Short Perspective

A Perspective on Conservation Technologies for Endangered Marine Birds

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Abstract

Seabirds are species in a collection of avian orders that live on and feed in saltwater and include penguins; albatrosses and petrels; gannets and cormorants; and gulls, terns, and auks. They are at risk from human activities with habitat loss, fisheries bycatch, food shortages, introduced predators and pollution impact. These effects are all exacerbated by human-induced climate change. Many researchers, non-governmental organizations, communities, and governments are working to conserve endangered seabird species by developing and implementing technologies and conservation management systems to assist seabird conservation. More recently moves are afoot to ensure organizations share data and outcomes.

Introduction

The International Union for Conservation of Nature's Red List [1] estimates that 31% of seabird species are at risk and endangered. Developments in tracking technologies over the last two decades have made extensive inroads into bettering our understanding of a variety of factors, such as climate change [2] and data sharing [3-6], that impact seabird conservation interventions [7]. Priorities for the welfare, wellbeing, and preservation of the species at risk, require improvements to the quality and efficiency of global conservation responses and collaborative, ongoing and dynamic responses working with evolving, more detailed and richer datasets [8].

Through shifts in technology use for conservation assessments and interventions for endangered seabirds, research has grown and developed and subsequently what is being studied has changed as methods have evolved. Detailed information can assist conservationist scientists and practitioners to improve survival estimations with more data on breeding behaviour, foraging and nesting areas providing an increased understanding of activity patterns and habitat use [9]. Information such as annual revisit frequencies of individuals and pairs [10], return, duration and departure dates for courtship, egg-laying periods, incubation shifts and chick feeding stints produce a thorough understanding of the daily lives of individuals, the population dynamics and physiology [10].

The Perspective

With significant differences in behavioural patterns between the breeding, migration and wintering stages, individual behaviours can be accurately predicted during multi-year migrations with enough detail to allow for intra-specific variation considerations [11]. Multiple factors impact foraging success [12]. More accurate mapping and detection of locations and depths of feeding events in marine ecosystems inform the different strategies animals use in foraging [13]. This emphasizes the importance of understanding and supporting interventions to improve resilience and to ensure conservation interventions can protect population numbers and habitat changes from climate change impacts. In addition, an improved understanding of foraging efforts are useful as an indicator of fish stocks health [13]. Advances in methods, such as using a four-trip sample, ensures improvements in cost-effective, accurate, efficient research that can find the home range of a species and ascertain more accurate predictions of home range size for other species [7].

We can see the impact that developing technologies and advancement in methods have had and are having upon conservation measures for improving our understanding of what is needed for the protection of not only the endangered seabirds but also the marine ecosystems they inhabit. There is a need for future work to gauge the environmental impact on habits and changes within food access webs comparative to

current datasets and a facility to incorporate larger datasets to continue expanding this work. Key here is the impact of climate change, with the expected increased frequency of hurricanes and storms, fluxes in food obtainability and probable emigration scales [2]. Further monitoring is critical to assess responses to the increase in stressors such as the presence and behaviour of fishing vessels, shipping routes, mining, infrastructure and prey to develop adapted conservation strategies [14,15]. Many current management plans do not address climate change variations and their impact on the likely future redistribution of resources, however scientists are starting to identify where this is needed by using distribution models from other marine species to inform fisheries management [16]. Approaches that model the dynamics of Marine Protected Areas are required to ensure reliable tracking of continuing requirements changes for optimal habitats, and general ecosystem management beyond colony/species-specific needs [17]. National, regional and global networks of marine protected areas need to be developed with the inclusion of key seabird sites into those networks and a consistent framework for using animal tracking data to delineate areas of global conservation importance [18]. This would allow greater integration into marine spatial planning and policy, with a standardised model to classify seabird conservation priority areas [18]. Additionally, it is essential that this dynamic model is accessible to identify potential fallout in planning human activities [19].

Marine planning to identify important seabird areas, high residence foraging locations and high conservation priority areas would combine habitat modelling with identified network marine and terrestrial Special Protection Areas [20]. Many feeding sites are located over productive waters connected to boundary currents, upwellings, canyons, seamounts, river outflows and other oceanographic and bathymetric features that regulate food availability. Including these areas in the protection strategies would provide entire ecosystem benefits. Adding intra- and inter-specific knowledge on competition across colonies and coastal geomorphology could predict seabird distributions based upon environmental variables and greatly improve marine planning to identify important seabird areas and high conservation priority areas [20,21].

Further work with ecotoxicological studies that cover annual cycles is needed to identify contamination risks, especially as warmer temperatures decrease ice concentration that increases Mercury concentrations. This is occurring in Arctic breeding and prominent non-Arctic nonbreeding areas, which in turn impacts the next season egg sizes and escalates associated threats to top predators [14]. Bird-borne miniaturized technology has demonstrated usefulness in assessing the contamination of marine systems within their wider ecosystems on a substantial spatial scale [22]. Tracking seabirds, who are apex predators within many marine ecosystems and key actors within food access webs, functions to monitor changes in feeding behaviour of seabirds and other species and assess environmental change and pressures. As marine predators, seabirds present as barometers of marine environmental health and their presence or absence can act as early indicators of change. This provides a better understanding of physiology, population dynamics and adaptions necessary to overcome climate change, as well as for researchers to implement further steps to ensure seabird and ecosystems survival [23].

With changing conditions, we see adaptations among individual adults within species. Unknown is what conditions lead these adults to re-enter a more exploratory stage to refine/reinvent their formerly learnt foraging and movement strategies. These individuals/species will have a selective advantage, with levels of genetic or cultural transmission, degrees of plasticity in responding to the environment, energetic and other physiological consequences, and effects (immediate or carry-over) on species survival and reproduction. Where changes happen fast, the degree of plasticity of the individuals impacts the capacity of the population to respond to changes in conditions [12,24].

Progress, development, and evolution are evident in technologies, knowledge production and data gathering and analysis methods. Earlier studies used radiotelemetry [25], satellite tracking [26,27], geolocators [10], global positioning system loggers, depth recorders and archival logging technologies. We see the transition to miniaturisation and a focus on combining data collection methods, with more miniature GPS-logging technology (weighing between 1% and 5% of the birds' body mass), and ship-based surveys and sensor data from instruments attached to individual birds, animals marked with passive integrated transponders (PIT tags) and automated recorders to monitor activity patterns. Bio-logging and gauging pollution impacts on species creates a richer picture of behaviours [12] (Figure 1).

Reducing intervention/handling times and working with smaller seabirds becomes progressively possible with increased miniaturisation. Precise, lightweight tracking attachments are crucial for the survival of the seabirds. Complexities in miniaturisation development elicited more data on heftier seabirds and a concentration on coastal vs ocean birds with easier access. More recently with animal-borne instruments (ABI) going into ocean observing systems, data on more endangered species in hard to access areas can accurately inform multiple factors impacting complicated conservation issues. Evolving technologies and methods address considerations such as weight of trackers, battery life, health impact and e-waste prevention and enable access to a level of detail previously unavailable. We can see individuals' patterns of behaviours vs species more generalised behaviours; migratory pathways with a separation in the foraging and resting areas for the species enroute; foraging

Figure 1: Bio-logging has developed an understanding of the diving behaviour and interspecies interactions of African penguins (Spheniscus demersus). This will help to plan conservation interventions as both the climate and populations of other species change [12]. Photo by Casey Allen on Unsplash.

and nest location disparities; variance in foraging styles between genders and in different sequences of gestation cycles, as well as intra-foraging impacts between species in cycles where food is short. The presence of other seabirds improved individual foraging success, but where predatory fish were also foraging diminished it, indicating that larger other species may impact the survival of smaller vulnerable endangered seabirds.

While accuracies with more sophisticated technology development provide ease of use, rigour and miniaturisation, many studies still require increasing reporting on specifications of the technology to improve comparability, reproducibility and testing for instrument effects [27]. Uniform methods to accurately estimate population trends and assess species vulnerability are needed. Future testing, revisiting and comparing to current datasets with cooperation between institutions to share data is agreed as imperative for success in conservation [2,3,7,9,10,1,2–15,17–22,25–36]. For effective marine conservation, a move away from small, limited sample studies requires a change in the culture for conservation biologists to adjust to a more functional approach. A computer-generated infrastructure for gathering, storing, trading and merging the analysis of disparate datasets (e-science) that researchers could use as a global resource [3] would be relatively new to process management within the ecology field. Shared data has the capacity to advance scientific understanding of real-time changes in marine ecosystems as they are impacted by global climate change. This could guide where marine protected areas are needed and designated with a focus on protecting central ecological processes that would preserve marine structures [30]. We see such examples emerging with Seabird Information Network [37], Bycatch Management Information System [4] and Seabird Tracking Data Portal [5] sharing data with online accessible systems.

Technology has surpassed current legal procedures, allowing scientists to conduct research on marine migratory species beyond national borders. National borders cannot restrict scientists' research regardless of where their tracked species may wander, swim or fly to. Bio-logging has disempowered coastal states' ownership and control of studies on marine migratory species and has expanded the ability of marine science to advance and sustain conservation programs (33).

Conclusion

Studies emphasise the need for future work to gauge the environmental impact on habitats and changes within food access webs. Comparing current datasets with revisiting and re-testing with larger future studies of longer duration to track changes and highlight recommendations for future conservation interventions is called for. Scientists emphasise a need for a dynamic systems approach for Marine Protected Areas management to account for changes on rapid, cyclical as well as small and large scales, in particular relation to climate change, pollution, and human intrusions. Much of the data is not yet accessible in online databases for other researchers or for the decision-makers that can ensure accelerating informed

progress. An open-source infrastructure is urgently needed to protect endangered marine life and support whole ecosystem effectiveness.

Management plans need to address climate change variations and impacts on the likely future redistribution of resources. Recommendations for future conservation-oriented seabird tracking include focusing on priority species, increasing marine protected areas, and enlarging regions with ethical, rational and efficient global tracking programs.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgement

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