Marine and Coastal

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Scoping study: New approaches to monitoring

FINAL REPORT

Sub-component: Maximising the utility of opportunistic and citizen science datasets for conservation management

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Cover images

Dwarf Minke Whale. RRRC Cairns.

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Executive summary

This project aimed to identify priority areas for methods development associated with better utilising citizen science datasets for conservation management. In particular, furthering understanding of the demographic parameters, and habitat use of seabirds, shorebirds and marine mammals for application in population assessments and for informing conservation plans (e.g. such as recovery plans for species listed under the *Environment Protection and Biodiversity Conservation Act* 1999). The report from this project contributes to a larger report that brings together the exploration of a range of methodologies for improving and expanding monitoring efforts to support conservation management.

This project focused primarily on a stakeholder workshop aimed at capturing Commonwealth, state and territory departmental and expert experiences in collecting, collating and utilising citizen science datasets to expand understanding and inform decision-making processes. Workshop attendees were tasked with identifying priority areas of methods development with a focus on seabirds, shorebirds and marine mammals, and associated research gaps that the NESP could potentially direct efforts to address in the future.

Overview of citizen science on shorebirds, seabirds and marine mammals

Research efforts discussed during the workshop included a range of programs/projects that spanned submission of opportunistic data with varying levels of detail to structured programs incorporating trained participants and the validation of data collected. Some of these efforts have been operating for long periods of time, highlighting the value of approaches in providing long time series of datasets, to recently implemented programs/projects that were substantially increasing data available from species in particular regions.

Approaches for analysing presence data (the most collected form of data) and the associated outputs that could be robustly generated from these were discussed. Fully integrative approaches that utilise data generated through systematic surveys and citizen science programs/projects are still in their infancy and are an emerging field of research. Integration of these two forms of datasets is not a trivial exercise; however, the potential for these approaches in enhancing the utility of citizen science datasets is significant.

The limitations of citizen science datasets and the opportunities they provide were discussed. It was noted that while citizen science can contribute important data to monitoring programs, it cannot replace formal systematic scientific approaches. This is because most citizen science datasets are biased to some degree, and often the form of these biases, including their sources, are not known. Citizen science approaches provide potential opportunities either by filling gaps that systematic surveys might have, or bolstering or strengthening population trend analyses, thereby reducing the number of systematic (and more expensive) surveys needed to attain population trends.

Increasing the utility of citizen science datasets

For citizen science datasets to contribute to addressing the information priorities needs for listed species, including seabirds, shorebirds and marine mammals, two important elements are required: (i) the amount of effort associated with observations and (ii) that observations are collected from pre-specified sites within a survey design (rather than collecting data from only the areas that citizens might prefer). Ways of facilitating the collection of this information include:

- Implementing roster systems that can address the collection of temporal effort
- Incorporating gridded spatial maps that citizens fill in to provide some indication of spatial effort
- Utilising smartphone applications that allow the collection of effort through space and time. Some of these can provide GPS locations, the start and end time of surveys and by incorporating a list of potential species, can provide presence and absence data without the user inputting specifics into the application. Technology was identified as a potential tool that could address a number of issues associated with gathering information on effort and facilitate the gathering of information without the need for data input by the user.

Criteria identified by workshop participants for contributing to a sustainable, well-designed citizen science program/project included:

1. An identified core group of citizens that can be engaged in the program/project
2. Good resourcing for supporting the program/project and in association:
    a. Effective support tools to facilitate the collection of data and associated effort needs
    b. Effective data quality systems for verifying and cleaning the data collected
    c. Efficient data management systems that support easy access to data and efficient use of data
    d. Effective communication and outreach on the program/project through multiple channels
    e. Ongoing commitment to the program/project
3. Multiple entry points for engagement that cater to the amount of time/effort/interest of citizens
4. Clear pathways or mechanisms for motivation
5. Mechanisms for citizens to provide feedback on programs/projects for continuous improvement of programs/projects
6. Systems that allow for evaluation of the relative value of modifications to the program/project
7. Direct links to management for ensuring coordination and effective use of outputs

Research directions

Priority areas for research identified by workshop participants that could be conducted to improve understanding, coordination and collaboration between citizen science programs/projects included:

1. A high-level audit and assessment of programs and projects. This would involve identifying current programs/projects, the various groups involved, how each program/project meets the criteria set out above and whether a cost-benefit analysis had been done, identifying gaps in meeting those criteria, current challenges faced by programs/projects in delivering outputs for use in management and the potential for cross-jurisdictional collaborations, particularly in building national datasets that address national priorities.
2. Facilitate a discussion between the various programs/projects working on individual species to identify how they might best coordinate their efforts, and how they might bring the data being collected by the various programs/projects together to provide data at a national scale that can then be utilised to meet the priorities for that species.
3. Development of a centralised site that provides advice and resources for citizen science programs/projects and serves as a coordination point for programs/projects.
4. A high-level analysis of the growth in citizen science programs/projects and the use of those data in governmental processes and decision-making.

Keywords: opportunistic data, citizen science data, marine mammal, seabird, shorebird, conservation management

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Introduction

Observations of marine species have rapidly diversified over the last decade, with increasing numbers of observations collected either through formal citizen science programs or opportunistically by citizens and then submitted into public databases. The collection of observations by citizens can often significantly increase the scale at which information on species is collected, with technological advances such as smartphone applications making citizen-based observing more accessible and more easily facilitated (Fischer et al. 2021). Within Australia, redmap (https://www.redmap.org.au/) is one example where citizens are encouraged to collect observations of marine species that they have not seen before in their local area. Over time, the project's aim is to identify changes occurring to species distributions. These can then be used to direct research efforts on particular species or into those areas where range shifts might be occurring, to better understand the drivers of change and the implications on species and ecosystems (Ramos et al. 2015; Stuart-Smith et al. 2016). Globally, eBird, (https://ebird.org/home) has amassed over 1 billion bird sightings and utilises these to produce annual spatial distribution maps that visualise changes in relative abundance, species ranges and species movements (Fink et al. 2020). The overall focus of this project is to determine climate change impacts on birds, including seabirds and shorebirds.

The drivers for participation in citizen science programs and in the collection of observations vary (Martin et al. 2016). Overall, the expectation of citizens contributing observations is that the data is incorporated into formal analyses and utilised either for scientific or management purposes, with outcomes that improve the current understanding and conservation of species. To facilitate this, many programs and projects provide open access to the data collected and actively engage with the research community to encourage the utilisation of datasets. As an example, over 150 publications (as listed on the eBird website) were produced from eBird data in 2022. There is increasing reliance on more informal and publicly driven approaches to the collection of observations given the costs of conducting formal surveys, particularly if accessing remote regions or if repetition of collection (across seasons or years) is needed.

While citizen science derived data has many uses (e.g., Fink et al. 2020), and when collected at scale can provide a significant contribution to scientific understanding (Fischer et al. 2021), integrating opportunistic observations with more formally collected observations (e.g., those collected through structured survey designs), is not straightforward. Traditional approaches for estimating population abundance and changes in species assemblages, abundances and distributions through time require some understanding of the effort associated with those observations, and how that effort is also distributed through time. Such information is, in most cases, missing from opportunistic observations, given the nature of those observations. In addition, many opportunistically collected datasets have varying observation, reporting and geographic biases resulting from their structure, approach, and focus (El-Gabbas and Dormann 2018). While some programs have incorporated frameworks for validating data, accounting for bias and assessing data quality (e.g., Pecl et al. 2019), addressing these biases remains challenging. Further, while effort has been placed into assessing the fitness of datasets for formal analyses (see review in Fischer et al. 2021), less effort has been placed into integrating datasets. As a result, citizen science datasets tend to be analysed separately (e.g., Martin et al. 2020), and integration of datasets remains largely limited to comparative analyses (e.g., Holt et al. 2014) or spatial mapping efforts (e.g., Bruce et al. 2014). As such, many datasets are underutilised, particularly in analyses used to establish the biological and population parameters of species. This reduces the capacity for such data to contribute to scientific efforts supporting current conservation management plans where measuring and monitoring population recovery are central measures of the success of those plans.

In order to take full advantage of this rapidly expanding resource, and ensure that efforts associated with the collection of these observations are not wasted, methods that can integrate opportunistically collected data with formal scientific datasets and/or facilitate their analysis are needed. This would expand the information required by conservation management plans and substantially improve the ability to determine the effectiveness of those plans.

This project has been developed as part of a larger scoping project that sits within one of the three outcome areas of the National Environment Science Program (NESP) Marine and Coastal Hub focused on improved and more cost-effective monitoring of marine resources. It has been structured with the aim of providing a first step in the development of potential integrative methods that can bring together opportunistic datasets with structured datasets. The project will predominantly deliver its outputs through a workshop (detailed here) and the development of a short brief (appended to this report) outlining the outcomes from the workshop and identifying a set of recommendations for methods development that can be used to inform further research planning.

The workshop: approach and aims

As a first step in the identification and development of integrative methods, a workshop was held at the CSIRO Marine Laboratories, Hobart, in December 2022. It brought together data holders, quantitative ecologists and statisticians to explore potential approaches that might be applied to facilitate the use of citizen science datasets and the potential for the integration of these datasets with structured scientific datasets. It aimed to identify what datasets might be best suited to integrative approaches (and what might not) and outline a pathway for identifying and developing those methods.

The workshop focused on datasets associated with seabirds, shorebirds and marine mammals. These taxa groups were chosen specifically as information on the presence, distribution, abundance and aspects of their reproductive ecology are frequently collected opportunistically or informally by researchers, conservation groups, Indigenous groups and the public. For some species within these three taxa groups, the only information available is informal or opportunistic. Establishing robust and reliable estimates of biological and population parameters that can then be utilised for informing conservation plans from these datasets in many cases has been limited to date.

Specifically, the workshop aimed to:

- Map out different types of data sets and methods that can be applied to them to progress/address conservation priorities;
- Outline practical steps for bringing datasets together;
- Identify key needs for facilitating the use of citizen science datasets in decision-making.

Workshop agenda

The workshop was held in hybrid mode across two half-days (Table 1). The first day largely focused on datasets, methods and applications. The second day focused on identifying key priorities for data on listed species within the context of the Environmental Protection and Biodiversity Conversation Act 1999 (EPBC Act) and what is needed in terms of methods development and data integration, particularly in utilising the datasets currently available.

Table 1. Workshop agenda.

Monday, December 5		
12:00-13:00	Sign-in and lunch	CSIRO reception/Riverview room
13:00-14:00	Introductions, Background to workshop, Objectives of workshop	Riverview Room/online
14:00-15:00	Datasets, methods and applications part 1	Riverview Room/online
15:00-15:30	Afternoon tea	Riverview Room/online
15:30-17:00	Datasets, methods and applications part 2	Riverview Room/online
17:00-19:00	Refreshments	Salamanca
Tuesday, December 6		
09:00-10:30	Progressing current datasets – where can gaps be filled?	Riverview Room/online
10:30-11:00	Morning tea	Riverview Room/online
11:00-12:30	Next steps: combining opportunistic and structured datasets- what is needed and what is possible?	Riverview Room/online
12:30-13:00	Wrap-up	Riverview Room/online
13:00-14:00	Lunch	Riverview Room

Workshop discussions

What is citizen science data?

The workshop began by exploring the perspectives of the group on what comprises citizen science data, noting that there are many definitions available in the literature (e.g., Eitzel et al. 2017, Vohland et al. 2021). In doing so, it was important to acknowledge the many interpretations of what comprises citizen science. Workshop participants identified that citizen science data:

- is collected by the public where time and capability are volunteered and involves active engagement with the public – the capacity in which people collect data contributes to the nuances around what is citizen science
- is collected by the community within certain parameters and is shared intellectual property
- is collected by individuals that approach citizen science in different ways and for different purposes
- is identified by how the data is collected, rather than the property of the data itself
- can be both collected in collaboration with scientists and without collaboration with scientists
- can range from extremely rigid datasets to very informal and opportunistic datasets, and while presence data is commonly collected, datasets are not necessarily presence only
- can often be initiated around a particular (local) question or purpose, and as datasets grow (in space and time), the data lends itself to questions that were never asked in the first place
- engagement can also be through contributions to data analysis, rather than only data collection
- facilitates an important awareness-raising component, with participation having flow-on effects on overall awareness of ecological problems/issues and influence on decision making

Datasets, methods and applications

Datasets

Four major attributes of datasets common to citizen science programs were identified: (i) presence-only (where absences are not recorded); (ii) presence-absence (where absences are recorded); (iii) count only (where zeros are not recorded); (iv) abundance (where zeros are recorded). Data in each contain varying information and varying biases. Additional information collected can assist in further interpretation of those datasets.

Elements of datasets that were recognised as important included:

- The dimensionality of the dataset. This dimensionality includes the use of the data to science, the questions that can be asked of the data, the inherent biases and the unrealised opportunities that might allow those biases to be accounted for (e.g., utilisation of new technologies to add structure to the data being collected). An example provided was the Backyard Bird smartphone application, which is designed to allow for a measure of effort to be collected in conjunction with bird species presence.
- The attributes of the citizens engaging in the collection of data, including their motivation and what information they are using to inform that motivation. This provides some insight into biases associated with the data and to what extent the data can be utilised.
- In most cases, extremely complex patterns of biases are associated with datasets. This limits the ability to extrapolate beyond those areas within which the data have been collected. As a result, an estimation of population abundance or quality of habitat cannot be made without making assumptions. In some cases, modelling can deal with some of these biases, but there will always be a substantial amount of uncertainty that models will not be able to address.
- Datasets are a factor of balancing inclusion/engagement with structured science programs. In many cases, citizens are not particularly interested in engaging in structured, randomised designs for data collection. It was also noted that some species have very specific habitat requirements, which need careful consideration in applying randomised sampling designs.
- The use of technology is increasingly allowing for the collection of additional information that may not have been able to be collected historically and can assist in acknowledging and overcoming biases in datasets.

Methods

There are many modelling approaches that can be utilised on citizen science datasets. However, it is the data itself and the attributes of those data that determine what might be derived from models (or other analyses). Three broad groups of methods that could be applied to presence data were discussed:

1. Presence-only data with no additional information can only be used to determine the minimum extent or range, and with information collected through time, a relative distribution map that is biased.
2. Presence-only data with some additional information on effort or a proxy that provides some information on sampling bias, can be used within a distribution model that accounts for sampling bias to provide a relative distribution map. However, it should be noted that such a model may not account for all biases.

3. Presence-only data with additional data such as absence, movement, counts, mark-recapture, occupancy etc., can be used within integrative models to provide a relative distribution map. If biases can be accounted for through these additional data, an absolute distribution map can be attained. Best practices that have been published in relation to eBird data were highlighted as an example of guidance for citizen science datasets in this regard (Strimas-Mackey et al. 2020).

An example of methods for integrating data from varying sources (highly structured survey designs, opportunistic sightings, more formal citizen science data) to determine the population abundance and spatial distribution of koalas was provided. This approach utilises a state-space model where the state is the unobserved distribution of koalas. Each of the various data types is then related to this state. It also incorporates a bias model that compares the presence-only data (which is numerous and widely geographically distributed) to scientifically structured surveys (which are less numerous and site-specific but importantly also incorporate detection probabilities) to determine how the presence-only data is biased. It then accounts for the bias in the presence-only data to determine a prediction of distribution based on the complete dataset. The approach therefore leverages off the broad geographic distribution of the presence-only data and the accuracy of the scientific data. The development of a front end for the model to allow it to be useable and useful for others is underway, and an extension of the model to account for preferential sampling (which tends to be a property of scientific sampling) is planned. This follows on from experience gained from other projects that have identified a development need for producing user-friendly flexible model fitting arrangements that can be applied widely.

It was noted that integrative modelling methods are new and developing and are in their infancy. It is not a trivial exercise to do, but it has the potential to be very powerful. Often there are a lot of assumptions needed and a lot of interpretation of the data.

Applications

Participants provided some examples of citizen science approaches, which are described in the next section.

Seabirds

Beach-washed seabirds on Australia’s coastlines, although first collected for other reasons, are now being recognised as potentially useful within the context of offshore wind farms. To date, however, these records are often presence-only data as information on absences (when there are no beach-washed birds at a location) has rarely been recorded. Further, historical data are limited and spatially and temporally constrained. Other than a few peer-reviewed publications on seabird wrecks (e.g., Brown et al. 1986, Norman and Brown 1987, Norman et al. 1991), reports of seabird wrecks have generally been ad-hoc and not systematic (Glencross et al. 2021). It was noted that these surveys do not account for cryptic mortalities and may also capture a biased component of the population that is less fit from an evolutionary perspective than the larger population. Annual ‘wrecks’ of juveniles departing colonies of some species (e.g. short-tailed shearwater *Ardenna tenuirostris*) may provide species-specific or location-specific data for broader, regional studies.

Shorebirds

The development of datasets on shorebirds provides an example of citizen science that has been organic and driven from the bottom up. These efforts are providing legacy insights into shorebird species trends nationally and internationally that could never have been generated any other way. Australia's efforts have been instrumental in understanding migratory shorebird population declines. There are several community groups that have been collecting observations on migratory shorebirds for a long time (some locations have been sampled in a structured manner since the 1960s and 1970s), resulting in extended time series.

Most shorebirds are widespread across suitable habitats and may be found all around Australia. Many species breed in countries north of Australia (e.g., central and northern Asia) and migrate south to Australia during their non-breeding season. Collection of presence and, in association, count data has been facilitated because coastal aggregations of migratory shorebirds congregate to roost during high tide periods in predictable ways. This allows them to be located relatively easily and counted with some level of accuracy through time. Many groups utilise standardised methods for recording species, resulting in consistent effort in many locations since the mid-1990s. This consistency has produced strong spatial representation of counts. Noting this, most of the focus of the analyses of these data has been on attaining counts at particular locations and tracking changes in those counts through time (e.g. Clemens et al. 2016), rather than determining the distribution of species (but see Hansen et al. 2016, 2021, 2022).

Analyses of citizen science data have identified that migratory shorebird populations have declined dramatically since the late 1970/early 1980s, although the tools to assess these declines from a national perspective were lacking at that time. Since then, there has been a lot of interest in understanding trends in migratory shorebird abundances and what might be causing these declines, with these long-term datasets enabling such analyses. Trend estimates for some migratory shorebird species have been derived from complex Bayesian models and involve rigorous data quality control (e.g., Studds et al. 2017, Murray et al. 2018), while population estimates, for the most part, have been empirical because of localised anomalies in the data.

A limitation is that there are relatively few sites in Australia where counts of migratory shorebirds have been collected consistently through time. This poses both temporal and spatial challenges to analyses. Another issue with the data is that migratory shorebird species move between the sites that they visit and, within a site, can vary how they utilise that site. This can make them difficult to locate and count and results in variability in counts at a site throughout the season. For many Australian locations, there may be only one annual summer count per year available, and how the count is biased by the movements of shorebirds is unknown. This means that for some species, it has been impossible to attain estimates of abundance and to derive estimates of population trends with any certainty (although see Hansen et al. 2022).

A primary use of count data collected from migratory shorebirds is in relation to the Ramsar convention (www.ramsar.org). This convention is focused on identifying internationally important wetlands, including habitat for shorebirds. Important habitats are defined as those that contain 1% or more of a species or a migratory species' flyway population. To determine if a habitat meets this criterion, an estimate of the number of shorebirds using the site and an estimate of the shorebirds in the flyway is required. This requires information on populations to be gathered both within and beyond Australia. The Australian Government has commissioned two attempts to estimate these numbers, with the first published by Hansen et al. (2016) and the second recently completed by Birdlife Australia.

The estimations required to determine if a wetland site qualifies to be recognised under the convention are challenging and involve extrapolating count estimates beyond the locations where reliable count data have been collected. Many coastal and wetland habitats around Australia, but especially in northern Australia, are unsurveyed and very few sites have been surveyed repeatedly through time. This is an issue because about half of the migratory shorebird species that occur in Australia seasonally visit northern areas that are remote and difficult to access, particularly on a regular basis. Indigenous ranger groups have been collecting quality data from the Gulf of Carpentaria and western Cape York regions over many years, and there is great potential for those efforts to be expanded to assist in filling some of the gaps across the region.

Funding of observing efforts for shorebirds across the board has been sporadic, and the distribution of funds inconsistent (funding had not been focused from a national perspective), resulting in some fragmentation of survey datasets. In the late 1990s, Birdlife Australia placed concerted efforts into the collation and consolidation of data into a central database to begin to align datasets. Efforts to achieve this are still ongoing. The extended period of this effort is because these datasets are part of the identity of the various groups collecting data on shorebirds, and the process has required careful discussions to build trust and develop agreed methods for organising, attributing and using the data. Ongoing support for the maintenance of this database is challenging, particularly as it has grown into a large, complex and technical dataset. Because some datasets have not been contributed to the national database, ensuring the interoperability of datasets is important to facilitate regular submissions of individual analyses/summaries that can contribute to regional and national assessments.

The challenge of integrating shorebird data into decision-making processes was highlighted, as often datasets are not used in planning and decision tools; rather, their use has been subject to negotiations between individual parties. There have been some improvements with increasing use in industry development proposals, but often data are not used unless they are findable and accessible in internal government databases. This highlighted some of the internal and external challenges around the recognition, attribution and use of datasets, the limitations associated with the admission of datasets into government databases and the sensitivities around sharing of data, all of which require extensive ongoing consultation.

To date, integrating counts and abundance estimates with population trends within a framework has not been done.

Marine mammals

Dolphin Watch (Western Australia)

The Dolphin Watch program (https://www.riverguardians.com/projects/dolphin-watch/project-background) is focused on monitoring a small population of approximately 20 Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) that are found in the Swan and Canning River estuary. Since beginning the program, which was initially a response to a mass mortality event that occurred in 2009 in the estuary, monitoring of populations has expanded to Madurah (south-west Western Australia) and Roebuck Bay (north-west Australia) supported through a collaboration between the Western Australian Government Department of Biodiversity, Conservation and Attractions, Edith Cowan University and Murdoch University (https://www.riverguardians.com/projects/dolphin-watch). The range of species and associated population sizes monitored varies across the program locations.

The population of bottlenose dolphins that are monitored in the Swan-Canning Riverpark occurs in a region of high human density and so is exposed to a number of stressors. The population utilises the whole of the estuary and is thought to have some exchange with a population of around 200 dolphins that occur in Cockburn Sound, although the level of exchange has not been quantified and the home range of the Riverpark dolphins is different to that of the Cockburn Sound dolphins. The program is focused on understanding the ecology of the dolphins and their interactions with human activities to better understand the overall marine and estuarine environment and comprises monitoring sightings and their locations, and reporting entanglements and injuries to support management.

The broader aims of the program are to also increase public awareness of the dolphin population, change the behaviour of human populations within each coastal region, as well as collect key information on the movements and extent of habitat use of the population across seasons. Developed out of a systematic survey, the citizen science component of the program focuses on training citizen scientists to augment the resource-intensive and expensive systematic surveys. The systematic surveys are conducted on a monthly basis and aim to provide a comparative dataset that allows for the assessment of the utility of the citizen science dataset and whether or not the citizen science dataset could be used as a monitoring tool. These comparisons have led to recommendations for the ongoing and future focus of the citizen science component of the program. For example, initially, data collected by citizen scientists were presence-only within broad zones, and over time the program has moved to the collection of presence and absence and the use of a smartphone application that allows for recording of the survey tracks of the citizen scientists while they search for dolphins.

The citizen science program is also used to collect observations of dolphins from areas that the vessel surveys can’t reach to fill spatial gaps in the dataset across the whole estuary. The program has since progressed to collect higher spatial resolution data via the development of a smartphone application that allows citizen scientists to record GPS locations. A focus of the program is to now identify methods for integrating the two datasets more directly and producing robust model outputs. Preliminary analyses have been undertaken using a Generalised Additive Model (GAM) framework. Future directions will include analyses that capture presence-absence data more reliably through the smartphone application and aims to identify other sources of data that can serve as model input parameters to account for inherent biases of data that have limited effort information.

Further discussion on potential analyses that could be applied by this program focused on a family of models that have an underlying Poisson model. A key question raised in the use of these models is: can they be used generally or is there a component of bespoke model development required?

The haul-out seal database (Victoria)

This citizen science program was started in 1997 and consists of the public sending in photos of seals that have either been hauled out or are deceased at locations around Phillip Island. These photographs are submitted into a database and have proved useful over time to be able to determine general patterns in haul-outs and what is typical in terms of temporal patterns in beach-washed animals. This has been useful in identifying unusual mortality events and in association with planning for implementing necropsies of animals. The program now provides a good baseline dataset for starting to look at the effects of climate change.

SealSpotter (Victoria)

The SealSpotter program consists of regular surveys undertaken several times during the breeding season at two sites, during which static photos of the seal breeding colonies are taken using a drone and a standardised method (McIntosh et al. 2018). These photos are uploaded into a publicly open web portal. Each image is then accessed randomly by the public and the seals within the image are counted up to 10 times. The counts are then assessed for majority agreement on counts for different age classes (e.g., juvenile/adult), dead/live pups, and seals with entanglements. Any counts outside the 95% confidence intervals are disregarded. Counts are regularly checked with those of an expert to assess the performance of the citizen science dataset. In general, after quality control, 4-6 counts from each photo are usable. The annual counts from this program augment systematic surveys conducted every five years to monitor the population (McIntosh et al. 2022) and provide valuable fine-scale data to interpret broader metapopulation trends. The outputs from the program are also being used to assess the accuracy of drone-based counts (Sorrell et al. 2019) and interactions of marine wildlife with marine litter (Claro et al. 2019).

It was noted that with the portal being completely open, it was extremely important to be able to protect the identity of participants and any information they provide. In the case of the SealSpotter program, information provision had to be voluntary and any information on the age of participants was based on broad classifications that prevented individuals from being identified, particularly those under the age of 18 years.

Southern right whale sightings (NSW)

With increasing numbers of southern right whales (SRWs) in New South Wales (NSW) waters, an associated increase in the data and photographs being collected opportunistically by the public was being observed. However, most data and photographs submitted were of very low quality. At the same time, there were a number of recreational drone pilots taking photos of SRWs of good quality and posting them to social media. The program was developed with the aim of engaging with and recruiting drone pilots with the specific capability to collect data associated with sightings. The project applied for animal ethics approval which placed some flight restrictions around the drones noting that these limitations are less restrictive than they are in other states (approach distances are less than in other states – see below).

To ensure the data being collected was useful for photo-identification purposes, the NSW Parks and Wildlife Service first recruited potential pilots into a system where they were assessed for their skill set. Each pilot then had to undertake some training to gain an understanding of the types of images that would be useful for photo identification. Each pilot is required to have CASA registration, drones with suitable capabilities for taking photos of a particular quality, and the expertise needed to fly drones in public spaces. The project has been running for two years, with a cohort of close to 30 pilots in each year.

Photos collected are not aimed at attaining information on presence or absence, but rather when a sighting is recorded to be able to respond as quickly as possible, with the intention of gathering suitable individual photo identification photographs of the individual(s) sighted. In this regard, the program has a two-dimensional approach in that it: first relies on the broader community of citizens to register a sighting and then, second, relies on the specialised volunteers gathering the higher resolution sighting data.

Since starting the program, the number of sightings has increased from an average of 12-20 sightings per year in 2019 to over 115 individual sightings in 2022. Of the 115 sightings, about 50 sightings have been accurately photographed by the program's pilots and from this dataset, information on the movement patterns of individuals has been able to be determined (it was noted that the 50 sightings comprised only ten adults and five calves). Although the program has only been running for two years, it has been able to identify that individual SRWs were repeatedly and reliably using specific bays with particular characteristics along the NSW coast. Sightings and associated photographs are contributed to the South East Australia SRW Photo-ID Catalogue (SEA-SRW PIC) database.

The program has significantly improved the sightings information collected and the quality of images collected with each sighting. The data will allow for the determination of habitat use and relationships between habitat use and environmental variables. Such information will be important for state-based marine estate management and marine spatial planning. An added benefit from the program has been increased compliance with pilots now very diligent in reporting non-compliance.

It was noted that the legal approach height for drones in NSW was 100 metres, whereas, in other states, it is 500m. These differences would affect the utility of applying such a program within other jurisdictions. It was also noted that to be able to collect images vertically from 100m and above an animal requires a 20-megapixel or above camera and, as a result, the program was probably operating at the limits of what was possible with recreational drones.

It was noted that an exemption to the 100m approach height for the pilots was not sought because one of the conditions associated with the recruitment of pilots into the program is that they retain ownership of the images. They, therefore, can use the images for their own purposes on the basis that the images are tagged in such a way that it is made clear that the photographs were collected by a research authority and from 100 metres (e.g., SRW@100m). This serves as an example of best practice for other drone pilots in NSW who are an audience that are difficult to engage with.

One of the positive benefits to come out of the program is that pilots across 2,000km of coast who mostly didn't know each other, now have active discussions on sightings, response activities, weather, technical drone issues, product comparisons, etc. In addition, because the pilots post their images on local social media, many have their own mini networks to help alert them to local sightings. The outcome of this is that once an SRW is in the vicinity of the coastline, it is quickly reported and the number of days when individuals go missing after being sighted is significantly reduced. This results in greater confidence in the interpretation of habitat preferences and the identification of potential emerging nursery sites.

The potential for the utility of this approach, as technology improves, was identified as a factor that could expand the applicability of this approach to a broader range of species.

Southern right whale sightings (Victoria)

Photographers in Victoria and particularly around Logan’s Beach have been gathering good-quality photographs of adults from shore-based locations for a number of years. The Department of Environment, Land, Water and Planning (DEWLP) have been supplementing this dataset with photos of calves taken with drones. The high-quality photographs collected with drones allow individual calves to be followed through time and provide a record of how the callosity formations on the top of the calf’s head develop as the individual ages. The drone work also allows for photographs to be collected from areas that are more inaccessible to the public.

All photographs collected by the public are stored in the SEA SRW PIC database, which contains photos from the 1990s onwards and sightings from the 1980s onwards. The catalogue has always incorporated sightings and photographs from the public, but in the last three years, some effort has been put towards formalising this input through the development of an online platform called “Whaleface”. This platform allows anyone to register to access the platform and submit their sightings and photos. The platform also provides a mechanism for communicating with users, informing them of how their sightings and photographs are being used and any outputs, such as publications from the catalogue.

The mark-recapture data derived from multiple photographs of the same individuals collected through time has been incorporated into a Popan population mark-recapture model to derive a population estimate. The data used to populate the model is a mixture of opportunistic and more structured data, including data from a small number of systematic aerial surveys. Some of the data comes from the Logan’s Beach platform, where people have been stationed most days during the period that animals are present. The citizens stationed at the platform undertake 30-minute scans of the beach, thereby providing some information on effort at that location. The model assumes that effort is consistent through time and that all individuals have an equal probability of capture, so the data used to populate the model are not ideal regarding these two assumptions. Given the behaviour and distribution of SRWs in Victorian waters, it is assumed that females would likely be detected if present, and by only including data associated with breeding females in the model, the assumption of equal probability of capture would be met. This may not be an appropriate assumption to make in other areas.

A logical next step for this dataset is to explore whether the collection of additional citizen science data can inform further population modelling or if it is more appropriate to identify that data from citizen science projects can't be used for population modelling (and direct those datasets to resolve other aspects of the biology of the species such as movement and habitat use).

It was noted that aerial surveys of the Victorian coast were planned during 2023 to support the drone work that was being undertaken. As part of this program of work, comparisons between the sightings obtained by the aerial surveys and those collected by citizens were planned. Based on detection rates, an evaluation of the robustness of the citizen science-based data for use in population modelling will be undertaken.

Southern right whale sightings (Western Australia)

Drones are also being utilised in southwest Western Australia to collect images for identification purposes. As an example, the Southwest Whale Ecology Study (SouWEST; http://souwest.org) aims to strategically, and through a coordinated approach, launch drones operated under permit from 5-6 accessible locations on land to record sightings and collect photographs that can then be used for photo-identification purposes. The launch of these drones from strategic locations is assisted by a citizen science team coordinated by Western Whale Research that records all whale species passing an area of the coast from a whale lookout (and have done this since 2004). Communications from this team and from a local whale watch operator inform the drone team of whales travelling through the area, which is facilitated in part by communication via WhatsApp. There are several other citizen science programs focused on southern right whales operating in Western Australia.

Opportunities and limitations

It was noted that while citizen science can contribute important data to monitoring programs, it cannot replace formal systematic scientific approaches. This is because most citizen science datasets are biased to some degree and often the form of these biases, including their sources, are not known. For example, in some cases, such as marine mammal sightings, it would be difficult to determine to what degree factors such as access to social media, distance from home, difficulty with access, weather, time of day, day of week etc. might influence effort and therefore influence the biases in datasets. In other cases, some knowledge of biases is known, particularly if there are spatial biases influencing the data (e.g., where effort is biased towards areas where there are higher human activities or where citizens know they can find animals). Regardless, if these biases are not accounted for in modelling approaches, they inherently bias outputs from models, reducing confidence in model outputs. Both the EBird project and the Victorian Biodiversity Atlas (https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas) were noted to incorporate strong validation processes as part of efforts to reduce data biases.

Citizen science approaches however do provide potential opportunities, either by filling gaps that systematic surveys might have or bolstering or strengthening population trend analyses, thereby reducing the number of systematic (and more resource-intensive) surveys needed to attain population trends. In this regard, they can be used in combination with systemic approaches with wide benefits. Evaluating the potential opportunities that citizen science approaches can provide and the level of confidence in model outputs in terms of utility is likely to vary across species and where/how such outputs might be used.

It was noted that the eBird project had produced best practice modelling methods (https://cornelllabofornithology.github.io/ebird-best-practices/), providing users with some guidance on what data collected under the program could be used for. A number of workshop participants identified that being able to ascertain that the citizen science program works, even if it is not a gold standard systematic survey design, and that the biases or issues with the data can be addressed either through quality control adjustments or statistical solutions, was a major aim. This then allows for consistent monitoring of populations that is not only less expensive than formal surveys but is also achievable over the longer term.

The relationship between focal species and the success of citizen science programs was discussed. While it was acknowledged that having a focus on charismatic megafauna (such as dolphins) contributed to the success of a program, the role of raising awareness (through social media, catchy project titles, etc.) and community values was also noted.

Matching citizen science data with key data needs for species listing and recovery

A brief overview of the data requirements for listing (and de-listing) species and monitoring recovery under the EPBC Act was provided within the context of better understanding where citizen science datasets might assist in addressing knowledge needs. It was noted that due to the unavailability of Departmental staff with an understanding of these data requirements at the workshop, the overview was provided based on information available on the website of the Department of Climate Change, Energy, Environment and Water, discussions with departmental staff and user experience. As a result, participants were guided to the relevant information on the Department's website[1].

For a species to be listed or considered as recovered, data associated with several metrics is required (Table 1). Any listing must be able to demonstrate that there is adequate

[1] The relevant guidelines are: Guidelines for assessing the conservation status of native species according to the Environment Protection and Biodiversity Conservation Act 1999 and Environment Protection and Biodiversity Conservation Regulations 2000 and Guidelines for using the IUCN Red List categories and criteria available at: https://www.dcceew.gov.au/sites/default/files/env/pages/d72dfd1a-f0d8-4699-8d43-5d95bbb02428/files/tssc-guidelines-assessing-species-2021.pdf

information against these metrics and that those metrics clearly demonstrate that there is a need for the listing of a species or that there has been clear progress made to support the identification of the recovery of the species.

Ascertaining these metrics requires some understanding of:

a. number of populations/colonies
b. numbers contributing to the breeding population
c. information on (a) and (b) repeated through time
d. information on demographics (age- and sex-specific information on survival and fecundity)
e. habitat utilised, extent of utilisation and whether this varies through space and time, and
f. whether the above varies through space and time.

Additionally, in establishing these metrics, it is important to be able to separate natural variability from uncertainty due to a lack of information.

Table 1. Key metrics required for species listing and recovery. See text box for definitions of metrics.

Listing	Recovery*
Number of mature individuals	Number of mature individuals
Population trends (past and projected)	Population trends (past and projected)
Generation length	Generation length
Area of Occupancy (AOO) + trend	Area of Occupancy (AOO) + trend
Extent of Occurrence (EOO) + trend	Extent of Occurrence (EOO) + trend
Number of subpopulations + trend	Number of subpopulations + trend
Number of locations + trend	Number of locations + trend
Fragmentation	Fragmentation
Fluctuations	Fluctuations

* In addition, species recovery considers whether any of the key targets within recovery/conservation management plans have been met.

There are some clear issues in establishing these metrics for seabirds, shorebirds and marine mammals, particularly as information needed to establish the metrics and any changes occurring to them are largely not available. Further, without careful consideration of how these metrics might be measured, unintended biases could be introduced to the metrics, resulting in misinterpretation. Examples provided included:

- Geographic shifts (such as seasonal shifts or those associated with climate change) may compound ascertaining changes. For example, shifts may result in decreases in one area and increases in another which may not be determined if only one of those areas is monitored.
- Discontinuities in the distribution of species can introduce biases into the extent of occurrence. For example, if shorebirds are located around the shoreline of a lagoon, then the estimate of the extent of occurrence is that of the whole lagoon. However, the shorebirds are not utilising that whole area, only the edge of the lagoon.
- Varying spatial scales used for calculating the extent of occurrence and area of occurrence can introduce biases.
- Because of the requirement to be able to identify variability through time, it often takes a long time to achieve a signal. Depending on how long it takes to determine real change from variability, it may be too late to action management that might facilitate the recovery of spaces. This may be particularly problematic if using citizen science datasets, as it can take long periods of time before opportunistic datasets become useful for ascertaining changes in populations.

It was noted that it was likely that not all of the metrics were needed for a listing, particularly as some metrics would be easier to collect than others. In some cases, substituting surrogates such as model estimations may be acceptable where the situation for using a surrogate can be well argued, the method provides good evidence in a situation where there is no other information, and how uncertainty and any assumptions have been considered are clearly articulated. Examples of where estimates of extinction risk of population viability had been estimated on very sparse data with varying and sometimes opposing results were raised.

It was noted that a scoping project had been undertaken under the NESP Marine and Coastal Hub that incorporated an evaluation of research efforts against the priorities of recovery and conservation management plans for seabirds and marine mammals (https://www.nespmarinecoastal.edu.au/project-1-20/). In assessing whether the broader research literature reflected the research priorities identified in plans/conservation advice, few publications detailed such studies, potentially either reflecting the difficulty in achieving such linkages with data currently available or that there are other barriers to undertaking such integrative studies (e.g. access to the required datasets, analytical capability).

Current limitations and gaps

Participants highlighted that it was important to recognise that in collecting data to support these metrics, those data should not only be used to monitor where a population might be now, but also be used to estimate future population trajectories. This would then allow trigger points for action to be identified ahead of time. Issues associated with coordination across data collectors/holders, and those analysing datasets and estimating population projections were raised, as well as the role that dispersed and often sparse funding had in limiting coordination.

In considering the metrics, it was identified that it was not only important to monitor species populations, but equally important to measure the status and distribution of stressors on species, particularly given that it is the stressors that management can be applied to. The workshop was asked whether there are structured citizen science programs measuring stressors and coordinating those measurements with monitoring of species populations. In association, the workshop was asked whether there were specific efforts that could be directed towards better synthesising stressor data and making those data available so that information on stressors could be utilised in such a way.

Box 1. Definition of metrics utilised in listing/recovery of species

Population: the total number of individuals of the taxon

Population size: the total number of mature individuals in all areas (incl. all subpopulations)

Generation length: reflects the turnover rate of breeding individuals in a population – average age of the parents of the current cohort of newborn individuals

Extent of occurrence (EOO): the spatial spread of the areas currently occupied by the taxon. In the case of migratory species, EOO should be based on the minimum of the breeding or nonbreeding areas, but not both (b/c bulk of the population found in only one of these areas at any one time).

Area of occurrence (AOO): the area of suitable habitat currently occupied by the taxon. Similarly to EOO for migratory species AOO should be based on the minimum of the breeding or nonbreeding areas, but not both (b/c bulk of the population found in only one of these areas at any one time).

Fragmentation: situations where individuals are found in small and relatively isolated subpopulations. This often results from, but is different to, habitat fragmentation and requires knowledge of the area of occupation, dispersion behaviour and density of species.

Fluctuations: refers to population size or distribution area increasing and decreasing on a recurring basis. Important to distinguish the downward phase of a fluctuation from true reduction/decline - fluctuations with periods similar to or longer than the assessment period may be difficult to distinguish from declines.

Discussions noted that even when stressors were measured, often there is a knowledge gap between the threat and the actual impact on a species or population, particularly because linking stressors to actual impacts (e.g., changes in vital rates) is difficult. This is especially the case with stressors that are dispersed and pervasive. It was noted that precautionary approaches can be a mechanism through which the uncertainties on impacts on populations by stressors can be accounted for. However, in practice, precautionary approaches are difficult to implement without risk or vulnerability assessments that allow for some estimation or identification of what is precautionary or not. It was noted that there might be other factors that influence the application of precautionary approaches, including conflicts over the use of spaces, access to resources and economic interests. In the case of migratory species, the application of precautionary approaches is further complicated because many of the stressors on populations are located in areas outside of Australia. It was noted interactions between remote stressors and those occurring more locally can result in the compounding of local stressor effects.

An example of linking a stressor to impacts on a population was provided. Using a modelling framework, the likely outcomes of mortalities of little penguins caused by dog attacks on an average-sized little penguin population over a period of 1520 years were estimated. The value in undertaking this exercise was that it allowed the project team to identify the specific data needed to estimate population projections, and in association current monitoring gaps, and to be able to ascertain the outcomes of repeated stress events and stressors on populations. The value of undertaking either modelling or expert elicitation approaches to determining impacts is that these approaches can be first used to inform monitoring designs and their implementation and second, link these monitoring frameworks and the analyses of the data being collected to management actions to identify what is needed practically to achieve recovery. It was noted that the modelling approach described was an intensive process, and the ability to be able to apply it across all listed species was beyond current capability capacity and the available funding, but that this might be where citizen science could fill some gaps.

A second example focused on evaluating the effectiveness of management measures aimed at reducing dog disturbance on shorebirds in intertidal foraging areas was provided. The modelling approach utilised identified that the effectiveness of management was very low – a 3% benefit resulted from applying management actions. This highlighted that the local stressors on shorebirds are many and varied and the management options available to reduce individual stressors have quite small effects. In the case of shorebirds, the stressors that might be important are spatially specific to a particular breeding or feeding site, such that the stressors on one roosting site might be very different to those at a neighbouring roosting site. As a result, the optimal management actions required might be specific to a particular site. In this regard, citizen science could be a powerful surveillance tool at very fine spatial scales, with dedicated observers collecting information on stressors and populations from individual sites routinely through time to determine these site-specific characteristics.

In discussing the capacity of citizen science projects to collect information on stressors, the openness of citizens to collect information was identified as highly varied, particularly if there was a compliance component. It was noted that in fisheries, such approaches had been effectively applied to many species. Differences identified between fisheries and listed species frameworks were that:

- There are management frameworks in place that place controls on the industry
- The industry has agreed to those management frameworks, and in doing so, has agreed to modify their activities in response to management measures ahead of time
- The industry is providing data on populations that can be used to estimate abundance
- There is a direct loop between monitoring of fish populations, management and industry responses

In this regard, it was identified that fisheries data was a form of citizen science data. It is collected in a non-systematic way (fishers are going to places where they can catch fish and not going to places where they won't catch fish) and collected by the community. It was suggested that it would be worth evaluating how much time and effort has been placed into developing all of the components that contribute to management frameworks for fisheries. In addition, it would be worth identifying how much time it takes to recover a species when you do have such a supported management framework. It was noted that in the case of fisheries, given that people's livelihoods depend on the ongoing sustainability of the populations being fished, there was a different alignment of interest to other industries where interests are more focused on a different value proposition, and sustainability is more tied to achieving social license. In considering fisheries as a form of citizen science, it was noted that it was similar to those examples provided where a small group of dedicated photographers or drone pilots are recruited to provide data, rather than less structured forms of citizen science.

Opportunities for progressing the utility of citizen science

The two most important elements that could be considered as needing to be incorporated into citizen science programs/projects were (i) a record of the amount of effort associated with observations and (ii) ensuring that observations are collected from pre-specified sites within the survey design (rather than just where the citizen might want to go). Ways of facilitating this were identified, including:

- Implementing roster systems that can address the collection of temporal effort
- Incorporating gridded spatial maps that citizens fill in to provide some indication of spatial effort
- Utilising smartphone applications that allow for the collection of effort through space and time. Some of these can provide GPS locations, and the start and end times of surveys and incorporating a list of potential species can provide presence and absence data without the user inputting specifics into the application.

Information on effort and also facilitate data collection without the need for specific input by the user. Addressing issues associated with spatial coverage of programs/projects was identified as the most challenging to address, but that improvements that supported design-based approaches were possible. If implemented, they provided an opportunity to shift the culture of citizen science. These design-based approaches could be implemented within programs/projects that incorporated varying levels or options for input, and the associated data streams generated were easily distinguishable to the analyst.

In association, it was noted that in implementing design-based approaches, the limiting factor often was the level of engagement with citizens that was required to support participation. It was important to be able to inspire and continue to engage with those participating in projects with the same level of energy and motivation. Quite often, programs/projects were under-resourced, limiting the amount of engagement possible. Trying to encourage funders to support community engagement and technology development that could support engagement is quite difficult.

In considering the use of smartphone applications (apps), it was noted that developing apps was exceptionally expensive and required significant investment over multiple years, both to develop and maintain the app and to ensure it is user-friendly. Further, they require considerable investment to raise awareness of the use of the app, particularly in a universe of millions of apps and in maintaining the high-quality data generated from the app. In the case of the Dolphin Watch project app, rather than developing and maintaining a unique app, a fisheries reporting app was modified for the uses of the project. To develop a unique app, it was estimated that it would cost $30,000 to develop the app, $10,000 a year to maintain the app and then another $30,000 to implement improvements to the app. Utilising an already existing app meant that the costs were reduced to $10,000 to implement the adaptations required for the project. However, the ongoing utility of the app does rely on its ongoing maintenance by the fisheries agency and ongoing collaboration with the various agencies/institutions.

Key elements for success

Having discussed varying approaches and applications of citizen science, the workshop considered what might be the fundamental criteria that contribute to a sustainable, well-designed and supported citizen science program/project. The following key elements were identified by participants:

1. An identified core group of citizens that can be engaged in the program/project
2. Good resourcing for supporting the program/project and in association:
   a. Ongoing Effective support tools to facilitate the collection of data and associated effort needs
   b. Effective data quality systems for verifying and cleaning the data collected
   c. Efficient data management systems that support easy access to data and efficient use of data
   d. Effective communication and outreach on the program/project through multiple channels
3. commitment to the program/project

4. Multiple entry points for engagement that cater to the amount of time/effort/interest of citizens
5. Clear pathways or mechanisms for motivation
6. Mechanisms for citizens to provide feedback on programs/projects for continuous improvement of programs/projects
7. Systems that allow for evaluation of the relative value of modifications to the program/project
8. Direct links to management for ensuring coordination and effective use of outputs

In considering how citizen science can contribute important data to monitoring programs, particularly for addressing knowledge gaps for listed species (see section 3.2.4), two important initial steps should be undertaken when developing programs/projects:

1. Identification of the information priorities for a particular species (e.g., as articulated in recovery or conservation management plans), how much data is required to meet those priorities and what are the tangible benefits of meeting those priorities
2. A form of a cost-benefit analysis that weighs up the costs of a citizen science program/project with those associated with carrying out systematic scientific approaches. This would not only consider the financial costs of developing each form of program/project but also what data was achievable from each program/project (and how robust these data might be), what are the benefits each provides to overall monitoring of the species and how easily the programs/projects could be maintained (and in association the data generated).

The role of government agencies through the process of issuing permits in establishing provisions for coordination, data availability and delivery of information was discussed.

Next steps

To assist the NESP in identifying areas for future investment, it was identified that useful next steps would be to:

1. Conduct a high-level audit and assessment of programs and projects. This would involve:
    a. Identifying existing citizen science programs/projects on seabirds, shorebirds and marine mammals, and as part of the audit, identify the various groups (community, Indigenous, research, non-governmental, governmental etc.) that are part of each program/project
    b. Identify where and how each program/project meets the key criteria outlined in section 3.4.1 and whether each has been developed on the basis of the two initial benefit analysis steps also outlined in section 3.4.1
    c. Based on (b), identify gaps in programs/projects, including:
        i. Whether the program/project utilises a statistical solution to address information priorities or whether there is a requirement to develop statistical solutions to address information priorities
        ii. If a statistical solution is not available, whether a design-based solution is required for the program/project to be able to deliver data that meets the information priorities for the species (e.g., increased resources, improved technology, greater engagement etc.)
        iii. What might be some of the challenges in providing outputs from programs/projects for use in management (e.g., translation of raw data into useable products/accessible literature, development of pathways for supporting the uptake of information in state/territory and national decision making);
    d. Identify the potential for cross-jurisdictional collaboration/coordination/exchange of knowledge/expansion of programs/projects.

It was noted that some of the elements of (c) and (d) could be conducted as individual projects. Some previous work conducted under the Threatened Species Recovery Hub (https://www.nespthreatenedspecies.edu.au/projects/citizen-science-for-threatened-species-conservation-and-building-community-support) was highlighted. This project undertook a national review of citizen science programs/projects on threatened species and could be a potential starting point for such an audit.

2. Bring the various programs/projects working on individual species together, identify how they might best coordinate their efforts, and how they might bring the data being collected by the various programs/projects together to provide data at a national scale that can then be utilised to meet the priorities for that species.

It was noted that some efforts had already been undertaken to facilitate such coordination under the NESP Marine Biodiversity Hub (e.g., https://www.nespmarine.edu.au/project/project-a13-estimation-population-abundance-and-mixing-southern-right-whales-australian-and) and some further coordination of SRW datasets is being facilitated through a project under the NESP Marine and Coastal Hub 2023 Research Plan. It was also noted that information on movements, in particular those data collected via the satellite tracking of shorebirds, was mostly collected by citizen scientists rather than researchers (in the case of seabirds and marine mammals most information on movements is collected by researchers). At present, those data are not well coordinated, and most datasets are being kept privately rather than being archived into central repositories such as Movebank or the Birdlife International tracking database. It was noted that some of the underlying factors associated with citizen science programs/projects, such as being driven by passionate citizens, often lacking scientific involvement, and often funded through private mechanisms, might contribute to those involved in those programs/projects not seeing the value in sharing data or making data accessible for use in management contexts.

3. Development of a centralised site that provides advice and resources for citizen science programs/projects, such as information on legislative and permitting requirements, best practices, network contacts, linkages to species priorities, and how more formal scientific approaches could be utilised/incorporated into programs/projects.

The development of a centralised site would serve as a coordination point for programs/projects and serve to build a community network that supports best practices, including upholding FAIR data practices. This would facilitate greater access and use of data for management purposes.

4. A high-level analysis of the growth in citizen science programs/projects and the use of those data in governmental processes and decision-making. Such an analysis might consider what proportion of biodiversity information comes from citizen science in relation to more formal science programs, and are there particular data sources that are favoured over others and what might be driving that use in decision-making. It could also consider evaluating the uncertainties or error rates in citizen science datasets and to what degree they might be quantified and, in association, what analyses these datasets are best suited to.

It was noted that in the process of undertaking a state-wide threatened species risk assessment in NSW and in association collating available datasets, very few citizen science datasets were able to be used. This was because very few provided long-term, well-structured and easily accessible datasets that could support a risk assessment. However, a parallel social risk assessment identified threatened species as an important issue. This highlighted the relevance of the social engagement elements of citizen science programs/projects to governmental processes and decision-making. The broader value of citizen science programs/projects from a social perspective, particularly in influencing conservation and environmental outcomes, was recognised as particularly important.

In considering how coordination and facilitation of the use of citizen science in management and decision-making could be improved, it was noted that the development of the offshore wind sector and the specific information requirements associated with understanding stressors and impacts of the sector on listed species was a priority for the Department of Climate Change, Energy, Environment and Water. It was highlighted that in order to understand to what degree species might be resilient to stressors caused by activities such as offshore wind installations, it was essential that some information on species abundance, distribution and changes in these through time be collected. While citizen science programs/projects were unlikely to provide information on abundance and changes in abundance, the above-recommended audit and coordination activities had the potential to identify where current programs/projects might be built on to provide information of relevance to understanding impacts on species. In association, two citizen science datasets focused on seabirds were highlighted as having the potential to provide some information on baselines prior to the offshore wind sector being developed and, in the future, being able to track change through time once installations are being built and are operational: (i) beach-washed seabirds (see also section 3.2.3) and (ii) annual at-sea surveys for seabirds. The utility of Ships of Opportunity was discussed as a potential area for the development of citizen science programs/projects for collecting information on flyways, species distributions and species presence.

Other considerations

The review of the workshop report identified citizen science projects, not discussed during the workshop, that have been collecting data on seabirds at sea around Australia and outside of the Australian marine estate since the 1940s. These have employed different survey methodologies, although those undertaken by Birdlife Australia have been utilising international survey protocols since the early 1980s. Historical data from the 1940s to the early 2000s have been collated and digitised. In 2016/17, BirdLife Australia initiated a coordinated at-sea survey program with dedicated observers on research vessels operating in Australian waters and into the Southern Ocean. The data collected by Birdlife Australia is now facilitating some analyses of trends in at-sea populations (e.g., Sojitra et al. 2022).

In considering where current citizen science programs/projects might be built on to provide information of relevance to understanding impacts on species, it is worth noting that an evaluation of the impacts of offshore wind farms on birds has been published (Reid et al. 2022). This risk evaluation may provide some guidance in identifying citizen science projects of relevance and datasets being produced that can support the priorities identified by the risk evaluation.

The evaluation regarded all regions around Australia as being equally likely to have offshore wind developments (i.e., all waters of Australia's Exclusive Economic Zone from the shore to 200 nautical miles) with susceptibility of species to impacts based on flight height, flight manoeuvrability and the ability of species to move to other habitats to forage. Lower weighting was placed on the ability to switch habitats and on those species that are external migrants or transit through regions. It should be noted that at least in the near future, offshore wind developments are not likely to be equally distributed throughout Australia's waters and will be limited in their distance from shore by the need to be proximal to onshore infrastructure.

The risk evaluation identified a number of species at high risk of impacts by offshore wind farms (Table 2). Areas with the highest risk scores included coastal regions of Queensland, the Northern Territory and northern Western Australia and inshore regions of Queensland, the Northern Territory and Bass Strait[2].

To further evaluate the risk of offshore wind developments to bird species and monitor for impacts, Reid et al. (2022) identified that surveys at local, regional and national scales that can provide baseline information on bird populations are required. This is potentially an area where citizen science projects can provide informative data, both now and into the future, particularly for establishing species and site-specific population trends. Information being collected by such projects would be highly relevant for the desk-based review identified by Reid et al. (2022) as the first step in evaluating the baseline data available for measuring the impacts of birds from offshore wind farms. Citizen science projects are already underway and could contribute to step three in this process, where conducting surveys is identified. Given the priority list of species at highest risk identified by Reid et al. (2022), coordination across a number of countries would be required, as many of the albatross species identified

[2] Areas with a risk of greater than 100 are listed with each area in each coast/inshore/offshore ocean region listed from highest to closest to a score of 100

as high risk either breed exclusively outside of Australia or have breeding sites outside of Australia. As a result, population data would need to be collected across their whole range in order to provide a comprehensive understanding of population trends and, in association, impacts.

Improvements to the risk assessment were identified as requiring a better understanding of the flight heights of birds, as these were largely unknown for most species, and an understanding of the dispersive and migratory behaviours of birds. Some of the citizen science projects utilising telemetry to understand the movement of species might be useful in this regard.

Table 2. Species identified by the risk assessment in Reid et al. (2022) that are at high risk to impacts from offshore wind energy.

Common name	**Species name**
Orange-bellied parrot	*Neophema chrysogaster*
Furneax white-fronted tern	*Sterna striata incerta*
Western hooded plover	*Thinornis cucullatus tregellasi*
Swift parrot	*Lathamus discolor*
Shy albatross	*Thalassarche cauta*
Far Eastern curlew	*Numenius madagascariensis*
Anadyr bar-tailed godwit	*Limosa lapponica anadyrensis*
Northern royal albatross	*Diomedea sanfordi*
Eastern Antipodean albatross	*Diomedea antipodensis antipodensis*
Grey-headed albatross	*Thalassarche chrysostoma*
Gibson’s albatross	*Diomedea antipodensis gibsoni*
Wandering albatross	*Diomedea exulans*
Campbell albatross	*Thalassarche impavida*
Indian yellow-nosed albatross	*Diomedea amsterdamensi*

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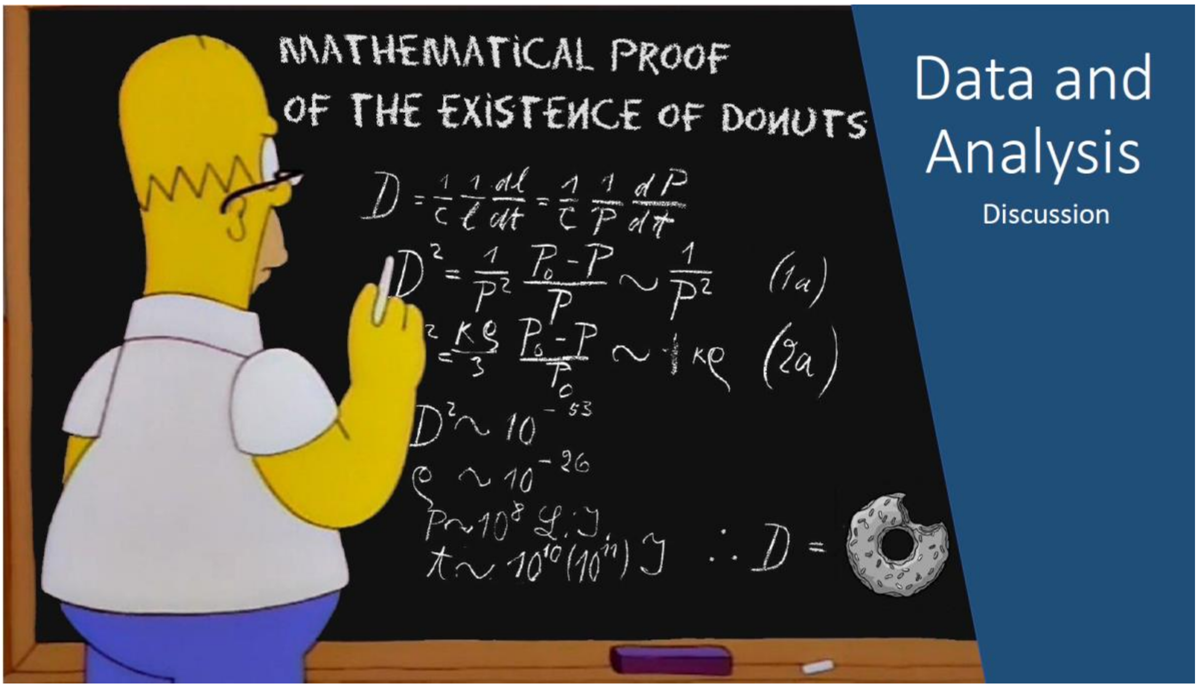
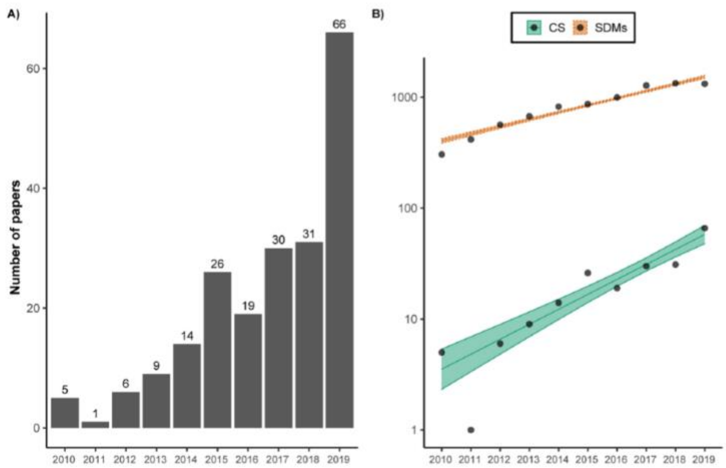
Appendix 1: Workshop presentations



Citizen Science use in Species Distribution Modelling



Feldman et al (2012) *Trends and gaps in the use of citizen science derived data as input for species distribution models: A quantitative review*

Fig (a) Annual number of papers that have used species distribution models (SDMs) with citizen science (CS) data; (b) generalized linear model with Poisson distribution of the total papers using SDMs (blue) and the papers using CS data (red) across the 10-year period covered by our review (difference in slopes: -0.16, Z = -5.4, P < 0.001), resulting in publication growth of 16% for SDMs and 36% for CS on average per year.

Today's Aim

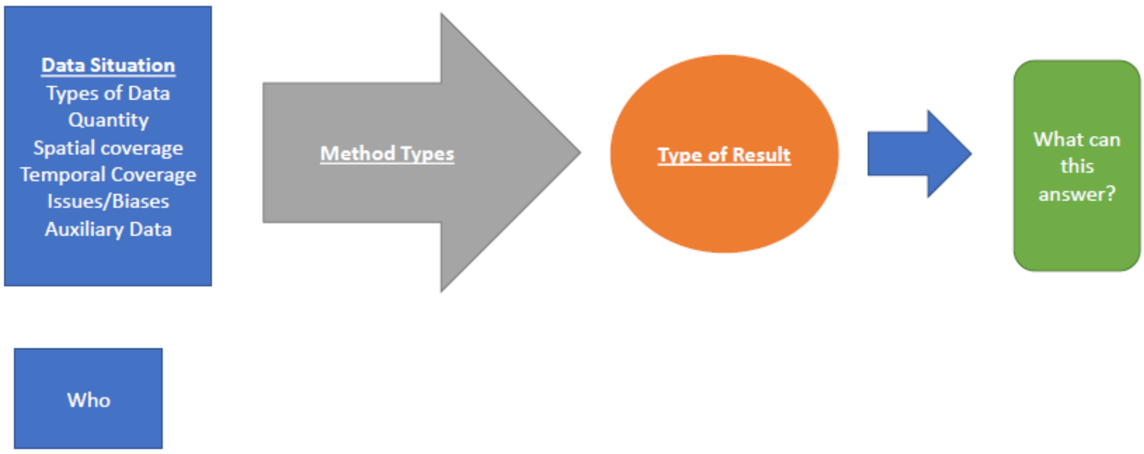
- Map current species data to what it can tell us (via available methods)
- These slides are just a framework to get the discussion started. We have made a start on some of the topics to get us going.

This Icon is to remind us to discuss add/re-shape what is there

Our Agreed Terminology + Acronyms

Type	Meaning
Opportunistic Data	Not as in collaboration as citizen Sci
Citizen Science Data	Bec= Data collected within certain parameters for a specific reason – collected by community Chandra = in collaboration with scientists, Richard – Good definition in literature Not Data Type/property of data but how its collected Spoon – Data collected by community vs citizen eg viewing photos Data collected by the public for scientific purpose Public see that they are contributing to scientific knowledge
SDM	
Presence Only Data	
PA only	
Count only	
Count/abundance survey	

Framework

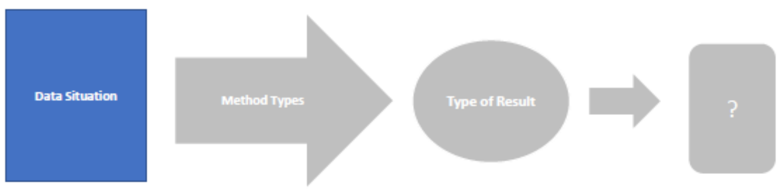


Who?

- People's motivation for contributing to citizen science
- Effects considerations on how structured the citizen science project can be.
- Citizen's location/coverage important
- Some CS projects driven by a question others driven by available public resource
- Often CS projects start to answer a local question then increase and can be used to answer questions beyond the original.
- Spoon Q: Is who asks the question define if CS?? E.g asking fishers at boat ramps vs a web site
  Scott thinks they are both CS
  - Answer may be about controlling sampling/effort?

Who? Cont

- Chandra – Qualitative focus – Collecting a sample
- Rowan – Capacity in which people are collecting the data eg if a scientist does it for fun (diving) that would be citizen science.
- Karen scientists are interviewing public rather than public volunteering.
- Scott – Design vs Undesigned
- Scott/Bec – Definition based on ownership and shared IP
- Data collected by citizens but data collection sound
- Jonathon- Citizen sci is engaging public in the project
- Karen – There are various interpretations and we need to acknowledge that



DATA

‘All’ Data Types in this domain?

Type	Example
Photo- ID	Photo of Southern right whales can match
Status Data	

Auxiliary Data

- Other biological data (e.g. mortality)
- Detection Probability (e.g Double Platform data)
- ?

Types of Data

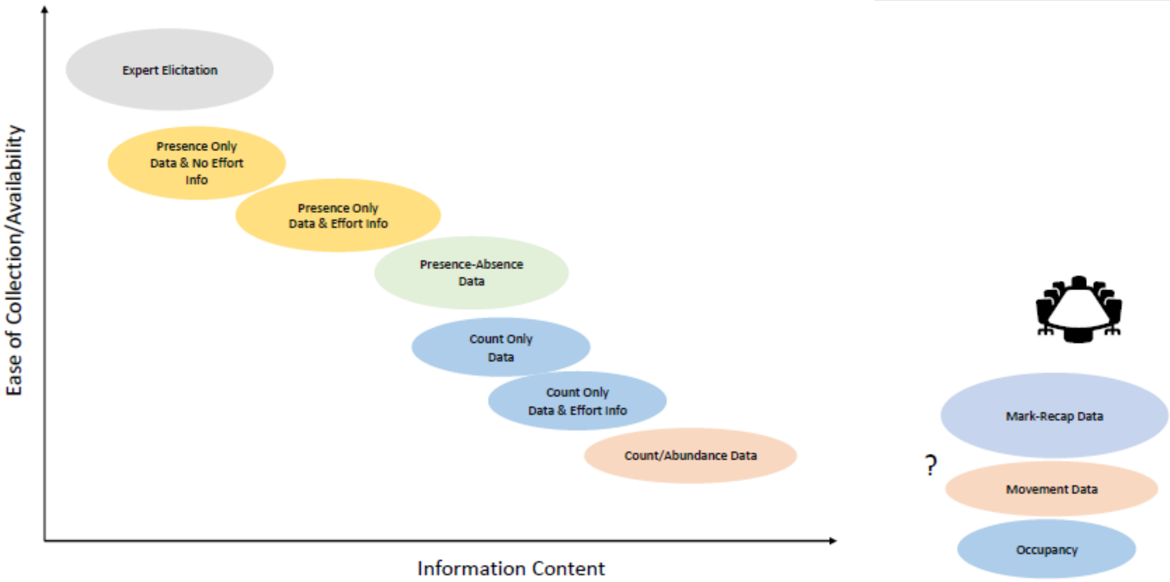
- Presence Only
- Presence/Absence Only

- Beach washed birds = survey of losers

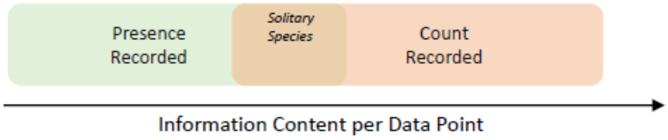
Discussion of aspects of CS

- Jonathon-Dimensionality of data
  - What are biases?
  - Add structure to the way citizen sci data is collected
  - eg backyard bird app with 15mins of effort built into the system/app
- Toby – Public engagement is important.
- Chandra – Are we looking at technology involved?
  - Karen - Won't focus but will be part of the discussion of what it can do
- Kasey – motivation of citizens is very important (eg photographers at Logan Beach) very engaged citizens are chasing where the whales are (sampling bias) to get where whales are not need a different type of citizen. Mandy – complex system for how communicating
- Spoon – attributes of the observers is part of the data set!!
- Richard = Always will have extremely complicated biases underlying. Can't extrapolate. Big issue. Always will be uncertainty. Tightrope between inclusion and getting people involved and statistical robust design.
- Gov needs to be involved with professional surveys to fill gaps.
- Toby – parallels to Fisheries (collecting fisherman data) often numerous data sets but difficult to extract. Still need ongoing designed surveys fundamental basic science Chandra – Complementary data/surveys/Integration
- Eric – [See chats] Peter [see Chats]

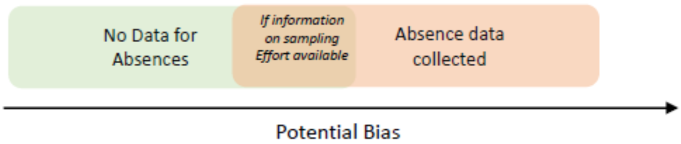
Not all Data is Created Equal



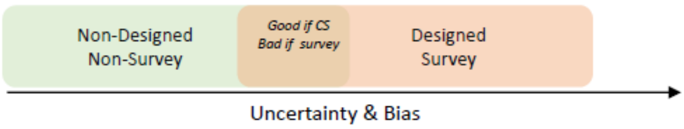
Why some data is lower on plot?



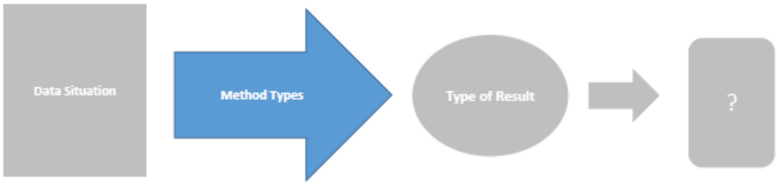
e.g 2 data point data set locations are
In good and bad habitat.
Abundance = higher count in good location
Presence = a presence in both locations
But if you had more presence data you would see a signal of more presence data in good habitat



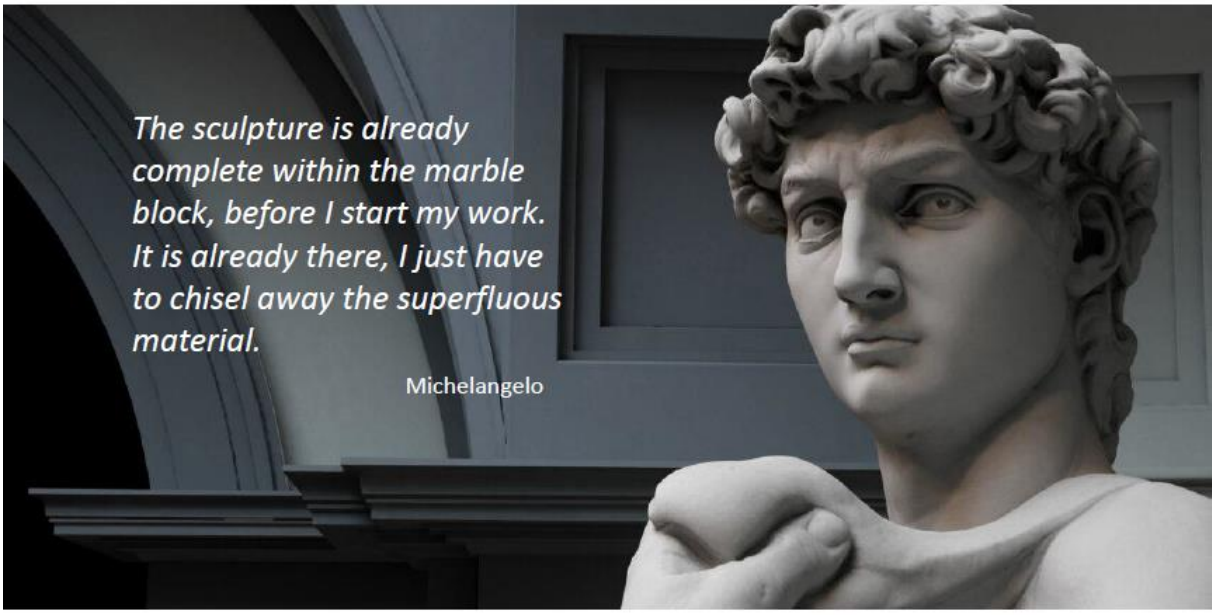
e.g. If our citizen science mainly collect data near cities then without absence data (or correction) we will think the species like cities.



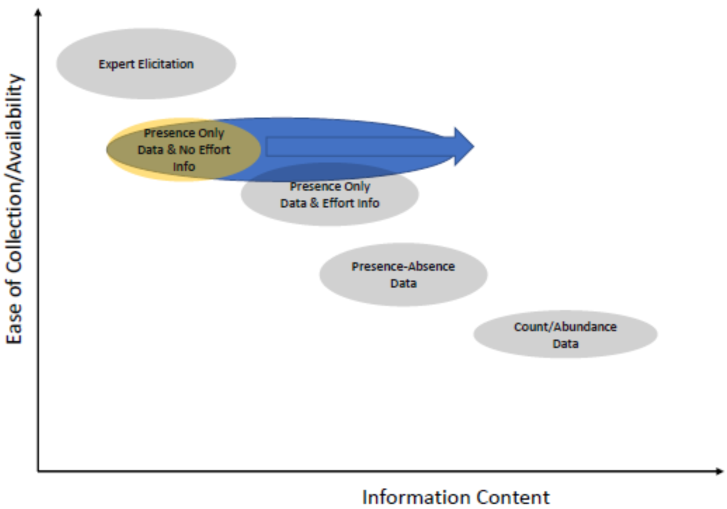
e.g. a) non-standard or documented sampling protocols/search area/observer skill/errors
b) Population and covariate Coverage



Methods/Models



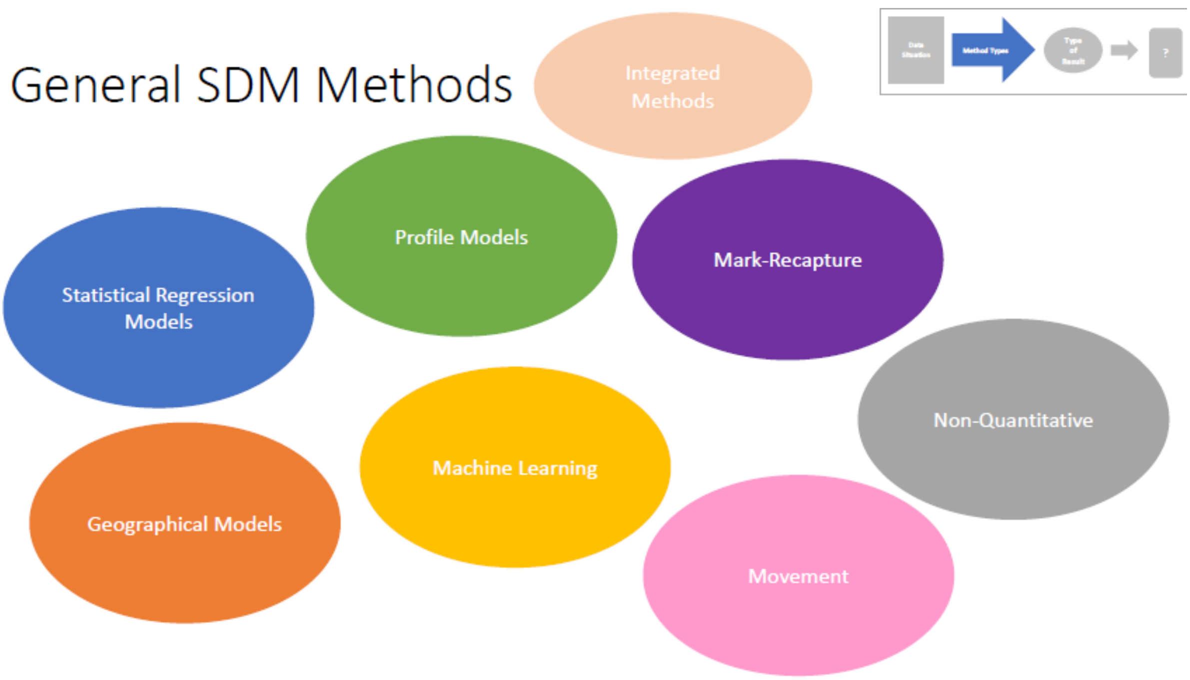
Information is in Data
Methods just unlock it?

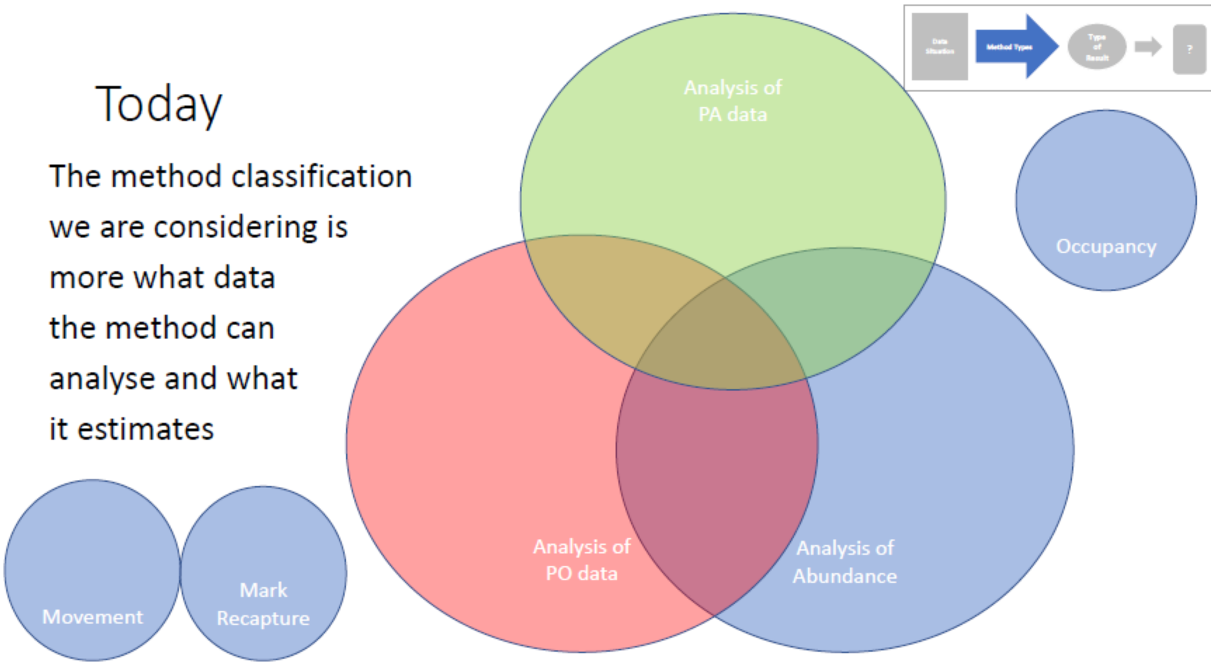


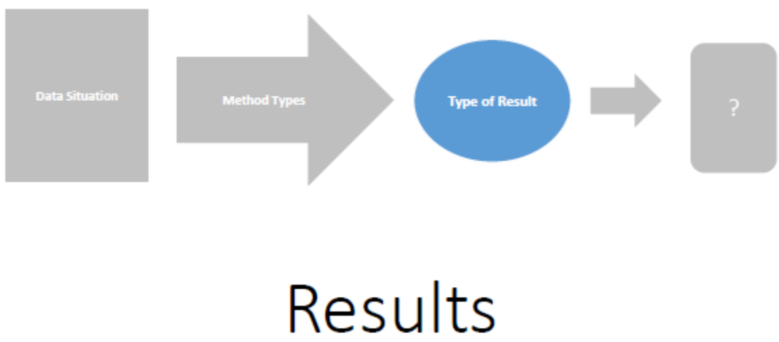
We don't need to dig into the brand of hammer

Or even the type of hammer

Possibly not even the tool at all. Just what we can make from each block of wood

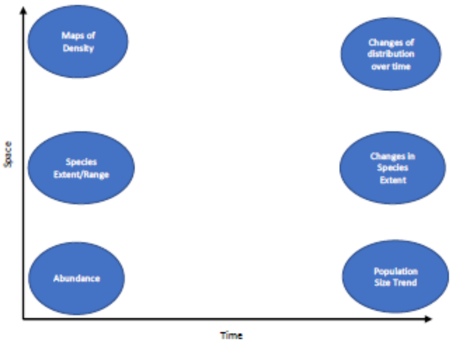



Today
The method classification we are considering is more what data the method can analyse and what it estimates
Analysis of PA data
Occupancy
Analysis of PO data
Analysis of Abundance
Movement
Mark Recapture


Data Situation
Method Types
Type of Result
?
Results

Properties of results?

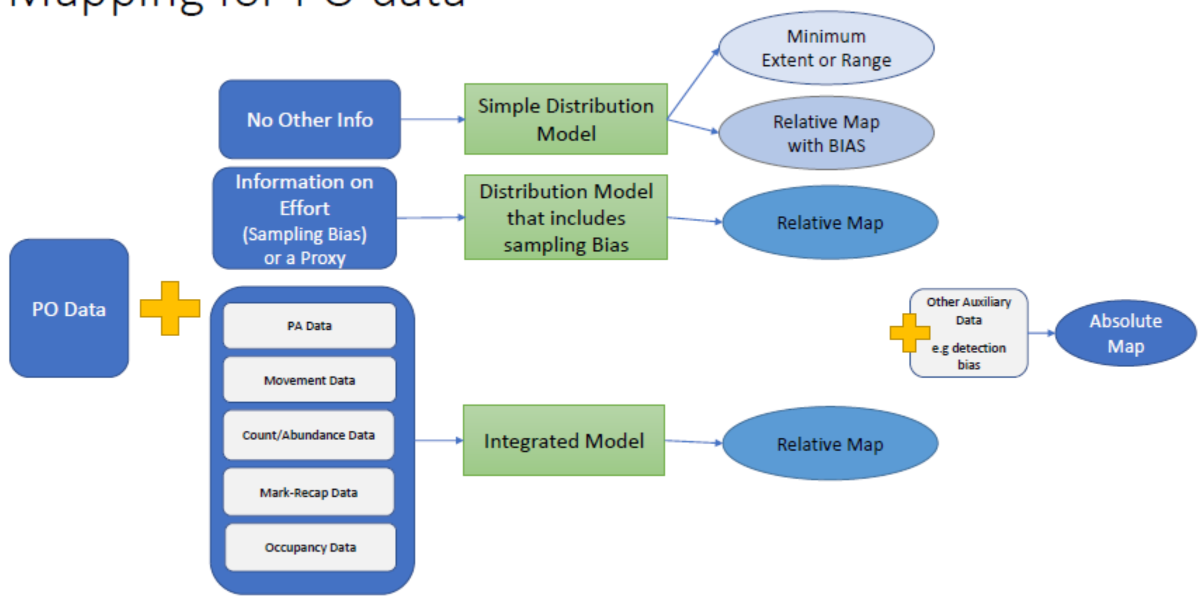
- Temporal vs Spatial
- Bias
- Absolute vs Relative
- ?



Properties of Data=> Implications for Results

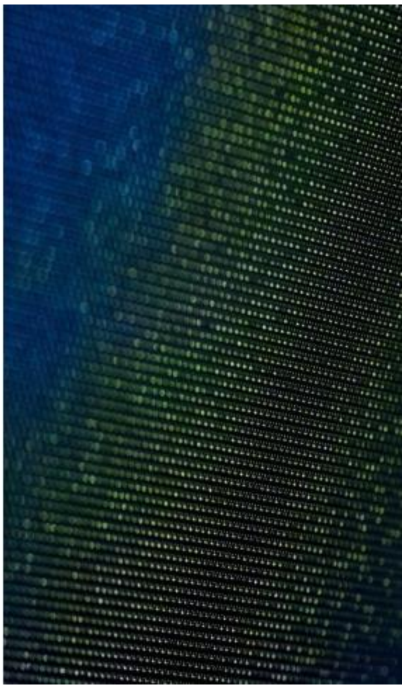
Property (From before)	Example	Implication
Biased but consistent bias thru time	People miss birds that are there but the rate this happens does not change over time	Trend will not be biased
Bias changes over time	Team get better at detecting birds over time	Trend will be wrong
Sampling effort changes over time	Over time more people are hearing of the citizen science program and sending sightings in	Trend will be wrong
Biased but spatially bias is same everywhere		Maps will not be biased at a given time
Bias changes in space	Sightings are more likely to be near roads	Maps will be wrong
Selection/Detection Bias	Male humpbacks are jumping out of the water so likely to be photographed. Female/calf pairs more cautious of boats.	Trend/Maps/abundance can be biased

Mapping for PO data



Examples

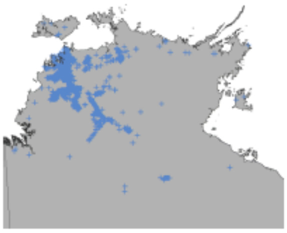
- **Gamba Grass** – PO data + Sampling effort Proxy
- **Wombats** – PO data + Sampling effort based on distribution on presences
- **Shearwater** - Abundance Only data
- **Nightingale** - Comparison of citizen science PO, PA and Abundance data
- **Large Whales** – Comparison of PO vs PA methods
- **Koalas** - Integrated Modelling in action
- **Red Gum** – Data……When Less is More



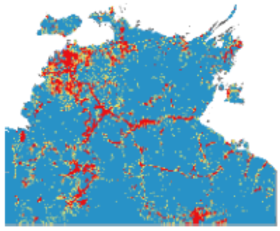
David/Scott et al.

Example 1: *Gamba Grass*
PO data with sample effort Proxy

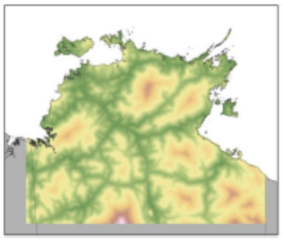
- Use PO date for other species from same programme. As If they detected other weeds in other locations its telling us they looked there and likely didn't see gamba grass
- Used integrated model (see Koalas)
- Also distance to road/accessibility
  - For marine applications things like distance to coast, human population density etc.



Gamba Grass PO data



All weeds PO data



Accessibility Distance to roads

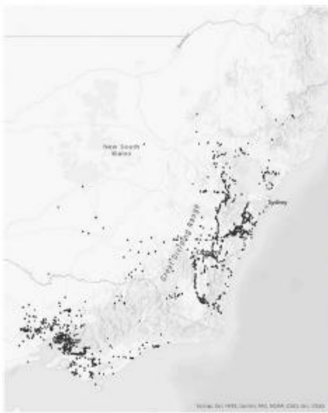
Mayadunnage et al. (2022)

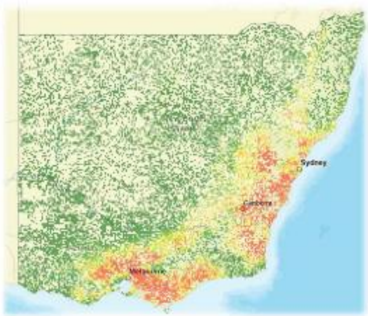
Example 2: *Wombat Road Kill*
Background points

- WomSAT, a website and application where citizen scientists can upload sightings of wombats
- Used MaxEnt
- Background points added

"For our background model, the background points were selected within a minimum convex polygon encompassing all the presence data. For the density model, a raster layer was prepared based on wombat roadkill presence data and we used this layer as a bias file."

Danger??





Martin et al (2020)

Example 3: Balearic Shearwater

Abundance only data

- Abundance only data has more information than PO data
- Modelled "Abundance given present"
- Random Forest regression models.

This will have a stronger relationship to habitat than PO but will it still be plagued by biases as you don't know the habitat where there are absences?

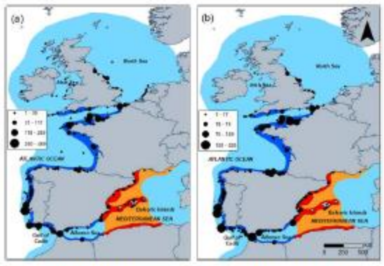


Fig: Observations of Balearic shearwaters considered in the analysis. *a) pre-breeding migration b) post-breeding migration;*

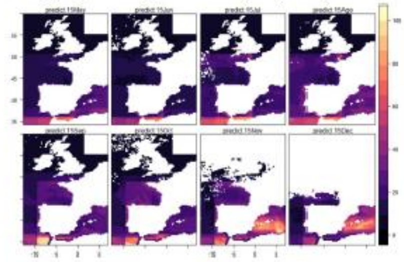


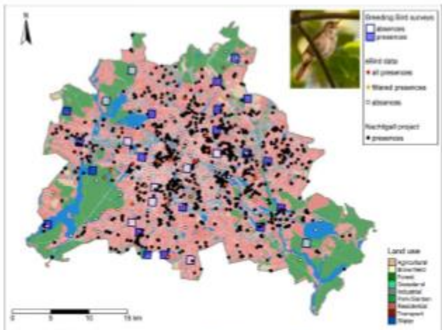
Fig: Predicted abundance of Balearic shearwater

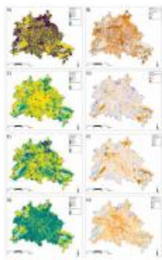
Example 4: Urban Nightingale

PO Data vs PA Data vs Abundance

Planillo et al 2021

- Found "the distribution model based on opportunistic data failed to identify the most relevant areas for the species in the outskirts of the city, even after correcting for sampling"
- "Results point to the existence of other unknown factors that are not possible to correct."
- They recommend:
  - Citizen Science projects aimed at SDM should be designed to avoid data bias.
  - Environmental gradients should be considered in CS project designs.
  - Recording species absences could improve opportunistic data quality.



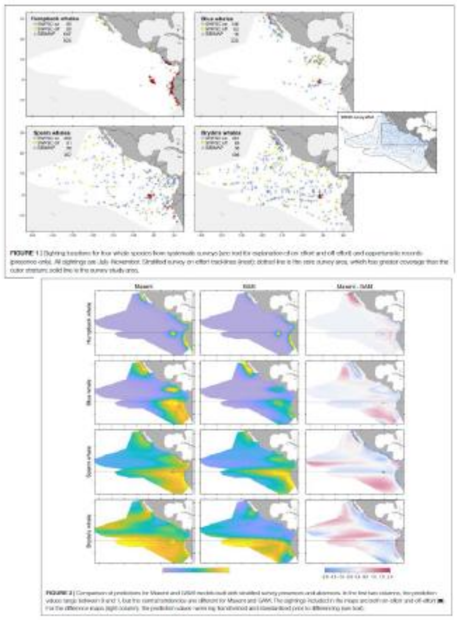


Fiedler et al 2018

Example 5: Large Whales

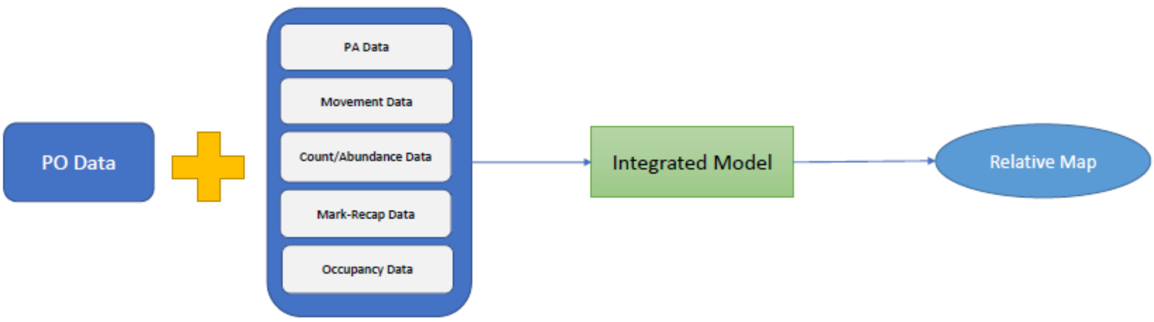
Comparison of PA and PO modelling

- Eastern tropical Pacific Ocean: humpback, blue, Bryde's, and sperm whales
- Used GAMS (PA) and maxent (PO)
- Found spatial bias in PO predictions can be caused using pseudo-absences
- "Predictions of uncommon large whale distributions from Maxent or other presence-only techniques may be useful for science or management, but only if spatial bias in the observations is addressed in the derivation and interpretation of model predictions."



Integrated Modelling

- Area still actively in development
- Methods to handle all data type combinations do not exist yet



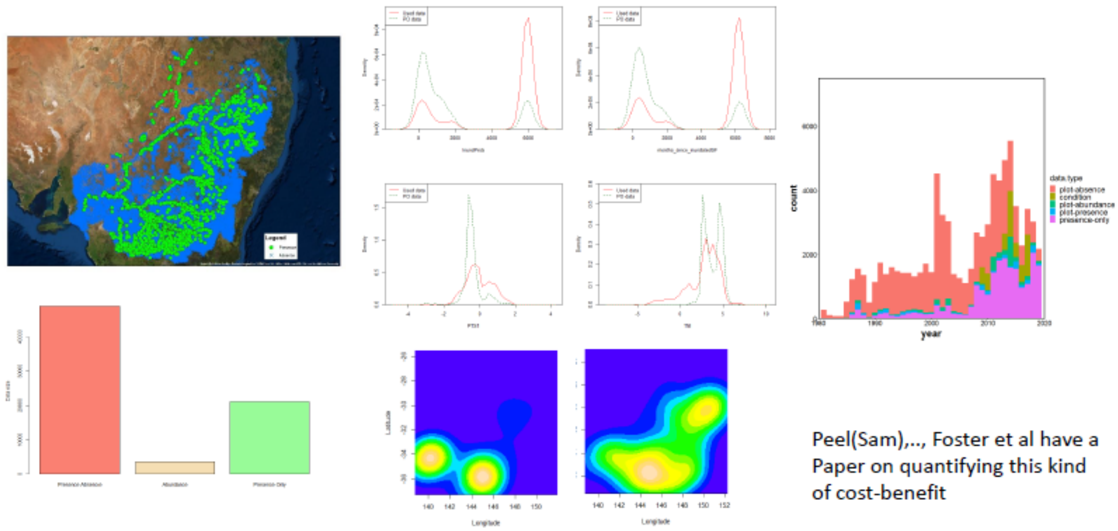
Scott Foster et al.

Example 6: Koalas Integrated Model

David/Scott et al.

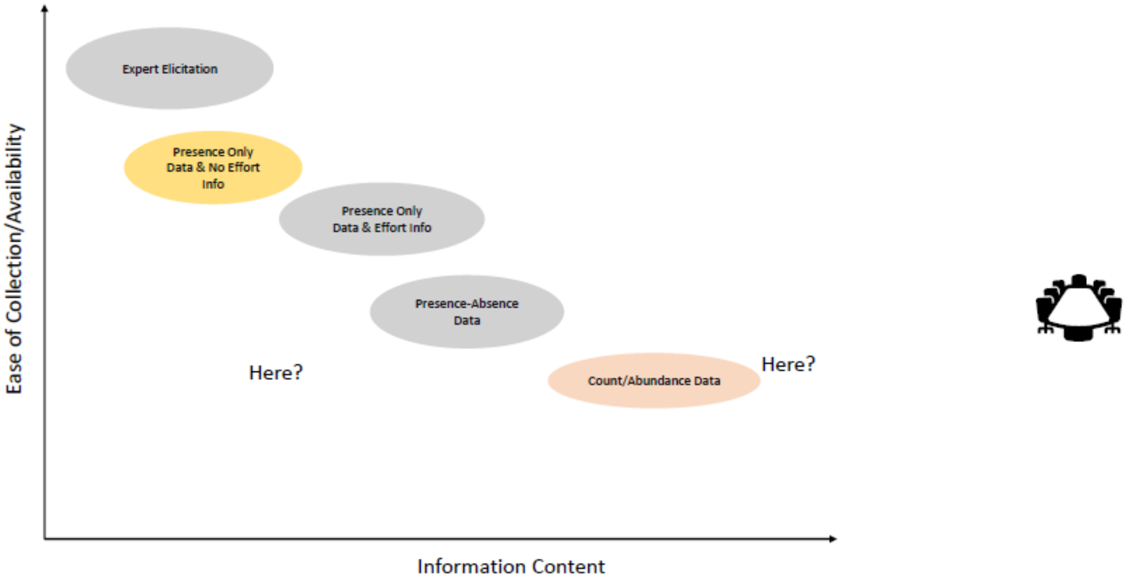
Example 7: When Less is More

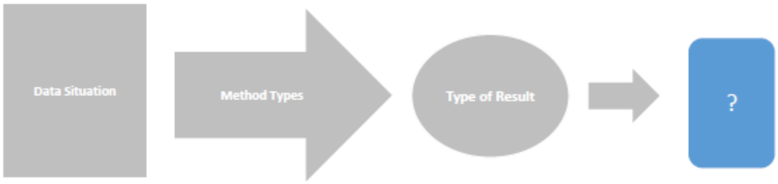
Red Gum Murray Darling



Peel(Sam),.., Foster et al have a Paper on quantifying this kind of cost-benefit

When Less is More –The sum can be less than it's parts?





Questions that can be answered with the result

What do we need to know for each species?

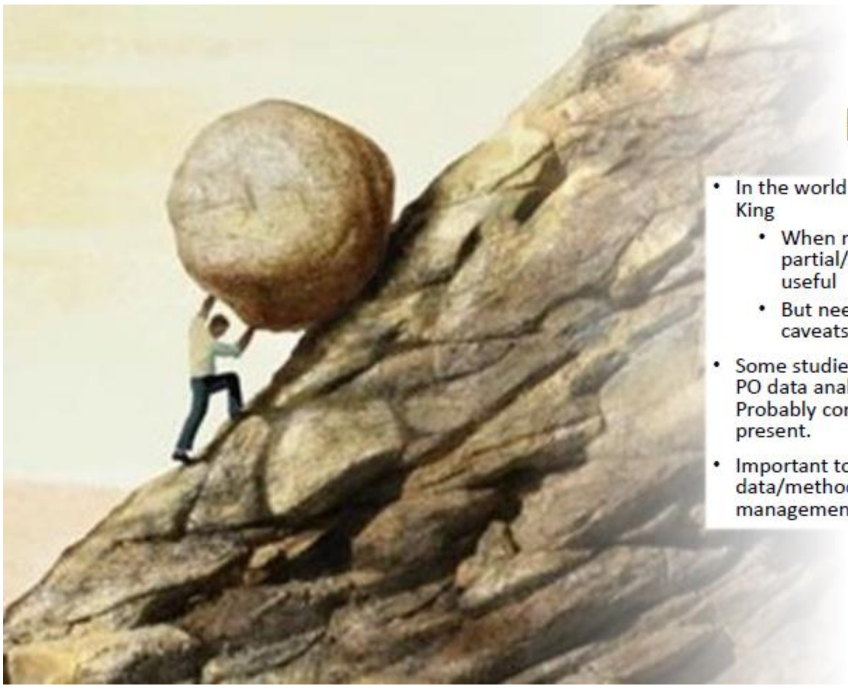
- ?

What do we need from the analysis for these uses?

- ?

How should we evaluate if CS useful for Species?

- What information do we need to consider?

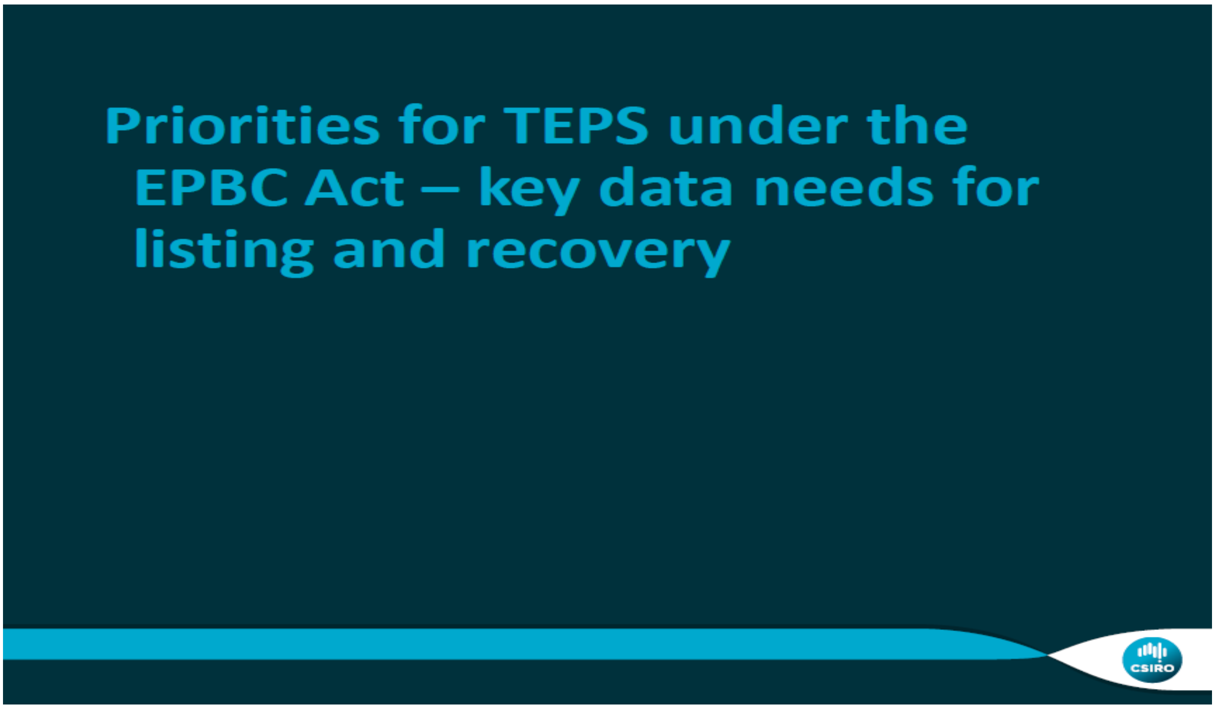


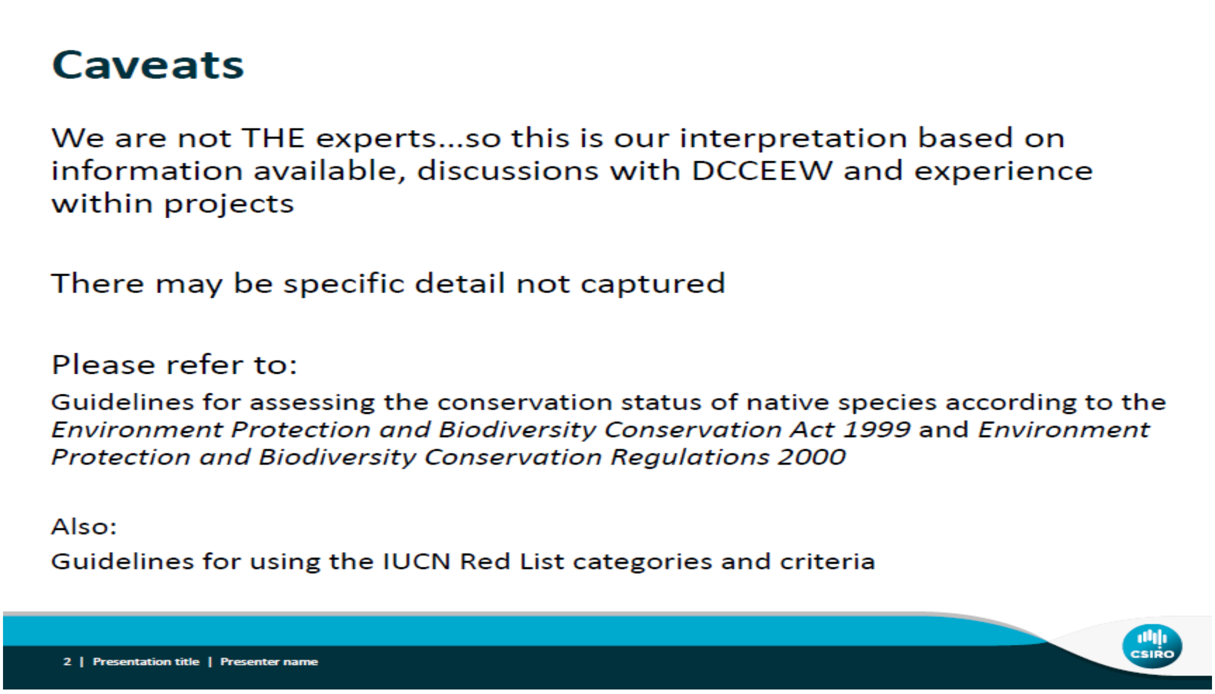
Hopeless?

- In the world of the blind the one-eyed man is King
  - When nothing is known even partial/biased information can still be useful
  - But need to be open and clear about caveats/assumptions/biases
- Some studies have found agreement between PO data analysis and PA data(Elith et al. 2006). Probably comes down to if sampling bias is present.
- Important to know from the onset when the data/methods available can possibly answer management questions

Example 10 : Practical steps to improve citizen science data?

- Johnston et al. Analytical guidelines to increase the value of citizen science data: using eBird data to estimate species occurrence
  1) the use of complete checklists (where observers report all the species they detect and identify); and
  2) the use of covariates describing variation in effort and detectability for each checklist. Occupancy models were more robust to a lack of complete checklists and effort variables. Improvements in model performance with data refinement were more evident with larger sample sizes


Priorities for TEPS under the EPBC Act – key data needs for listing and recovery
CSIRO


Caveats
We are not THE experts...so this is our interpretation based on information available, discussions with DCCEEW and experience within projects
There may be specific detail not captured
Please refer to:
Guidelines for assessing the conservation status of native species according to the *Environment Protection and Biodiversity Conservation Act 1999* and *Environment Protection and Biodiversity Conservation Regulations 2000*
Also:
Guidelines for using the IUCN Red List categories and criteria
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CSIRO

Key metrics

Listing:
Number of mature individuals
Population trends (past and projected)
Generation length
Area of Occupancy (AOO) + trend
Extent of Occurrence (EOO) + trend
Number of subpopulations + trend
Number of locations + trend
Fragmentation
Fluctuations

Recovery:
Number of mature individuals
Population trends (past and projected)
Generation length
Area of Occupancy (AOO) + trend
Extent of Occurrence (EOO) + trend
Number of subpopulations + trend
Number of locations + trend
Fragmentation
Fluctuations

Whether any key targets within recovery/conservation management plans have been met

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Definitions

Population: the total number of individuals of the taxon

Population size: the total number of mature individuals in all areas (incl. all subpopulations)

Generation length: reflects the turnover rate of breeding individuals in a population – average age of the parents of the current cohort of newborn individuals

Extent of occurrence: the spatial spread of the areas currently occupied by the taxon. In the case of migratory species, EOO should be based on the minimum of the breeding or nonbreeding areas, but not both (b/c bulk of the population found in only one of these areas at any one time).

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Definitions

Area of occurrence: the area of suitable habitat currently occupied by the taxon. Similarly to EOO for migratory species AOO should be based on the minimum of the breeding or nonbreeding areas, but not both (b/c bulk of the population found in only one of these areas at any one time).

Fragmentation: situations where individuals are found in small and relatively isolated subpopulations. This often results from, but is different to, habitat fragmentation and requires knowledge of the area of occupation, dispersion behaviour and density of species.

Fluctuations: refers to population size or distribution area increasing and decreasing on a recurring basis. Important to distinguish the downward phase of a fluctuation from true reduction/decline - fluctuations with periods similar to or longer than the assessment period may be difficult to distinguish from declines.

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Datasets required

All require some understanding of:

(i) number of populations/colonies

(ii) numbers contributing to the breeding population

(iii) information on the above repeated through time

(iv) information on demographics (age- and sex-specific information on survival and fecundity)

(v) habitat utilised, extent of utilisation and whether this varies through space and time

And whether the above varies through space and time

Important: need to separate natural variability *from* uncertainty due to lack of information

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Issues

Often not all information is known – e.g. not all colonies are monitored, not all subpopulations are known, not all potential habitat is known

Some populations may be geographically shifting – decreases in one area may not represent real decreases, extent of occurrence might be shifting

Discontinuities in species distribution can introduce biases into EOO

Varying spatial scales used for calculating EOO and AOO can introduce biases

Often takes a long time to achieve a signal – is this too late?

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Questions

Can these requirements realistically be achieved?

Where might citizen science be useful?

What might be some "tweaks" that could be added to citizen science data to improve its utility (reduce biases)

Where might be the balance in the collection of systematic data and citizen science data

- Where is the sweet spot in engaging citizens in science

Where might there be opportunities for testing modelling approaches/further developing modelling approaches that can integrate multiple datasets?

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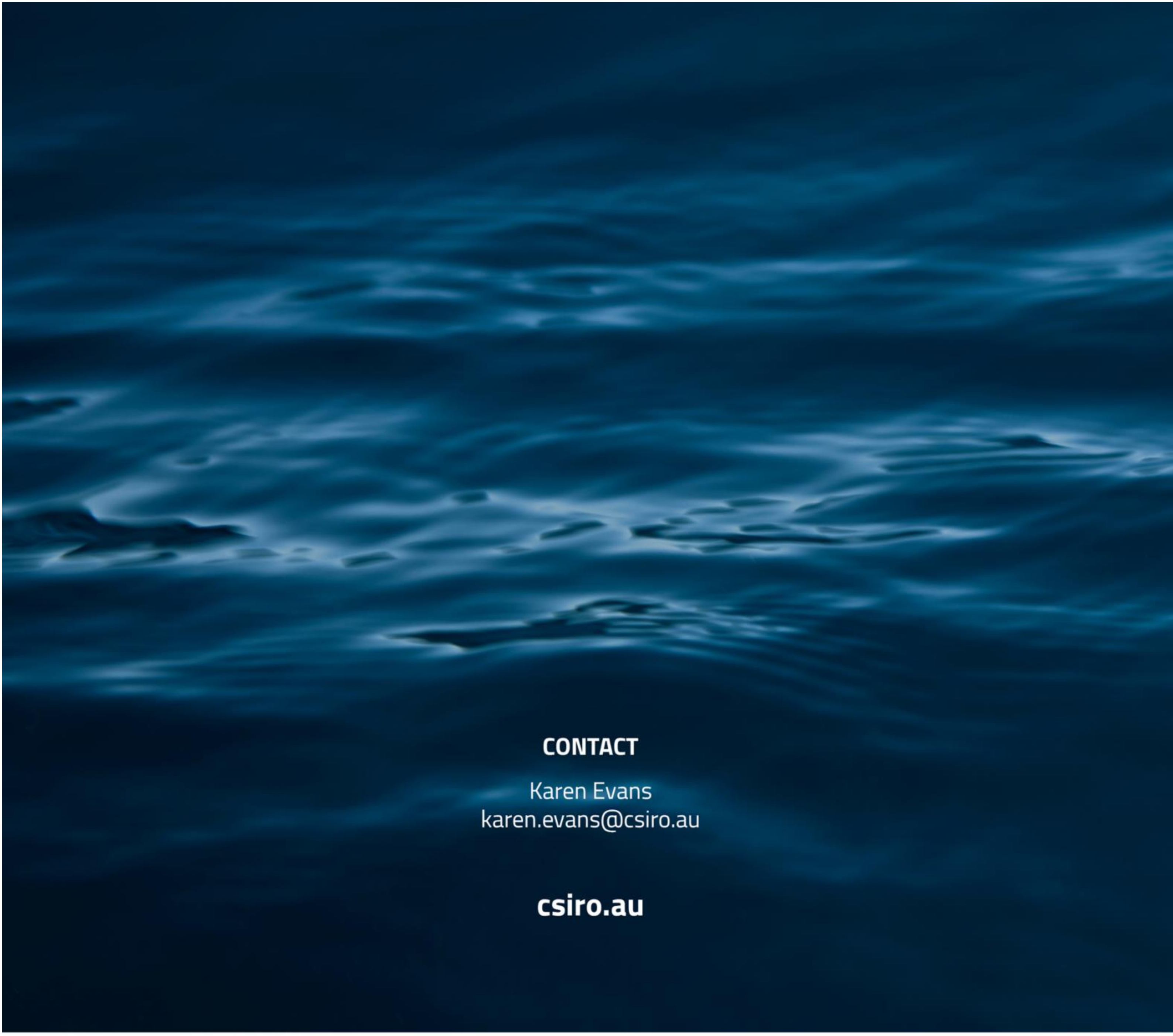

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