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Seabird and reef conservation must include coral islands

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Abstract :

Tropical seabirds exert key roles in reef ecosystems but face growing threats from climate change, especially on coral reef islands (CRIs). Therefore, we advocate for a more comprehensive, global data exchange on CRIs and CRI-dependent seabirds and outline steps for improving their study and conservation.

Main Text

Coral Reef Islands: key(s) to tropical seabird ecology

Coral Reef Islands (CRIs) are low-lying, sedimentary structures formed by the accumulation of carbonated debris next to or above coral reef ecosystems [1-2]. CRIs support unique communities of plants and animals and are home to some of the largest colonies of tropical seabirds worldwide [3] (Text Box 1, Table S1). While it is well-known that healthy reefs are key to maintaining CRI ecosystems, recent studies have emphasised the critical role that seabird populations play toward sustaining reef health [4-5] (Figure 1). Despite their ecological significance, CRI seabird communities have not yet been the subject of large-scale consistent biogeographical analyses and their vulnerability to climate change remains to be assessed. Accelerated coastal erosion and reef decline will expectedly add to a wide array of ecological threats currently impacting seabirds (*e.g.* invasive alien species, human disturbance, plastic pollution) that already make them one of the most threatened groups of vertebrates [6]. Therefore, we urgently advocate for conservation-oriented initiatives centered on CRI seabirds and outline steps that can enhance tropical seabird management.

The coral reef crisis reaches beyond aquatic ecosystems

Coral reefs have received extensive attention from the research community in the past decades as one of the ecosystems most severely threatened by climate change [7]. Their projected degradation will likely extend beyond subaquatic communities, notably in CRIs that are also the products of healthy reef ecosystems. CRIs are present in oceanic, coastal and lagoonal systems throughout the intertropical area and range from a few dozen square meters (*e.g.* Swain Reefs cays, Australia) to several tens of square kilometers (*e.g.* Europa Island, France) [1-2, 10]. As low-lying geological structures, CRIs are expected to be at risk from future sea level rise and associated coastal erosion [1-2, 10]. Indeed, recent *in situ* observations and predictions of CRI geomorphological dynamics have shown that moderate sea level rise may favor island growth if carbonate supply is maintained [1, 10], while abrupt sea level rise leads to a fast erosion of island surface [2]. Since the predicted global degradation of reef functioning induced by ocean warming and acidification could severely alter the production of carbonated materials (*e.g.* coral skeletons, invertebrate shells) [11], the likelihood of a substantial decay of CRIs is high. Furthermore, examples from the Pacific region indicate that coastal urbanization reduces CRI resilience to erosion, putting additional pressure on already-threatened islands [12]. Although the extent to which CRIs will be impacted by climate change remains uncertain, as well as the exact timing and geographical scope of such degradation, we expect that CRI-dependent ecological processes and ecosystem services will undergo significant alterations by the end of the century.

CRI seabirds provide key yet understudied ecosystem services

While the importance of seabirds for trophic regulation and their role as bio-indicators of ecosystem health are well established [13], their influence on the functioning of coral reef ecosystems has been highlighted only recently [4-5, 14]. Specifically, nitrogen concentration through guano deposits increases nutrient availability in marine and terrestrial ecosystems adjacent to seabird colonies, which enhances the health and productivity of neighboring reefs [4-5]. Therefore, maintaining or restoring tropical seabird communities next to coral reefs can contribute to reef functioning, while also sustaining the ecological roles of seabirds [5, 14]. Conversely, a decline of tropical seabirds may impair local reef functions and alter coastal and pelagic trophic networks. Eventually, degraded coral reefs directly impact nature contributions to human societies (food production, coastal protection, cultural values) [8] and add further pressure on seabird populations (habitat degradation, reduced prey availability for coastal foragers), creating a negative feedback loop. Since seabirds breeding on CRIs rely the most on reef functioning among tropical seabirds (Text Box 1), we believe their conservation is inseparable from reef conservation itself, and vice-versa.

To date, no quantitative assessment of conservation issues associated with CRI seabirds has been undertaken. The contribution of CRI-dependent colonies to the taxonomic and phylogenetic diversity of the global seabird community, or to the functioning of marine or terrestrial ecosystems and services remain poorly characterized, as well as their vulnerability to climate change and other anthropogenic threats. These knowledge gaps currently restrict the ability of managers and researchers to (1) identify CRI-dependent species and assess their spatio-temporal dynamics, (2) map the current and future risks faced by CRI seabirds and (3) prioritize conservation targets when developing environmental policies. Therefore, we believe that urgent action is needed within the research and management communities to promote international cooperation and conservation-oriented monitoring devoted to CRI seabirds.

Multiple challenges must be overcome to improve the conservation of CRI seabirds

We view the current knowledge limitations on CRI seabirds as a product of multiple, co-occurring causes:

- The geographical dispersion and remoteness of CRIs across tropical waters, along with the partially non-seasonal breeding regime of many tropical seabird species, increase the uncertainty around population size and demographic trends estimates, thus impairing the assessment of conservation status;
- The lack of a dedicated research and exchange network hinders data sharing among scientists and managers who monitor and study CRI seabirds;
- The lack of holistic approaches integrating both marine and terrestrial ecosystems limits the current knowledge on ecological processes that occur at their interface.

Here we outline five steps that aim to improve the knowledge and conservation of CRI seabirds:

Step 1 – Urge managers and researchers toward a global research & management initiative

We believe that stronger emphasis needs to be put on the ecological importance of CRI seabirds and associated conservation issues within the research community and beyond. Communication efforts through wide-ranging media are key to fostering interest among scientists and managers internationally. This work aims to serve as a first step in bringing together specialists of tropical seabird ecology and monitoring, reef ecology and CRI geomorphological dynamics, with the hope of (1) laying the basis of an international exchange network dedicated to CRI seabirds and (2) promoting the incorporation of seabirds into future studies addressing the coral reef crisis.

Step 2 – Gather and standardize data on seabirds and CRIs

Developing a large-scale research network will promote and facilitate data sharing among partners. A future shared database should include data on both CRI seabirds (observation and census data) and CRIs themselves (geomorphology, habitat availability, threats). Future data acquisition must be supported by robust guidelines to improve the usability of census data for conservation purposes and the reliability of interregional comparisons. Once operational, a common database would help managers and researchers discuss current monitoring programs on CRI seabirds, direct efforts to regions that lack adequate surveys and identify priorities for further monitoring and conservation schemes.

Step 3 – Describe and analyze spatio-temporal dynamics of seabirds on CRIs

The study of up-to-date, large scale and standardized monitoring data on CRI seabirds would facilitate accurate assessments of global distribution and population trends, and consequently regional and global conservation statuses. In particular, a critical analysis of seabird biogeography on CRIs would help evaluate the impact of ecological (*e.g.* resource and breeding habitat availability), geographical (*e.g.* remoteness, island geomorphology) and anthropogenic factors (*e.g.* human disturbance, invasive alien species) on seabird abundance, breeding success and phenology.

Step 4 – Quantify the contribution of CRI seabirds to marine/terrestrial ecosystems and to human societies

Further study of the qualitative and quantitative contributions of CRI seabirds to the functioning and resilience of marine and terrestrial ecosystems is needed. A better understanding of the ecological and socio-economic importance of CRI colonies could be used as an incentive for promoting the management and restoration of seabird communities not yet included in environmental policies [15]. Such a goal would likely be best achieved by developing holistic ecosystem monitoring in locations of interest, taking into account all relevant biotic and abiotic components with seabird interactions. Evaluating the economic contribution of CRI seabirds to human societies also calls for the characterization of all direct (*e.g.* egg or chick harvest, guano extraction, ecotourism) and indirect services (*e.g.* influence on reef health, fish stocks, coastal erosion) that they provide.

Step 5 – Assess the present and future vulnerability of CRI seabirds

Matching the current spatial distribution of seabirds on CRIs with current and predicted anthropogenic threats will produce risk assessments and plausible scenarios of the future of CRI-dependent species, which are key tools for orienting future research and management policies in the face of environmental change. Additionally, the overlap between seabird colonies and other reef-dependent communities (fishes, corals, sea turtles, invertebrates) could be investigated to evaluate the scope of cross-taxa management.

CRI seabirds are highly relevant to ecosystem-oriented management

While the current conservation statuses of CRI seabirds are more favorable than some other seabird groups (Text Box 1), they are still an important conservation focus because it is the widespread, still-abundant species that provide a quantitatively greater contribution to ecosystem processes and services than low-numbered, area-restricted, and typically more threatened, species. This makes research and conservation efforts targeted at CRI seabirds pertinent in the context of global change, as species with large population numbers and wide-ranging distribution likely hold the greatest potential for sustaining the ecological resilience of tropical insular ecosystems.

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Display items

Figure 1: Legend

Figure 1: A: Visual summary of the ecological roles of seabird species that breed on Coral Reef Islands (CRI, left) and overview of the anthropogenic threats facing CRI seabirds (right). B: Murphy's Petrel (*Pterodroma ultima*) on the rodent-free, unhabitated atoll of Morane, French Polynesia. C: Roseate tern (*Sterna dougallii*) and black-naped tern (*Sterna sumatrana*) colony nesting on a coral reef islet, Southern Lagoon of New Caledonia. D: Complex plant cover and multi-species seabird colony on Surprise Island, d'Entrecasteaux Reefs, New-Caledonia. E: Masked booby (*Sula dactylatra*) nests within the world's largest known colony of the species, Clipperton atoll, Eastern Pacific. Pictures © Éric VIDAL/IRD; Tristan BERR/IRD-UNC

Text Box 1: *Overview of Important Bird Areas containing Coral Reef Islands*

Geographical and population data from BirdLife International's Important Bird and Biodiversity Area (IBA) network was used to produce first estimates of (1) the number of seabird species that depend fully or partially on Coral Reef Islands for breeding and (2) the proportion of each species' global population that nest on CRIs. An initial dataset comprising 3932 IBAs was filtered to retain only IBAs with at least one breeding seabird population and one CRI. This yielded 251 single IBAs (panel I), which were further classified into three categories: CRI-only (209, 83%); mix of rocky islands and CRIs (36, 14%); single island of mixed origin (6, 3%). 538 breeding records for 52 seabird species were retrieved within the 209 CRI-only IBAs, with a mean of 2.6 ± 2.2 (± sd) records per IBA. On average, a species was present in 9.8 ± 9.3 IBAs (median = 7). Colony size estimates were then homogenized and summed to produce overall estimates of population sizes across the selected IBAs, and matched against global estimates of population sizes for each species (II) (Supplementary S1).

Localisation

The IBAs retained in this analysis are scattered across the waters of 57 distinct territories belonging to 43 countries. Five countries (Australia, Bahamas, France, United Kingdom, United States) make up 55% (114/209) of the IBA set.

Species dependence toward CRIs

At least 23 species concentrate ≥50% of their global breeding population on CRIs (II). For at least seven species: Wedge-tailed Shearwater (*Ardenna pacifica*), Henderson, Phoenix, Bonin and Murphy's Petrels (*Pterodroma atrata, P. alba, P. hypoleuca, P. ultima*), Black and Brown Noddies (*Anous minutus, A. stolidus*), this proportion rises to ≥80%. In the context of expected decline of CRI ecosystems, the large-scale monitoring and study of those taxa should therefore be prioritized, even though species that breed on CRIs currently have more favorable conservation status than other seabird species (III).

Text Box figure captions:

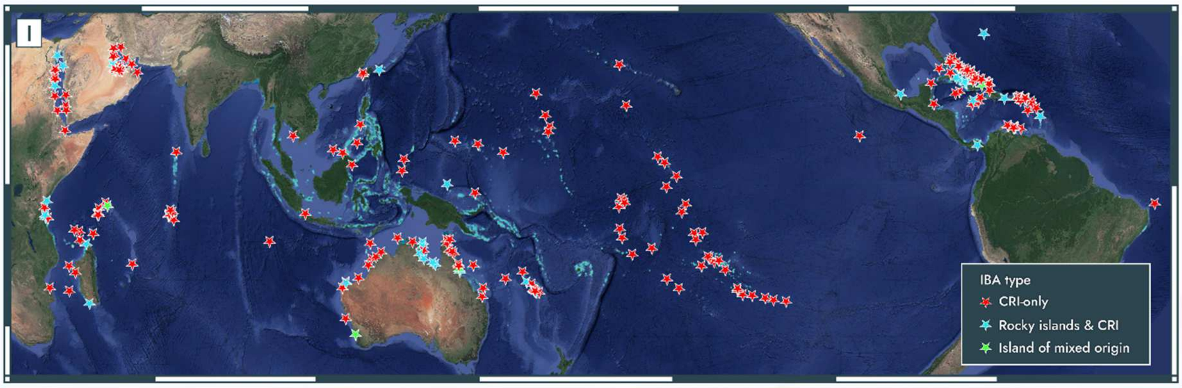
I: Global map of 251 IBAs that contain at least one Coral Reef Island and one breeding seabird population, classified by island type (CRI-only, mix of CRIs and rocky islands, single island of mixed origin).

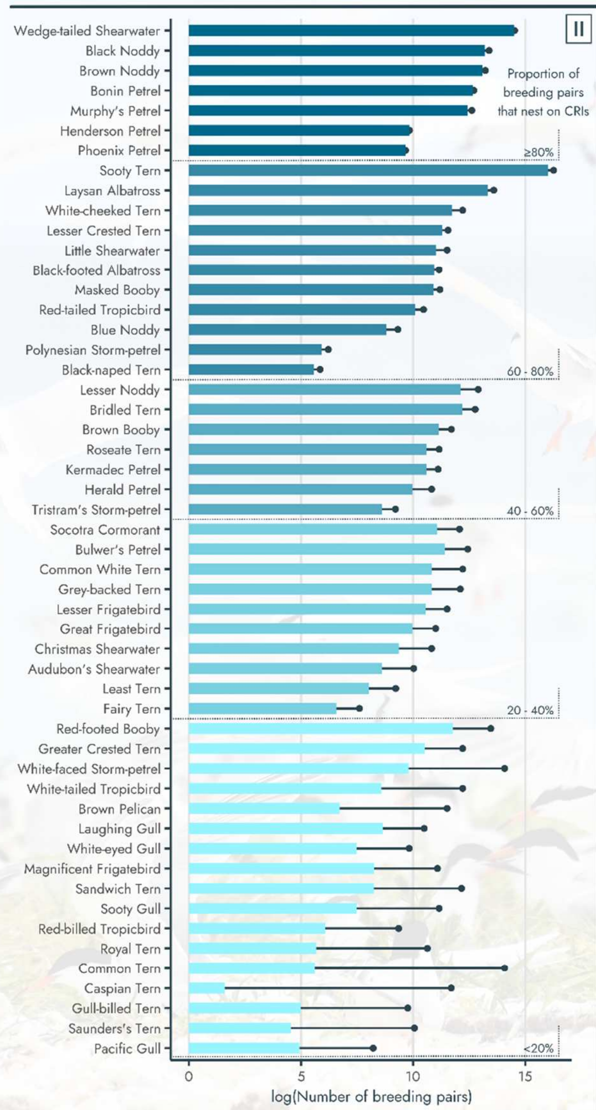
II: Population size estimates for 52 seabird species breeding within the 209 CRI-only IBAs. Bars show the number of breeding pairs of each species summed across the 209 IBAs, while dots show global estimates of population sizes. Source: BirdLife International 2022.

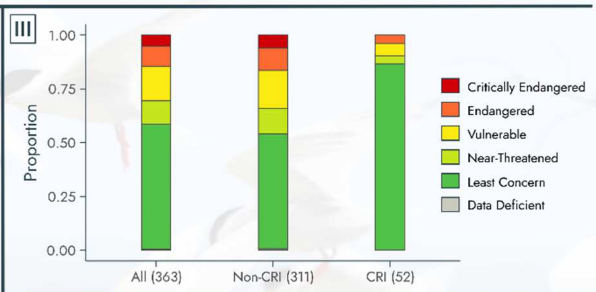
III: Comparison of RedList conservation statuses between the 52 selected species and the rest of seabird species.

Text Box 1 – *suggested layout*

Text Box 1 - Overview of Important Bird Areas containing Coral Reef Islands







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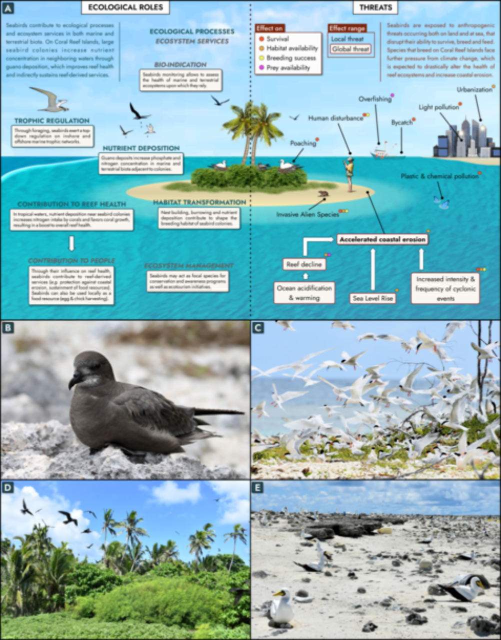
Declaration of interests

The authors declare no conflicts of interest.


A
ECOLOGICAL ROLES
Seabirds contribute to ecological processes and ecosystem services in both marine and terrestrial biota. On Coral Reef Islands, large seabird colonies increase nutrient concentration in neighboring waters through guano deposition, which improves reef health and indirectly sustains reef-derived services.
ECOLOGICAL PROCESSES
ECOSYSTEM SERVICES
BIO-INDICATION
Seabirds monitoring allows to assess the health of marine and terrestrial ecosystems upon which they rely.
TROPHIC REGULATION
Through foraging, seabirds exert a top-down regulation on inshore and offshore marine trophic networks.
NUTRIENT DEPOSITION
Guano deposits increase phosphate and nitrogen concentration in marine and terrestrial biota adjacent to colonies.
CONTRIBUTION TO REEF HEALTH
In tropical waters, nutrient deposition near seabird colonies increases nitrogen intake by corals and favors coral growth, resulting in a boost to overall reef health.
HABITAT TRANSFORMATION
Nest building, burrowing and nutrient deposition contribute to shape the breeding habitat of seabird colonies.
CONTRIBUTION TO PEOPLE
Through their influence on reef health, seabirds contribute to reef-derived services (e.g. protection against coastal erosion, sustainment of food resources). Seabirds can also be used locally as a food resource (egg & chick harvesting).
ECOSYSTEM MANAGEMENT
Seabirds may act as focal species for conservation and awareness programs as well as ecotourism initiatives.
THREATS
Effect on
Survival
Habitat availability
Breeding success
Prey availability
Effect range
Local threat
Global threat
Seabirds are exposed to anthropogenic threats occurring both on land and at sea, that disrupt their ability to survive, breed and feed. Species that breed on Coral Reef Islands face further pressure from climate change, which is expected to drastically alter the health of reef ecosystems and increase coastal erosion.
Urbanization
Overfishing
Light pollution
Human disturbance
Bycatch
Poaching
Plastic & chemical pollution
Invasive Alien Species
Accelerated coastal erosion
Reef decline
Ocean acidification & warming
Sea Level Rise
Increased intensity & frequency of cyclonic events
B
C
D
E