

Marine IBA toolkit

Standardised techniques for identifying priority sites for the conservation of seabirds at-sea



This document should be cited as:
BirdLife International (2010). Marine Important Bird Areas toolkit: standardised techniques for identifying priority sites for the conservation of seabirds at sea. BirdLife International, Cambridge UK. Version 1.2: February 2011

Editor: Ben Lascelles, Global Marine IBA Officer.
Email: ben.lascelles@birdlife.org

Contents

Executive Summary

The Important Bird Area (IBA) Programme of BirdLife International has been used to identify priority sites for conservation for over 30 years. Until recently the programme has focused primarily on terrestrial and freshwater environments, but in the last decade there has been an expansion of the work within the BirdLife Partnership to identify IBAs in the marine environment.

Extending the IBA programme to the oceans, while a logical and significant development, has posed both conceptual and practical challenges. To assist with tackling some of these issues, and to draw together existing experience, several workshops have been held at both a national and regional level to develop guidance and propose methodologies. Those people who attended these workshops, and have contributed insights, examples and expertise to this process are listed under the contributors section overleaf.

This document represents a culmination of these workshops, where the outputs from them have been combined to create a toolkit for identifying and delimiting marine IBAs[1] in a consistent and comparable manner. It provides guidance on the treatment and analysis of a range of data types that have proved useful in the marine IBA process to date.

It recommends some rules (shown in blue boxes) that should be followed when undertaking a marine IBA analysis to ensure a global standard is maintained.

It provides examples (shown in green boxes) of marine IBA work undertaken within the BirdLife Partnership and illustrations developed by the Secretariat.

And it provides information reviews (shown in yellow boxes) of a range of analysis techniques and data sources which can be used to determine which may be most appropriate to use, and in what circumstances.

Ultimately this document is intended as a resource for BirdLife Secretariat and Partner staff as to the most appropriate data sources and methodologies to use when identifying IBAs in the marine environment. It is also intended as a working document and will be updated as appropriate when new examples and techniques become available.

[1] The term “marine IBA” is used here as shorthand for those IBAs that can be regarded as marine in nature because of the seabird populations they contain, but this is not intended to imply that they are fundamentally distinct from other IBAs.

Contributors:

BirdLife International Secretariat and Global Seabird Programme
David Diaz, Ivan Ramirez, John Croxall, Lincoln Fishpool, Mayumi Sato, Phil Taylor, Susan Waugh.

SPEA workshops
Ana Meirinho, Ben Lascelles, Carlota Viada, Ivan Ramirez, Kees Camphuysen, Martin Poot, Patricia Amorim, Pedro Geraldes, Peter Van Horssen, Stefan Garthe, Vitor Paiva.

SEO workshop
Álvaro Barros, Asunción Ruiz, Ben Lascelles, Beneharo Rodríguez, Carlota Viada, Fabian Rabuffetti, Ivan Ramirez, José Manuel Arcos, Juan Bécares, Pedro Geraldes, Victoria Saravia.

Participants in Chize tracking workshop
Amélie Lescroël, Ana Meirinho, Annette Scheffer, Autumn-Lynne Harrison, Ben Lascelles, Bernard Deceuninck, Clara Peron, Charlie Bost, Claire Tancell, David Grémillet, David Pinaud, Frances Taylor, Hélène Gadenne, Henri Weimerskirch, Ivan Ramirez, Janos Hennicke, Jean Baptiste Thiebolt, Karine Delord, Maite Louzao, Maria Bogdanova, Patrick Pinet, Philip Taylor, Richard Phillips, Susan Waugh, Vincent Bretagnolle, Vitor Paiva.

Other contributors
André Raine, Claudio Celada, Helen Raine, Kate Tanner, Mark Bolton, Nigel Varty, Thierry Micol

1. Introduction

Seabirds come in many shapes and sizes, from the diminutive phalaropes to the great albatrosses with the biggest wingspan in the bird world. Despite these structural differences, all seabirds share a common reliance on the marine environment for most of their lives. Many seabird species are spectacularly mobile, travelling many thousands of kilometres across international waters and multiple Exclusive Economic Zones, and only return to land to breed.

For many seabirds their key breeding sites are relatively well known, and a small proportion already receives some form of protection. In contrast, their habits at-sea are often poorly understood and the areas most important for their survival have rarely been defined in any systematic way.

Key land-based threats, such as the reduction of suitable breeding sites due to habitat loss and decreased productivity as a result of introduced predators, are among the more straightforward to identify and address. But as seabirds spend most of their life away from these sites, there is an ever-increasing need to develop and apply measures that will adequately protect them during their time at-sea. While there has been good progress in the reduction of levels of seabird bycatch by long-line fisheries in some regions, it remains a serious problem. Combined with growing threats from offshore wind-farm developments, expanding fisheries, increased traffic in shipping lanes and planned exploitation of at-sea mineral resources, there are ever-increasing pressures on the marine environment. Without sensible planning, many seabirds (and associated marine biodiversity) are likely to suffer as a result of these activities.

Given the extended periods of time they spend at sea, the multiple threats they face there and the vast distances they cover, identifying a network of priority sites for conservation in the marine environment is vital to ensure the future survival of many seabirds. As in the terrestrial environment, the IBA programme offers a convenient methodology for identifying these sites in a consistent manner.

The oceans cover 70% of the earth's surface, and while much of this environment appears featureless on the surface, seabirds repeatedly utilise a range of suitable habitats within the wider seascape and can occur regularly and predictably at sites, often in large numbers. The attraction of these sites is invariably driven by a range of oceanographic processes that combine to regulate productivity and food availability to seabirds. Among the features shown to be important for seabirds are: islands, shelf breaks and seamounts (e.g. Haney *et al.*1995; Thompson 2007; Rogers 2004); specific benthic habitats (e.g. Velando *et al.* 2005); specific food sources, both directly (e.g. Klages and Cooper 1997) and indirectly (Hebshi *et al.*, 2008); upwellings (e.g. Duffy 1989; Crawford 2007); eddies (Hyrenbach 2006); as well as frontal regions, convergence zones and tidal currents (Ladd *et al.* 2005). Many of these sites have the potential to be identified as IBAs, given adequate data to prove their significance and demonstrate that one or more of the selection criteria have been met.

2. Important Bird Areas (IBAs)

2.1 Concept and aim

BirdLife International's mission is "to conserve wild birds, their habitats and global biodiversity, by working with people towards sustainability in the use of natural resources" (BirdLife International 2004a). BirdLife's strategy to achieve this mission integrates species, site and habitat conservation with sustaining human needs, and is implemented by the BirdLife Partnership in over 100 countries and territories worldwide. The site-based component of this approach, the Important Bird Area (IBA) Programme, complements other programmes that focus on species and habitats.

Sites are discrete areas of habitat that can be delineated and, at least potentially, managed for conservation. Since biodiversity is not distributed evenly across the globe, the protection of a carefully chosen network of sites can represent a cost-effective and efficient approach to conservation, because a relatively small network can support disproportionately large numbers of species. Effective protection of sites can address habitat loss and over-exploitation, two major causes of biodiversity loss. Site conservation can often include a significant degree of human use. Sites are, for these reasons, a major focus of conservation investment by government, donors and civil society. In particular, they form the basis of most protected area networks (BirdLife International 2004b, 2008b).

As well as being an important conservation focus in their own right, birds are, as a group, good indicators of wider biodiversity. This is because they have generally well understood distributions and habitat requirements; a greater amount of information is available on the status and distribution of the world's birds than is the case for any other major taxonomic group (BirdLife International 2004b, 2008b). They are, in addition, relatively easy to identify and record in the field and can act as flagships for conservation. Birds can be a highly effective means of setting geographical priorities for conservation in the absence of detailed information on other taxa (Brooks *et al.* 2001, Tushabe *et al.* 2006).

BirdLife's IBA programme therefore aims to identify, document, safeguard, manage and monitor a network of sites of international importance for birds, across the geographical range of **those bird species for which a site-based approach is appropriate**. Patterns of bird distribution are such that, in most cases, it is possible to select sites that support many species, so that conservation effort and resources can be applied most effectively.

Overall, the IBA programme is a method of identifying the most significant places on earth for birds. These sites—IBAs—can then form the basis for more detailed conservation planning, and the focus for practical advocacy, action and monitoring.

More details about the IBA Programme can be found at:
www.birdlife.org/action/science/sites/index.html

2.2 IBA Criteria

Important Bird Areas (IBAs) are identified using a standardised set of data-driven criteria and thresholds. As such, they ensure that the approach can be used consistently worldwide (Fishpool *et al.* 1998). When originally devised they were intended for application only in Europe as they were designed to be compatible with European Union legislation (Osieck and Mörzer Bruyns 1981, Grimmett and Jones 1989). Following the success of the approach in Europe, and the subsequent decision to extend the programme worldwide, it was apparent that there were numerous benefits—ease of understanding and usage, comparative analyses, power of justification and advocacy etc.—to adopting a standardised approach.

Rule Box 1: Categories and criteria used to select IBAs at the global level. Studies to date have shown that these criteria can be used to identify marine IBAs. Sites may qualify for multiple categories and criteria. To date only A1 and A4 have been applied for seabirds, the possibility (and benefits) of the application of A2 and A3 is currently being explored.

Category A1 - Globally Threatened Species
The site regularly holds significant numbers of a globally threatened species, or other species of global conservation concern.
The site qualifies if it is known, estimated or thought to hold a population of a species categorized on the IUCN Red List as globally threatened (Critical, Endangered and Vulnerable). The list of globally threatened species is maintained and updated annually by BirdLife International.
Category A2 - Restricted-range Species
The site is known or thought to hold a significant component of the group of species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA).
Endemic Bird Areas are defined as places where two or more species of restricted-range, defined as those whose global breeding distributions are of less than 50,000 km^2, occur together—see Stattersfield *et al.* (1998). A Secondary Area (SA) supports one or more restricted-range species, but does not qualify as an EBA because fewer than two species are entirely confined to it.
Category A3 - Biome-restricted Assemblages
The site is known or thought to hold a significant component of the group of species whose distributions are largely or wholly confined to one biome.
Biome-restricted assemblages are groups of species with largely shared distributions which occur mostly or entirely within all or part of a particular biome.
Category A4 - Congregations
i) Site known or thought to hold, on a regular basis, ≥ 1% of a biogeographic population of a congregatory waterbird species. *ii) Site known or thought to hold, on a regular basis, ≥ 1% of the global population of a congregatory seabird or terrestrial species.* *iii) Site known or thought to hold, on a regular basis, ≥ 20,000 waterbirds or ≥ 10,000 pairs of seabirds of one or more species.* *iv) Site known or thought to exceed thresholds set for migratory species at bottleneck sites.*

The resulting categories of IBA and the criteria used to select them at the global level are listed in Rule Box 1. The IBA categories and criteria refer to the two essential attributes used to identify priorities for conservation: vulnerability (A1) and irreplaceability (different aspects of which are covered by A2, A3 and A4). More detailed explanation of the criteria, and how they have been applied in different regions, can be found in Heath and Evans (2000), Fishpool and Evans (2001), BirdLife International (2004c), BirdLife International and Conservational International (2005), BirdLife International (2008a) and Devenish *et al.* (2009); see also the Datazone of www.birdlife.org.

3. Background to marine IBAs

Although the identification stage of the Important Bird Area programme is currently approaching 'completion' in terrestrial (including inland and coastal wetland) environments, the process is still at an early stage in the marine realm. Extending the IBA programme to the oceans, while a logical and significant development, has posed both conceptual and practical challenges.

As it did with the IBA programme at its inception, work on the means by which marine IBAs might be identified began in Europe, in response to the recognition that the European Union's Habitats and Birds Directives applied to waters under the national jurisdiction of the Member States. IBAs have formed a significant scientific reference for the designation of Special Protected Areas under the Birds Directive and it was therefore appropriate that the IBA selection criteria should be reviewed and, as necessary, adapted (and guidelines developed for their application), in order to use them to identify marine IBAs.

Rule Box 2: Four 'types' of different aspects of seabirds' at-sea activities recognised by Osieck (2004) that might be suitable for marine IBA identification.

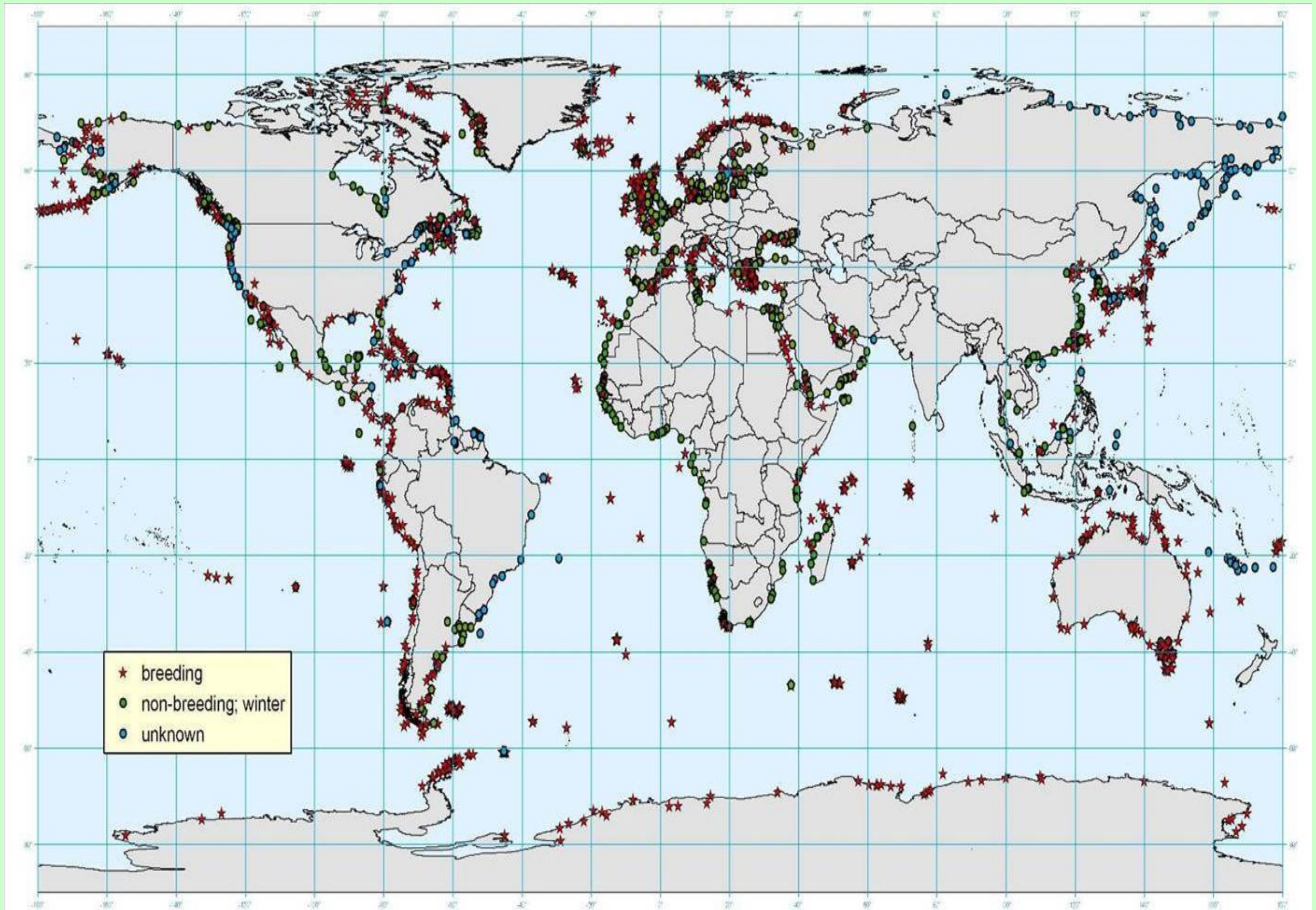
Seaward extensions to breeding colonies
While many seabird breeding colonies have already been identified as IBAs, their boundaries have been, in almost all cases, confined to the land on which the colonies are located. The boundaries of these sites can, in many cases, be extended to include those parts of the marine environment which are used by the colony for feeding, maintenance behaviours and social interactions. Such extensions are limited by the foraging range, depth and/or habitat preferences of the species concerned. The seaward boundary is, as far as possible, colony and/or species-specific, based on known or estimated foraging and maintenance behaviour.
Non-breeding (coastal) concentrations[2]
These include sites, usually in coastal areas, which hold feeding and moulting concentrations of waterbirds, such as divers, grebes and benthos-feeding ducks. They could also refer to coastal feeding areas for auks, shearwaters etc.
Migratory bottlenecks
These are sites whose geographic position means that seabirds fly over or round in the course of regular migration. These sites are normally determined by topographic features, such as headlands and straits.
Areas for pelagic species
These sites comprise marine areas remote from land at which pelagic seabirds regularly gather in large numbers, whether to feed or for other purposes. These areas usually coincide with specific oceanographic features, such as shelf-breaks, eddies and upwellings, and their biological productivity is invariably high.

Osieck (2004) reviewed all marine IBA-relevant work within the European Union up to that date and distinguished four 'types' of marine IBAs, shown in Rule Box 2. These have formed the basis for subsequent studies into how the existing criteria and boundary delimitation guidelines need to be adapted for marine application and to assess the extent to which each type is amenable to site-based conservation.

Following work undertaken by BirdLife Partners in Europe, it was concluded that the identification of IBAs and the application of IBA criteria in the marine environment is possible under the existing IBA criteria. These studies concluded that some methodologies are generally applicable to account for the practical challenges of identification and delimitation of marine IBAs. The conclusions from these projects have been further tested and amended as appropriate, to ensure that the methodologies used are applicable on a global scale.

[2] It should be noted that there is some overlap between non-breeding (coastal) congregations and areas for pelagic species which are continuations of a theme.

Example Box 1: Global map of existing IBAs triggered by seabirds, showing season of occurrence of trigger species at a site. Data correct as of August 2008. Data courtesy of BirdLife International World Bird Database.



In 2007 Birdlife conducted an analysis of the existing IBA datasets to identify the IBAs which may be considered as candidate marine IBAs, on the basis of the seabird species they hold which trigger IBA criteria (Howgate and Lascelles 2007). This study found that across 158 countries and territories worldwide, some 2,106 IBAs have been identified because they hold more than threshold numbers of one or more seabird species. The study was updated in 2008, and attempted to assign each IBA to one or more of the four types of marine IBA recognised by Osieck (2004). This highlighted the fact that over 1,300 sites potentially require boundary revisions to include high-use marine areas close to breeding colonies. It also found that a further 600 or so IBAs have been identified for seabirds when on passage and during the non-breeding season, but that fewer than 15 truly pelagic sites had been identified and delimited.

4. Marine IBA identification protocol

This document outlines a general protocol to follow when identifying and delimiting marine IBAs, following this scheme should be seen as the ideal scenario, that will result in the most robust and defensible sites. The process has been broadly broken down into 8 steps that can be followed, shown in Rule Box 3.

Rule Box 3: An outline of the steps to follow when undertaking a marine IBA programme, and the relevant sections of this document that cover each step.

1. Identify list of priority species for marine IBA analysis (based on e.g. data availability, threat status, convention listing). **Section 5.**

2. Data gathering. **Section 6.**
    a. Gather available data on seabird-distribution (both self-collected and from external sources), as well as data on environmental variables (e.g. for habitat modelling, boundary delimitation).

    b. Create Geographical Information System (GIS) layers of these data on a species by species basis. Environmental variables and seabird distributions at sea should be organised to allow comparison between different months/seasons/years. If it is not possible to convert data into a GIS-compatible format, these can still be used as supporting information

3. Determine which layers should be regarded as primary and supplementary for identification and delineation (apply weightings as appropriate). **Section 7.**

4. Identify candidate sites for each species (using the methodologies and guidance that follows to ensure a consistent approach). **Section 6.**

5. Apply IBA criteria and thresholds to candidate sites on a species by species basis, to confirm they merit being identified as marine IBAs. **Section 8.**

6. Delimit final boundaries for sites triggering IBA criteria. When appropriate, overlap sites for different species located in the same area to merge them into a single marine IBA. Re apply IBA criteria for the final delimited area as required. **Section 9.**

7. Produce IBA site description and propose IBA in the World Bird Database. **Section 10.**

8. IBA reviewed and confirmed or rejected by BirdLife Secretariat

It should be noted that, depending on the data availability within specific countries/regions, it may be possible to identify marine IBAs without following steps 1-6 shown in Rule Box 3. However, this scheme should be seen as the ideal scenario that will result in a consistent global approach.

Large areas of the marine environment remain unsurveyed for seabirds in a systematic manner, particularly in areas beyond national jurisdiction, and for those that have been surveyed there is often a lack of temporal data making it difficult to determine how regularly important areas really are. Ban (2009) reviewed the number of datasets required to identify candidate sites for Marine Protected Areas (MPAs), and found that there was a degree of diminishing returns upon adding further datasets, such that sites identified using existing datasets, despite their limitations, did not alter greatly with the subsequent addition of new datasets. Ban (2009) recommended proceeding with MPA planning with existing datasets, rather than postponing planning in favour of further data collection.

5. Identifying priority species for marine IBA analysis

BirdLife taxonomy (BirdLife International 2009a) currently recognises approximately 340 extant species as seabirds, defined as species for which a large proportion of the total population rely on the marine environment for at-least part of the year (see Rule Box 4).

In theory all seabird species are suitable for a marine IBA analysis, though some marine IBA projects have found it useful to define a list of priority species in the first instance. This list could be defined using threat status, inclusion on relevant policy agreements, or other means to decide which species may be seen as the highest priority. Data availability may also play a role in deciding which species are most suitable for a marine IBA analysis.

Some species (e.g. some Pterodroma) feed in such a dispersed manner at sea that they are unlikely to ever reach IBA threshold numbers in any location. This means that conservation of them might be better achieved through broader, ocean basin level, conservation measures and management rather than a marine IBA site based approach. This should also be considered when defining a priority species list and also in the analysis of sites that follows. The IBA guidance (BirdLife International 2009b) states that "*not all species may be suitable for an IBA approach*" and the same holds true in the marine environment.

Threatened species of seabirds are clearly a priority for conservation action, and suitable management of the most important at-sea areas for these species is likely to be vital. The current red list status of each species can be checked via the Birdlife datazone www.birdlife.org/datazone/species/index

Some species are also listed as priorities for action within various conservation agreements (e.g. EU Bird's Directive, Agreement on the Conservation of Albatrosses and Petrels, Convention on Migratory Species). Species that are listed on relevant international, regional and/or national agreements should be considered as priorities for marine IBA analysis. Being listed on a convention often provides a legal mechanism for promoting the most important sites for protection and/or management with signatory countries.

Data availability is also likely to play a role in determining which species are priorities for marine IBA analysis. Clearly trying to identify sites at-sea for a poorly known Pterodroma with few confirmed sightings is going to be much more difficult than defining sites for well studied species whose at-sea distribution and abundance are well known.

Rule Box 4: Showing bird families that are considered seabirds by BirdLife International, also showing the type of marine IBA that may be most relevant for each family, the likely key data sources for species in these families, and the relevant IBA criteria under A4 (which distinguishes between waterbirds as defined by Ramsar and uses Waterbirds Population Estimates published by Wetlands International to determine thresholds, and more traditional seabirds).

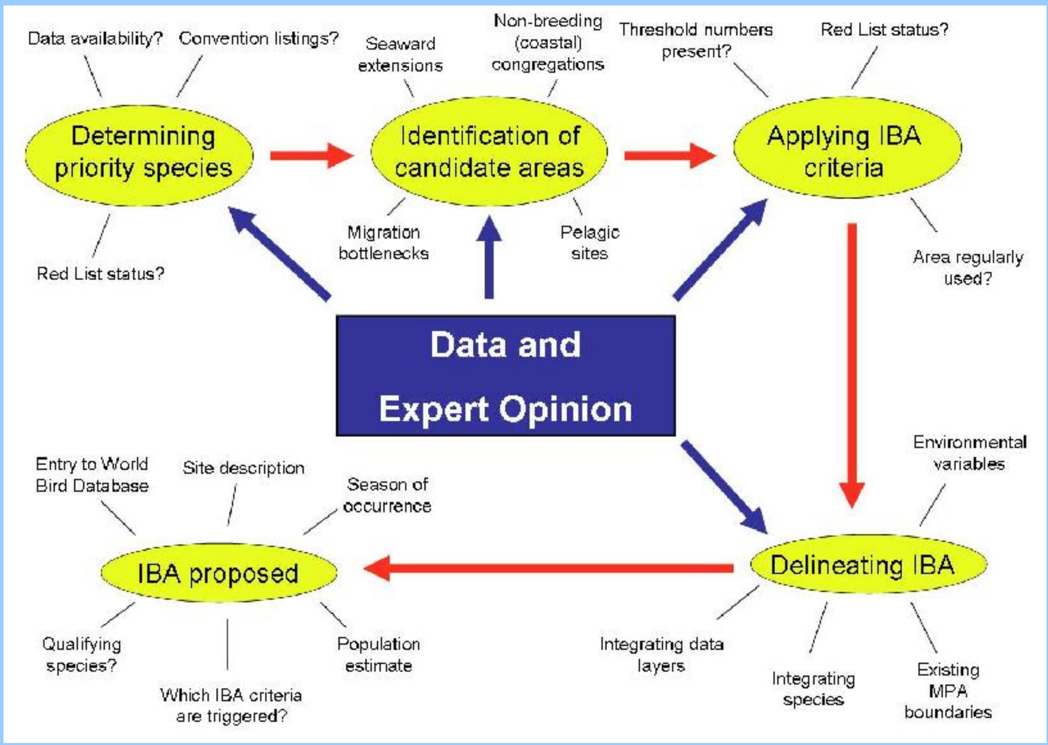
few = applicable to a few species from this family at some sites; some = applicable to some species from this family at some sites; most = applicable to most species from this family at some sites; all = applicable to all species from this family at some sites; ? = unknown

Family latin name	Family common name	Type of marine IBA				Key data sources & their usefulness					IBA criteria	
		Seaward extension	Non-breeding coastal congregation	Migration bottleneck	Pelagic sites	BirdLife SBFRD	tracking	at-sea survey	habitat modelling	observation from land	A4i	A4ii
Merginae	seaduck	few	all	some	few	most	few	most	all	most	yes	
Podicipediformes	grebes	few	all	some	few	most	few	most	all	most	yes	
Gaviidae	divers	few	all	some	few	most	few	most	all	most	yes	
Spheniscidae	penguins	all	some	few	most	most	most	most	most	few		yes
Diomedeidae	albatrosses	some	some	few	all	few	all	most	some	few		yes
Procellariidae	fulmars, prions, shearwaters, gadfly and other petrels	some	most	most	all	some	some	some	some	some		yes
Pelacanoididae	diving-petrels	?	most	few	some	few	few	some	few	few		yes
Hydrobatidae	storm-petrels	?	few	few	some	few	few	some	few	few		yes
Pelecanidae	pelicans	all	most	few	some	most	most	most	some	most	yes	
Sulidae	gannets and boobies	all	most	some	some	most	most	most	most	most		yes
Phalacrocoracidae	cormorants	all	most	few	few	all	few	most	all	all	yes	
Fregatidae	frigatebirds	?	some	?	some	few	some	some	none	few		yes
Phaethontidae	tropicbirds	?	?	?	few	few	some	some	none	few		yes
Stercorariidae	skuas	some	some	few	some	some	few	most	few	few		yes
Laridae	gulls	some	most	most	some	most	few	most	some	most	yes	
Sternidae	terns	all	most	most	few	all	few	most	most	most	yes	
Alcidae	auks	all	most	most	few	all	some	most	most	some		yes

6. Data sources

All marine IBA studies to date have found that data play a fundamental role in both the identification and delimitation of marine IBAs (see Rule Box 5). They have demonstrated that data gathering and analysis is perhaps of greater importance than on land, because of the extra challenges in the identification and delineation of defensible sites and boundaries in often apparently featureless seascapes. This section covers the key data sources for marine IBA identification, and recommends methods for their analysis.

Rule Box 5: Flow chart showing how data and expert opinion form a central part of marine IBA identification, and can be used to inform each stage of the process.



Data-gathering is usually focused around a combination of four major sources: a) At-sea surveys b) Land-based counts of breeding populations and/or of migratory/passage seabirds c) Seabird tracking and d) Literature reviews and expert opinion.

Data analysis uses a combination of various techniques to help: a) Create density and distribution grids for species and/or areas b) Develop predictive distribution and density models for each species based on its relation to a number of environmental variables and c) Apply numerical thresholds to highlight those sites that qualify as marine IBAs.

The collection of data on the at-sea distribution of seabirds is time consuming and expensive and long time-series are often needed before clear patterns of predictable distribution and usage emerge. However, there is already much information available on seabird distribution at-sea, collected via a range of survey techniques, though these have rarely been collated in a consistent manner, which is necessary to undertake analyses of the most important sites. In the first instance it will be helpful to conduct a literature review to determine what data exist, who the data holders are, and what some of the limitations to the datasets might be.

Data from seabird tracking studies and at-sea surveys are likely to be the core component of any marine IBA analysis, and gathering and obtaining access to relevant datasets is an important step. To date there have been few attempts to collate this data into common databases, either at national, regional or global scales, a few examples of where this has occurred are shown in Information Box 1, and these sites can be used to begin the data gathering process.

Information Box 1: Examples of databases that have collated data on the at-sea distribution of seabirds

- Ocean Biogeographic Information System (OBIS): www.iobis.org
- Global Procellariiform Tracking Database: www.seabirdtracking.org
- Global Sea Turtle network: www.seaturtle.org
- North Pacific Pelagic Seabird Database (NPPSD) http://alaska.usgs.gov/science/biology/nppsd/index.php

Information on oceanographic variables is likely to provide important complementary information to any marine IBA study, and will help provide guidance for selecting final IBA boundaries, inputting to habitat suitability models and predicting locations of candidate sites in unsurveyed areas. Some of the most helpful oceanographic data layers for marine IBAs are shown in Information Box 2

Information Box 2: Key environmental variables that have been shown to be useful in predicting seabird distribution at-sea.

Environmental Variable	Source	Format
Bathymetry	http://www.bodc.ac.uk/data/online_delivery/gebco/	One Minute arc Grid
Salinity	http://www.nodc.noaa.gov/General/salinity.html	Not remotely sensed, from cruise data
Upwellings/eddies		
Seamounts	http://seamounts.sdsc.edu/	Grid references
Wind speed	http://podaac.jpl.nasa.gov/DATA_CATALOG/quikscatinfo.html	Range of products and resolutions
Sea surface temperature	http://www.cdc.noaa.gov/data/gridded/data.noaa.oisst.v2.html	Monthly Mean and Long Term Mean
Chlorophyll a	http://oceancolor.gsfc.nasa.gov/ftp.html	Daily, Monthly, Seasonal, Annual
Distance from land	http://aprsworld.net/gisdata/world/	Land Shapefile, distance must be calculated using Arc Spatial Analyst.

Once data are collected they need to be analysed to allow for the identification of candidate sites, this is most easily achieved through use of Geographic Information Systems (GIS), where layers of data can be created and combined for different species, seasons, years and areas as appropriate.

The following section looks at some of the datasets that have proved to be important in the identification of marine IBA to date, and highlights approaches that have been used to analyse the data. It also outlines some key considerations for each dataset, and identifies some of the limitations.

6.1 Identification of breeding sites and seaward extensions

Identifying seabird colonies that fulfil IBA criteria is perhaps the simplest starting point when initiating a marine IBA programme. In many cases these colonies have already been identified as IBAs during terrestrial analysis (see Howgate and Lascelles 2007), which is approaching full coverage globally. In some cases these IBAs already contain marine extensions, although almost always these have been shown to be insufficient in size or shape by more in-depth assessments.

Reviewing existing IBAs triggered by breeding seabirds to determine those that may require boundary alterations is a priority step. Identifying the most important at-sea areas around these breeding colonies is vital to ensure that the areas used most intensively by the breeding population are adequately included within the IBA network. Identification and subsequent management of these areas is likely to ensure that sufficient resources (i.e. food) are available to allow for successful breeding, and thus recruitment to the wider population, to take place.

For those breeding sites that have not yet been assessed against IBA criteria there are often historical data available via the literature to determine whether threshold numbers of seabirds are found at a site, and would thus qualify as an IBA. Even where good data do not exist, site visits to assess the number of birds present is often relatively straightforward, though this can be logistically difficult and/or expensive at some locations.

Colonies represent locations where large numbers of birds are predictably present for a defined proportion of the year. During this time, at-sea activities of breeding birds are invariably geographically restricted. A seabird's foraging range is determined by the complex interaction of many factors. The wide variation in maximum foraging ranges among species is ultimately determined by phylogeny: the inheritance of physical and behavioural characteristics that impose constraints on their foraging ecology. The duration of their incubation shifts, chick metabolism, the need for chick defence, mode of carrying prey and flight dynamics combine to impose physiological outer limits on the range over which they can forage if they are to breed successfully (e.g. Flint 1991, Ricklefs and Schew 1994).

Ideally, remote-tracking of an adequate sample of individuals of each IBA trigger species at each site should be carried out over several years to identify the most important areas. However, the resources required to do this mean that this is not likely to be feasible for more than a few sites. Therefore, we have to use empirical data on the foraging preferences of species studied at one site to model or estimate foraging ranges at other sites. We may also need to extrapolate from well-studied species to close relatives (e.g. congeners) for which no, or insufficient, data are available. Care should, of course, be taken in drawing conclusions when doing this and, wherever possible, the most closely related and/or ecologically most similar species should be used as surrogates.

One simple approach to identifying the most important areas around breeding colonies is to use foraging distances ('foraging radius') to define boundaries, on the basis that this will encompass most of the key foraging habitats required by a species when breeding. With this in mind, BirdLife has compiled a database of seabird foraging ranges and ecology. The aim of the database is to provide an authoritative global dataset that can be used as a key tool to help delimit the extent of marine IBAs adjacent to major breeding colonies, as well as highlight gaps in our knowledge of foraging behaviour and thus priorities for future research.

6.2 BirdLife International Seabird Foraging Range Database

Compiling the database has involved a comprehensive review and collation of published information on seabird foraging behaviour. Additional information has been sought from a large number of seabird experts worldwide, who have helped identify and fill gaps via the provision of further references or of unpublished information. The results of the literature review have been transferred to the database, where entries include as much as possible of the following information; date and location of the study, stage of the breeding season, foraging distance, trip duration, dive depth, habitat/prey associations, data quality and survey methods.

Species and/or family factsheets providing information from key foraging studies and references are being created to illustrate how the proposed distances and delimitation approaches might be selected for each species.

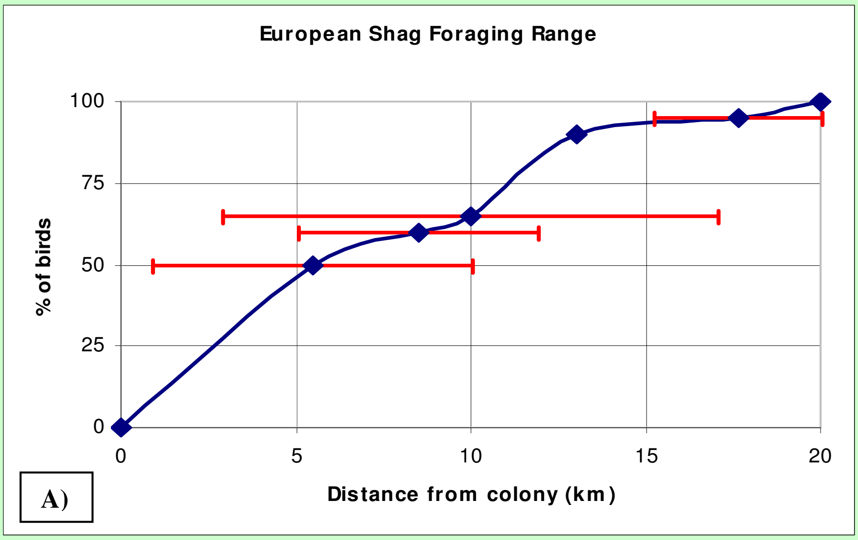
With this information it has been possible to develop some standardised approaches to marine IBA identification and delimitation using foraging radii as a basis. Such an approach has been used before to guide the seaward extension of seabird IBAs (e.g. RSPB 2000), but this was based on a geographically limited literature review and provided more general guidelines for suites of species. By making the BirdLife Seabird Foraging Database as site- and species-specific as possible and, where appropriate, combining this information with environmental variables known to be important to each species (e.g. bathymetry, habitat associations, key prey species), identification and delimitation may be made as accurately as possible, and should minimise the inclusion of less significant areas within an IBA.

Information contained in the BirdLife Seabird Foraging Database was provided to, and tested by; BirdLife Partners in France, by the Ligue pour la Protection des Oiseaux (LPO), and Italy, by the Liga Italinana Protezione Uccelli (LIPU), as well as by a marine research institute in Peru, Centro para la Sostenibilidad Ambiental at Universidad Peruana Cayetano Heredia (CSA-UPCH). These tests have confirmed the utility of the database. They also highlighted that the approach may not be suitable for those species that forage at great distances from the colony, since the size of the areas encompassed are likely to be of limited use in management terms and/or as IBA boundaries.

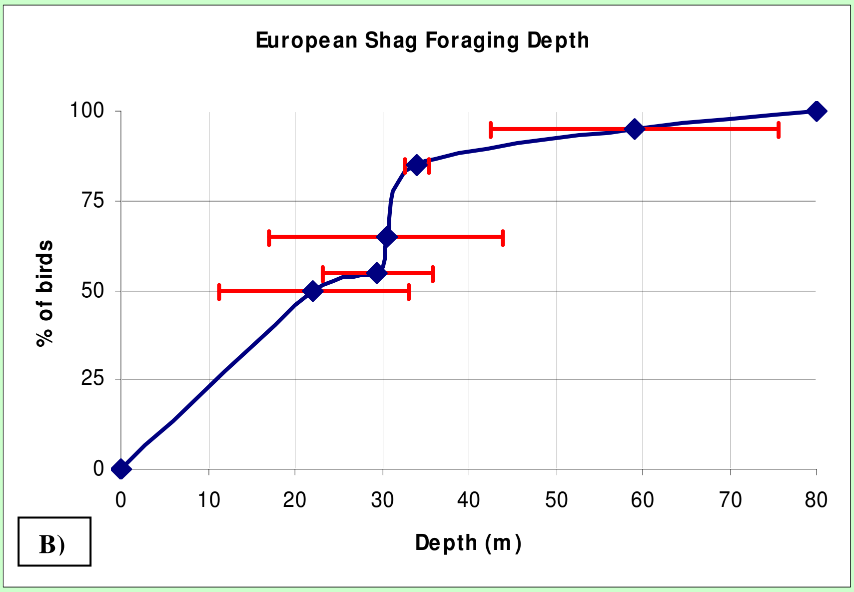
Rule Box 6 explains how the process of a seaward extension may be undertaken. It shows a theoretical example of the application of the foraging distance approach at a breeding site of the European Shag *Phalacrocorax aristotelis*. The example uses the information held within the BirdLife Seabird Foraging Range Database to promote key distances, depths and habitats for this species (summarised in Example Box 2). The same process could be applied for any species, though the distances, habitats and depths used will vary. This approach promotes the use of a consistent methodology, while also taking account of local conditions, and allowing for site-specific boundaries to be determined based on the best available information for a given species. The resulting map is a simple foraging habitat suitability model, and shows likely key feeding areas around breeding colonies during the breeding season. Based on existing knowledge of the foraging range and behaviour of a given species, these areas are likely to hold significantly higher numbers of birds than surrounding areas of less suitable habitat. A small amount of additional data is often available (e.g. from land-based observation or at-sea surveys) which can often lend support to the identification of these areas, and thus confirm their inclusion within the IBA network.

Example Box 2: Summary information from the BirdLife Seabird Foraging Range Database for the European Shag *Phalacrocorax aristotelis*

- *Foraging range:* Max 20km, mean max 16.93km, mean 6.53km
- *Foraging depth:* Max 80m, mean max 53.5m, mean 24.91m
- *Foraging trip duration:* mean 1.42 hrs (n=10)
- *Key habitats:* Shallow waters, sandbanks, gravel banks, tidal flow
- *Key prey items:* Benthic, demersal and schooling, pelagic fish, especially sandeels



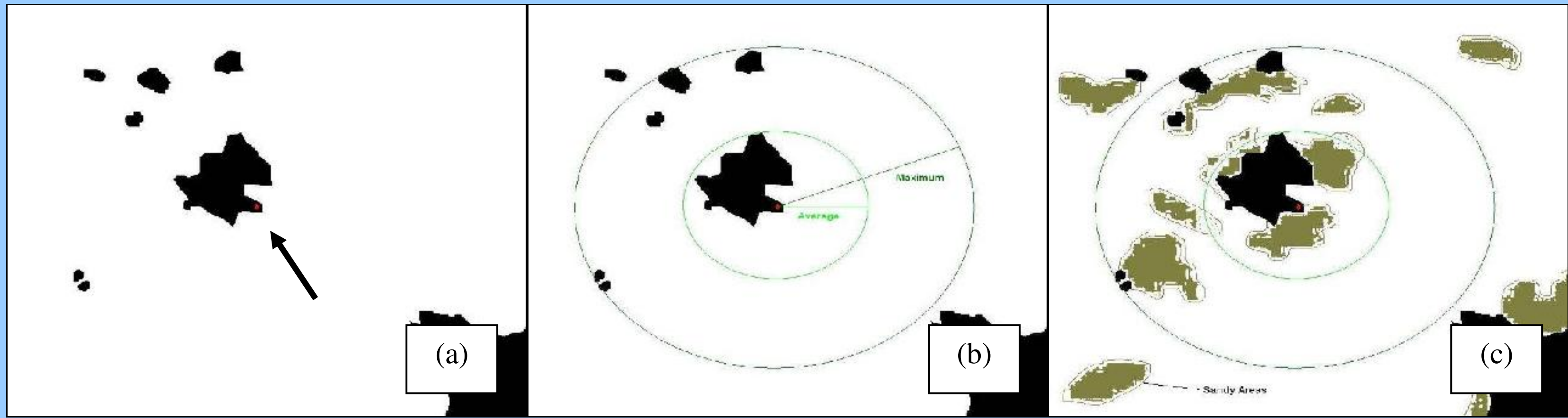
A) Cumulative frequency (with standard deviation), and proportion (%) of birds found foraging at different distances from the colony. At 20km (the maximum foraging range given) 100% of the birds are found between here and the colony. Source: BirdLife Seabird Foraging Range Database.



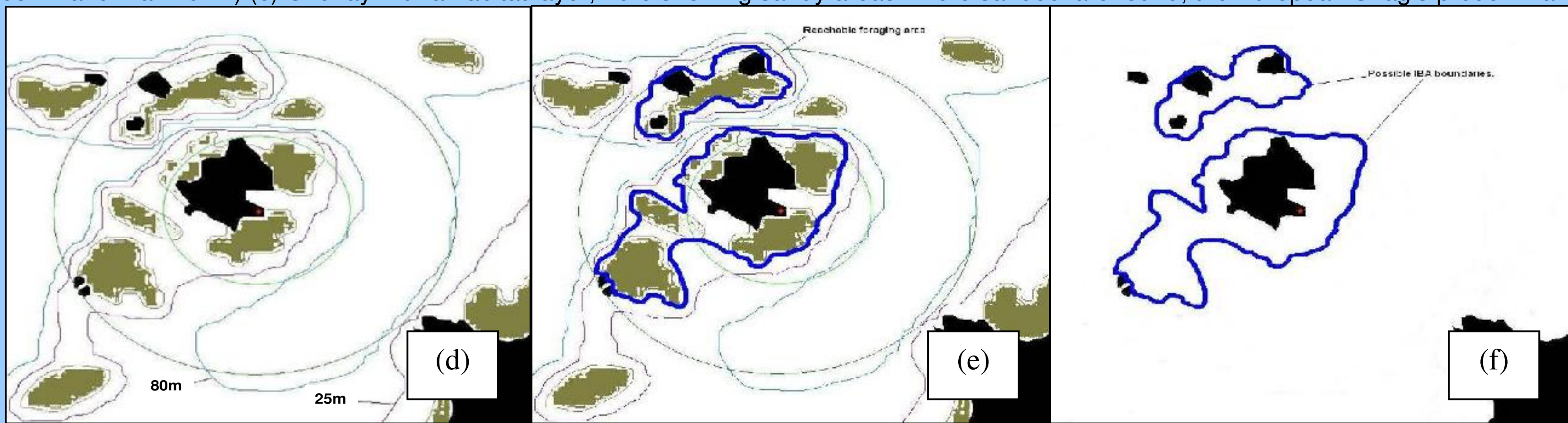
B) Cumulative frequency (with standard deviation), and proportion (%) of birds found within different foraging depths around the colony. At 80m (the maximum foraging depth recorded) 100% of the birds are found between here and the surface. Source: BirdLife Seabird Foraging Range Database

If you would like to conduct an IBA investigation using the seaward-extension approach and require information on particular species held within the BirdLife Seabird Foraging Range Database, contact seabirds@birdlife.org.

Rule Box 6: Theoretical example of the application of the foraging distance approach at a breeding site of the European Shag *Phalacrocorax aristotelis*. Foraging range, dive depth and habitat preferences taken from BirdLife Seabird Foraging Range Database.



(a) Red spot (with arrow) represents the location of the breeding colony IBA. (b) Apply average and maximum foraging radii around the colony (in this case mean 6.53km and max 20km).(c) Overlay with a habitat layer, here showing sandy areas where sandeel are found, the European Shag's predominant prey.



(d) Overlay with a bathymetry layer: here the 25m and 80m contours are shown; the European Shag can dive to a maximum of 80m depth (mean 24.91m)
(e) Based on the foraging ecology of this species we can determine which sandy areas lie within 20km of the colony, and at a depth of <80m, and are thus likely foraging areas. (e) The boundaries to these areas can be isolated and used to form possible IBA boundaries.

6.3 Expert opinion

To date, the process of marine IBA identification and delimitation has been guided by systematic, data-driven methods to ensure consistency of approach and comparability between species and regions. However, use of data-driven methods should not preclude the use of information from expert workshops or other previous approaches for setting conservation priorities. Indeed, an initial step in identifying potential at-sea areas is often to use expert opinion, which is generally readily available and inexpensive. Moreover, such consultation fosters increased participation in, and understanding of, the process, and does not require digitized information—participants can use existing maps and overlays to make proposals.

However there can be drawbacks with adopting expert led approaches. Ervin *et al.* (2010) found that solely using expert opinion to optimize the connectivity of sites for multiple species requires effective group decision-making and leadership, a clear understanding of the needs of each species and the effects of different scenarios and tradeoffs, and, typically, is very time consuming. Baldwin *et al.* (2008) found that expert recommendations reflected strongly the missions and goals of their parent organizations and recommended that expert opinion, if integrated into conservation planning research, be documented and interpreted according to qualitative research methods, so that practitioners and researchers may understand how planning decisions were made, and improve the replicability of conservation planning studies.

Example Box 3: Expert led approach to identifying candidate marine IBAs in the California Current

As part of the Barrow to Baja Initiative, partners convened a technical committee to discuss seabird species, datasets, and to identify candidate marine IBAs. Invited experts had spent many years working on seabirds in the region. Eight wall-sized maps with bathymetry were produced that showed candidate marine IBAs identified by the Howgate and Lascelles (2007) report. These were marked as squares on the map and colour-coded to indicate where IBA criteria had been met. Experts then annotated the maps. A note taker was stationed at each set of maps to capture the expert comments and details of the relevant datasets. Experts were also encouraged to draw boundaries with knowledge of foraging in mind. Note that fewer IBAs were selected by the experts than were identified by Howgate and Lascelles (2007). The expert drawn candidate marine IBAs were then digitized into GIS and validated with survey data in subsequent steps. The expert maps were also used to help guide boundary delimitation and determine when to aggregate sites.

A candidate list of marine IBAs may be identified based on the literature review, by organising expert workshops, or contacting experts remotely and asking them to indicate the areas they think may be most suitable as IBAs (see Example Box 3). Participatory mapping approaches have been extensively developed while expert workshops to designate priority areas have been used successfully in the past across a wide range of taxa. Expert opinion is likely to help refine the process in all stages of marine IBA identification and can be particularly important when inferring the results of data analysis and determining if a network of sites is appropriate.

An initial list of marine sites identified by expert opinion is highly likely to require additional data to confirm their status as IBAs. Underlying data are often vital to assessing if criteria have been met, and in defining boundaries that are both readily understandable and defensible, particularly if the sites are going to be used to advocate for management and/or protection.

6.4 Tracking Data

Recent advances in technology have meant that tracking devices can be attached to a wide range of seabirds, and can yield vital information on seabird distribution over space and time (see Burger and Shaffer 2008 for an overview), thus providing a key tool for conservation in the marine environment (Bigrad *et al.* 2010). Tracking data are likely to form a core component of any marine IBA analysis.

A particular benefit of tracking data is that it provides excellent information on the distribution of tracked birds across time and space, making it possible to identify areas that are used most intensively over prolonged periods. However, one issue is that results will generally be based on small sample sizes compared to the overall population, and extrapolating results from tracked individuals to the wider population can be problematic. This is because tracking data cannot usually provide information on overall abundance within a given area, which is necessarily important when assessing a site against IBA thresholds. Where possible, additional sources such as at-sea survey data should be used to provide this kind of information, and confirm abundance within high use areas.

There are a variety of tracking devices available, and the methods for collection, analysis and interpretation of data from each device need to be carefully considered to ensure that information is used in the most appropriate manner. Information Box 3 compares six tracking devices that are commonly used to study seabird distribution.

Once data have been collected from these devices it needs to be analysed. Ultimately the task is to use location data (points) to propose IBA boundaries (areas representative at the population level). Seabirds undertake a number of different activities during their time at sea, including feeding, travelling, roosting, resting and courtship, some or all of which may be suitable for inclusion in the IBA network. Data can often been treated or filtered to identify candidate sites prior to defining IBAs at the population level. During this process it may be possible to determine what activity is occurring in each area.

Marine IBA studies based on tracking data have generally focused on seabird feeding areas as priority sites, as this is where highest concentrations of birds most frequently occur and because of their role in maintaining overall populations (linked to energy acquisition). It is also important to consider that for the IBA criteria to be applicable threshold numbers of birds need to be known or though to be present, and this is most likely in areas holding high concentrations or experiencing regular turn-over of birds through a site.

Information Box 3: Comparison of six devices currently available and commonly used for tracking seabirds, all these characteristics need to be considered when choosing the most appropriate device for a given seabird, and the choice of device can affect the future analysis and interpretation of data.

Tracking Method	Accuracy	Scale of areas identified[3]	Weight (grams)	Lifespan of device	Data recovery	Logistics & constraints	Cost
Global Positioning Satellite (GPS) – loggers	High (metres)	Macro Meso Micro	Medium to heavy (≥ 10g)	Low (days to weeks)	Device recovery necessary	Tagging team needs to be at site for several days/weeks	Medium
Platform Terminal Transmitters (PTT)	Medium (few km)	Macro Meso	Medium to heavy (≥ 9g)	High (solar powered devices up to years)	Real-time data downloaded via satellite	Requires renting of satellite time	Medium-High
Argos / GPS-PTT	High (metres)	Macro Meso Micro	Heavy (≥ 22g)	High (solar powered devices up to 1+ years)	Real-time data downloaded via satellite	Requires renting of satellite time Few fixes stored each day	High
Very High Frequency (VHF) Radio-tags	Medium (few km)	Macro Meso	Light (< 1g)	Medium (weeks to months)	Real-time collection of data at site	Requires >1 team working simultaneously to gather good quality data	Low-Medium
Geolocators (GLS) - loggers	Low (>100 km) Poor accuracy near equator and equinoxes	Macro	Light (≤ 1g)	Medium to high (up to 3+ years)	Device recovery necessary	Data analysis complex, may need expert assistance	Low-Medium
Compass - loggers	Medium (few km)	Macro Meso	Medium to Heavy (≥ 17g)	Low (days to weeks)	Device recovery necessary	Tagging team needs to be at site for several days/weeks Data analysis complex	Medium

[3] For the purposes of IBA identification, we propose to classify seabird at-sea distribution on the following scale:
- Mega-scale (>3000 km²); approximates to a regional scale
- Macro-scale (1000-3000 km²); relates to areas of higher or lower productivity within them (e.g. frontal zones)
- Meso-scale (100-1000 km²); relates to the interactions between larger scale features (e.g. eddies)
- Micro-scale (1-100 km²); relates to specific parts of large scale features, or specific individual features (e.g. seamounts)

Example Box 4: Untreated PTT tracks of Laysan Albatross *Phoebastria immutabilis*, obtained from non-breeding birds tagged in the Aleutian Islands (n = 18 tracks); breeders at Tern Island, French Frigate Shoals, Hawaii (n = 174); and breeders at Guadalupe, Mexico (n = 101).

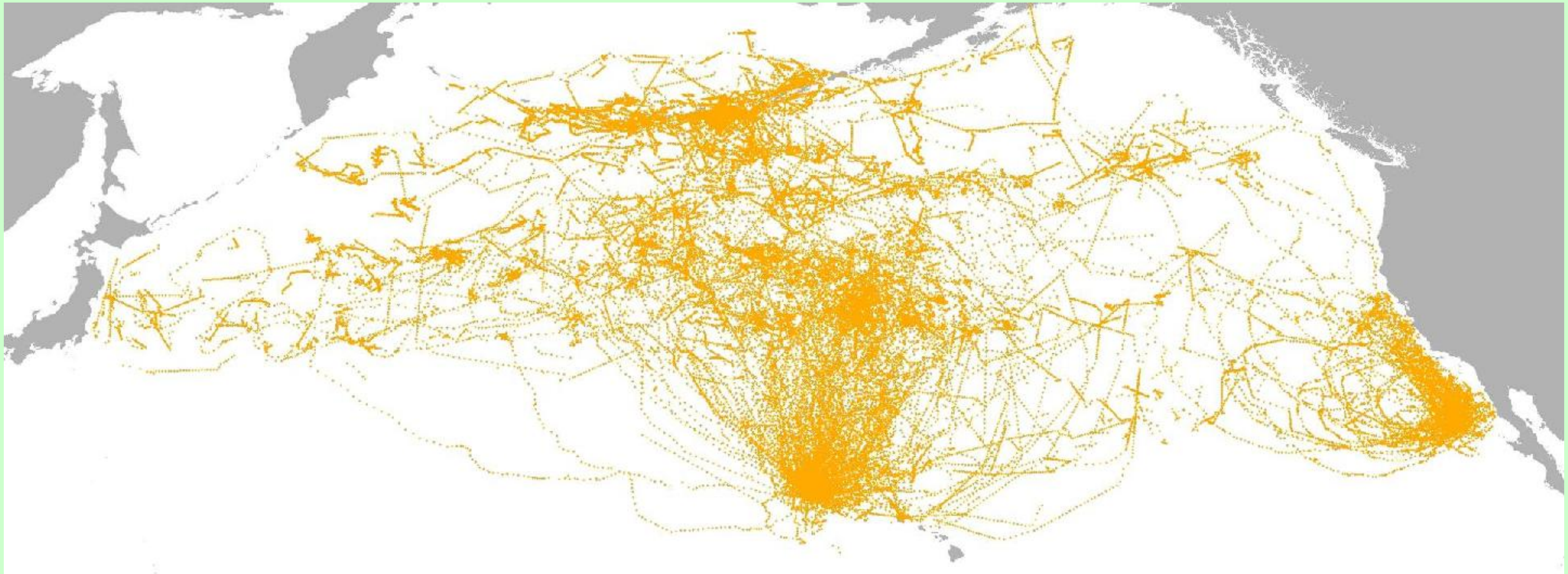


Image courtesy of the Global Procellariiform Tracking Database. Tracking data provided by Dave Anderson (Wake Forest University), Rob Suryan (Oregon State University), Scott Shaffer and Michelle Kappes (both University of California).

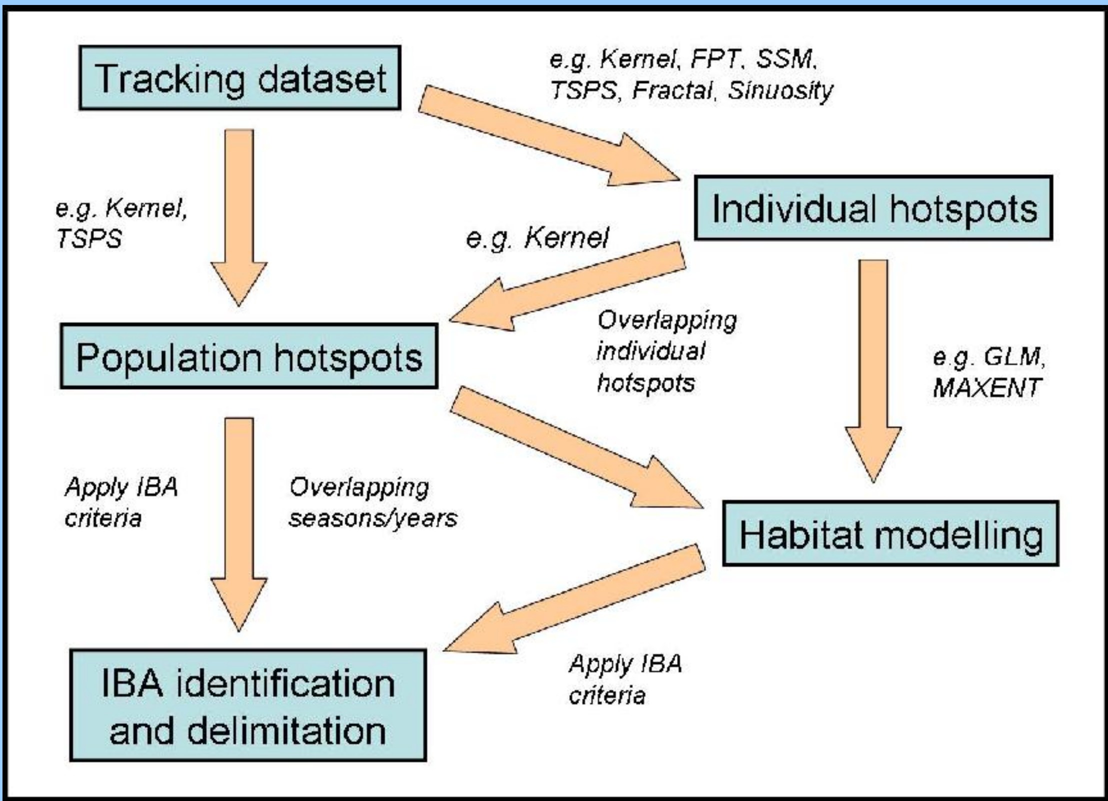
Example Box 4 shows an untreated PTT tracking dataset for the Laysan Albatross, and illustrates their extensive pelagic distribution across the North Pacific. A number of analyses can be performed on these data to identify the most important areas within them. However, it is important to consider a few issues inherent in such data before proceeding. These include the influence that the location of bird-capture sites may have on the dataset as a whole; large peaks of activity often occur close to the capture site and may mask other important areas occurring at a distance (so it may be worth determining the main areas around capture sites initially, and then filtering the data to remove these points so that more distant sites can be identified more easily).

6.4.1 Best practice analysis

To assess some of the issues relating to the use of tracking data for marine IBA identification purposes, BirdLife convened a meeting entitled "Using seabird satellite tracking data to identify marine IBAs: a workshop to determine how to achieve this" which was held at the Centre National de la Recherche Scientifique's (CNRS) Chizé laboratory, France in June 2009.

This workshop was attended by thirty international experts. They provided tracking data obtained from a variety of seabird families and across a wide range of geographical areas (e.g. tropical, temperate, and polar). The workshop discussed and tested more widely the proposed methodologies resulting from the experiences of marine IBA identification in Spain and Portugal and refined them where necessary, to ensure their applicability to as wide a range of datasets as possible. A full report of this workshop can requested from seabirds@birdlife.org, and provides detailed discussion of many techniques for analysing tracking data. Some of the key findings are highlighted here.

Rule Box 7: Flow chart showing possible steps to follow for using tracking datasets to identify and delimit marine IBAs.



A range of analysis techniques are available to assess a tracking dataset and make inferences about the most important areas within it (e.g. Barraquand and Benhamou 2008; Johnson *et al.* 2008). The Chizé workshop considered six. Some techniques are more suited to an analysis of individual tracks while others can be applied to an entire dataset (see Information Box 4). Having identified the most intensively used areas via any of the available methodologies it may be useful to apply habitat modelling techniques to assist with delimiting boundaries and to find other areas of equally suitable habitat (see section 6.6 for further information on habitat suitability modelling).

Information Box 4: Comparison of analysis techniques for treating tracking data to identify candidate marine IBAs. Analysis techniques shown in white can only be applied to single tracks; whereas those in grey can be applied either to single tracks or entire datasets.

Analysis technique	Positives	Negatives	Level of training/expertise required	Key references
Sinuosity	Already based on bird behaviour Time explicit	May not be suitable for GLS	Low (can be used with any spreadsheet)	Benhamou (2004) Grémillet *et al.* (2004)
Fractal	Already based on bird behaviour Time explicit	May not be suitable for GLS	Medium to High	With (1994) Tremblay *et al.* (2007)
First-Passage Time (FPT)	Already based on bird behaviour Time explicit	Scale important as the birds search areas varies within it Cannot be used with GLS	Medium to High (needs use of complex software, e.g. R)	Fauchald and Tavera, (2003) Pinaud and Weimerskirch (2005)
State-Space Modelling (SSM)	Useful for noisy data (e.g. GLS) Assigns behaviour to each point	Complex to conduct Time consuming Needs additional understanding of species ecology	High	Patterson *et al.* (2008) Eckert *et al.* (2008)
Time Spent Per Square (TSPS)	Simple approach Time implicit	Results similar to kernel analysis but on a coarser scale	Medium (needs use of complex software, e.g. R)	Lopez-Mendilaharsu *et al.* (2009)
Kernel analysis	Quick and easy approach for hotspot analysis	Dependent on smoothing factor (h) If multiple tracks are merged individuals can bias results	Medium to Low	Horne and Garton. (2006b) BirdLife International (2004c)

Sinuosity, fractal, first-passage time and state-space modelling analyses all look to treat the data on a track-by-track basis. They attempt to define areas of importance in each track by isolating area-restricted search behaviour (i.e. behaviour related to feeding). While this information may be important in showing foraging areas, for IBA purposes these analyses need to be conducted on a track-by-track basis and the results then combined to identify the most important areas used by the tracked population.

Time spent per square (TSPS) and kernel analyses are suitable for analysis of individual tracks or whole datasets, and provide values showing the relative use of areas by the tracked individuals; they may therefore be very useful in identifying high-use areas. When applied to a single track, TSPS and kernel analyses identify areas used intensively by that tracked individual; when applied to an entire dataset they identify areas used intensively by the tracked population. The latter is very useful when handling large amounts of data. However, both techniques are very sensitive to sample bias; should the sample size be too small or the dataset biased towards one life-history stage or age category a complete dataset analysis would overestimate the importance of the regions being used by those stages/ages. This sensitivity should be kept in mind and when the dataset is considered too skewed, it may be more appropriate to analyse the tracks individually.

Rule Box 8: Chizé workshop conclusions on techniques for the analysis of tracking data to identify marine IBAs

Further trials (see Example Box 5) using the conclusions from the Chizé workshop, suggest that, regardless of the tracking data analysis technique employed, similar areas will be identified as important, although the actual outer boundaries of these may vary. Therefore, so far as a marine IBA analyses are concerned, no single analysis technique is especially favoured.

During the Chizé workshop and in the trials that followed, it has been possible to develop a number of GIS scripts that conduct the relevant analysis in an automated fashion.

The scripts developed to date include:

- first-passage time
- kernel
- time-spent-per cells

Further scripts under development

- Interpolation script
- Sinuosity
- Fractal

Using these scripts will help reduce the technical knowledge required for analysing tracking data, and should simply the process and help maintain a consistent approach. To obtain copies of the script please contact seabirds@birdlife.org.

Example Box 5: Comparison of tracking data analysis techniques showing that similar hotspots of activity can be identified using each. The example uses a track obtained from a Wandering Albatross *Diomedea exulans* tagged on South Georgia/Islas Georgias del Sur during the post-breeding period.
A). Kernel density analysis – 50% kernel. B). Sinuosity analysis – 180 degree turn within 10km.
C). Fractal analysis – 20km scale. D). First-Passage-Time analysis – 45km scale.

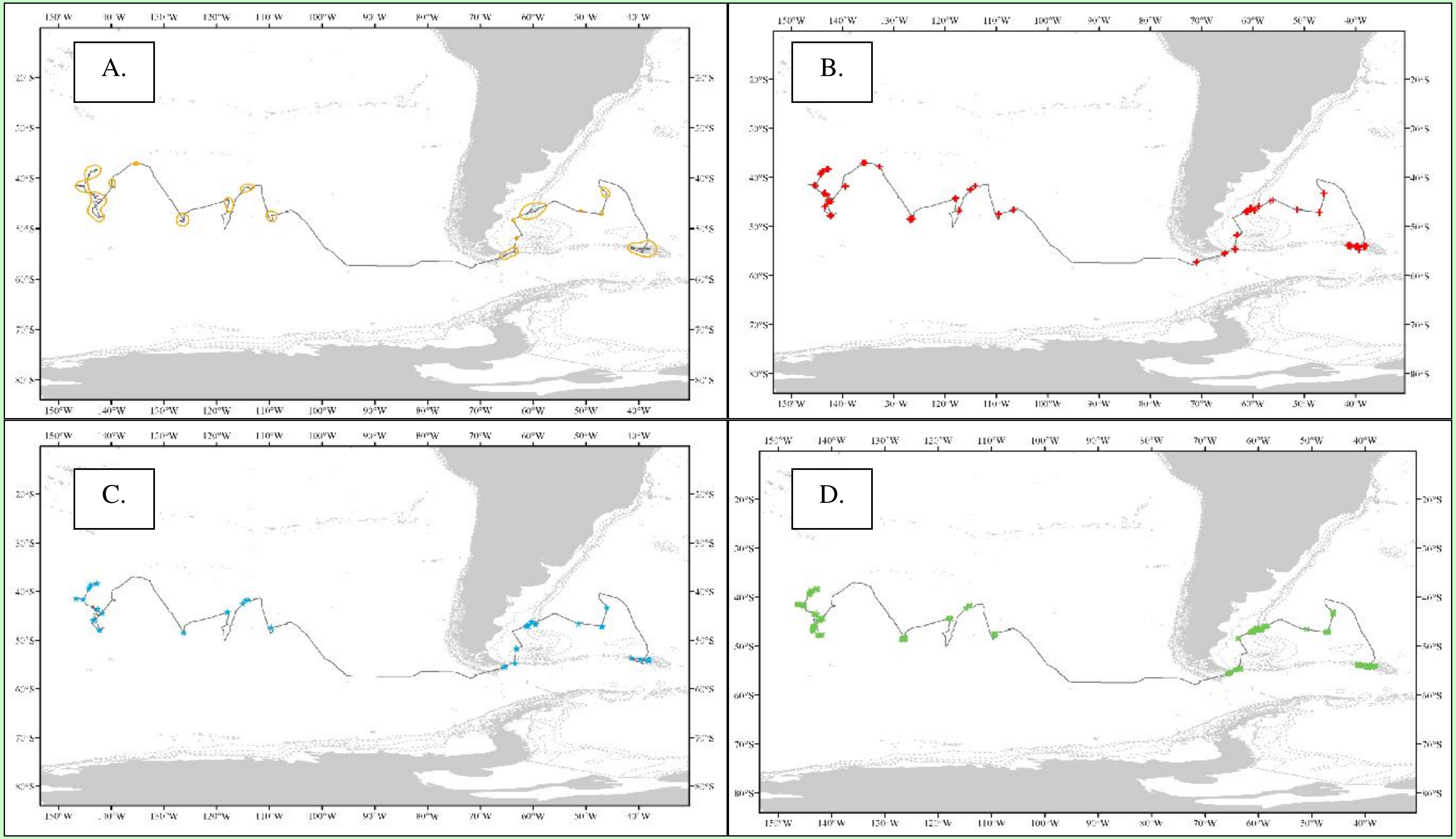


Image courtesy of the Global Procellariiform Tracking Database Data. Tracking data provided by Richard Phillips (British Antarctic Survey)

6.5 At-sea survey data

At-sea surveys have formed a central part of marine biology research for some time, although they can be costly and logistically difficult to undertake. At-sea survey data can be collected from either ship-board or aerial observation platforms. Variation in results between the different platforms may not be significant (Briggs *et al.* 1985, Ford *et al.* 2004, but see Camphuysen *et al.* 2004 for differences).

All kinds of at-sea survey data are likely to be useful for a marine IBA analysis, though the weighting given to each will vary with the exact methods of data collection and any biases involved. It should be considered that both ship-board and aerial surveys have limited capacity to determine bird age groups (e.g. adults vs. juveniles) and almost none to determine sex and provenance (see Information Box 5). While this does not cause significant problems for marine IBA identification, it does cause difficultly in linking at-sea feeding areas to specific colonies, and in determining if an area is encompassing the wider population of a species or only sex and/or age specific parts of the population.

Information Box 5: Comparison of aerial and ship surveys for achieving objectives

Survey/Monitoring Objective	Aircraft	Ship
1. Physical features relating to survey area		
Cover complex, low coastlines, and shallow water	***	*
Survey extensive areas of open water	***	***
Survey restricted areas of open water	*	***
Survey distant offshore waters	*	***
2. Complementary data, other than bird abundance and distribution		
Instantaneous gathering of complimentary oceanographic data	*	***
Flight lines and migration routes	*	**
Age/sex determination	*	**
Behavioural observations	*	**
Describing feeding patterns and foraging areas	**	***
Determining provenance (links to colonies)	*	*
3. Logistics and constraints		
Cost	**	*
Intensive coverage of small areas	*	**
Simultaneous coverage of large areas	***	*
4. Species surveys – distribution & abundance		
Divers – Gavia spp.	***	**
Large Procellariiform (e.g. shearwaters, albatross)	***	***
Small Procellariiform (e.g. storm-petrels)	*	**
Gannets and boobies – Sulidae spp.	***	***
Seaduck – e.g. eider, scoter	***	**
Gulls – Larid spp.	***	**
Terns – Sterna spp.	**	**
Auks – Alcid spp.	**	***
5. Species surveys – identification to species		
Divers – Gavia spp.	**	***
Large Procellariiform (e.g. shearwaters, albatross)	**	***
Small Procellariiform (e.g. storm-petrels)	*	**
Gannets and boobies – Sulidae spp.	***	***
Seaduck – e.g. eider, scoter	**	***
Gulls – Larid spp.	*	***
Terns – Sterna spp.	*	**
Auks – Alcid spp.	*	***

Source: adapted from Camphuysen *et al.* (2004)

By accurately collecting information on species distribution and abundance along systematic survey transects (Camphuysen and Garthe 2004, Webb and Durinck 1992), it is possible to calculate densities as well as create predictive models for assessing likely distribution in unsurveyed areas. Surveys that record both presence and absence are the most useful. Surveys that record presence only can also play a role, though they are likely to only provide supplementary information to be assessed in conjunction with other data sources.

6.5.1 Vessel-based surveys

Data collected from vessel-based surveys have proved to be very useful for the identification of marine IBAs because they allow estimates of seabird density and abundance to be calculated. They are, however, prone to a number of biases (Barbraud and Theibot, 2009). When designing a transect survey sample it is important to take these into consideration. Issues include:

- Repeat counting of birds (see Burnham *et al.*, 1980; Tasker *et al.* 1984; Gaston *et al.* 1987; Buckland *et al.* 1993)
- Imperfect detection ability (see Buckland *et al.* 1993; Becker *et al.* 1997, Barbraud and Thiebot 2009)
- Attraction vs repulsion of birds (see Wahl and Heinemann 1979; Hyrenbach 2001)
- Non-random sampling (see Buckland *et al.* 1993)

Repeat counting of birds is caused by a slow transect survey being repeatedly crossed by faster moving birds which are therefore likely to be receive multiple counts and thus overestimate the overall population. Tasker *et al.* (1984) developed a method that compensates for this bias by recording the number of birds within the survey transects at distinct intervals. This is now known as the ‘snapshot’ approach because of the sporadic and instantaneous nature of the survey counts. It is commonly used in at-sea surveys, usually at a frequency of no fewer than 10 minutes to allow for the birds that would have otherwise been counted twice to pass outside of the survey area. Numerous surveys (or slight variations of it) have used this method in a variety of geographic areas (see e.g. Ainley *et al.*, 1984; Piatt & Ford, 1993; Spear *et al.*, 1995; van der Meer & Leopold, 1995).

Spear *et al.* (1992) developed an alternative methodology known as the ‘vector’ approach that allows for continuous recording of seabird abundance during a transect, and removes repeat counting issues by recording ship speed and the flight speed and direction of each individual. This approach has been shown to increase accuracy (Clarke *et al.*, 2003).

As well as over-estimation issues, vessel-based surveys must also consider under-estimation caused by imperfect detection abilities, i.e. the probability the survey does not count all the birds that are within a transect. Rates of under-estimation are likely to vary with vessel type, weather condition, target species, experience of surveyors, height of surveyor above the water etc. Traditionally, surveys have determined the maximum distance from the surveying vessel in which detection probability is believed to be close to 1 (i.e. perfect detection), and used this as the transect width. In truth, however, detection probability is rarely as high as 1 (Barbraud and Thiebot, 2009). In order to account for this, as well as to allow for sightings from outside a fixed range to be included, many recent surveys have used distance sampling techniques (Buckland *et al.*, 1993), which allows estimates of detection probability to be made in multiple strips of varying distances from the vessel, which can then be used as correction factors when analysing overall density and abundance.

Finally, consideration should be given to the fact that vessel-based surveys may attract or scare off birds and this can bias the results accordingly. Many seabirds can be found following boats during surveys, and to avoid repeat counting issues it is recommended to conduct surveys of the water in front of the boat only. When a survey is specifically targeting species known to avoid vessels and therefore likely to avoid the survey area it may prove appropriate to survey areas well ahead of the boat, looking for birds before they have a chance to respond to the vessel.

Data collected from vessel-based surveys can be broadly split into three kinds; systematic surveys, random transect samples and ad-hoc presence-only samples, each are dealt with briefly below.

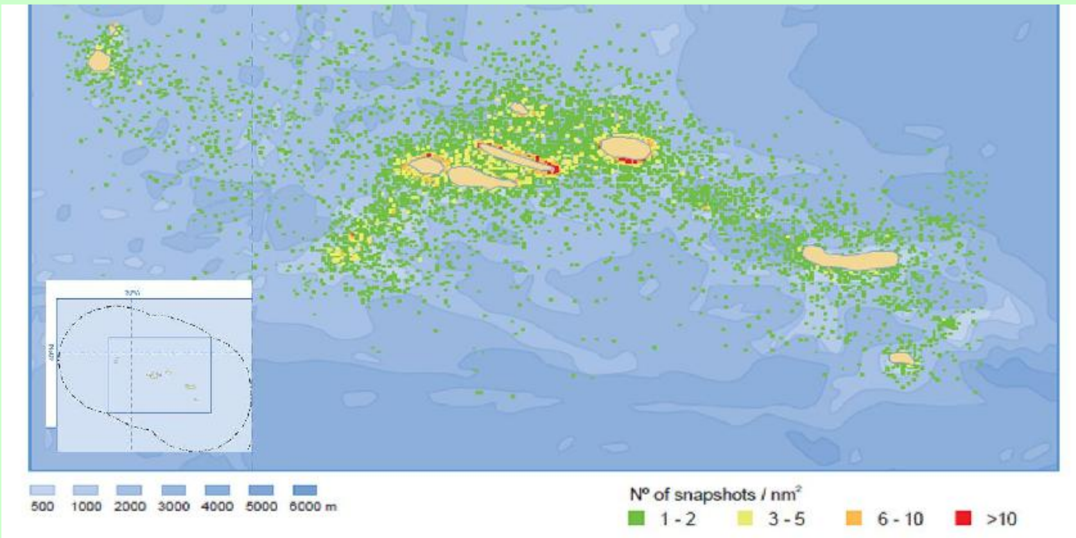
Systematic surveys

Exhaustive at-sea surveys over entire seabird ranges would involve covering such large areas that they are logistically prohibitive. Therefore, the most useful surveys are those designed and conducted in a systematic way, such that the data can be extrapolated reliably across the entire species' range. Where possible, transects should be designed to cover the study area in a systematic pattern, allowing maximum coverage and representation to the extremities of the area. Typically, such transects have been conducted perpendicular to the coast, perpendicular to each other or as a grid pattern.

Random transect samples

Issues of cost and logistics often limit access to platforms suitable for systematic at-sea surveys. In such cases, random transect sampling may be more appropriate (Ramírez *et al.*, 2008). Seabird surveys can often be made opportunistically on vessels with alternative primary functions (e.g. oceanographic research, coastguard, military, etc). Therefore, such studies have to make use of the transect already decided upon for the ship's primary use. This can be appropriate if the sample can be shown to be homogenous with the rest of the study area and the boat is not following specific oceanographic or biological features (e.g. like a fishing vessel following fish), as this is likely to result in significant biases. Hyrenbach *et al.* (2007) developed methods to determine the most appropriate strip width for conducting at-sea surveys of marine bird populations from platforms of opportunity.

Example Box 6: Number of seabird 'snapshots' recorded during opportunistic vessel-based surveys conducted in the Azores Archipelago, Portugal (2002-2006).



Data from Ramirez *et al.* (2008)

Ad-hoc presence-only samples

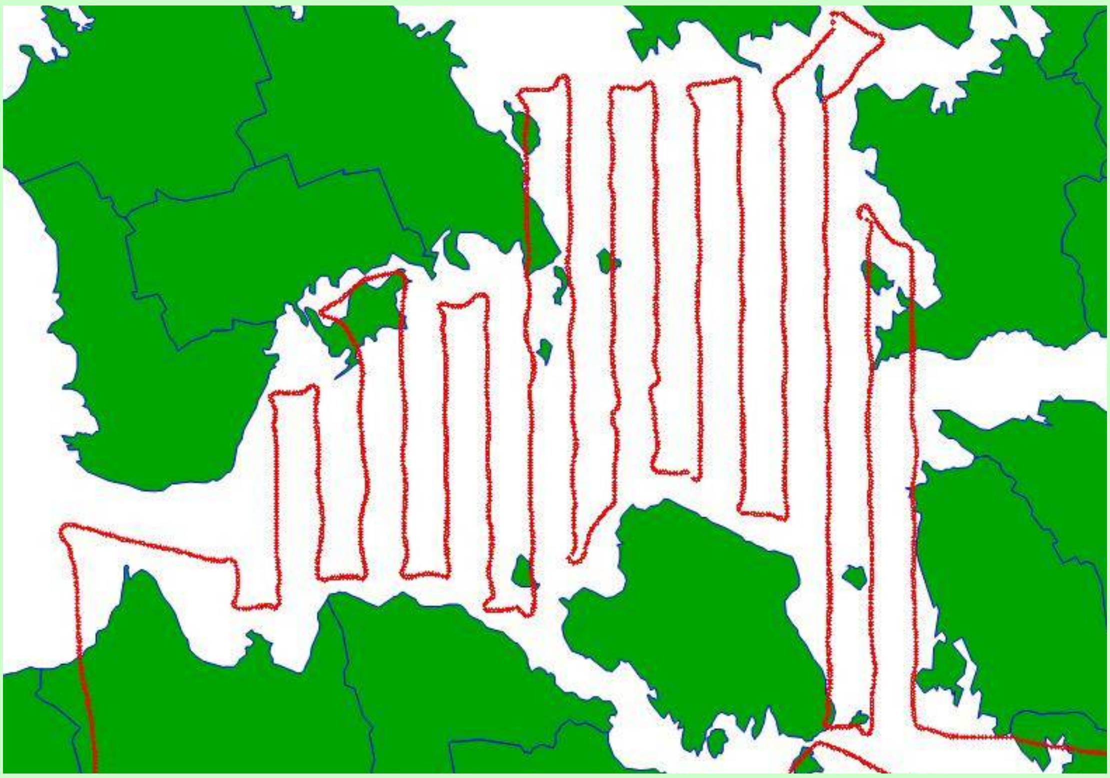
Much data on at-sea distribution are available from casual observations, such as those made during pelagic wildlife trips or on ferry crossings etc by citizen scientists. However, these data generally only record the presence of a species and, as such, their utility is limited. It is usually impossible to use these data to extrapolate to unsurveyed areas, though the data can prove useful for confirmation of candidate areas identified by other means (e.g. tracking data).

6.5.2 Aerial surveys

Aerial surveys can be particularly useful for surveying large areas in short periods of time, and are therefore useful in determining seabird distribution over greater scales than vessel-based surveys.

Aerial surveys may follow the same collection approaches as vessel-based surveys. However, fewer potential biases may be involved. In particular, it is not necessary to employ a snapshot methodology because observation flight speeds are faster than those of the birds, neither is it necessary to consider birds from the forward half of the platform only because, unlike boats, aircraft do not attract birds. Typically, airborne surveys employ a continuous-strip survey where any birds sighted are recorded, and are then analysed using the distance transect methodology described in Buckland *et al.* (1993).

Example Box 7: Aerial survey track (red line) flown on 9.05.2008 during the Estonian marine IBA LIFE Project. Transect lines are 3 km apart; Flight altitude during surveys was standardised at 100 m at a cruising speed of 170 km/ h (Cessna 172 aircraft) or 190 km/h (L-410 aircraft)



Data courtesy of Estonian Ornithological Society (EOS), BirdLife Partner in Estonia

For some taxa (e.g. terns, gulls, auks, divers) it can be difficult to identify to species level; other taxa (e.g. storm-petrels, phalaropes) are likely to be significantly under recorded due to their small size. Depending on the target of the surveys, it may be necessary to alter the height of transects to ensure that maximum detection probability and specific identification are achieved (Bretagnolle *et al.* 2003).

6.5.3 Assessment of at-sea survey data for IBAs

Many at-sea surveys have been undertaken, and in a few regions the results have been compiled into common databases (e.g. OBIS see Halpin *et al.* 2006); however, the majority of data collected from at-sea surveys have not been synthesised into common formats. For a marine IBA analysis it is necessary to identify the most important at-sea survey datasets (either through literature review or expert consultation) and seek access to the data.

While at-sea survey data only provides a snapshot of distribution and numbers at any given time (unless collected over many years), it can play a vital role in identifying the locations of candidate sites for marine IBAs, if threshold numbers of birds are exceeded, in informing habitat-suitability modelling (see section 6.6) and, ultimately, determining if sites qualify as IBAs.

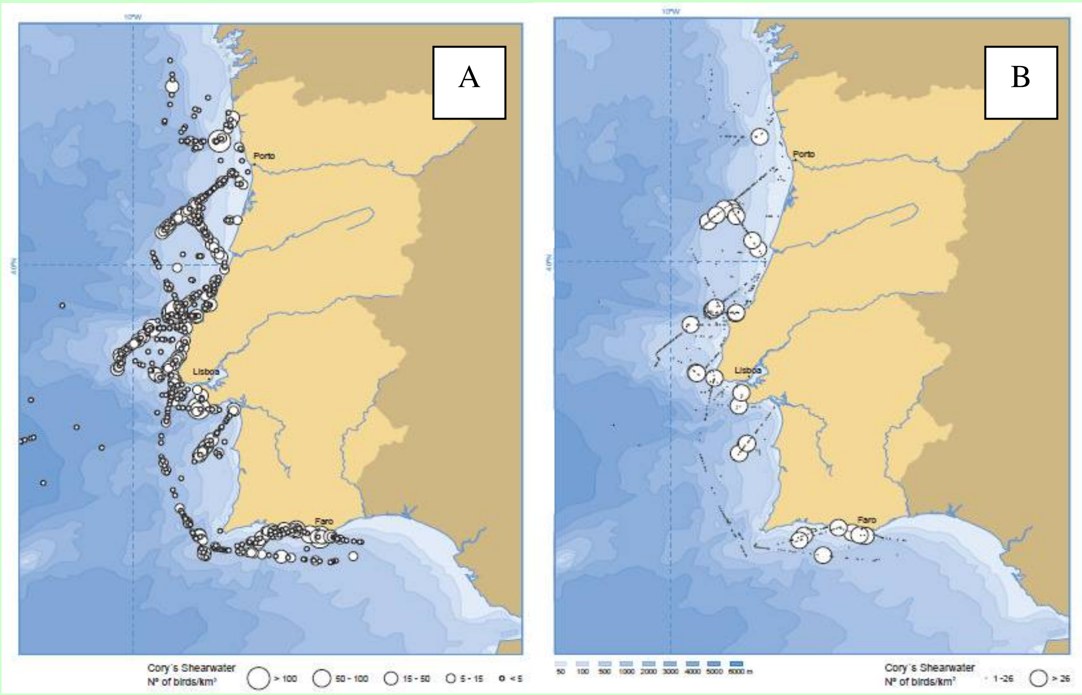
Raw data or those converted into density estimates (e.g. Ronconi and Burger 2009, Thomas *et al.* 2010) can easily be used to assess if IBA thresholds are met. Applying a scale which includes the relevant IBA threshold will clearly show the locations of observations that have recorded adequate numbers of birds. This approach may be most useful for threatened species with low population thresholds.

Raw data for some species can be messy and difficult to interpret, and previous marine IBA studies have found it useful to filter data using a 95th percentile to identify the locations of the largest numbers of birds identified during surveys (see Example Box 8). This approach is preferable to using a fixed threshold (e.g. 15 birds) as it maintains a consistency between species regardless of their relative overall abundance (i.e. the top 5% of observations are always shown).

Example Box 8: At-sea survey data showing the distribution of Cory's Shearwater *Calonectris diomedia* along the continental coast of Portugal during the breeding season (April to October, 2005-2007).

A). Shows raw data using a scale of values between 5 and 100 birds per km².

B). Shows the use of the 95th percentile (P = 26 birds/km²) to allow easier interpretation of the most important areas.



Data from Ramírez *et al.* (2008)

6.6 Habitat Modelling

Predictive models are based on the principles that equations and rule-sets can be constructed to represent the dynamics of a species distribution based on habitat preferences (Guisan and Zimmermann 2000). Ultimately, a habitat suitability model aims to identify suitable habitats within the core range of a species and provide a measure of the relationship between the two (Horne *et al.* 2008). 'Training' of these rules and equations are carried out using a 'training' dataset, i.e. a group of point localities indicating sites where the species has been detected (e.g. at-sea survey sightings or tracking data locations), and a series of maps of underlying environmental variables. Relationships between these datasets can be defined via a number of methods, some relatively simple and easy to interpret, whereas others, although often more accurate, are more complex and less easy to apply. The complex formulation of the algebra and rules within these models are discussed in detail by Guisan & Zimmerman (2000) and Hegel *et al.* (2010). However, to inform decisions on model suitability, a brief understanding of the main features of each of the most commonly used methods is given here.

There are now a number of automated software packages freely available that carry out the mathematical operations within the model, and require only limited input from the user (see Information Box 6). These include the BIOCLIM, DOMAIN, ENFA, GARP, Salford Systems softwares (TreeNet, RandomForest, MARS), Maxent software's and the 'gam', 'mcgv' and other codes for the main statistical packages (Valavanis *et al.*, 2008; MacLeod *et al.*, 2008; Guisan & Zimmerman, 2000).

6.6.1 Inputs to models

The choice of model is likely to be as much based on available data as it is on the desired outcome. There are three main types of input data: *presence-only* data, *presence-absence* data and *count* data. Presence-only data, although the least robust, is usually available in some form (e.g. museum specimens, opportunistic at-sea sightings, bycatch data); it is limited by the fact that no *absence* data are available. It is therefore not possible to differentiate between the limit of the species' range and the limit of the sampled area, nor whether clustered sightings actually represent a clustered population or are merely artefacts of uneven sample effort. Despite this, the availability of presence-only data and therefore the availability of presence-only predictions, make models based upon presence-only inputs well worth considering (Elith, *et al.* 2006).

It should be noted that tracking data may also be considered as a presence-only dataset, although their use in models is not normally possible with data in their raw form. Hotspots of activity are usually first defined via FPT, SSM, Fractal or Sinuosity Analyses and then used as 'training' data. This avoids the inclusion of sections of the track travelled by the individual where it is not actively using the associated environmental resources implied by the model.

In addition to the training dataset, predictive modelling requires data layers illustrating the distribution of various environmental variables. Some key variables shown to be of importance to seabirds include bathymetry, sea surface temperature, chlorophyll a distribution and distance from land. In recent years, these global datasets have become readily available via free online portals (see Information Box 2).

Information Box 6: Detailing six modelling approaches which have either already been applied to species in the marine environment or may potentially be useful in this context.

Modelling Approach	Tool	Key references
BIOCLIM	http://fennerschool.anu.edu.au/publications/software/anuclim/doc/bioclim.html	Busby, 1991 Wiley *et al.*, 2003
DOMAIN	http://alatools.pbworks.com/DOMAIN	Carpenter *et al.*, 1993 Valavanis *et al.*, 2008 Guisan & Zimmerman, 2000
ENFA	http://www2.unil.ch/biomapper/	Hirzel *et al.*, 2002 MacLeod *et al.*, 2008
GARP	http://www.nhm.ku.edu/desktopgarp/	Stockwell & Peters, 1999 Peterson & Kluza, 2003 Wiley *et al.*, 2003
Maxent	http://www.cs.princeton.edu/~schapire/maxent/	Phillips *et al.*, 2004 Yosh *et al.*, 2008 Kumar & Stohlgren, 2009
GAM	Available via MATLAB, S-Plus ("gam" command), R ("mgcv" package), etc.	Guisan *et al.*, 2002 Clarke *et al.*, 2003 MacLeod *et al.*, 2008 Moised & Frescino, 2002 Karnovsky *et al.*, 2005
GLM	Available via MATLAB, S-Plus ("gam" command), R ("mgcv" package), etc.	Canadas *et al.*, 2005 MacLeod *et al.*, 2008 Valavanis *et al.*, 2008

6.6.2 Assessment of habitat models for IBAs

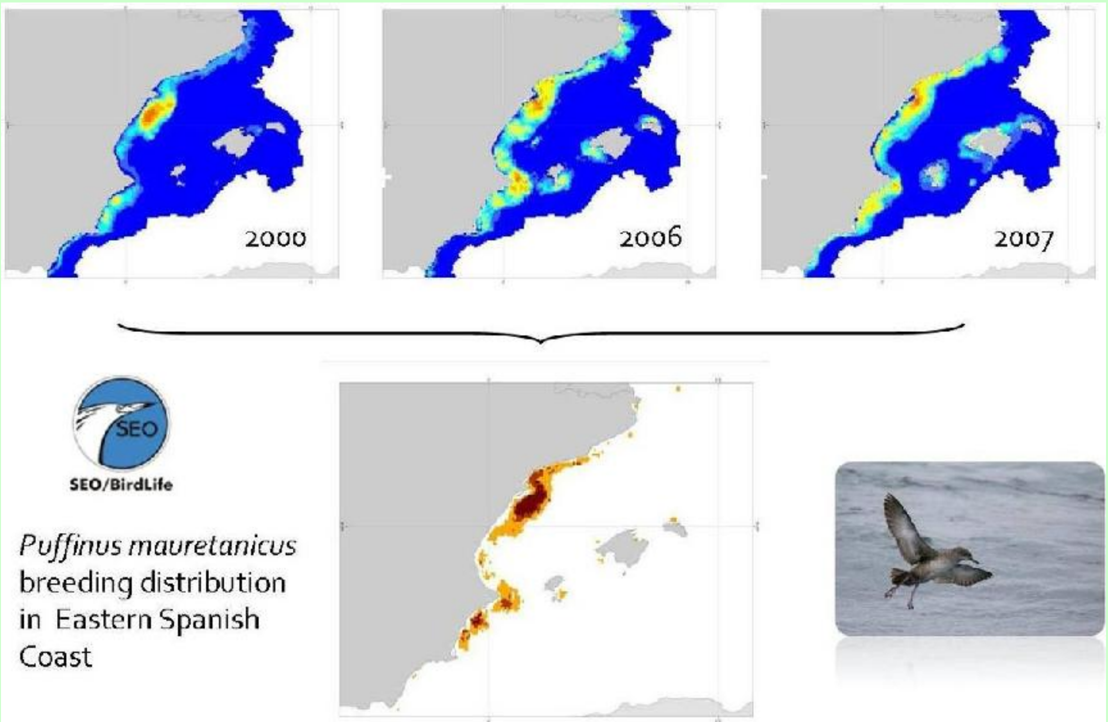
Three main uses of predictive habitat models have been outlined for marine IBA purposes:

- use of the suitable habitat estimations to delimit site boundaries,
- estimates of species abundance based on the probability of occurrence and/or direct density estimation,
- location of sites of apparently suitable habitat as priorities for future survey

During the marine IBA studies in Spain and Portugal no sites were identified based solely on data from models. In instances where the models explained the distribution of birds to a high degree, they were used to identify candidate areas, which were then confirmed with data from other sources (from boat-surveys not used in the model or from tracking data). However, in cases where the significance of the models was less good and varied depending on the species, location and time of year, it was concluded that such models should not be used to identify candidate sites.

Both projects found that integrating different yearly/seasonal models to highlight the areas predicted to be used most regularly was a helpful approach for identifying candidate sites (see Example Box 9 below). This was a good technique for determining the regularity of use of a site, see section 8.1.

Example Box 9: Integrating predictive habitat suitability models for the Balearic Shearwater *Puffinus mauretanicus* to show areas predicted to be used in multiple years



Data courtesy of SEO/BirdLife, BirdLife Partner in Spain.

Both projects found models to be very useful in defining IBA boundaries, and also in estimating the number of birds using a given area. For the latter, this was always based on the most conservative estimates in the models, so that the predicted populations were always minima, thereby increasing confidence that IBA thresholds had been met.

6.7 Other data sources

6.7.1 Bycatch and counts from fishing vessels
Fishing activities often provide a reliable supply of food for seabirds, including some items not naturally available to them. Wahle and Heinemann (1979) found that the mean abundance of seabird species is greater near potential attractants (fishing vessels) than away from them, and concluded that birds may be attracted to fishing vessels from up to 12 km away, with large vessels drawing birds from greater distances. Skov and Durinck (2001) also suggested that the scale of attraction of seabirds by fishing vessels occurred on a local scale (<10km). Distribution and abundance data collected from fishing vessels are therefore clearly biased.

Accidental bycatch during fishing activities has proved to be one of the greatest threats to seabird populations globally (see e.g. Nel and Taylor 2003; Lewison *et al.* 2005). In recent years many fisheries have implemented observer programs, where levels and locations of bycatch are recorded (e.g. Anderson *et al.* 2009). These provide information (points) on seabird distribution and abundance at-sea. However, there are clearly similar biases involved as with other counts from fishing vessels.

Therefore, candidate marine IBAs should not be identified solely on the basis of either bycatch data or distribution data collected from fishing vessels. However, data from either source may provide useful supportive information and could be used for confirmation of areas identified using less biased data sources.

6.7.2 Land-based observations
Much seabird data exist in the form of counts from coastal watch points such as headlands and bottlenecks. These can be useful for assessing seasonal distribution and abundance around particular locations (e.g. Clarke and Schulz 2005). Data collected from land have proved useful for identifying important rafting areas of shearwaters around breeding colonies (Ramírez *et al.* 2008), for assessing the number of seabirds passing through bottleneck sites (Arcos *et al.* 2009), and for assessing the overall distribution of some species that are restricted to the near-shore environment (Paiva *et al.* 2007). However, there are some important factors to consider:

- distribution of seabirds in the near-shore environment is often tied to weather events (e.g. there are likely to be more birds recorded during periods when there is a strong onshore wind)
- Recording of birds is limited by line of sight, which is likely to vary with the weather conditions, and also the species involved.
- There are issues relating to imperfect detection probability

6.7.3 Radar
Radar has been used to study bird movement in a range of locations, and through ground-truthing it is often possible to identify species (or merely families) on the basis of speed, flight behaviour and radar signal strength (e.g. Reynolds *et al.* 1997, Hamer *et al.* 1995).

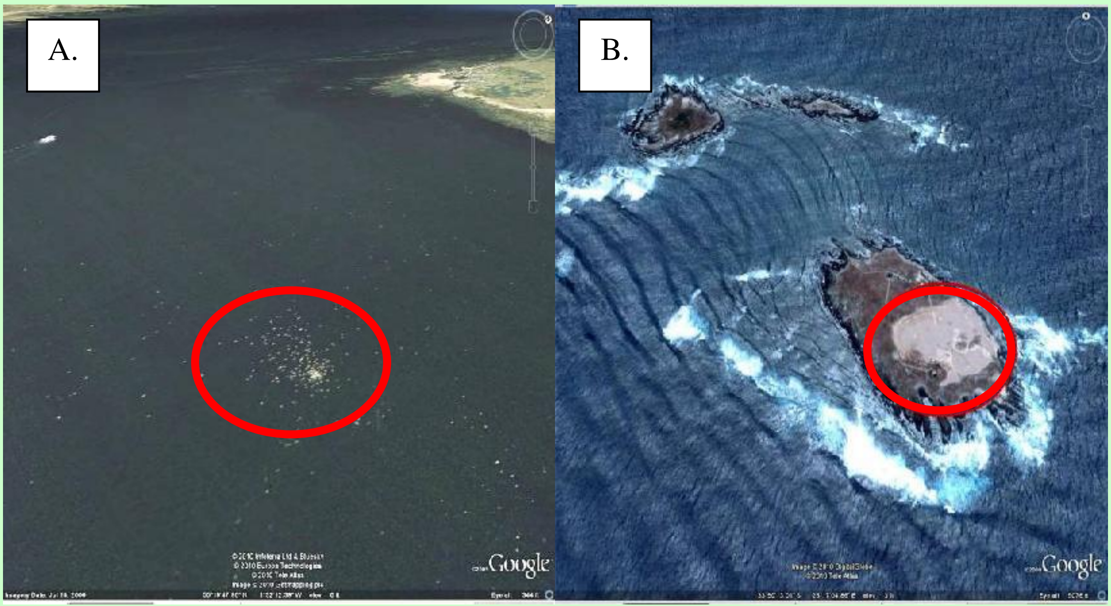
However, to date, the majority of studies using radar in relation to seabirds have occurred around breeding sites, and have been used to assess species and abundance in these areas. Its application at-sea would appear more problematic, as radar studies need to be undertaken from fixed anchor points, and this may only be possible from the largest vessels. Radar may offer some interesting possibilities for assessing the number of birds passing through seabird bottlenecks (e.g. Burger 1997).

6.7.4 Satellite imagery

With the expansion of remote sensing technologies, more and more detailed images of the earth's surface are becoming available, often for free (e.g. through Google Earth) or at reasonable price. This has provided a new resource for conservation planning, management and monitoring (see e.g. Kerr and Ostrovsky, 2003; Turner *et al.*, 2003; Buchanan *et al.*, 2008), although its uses in the marine environment have not yet been fully explored.

Fine-scale remote-sensing imagery of the oceans remains incomplete at a global scale and purchasing and viewing images of vast areas of ocean is both impractical and uneconomic. However, coverage of coastal areas (including at-sea) is more complete and much is viewable through Google Earth. While it may not be possible to search for and identify new sites through this medium at present (though this has not been tested), it may be possible to look for areas of congregation around known breeding colonies, or assess the amount of habitat being used for breeding by some species (see Example Box 10), particularly those species that nest colonially in the open and deposit large amounts of guano.

Example Box 10: Examples of seabird aggregations identified with Google Earth.
A). Apparent seabird feeding aggregation (terns or gulls?) off the coast of Coquet Island, Northumberland, UK; an IBA for large numbers of breeding terns, gulls and other seabirds.
B). Cape Gannet *Morus capensis* breeding colony on Bird Island, South Africa, an IBA for this species.



Source: Google Earth

A recent example of how remote sensing has been used to identify and delimit seabird breeding sites comes from Antarctica. Fretwell and Trathan (2009) used Landsat satellite images (see Information Box 7) to detect faecal staining of ice by Emperor Penguins *Aptenodytes forsteri* associated with their colony locations. The whole Antarctic continental coastline was analysed, and identified a total of 38 of these, 10 were new locations.

Information Box 7: Online remote sensing data sources, sensor descriptions, and learning resources.

Online remote sensing tutorials:
http://www.ccrs.nrcan.gc.ca/ccrs/learn/learn_e.html;
http://rst.gsfc.nasa.gov/start.html;
http://www.research.umbc.edu/~tbenja1/

Abbreviations: AVHRR, Advanced Very High Resolution Radiometer; CORINE, Coordination of Information on the Environment; HRVIR, High Resolution Visible and Infrared; MODIS, Moderate Resolution Imaging Spectroradiometer; NDVI, Normalized Difference Vegetation Index; NOAA, National Oceanic and Atmospheric Administration; NVCS, National Vegetation Classification System; SPOT, Systeme Probatoire d'Observation de la Terre; USGS, US Geological Survey; VGT, Vegetation sensor onboard SPOT 4 and 5 satellites.

Data source / information link	Spatial resolution (m)	Description	Website
Freely available satellite datasets for ecological applications			
Global and NDVI	1100 - 4000	AVHRR global/continental land cover products using six different classification schemes. Monthly NDVI composites. Data derived from 1992/1993	http://edcdaac.usgs.gov/glcc/glcc_version1.html#Global
SPOT/VGT composites	1000	10-day composites available from 1998 to present for SPOT4/SPOT5 vegetation sensors	http://free.vgt.vito.be/
University of Maryland Global Land cover Facility	Various	Very large satellite data archive including land cover products and processed satellite imagery with global coverage	http://glcf.umiacs.umd.edu/index.shtml
Global Land Cover 2000	1000	Global land cover mapping initiative based on vegetation data; will comprise a core data set for the global Millennium Ecosystem Assessment	http://www.gvm.sai.jrc.it/glc2000/defaultGLC2000.htm http://www.millenniumassessment.org
CORINE data page	250	High-resolution European land cover data	http://dataservice.eea.eu.int/dataservice/metadetails.asp?table=landcover&i=1
Canadian spatial data	Various	Various satellite and geospatial data	http://geogratis.cgdi.gc.ca/frames.html
USGS Gap Analysis Program	30	Classified Landsat 7 land cover data (based on NVCS) and species' habitat suitability maps	http://www.gap.uidaho.edu/
Home pages for commonly used sensors			
AVHRR	1100	Description of AVHRR data and various NOAA satellite missions	http://edcdaac.usgs.gov/1KM/avhrr_sensor.html
SPOT4/SPOT5	1000	Description of SPOT4 and SPOT5 missions and sensors (including VGT1 and VGT2 sensors, as well as HRVIR)	http://www.spotimage.fr/home/
Landsat 7	15-60	Description of sensor and data characteristics	http://landsat.gsfc.nasa.gov/
MODIS	250 - 1000	Description of sensor and data characteristics	http://modis.gsfc.nasa.gov/

Source: Adapted from Kerr and Ostrovsky (2003).

7. Integrating data layers to identify candidate marine IBAs

Once individual data layers, obtained from any of the methods described before, have been collected and analysed, it is necessary to integrate them to assess the most important areas by species (See Example Box 11). It is essential to assess data on a species-by-species basis, as this is how the IBA criteria are applied (except A4iii, for multi-species congregations).

As the sections above show, many datasets that do exist are commonly biased. It may be important to apply some kind of weighting to the datasets to ensure that only the most robust are used to identify sites, and those that may contain biases are only used as supplementary information. At this stage it is therefore useful to decide which data layers are regarded as primary, and which supplementary. Examples of how this might be achieved are shown in Rule Box 9 below. See also Chapter 6 of Ramírez *et al.* (2008) for a case study from Portugal.

Rule Box 9: Example of Primary and supplementary data layers for use in a marine IBA analysis.

Primary:

- Tracking datasets with large sample sizes collected over multiple seasons/years
- At-sea survey data collected in a systematic way recording presence/absence
- Land-based counts collected over multiple years

Supplementary:

- Tracking datasets with small sample sizes (e.g. <5 tracks from one season/year)
- Bycatch data
- At-sea distribution data collected from fishing boats or from ad-hoc surveys
- Habitat suitability models

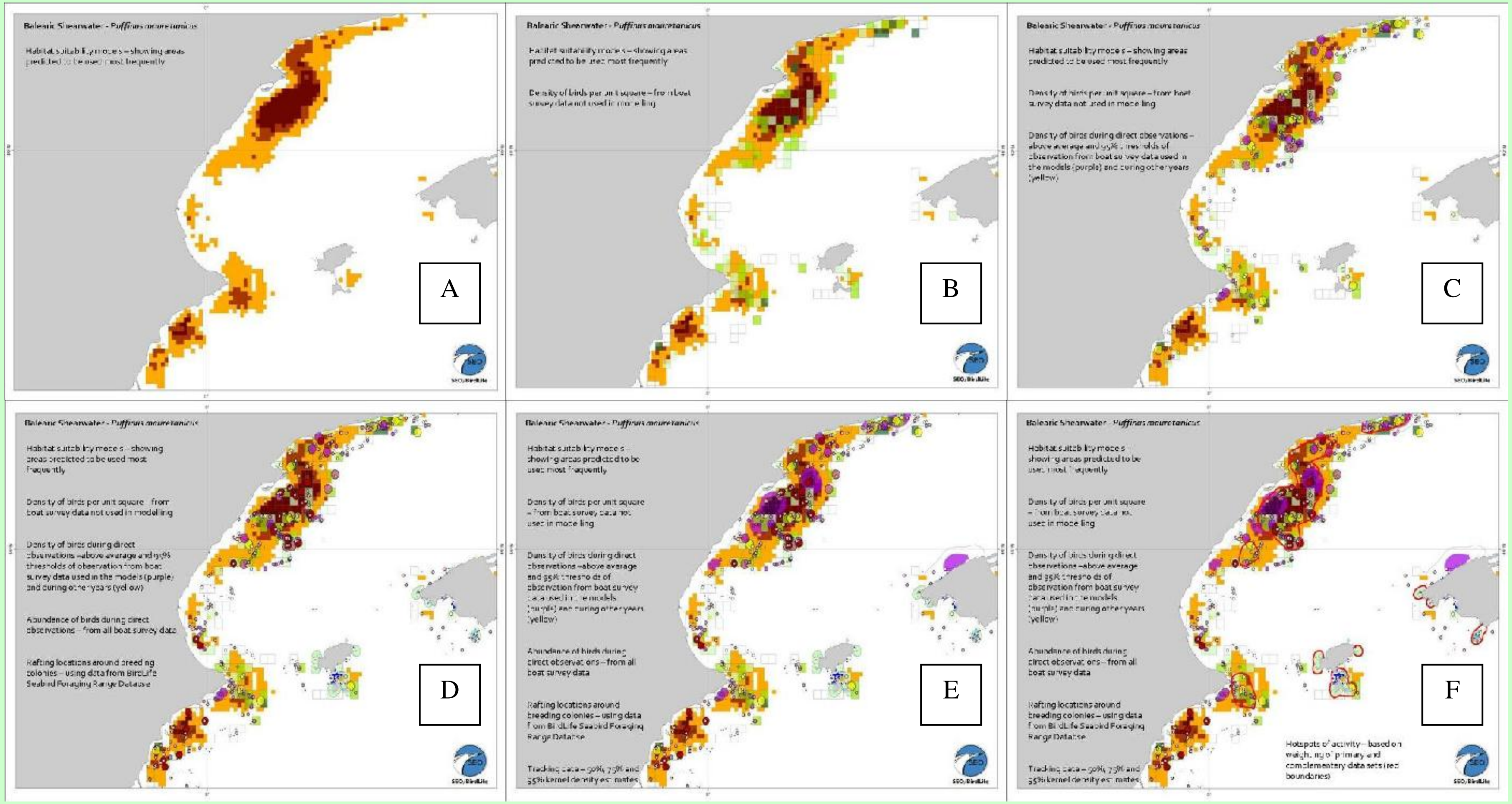
Once suitable weightings have been applied it is possible to begin site identification. Overlaying the data layers will identify areas of commonality and hence the most likely sites; these sites are then assessed against IBA thresholds. As a general rule, no marine IBA should be identified on the basis of supplementary quality data alone, and that sites identified where two primary data layers coincide or overlap are the strongest cases for recognition as IBAs. An approximate hierarchy of overlapping data layers is shown in Rule Box 10.

Rule Box 10: Data layer hierarchy for marine IBA analysis.

Data layer hierarchy for marine IBA analysis:

- 2 primary data layers coinciding or overlapping – the strongest case for a marine IBA, may be possible to lobby for its protection/management based on existing data
- 1 primary layer and one supplementary overlapping – strong case for a marine IBA identification
- 1 primary layer – depending on the quality of the data it may be possible to identify marine IBAs, otherwise these should remain as candidate sites in need of further research
- 2 supplementary layers overlapping – generally these should remain as candidate sites in need of further research, in some instances it may be possible to identify marine IBAs depending on the data involved
- 1 supplementary layer – insufficient data to identify marine IBAs, may identify candidate sites for further research

Example Box 11: Integration of data layers to determine candidate marine IBAs for the Balearic Shearwater in the Spanish Mediterranean.
A.) Habitat suitability models B). Density of birds per unit square (derived from at-sea survey data) C.) Density of birds at the 95 percentile (derived from at-sea survey data) D.) Rafting locations around breeding colonies (using Birdlife Seabird Foraging Range Database) E.) Tracking data (kernel analysis) F.) Identifying hotspots of activity as candidate marine IBAs.



Data courtesy of SEO/BirdLife, BirdLife Partner in Spain.

8. Application of the IBA criteria in the marine environment

As in the terrestrial environment, each site included in the initial list of candidate marine IBAs usually falls into one of three broad categories:

a. well-worked sites with adequate and up-to-date data;
b. less well known sites with older or poorer quality information;
c. areas for which there is little information but which are known or thought to hold good quality habitat wherein trigger species may be expected to occur

The first of these will probably qualify as IBAs in the absence of any further ornithological data, while the latter two represent survey targets. These are gaps that require additional field work to determine whether or not they hold trigger species in more than threshold numbers.

Once a list of candidate sites have been identified, it is necessary to assess each against the IBA criteria and thresholds. There are several things to keep in mind when seeking to apply the criteria in the marine environment, and these are dealt with briefly below:

8.1 Assessing regular use

Once data have been collected and analysed they need to be interpreted to assess against IBA criteria. Breeding seabirds typically have foraging areas that change in relation to the stage of the breeding cycle (and sometimes also the sex and the age/experience of the birds involved) and may vary considerably between years.

The IBA selection criteria explicitly require that *"regular use"* of a site be demonstrated. The 'stability' of a site therefore plays a key role in determining whether it qualifies as an IBA, as management of an IBA is much more feasible if it is shown that the site will be in the same location (e.g. around a seamount) or around a particular set of conditions (e.g. 10km either side of a convergence zone, even if the zone is not in the same location each year) in any given year.

Quantifying regular use will thus provide justification for whether one or more selection criteria may be met. Whenever possible, data from multiple years should be used to prove both stability and regular use.

Rule Box 11: Defining regular use for marine IBA purposes.

It has been proposed that for the purposes of marine IBA identification, regularity of use should be confined to the following condition:

"Areas visited by birds from more than one site or during different periods (i.e. seasons or years)"

Some assessment of regularity of use can be achieved via the initial analysis of the dataset, such as using the first four tracking data analysis techniques outlined in Information Box 4, and then integrating the results to see which areas are used by more than one bird/track.

To assess areas of regular use within an entiredataset requires the data to be split into relevant periods, and then integrating them to identify the areas that are used most regularly. While the exact definition of a 'period' will vary depending on the dataset and the ecology of the species concerned, it is usually advisable to exploit the data by dividing it into the most appropriate periods, as birds may be undertaking different activities in each. Stages of the breeding season (e.g. incubating, brooding, chick rearing etc), breeding vs non-breeding, quarters of the years, and different years all offer the potential for suitable/defensible definitions of a period. An example of this process can be seen in Example Box 12.

Example Box 12: Investigating regularity of use of areas by the Antipodean Albatross *Diomedea antipodensis,* using satellite tracking data obtained during the breeding and non-breeding seasons.

A). Distribution and overlap of the 50% Utilisation Distributions (UDs) during Brood Guard
B). Distribution and overlap of the 50% UDs during Incubating
C). Distribution and overlap of the 50% UDs Non-Breeding
D). Distribution of regularly used areas in multiple seasons or multiple years (A-C combined)

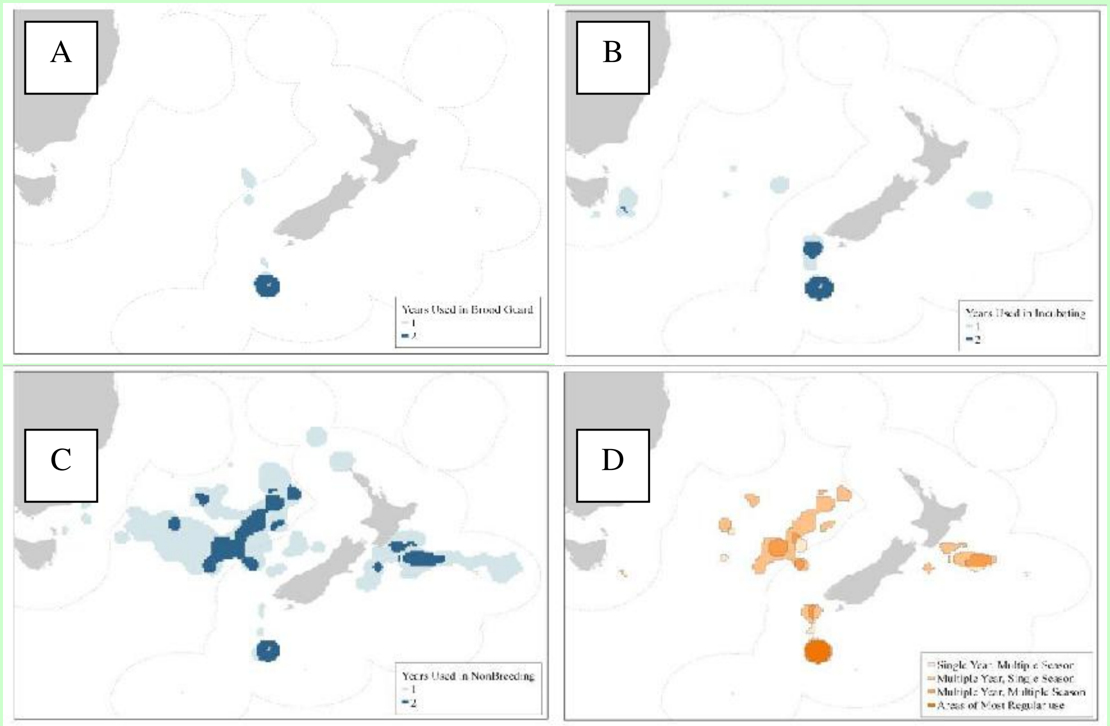


Image courtesy of the Global Procellariiform Tracking Database Data (tracking data provided by Kath Walker (Department of Conservation, New Zealand) and David Nicholls (Chisholm Institute, Australia)

Similar assessments of regular use can be made using at-sea survey data, and habitat suitability models (see Example Box 9).

Regularly used sites are likely to make the most compelling and easily understandable case for protection/management. It is worth noting that regular use can not only apply to static features such as seamounts and shelf breaks but can also do so for more dynamic features such as eddies, upwellings and fronts. To demonstrate the regularity of use and prove the link between species and site/process in these instances is likely to require more data and more complex analyses.

8.2 IBA thresholds

Demonstration of regular use of an area fulfils part of the requirements of IBA selection. In addition, however, assessments also need to be made as to whether thresholds of numbers of birds are met. Application of the IBA criteria requires counts or estimates to be made to determine if *"a site is known or thought to hold"* more than threshold numbers of birds.

Calculating seabird population estimates at candidate marine IBA can be a challenge. It is often possible to define accurately the most important areas using different sources of data, though it is not always possible to determine the percentage of a given colony or population using the area, or how frequently. There are potentially several options available for estimating the number of birds and thus determine if thresholds are met.

8.2.1 Confirmation from data layers

In the marine IBA inventories of Spain and Portugal, population estimates derived from boat surveys and/or modelling techniques were used to quantify the number of birds likely to be using a given site. In many parts of the ocean such additional quantitative information may not be available, thus being able to derive estimates of numbers from data on tracked individuals is essential for IBA criteria to be applied. To date, there have been few attempts to determine population sizes using tracking data, but there are several techniques (see section 8.3) under development that may offer some assistance in the future.

8.2.2 Extrapolation

Estimating population size using extrapolation makes the assumption that the observed birds (e.g. from tracking studies or at-sea surveys) are representative of the wider population. This may not be valid, particularly when the samples represent a very small percentage of the total population at a breeding site. Adequate sample sizes are essential when using tracking data for IBA identification, and extrapolations from tracked individuals to the wider population should only be made in cases where sample sizes have been proved to be representative. Comparisons between 'tracking hotspots' and 'boat survey hotspots' suggest that extrapolations from tracked individuals are likely to over-estimate the number of birds using a site at any given time (e.g. Santora *et al.* 2006, Ostrand *et al.* 1998).

8.2.3 Turnover

With up to half the breeding population tied to the colony for at least part of the year, the actual number of birds present at an at-sea site at any given moment is likely to be much lower than the total number of birds using that site over a fixed period of time (e.g. the breeding season). It is therefore often necessary to consider turnover rates at sites when assessing applying IBA thresholds. In an attempt to accommodate turnover, the African-Eurasian Waterbirds Agreement (AEWA) has proposed that:

"The 1% criterion has been fulfilled when 75% of the requisite numbers of birds have been recorded at one time, because of the turnover of birds at these sites. Where evidence from other sources (e.g. ringing studies) shows higher turnover rates, a site might still qualify even though the number of birds present at any one time is much lower than 75% of the 1% criterion (in some cases as low as 10-15%)."

The considerable differences between the behaviour and distribution of foraging seabirds and of waterbirds on migration mean that the 0.75% threshold may not necessarily be appropriate for seabirds. Further work is therefore needed to develop more satisfactory guidance on this topic.

8.3 Assessing thresholds using tracking data

Using tracking data alone to determine if threshold numbers of birds are present at a site can be problematic. The Chizé workshop provided some possible solutions for assessing overall abundance/density from tracking data, but this is still a developing field, and it is not yet possible to define clear methodologies for achieving this. For some threatened species with low numeric thresholds, it may be possible to determine the actual number of tracked individuals that have visited an area, but for the majority of species such numbers will be significantly below the thresholds. Estimates of the population in a given area within a given period may be made by extrapolation, based on the assumption that the tracked individuals are representative of the wider population. However, this may not be valid, particularly since the tracked individuals usually represent a very small percentage of the total population at a site. It is therefore particularly important to consider sample size (Lindberg and Walker 2007).

Example Box 13: Setting a standard method for determining if threshold numbers of birds are thought to be present in the marine IBAs of Spain and Portugal.

Difficulties in assessing if threshold numbers of birds were present at a site led Partners in Portugal and Spain to define a standard method that could enable the minimum and maximum values to be estimated. Direct counts of seabirds in the IBA were used preferentially as the species effective population. In cases where the populations had to be calculated using an estimate, the mean of the bird densities for each species was used within it's season of most significant presence in the area (either from modelling or densities determined from at-sea surveys). The values obtained were then extrapolated to the total area of the IBA, so as to obtain a population estimate for each species using it.

The Chizé workshop concluded that two methodologies were suitable for determining if the sample size could be considered representative of the wider population. A simple sub-sampling method and 'bootstrapping' (e.g. Manly 2006) were proposed. Both methods are based on the idea that by randomly selecting subsets of a tracking dataset it is possible to determine the sample size required for maximum coverage to be achieved (i.e. the point at which adding more tracks does not increase the overall distribution) and therefore the point at which the sample size is representative.

If the sample size of tracked birds is relatively large, and shown to be representative, then it may be possible to extrapolate the results to the wider population. However, as noted in section 8.2.2 extrapolations are likely to overestimate the number of birds using a site at any given time. Therefore, it is recommended that the lowest estimates are used to assess whether IBA thresholds have been met.

If the tracking dataset cannot be considered representative of the wider population then some additional quantative data will be required. In such instances the marine IBA projects in Portugal and Spain, used at-sea survey data and/or modelling techniques to quantify the number of birds likely to be using a given site.

It should be noted that BirdLife follows the Ramsar Convention in defining those species classified as waterbirds, and use Waterbirds Population Estimates published by Wetlands International to determine thresholds and hence which species IBA criteria A4i applies to. To get the most up to date thresholds please contact the relevant IBA regional coordinators at the appropriate BirdLife regional office.

9. Defining boundaries

Extensive experience already exists regarding how best to define and delimit an IBA within the terrestrial environment (see BirdLife International 2009b). Following this guidance, an IBA is defined and delimited so that, as far as possible, it:

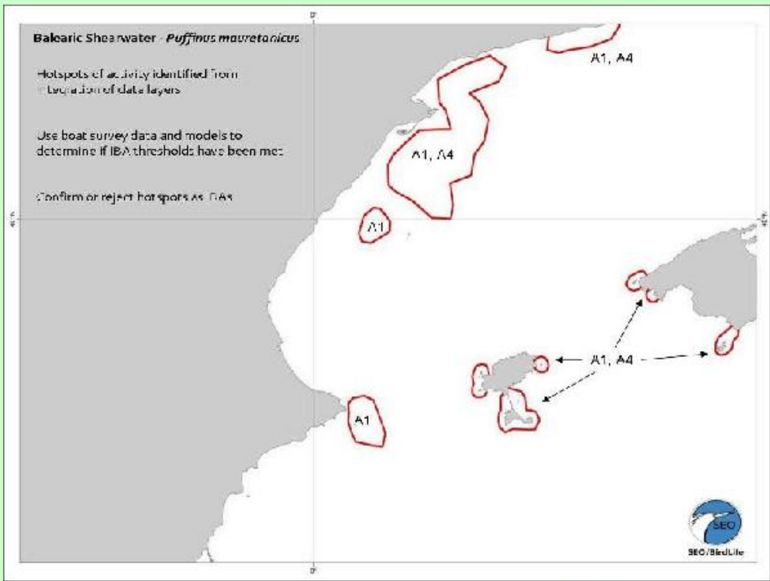
a) is different in character, habitat or ornithological importance from surrounding areas;
b) exists as a Protected Area, with or without buffer zones, or is an area that can be managed in some way for conservation;
c) is an area which provides the requirements of the trigger species (i.e. those for which the site qualifies) while present, alone or in combination with networks of other sites.

Note that (a) may not apply in extensive areas of continuous, relatively uniform habitat (e.g. the marine environment), and that this definition may not always be applicable to bottleneck sites for migratory birds. In many cases, deciding where to put the IBA boundary is straightforward, often dictated by obvious habitat boundaries or guided by existing Protected Area boundaries, land ownership or management boundaries, etc. In others, establishing where the edges should be located requires consultation, field work and/or data analysis. As each site, and its local context, is unique, there are no fixed rules that be can applied, only guidelines. Similarly, there is no set maximum or minimum size for an IBA—what is biologically sensible has to be balanced against practical considerations of how best the site may be conserved, which is the main priority. Common sense needs to be used in all cases: what is most likely to be effective in conserving the site under prevailing conditions and circumstances, locally and nationally?

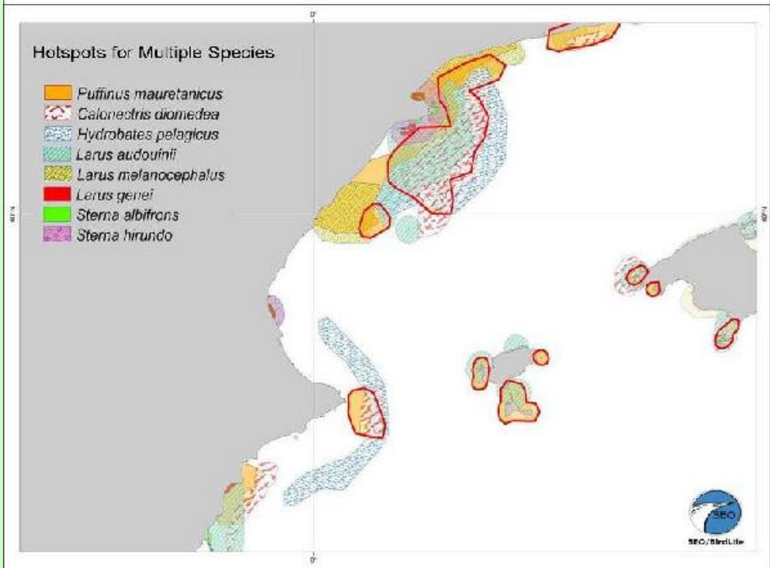
Candidate IBAs for individual species need to be assessed for areas of overlap and, where appropriate, combined. In other words, where areas do overlap, or fall close together, decisions will need to be made as to whether the site would be better treated as one larger IBA, or as several smaller ones. Example Box 14 shows an example from Spain of how overlapping species IBAs were used to define a final network of sites.

Where possible, the boundaries should be determined or at least influenced by those of the underlying habitats and oceanographic processes which cause the birds' presence in the area. Habitat suitability modelling has proved a useful method for deciding where final boundaries should lie, particularly when making an assessment of whether unsurveyed areas adjacent to high use areas should be included within the boundaries. Bathymetry can also play an important role, particularly as it is a readily available data layer, and is easily understandable to a wide range of maritime user groups.

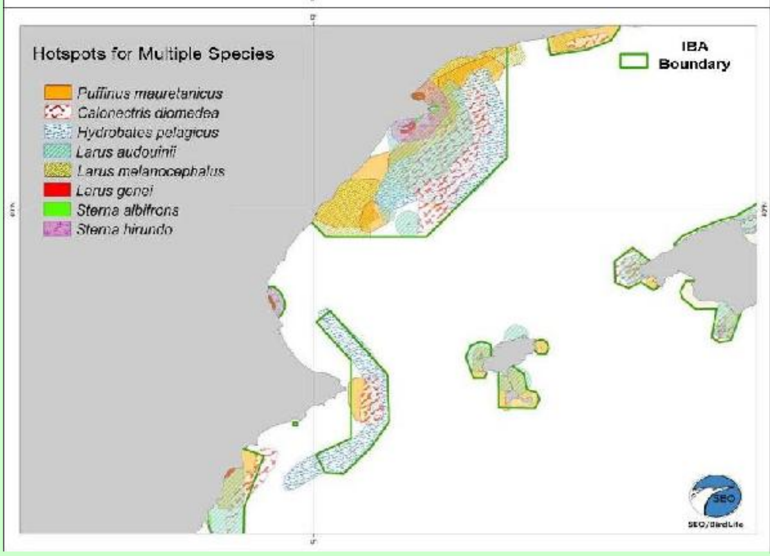
Example Box 14: Stages in the setting of boundaries to determine the final IBA network on the Mediterranean coast of Spain.



Once hotspots of activity have been identified for each species, the relevant selection thresholds are applied



The next stage is to integrate the species layers. Where there are overlaps of more than one species, it is usually appropriate to combine to form a single IBA.



Final IBA boundaries can then be drawn. Some sites are likely to have multiple qualifying species, with a range of criteria met. Each species' distribution within the IBA can be used to inform management plans and potential zoning of activities.

Data courtesy of SEO/BirdLife, BirdLife Partner in Spain.

10. Description, submission and confirmation of IBAs

The same standards apply in the marine environment as for identifying IBAs in terrestrial and freshwater areas. As well as data on trigger species, it is also necessary to collect additional information. For all sites, key data should be collected on the location (coordinates and polygons), site characteristics, other (non-trigger) avifauna present, major habitats, land-uses, significant threats, protection status, conservation activities underway, other biodiversity and key literature sources.

Once relevant site data have been collected, the BirdLife Partner organisation or equivalent propose the set of IBAs for the Birdlife Secretariat to check and validate, to ensure that the criteria have been interpreted and applied correctly and that the approach taken is consistent with that adopted elsewhere. Involving the Secretariat from an early stage, and consulting them as proposals are developed will help streamline the process and avoid any unnecessary complications.

IBA information may sometimes be published separately in several places – including regional and national directories, and national update documents. This could lead to confusion if the lists and other information do not agree with each other. For this reason, it is essential that one set of information is considered definitive. The definitive set is that held in the BirdLife World Bird Database (WBDB). The web-enabled WBDB allows updates and revisions to IBA information to be entered directly by the designated national IBA co-ordinators. It is also possible to add new sites and downlist existing ones as required. Changes to the IBA list itself must follow the general rules of the IBA update process (BirdLife International, 2009b). They must also be checked by Secretariat staff to ensure consistency of standards. Once verified, these changes are incorporated into the 'official' WBDB and become the definitive data made available by BirdLife to the outside world.

A brief summary of some key attributes to record at IBAs, with a specific reference to marine sites, is given below.

Species
The species and scientific name of the IBA trigger species should be noted. Species names should follow BirdLife taxonomy (BirdLife International, 2009a) to allow for easy entry to the World Bird Database, and for regional/global assessments to be made.

Population and IBA criteria
It is essential to record the methods employed to determine population sizes. Previous marine IBA studies have found it beneficial to provide a range of values (min-max) and provide some additional measure of reliability (see Example Box 15). It is then essential to give the list of species, and the criteria they are proposed as triggering, for each site.

Example Box 15: Additional information used in Portugal to assess the reliability of marine IBA population estimates.

Reliability	Meaning
A	Reliable. Error margin estimated at under 10%
B	Incomplete. Error margin estimated at under 50%
C	Poor. Error margin could be over 50%
D	Unknown.

Source: Ramírez *et al.* (2008)

Site description
It is necessary to provide a brief narrative description of the site, including the features and conditions that make the site important to seabirds. For example a site may be located in relation to a seamount, and seabirds gather here due to the upwelling caused by the seamount and the resultant food sources that become available at the surface. Therefore any alteration to the topography of the seamount is likely to affect food availability at the surface and potentially negatively impact on the seabird species that qualify.

Season of occurrence
Defining whether the IBA qualifies during the breeding, non-breeding or passage periods is important as this allows for analysis of networks of sites across ocean basins to be undertaken, and can help in determining if the network provides adequate and representative coverage during all life history stages. It may also be useful to define if the marine IBA is being used as a feeding, rafting or transit area, as this may have management implications (see Example Box 16).

Example Box 16: Additional information used in Portugal to assess the use of marine IBAs.

Use	Meaning
1	The species uses the IBA almost exclusively for feeding and/or resting
2	The species uses the IBA regularly for feeding and/or resting
3	The species uses the IBA regularly in transit

Source: Ramírez *et al.* (2008)

Sources of data/boundary delimitation notes
This section should broadly describe the types and origin of the data used to characterize the IBA and define its boundary. This information will provide important justification as to why the IBA was chosen as being a conservation priority. Specifying the sampling methods used and any analysis that may have been undertaken should also be included (See Example Box 17).

Example Box 17: Data sources used to characterise the São Jorge - Northeast marine IBA (PTM09) in the Azores archipelago, Portugal.

- ESAS at-sea surveys (2005-2007)
- Cory's Shearwater statistical models, based on POPA at-sea survey data (2002-2006)
- Common Tern *Sterna Hirundo* statistical models, based on POPA at-sea survey data (2002-2006)
- Cory's Shearwater raft counts from land based observations (DOP-IMAR UAç)
- Roseate Tern *Sterna dougalli* breeding colony surveys (DOP-IMAR UAç)
- Other marine surveys (Monteiro *et al*. 1999)

Source: Ramírez *et al.* (2008)

Other species/taxa present at the site
During the data analysis and candidate marine IBA identification processes it is likely that areas will be identified that appear important to a species, but that do not occur in sufficient numbers to exceed IBA thresholds. In IBA site descriptions it is worth noting those other species that occur at the IBA, but not in threshold numbers.

Seabirds are widely regarded as excellent indicators of the "health" of the marine environment (Parsons *et al.* 2008, Gregory *et al.* 2003, Zöckler and Harrison 2004), being easily observed, identified, reliably surveyed and monitored. Thus, hotspots for seabirds are frequently those vital for other marine coastal and pelagic biodiversity (Falabella *et al.* 2009), for many taxa of which few reliable distributional data are available. Therefore any observations of other interesting taxa found within the IBA should be noted in the site description.

References

Abrams R.W. (1983) Pelagic seabirds and trawl-fisheries in the southern Benguela Current region. *Marine Ecology Progress Series*. 11: 151-156.

Ainley, D.G., O'Connor, E.F., and Boekelheide, R.J. (1984) The marine ecology of birds in the Ross Sea, Antarctica. *Ornithological Monographs.* 32: 1–97.

Anderson, O., Booker, H., Frere, E. and Small, C. (2009) *Data Collection Protocols for Reporting Seabird Bycatch in IATTC Industrial Longline Fisheries.* Paper prepared for the Seabird Technical Meeting of the IATTC Stock Assessment Working Group. 11th May 2009 Del Mar, California, USA.

Arcos, J.M., Bécares, J., Rodríguez, B. and Ruiz, A. (2009) *Áreas Importantes para la Conservación de las Aves marinas en España*. LIFE04NAT/ES/000049-Sociedad Española de Ornitología (SEO/BirdLife). Madrid. (In Spanish).

Baldwin, E., Beazley, K. and Reining, C. (2008) *Where does conservation get stuck?: including expert opinion in large-scale conservation planning.* Paper presented at the annual meeting of the International Congress for Conservation Biology, Convention Centre, Chattanooga, TN.

Ban, N.C. (2009) Minimum data requirements for designing a set of marine protected areas, using commonly available abiotic and biotic datasets. *Biodiversity Conservation* 18: 1829-1845.

Barbraud, C. and Thiebot, J-B. (2009) On the importance of estimating detection probabilities from at-sea surveys of flying seabirds. *Journal of Avian Biology* 40: 584-590.

Barraquand, F. and Benhamou, S. (2008) Animal movements in heterogeneous landscapes: Identifying profitable places and homogeneous movement bouts. *Ecology* 89: 3336-3348.

Becker, B.H., Beissinger, S.R. and Carter, H.R. (1997) At-sea density monitoring of Marbled Murrelet in central California: methodological considerations. *Condor* 99: 743-755.

Benhamou, S. (2004) How to reliably estimate the tortousity of an animal's path: straightness, sinuosity or fractal dimension? *Journal of Theoretical Biology* 229: 209 – 220.

Bigrad, S.J., Block, B.A., Costa, D.P. and Godley, B.J. (2010) Bio-logging technologies: new tools for conservation. *Endangered Species Research* 10: 1-7.

BirdLife International (2004a) *A strategy for birds and people: responding to our changing world*. Cambridge, UK: BirdLife International.

BirdLife International (2004b) *State of the world's birds: indicators for our changing planet.* Cambridge, UK: BirdLife International.

BirdLife International (2004c) *Important Bird Areas in Asia: key sites for conservation.* Cambridge UK: BirdLife International (BirdLife Conservation Series No. 13).

BirdLife International (2004c) *Tracking ocean wanderers: the global distribution of albatrosses and petrels.* Results from the Global Procellariiform Tracking Workshop, 1–5 September, 2003, Gordon's Bay, South Africa. Cambridge, UK: BirdLife International.

BirdLife International (2008a) *Important Bird Areas in the Caribbean: key sites for conservation.* Cambridge, UK: BirdLife International (BirdLife International Conservation Series No. 15).

BirdLife International (2008b) *State of the world's birds 2008: indicators for our changing planet.* Cambridge, UK: BirdLife International.

BirdLife International (2009a) *The BirdLife checklist of the birds of the world, with conservation status and taxonomic sources.* Version 2. Downloaded from:
www.birdlife.org/datazone/species/downloads/BirdLife_Checklist_Version_2.zip

BirdLife International (2009b) *Important Bird Areas - guidance on defining/amending boundaries and on de-listing.* Version 3.0: 18 June 2009. Cambridge, UK: BirdLife International. (Internal report).

BirdLife International and Conservation International (2005) *Áreas Importantes para la conservacíon de las aves en los Andes tropicales: sitios prioritarios para la conservacíon de la biodiversidad.* Quito, Ecuador: BirdLife International (BirdLife Conservation Series No. 14). (In Spanish).

Bretagnolle, V., Certain, G., Houte, S. and Métais, M. (2003) Distribution maps and minimum abundance estimates for wintering auks in the Bay of Biscay, based on aerial surveys. *Aquatic Living Resources* 17: 353–360.

Briggs, K.T., Tyler, W.B. and Lewis, D.B. (1985) Aerial surveys for seabirds: methodological experiments. *Journal Wildlife Management* 49: 412-417.

Brooks, T., Balmford, A., Burgess, N., Hansen L. A., Moore, J., Rahbek, C., Williams, P., Bennun, L., Byaruhanga, A., Kasoma, P., Njoroge, P., Pomeroy, D. and Wondafrash, M. (2001) Conservation priorities for birds and biodiversity: do East African Important Bird Areas represent species diversity in other terrestrial vertebrate groups? *Ostrich* 15: 3–12.

Buchanan, G.M., Nelson, A., Mayaux, P., Hartley, A. and Donald, P.F. (2008) Delivering a global, terrestrial, biodiversity observation system through remote sensing. *Conservation Biology* 23 (2): 499–502.

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. (1993) *Distance Sampling: Estimating abundance of biological populations*. Chapman & Hall, London. UK.

Burger, A.E. (1997) Behaviour and numbers of Marbled Murrelet measured with radar. *Journal Field Ornithology* 68(2): 208-223.

Burger, A.E. and Shaffer, S.A. (2008) Application of tracking and data-logging technology in research and conservation of seabirds. *Auk* 125(2): 253-264.

Burnham, K.P., Anderson, D.R., and Laake, J.L. (1980) Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 72: 1-202.

Camphuysen, K.C.J. and Garthe, S. (2004) Recording foraging seabirds at sea: standardised recording and coding of foraging behaviour and multi-species foraging associations. *Atlantic Seabirds* 6(1): 1-32.

Camphuysen, K.C.J., Fox, T.A.D., Leopold, M.M.F. and Petersen, I.K. (2004) Towards standardised seabirds at-sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.: a comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments. Report commissioned by COWRIE. Royal Netherlands Institute for Sea Research.

Clarke, E.D., Spear, L.B., McCraken, M.L., Marques, F.F.C., Borchers, D.L., Buckland, S.T. and Ainley, D.G. (2003) Validating the use of generalized additive models and at-sea surveys to estimate size and temporal trends of seabird populations. *Journal of Applied Ecology* 40: 278–292.

Clarke, R.H. and Schulz, M. (2005) Land-based observations of seabirds off sub-Antarctic Macquarie Island during 2002 and 2003. *Marine Ornithology* 33: 7-17.

Crawford, R.J.M. (2007) Food, fishing and seabirds in the Benguela upwelling system. *Journal of Ornithology* 148: 253–260.

Devenish, C., Díaz Fernández, D.F., Clay, R.P., Davidson, I. and Yépez Zabala, I., eds. (2009) *Important Bird Areas Americas - Priority sites for biodiversity conservation*. Quito, Ecuador: BirdLife International (BirdLife Conservation Series No. 16).

Duffy, D.C. (1989) Seabird foraging aggregations: a comparison of two southern upwellings. *Colonial Waterbirds* 12: 164–175.

Eckert, S.A., Moore, J.E., Dunn, D.C., van Buiten, R.S., Eckert, K.L. and Halpin, P.N. (2008) Modelling Loggerhead Turtle movement in the Mediterranean: importance of body size and oceanography. *Ecological Applications* 18(2): 290–308.

Elith, J., Graham, C.H., Anderson, R.P., Dudík, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J. McC., Peterson, A.T., Phillips, S.J., Richardson, K.S., Scachetti-Pereira, R., Schapire, R.E., Sobero´n, J., Williams, S., Wisz, M.S. and Zimmermann, N.E. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29: 129-151.

Ervin, J., Mulongoy, K.J., Lawrence, K., Game, E., Sheppard, D., Bridgewater, P., Bennett, G., Gidda, S.B. and Bos, P. (2010) *Making Protected Areas relevant: a guide to integrating protected areas into wider landscapes, seascapes and sectoral plans and strategies.* CBD Technical Series No. 44. Montreal, Canada: Convention on Biological Diversity.

Falabella, V., Campagna, C. and Croxall, J.P. eds. (2009) *Atlas del Mar Patagonico: especies y espacias.* Buenos Aires: Edicions del Foro. (In Spanish).

Fauchald, P. and Tveraa, T. (2003) Using first-passage time in the analysis of area-restricted search and habitat selection. *Ecology* 84(2): 282–288

Fishpool, L.D.C. and Evans, M.I., eds. (2001) *Important Bird Areas in Africa and associated islands: priority sites for conservation.* Cambridge UK: BirdLife International (BirdLife Conservation Series No. 11).

Flint, E.N. (1991) Time and energy limits to the foraging radius of Sooty Terns *Sterna fuscata*. *Ibis* 133: 43–46.

Ford, R.G., Ainley, D.G., Casey, J.L., Keiper, C.A., Spear, L.B. and Balance, L.T. (2004) The biogeographic patterns of seabirds in the central portion of the California Current. *Marine Ornithology* 32: 77–96.

Fretwell, P.T. and Trathan, P.N. (2009) Penguins from space: faecal stains reveal the location of Emperor Penguin colonies. *Global Ecology and Biogeography* 18(2): 543-552

Gaston, A.J., Collins, B.L. and Diamond, A.W. (1987) The 'Snapshot' count for estimating densities of flying seabirds during boat transects: a cautionary comment. *Auk* 104(2): 336-338.

Gauthreaux, S.A.Jr. and Belser, C.G. (2003) Radar, ornithology and biological conservation. *Auk* 120: 266-277.

Gregory, R.D., Noble, D., Field, R., Marchant, J., Raven, M. and Gibbons, D.W. (2003) Using birds as indicators of biodiversity. *Ornis Hungarica* 12–13: 11–24.

Grémillet, D., Dell'Omo, G., Ryan, P.G., Peters, G., Ropert-Coudert, Y. and Weeks, S. (2004) Offshore diplomacy, or how seabirds mitigate intra-specific competition: a case study based on GPS tracking of Cape Gannet from neighbouring breeding sites. *Marine Ecology Progress* Series 268: 265-279.

Grimmett, R.F.A. and Jones, T.A. (1989) *Important Bird Areas in Europe*. Cambridge, UK: International Council for Bird Preservation (Technical Publication 9).

Guisan, A. and Zimmermann, N.E. (2000) Predictive habitat distribution models in ecology. *Ecological Modelling* 135: 147–186

Klages, N.T.W. and Cooper, J. (1997) Diet of the Atlantic Petrel *Pterodroma incerta* during breeding at South Atlantic Gough Island. *Marine Ornithology* 25: 13–16.

Halpin, P.N., Read, A.J., Best, B.D., Hyrenbach, K.D., Fujioka, E., Coyne, M.S., Crowder, L.B., Freeman, S.A. and Spoerri, C. (2006) OBIS-SEAMAP: developing a biogeographic research data commons for the ecological studies of marine mammals, seabirds, and sea turtles. *Marine Ecology Progress Series* 316: 239–246.

Hamer T.E., Cooper B.A. and Ralph C.J. (1995) Use of radar to study the movements of Marbled Murrelet at inland sites. *Northwestern Naturalist*, Vol. 76, No. 1, Symposium Issue: Biology of the Marbled Murrelet: Inland and at the Sea (Spring, 1995): 73-78.

Haney, J.C., Haury, L.R., Mullineaux, L.S. and Fey, C.L. (1995) Sea-bird aggregation at a deep North Pacific seamount. *Marine Biology* 123: 1–9.

Heath, M.F. and Evans, M.I., eds. (2000) *Important Bird Areas in Europe: priority sites for conservation.* Cambridge UK: BirdLife International (BirdLife Conservation Series No. 8).

Hebshi, A.J., Duffy, D.C. and Hyrenbach, K.D. (2008) Associations between seabirds and sub-surface predators around Oahu, Hawaii. *Aquatic Biology* 4: 89–98.

Hegel, T.M., Cushman, S.A., Evans, J. and Huettmann, F. (2010) Current state of the art for statistical modelling of species distributions. In: Cushman S, Huettmann F (eds.) *Spatial Complexity, Informatics, and Wildlife Conservation*: 273-311.

Heinemann, D. (1981) A range finder for pelagic bird censusing. *Journal Wildlife Management* 45(2): 489-493.

Horne, J.S. and Garton, E.O. (2006) Likelihood cross-validation vs. least squares cross-validation for choosing the smoothing parameter in kernel home range analysis. *Journal of Wildlife Management* 70:641-648.

Horne, J.S., Garton, E.O. and Rachlow, J.L. (2008) A synoptic model of animal space use: Simultaneous estimation of home range, habitat selection, and inter/intra-specific relationships. *Ecological Modelling* 214: 338-348.

Howgate, E. and Lascelles, B. (2007) *Candidate marine Important Bird Areas (IBAs): global status and progress.* Cambridge, UK: BirdLife International. (Internal report).

Hyrenbach, K.D. (2001) Albatross response to survey vessels: implications for studies of seabird distribution, abundance and prey consumption. *Marine Ecology Progress Series* 212: 283-295.

Hyrenbach, K.D., Henry, M.F., Morgan, K.H., Welch, D.W. and Sydeman, W.J. (2007) Optimizing the width of strip transects for seabird surveys from vessels of opportunity. *Marine Ornithology* 35: 29–38.

Hyrenbach, K.D., Veit, R.R., Weimerskirch, H. and Hunt, G.L. (2006) Seabird associations with meso scale eddies: the subtropical Indian Ocean. *Marine Ecology Progress Series* 324: 271–279.

Johnson, D.S., Thomas, D.L., Ver Hoef, J.M. and Christ, A. (2008) A general framework for the analysis of animal resource selection from telemetry data. *Biometrics* 64: 968-976.

Kerr, J.T. and Ostrovsky, M. (2003) From space to species: ecological applications for remote sensing. *Trends in Ecology and Evolution* 18(6): 299-305.

Ladd, C., Jahncke, J., Hunt, G.L., Coyle, K.O. and Stabeno, P.J. (2005) Hydrographic features and seabird foraging in Aleutian passes. *Fisheries Oceanography* 14 (Suppl.1): 178–195.

Lewison, R.L., Nel, D.C., Taylor, F., Croxall, J.P. and Rivera, K.S. (2005) Thinking big - taking a large-scale approach to seabird bycatch. *Marine Ornithology* 33: 1–5.

Lindberg, M.S. and Walker, J. (2007) Satellite telemetry in avian research and management: sample size considerations. *Journal of Wildlife Management* 71: 1002-1009.

Lopez-Mendilaharsu, M., Rocha, C., Miller, P., Domingo, A. and Prosdocimi, L. (2009) Insights on Leatherback Turtle movements and high use areas in southwest Atlantic Ocean. *Journal of Experimental Marine Biology* 378(2): 31-39.

MacLeod, C.D., Mandleberg, L., Schweder, C., Bannon, S.M. and Pierce, G.J. (2008) A comparison of approaches for modelling the occurrence of marine animals. *Hydrobiologia* 612 : 21 – 32.

Manly, B.F.J. (2006) *Randomization, Bootstrap and Monte Carlo Methods in Biology.* Taylor & Francis, UK.

Nel, D.C. and Taylor, F.E. (2003) *Globally threatened seabirds at risk from longline fishing: international conservation responsibilities.* Paper presented by BirdLife to the meeting of the UN Food and Agriculture Organisation Committee on Fisheries, Rome, 2003.

Osieck, E. R. (2004) *Towards the identification of marine IBAs in the EU: an exploration by the Birds and Habitat Directives Task Force.* Cambridge, UK: BirdLife International. (Internal report).

Osieck, E.R. and Mörzer Bruyns, M.F. (1981) *Important Bird Areas in the European Community.* Cambridge, UK: International Council for Bird Preservation.

Ostrand, W.D., Drew, G.S., Suryan, R.M. and McDonald, L.L. (1998) Evaluation of radio-tracking and strip transect methods for determining foraging ranges of black-legged kittiwakes'. *The Condor* 100: 709-718

Paiva, V.H., Ramos, J.A., Martins, J., Almeida, A and Carvalho, A. (2007) Foraging habitat selection by Little Terns *Sternula albifrons* in an estuarine lagoon system of southern Portugal. *Ibis* 150(1): 18-31.

Parsons, M., Mitchell, I., Butler, A., Ratcliffe, N., Frederiksen, M., Foster, S. and Reid, J.B. (2008) Seabirds as indicators of the marine environment. *ICES Journal of Marine Science* 65: 1520–1526.

Patterson, T.A., Thomas, L., Wilcox, C., Ovaskainen, O. and Matthiopoulos, J. (2008). State–space models of individual animal movement. *Trends in Ecology and Evolution* 23(2): 87-94

Piatt, J. and Ford, G. (1993) Distribution and Abundance of Marbled Murrelet in Alaska. *Condor* 95(3): 662-669.

Pinaud, D. and Weimerskirch, H. (2005) Scale-dependant habitat use in a long-ranging central place predator. *Journal of Animal Ecology* 74: 852-863.

Ramírez, I., Geraldes, P., Meirinho, A., Amorim, P. and Paiva V. (2008) *Áreas Importantes para as Aves Marinhas em Portugal – Importnat Areas for seabirds in Portugal.* Projecto LIFE04 NAT/PT/000213 – Sociedade Portuguesa Para o Estudo das Aves. Lisboa. (In Portuguese and English).

Ricklefs, R.E. and Schew, W.A. (1994) Foraging stochasticity and lipid accumulation by nestling petrels. *Functional Ecology* 8: 159–170.

Reynolds, M.H., Cooper, B.A. and Day, R.H. (1997) Radar study of seabirds and bats on Windward Hawai'i. *Pacific Science* 51(1): 97-106.

Rogers, A.D. (2004) *The biology, ecology and vulnerability of seamount communities.* Cambridge, UK and Gland, Switzerland: British Antarctic Survey and International Union for Conservation of Nature & Natural Resources.

Ronconi, R.A. and Burger, A.E. (2009) Estimating seabird densities from vessel transects: distance sampling and implications for strip transects. *Aquatic Biology* 4: 297-309.

RSPB (2000) *The development of boundary selection criteria for the extension of breeding seabird special protection areas into the marine environment.* Discussion paper presented by BirdLife International to the Meeting of the Biodiversity Committee (BDC), OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, Vlissingen, 20-24 November 2000.

Santora, J.A., Trivelpiece, W.Z. and Warren, J.D. (2006) Corroboration of simultaneous satellite tracking and ship-based surveys for estimating chinstrap penguin (Pygoscelis antarctica) distribution and correlation with Antarctic krill. *SCAR XXIX*, Hobart, Tasmania, July 2006.

Skov, H. and Durinck, J. (2001) Seabird attraction to fishing vessels is a local process. *Marine Ecology Progress Series.* 214: 289–298.

Spear, L.B, Nur, N. and Ainley, D.G. (1992) Estimating absolute densities of flying seabirds using analyses of relative movements. *Auk* 109: 285 – 389.

Spear, L.B., Sydeman, W.J. and Pyle, P. (1995) Factor affecting recruitment age and recruitment probability in Western Gull. *Ibis* 137: 352 – 359.

Tasker, M.L., Jones, P.H., Dixon, T. and Blake, B.F. (1984) Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *Auk* 101: 567-577.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A. and Burnham, K.P. (2010) Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47: 5-14.

Thompson, D.R. (2007) Air-breathing visitors to seamounts: importance of seamounts to seabirds. Pp. 244–251 in T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan and R.S. Santos eds. *Seamounts: ecology, conservation and management*. Oxford: Blackwell.

Tremblay, Y., Roberts, A.J. and Costa, D.P. (2007) Fractal landscape method: an alternative approach to measuring area-restricted searching behaviour. *Journal of Experimental Biology* 210: 935 – 945.

Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterline, E. and Steininger, M. (2003) Remote sensing for biodiversity science and conservation. *Trends in Ecology and Evolution* 18(6): 306-314.

Tushabe, H., Kalema, J., Byaruhanga, A., Asasira, J., Ssegawa, P., Balmford, A., Davenport, T., Fjeldså, J., Friis, I., Pain, D., Pomeroy, D., Williams, P. and Williams, C. (2006) A nationwide assessment of the biodiversity value of Uganda's Important Bird Areas network. *Conservation Biology* 20: 85–99.

Valanis, V. D., Pierce, G. J., Zuur, A. F., Palialexis, A. Saveliev, A., Katara, I., Wang, J. (2008) Modelling essential fish habitat based on remote sensing, spatial analysis and GIS. *Hydrobiologia* 612: 5 – 20.

Van der Meer, J. and Leopold, M.F. (1995) Assessing the population size of the European Storm-petrel (*Hydrobates pelagicus*) using spatial autocorrelation between counts from segments of criss-cross ship transects. *ICES Journal Marine Science* 52: 809-818.

Velando, A., Munilla, I. and Leyenda, P.M. (2005) Short-term indirect effects of the 'Prestige' oil spill on European Shags: changes in availability of prey. *Marine Ecology Progress Series* 302: 263–274.

Wahl, T.R. and Heinemann, D. (1979) Seabirds and Fishing Vessels: Co-Occurrence and Attraction. *Condor* 81(4): 390-396

Webb, A. and Durinck, J. (1992) Counting birds from ship. In: *Manual for aeroplane and ship surveys of waterfowl and seabirds*, J. Komdeur, J. Bertelsen and G. Cracknell, eds. 24-37. Slimbridge, International Waterfowl and Wetlands Research Bureau. (IWRB Special Publication No.19.)

With, K.A. (1994) Using fractal analyses of animal movement: a critique. *Ecology* 77: 2086–2090.

Zöckler, C., and Harrison, J. (2004) *Data management and communication for the Circumpolar Biodiversity Monitoring Program: a cooperation strategy between CAFF and UNEP-WCMC*. Akureyri, Iceland: CAFF International Secretariat, (CAFF CBMP Report No. 8).