The following supplements accompany the article

Research priorities for seabirds: improving conservation and management in the 21st century

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Supplement 2. Full list of unique responses received by the authors of the manuscript when asked to list the 10 most important research questions that would assist in effective seabird conservation over the next decade. Responses below are ranked based on the number of responses received

Foraging ecology

Obtain precise information on the foraging grounds of seabirds aided by state of the art technology
Better understanding of diet of non-breeding seabirds
How consistent is foraging behaviour within individual birds and how does this affect population trends within species?
To what degree may seabird species vary their foraging range with respect to changes in food availability?
How and over what spatial scale do seabirds detect enhanced feeding conditions?
Foraging ecology
Wintering trophic ecology of seabirds
How hard are seabirds working to obtain food, and what is the variance and ceiling on their effort?
How different is the foraging behaviour of non-breeding seabirds from that of breeders?
To what extent is seabird assimilation efficiency modulated by prey abundance?

Demography, population dynamics and trends

Assess the health state of metapopulations by mapping globally the frequency distribution of colony sizes within species
Determine risk of global extinction of small populations owing to demographic stochasticity
What is the ability and rate of (breeding) dispersion of species/populations typically characterised by high filopatry and long lifespans?
Understanding which are the key factors regulating the population dynamics of seabirds
General distribution and abundance of all breeding colonies
The population trends of the 5 biggest colonies for each colonial species
What are the main drivers of seabird population changes in the (early) 21st century?
Assessing the relative importance of food availability, predators, disease, bycatch, pollution
What are the population trends in seabird populations?
Population sizes / trends for burrowing species living in dispersed colonies (e.g. petrels / storm-petrels)
What are the greatest threats to seabird population viability?
'Status and Trend': What is abundance and what is population trend?
Developing methods for censusing difficult-to-monitor species is a research issue, and an important one for many rare and secretive species.
Which seabird species are at greatest risk of extinction, and what patterns can be drawn from them?
What is the dimension and particularities of floating population etc.?
Which seabird species are in decline across the whole of their current breeding range?
Are demographic data available for these species to allow identification of which parameter is driving the decline; is there consistency across the range?
What are the roles of non-breeders in buffering population change?
Increasing data and method reliability on non-breeding numbers and their dynamics in population viability
Increasing knowledge on the ecology of the non-breeding fraction of populations
What processes drive mass breeding failures of seabirds in the northeast Atlantic?
What can we do to mitigate mass breeding failures?
Mortality of seabirds by area and season
What is the mortality factor of the main threats for each population? Sometimes main threats do not receive enough attention and are not included in action plans
We need to improve and update the survival and other parameter estimations in order to asess the impact of many threats in the demography
Long-term studies are crucial to monitor these changes in key geographic areas
Which are the most important factors actually affecting demographic parameters in seabirds?
How will populations of seabirds respond to changes in the number and quality of fledglings?
How will populations of seabirds respond to increased adult mortality?
To what extent does sex-specific variability in foraging affect population viability?
Do sexually dimorphic seabirds adjust the sex ratio at birth (i.e. before laying) according to current or anticipated food availability?
Can demographic parameters or foraging behaviour be used as indicators of environmental change over large geographic areas?
What are the key influences and trigger levels affecting breeding frequency?
How much of seabird survival may be attributed to learning?
What determines the likelihood that seabird young will return to their natal colonies to breed?
Demography (what are the factors affecting population trends)
What is the capacity to respond to catastrophic events in seabird populations?
Analysis of connectivity among populations, rescue effect and capacity to new colonizations
Population figures at different scales (global, regional, local) are key information to assess the role of seabird secies in the marine environment
Improving population estimates
Address the high complexity of getting accurate estimates for some species and to work out new approaches to improve these estimates in a feasible way
Effective models to assess extinction risk
What are the best methods for monitoring status and trends of seabirds (logistically and statistically efficient)?
Approaches to improve seabird demographic studies

Climate change and population response to environmental variability

Model the future impact of climate change on vital rates and detect the most vulnerable regions and populations
The influence of climate change on interference- and exploitative competition as a function of colony size
To what degree will climate change effects be expressed in seabird colonies of differing size?
Understanding which are the key factors regulating the population dynamics of seabirds
Development of methods that allow accurate interptretation of seabird data (breeding performance, distribution patterns, population trends)

What are the likely impacts of climate change on seabird populations?
Global climate variation impacts on seabirds
How can we improve the resilience of seabird populations within a scenario of increasing climate variability?
How will climate change affect seabird demography through their prey base?
Will breeding seabirds be able to track climate-driven changes in prey distribution, or is site fidelity too strong?
How will ocean acidification affect seabirds?
How will changes to suitable habitats for breeding, as a result of global change, affect seabird populations?
How will changes to oceanographic conditions as a result of human pollution and climate change affect marine ecosystems?
What will climate change impacts be?
How can climate change impacts be mitigated?
Will global warming ultimately have negative impacts on the distribution and spatiotemporal dynamics of seabird movements?
How will climate-induced changes in prey distributions affect seabirds?
What effect will climate-induced changes on prey life-cycles have on seabirds?
Can we understand and predict the bottom-up effects of global change (acidification, temperature rises) on primary productivity, food-chains and seabird guilds?
What are the cumulative and synergistic effects of anthropogenic and ocean climate perturbations?
How do different seabird species respond to ocean climate change?
Response to changes in ocean regimes/climate change
Ranking seabird species by their sensitivity to the agents of global change (mainly climate change and prey availability, invasive species and by-catch mortality)
Identifying mechanisms (at population and individual levels) of seabirds to buffer against agents of global change
What are the current and future impacts of global environmental change on seabird populations?
Can we predict the response of seabird populations to changing climate (cycles and global warming).
How will global change affect foraging conditions for breeding seabirds?
Impact of climate change
Impacts of climate variability and change
Map the interannual variability on basic vital rates along geographical gradients as a proxy of influence of environmental stochasticity
Map the risk of catastrophes (both due to natural causes such as hurricanes and human-caused events such as oil spills) globally
Monitoring changes in the marine environment.
Ocean productivity and impacts on seabird trends
Can we understand and predict the effect of coral reef decline on seabirds?
How can seabirds be best engaged to monitoring the changing conditions of the marine environment?
Changes in prey distributions and seabird foraging energetics in response to shifts in currents
How will seabirds react if foraging conditions around breeding sites deteriorate?

Genetics

Assess degree of gene flow between patches of metapopulations
Quantifying movement within and among populations
Genetic structure of seabird colonies
Using genetics to inform conservation
What can the integration of molecular evolution and movement patterns tell us about the connectivity, radiation and evolution of seabird populations?
Spatial structure of colonies and population networks

Invasive and non-native predators and plants

Synthesize the degree of success of campaigns addressed to the eradication of alien predators (such as feral cats or rats) on islands by means of meta-analysis
Removal of introduced predators on seabird islands
What can be done to increase the effectiveness of eradication techniques directed to alien predators?
How can invasive mammals be more effectively controlled?
Is cat and rat erradication a cost-effective measure to improve seabird conservation?
What factors determine the spatial and inter-specific variation in the impact of invasive alien predators on seabirds?
Can we advance the technology for eradication and control of invasive mammals on seabird islands?
Population-level responses to land predator removals / habitat restoration
Impacts and responses to land predator removals and invasive plants
What is the impact of introduced mammals (both predators and grazers) at seabird breeding colonies?
What are the best techniques for eradication/control of introduced predators at breeding colonies?
What are the best methods to eradicate introduced predators on seabird islands? We already KNOW the

devastating impact of introduced predators
Can we develop an efficient way to eradicate introduced rodents (especially mice) from islands?
Importance of introduced predators
Methods that improve our ability to eradicate introduced predators

At-sea distribution/spatial ecology

Improve knowledge on distribution, numbers and impacts on wintering grounds
Understanding distribution patterns at sea, at different spatial and temporal scales
Role of seabirds at sea, as well as to design adecuate conservation strategies, particularly the designation (and management) of Marine Protected Areas (MPAs)
Multisite, multi-year studies combining demographic, biotelemetry, population genetic and behavioural approaches
What areas are important for seabirds (in both summer and winter)?
How can we gain better insights into the non-breeding season ecology of seabirds?
Global monitoring system of seabirds
Where are the main migration pathways for seabird species that overlap with oil, fish, gas and other major developments in coastal and marine areas? (penguins)
Spatial ecology issues linked to the responses of seabirds to global changes
Link source-sink processes, habitat selection and risks of ecological traps at various spatial scales
What determines space use of non-breeding seabirds, particularly in offshore areas?
Identification of important areas for seabirds in offshore areas (outside EEZs)
How should breeding and stopover sites be protected?
What are the factors driving the spatial distribution of foraging?
What are the factors driving spatial distributions of nesting?
Is the spatiotemporal dynamics of seabirds at sea repeatable and predictable and at what spatial and temporal scales?
Winter-time at-sea distributions and diet
For protected species, at-sea distribution of different age-classes / sexes / breeding-status individuals
Describe entire ocean migration and use by the seabirds, analogous to what has been done for terrestrial species.
How are seabird colonies and wintering areas connected by their movement patterns?
At-sea distribution of different age-classes / sexes / breeding-status individuals
Where are the key wintering areas for seabird species?
What factors determine seabird movements, their tortuosity, their extents and ultimately their space use?
Do sexes, pre-breeders, breeders use similar areas?
Do wintering distributions of individuals from different colonies overlap or do colonies have distinct wintering areas?

Fisheries

Map the risk of impact of longline fishing globally
To what extent does fishery-related (bycatch) mortality impact seabird populations?
What can we do to mitigate fishery-related mortality?
Seabird bycatch mitigation techniques (political, sociological, educational and other human dimensions of problem)
How much and where is seabird bycatch taking place?
Mapping and quantifying seabird bycatch in standing fishing gear
What are the direct impacts of commercial fishing in seabird populations? Quantify the mortality in seabirds at different fishing gears.
Impacts and mitigation of bycatch
Is the longlining fishery sustainable and what are the maximum sustainable bycatch rates?
Age / Colony composition of fisheries bycatch
Age and sex-specific effects of fisheries bycatch
Increasing studies on impact on population dynamics of factors affecting adult mortality from fisheries, industrial and artisanal, and invasive species
What is the impact of incidental mortality in fisheries on seabird populations (albatrosses and petrels)?
In which areas is there the greatest risk of incidental mortality for threatened species?
What are the most effective mitigation techniques to reduce seabird capture rates in longline fisheries?
What is the impact of fisheries bycatch on seabird populations?
How many birds (by species/age/sex) are killed by different fisheries annually?
What is the origin (by breeding colony) of seabirds with multiple colonies that are killed by various fisheries?
What are the demographic consequences of fishery mortality?
Are 'high quality' birds (adults with above average reproductive output) less likely to be killed by fisheries than other birds?
Can we use population modelling to assess the impact of reductions in survival caused by bycatch?
Impacts of discards

Can fishery discards be used as a management tool for seabird conservation?
Within population and across species reliance on fishery discards
What role do fisheries discards have in the maintenance of seabird populations?
Impact of fisheries on the marine environment, and the multiple ways that they can interact with seabirds
Seabird bycatch that could drive some species to extinction.
Seabird bycatch, well-studied in some regions of the world, but for others extremely scarce, even in areas where seabirds have been largely studied, e.g. Europe
What will the responses of seabird populations to changes in fishery practices be (e.g. discarding)?
What can we do to mitigate the negative aspects of changes in fishery practices?
Reducing conflicts between fishers and birds
In areas with intense overlap with commercial fisheries, where, when and how do birds forage?
Data to design spatially explicit fisheries management schemes, particularly in areas where concentrated harvest occurs (Antarctica, forage fish species like krill)
To what extent do fishery and seabird activites overlap in targets, space and time?
What is the impact of competition with human fisheries on seabird populations?
What is the level of competition for the same prey between seabirds and fisheries?
Fisheries impact
Interactions of impacts, especially climate and fisheries (supply-side dynamics, not bycatch)
In tropical and subtopical portions of the world ocean, to what degree has reduced frequency of prey increased the energetic pressure of tuna-obligate species?
Are fisheries leaving enough small pelagics for marine predators?
Impacts and mitigation of overfishing
Can we understand and predict the effect of commercial fisheries collapse on seabird populations?
Can we determine the effects of best practice in fisheries management (no-take zones, healthy catch limits, low bycatch) on seabird populations?
How do fisheries affect the natural food supply of seabirds?
For species that are in competition with fisheries for food, how are conflicts to be resolved?
Impacts of fishing on marine food webs

Trophic dynamics

While we can readily determine the types of prey eaten by seabirds, what is the functional response of seabirds to prey or the needs of competing predators?
Biopysical contribution of top predators toward elevating the 'carrying capacity' of marine foodwebs/ecosystems
Can critical prey levels for current populations be determined?
Can critical prey levels be used to underpin ecosystem based management of marine resources in general and fishery management?
Incorporating the biomass needs of seabirds into fishing catch limits, mainly for species or areas with intense overlap with commercial fishing activity.
Bioenergetic modelling, stable-isotopes analyses, traditional data studies
To what degree has removal of seabirds from open-ocean marine fodwebs increased sensitivity of marine ecosystems to physical forcing?
Understanding the role of seabirds in the marine environment: position in the food webs, impact on the ecosystem, interactions with other organisms
What are the prey biomass needs of seabirds?
Ecosystem-based management requires a better understanding of the trophic interactions
What is the impact of generalist predators (gulls, skuas, giant petrels, etc.) on seabird populations in a non-equilibrium and rapidly changing world?
What are the Marine Resources Availabilities, natural and human induced?
Can the use of seabirds as effective and quantative tools to monitor fish stocks and/or other aspects of the marine environment move beyond the theoretical?
How will populations of seabirds respond to competition with recovering marine mammals populations such as whales and seals?
Can we understand and predict the top-down effects of changing vertebrate numbers (changes in commercial fish, whales, pinnipeds) on seabird guilds?
What is the minimum threshold density of prey required to sustain productivity (what is functional/numercial response)?
Using resources in archives (national and company archives) to gain a better understanding of biodiversity issues in oceans and on islands
Using historical records to understand trophic dynamics prior to perturbations caused by sealing (removal of predators) and fishing (removal of food).
Relationships to recovering fish and marine mammals
Seabirds as ecosystem indicators/role in ocean observing systems
What is the current status of important prey, and what is the likelihood that they will be adversely affected by

climate change or other drivers?
Can indirect methods of diet assessment be used to identify prey eaten outside the breeding season?
For well-studied species what are the relationships between breeding success and prey abundance?

Impacts of other anthropogenic factors/Conservation strategies/Policy

What are the imapcts of pollutants and oceanic debris on seabird populations?
Risk of oil pollution to focal seabird populations?
What are the true impacts of plastic?
Is hydrocarbon transport a serious global threat for seabirds?
Demographic effects of plastic ingestion / pollutants
Trends in plastic ingestion and pollutant loads
Demographic impact of plastic ingestion / pollutants
What are the impacts of pollution on seabird populations?
What are the cumulative, sublethal effects of POPs on seabirds?
Assessing the dimension of threats both on land and at sea
What are the impacts of new uses of the marine environment which lead to new threats that need to be assessed (e.g. windfarms)?
What is the impact of tourist activity on seabirds in terms of stress, habitat modification to provide facilities, disease transmission and increased risks associated?
What are the most efficient and revolutionary marine conservation tools to protect seabirds?
Changes in land use impacts on seabirds
Impacts of tourism on seabirds
Tourism has been one the fastest growing activities on our planet. Most spectacular colonies are igeneral the ones opened for visits
How serious is targeted catch of seabirds (albatrosses, shearwaters, terns, etc.) by impoverished human communities and what can be done to reduce its impact?
Are future developments in offshore windmill farms going to have a significant impact on seabird conservation?
How will human developments on coasts and islands affect the availability of suitable sites for breeding colonies?
Will seabird populations continue to adapt to urban or human-modified environments?
To what extent are nesting or feeding seabirds disturbed by tourist or leisure activity?
What evidence is there that natural selection might be mitigating man-induced detriment?
What evidence is there that seabirds are learning to mitigate man-induced detriment?
Will translocations be a useful and practical tool in the context of climate change?
Procedures to identify and manage MPAs
Why and when should (apparently and locally) abundant species, such as many colonial seabirds, deserve attention about their conservation?
Is there a greater need for biologists working in comparable systems to learn from each other?
Is there evidence that rehabilitated seabirds are less likely to become re-injured?
How effective might model seabirds be in inducing birds to colonize appropriate areas?
Are current international policies enough to guarateee conservation of long distance migratory seabirds?
How do we promote and accelerate the recolonization and recovery of seabird populations on restored islands?
Marine Protected Areas (MPAs) regarding seabirds: a new concept is necessary
How suitable/relevant can marine protected areas be as a tool for seabird conservation?
How large should marine protected areas be, and where should they be located?
Is the current definition of ’spatially static’ potected areas adequate for seabird conservation?

Disease

Circulation of infectious agents and potential for disease spread within/among seabird populations
What factors affect the circulation of parasites (micro- and macro-parasite) and what effects can they have on host populations?
Developing mitigation measures for disease epidemics
How important are (new and expanding) diseases for seabird population regulation? Can seabird researchers and tourists contribute to spread disease?
What are the impacts of parasites and pathogens on seabird populations?
As the range, frequency and scale of epizootics increase, understanding and monitoring diseases (avian cholera, avian malaria, botulism, etc) is a priority