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Tracking the global application of conservation translocation and social attraction to reverse seabird declines

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The global loss of biodiversity has inspired actions to restore nature across the planet. Translocation and social attraction actions deliberately move or lure a target species to a restoration site to reintroduce or augment populations and enhance biodiversity and ecosystem resilience. Given limited conservation funding and rapidly accelerating extinction trajectories, tracking progress of these interventions can inform best practices and advance management outcomes. Seabirds are globally threatened and commonly targeted for translocation and social attraction ("active seabird restoration"), yet no framework exists for tracking these efforts nor informing best practices. This study addresses this gap for conservation decision makers responsible for seabirds and coastal management. We systematically reviewed active seabird restoration projects worldwide and collated results into a publicly accessible Seabird Restoration Database. We describe global restoration trends, apply a systematic process to measure success rates and response times since implementation, and examine global factors influencing outcomes. The database contains 851 active restoration events in 551 locations targeting 138 seabird species; 16% of events targeted globally threatened taxa. Visitation occurred in 80% of events and breeding occurred in 76%, on average 2 y after implementation began (SD = 3.2 y). Outcomes varied by taxonomy, with the highest and quickest breeding response rates for Charadriiformes (terns, gulls, and auks), primarily with social attraction. Given delayed and variable response times to active restoration, 5 y is appropriate before evaluating outcomes. The database and results serve as a model for tracking and evaluating restoration outcomes, and is applicable to measuring conservation interventions for additional threatened taxa.

seabird | translocation | social attraction | restoration | data synthesis

The significant declines of Earth's species due to anthropogenic activities have led to global losses of biodiversity (1), with profound changes to ecosystems and cascading impacts on human livelihoods and global economies (2, 3). In response, conservation interventions seek to reverse extinction trends (4, 5). Translocation and social attraction are active interventions used to accelerate recovery of a target species or ecosystem (6) by moving or attracting organisms to a restoration site (7–9). Goals include reintroducing a previously extirpated species, restoring lost ecosystem processes, or reinforcing an existing population (7). With the accelerating pace of climate change, translocation and social attraction can be important tools for facilitating adaptation and enhancing resilience of at-risk species, such as populations occurring on coastlines eroding from sea-level rise and storms (10, 11).

Tracking translocation and social attraction methods and outcomes improves best practices and speeds recovery (12, 13). Previous syntheses of these conservation interventions differed in collation methods and outcomes, yet many highlighted a lack of long-term project monitoring and adaptive practices, sometimes leading to failed, uncertain, or unassessed outcomes and challenges (14–18). Underreporting of failures leaves conservation managers with a biased view of success and unfamiliarity with risks, especially because lessons learned from failures are valuable to advancing conservation (19, 20). These are common problems across conservation interventions, highlighting data gaps that can hinder conservation effectiveness (21). Given that translocations in particular can be costly and complex and involve risks, including species mortality during transfer or rearing, learning from past projects can maximize the probability of success and acceptability (16, 18).

Seabirds are the most threatened bird group and are thus common conservation targets (22, 23). Approximately 30% of the 360 recognized seabird species are at enhanced risk of extinction, primarily by invasive mammalian predators at breeding sites (22, 23). Seabirds are important marine predators and can be ecosystem engineers on their breeding islands and surrounding waters; thus, their global declines have ecosystem-wide

Significance

Tracking evidence of species restoration can improve best practices and management outcomes. Seabirds are globally threatened and respond positively to restoration, particularly on islands where threats can be mitigated at landscape scales. We developed the Seabird Restoration Database—a compendium of translocation and social attraction efforts systematically synthesized from nearly 1,400 resources and over 300 experts to inform seabird restoration best practices. The database includes 851 events targeting 138 species in 551 locations and 36 countries. Outcomes varied by taxonomy and were positive: 80% of events resulted in visitation and 76% achieved breeding, within 2 y of implementation on average. These outcomes demonstrate the efficacy of restoration actions for recovering seabird populations and the database provides a baseline for tracking conservation progress.

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consequences (24–26). While seabirds often respond well to management actions, such as removal of invasive species from islands (27), recovery is not guaranteed, particularly in species with high natal philopatry and where they have been extirpated for multiple generations (28, 29). Translocation and social attraction (hereafter termed "active seabird restoration") can overcome these issues and reduce recovery times. In 2012, a review of active seabird restoration identified 128 examples targeting 47 species in 14 countries since 1973 (9). While this review was instrumental in placing active seabird restoration practices into a global context, like similar conservation literature reviews for other taxa (14), the research was English language-biased and did not collate data to evaluate outcomes. There remains a lack of widespread evidence for selecting and applying active seabird restoration methods with the greatest chances of success (30).

To assist conservation managers seeking to restore seabird populations, we created the Seabird Restoration Database, a data center of global active seabird restoration efforts. The primary aims of this study were to 1) describe the global application of active seabird restoration, and 2) quantify outcomes based on practitioner success in implementation and restoration success as indicated by visitation and breeding of target seabirds. We examined factors that affect breeding outcomes to inform planning decisions, including implementation time budgets. The results of this study, including the methods for designing and publicizing the Seabird Restoration Database, can serve as a model for other taxa targeted for conservation interventions.

Results

We documented 851 active restoration events in 551 locations targeting 138 seabird species between 1954 and 2021 (Fig. 1*A*). The duration of events averaged 5 y (SD = 6) and most were completed events (52%; *SI Appendix*, Table S1). Restoration activity increased dramatically in the 1990s, with most events starting in the 2010s (Fig. 1 *B–D*). Social attraction was applied in 802 events (94%), including 52 events paired with translocation, while 49 events used translocation only (Fig. 2).

The 851 events were part of 338 seabird restoration projects. The project goals were primarily species conservation (75%), research (11%), and ecosystem restoration (8%) (*SI Appendix*, Table S2). These projects were attempting to mitigate threats from habitat loss (29%), human–wildlife conflict (18%), and invasive species (17%; *SI Appendix*, Table S3).

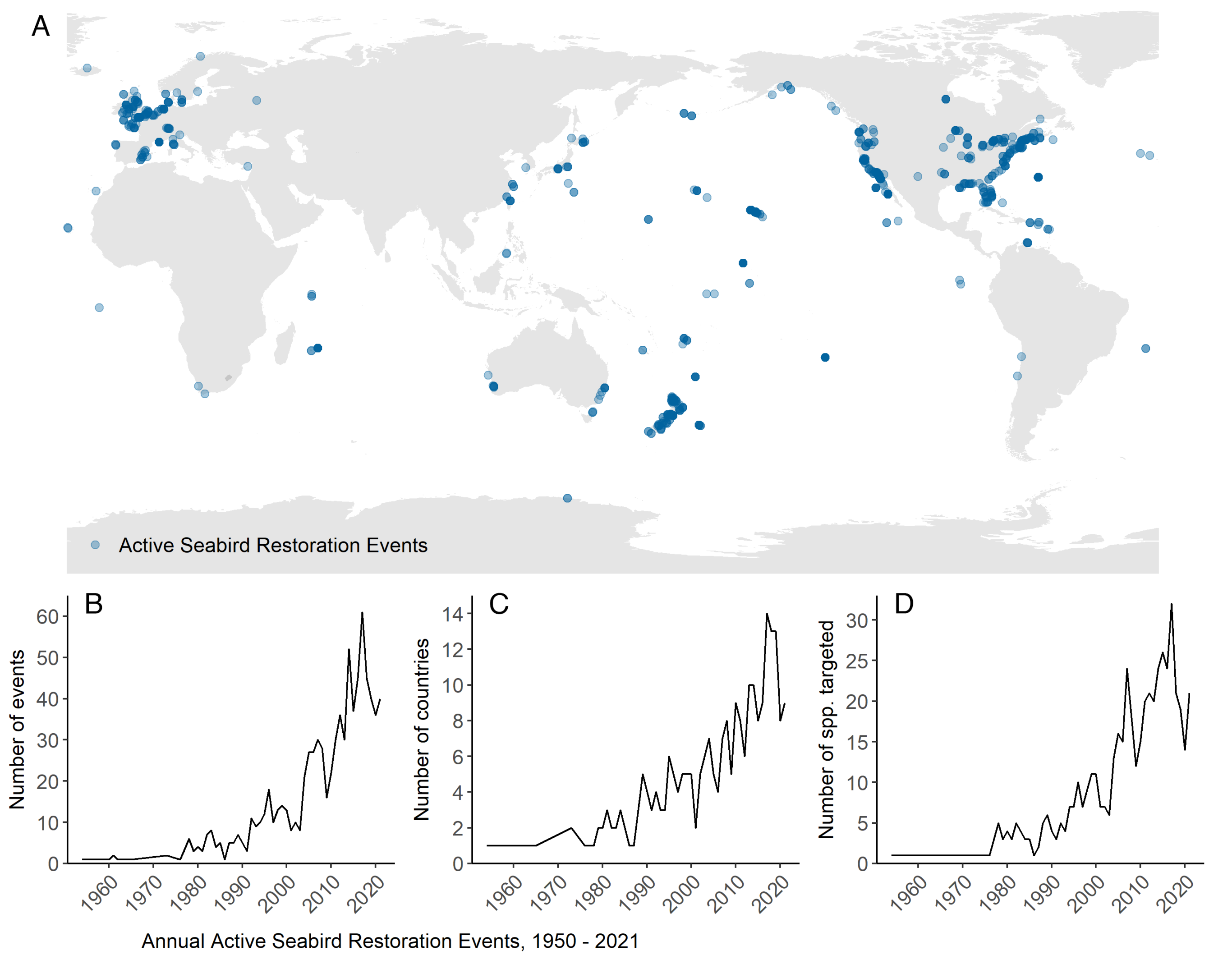

Fig. 1. Global active seabird restoration events, 1954 to 2021. An event was defined as a restoration effort targeting a single seabird species at a particular site, and within a discrete length of time. (*A*) Restoration sites where each dot is an event; darker dots indicate more events at a site (sensitive data excluded). (*B–D*) Annual trends in the number of events, number of countries implementing events, and number of seabird species targeted, respectively.

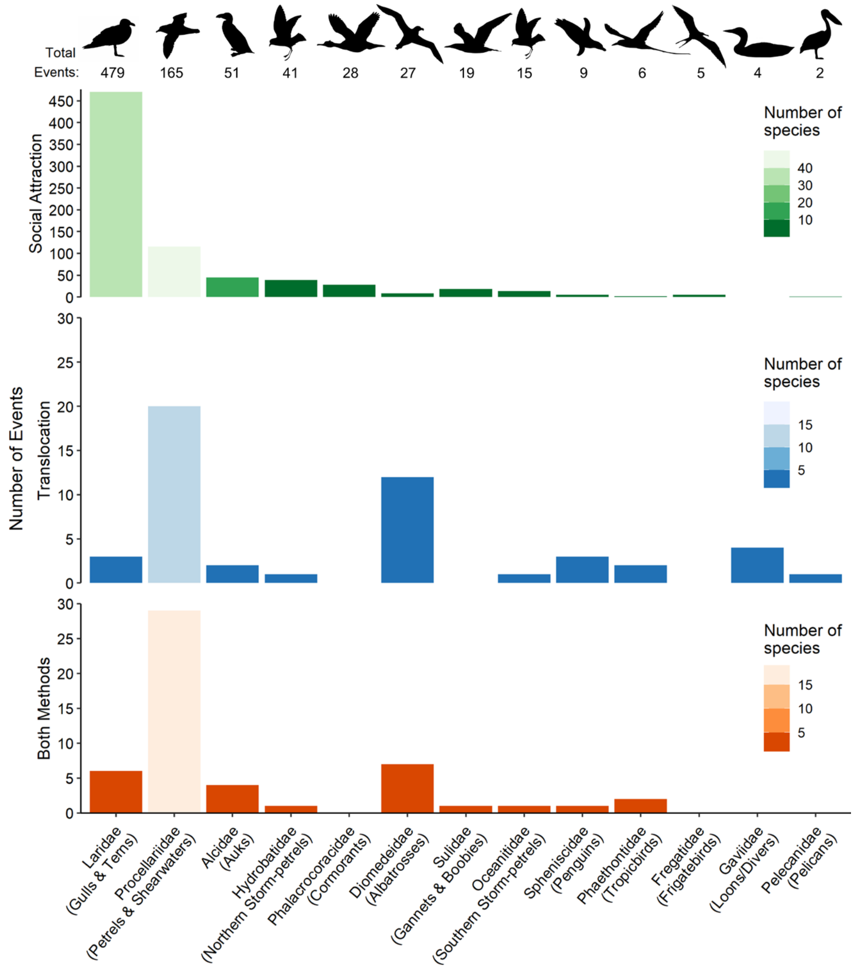

Fig. 2. The 851 active restoration events by seabird family and active restoration methods: social attraction only, translocation only, and events using both methods. Colors are shaded according to the number of seabird species within each data bar.

The 551 restoration sites spanned latitudes (–66.671° to 69.644°), with 357 sites (63%) on islands and 194 (37%) on continental areas. Artificial habitat (e.g., rafts, boats, rooftops, levees) made up 189 restoration sites (34%). Threat management at the restoration site primarily targeted invasive and problematic native animals (58% of sites; 23% of sites lacked data).

The restoration sites were in 36 countries, including 12 territories plus Antarctica (*SI Appendix*, Table S4). Six percent of events occurred in 11 UN-designated Small Island Developing States. Ninety percent of events were in 24 high-income countries, 9% of events in nine upper middle–income countries, and 1% of events in three lower middle–income countries. Six countries (including territories) accounted for 80% of all restoration events: the United States (40%), New Zealand (15%), the United Kingdom (10%), Mexico (6%), Canada (5%), and France (5%). New Zealand implemented the most translocations (36%) and the United States implemented the most social attractions (40%).

Of the 138 species targeted, 43 (31%) were globally threatened, representing 39% of all globally threatened seabirds targeted in 139 events (16%; *SI Appendix*, Table S5). Thirty-four species in the family Laridae (26 tern and 8 gull species) were targeted in 479 events (56%) in 372 locations, primarily with social attraction (470 events; 98%). Forty-nine species in the family Procellariidae (30 petrel and 19 shearwater species) were targeted in 165 events (19%) in 95 locations, applying social attraction in 116 events (70%), translocation in 20 events, and both methods in 29 events (Fig. 2). Sixty-eight percent of events (575) were initiated at restoration sites where the target seabird colony was absent.

Social attraction stimuli were primarily decoys (563 events, 75%) or audio playbacks (551 events, 63%), which were commonly used together (40% of events). Other stimuli included sounds or decoys of congeners (30 events), mirrors (20 events), and scent (24 events). Translocations primarily involved chicks (74 events, 71%), eggs (11, 11%), adults (5, 6%), or a combination of age classes (7, 6%). Social attraction events averaged 4 y (SD = 5, max = 41 y) and translocation events averaged 3 y (SD = 6, max = 33 y), with 3 cohorts (1 to 13 cohorts per event; annual implementations did not always occur). Events combining social attraction and translocation averaged 12 y (SD = 8, max = 30, median = 8) whereby translocation stopped at year 4 on average and social attraction continued. A median of 103 individuals were translocated per event (range = 5 to 954, excluding an outlier that translocated over 2,000 chicks). Artificial nests or nest boxes to facilitate breeding conditions and monitoring accessibility were used in 392 events (46%). Reported challenges during implementation were primarily environmental conditions (467 events, 55%) such as flooding or habitat quality, and/or predation by invasive or native species (462 events, 54%).

Outcomes. Ninety-seven percent of events (496 of 510 events evaluated) were considered successfully implemented (394 and 102 events were achieved or partially achieved; Fig. 3). Of these 496 successfully implemented events, 339 could be assessed for

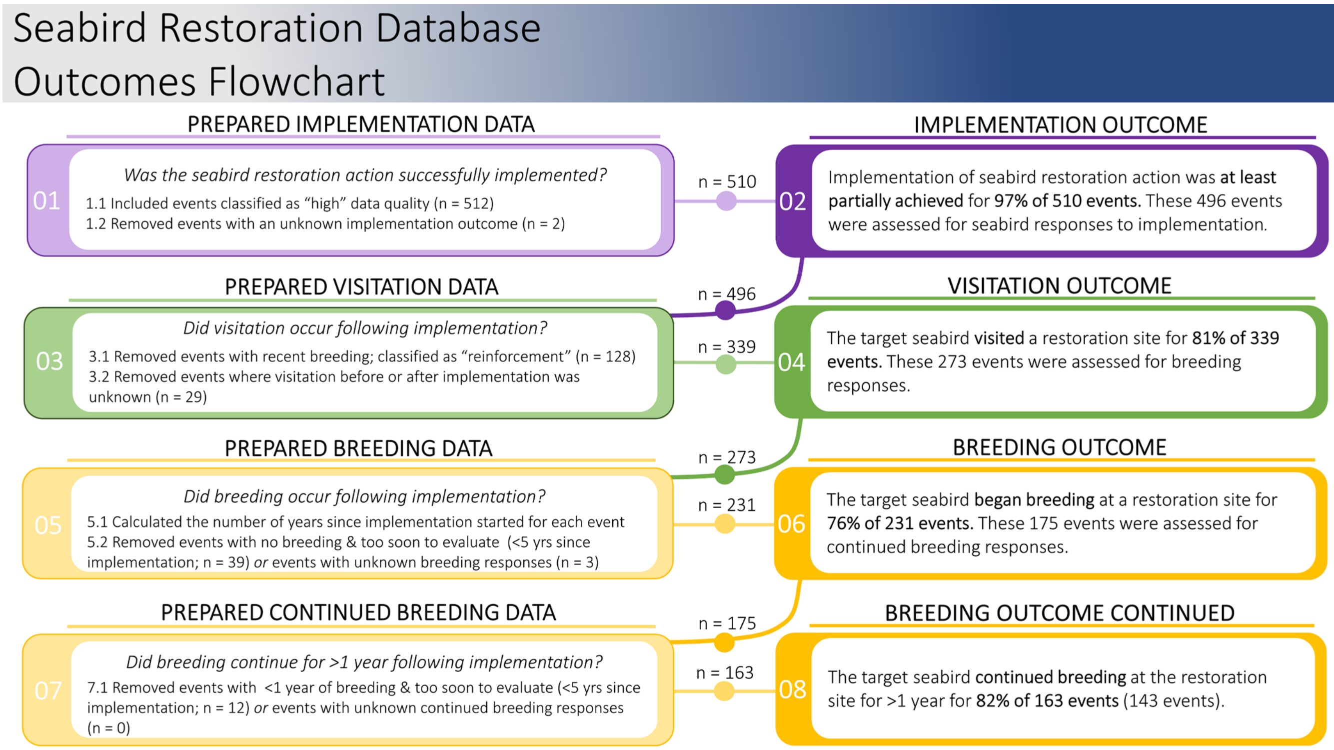

Fig. 3. Process for evaluating outcomes of active seabird restoration events.

seabird visitation following implementation, of which 81% had visitation by the target species (273 events). Of the 273 visitation events, 231 could be assessed for breeding response, of which 76% had breeding (175 events). Of the 175 breeding events, 163 could be assessed for a continued (>1 y) breeding response, of which 82% had continued breeding (143 events). Success varied among taxonomic groups and increased slightly with project duration but was not affected by latitude nor whether implementation occurred on an island vs. continent (*SI Appendix*, Fig. S1 and Tables S6 and S7). Charadriiformes had higher breeding responses than those of Procellariiformes or Suliformes, with better outcomes on artificial habitats (*SI Appendix*, Fig. S2).

On average, seabirds visited within 0.9 y of implementation (256 events, range = 0 to 16, SD = 2.1 y) and were breeding within 2.0 y (174 events, range = 0 to 17, SD = 3.2 y). This response timing varied significantly among seabird families (visitation $X^2 = 59.7$, df = 6 families, $P < 0.001$; breeding $X^2 = 73.6$, df = 3 families, $P < 0.001$; Fig. 4). On average, larids took 0.2 y to visit (SD = 0.7) and 0.6 y to breed (SD = 1.3), while procellariids took 2.8 y to visit (SD = 3.5) and 5.3 y to breed (SD = 3.8). Procellariid visitation responses also were slower than those by sulids (gannets and boobies; $P = 0.006$; *SI Appendix*, Tables S8 and S9).

Discussion

The Seabird Restoration Database builds upon previous restoration summaries (9, 31, 32) and systematic reviews (33) to provide a scientific foundation of evidence from which managers can make informed conservation decisions. This database is one of the few datasets that systematically tracks the global progress and outcomes of a restoration activity, including failed outcomes (19, 20, 33). The scientifically driven hindsight from the Seabird Restoration Database improves knowledge of active seabird restoration and was designed to influence best practices, priority setting, and fundraising, particularly for threatened species. Further research can be undertaken to combine this dataset with other evidence-based threat and conservation datasets (e.g., refs. 22, 23, and 34–36) and incorporate information into frameworks for active seabird restoration decision-making (7, 37, 38).

Global Restoration Outcomes. Seventy-six percent of the events for which breeding could be measured showed a positive breeding response to active restoration techniques, highlighting the efficacy of active restoration tools for recovering seabird populations at a global scale. Previous reviews (9, 14, 15) of translocation and social attraction for seabirds and other taxa provided insights on likely factors associated with positive outcomes, such as habitat quality, predator management, monitoring capacity, and other ecological factors, which align with this study. Life history strategies among seabird groups also influenced the methods and outcomes of active restoration (39). For example, Charadriiformes (gulls, terns, and auks) were strong candidates for active restoration with the highest predicted breeding outcomes, often achieved quickly, particularly when implemented on artificial habitats where managers can manipulate habitat and control threats, such as from predation or flooding. The colonial behavior, low natal philopatry, and quick generation times of Charadriiformes, particularly the gulls and terns (Laridae), likely helped them to colonize new sites quickly (40), including on artificial habitats. Together, these results provide widespread evidence supporting the efficacy of active restoration, which can address urgent calls to prevent extinctions of at-risk seabirds, particularly for those that are predicted to disappear across much of their native range by the end of the century (30).

This study also revealed that a minimum 5-y investment is appropriate for implementation and long-term monitoring to assess outcomes, especially for seabirds with long generation times, like Procellariiformes. This result provides managers with a tangible a-priori timeframe in which to plan, apply for funding, and expect outcomes. While long-term projects can be difficult to finance, success is more likely when partnerships exist among

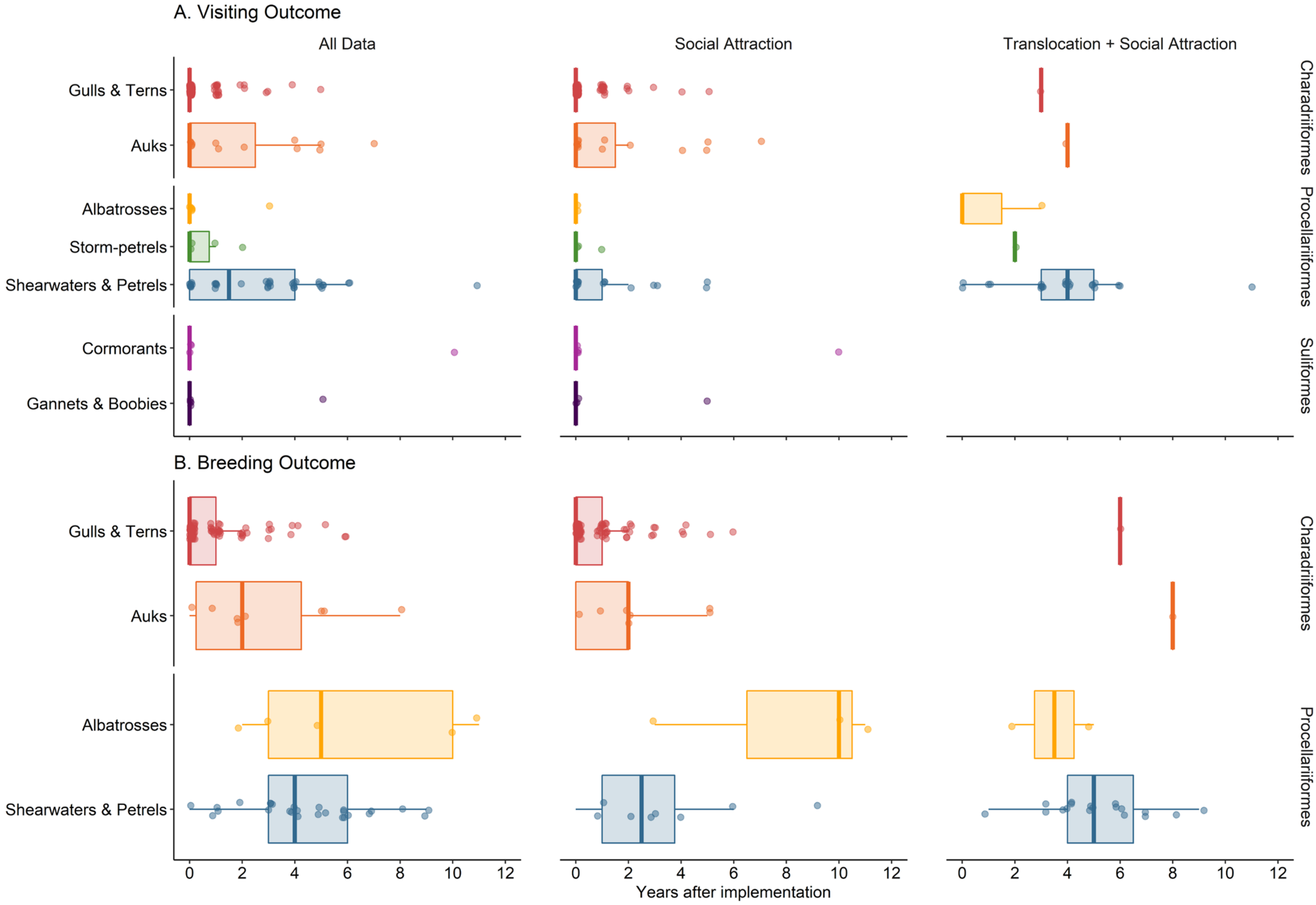

Fig. 4. Timing of the first seabird response after implementation of active restoration. Boxplots display median values and interquartile ranges. Data included are events where a colony was not present prior to active restoration, where implementation goals were at least partially achieved, and where data were rated as "high" data quality. Families with < 5 records per response type were removed from analysis. (*A*) Time until first visitation after implementation. (*B*) Time until first breeding after implementation. Each point represents one event, darker points represent more events at that time.

government, nonprofit organizations, and local communities (9). These practices also provide opportunities for public engagement, which promotes awareness, local stewardship, and project support (8, 17).

Restoration Goals. Species conservation was the primary goal of active seabird restoration, while research, community engagement, and ecosystem restoration were often additional project goals. For example, ecosystem restoration was the primary goal in 8% of projects, but nearly a quarter of all projects aimed for this alongside species conservation. Seabirds can be ecosystem engineers, particularly on islands where they perform seed dispersal, soil turnover, habitat creation, and transfer of marine nutrients to land, supporting plant production and terrestrial food webs (41, 42) and improving nearshore marine ecosystems (26). Global declines in seabirds have had ecosystem-wide effects (24, 25), highlighting the importance of conserving this bird group for ecosystem benefits.

While information was not available for every restoration site, we found that invasive and problematic native animal management were common supplemental activities to active restoration. Many seabird species evolved in the absence of terrestrial predators, and are inherently vulnerable to predation, particularly by invasive mammals on islands (43). Invasive species eradications have occurred on nearly 1,000 islands worldwide (33), establishing safe sites for active seabird restoration, particularly when seabirds may not return without human assistance (44). Control of native seabird predators, such as native mammals and gulls, whose populations are often enhanced by humans, was a common management action at continental and nearshore island restoration sites (40, 45).

Focal Taxa and Geographies of Active Seabird Restoration. Gulls and terns (Laridae) and shearwaters and petrels (Procellariidae) were the most frequently targeted seabirds for active restoration, with differing restoration methods and outcomes largely due to differences in ecology and life history. Laridae, which are highly colonial and exhibit low natal philopatry, were primarily targeted using social attraction, had quick average response times (within the first year of restoration), and had the highest breeding response rate, at 83%. Ninety-five percent of larid restoration events targeted terns, likely due to their conservation status. While most terns are considered of least concern globally (46), many species are threatened at national or regional scales (47), including the top four species targeted: Common Tern (*Sterna hirundo*), Roseate Tern (*Sterna dougallii*), Least Tern (*Sternula antillarum*), and Little Tern (*Sternula albifrons*). These species experience declines from habitat loss, predation, and competition from artificially increased gull populations, while sea level rise and increased storm intensity threaten beach-nesting populations (46, 47). Active restoration alongside habitat protection and control of predators has delivered important conservation outcomes for these species (32, 48, 49).

Nearly 20% of events targeted 49 Procellariidae species, representing 51% of this globally threatened seabird family (35). While social attraction was frequently used, 49% of all translocations targeted this family, often alongside social attraction which can be operational for many years at relatively low costs even after a translocation is completed (39). As with Laridae, Procellariidae breeding response rate was high (79%), but took longer to initiate (5 y on average), consistent with their delayed onset of breeding (2 to 8 y to begin breeding) (50). To achieve success, project implementation and monitoring for outcomes should consider exceeding the age at first breeding for each seabird family. Similarly, Procellariiformes, which includes families with the largest and smallest seabird species (Albatrosses and Storm-petrels), had variable responses to active restoration, likely driven by differences in life history along with abundance and threat status (29, 35). The distance of current seabird colonies to restoration sites influences the probability of immigration of prospecting birds and likely also influences restoration outcomes (29). This is most relevant for social attraction, which is commonly paired with translocation to entice returning translocated birds to breed. Future research on the influence of source colonies on restoration outcomes, along with an examination of active restoration events at finer taxonomic levels, and the incorporation of life history traits, geography, method details (e.g., stimuli used in social attraction or number of individuals translocated), and supplemental management actions (14, 29), will further explain active restoration best practices and guide practical restoration planning and prioritizing to reverse seabird declines.

Eighty percent of events were implemented in six high- and upper middle–income countries, including overseas territories. This result implies that conservation funding for seabirds is concentrated in wealthy nations. These countries—the United States, New Zealand, the United Kingdom, Mexico, Canada, and France—and their territories are also breeding grounds for the majority of the world's seabirds (46), demonstrating the global effort to restore seabirds. Despite this, just 1% of active restoration events occurred in lower middle- and low-income countries, and only 6% occurred in Small Island Developing States. Given environmental and socioeconomic challenges in these localities, and the positive role of seabirds on ecosystem function and productivity, particularly through their nutrient inputs (26, 51), restoration here could have wide-ranging cobenefits to both biodiversity and human livelihoods (52, 53).

While one-third of all seabird species were targets of active restoration, we observed a bias in the concentration of these efforts: 56% of events targeted just 12 species, primarily terns, and 16% of events targeted globally threatened species, representing just 39% of all globally threatened seabirds. There is significant need and opportunity to apply active seabird restoration to more taxa, particularly threatened species, and across more geographies, including cases of assisted migration where current and historical colonies will no longer be viable under future climate scenarios (39).

Global Systematic Reviews for Assessing Conservation Outcomes. Our rigorous systematic literature review, expert consultation, and data collation into standardized categories for measuring outcomes provided a global understanding of active seabird restoration methods and outcomes and can serve as a model for other taxa requiring conservation interventions. The number of events identified in this study is six times higher than that reported in 2012 (9). This change reflects an increase in annual active seabird restoration events since the 2010s, which approximately doubled in that decade compared to those of previous decades (Fig. 1 *B*–*D*), and the power of our systematic review process, which uncovered more than 350 restoration events from before the 2010s compared to the 128 events reported previously (9). Notably, we detected a sudden decrease in events in 2020, coinciding with the global response to the COVID-19 pandemic, followed by an increase in 2021.

There are trade-offs from summarizing conservation interventions at the global scale (*SI Appendix*, *Appendix 1*) (33), yet our dataset represents a dynamic product informed by the best information available at the time of collection. Given reporting lags and the timescale of restoration, the number and status of events will change over time, and may have already changed by the time of this publication. Sustained commitment to updating the database will maintain data relevance and track progress of active seabird restoration events over time. Support for similar knowledge products for nonseabird taxa will further inform best practices and accelerate the conservation decision-making process for biodiversity conservation overall.

Materials and Methods

Summary. Between 2020 and 2021, we built the Seabird Restoration Database (54), a publicly available global compendium of translocation and social attraction efforts designed to improve knowledge transfer among practitioners seeking to recover seabird populations. The database provides a standardized framework allowing for evidence-based syntheses of seabird restoration methods and outcomes, both globally and regionally.

We followed standards for translocation described by the International Union for the Conservation of Nature (IUCN) (7). These definitions did not include social attraction; thus, we use the broader term "active seabird restoration" to describe the deliberate, human-aided movement or attraction of seabirds to a restoration site to establish or enhance a colony. Social attraction involves mimicking a breeding colony using visual, olfactory, and/or auditory cues to signal suitable breeding conditions, which often lures young seabirds that are prospecting (selecting) nest sites for the first time (40, 55). When existing colonies of a target seabird are too far from restoration sites for breeders to be attracted, translocation often becomes necessary, particularly for species with high natal philopatry (32, 39). Translocation involves physically moving seabirds, typically chicks, from one location to another, and caring for them until they fledge, with the goal of the chicks returning to form a colony when they reach breeding age. With either method, restoration sites are typically identified based on habitat suitability, potential for threat reduction, the history of seabird breeding, and accessibility by practitioners. Artificial nests (especially underground burrows) can often supplement social attraction and translocation projects (39, 56).

Data Collection. We collected data using a rigorous systematic review process (33, 57, 58). Seabird species taxonomy and threat status were defined by the IUCN Red List, provided by BirdLife International (46), which included distribution maps of all 368 seabird species. First, we reviewed literature cited in previous syntheses (9, 31, 38). Next, for each species, we conducted an online search for restoration activities by region of occurrence using keyword searches applied in various combinations: species common name, species scientific name, *"restoration," "reintroduction," "translocation," "social attraction,"* the country and/or region of occurrence, "*report,*" and/or "*plan.*" We used additional keywords in combination with the above to obtain additional details about each event and restoration site: "*invasive species," "management,"* most recent year of activity (i.e., *2019, 2020*), *"monitor,"* and *"breeding."*

We reapplied the above terms to search for relevant information within each document. If the species occurred in a non-English-speaking country, we used Google Translator to identify the keywords in the target language and to read documents or we consulted experts for translation assistance. Once the systematic search was complete, we contacted experts to fill remaining data gaps, review the collected data, and/or provide details of unpublished projects. If no information was found for a species or within a country, we contacted an expert on that seabird group and/or country and inquired about projects. We provided multiple ways for experts to share information, including a data entry spreadsheet and a link to an online survey (*SI Appendix*, Fig. S3). If the systematic search and expert consultation yielded no information, we marked that species or region as having "no restoration" efforts. This included when we contacted experts but did not receive a response.

We referenced 1,447 sources, including 1,144 written records (including 594 reports, 416 websites, and 118 publications) and 303 personal communications.

The personal communications included correspondences with 349 experts in 46 countries and territories who provided project details and/or contacts of other experts (644 experts from 79 countries and territories were initially contacted). Data were entered into a Microsoft Access Database (V. 2206) and are available online at seabirddatabase.org.

Data Definitions. The Seabird Restoration Database was developed with explicit data categories and definitions (*SI Appendix*, Table S10 and *Appendix 1*), with three major data components: restoration project, site, and event, of which the latter includes method and outcome details for each seabird targeted by a project at a restoration site.

We defined a restoration project as an overarching management program that implemented translocation and/or social attraction for one or more seabird species at one or more restoration sites within a discrete time period (e.g., Project Puffin targeted 9 species in 11 sites and comprised 26 events). Typically, a project contained a species and/or land management plan, was implemented by one or more conservation organizations, and had specific goals for using active restoration methods. While projects typically had more than one goal, we documented the primary goal based on predefined categories: species conservation, ecosystem restoration, legal mandate, research, community engagement, indigenous use, unknown, or other. Most seabirds are globally threatened by at least two threats (22). We documented the primary and secondary seabird threats that active restoration sought to mitigate through the project: invasive species, problematic native species, habitat loss, climate change, human–wildlife conflict, poaching, pollution/lights, at-sea threats, other, or unknown.

We defined a restoration site as where seabirds were lured or deliberately moved via social attraction and/or translocation. For each site, we recorded the site name, coordinates, and country, and if the site was on an island or continent, and if it was a natural or artificial habitat. Some sites included multiple locations reported as one contiguous site. Sites were marked as "sensitive" if requested by the expert and were not to be made public. For countries, we used standard country or area codes from (59) and collected subsequent information on country status (60), hereafter referred to as "country" or "territory," and World Bank income categories (61). If income was unreported at the territory level, we assigned income of the associated sovereign country.

Management of ongoing seabird threats at restoration sites is a key factor in the success of active restoration (14). For each site, we collated data on threats that impact seabirds (*SI Appendix*, Table S10 and *Appendix 1*) and management of these threats. This information was not always reported (17% of all sites lacked complete data on management) and this metric was therefore not applied in our model of global outcome determinants.

We defined an event as an activity using social attraction and/or translocation targeting a single species at a restoration site within a predefined project. For each event, we evaluated the data quality and categorized it as high, medium, low, or unknown (*SI Appendix*, Table S10 and *Appendix 1*). We excluded events with unknown data quality from analyses.

An event contained details for each method (social attraction and/or translocation), including start and end years of implementation, status (ongoing, complete, incomplete, planned, unknown), stimuli used in social attraction, total number of transferred individuals and cohorts (one per year) in translocations, the presence of nest provisions (e.g., nest boxes), and implementation outcome, based on the ability of the practitioner to implement social attraction and/or translocation (achieved, partially achieved, not achieved, unknown). We also recorded challenges reported as impacting outcomes within each event, based on standard categories (*SI Appendix*, Table S10). Nonetheless, challenges were underreported; thus, a lack of evidence does not confirm the absence of a challenge.

For every event, we also documented the response to implementation, based on visitation and breeding of the target species, measured before and after the start of the event. Visitation included the presence of the target seabird in the air or on the ground at the restoration site; breeding included the presence of an active nest (hatching or fledging success was not evaluated). We recorded the first year of visitation and breeding since implementation began and colony sizes before and after implementation. Colony size postimplementation represented the most recent numbers available and was coupled with the year those data were collected or published. In some cases, the data were older than 10 y and thus the current status of a colony may be unknown.

Evaluating Restoration Outcomes. We followed a systematic process for evaluating outcomes and calculating success rates of 1) restoration implementation by the practitioner and 2) response of seabirds to implementation via a) visitation, b) breeding, and c) continued breeding (Fig. 3). This process only included high-quality data (n = 512), which excluded events that had a "planned" status. If both social attraction and translocation occurred in an event, we used the highest combined implementation outcome and excluded events with an unknown outcome, resulting in 510 events for analysis. We calculated implementation success as: [achieved + partially achieved]/[achieved + partially achieved + not achieved].

Next, we evaluated successfully implemented events for seabird visitation. We excluded events where it was unknown if the target seabird was visiting before or after implementation (n = 29) and excluded events that reinforced an existing breeding population (n = 128) because seabirds provide social cues to prospecting seabirds (55), which may confound a measured response to active restoration. We calculated successful visitation as: visitation/[visitation + no visitation]. Next, we evaluated successful visitation events for breeding. Because seabirds have slow reproductive rates [average age of first breeding = 5 y, range 2 to 9 y (50)], we identified which events started less than 5 y ago (2018 to 2021) and excluded those events without breeding because it may have been too soon to evaluate outcomes. We also excluded events with unknown breeding status. We calculated breeding success as: breeding/[breeding + no breeding]. Lastly, we recorded breeding events that occurred for >1 y to understand the potential for long-term success. We recognize that the result may be inflated because the philopatric behavior of seabirds makes it likely that a seabird that bred previously will return to breed (50). Furthermore, projects with a breeding response are more likely to continue monitoring for continued breeding than those without a breeding outcome.

To evaluate the timing of visitation and breeding responses, for each response metric, we determined the number of years between the start of implementation and the first year of a response by subtracting the start year from the response year (we applied the earliest start year for events using social attraction and translocation). We tested for differences in response timing among seabird families using a Kruskal–Wallis one-way *ANOVA* for each response metric followed by pairwise post-hoc Dunn's tests. We combined storm-petrels (Hydrobatidae, Oceanitidae) into a single functional family and removed families with fewer than five records from the analysis. All analyses were performed in R version 2022.07.1 (62)

We examined drivers of breeding outcomes using factors from our database that were suitable at a global level: taxonomic order, active restoration method, latitude, artificial vs. nonartificial habitat, island vs. continental restoration sites, and event duration (*SI Appendix*, *Appendix 2*). We applied these factors in a binomial generalized linear model and with a model selection process that computed the fit of all combinations of factors using the "dredge" function in the "MumIn" package in R (63, 64). We selected the highest ranked model (lowest corrected Akaike's Information Criteria [AICc] value) and reviewed the probabilities of breeding for each term (*SI Appendix,* Table S6 and S7).

Data, Materials, and Software Availability. Data from the Seabird Restoration Database are open access and can be found at https://www.seabirddatabase.org/ (54). Data from the database and the code used in this analysis are available via the Zenodo Digital Repository at https://doi.org/10.5281/zenodo.7764785 (65)

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