Tristram's Storm-petrel	Nesting Prospecting Nesting Nesting
2015 – 2021	Hawaiian Islands	Kauai	Sound Systems & Artificial Burrows	Hawaiian Petrel Newell's Shearwater	Nesting Prospecting
2016 – 2019	California Current	Socorro	Artificial Burrows	Townsend's Shearwater	Nesting
2017 – 2020	California Current	Guadalupe	Decoys & Sound Systems Artificial Burrows	Laysan Albatross Guadalupe Murrelet	Nesting Nesting
2017 – 2019	California Current	Zapato Islet	Decoys	Black-footed Albatross	Prospecting
2017 – 2019	California Current	Todos Santos Coronado San Jeronimo San Benito Oeste Natividad San Roque Asuncion	Artificial Burrows & Sound System	Ashy Storm-petrel Ainley's Storm-petrel Black-vented Shearwater Cassin's Auklet Guadalupe Murrelet Scripps's Murrelet Townsend's Storm-petrel	Nesting – Todos Santos Nesting – Coronado, San Roque, Asuncion
2017 – 2019	California Current	Clarion	Decoys Artificial Burrows & Sound Systems	Laysan Albatross Townsend's Shearwater	Nesting
2021	Hawaiian Islands	Lehua	Sound Systems & Artificial Burrows	Hawaiian Petrel	TBD

Table 5. NFWF funded habitat restoration projects.

Year	Focal Geography	Island	Acres	Restoration Type	Project Status	Focal Species
2011 – 2012; 2014 – 2016	Chilean Islands	Santa Clara	unk	Native plant restoration	Completed	Pink-footed Shearwater
2012 – 2013	Chilean Islands	Robinson Crusoe	11.1	Native plant restoration	Completed	Pink-footed Shearwater
2012 – 2014	Hawaiian Islands	Lanai	61.6	Strawberry Guava removal	Completed	Hawaiian Petrel Newell's Shearwater
2014 – 2015	California Current	Santa Barbara Island	8.3	Native plant restoration	Completed	Scripps's Murrelet
2011 – 2023	Hawaiian Islands	Midway Atoll	1,453	*Verbesina* removal Native plant restoration	In Progress	Black-footed Albatross Laysan Albatross
2012 – 2022	Hawaiian Islands	Kure Atoll	188	*Verbesina* removal	In Progress	Black-footed Albatross Laysan Albatross
2016 – 2021	Hawaiian Islands	Nihoku Restoration Site, Kauai	7	Christmas berry shrub removal Native plant restoration	In Progress	Hawaiian Petrel Newell's Shearwater
2021 – 2022	Hawaiian Islands	Lehua	15	Invasive plant removal	Proposed	Hawaiian Petrel

Table 6. NFWF funded seabird bycatch reduction projects

Year(s)	Fishery	Focal Geography	Action Taken	Description	Focal Species
2012 – 2019	Russian Far East Fisheries	Alaska	Fishery Closure Gear Technology	Driftnet fishing ban Streamer Lines	Laysan Albatross
2015 - 2017	West Coast Sablefish Fishery	California Current	Gear Technology	Streamer Lines Night setting	Black-footed Albatross
2015 - 2017	Alaskan Demersal Longline Fisheries	Alaska	Gear Technology	Streamer Lines	Black-footed Albatross Laysan Albatross
2015 – 2017	Hawaii Longline Swordfish Fishery	Hawaii	Gear Technology	Seabird Curtain	Black-footed Albatross Laysan Albatross
2015 – 2017	Chilean Purse Seine Fishery	Chilean Islands	Gear Technology	Modified Purse Seine Design	Pink-footed Shearwater
2015 – 2017	Peruvian Drift Net Fishery	Chilean Islands	Gear Technology	Net Illumination	Pink-footed Shearwater
2021	Hawaii Longline Fishery	Hawaii	Gear Technology	Weighted Hook Design	Black-footed Albatross Laysan Albatross
2021 – 2022	Alaska Gillnet Fisheries	Alaska	NA	Seabird Bycatch Analysis	NA

Table 7. NFWF funded island-based monitoring.

Island	Archipelago	Monitoring Type	Focal Species
Kodiak	Alaskan Islands	Standard & Acoustic	Kittlitz's Murrelet & Aleutian Tern
Hawadax	Aleutian Islands	Standard & Acoustic	NA
Ta'u	American Samoa	Acoustic	Newell's Shearwater
Tutuila	American Samoa	Acoustic	NA
Asuncion	Baja California Pacific Islands	Standard	Guadalupe Murrelet
Clarion	Baja California Pacific Islands	Standard	Townsend's Shearwater, Laysan Albatross, Black-footed Albatross
Coronado	Baja California Pacific Islands	Standard	Ashy Storm-petrel, Guadalupe Murrelet
Guadalupe	Baja California Pacific Islands	Standard	Guadalupe Murrelet, Laysan Albatross
Natividad	Baja California Pacific Islands	Standard	Guadalupe Murrelet
San Benedicto	Baja California Pacific Islands	Standard	Townsend's Shearwater
San Benito Oeste	Baja California Pacific Islands	Standard	Guadalupe Murrelet, Scripps's Murrelet
San Jeronimo	Baja California Pacific Islands	Standard	Guadalupe Murrelet
San Martin	Baja California Pacific Islands	Standard	Ashy Storm-petrel, Guadalupe Murrelet
San Roque	Baja California Pacific Islands	Standard	Guadalupe Murrelet
Socorro	Baja California Pacific Islands	Standard & Acoustic	Townsend's Shearwater, Laysan Albatross, Black-footed Albatross
Todos Santos	Baja California Pacific Islands	Standard	Ashy Storm-petrel, Guadalupe Murrelet
Point Reyes National Seashore	California Coast	Standard	Ashy Storm-petrel
South East Farallon Island	California Coast	Standard & Acoustic	Ashy Storm-petrel
East Anacapa	Channel Islands	Standard	Scripps's Murrelet
Middle Anacapa	Channel Islands	Standard	Scripps's Murrelet
Prince	Channel Islands	Standard & Acoustic	Ashy Storm-petrel, Scripps's Murrelet
San Clemente	Channel Islands	Acoustic	Ashy Storm-petrel
San Miguel	Channel Islands	Standard	Scripps's Murrelet
San Nicolas	Channel Islands	Acoustic	Ashy Storm-petrel
Santa Barbara	Channel Islands	Standard & Acoustic	Ashy Storm-petrel, Scripps's Murrelet
Santa Catalina	Channel Islands	Standard	Scripps's Murrelet
Santa Cruz	Channel Islands	Standard	Ashy Storm-petrel
Scorpion	Channel Islands	Acoustic	Ashy Storm-petrel

Island	Archipelago	Monitoring Type	Focal Species
West Anacapa	Channel Islands	Standard	Scripps's Murrelet
Castle	Del Norte County	Acoustic	Ashy Storm-petrel
False Klamath	Del Norte County	Acoustic	Ashy Storm-petrel
Middleton	Gulf of Alaska	Standard	NA
Santa Maria	Gulf of Aruco	Standard	Pink-footed Shearwater
Hawaii	Hawaiian Islands	Standard & Acoustic	Hawaiian Petrel, Newell's Shearwater
Kauai	Hawaiian Islands	Standard & Acoustic	Hawaiian Petrel, Newell's Shearwater
Lanai	Hawaiian Islands	Standard & Acoustic	Hawaiian Petrel
Lehua	Hawaiian Islands	Acoustic	Newell's Shearwater
Maui	Hawaiian Islands	Standard & Acoustic	Hawaiian Petrel, Newell's Shearwater
Molokai	Hawaiian Islands	Standard & Acoustic	Hawaiian Petrel, Newell's Shearwater
Oahu	Hawaiian Islands	Standard & Acoustic	Hawaiian Petrel, Newell's Shearwater
Blank	Humboldt County	Acoustic	Ashy Storm-petrel
Green	Humboldt County	Acoustic	Ashy Storm-petrel
Little River	Humboldt County	Acoustic	Ashy Storm-petrel
Prisoner	Humboldt County	Acoustic	Ashy Storm-petrel
Mocha	Juan Fernandez Islands	Standard	Pink-footed Shearwater
Robinson Crusoe	Juan Fernandez Islands	Standard	Pink-footed Shearwater
Santa Clara	Juan Fernandez Islands	Standard	Pink-footed Shearwater
Bird Rock	Marin County	Standard & Acoustic	Ashy Storm-petrel
Stormy Stack	Marin County	Acoustic	Ashy Storm-petrel
Casket Rock	Mendocino	Standard	Ashy Storm-petrel
Caspar Pt	Mendocino	Acoustic	Ashy Storm-petrel
Franklin Smith Rock	Mendocino	Standard & Acoustic	Ashy Storm-petrel
Newport	Mendocino	Acoustic	Ashy Storm-petrel
Stillwell Point Rock	Mendocino	Standard & Acoustic	Ashy Storm-petrel
Westport	Mendocino	Acoustic	Ashy Storm-petrel
Wharf Rock	Mendocino	Standard & Acoustic	Ashy Storm-petrel
Castle	Monterey County	Acoustic	Ashy Storm-petrel

Island	Archipelago	Monitoring Type	Focal Species
Hurricane	Monterey County	Acoustic	Ashy Storm-petrel
Fool Island	Naked Islands	Acoustic	NA
Naked Island	Naked Islands	Acoustic	NA
Storey Island	Naked Islands	Acoustic	NA
Alamagan	Northern Marianas	Acoustic	NA
Guguan	Northern Marianas	Acoustic	NA
Sarigan	Northern Marianas	Acoustic	NA
Kure Atoll	NW Hawaiian Islands	Standard	Black-footed Albatross, Laysan Albatross
Midway Atoll	NW Hawaiian Islands	Standard & Acoustic	Black-footed Albatross, Laysan Albatross
Tern	NW Hawaiian Islands	Standard	Laysan Albatross
St. George	Pribilof Islands	Standard	Red-legged Kittiwake
St. Paul	Pribilof Islands	Standard	Red-legged Kittiwake
Piedras Blancas Outer Islet	San Luis Obispo County	Acoustic	Ashy Storm-petrel
Ano Nuevo	San Mateo County	Acoustic	Ashy Storm-petrel
Gull	Sonoma County	Acoustic	Ashy Storm-petrel

Table 8. Non-focal species or subspecies expected to benefit from NFWF funded actions. IUCN Status': CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern. *indicates single island endemic species or subspecies.

Common Name	IUCN Status	Species Type	NFWF Islands
Ainley's Storm-petrel	VU	Seabird	Guadalupe
American Kestrel	LC	Landbird	Guadalupe, San Benito Oeste
Anna's Hummingbird*	LC	Landbird	Guadalupe
Antarctic Tern	LC	Seabird	Gough
Arctic Tern	LC	Seabird	Naked
Atlantic Petrel	EN	Seabird	Gough
Atlantic Yellow-nosed Albatross	EN	Seabird	Gough
Austral Blackbird	LC	Landbird	Alejandro Selkirk
Austral Thrush	LC	Landbird	Alejandro Selkirk, Robinson Crusoe
Band-rumped Storm-petrel	LC	Seabird	Kauai, Lehua
Barn Owl	LC	Landbird	Lehua
Black Noddy	LC	Seabird	Kure, Johnston, Lehua, Midway
Black Oystercatcher	LC	Shorebird	Middleton, Naked, Peak, Storey
Black Storm-petrel	LC	Seabird	San Benito Oeste
Black-bellied Storm-petrel	LC	Seabird	Gough
Black-legged Kittiwake	VU	Seabird	St. George, Middleton
Black-vented Shearwater	NT	Seabird	Guadalupe, San Benito Oeste
Blue Petrel	LC	Seabird	Gough
Bonin Petrel	LC	Seabird	Oahu, Kure, Midway
Brandt's Cormorant	LC	Seabird	San Benito Oeste
Broad-billed Prion	LC	Seabird	San Benito Oeste
Brown Booby	LC	Seabird	Kure, Johnston, Lehua, Midway
Brown Noddy	LC	Seabird	Kure, Johnston, Lehua, Midway
Brown Pelican	LC	Seabird	San Benito Oeste
Brown Skua	LC	Seabird	San Benito Oeste
Bulwer's Petrel	LC	Seabird	Kure, Johnston, Lehua, Midway
Burrowing Owl	LC	Landbird	San Benito Oeste

Common Name	IUCN Status	Species Type	NFWF Islands
Burrowing Owl – subspecies 2*	LC	Landbird	Guadalupe
Canada Goose	LC	Waterfowl	Middleton
Cassin's Auklet	NT	Seabird	Guadalupe, San Benito Oeste
Cattle Egret	LC	Landbird	Lehua
Christmas Shearwater	LC	Seabird	Kure, Johnston, Lehua, Midway
Clarion Mourning Dove	LC	Landbird	Socorro
Common Diving Petrel	LC	Seabird	Gough
Common Murre	LC	Seabird	St. George
Common Raven	LC	Landbird	San Benito Oeste
Common Side-blotched Lizard	LC	Reptile	San Benito Oeste
Costa's Hummingbird	LC	Landbird	San Benito Oeste
Craveri's Murrelet	VU	Seabird	San Benito Oeste
Crested Auklet	LC	Seabird	St. George
Double-crested Cormorant	LC	Seabird	San Benito Oeste
Dusky Canada Goose	LC	Waterfowl	Naked
Spotted Towhee	LC	Landbird	Guadalupe
Glaucous-winged Gull	LC	Seabird	Middleton, Naked
Gough Finch*	CR	Landbird	Gough
Gough Moorhen*	VU	Waterbird	Gough
Gray-backed Tern	LC	Seabird	Kure, Johnston, Midway
Great Frigatebird	LC	Seabird	Kure, Johnston, Lehua, Midway
Great Shearwater	LC	Seabird	Gough
Great-winged Petrel	LC	Seabird	Gough
Green-backed Firecrown	LC	Landbird	Alejandro Selkirk, Robinson Crusoe
Grey Petrel	NT	Seabird	Gough
Grey-backed Storm-petrel	LC	Seabird	Gough
Grey-backed Tern	LC	Seabird	Lehua
Guadalupe House Finch*	NA	Landbird	Guadalupe
Guadalupe Junco*	EN	Landbird	Guadalupe

Common Name	IUCN Status	Species Type	NFWF Islands
Guadalupe Rock Wren*	LC	Landbird	Guadalupe
Hawaiian Goose	VU	Waterfowl	Kauai
Hermit Thrush	LC	Landbird	Naked, Peak, Storey
Horned Puffin	LC	Seabird	Naked, St. George
Juan Fernandez Tit-tyrant	NT	Landbird	Robinson Crusoe
Juan Fernandez Firecrown*	CR	Landbird	Robinson Crusoe
Juan Fernandez Petrel*	VU	Seabird	Alejandro Selkirk
Juan Fernandez Red-backed Hawk	LC	Landbird	Alejandro Selkirk
Juan Fernandez American Kestrel	LC	Landbird	Alejandro Selkirk, Robinson Crusoe
Kergulean Petrel	LC	Seabird	Gough
Kermadec Petrel	LC	Seabird	Alejandro Selkirk
Leach's Storm-petrel	VU	Seabird	San Benito Oeste
Least Auklet	LC	Seabird	St. George
Least Storm-petrel	LC	Seabird	San Benito Oeste, Todos Santos, Coronado, San Jeronimo, Nativitdad, San Roque, Asuncion
Least Tern	LC	Seabird	Midway
Little Tern	LC	Seabird	Midway
MacGillivray's Prion	EN	Seabird	Gough
Marbled Murrelet	EN	Seabird	Naked Island
Masafuera Rayadito*	CR	Landbird	Alejandro Selkirk
Masatierra Petrel	VU	Seabird	Alejandro Selkirk, Robinson Crusoe
Masked Booby	LC	Seabird	Kure, Johnston
Mourning Dove	LC	Landbird	Guadalupe
Northern Flicker	LC	Landbird	Guadalupe
Northern Fulmar	LC	Seabird	St. George
Northern Rockhopper Penguin	EN	Seabird	Gough
Parakeet Auklet	LC	Seabird	Naked, St. George
Pelagic Cormorant	LC	Seabird	Middleton
Pigeon Guillemot	LC	Seabird	Naked, Peak, Storey

Common Name	IUCN Status	Species Type	NFWF Islands
Red-breasted Nuthatch	LC	Landbird	Guadalupe
Red-faced Cormorant	LC	Seabird	St. George
Red-footed Booby	LC	Seabird	Kure, Johnston, Lehua, Midway
Red-tailed Tropicbird	LC	Seabird	Kure, Johnston, Lehua, Midway
Rhinoceros Auklet	LC	Seabird	Middleton
Ruby-crowned Kinglet*	LC	Landbird	Guadalupe
San Benito Rock Wren	NA	Landbird	San Benito Oeste
San Benito Side-blotched Lizard	NA	Reptile	San Benito Oeste
San Benito Sparrow	NT	Landbird	San Benito Oeste
Short-eared Owl	LC	Landbird	Alejandro Selkirk
Short-tailed Albatross	EN	Seabird	Kure
Socorro Blue Lizard*	EN	Reptile	Socorro
Socorro Dove*	EW	Landbird	Socorro
Socorro Elf Owl*	NA	Landbird	Socorro
Socorro Ground Dove*	NA	Landbird	Socorro
Socorro Mockingbird*	CR	Landbird	Socorro
Socorro Parakeet*	NA	Landbird	Socorro
Socorro Parula*	NT	Landbird	Socorro
Socorro Red-tailed Hawk*	NA	Landbird	Socorro
Socorro Towhee*	EN	Landbird	Socorro
Socorro Wren*	NT	Landbird	Socorro
Socorro Yellow-crowned Night Heron*	LC	Shorebird	Socorro
Soft-plumaged Petrel	LC	Seabird	Gough
Sooty Albatross	EN	Seabird	Gough
Sooty Tern	LC	Seabird	Kure, Johnston, Midway
Southern Giant Petrel	LC	Seabird	Gough
Spruce Grouse	LC	Landbird	Naked, Peak, Storey
Stejneger's Petrel*	VU	Seabird	Alejandro Selkirk
Subantarctic Shearwater	LC	Seabird	Gough

Common Name	IUCN Status	Species Type	NFWF Islands
Thick-billed Murre	LC	Seabird	Middleton, St. George
Townsend's Storm-petrel	EN	Seabird	Guadalupe
Tristan Albatross	CR	Seabird	Gough
Tristram’s Storm-petrel	LC	Seabird	Oahu, Kure, Midway
Tufted Puffin	LC	Seabird	Middleton, Naked, St. George
Wedge-tailed Shearwater	LC	Seabird	Kure, Johnston, Lehua, Midway, Oahu, Kauai
Western Gull	LC	Seabird	Guadalupe, San Benito Oeste
Western Meadowlark	LC	Landbird	Guadalupe
White Tern	LC	Seabird	Kure, Johnston
White-bellied Storm-petrel	LC	Seabird	Alejandro Selkirk
White-faced Storm-petrel	LC	Seabird	Gough
White-tailed Tropicbird	LC	Seabird	Johnston
White-throated Swift	LC	Landbird	Guadalupe
Yellow-crowned Night-Heron	LC	Waterbird	San Benito Oeste

Appendix 3. Grantee peer-reviewed publications and reports

Publications Resulting from NFWF-Funded Projects

Peer-reviewed:

Adams, J., J.J. Felis, M. Czapanskiy, R.D. Carle, P.J. Hodum. 2019. Diving behavior of Pink-footed Shearwaters *Ardenna creatopus* rearing chicks on Isla Mocha, Chile. Marine Ornithology 47: 17 – 24

Aguirre-Munoz, A. *et al.*, 2011. Island restoration in Mexico: ecological outcomes after systematic eradications of invasive mammals. Pages 250-258 in: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

Artukhin, Y.B., A.V. Vinnikov, D.A. Terentiev, O.I. Il'in. 2013. Streamer lines — effective seabird scarer for demersal longline Fishery.Izv. TINRO. 175: 277–290

Artukhin, Y.B., A.V. Vinnikov. 2014. The problem of seabird bycatch on the demersal longline fishery for Pacific cod and other fishes in the Far East Fisheries Basin of the Russian Federation. In book: Pacific cod of the Far Eastern waters of Russia. Chapter 5.4 pp 266 – 279. Moscow: VNIRO Publishing.

Aslan, C.E., A. Aslan, D. Croll, B. Tershy, and E.S. Zavaleta. 2014. Building Taxon Substitution Guidelines on a Biological Control Foundations. Resoration Ecology 22: 437-441

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Bedolla-Guzmán, Y., F. Méndez-Sánchez, A. Aguirre-Muñoz, M. Félix-Lizárraga, A. Fabila-Blanco, E. Bravo-Hernández, A. Hernández-Ríos, M. Corrales-Sauceda, A. Aguilar-Vargas, A. Aztorga-Ornelas, F. Solís-Carlos, F. Torres-García, L. Luna-Mendoza, A. Ortiz-Alcaraz, J. Hernández-Montoya, M. Latofski-Robles, E. Rojas-Mayoral and A. Cárdenas-Tapia. 2019. Recovery and current status of seabirds on the Baja California Pacific Islands, Mexico, following restoration actions. In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) (2019). Island invasives: scaling up to meet the challenge, pp. 531–538. Occasional Paper SSC no. 62. Gland, Switzerland: IUCN. Attachment 2

Becker, B.H., H.R. Carter, R.P. Henderson, A.M. Weinstein, M.W. Parker. 2016. Status and monitoring of Ashy Storm-petrels *Oceanodroma homochroa* at Point Reyes National Seashore, California, 2012 – 2015. Marine Ornithology 44: 63 – 70

Beltran, R.S., N. Kreidler, D.H. Van Vuren, S. Morrison, E. Zavaleta, K. Newton, B.R. Tershy, and D. Croll. 2014. Passive recovery of vegetation from herbivore eradication on Santa Cruz Island, California. Restoration Ecology DOI: 10.1111/rec.12144

Borker, A.L., M.W. McKown, J.T. Acerman, C.A. Eagles-Smith, B.R. Tershy, and D.A. Croll. 2014. Vocal Activity as a Low Cost and Scalable Index of Seabird Colony Size. Conservation Biology. DOI:10.1111/cobi.12264

Borker, A.L., P. Halbert, M.W. Mckown, B.R. Tershy, D.A. Croll. 2015. A comparison of automated and traditional monitoring techniques for Marbled Murrelets using passive acoustic sensors. Wildlife Society Bulltein. DOI: 10.1002/wsb.608

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Brooke, M. d. L., E. Bonnaud, B. J. Dilley, E. N. Flint, N. D. Holmes, H. P. Jones, P. Provost, G. Rocamora, P. G. Ryan, C. Surman and R. T. Buxton. 2017. Seabird population changes following mammal eradications on islands. Animal Conservation 21: 3-12

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Carle, R.D., J.N. Beck, D.M. Calleri, M.M. Hester. 2015. Temporal and sex-specific variability in Rhinoceros Auklet diet in the central California Current system. J Marine Systems 146: 99 – 108

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Appendix 4. Seabird mPVA model description

MethodsX manuscript submission August 2021

Method Article – Title Page

Title	*Seabird meta-Population Viability Model (mPVA) Methods*
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Keywords	• *Conservation* • *Population Model* • *Extinction Risk*
Direct Submission or Co-Submission *Co-submissions are papers that have been submitted alongside an original research paper accepted for publication by another Elsevier journal*	*Please select* Co-submission with manuscript GECCO-D-20-00765, under minor revision review at Global Ecology and Conservation.

ABSTRACT

- *Max. 200 words*

The seabird metapopulation viability model (mPVA) is a generalized framework for projecting abundance and quasi-extinction risk for 102 seabird species under various conservation scenarios. The mPVA features a stage-structured demographic projection matrix embedded within a spatial metapopulation matrix, thereby accounting for breeding island characteristics (e.g. size, location, invasive species presence) and proximity to other colonies when projecting trends. Population data and prior estimates for demographic parameters were derived from published studies, grey literature, and expert review with contributions from over 500 experts. Invasive species impacts on vital rates were estimated using a Bayesian state-space model with covariates related to focal seabird biology, breeding colony characteristics, and invasive species characteristics. The effect of multiple invasive species was accommodated using a competing hazards approach. The mPVA incorporates environmental and demographic stochasticity, density dependence, spatiotemporal autocorrelation and parameter uncertainty. Results can be compared for current (no intervention) scenarios vs. specific conservation scenarios, including removal of invasive species from particular breeding islands, translocation/reintroduction to an additional breeding island, and at-sea mortality amelioration. Simulation of these common conservation actions provides seabird managers with the ability to quantitatively assess the potential change in abundance and quasi-extinction risk prior to implementation, a key step in conservation planning.

- *Contain between 1 and 3 bullet points highlighting the customization rather than the steps of the procedure.*

The mPVA can project customized conservation scenarios for individual species including:

  - *The seabird mPVA can be used to simulate the removal of individual or suites of invasive species from specified breeding islands.*
  - *The seabird mPVA can be used to simulate the translocation or reintroduction of a specified population size to an island of a specified location and size.*
  - *The seabird mPVA can be used to simulate at-sea mortality amelioration by specifying an annual reduction in at-sea deaths*

SPECIFICATIONS TABLE

Subject Area	Environmental Science
More specific subject area	*Population Modeling*
Method name	*Meta-Population Viability Model*
Name and reference of original method	*Caswell, H. 2001. Matrix population models: construction, analysis, and interpretation. 2nd ed edition. Sinauer Associates, Sunderland, MA..*
Resource availability	*NA*

Overview

The meta-Population Viability model (mPVA) is based around a stage-structured projection matrix (Caswell 2001), with spatial structure incorporated by embedding demographic matrices for semi-discreet sub-populations (generally Islands or Island groups) within a larger meta-matrix structure representing the dynamics of the entire species. The advantage of including spatial and demographic structure in our model is that the impacts of many threats (invasive species, fishing by-catch) are both spatially explicit and stage-specific, and thus the conservation benefits of mitigation efforts (such as removal of invasive species, fishing regulations, etc.) can be best-evaluated by modeling their effects on the appropriate demographic stages and/or sub-populations, and then translating these into species-level impacts (Desholm 2009).

Parameterization of the matrix model is accomplished using publicly available data contained in the IUCN Red List of Threatened Species version 2018.2 (IUCN 2018), additional data contained in the Threatened Island Biodiversity Database (TIB_Partners 2018), literature-reported values of seabird vital rates, and solicited expert opinion. To estimate the demographic impacts of invasive species (that is, to estimate their effects on baseline vital rates), we use published time series data on seabird abundance at islands where invasive species occur and/or where invasive species have been removed. We fit a Bayesian state space model to these time series to estimate the additional hazards associated with invasive species: the hazard function includes covariates for invasive type, nesting type, body size, island size, and number of co-occurring invasive species (allowing for compensatory mortality at islands with >1 invasive species present – see below, “Model Parameterization”). We then use the parameterized mPVA model to simulate population dynamics of threatened and endangered seabirds, with starting abundances initialized using the most recent IUCN red list status reports.

Simulations account for environmental and demographic stochasticity, density dependence, spatial and temporal autocorrelation in vital rates, and appropriate levels of uncertainty in all parameters. We summarize results in terms of the proportion of simulations dropping below a quasi- extinction threshold within a 100-year period, and compare mPVA projections under alternative scenarios to evaluate the relative conservation benefits (in terms of their effects on quasi-extinction likelihood) of various management options, including 1) invasive species removals, 2) at-sea mortality mitigation; 3) re- introductions to previously-occupied islands; and 4) translocation to potential breeding islands.

Model Structure

The seabird mPVA is a generalizable mathematical structure for projecting the expected abundance over time of threatened seabird species on islands known to support breeding populations. Following general convention, we use a single-sex projection matrix (Caswell 2001) to describe the demographic transitions of independent (non-chick) female sea birds for population *i* in year *t* (Lebreton and Clobert 1991, Lewison and Crowder 2003, Doherty et al. 2004, Beissinger and Peery 2007). We assume a pre-breeding census, and thus the youngest tracked age class consists of juveniles approaching 1-year of age (i.e. chicks born the previous year that have survived both the breeding season and their first winter). To reduce model complexity and number of parameters we collapse year-classes to stages (Desholm 2009), such that individuals are classified by developmental/reproductive status into three life history stages: 1) sub-adults, 2) breeding adults, and 3) non-breeding adults.

We represent the number of individuals in stage *a* in breeding population *i* at year *t* as $n_{a,i,t}$, and represent total female abundance for population *i* at year *t* as $N_{i,t}$ (where $N_{i,t} = \Sigma n_{a,i,t}$). The three stages are linked demographically in that sub-adults grow and develop to become adults, breeding adults transition to non-breeding adult status (and vice versa) based on behavioral decisions or external constraints, and breeding adults contribute to the sub-adult stage via successful reproduction (ie. by producing offspring that hatch, fledge and recruit to the sub-adult stage). These demographic transitions are represented mathematically as population projection matrix $A_{i,}$

$$A_{i,t} = \begin{bmatrix} s_1(1-g) & \frac{e}{2}\cdot h \cdot f \cdot s_0 & 0 \\ s_1 \cdot g & s_2 \cdot b & s_3 \cdot b \\ 0 & s_2(1-b) & s_3(1-b) \end{bmatrix} \quad (1)$$

where matrix elements are comprised of one or more vital rates including annual survival (*s*), growth transition probability (g), adult annual breeding probability (*b*), average number of eggs produced per breeding pair (*e*), hatching success rate (*h*) and fledging rate of chicks (*f*). Note that s_0 represents the survival of fledged chicks for their first winter, while s_1 represents sub-adult survival rate, s_2 represents breeding adult survival rate, and s_3 represents non-breeding adult survival rate. All vital rates are expected to vary stochastically over time (environmental stochasticity), thus the parameterized cell values of $A_{i,t}$ will vary from year to year (see methods for simulations, below).

To estimate the probability of transitioning from sub-adult to adult stage (g) we use the standard equation for fixed-duration age classes (Caswell 2001):

$$g = \left(\frac{(^{s_1}/_{\lambda})^T - (^{s_1}/_{\lambda})^{T-1}}{(^{s_1}/_{\lambda})^T - 1} \right) \quad (2)$$

where *T* represents the time from recruitment to the average age of first reproduction (*AFR*) and λ is the annual deterministic growth rate associated with a particular matrix parameterization. Equation 2 must be solved iteratively: λ is initially set to 1, equations 2 and then 1 are solved, λ is re-computed as the dominant eigenvalue of $A_{i,t}$, and the calculations repeated until the value of λ stabilizes to 2 decimal places.

Populations of seabirds breeding on oceanic islands are generally embedded within a larger meta-population, consisting of breeding populations at different islands between which there is some level of dispersal and thus demographic connectivity. Multiple breeding populations are accommodated in our model by taking the block diagonal of matrix $A_{i,t}$ across k different sub-populations:

$$C_t = \begin{bmatrix} A_{1,t} & \emptyset & \cdots & \emptyset \\ \emptyset & A_{2,t} & \cdots & \emptyset \\ \vdots & \vdots & \ddots & \vdots \\ \emptyset & \emptyset & \cdots & A_{k,t} \end{bmatrix} \quad (3)$$

where ∅ represents a 3x3 matrix of 0s. To allow for stage-specific dispersal between sub-populations, we first create dispersal matrix D to describe dispersal probabilities (d_i) for each life history stage:

$$D = \begin{bmatrix} d_1 & 0 & 0 \\ 0 & d_2 & 0 \\ 0 & 0 & d_3 \end{bmatrix} \quad (4)$$

We next create an inter-population connectivity matrix, *IP*, with diagonal fixed at -1 and non-diagonal elements $p_{i,j}$ describing the probability that an individual dispersing from population *i* will immigrate to population *j* based on the pairwise distances between populations:

$$IP = \begin{bmatrix} -1 & p_{2,1} & \cdots & p_{k,1} \\ p_{1,2} & -1 & \cdots & p_{k,2} \\ \vdots & \vdots & \ddots & \vdots \\ p_{1,k} & p_{2,k} & \cdots & -1 \end{bmatrix} \quad (5)$$

To estimate $p_{i,j}$ we assumed an exponential distribution of dispersal distances with mean value approximated by the mean of literature-reported values of taxa-specific dispersal distances (δ); we use this distribution to calculate the probability density at each pairwise distance ($i \neq j$) and then re-normalize such that $\Sigma p_{i,j} = 0$ for each matrix column in equation 5.

To describe annual dynamics of the entire meta-population, we integrate matrices *C*, *D* and *IP* following Caswell 2001, taking the Kronecker tensor product of matrices *IP* and *D* to create a regional dispersal matrix U (i.e. $U = IP \otimes D$) then multiplying *U* and *C* to create meta-population projection matrix M_t:

$$M_t = U \times C_t + C_t \quad (6)$$

Annual population dynamics are then computed by taking the product of M_t and the population vector $n_{a,i,t}$, using standard methods of matrix multiplication:

$$n_{a,i,t+1} = M_t \times n_{a,i,t} \quad (7)$$

In demographic simulation models it is generally important to account for negative density-dependence (the tendency of population growth to decline towards 0 as populations approach environmental carrying capacity or *K*), to avoid unrealistic expectations of unconstrained growth. For threatened seabird demographic models this step is often unnecessary, as current densities are far below historical levels likely to represent K. However, given the time frame of prospective simulations (100 years; see below) and the potential for rapid growth of colonies once critical threats are removed (Brooke et al. 2018), it was necessary to include density-dependence within the mPVA structure. Population regulation in most species occurs due to density-dependent variation in one or more vital rates, although the mechanism and vital rates involved differ by species. For example, Common Guillemots (*Uria aalge*) breeding on the Isle of May, Scotland, experienced density-dependent reduction in breeding probability (Crespin et al. 2006), while Magellanic Penguins (*Spheniscus magellanicus*) experience reductions in fledging success at high densities (Stokes and Boersma 2000). In general, both theory and empirical evidence suggest that density-dependent variation is most likely to occur in vital rates with low elasticities (Pfister 1998); thus, for most seabirds, we would expect population regulation to occur via density-dependent variation in fledging success or juvenile survival, as opposed to adult survival. We therefore modified our model to allow for density-dependent reductions in fledging success (f) as populations approach local K, using the non-linear function:

$$f_{dd} = f \Big/ \left(1 + \left[\frac{N_{i,t}}{K_i}\right]^{\theta}\right) \tag{8}$$

In equation 8, f_{dd} (density-dependent fledging success) varies as a non-linear function of the proportional abundance of a colony relative to K. By evaluating a range of θ values from 2-10, we allow for uncertainty in the "shape" of density dependent function, although in general $\theta > 1$ implies minimal change in f_{dd} at densities below 2/3 of K and then accelerating declines in f_{dd} as density approaches K (Figure 1). A more substantial challenge was to assign values of K for each seabird/island combination. While K has not been defined for most species (let alone specific breeding populations), we can approximate it by multiplying maximum nest density (η) by the potential "Area of Occupancy" (AoO) for the species. Measurements of nest densities are reported in the literature for many species, and the AoO metric is reported by IUCN for many threatened seabirds (IUCN 2018).

Model Parameterization

Baseline Vital Rates

The principal benefit of a generalizable seabird mPVA model is that analytical methods are consistent across all seabird species, and thus results (in terms of both quasi-extinction risks and mitigation benefits) can be directly compared across taxa. This beneficial feature also represents a challenge, in that robust estimates of vital rates necessary to parameterize the model have only been published for a fraction of extant seabird species. Moreover, even the literature for data-rich species provides estimates for a sub-set of the total parameters required for the model.

We addressed this challenge by conducting a comprehensive literature search to extract parameter estimates from published reports, and we treat the distribution of reported values as Bayesian priors for our model. Specifically, we reviewed both the primary literature and grey literature (unpublished reports, conference proceedings) to extract all available estimates of vital rate parameters (s_a, b, AFR, e, h, f, d_a, δ and η; Table 1), and their associated standard errors (σ_v), for as many species as possible. These were entered into a new table within the Threatened Island Biodiversity Database, augmented by the results of an expert opinion survey mailed to researchers and experts in seabird biology during Fall 2016. The resulting table included at least some estimated values for each parameter, for each seabird family. We next stepped through each seabird species of interest and extracted from the database all parameter estimates available for species from the same taxonomic family as the focal species. We weighted these published estimates in terms of taxonomic relatedness: specifically, we replicated estimates 20x if they were from the same species, 5x if they were from the same genus (but different species) and 1x if they were from a different genus (but same family) from the focal species. We then fit probability density distributions to each sample of estimates, using maximum likelihood estimation (MLE) techniques implemented in R (using library "fitdistr"). In the case of rate parameters (s_a, *b*, *h*, *f* and d_a) we first logit-transformed the sampled estimates and then fit normal distributions to the logit values; for integer parameters (*e* and AFR) we fit Poisson distributions; and for dispersal distances (δ) and nest densities (η) we fit log-normal distributions. These MLE-fitted distributions represent the best available prior knowledge about the likely range of values for each parameter value, for each seabird species. For those species or genera that have been well-studied, and for which there are abundant data available, the prior distributions were well defined, whereas for data-poor species the prior distributions were poorly defined, or "vague" (see Figure 2).

Estimating Carrying Capacity

Given the simplifying assumption that the key limiting resource for most seabird breeding populations is appropriate nesting habitat (defined as high quality nest sites at mostly predator-free locations proximal to prey resources), we can derive a rough approximation of carrying capacity (*K*) by multiplying maximum nest density by the total area of appropriate habitat. For many species, information was available from IUCN on the "Area of Occupancy" (AoO), although for most species only a sub-set of AoO represents appropriate nesting habitat. Using those species for which historical data were available on maximum population size (pre-decline) and AoO, we fit a linear model to predict the proportion of AoO used for nesting, with covariates of adult body size and taxonomic family, and used this function to create a scaled value (AoO*) representing total suitable nesting habitat. To estimate *K* at the species level, we multiply range-wide AoO* by mean nest density (η) for each species to estimate range-wide *K*. We then partition this total *K* among the currently occupied breeding locations; however, this step is challenging because equilibrium colony sizes are not equal or random across islands, but rather vary as a function of island size (larger islands generally support larger colonies, but the relationship is non-linear because suitable nesting habitat usually comprises a higher proportion of smaller islands). We therefore used all available survey data to fit a generalized linear mixed-effect model (GLMM) to predict the proportional allocation of seabird equilibrium abundance to each colony (*P*(*i*)) as a function of island size and number of breeding colonies:

$$logit(P(i)) \sim \log(Area_i) + NI + \frac{Area_i}{\sum_{i=1:NI} Area_i} + \log(Area_i) \times NI + NI \times \frac{Area_i}{\sum_{i=1:NI} Area_i} + (1|Family) \qquad (9)$$

where *NI* is the number of distinct islands or breeding populations, and taxonomic family is included as a random effect. Equation 9 was evaluated for *NI*-1 colonies, and the remaining colony was assigned the remainder such that $\Sigma P(i) = 1$. This model provided a reasonably good fit to the available data and was used to generate expected proportional allocations of range-wide *K* among breeding colonies (subject to the constraint that K_i was required to be at least 2x the current estimated abundance). We note that, for most species on most Islands, the resulting estimates of *K* were more than 10x the current abundance estimates.

Invasive Impacts

Multiple studies have documented substantial negative impacts of invasive species on island-breeding seabird colonies (see Jones et al. 2008). However, in most cases the impacts of invasive species are reported in terms of their population-level impacts on abundance or trends, rather than in terms of per-capita effects on specific vital rates. Moreover, these published accounts are generally situation-specific, and thus extrapolating from these case studies to other seabird species and islands is difficult. Therefore, to provide a consistent and repeatable approach for predicting the effects of invasive species on seabird vital rates, we developed a Baysesian state-space model with which to estimate generalized invasive impacts, incorporating the effects of known co-variates (e.g. class of invasive species, seabird nesting strategy, seabird body size, etc.) while accounting for uncertainty. We used published data on the population trends of seabirds at islands having different suites of invasive species, as well as population trends of seabirds at islands from which invasive species had been removed, to fit this model. To accommodate simultaneous impacts from multiple invasive species (i.e. competing risks), we use a proportional hazards approach to model invasive effects on key vital rates (Breslow 1975, Fine and Gray 1999).

To model invasive impacts, we first assume that the effects of invasive species on breeding seabirds can be described in terms of changes to either or both of two vital rates, fledging success (f) and adult survival (s_2). We recognize that other vital rates could also be impacted (hatching success, breeding success, juvenile survival), however given the mPVA matrix structure (Equation 1) these effects would be mathematically indistinguishable from effects to f or s_2. We next assume that the additional hazards associated with invasive species effects will modify baseline vital rates as follows:

$$f' = f^{\exp(\gamma_f)} \quad and \quad {s_2}' = s_2^{\exp(\gamma_s)} \tag{10}$$

where γ_f and γ_s represent the cumulative log hazard ratio associated with invasive effects on fledging success and adult survival rates, respectively. Expressing hazard ratios in log form simplifies calculations and data fitting, as multiple independent hazards are additive in log form (Breslow 1975). If we define hazard ratio Δ_x as the proportional change in mortality risk for eggs or nestlings associated with the presence of invasive species x (e.g. Δ_x = 1.1 indicates a 10% increase in mortality risk), and further assume that effects of multiple invasive species are independent and additive, then the cumulative log hazard ratio associated with invasive effects on fledging success (γ_f) would be calculated as the sum of $log(\Delta_x)$ for invasive species x = 1, 2, …X_i (if there are X_i invasive species at breeding site i). However, because of the brief duration of breeding seasons and concentrated nature of seabird breeding colonies on oceanic islands, it is reasonable to expect that mortality from multiple invasive species is at least partially compensatory rather than purely additive (Carey 1989, Heisey and Patterson 2006). Also, we might expect mortality impacts from invasive species to be more acute on smaller islands, where the potential for refuge from predators is minimal. Accordingly, we compute cumulative log hazards of invasive effects on fledging success at site i as:

$$\gamma_{f,i} = \left[\sum_{x=1}^{x=X_i} log(\Delta_x)\right] \times \left({}^{1}/_{X_i}\right)^{\phi} \times \left({}^{1}/_{Area_i}\right)^{\psi} \tag{11}$$

In equation 11, the second term on the right adjusts for compensatory mortality, with parameter ϕ determining the degree to which mortality is compensatory (mortality is purely compensatory as $\phi \rightarrow 1$, purely additive as $\phi \rightarrow 0$, and $0<\phi<1$). The third term on the right of equation 11 adjusts for the effect of island size ($Area_i$ expressed in units of km^2), such that per-capita impacts decrease with larger Island size when parameter $\psi > 0$. Both ϕ and ψ are treated as parameters to be fit.

The cumulative log hazards associated with invasive effects on adult survival are calculated almost identically to equation 11. We note however that the proportional effects of invasive species on adult survival are generally somewhat lower than the effects on chicks and may vary depending on adult size and the type of invasive species (with some invasive species posing no threat to adult seabirds). We therefore replace the nestling hazard ratio Δ_x with an adult hazard ratio, Ω_x, and then estimate cumulative log hazards of invasive effects on adult survival as:

$$\gamma_{s,i} = \left[\sum_{x=1}^{x=X_i} log(\Omega_x)\right] \times \left(1/_{X_i}\right)^{\phi} \times \left(1/_{Area_i}\right)^{\psi} \quad (12)$$

where $\log(\Omega_x)$ is calculated as:

$$log(\Omega_x) = \zeta_x \times \beta_1 \times log(\Delta_x) \left(1/_{AdSz + 1}\right)^{\beta_2} \quad (13)$$

In equation 13, β_1 and β_2 are fitted parameters that adjust adult hazards relative to chick hazards as a function of adult body size, and ζ_x is a binomial switch variable that determines whether a given invasive species represents a measurable risk to adults, based on published accounts and/or expert opinion (ζ_x = 0 for herbivores and most birds, ζ_x = 1 for carnivores, most omnivores, and rats).

We use Bayesian methods to estimate the scalar parameters ϕ, ψ, β_1, and β_2, and we treat Δ_x as a hierarchical parameter drawn from a normal distribution, $\Delta_x \sim \boldsymbol{N}\left(\bar{\Delta}, \sigma_{\Delta}\right)$, where $\bar{\Delta}$ and σ_Δ are additional parameters to be fit. To limit the number of fitted parameters we did not estimate unique values of Δ_x for each combination of invasive species and seabird, but rather for each combination of nesting type (arboreal, burrow, cliff, crevice, crevice/burrow, surface) and 5 categories of invasive species (bird, carnivore, herbivore, omnivore, rat). Our observed data were time series of survey counts ($O_{i,t}$) at islands supporting different suites of invasive species, as well as survey counts at islands where invasive species had been present but then were removed (Brooke et al. 2018). The latent (unobserved) variable was the true abundance of each seabird species at each island ($N_{i,t}$), assumed to be affected by the presence of (or removal of) invasive species. For each available survey estimate, $O_{i,t}$ was assumed to be drawn from a Poisson distribution with mean $N_{i,t}$. The dynamics of $N_{i,t}$ were calculated using standard matrix multiplication methods, with projection matrices constructed and parameterized according to equations 1, 2, 10-13 (note that for this analysis we ignored density-dependence and inter-island dispersal). Priors for baseline vital rates were set according to the methods described above, and we used uninformative priors for $N_{i,1}$ and for the parameters that determined invasive species effects (ϕ, ψ, β_1, β_2, $\bar{\Delta}$ and σ_Δ). The model was coded in R and JAGS (Just Another Gibbs Sampler) and solved using Markov Chain Monte Carlo methods to find the values of the parameters most likely to result in the observed data. We ran 20 parallel chains for a burn-in period of 5000 replications and then saved a total of 10,000 samples, using these to describe the posterior distributions for invasive species effects parameters.

Initializing Meta-Population and Incorporating Information on Current Trends

Before running simulations of the mPVA for a seabird species of interest, the model was initialized with starting abundances at each breeding island. For some threatened species, estimates of the total number of adult birds or the number of breeding pairs are available for each occupied island. These data were obtained through searches of primary and grey literature as well as from BirdLife International species factsheets (http://datazone.birdlife.org/species/spcreferences). When island specific estimates of total birds are available, we simply divide the value in half (to obtain the estimated total number of female birds) and then multiply by the stationary stage distribution (SSD) associated with the parameterized matrix model (Caswell 2001), in order to create the initial population vector $n_{a,i,1}$. When island specific estimates of breeding pairs are available, we use this value to estimate $n_{2,i,1}$, and then calculated scaled estimates of sub-adults and non-breeding adults using the SSD. For many other species, estimates of abundance are only available for the entire population, and so the estimate must be partitioned among breeding sites/islands. We accomplish this using the fitted proportional allocation function (Equation 9) to partition the total number of female birds among breeding colonies, accounting for prediction uncertainty and sampling error as described above for "Estimating Carrying Capacity". The total number at each island is then divided among stages according to the SSD.

For most threatened seabird species of interest, the IUCN Red List also includes information on current population trends for each species. We used this information to update the prior distributions of parameter estimates for each species, thereby ensuring that the mPVA model simulations were consistent with the best available information on current trends. To accomplish this, we created *a priori* quantitative definitions for the expected values of λ (annual growth rates) corresponding to the qualitative descriptions of status/trends in the IUCN red list (Increasing, Stable, Decreasing). Based on reported quantitative trend values available for a sub-set of species, we assumed modal lambda values of 1.02, 1.00 and 0.98 for Increasing, Stable and Decreasing, respectively; however, recognizing the uncertainty associated with the qualitative status designations we also allowed for a distribution of uncertainty around each modal value. Specifically, for each classification we assigned relative weights (w_λ, where $\Sigma\ w_\lambda = 100$) corresponding to our expectations about the likelihood of each potential value of lambda for a given status, assuming a distribution of possible log(lambda) values with standard deviation = 0.03 (Table 2). Using these weights as sample sizes, we created a vector of 100 "observed trend values" for each species/island combination, corresponding to the reported trends in the IUCN Red List. We then created a Bayesian model (coded using JAGS software) to estimate posterior distributions for all model parameters, given the set of prior expectations (i.e. the MLE-fitted distributions for baseline vital rates and posterior distributions for invasive threat function parameters) and the observed trend values. As described above (see "*Invasive Impacts*"), equations 1-2 and 10-13 were used to calculate expected dynamics of the latent variable ($N_{i,t}$) and thus the mean annual growth rate ($\hat{\lambda}$) associated with a given set of parameter values; the observed trend values were assumed to be drawn from a log-normal distribution with mean of $\hat{\lambda}$ and standard error σ_λ (itself a fitted parameter). We saved 5000 samples from the Bayesian posterior distributions for each parameter, for each species/island pair, and used these to parameterize model simulations (see below).

Running Simulations to Assess and Compare Relative Risk

To evaluate the relative degree of extinction risk for seabird species, and to examine and compare the potential benefits of alternative management actions, we conducted forward simulations using the mPVA model. After drawing parameter values randomly from their appropriate uncertainty distributions, we simulated 100 years of population dynamics for each species, with the effects of year-to year variation in environmental conditions (environmental stochasticity) represented by adding a zero-centered random normal term to the logit-transformed vital rates. We assumed that annual deviations from average survival were perfectly correlated across stages but with the magnitude of variance (σ_e) allowed to differ by stage: for species having reliable data on the magnitude of annual variance in vital rates we used these data to set σ_e, otherwise we used default values of σ_e = 1 for fledging survival rates and σ_e = 0.5 for all other stages. We next adjusted environmental stochasticity to incorporate temporal and spatial autocorrelation: we used the "filter" function in R (which uses a Fast Fourier Transform to convolve a time series of random values to achieve a specified autocorrelation) to transform the annual deviations, setting the average first-order correlation across years to ρ = 0.67. We used the inverse matrix of between-colony distances to parameterize spatial autocorrelation, scaled such that two colonies 100km apart would have correlated annual deviations with ρ = 0.9, while two colonies 1000km apart would have correlated annual deviations with ρ = 0.5. Finally, when the population abundance at a breeding colony dropped below 100, we adjusted the calculation of annual demographic transitions to allow for demographic stochasticity: specifically, adjusted survival parameters were drawn from a beta distribution with mean equal to the expected value and variance equal to (p * q)/n (where p is the mean expected value, q = 1 – p, and n is the number of individuals in the stage experiencing the survival rate).

We iterated the population dynamic simulations many times so that the distribution of results could be used to describe the uncertainty associated with model projections (Figure 3). We ran simulations for the "default scenario", corresponding to the current species distribution, abundance and array of threats, and under "alternative scenarios" corresponding to various management actions (invasive species removals, reductions of by-catch or other at-sea mortality, translocations, or re-introductions). As a metric of comparison, we use quasi-extinction probability (QEP), defined as the relative likelihood that model-projected abundance would drop below a quasi- extinction threshold within a 100-year period. Quasi-extinction thresholds (QE) are often used in PVA models as a surrogate for absolute extinctions (Brook et al. 2000, Reed et al. 2002), describing the point at which abundance is so low that true extinction risk due to natural catastrophes, demographic stochasticity or loss of genetic diversity becomes unacceptably high. There are no universally accepted definitions of QE (but see Holmes et al. 2007): values of N=500 have been suggested based on genetic considerations, but lower values (100 or 50) may be more appropriate for large/rare species. We set QE to 50 females (100 individuals) for species with an initial population exceeding 200 breeding pairs, or to 10 females for those species with an initial population less than or equal to 200 breeding pairs.

We used two hierarchical levels of replication for model simulations. An outer loop was used to account for parameter uncertainty, whereby for each of 100 replications (NS_1 = 100) we made random draws of all parameter values from their joint posterior distributions (as described in the sections above). For each outer loop replication, we conducted an inner loop of 100 iterations (NS_2 = 100) of the 100-year simulation, to account for uncertainty associated with environmental and demographic stochasticity and sampling error. The distribution of simulation outcomes from the inner loop was used to calculate a point estimate of projected abundance (N_{proj}) and QEP (proportion of simulations dropping below QE) for each iteration of the outer loop (Figure 3). We then calculated the median, standard error and inter-quartile range of N_{proj} and QEP distributions across outer loop replicates. These metrics were used to evaluate relative risk for seabird species and to compare the efficacy of alternative management scenarios. We emphasize that QEP values are intended as relative measurements of risk only, and not intended to be accurate predictions of extinction risk (Ludwig 1999, Reed et al. 2002).

Tables

Table 1. Seabird Vital Rate Parameters

s_a	Adult Survival
b	Adult annual breeding probability
AFR	Age of first reproduction
E	Average number of eggs produced per breeding pair
H	Hatching success rate
F	Fledging rate of chicks
d_a	Dispersal probability of adults
δ	Dispersal distance
η	Nest density

Table 2. Weights used to define "observed values" for annual trend (λ) associated with qualitative descriptions of trends in IUCN status reports. The distribution of λ weights provides an approximation of the uncertainty associated with quantitative population trends.

Lambda	Increasing	Stable	Decreasing	Unknown
0.9	0	0	0	1
0.91	0	0	1	1
0.92	0	0	2	2
0.93	0	1	3	3
0.94	0	2	6	3
0.95	1	3	8	5
0.96	2	5	11	6
0.97	3	8	12	7
0.98	6	11	13	9
0.99	8	13	12	10
1	11	14	11	10
1.01	12	13	8	10
1.02	13	11	6	9
1.03	12	8	4	7
1.04	11	5	2	5
1.05	8	3	1	4
1.06	6	2	0	3
1.07	4	1	0	2
1.08	2	0	0	1
1.09	1	0	0	1
1.1	0	0	0	1
Tally Wts	100	100	100	100

Figures

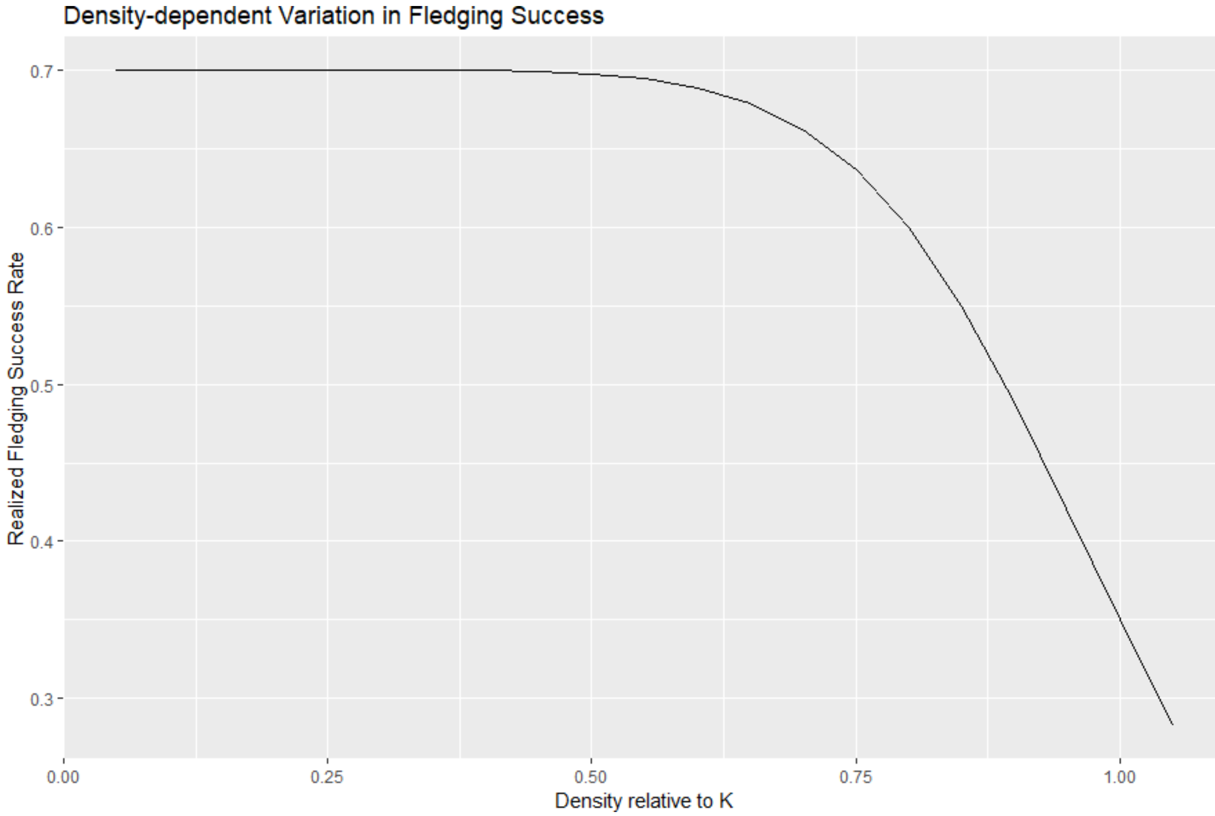


Figure 1. Density-dependent variation in realized Fledging Success rate, as modeled using equation 9 (see text for details). At densities below 50% K there is no measurable decrease in baseline fledging success (shown as 0.7 in this example), but as population density increases above 50% K there is an accelerating decrease in fledging success, resulting in zero population growth as the population approaches *K*.

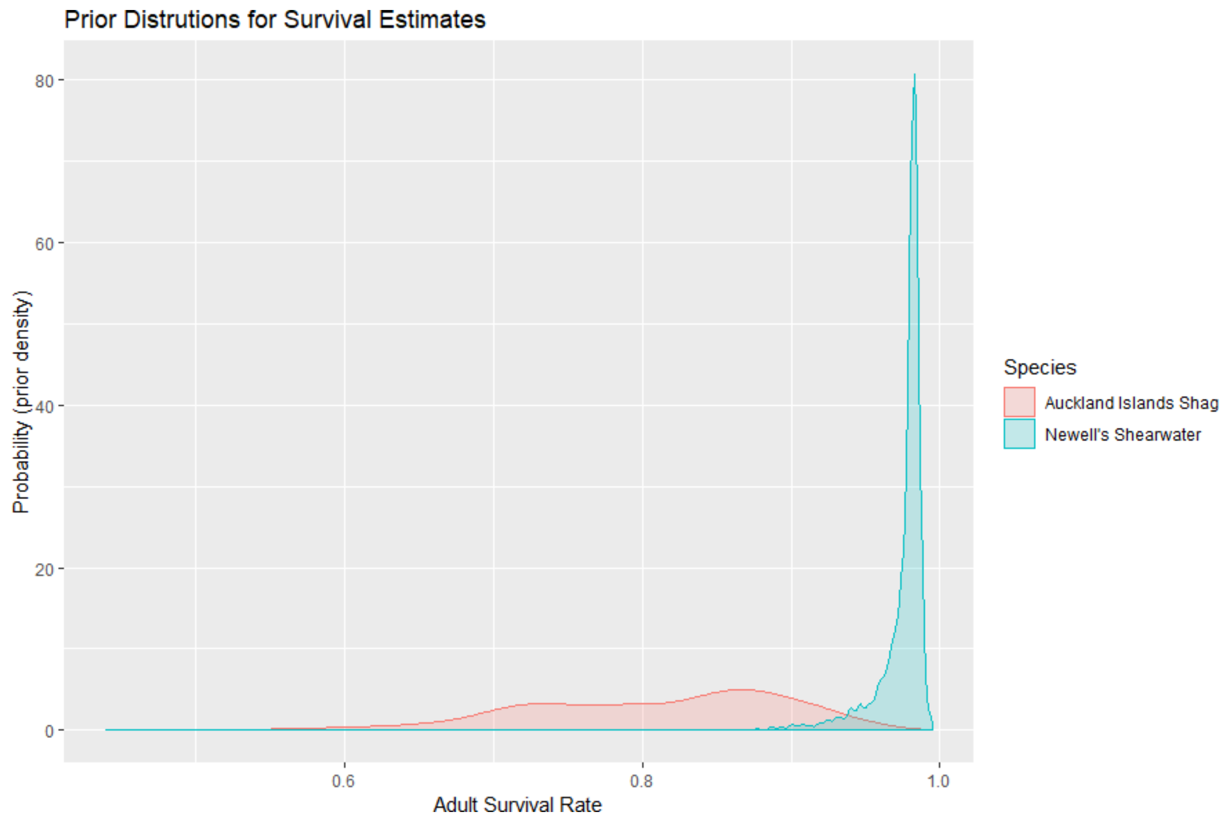
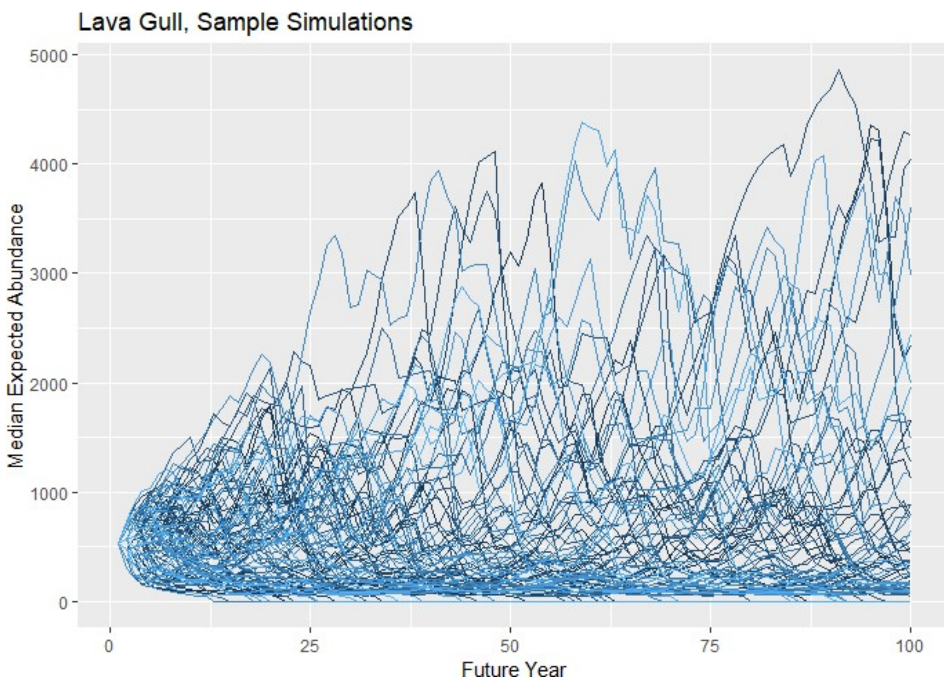


Figure 2. Prior distributions of our estimates for adult survival rate for two species, based on literature searches for published information. The data rich species (blue) has 5 published species-specific estimates, and 107 estimates for the taxonomic Family. The data poor species (red) has no species-specific estimates and only 17 estimates for the taxonomic Family, and the smaller sample size results in a greater degree of uncertainty in the prior distribution.



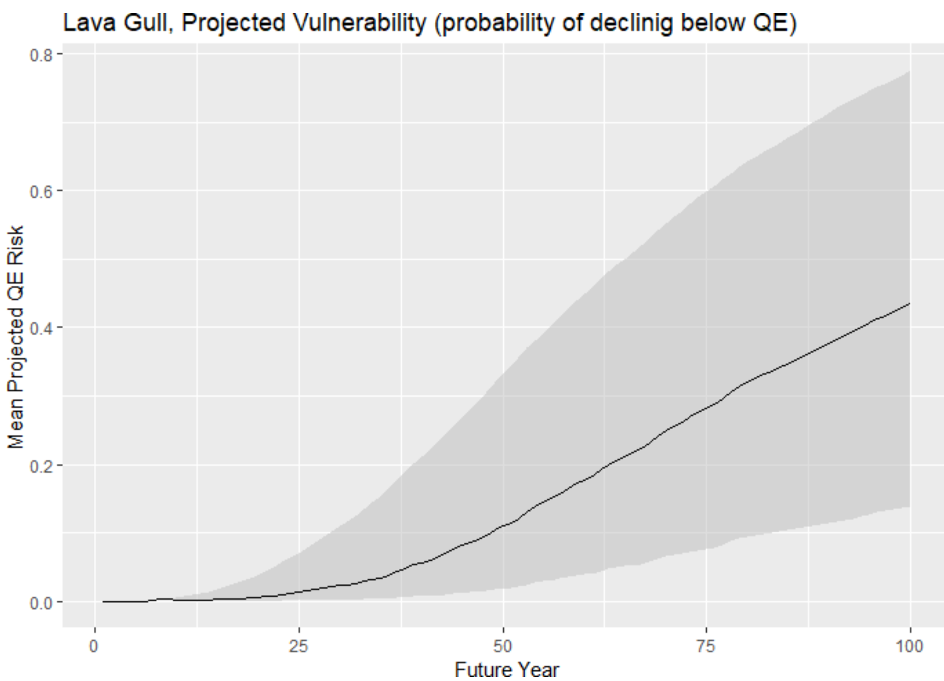


Figure 3. TOP PANEL: Sample population abundance trajectories over a 100-year period as projected by simulations of the mPVA model run for a sample species (Lava Gull). Each line shows a single 100-year simulation, with variation between lines representing uncertainty due to sampling error and environmental stochasticity. Simulation runs that drop below the QE threshold (50 females) are assumed to go extinct. BOTTOM PANEL: Projected vulnerability for sample species plotted over time, where projected QE risk is defined as the proportion of simulations that decline below the QE threshold. Solid line shows mean values and grey shaded band indicates the inter-quartile range for all simulations.

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Declaration of interests: *[MANDATORY – Delete as appropriate]*

X The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Supplementary material *and/or* Additional information: *[OPTIONAL. We also give you the option to submit both supplementary material and additional information. Supplementary material relates directly to the work that you have submitted and can include extensive excel tables, raw data etc. We would also encourage you to include failed methods or describe adjustments to your methods that did not work. Additional information can include anything else that is not directly related to your method, e.g. more general background information, useful links etc. Introduction is not a section included in the MethodsX format. This information could be moved to the end under Additional Information.*

***References:** *[Include at least one reference, to the original publication of the method you customized.]*

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