NESP Marine and Coastal Hub Workshop

Bass Strait Ecosystem and Offshore Renewable Energy

Day 2: Species distribution and offshore wind impact pathways

Date: Date: Thursday 10th April 2025 (11:00 – 15:00 AEDT)

Meeting Purpose: This workshop aims to describe the status of species modelling and consideration of potential impact pathways that is being conducted through NESP Marine and Coastal Hub research to support the development of an offshore wind industry in the region.

Location: CSIRO Auditorium and Virtual Attendance

Outline of Day 2

Timing	Item	Presenter
11:00 – 11:10	Welcome and outline of day 2	Alan Jordan (UTAS)
11:10 – 11:30	Integrated species distribution modelling	Skipton Wolley (CSIRO)
11:30 – 11:50	Population dynamics modelling: Leslie Matrix model for Southern Right Whales	Maud El Hachem (CSIRO)
11:50 – 12:10	Population dynamics modelling: Shy Albatross	Robin Thomson (CSIRO)
12:10 – 12:30	Population dynamics modelling: Priority shorebirds	Marcel Klaasen (Deakin University)
12:30 – 12:50	Population viability analysis: Orange Bellied Parrots	Nick Beeton (CSIRO)
12:50 – 13:30	Lunch Break	
13:30 – 13:50	Background and OWF development noise generation	Christine Erbe (Curtin University)
13:50 – 14:10	Noise Impacts and priority cetaceans	Sophia Volkze (UTAS)
14:10 – 14:30	Potential EMF effects	Andrew Gill (AIMS)
14:30-14:40	Workshop synthesis and next steps	Keith Hayes (CSIRO)
14:40 – 15:00	Q&A session	
15:00	Meeting close	

Integrated species distribution modelling

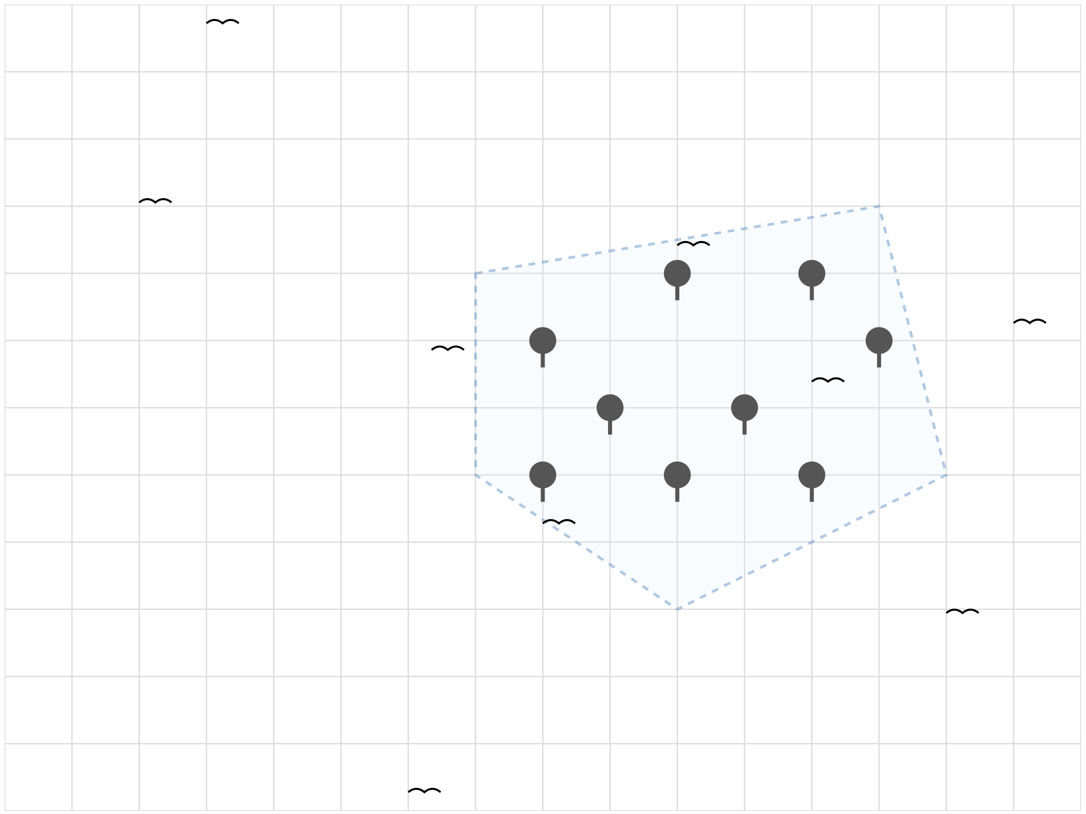
Birds in space and time

Skipton Woolley | 10-04-2025

Distribution of birds in space and time

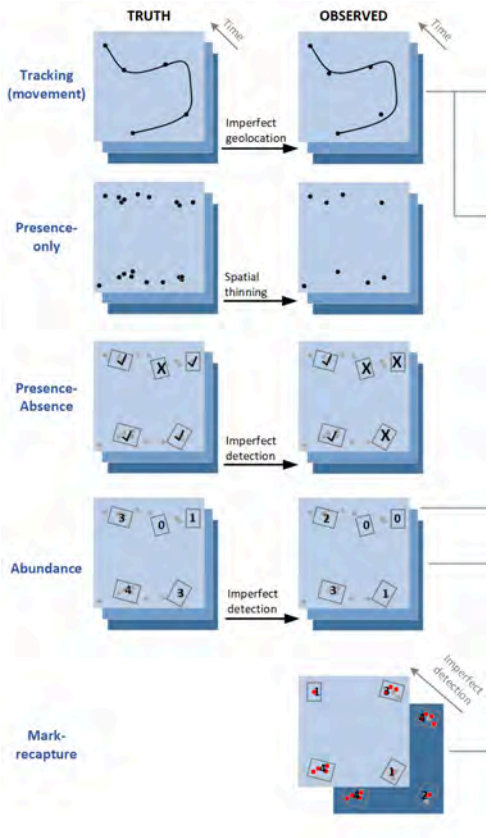
- Use of species distribution models (SDMs) is one way to understand the distribution of a species in space (and time).

- Predictions from SDMs can be used to understand how at risk species respond to human-induced disturbances or environmental change.



Basic ISDM idea

- We might assume that there is a 'true' (latent) distribution of a species that we observe with different methods, data or knowledge.
- Link different data types (e.g ad-hoc sightings and quantitative surveys) data via a joint likelihood
    - In the hope to get greater spatial/temporal coverage
    - Correct for observational biases contained within data types (disentangle sighting process)
- Survey data is typically at a population level, each record represents the presence, presence/absence, count or detection of individual(s) in a population (sub-pop)
- GPS data is at an individual level, each GPS ping is essentially a record of single individual in space and time

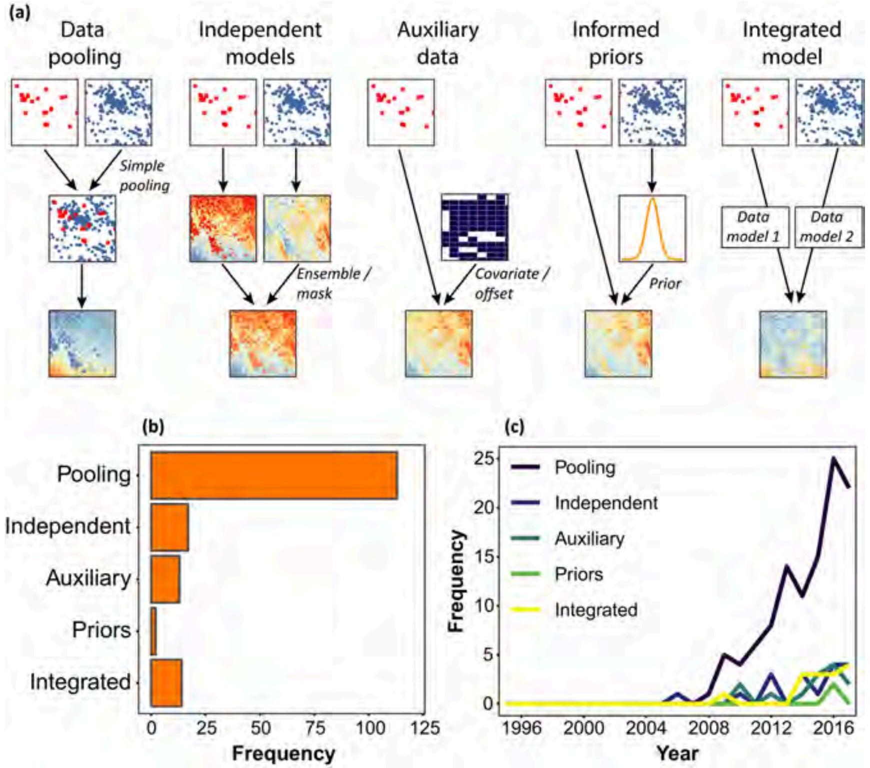


Adapted from Isaac et al., 2020 - courtesy of Keith

Correct for biases in data types

- The idea is to integrate different data types to better understand distribution, there are a number of ways to do this, such as:
    - Data pooling
    - Ensemble independent models
    - Offset (say when effort is known)
    - Informative priors
    - Integrated models (joint likelihoods)

- Recent developments in ISDMs literature tend to be integrated models within a spatial point process framework (e.g Fithian et al., 2015; Isaac et al, 2020)



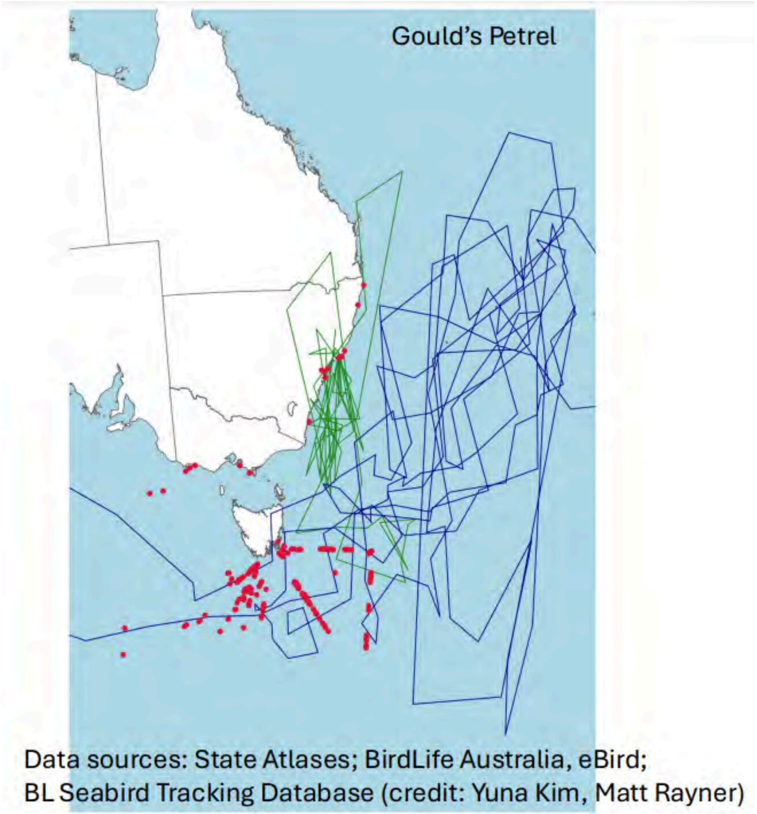
Fletcher et al., 2019

Real world data

Here is an example from the Gould's Petrel

- PO and eBird surveys typically contain sighting bias we wish to correct for.
- GPS data is independent of this, but typically biased to tagging location.
- Other data types are likely to contain different artefacts we wish to handle.

GPS data is one of main sources of information, so let's try and set-up an SDM approach that can meld these data in to an ISDM framework



Different data types for Gould's Petral - courtesy of Myriam

Spatio-temporal point process

If we assume that a GPS tracks can be used to understand the spatial-temporal use of the environment, or habitat preference, we can attempt to model the distribution of a species using a spatio-temporal Log-Gaussian Cox Process:

$$Y(i,s,t) \mid \lambda(i,s,t) \sim \mathrm{Poisson}(\lambda(i,s,t))$$

$Y(i,s,t)$ will be the count of GPS pings/locations within a grid cell for an individual bird (i), the grid cells will be bounded within a spatial region $\mathcal{A}$.

Depending on the resolution of telemetry data some kind of interpolation or smoothing (HMM) could be done to massage the GPS locations and frequency of data.

Spatio-temporal point process

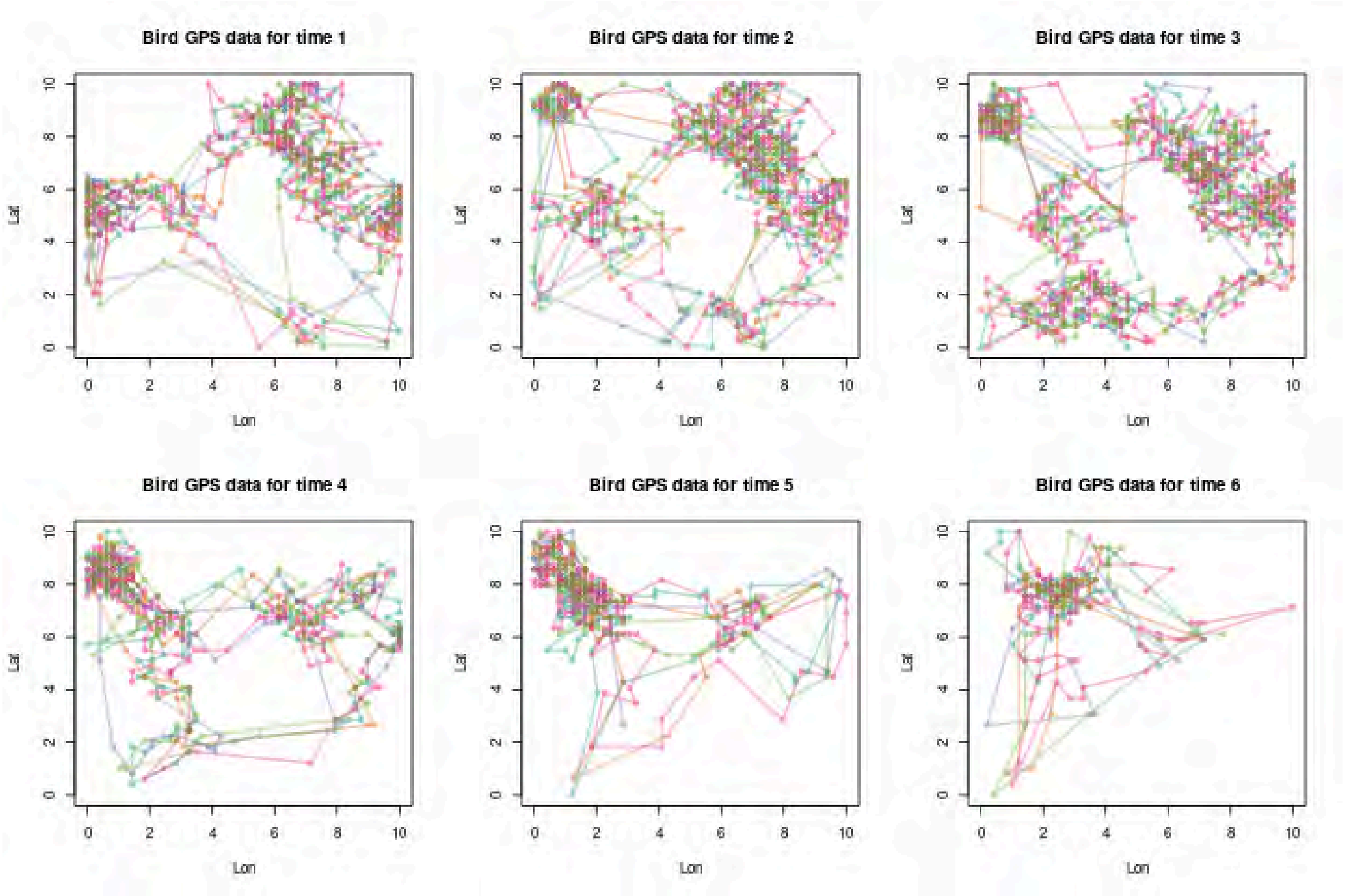
The **log-intensity function** is modelled as:

$$\log \lambda(i,s,t) = \alpha_i + X(s,t)^\top \boldsymbol{\beta} + W(s)^\top \boldsymbol{\delta} + Z(s,t)$$

- $\lambda(i,s,t)$ is the intensity function for each individual bird in the population (sub-pop).
- α_i represents the individual specific intercept.
- $X(s,t)$ represents environmental/habitat observed covariates (fixed effects) in space and time.
- $\boldsymbol{\beta}$ is a vector of regression coefficients associated with the environmental/habitat fixed effects.
- $W(s)$ represents a spatial sighting process in space, e.g distance from tagged colony.
- $\boldsymbol{\delta}$ represents a spatial sighting process in space, e.g distance from tagged colony.
- $Z(s,t) \sim \mathcal{GP}(0, C((s,t),(s',t')))$ is a Gaussian Process (GP) with mean zero and covariance function C, capturing spatial and temporal dependencies (not captured by fixed effects).

In a Bayesian context, each of the parameters in the model would have a prior distribution, which would be important in the context of the parameter model. For example, choices on hierarchical priors might inform partial-pooling of intercepts. I have not reported them here for some sense of brevity.

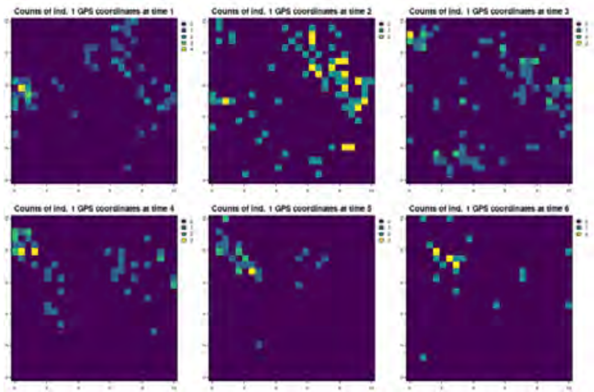
STPP with simulated data



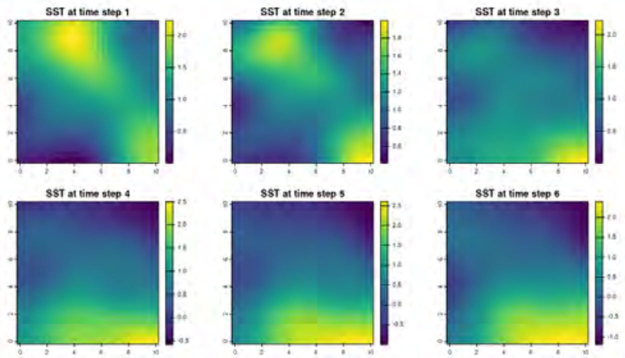
Simulated individual bird GPS tracks for six discrete time steps

STPP with simulated data

- We can count the number of GPS locations per individual per grid-cell to get an understand on habitat utilisation/preference on an individual, the idea being locations that have more GPS locations are places the bird spends more time/uses.
- Over multiple individuals we can start to infer (sub-)population level preference/distribution of the species and response to environmental conditions.
- We can also control for biases in the data such as distance from tagged colony.
- The spatial-temporal random effect will help capture the spatial-temporal movement of individuals that can not be directly captured via covariates.
- Potential to incorporate mechanistic process in the model to understand disperal or home range dynamics (e.g. Niven et al., 2025)



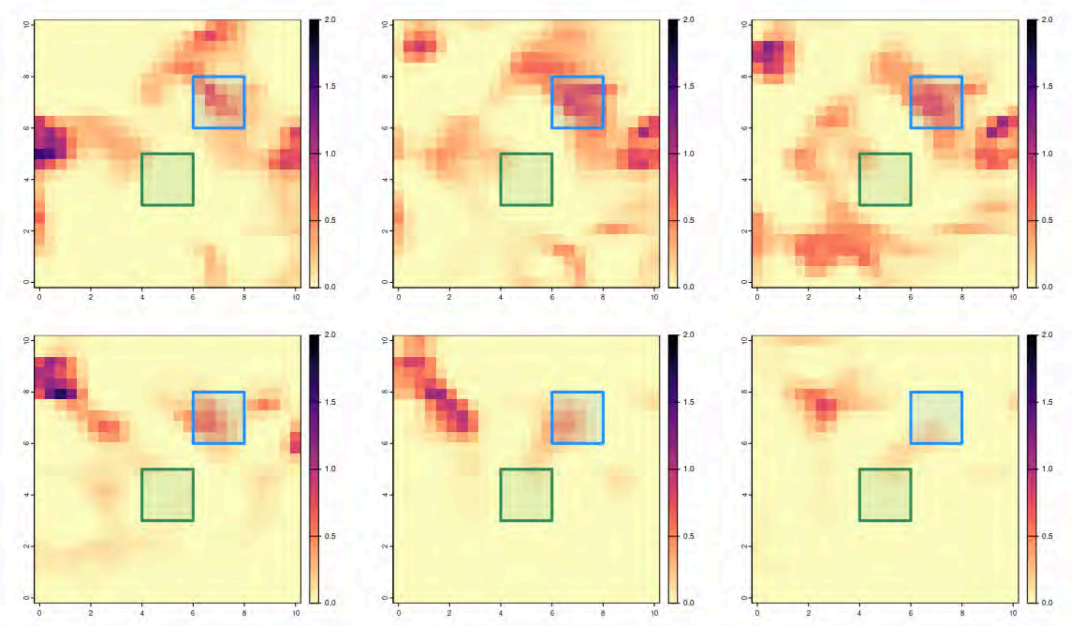
Count of GPS points per cell across region at each time step



Simulated sea surface temperature to use as a covariate in STPP

STPP with simulated data

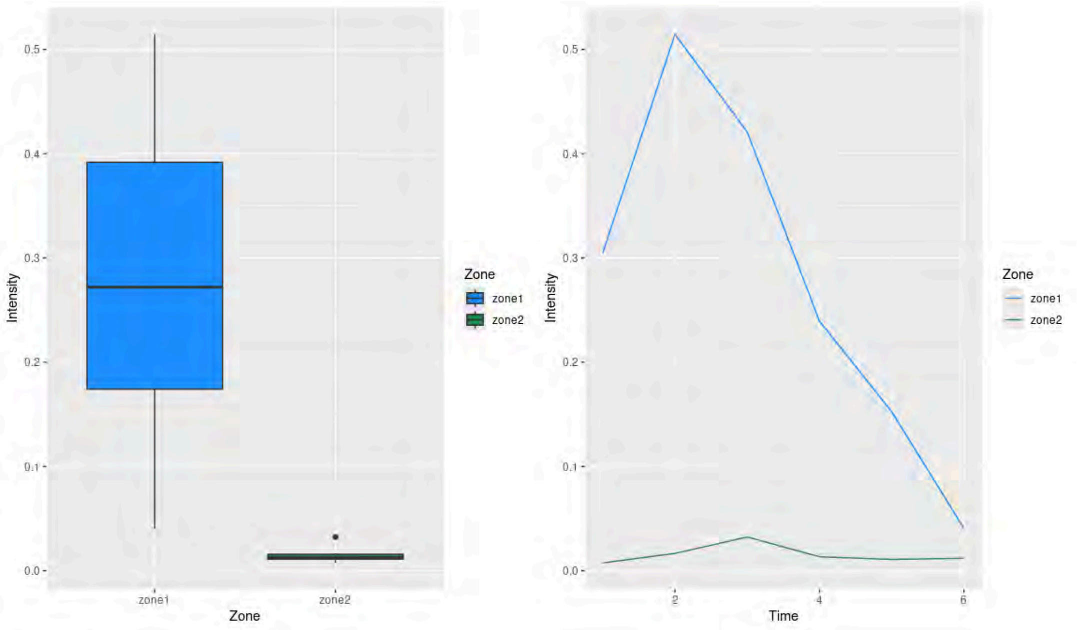
- Once we have fitted the model we can make predictions on the likely intensity of individuals in a cell and understand how there distribution might change at different time of the year or if they follow certain ecological processes (e.g wind, NPP or food availability)
- We could also look at the predicted intensity of all individuals, but summing over individual predictions.
- We could look at the predicted intensity and the spatial intersection with a proposed offshore wind development, to start to understand the risk to individuals or the (sub-)population.



Predicted intensity of individual 1 from GPS data at each time step; blue and green boxes represent potential off-shore wind development zones.

STPP with simulated data

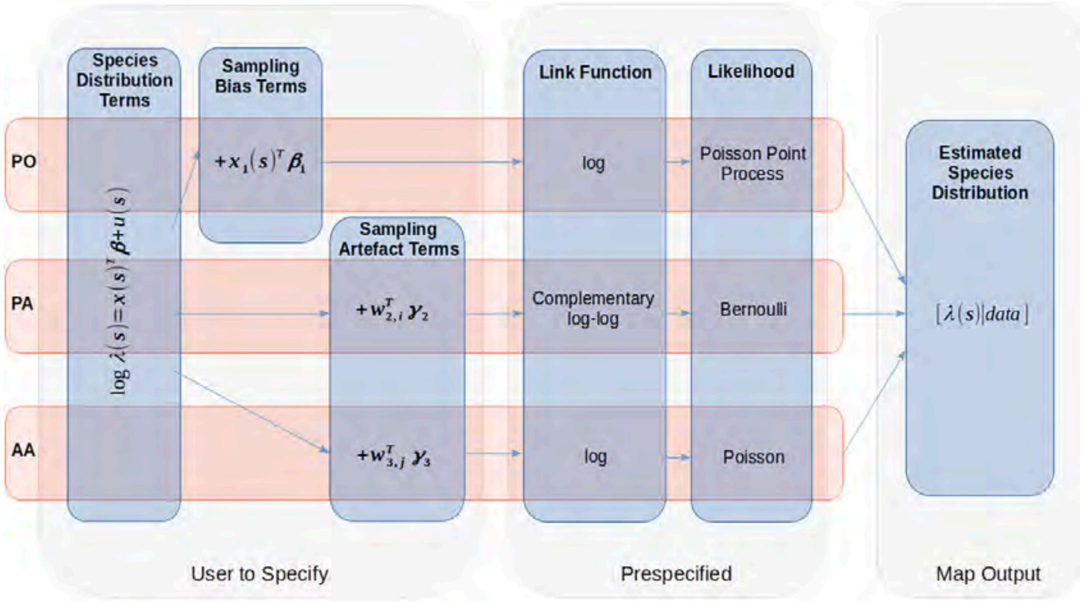
- We can summarise the intensity in the proposed offshore wind development zones to understand the relative intensity of an individual(s) in each region.
- This might give insight into the frequency that birds use certain areas.



Zonal summaries of bird intensities in each 'proposed' wind development area.

Integration with other models/data

- To date I have just developed a spatial-temporal point pattern for GPS data, but the same point pattern framework can be used to handle different survey/data types, such as:
    - Presence-only data (e.g ALA, OBIS, eBird)
    - Presence-absence (e.g eBird)
    - Counts (relative abundance) (e.g eBird)
    - Mark-recapture
    - Areal/distance surveys



Example of an integrated model using the RISDM package; Foster et al., 2024

Important considerations

- Do we need an integrated framework?
    - At the very least we need an approach that can handle the diverse range of ways data is collected.
    - This might be via ensembling/combining independent models, data pooling or full model-based integration with joint likelihoods.
- Can we link individual/sub-population processes to overall population level?
    - Some folk have started to think about this problem explicitly with telemetry data and typical population level surveys (Buderman et al., 2025).
    - But are these commensurate processes?
- What data sources do we trust to best inform species distribution?
    - We typically ignore this, but we could put more weight on certain data types explicitly in this framework (via priors).

References

- Buderman, F.E., Hanks, E.M., Ruiz-Gutierrez, V., Shull, M., Murphy, R.K. and Miller, D.A., 2025. Integrated movement models for individual tracking and species distribution data. Methods in Ecology and Evolution, 16(2), pp.345-361.
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- Niven, H.I., Jeglinski, J.W., Aarts, G., Wakefield, E.D. and Matthiopoulos, J., 2025. Towards biologically realistic estimates of home range and spatial exposure for colonial animals. Methods in Ecology and Evolution.

Population Dynamics Modelling: Leslie Matrix model for Southern Right Whales

Maud El-Hachem, PhD
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Summary of the presentation

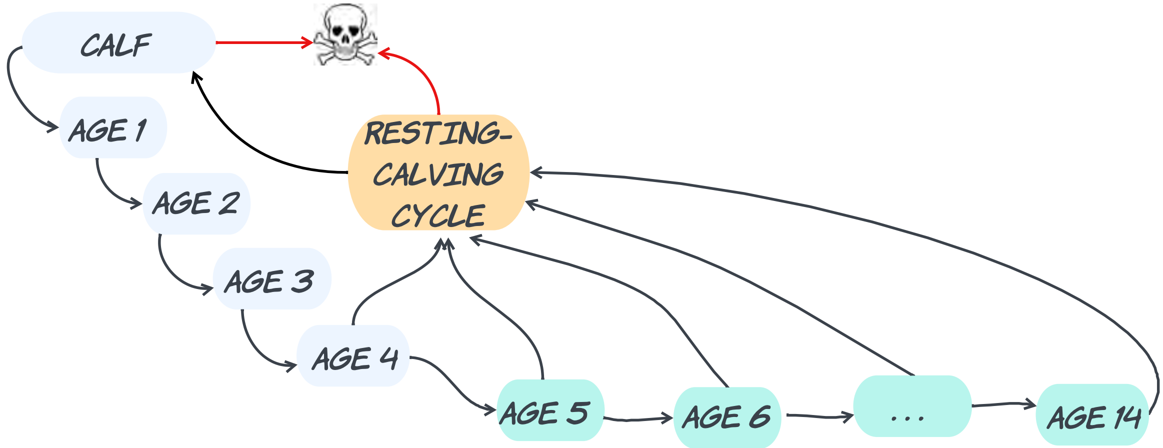
- Leslie matrix: numerical solutions and stability
- Estimating the parameters of the Leslie matrix from observations data
- Application: Interim Population Consequences of Disturbance

Image: Gregory "Slobirdr" Smith - Southern Right Whale (Eubalaena australis)
en.wikipedia.org/wiki/Southern_right_whale#/media/File:Southern_Right_Whale_(Eubalaena_australis)_(16358018502).jpg

Leslie matrix model

- The matrix represents the transition of individuals between age classes based on survival and fecundity rates.
- Leslie matrix helps predict age distribution and overall growth rate.
- The matrix assumes a closed population without migration and with unlimited resources.
- The matrix is used for female populations because it relies on the birth rate.
- The Leslie matrix model helps assessing the impact of various factors on survival and reproduction of the whales.

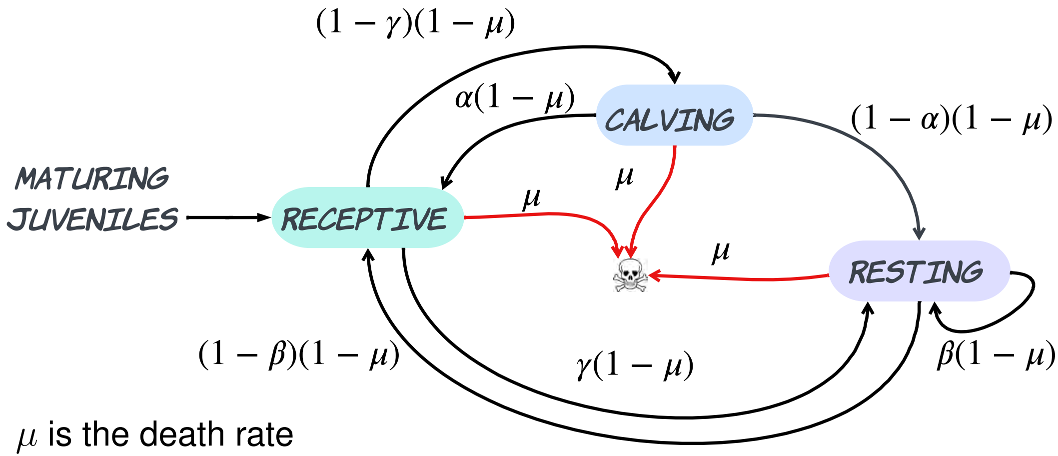
Leslie matrix model



Cooke J, Rowntree V, Payne R. (2001). Estimates of demographic parameters for southern right whales (*Eubalaena australis*) observed off Península Valdés, Argentina. Argentina. Journal of Cetacean Research and Management (Special Issue). 2. 10.47536/jcrm.vi.297.

Peel D, Jones LL, Evans K (2024). Subcomponent 3: Expanding utilisation of southern right whale datasets for estimation of national population parameters. Final Report.

Directed graph of female reproductive cycle



- μ is the death rate
- α is the probability of a calving whale becoming receptive next year without resting (standard cycle is three years)
- β is the probability of a whale taking an additional resting year
- γ is the probability that a receptive whale goes into resting without passing by calving ($\gamma = 0$ means no abortion, no perinatal/postnatal death)

Leslie Matrix

Calf	1Y	2Y	3Y	4Y	Y5	...	14Y	Calv.	Rest.	Rec.	Dead	
0	$0.5S$	0	0	0	0	...	0	0	0	0	$(1-0.5S)$	Calf
0	0	1	0	0	0	...	0	0	0	0	0	1Y
0	0	0	1	0	0	...	0	0	0	0	0	2Y
0	0	0	0	1	0	...	0	0	0	0	0	3Y
0	0	0	0	0	$1-\phi_5$	...	0	0	0	ϕ_5	0	4Y
...	...	...	...	...	...	...	...	...	...	...	...	...
0	0	0	0	0	0	...	$1-\phi_{14}$	0	0	ϕ_{14}	0	13Y
0	0	0	0	0	0	...	0	0	0	1	0	14Y
1	0	0	0	0	0	...	0	0	$(1-\alpha)(1-\mu)$	$\alpha(1-\mu)$	μ	Calv.
0	0	0	0	0	0	...	0	0	$\beta(1-\mu)$	$(1-\beta)(1-\mu)$	μ	Rest.
0	0	0	0	0	0	...	0	$(1-\gamma)(1-\mu)$	$\gamma(1-\mu)$	0	μ	Rec.
0	0	0	0	0	0	...	0	0	0	0	1	Dead

where S is the survival rate and ϕ_a is the probability that a female becomes mature at age a

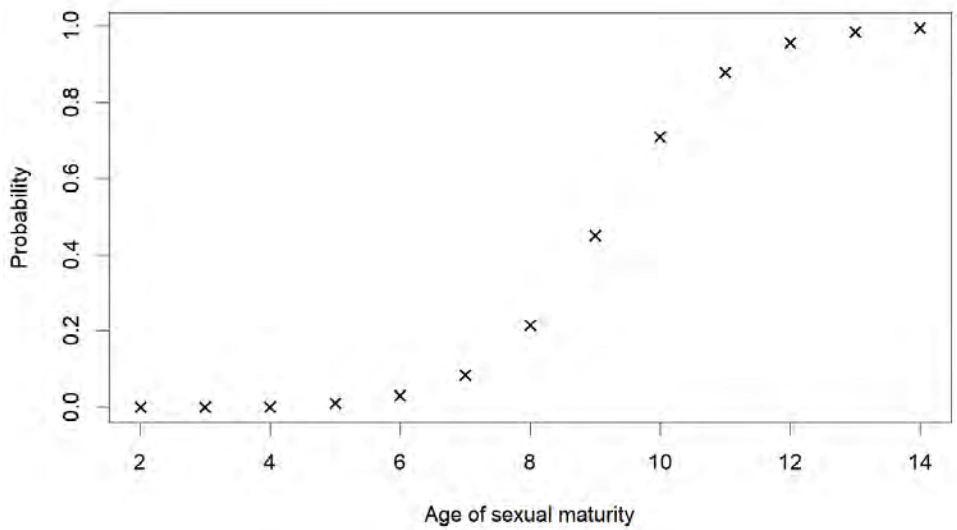
$$\underbrace{\mathbf{z}_{t+1}}_{\substack{\text{updated population} \\ \text{a vector of 19 by 1}}} = \underbrace{\mathbf{L}}_{\substack{\text{Leslie matrix} \\ \text{of size 19 by 19}}} \underbrace{\mathbf{z}_t}_{\substack{\text{current population} \\ \text{a vector of 19 by 1}}}$$

Probability of a female become sexually mature

For $a = 5..14$

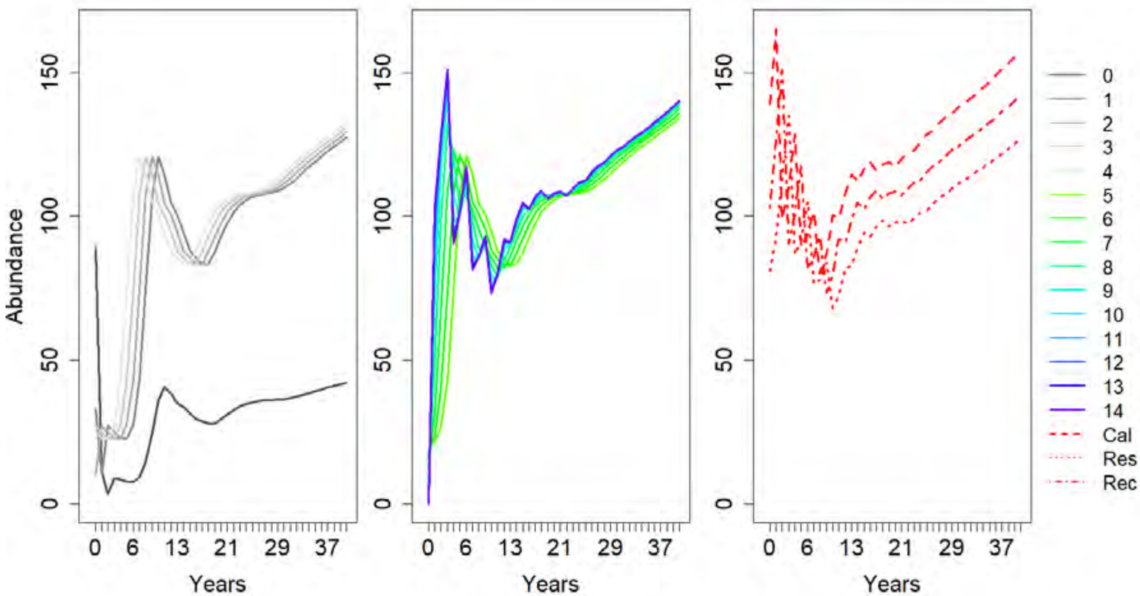
$$\phi_a = \frac{\exp(\kappa + \lambda * a)}{(1 + \exp(\kappa + \lambda * a))}$$

Example where $\kappa = -10.021$ and $\lambda = 1.091$



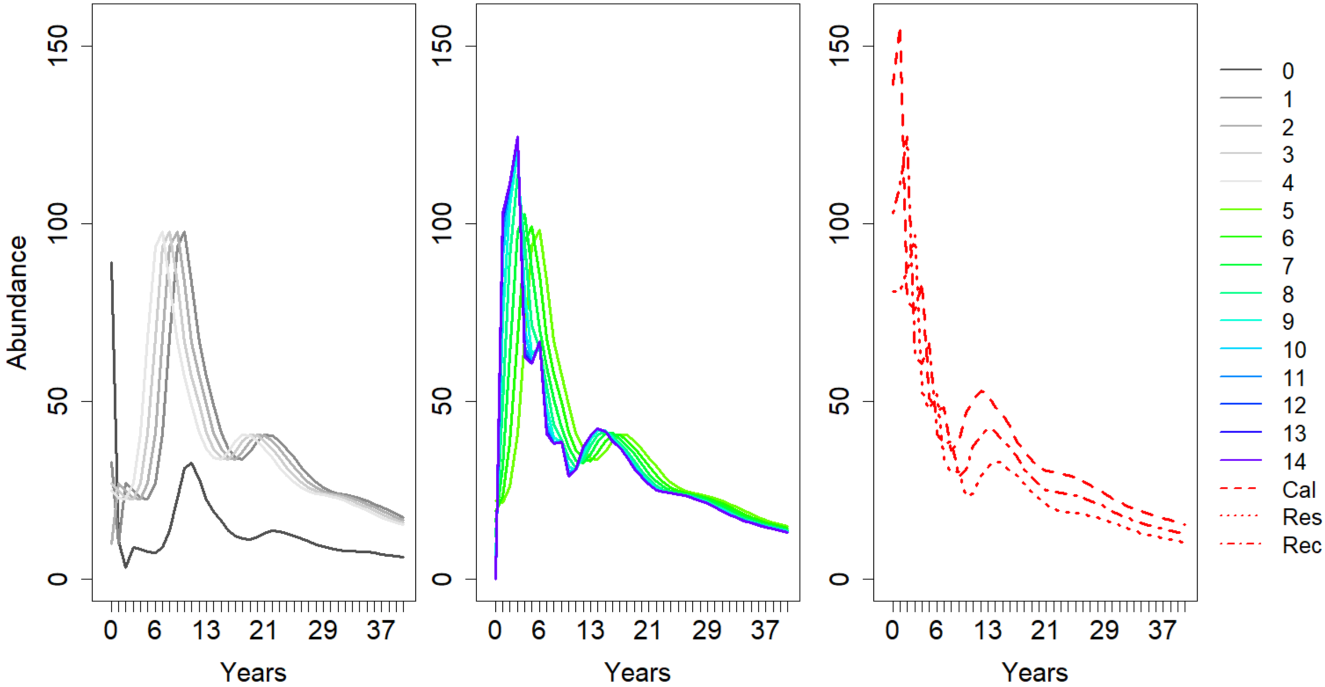
Numerical solutions

Using the estimated mean from Peel, Jones and Evans (2024) for the parameters: $S = 0.669$, $\alpha = 0.104$, $\beta = 0.095$, $\mu = 0.085$, $\gamma = 0$, $\kappa = -10.021$ and $\lambda = 1.091$
My own initial conditions: $\{89, 33, 10, 27, 25, 22, 19, 16, 12, 6, 2, 0, 0, 0, 0, 139, 81, 103, 0\}$



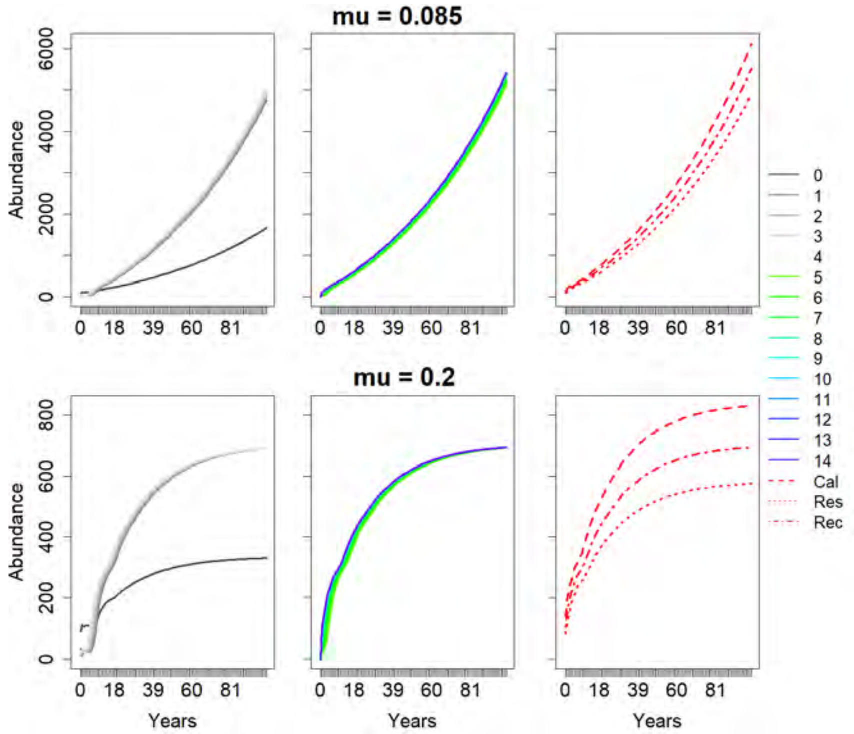
Numerical solutions

Same initial conditions, same parameters, $\mu = 0.2$ (was 0.085)



Numerical solutions

Modified initial conditions: $\{89, 33, 10, 27, 25, 22, 19, 16, 12, 6, 2, 0, 0, 0, 0, 139, 81, 103, \textcolor{red}{150}\}$



Eigenvalues of $\mathbb{L}$

$S = 0.669$, $\alpha = 0.104$, $\beta = 0.095$, $\gamma = 0$, $\kappa = -10.021$ and $\lambda = 1.091$, and μ varying

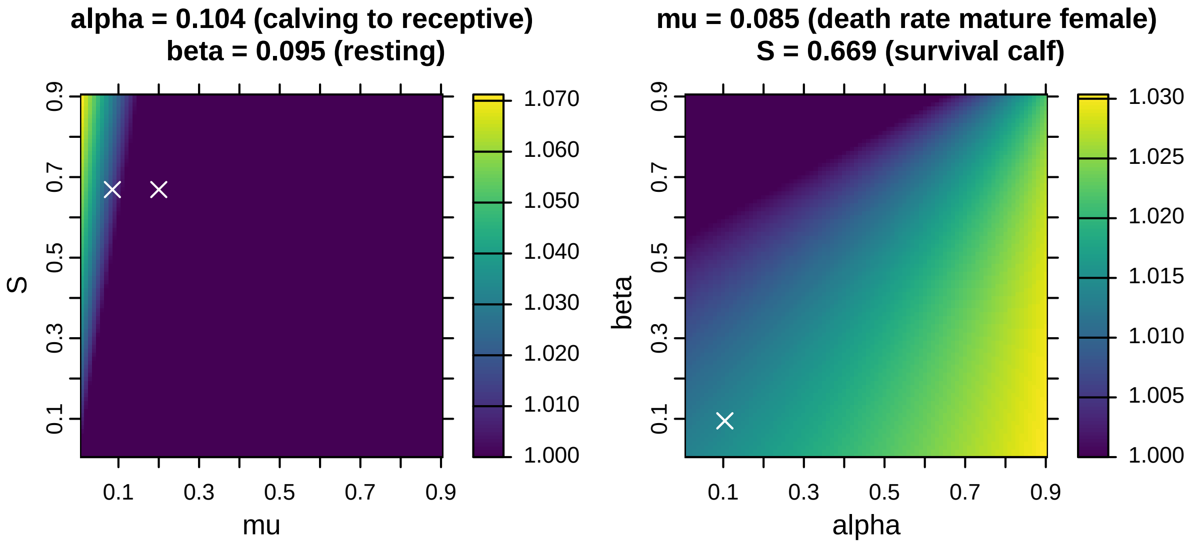
19 eigenvalues by row (for each case of μ)

μ																			
.01	**1.058**	1.00	.466	.466	.766	.766	.351	.351	.118	.118	.491	.491	.513	.424	.138	.094	.047	.012	.012
.03	**1.045**	1.00	.459	.459	.766	.766	.352	.352	.115	.115	.494	.494	.516	.423	.138	.092	.047	.012	.012
.05	**1.033**	1.00	.453	.453	.766	.766	.353	.353	.112	.112	.497	.497	.518	.423	.138	.090	.047	.012	.012
.07	**1.022**	1.00	.447	.447	.765	.765	.354	.354	.109	.109	.500	.500	.520	.422	.138	.088	.047	.012	.012
.09	**1.011**	1.00	.764	.764	.441	.441	.355	.355	.105	.105	.502	.502	.522	.422	.138	.086	.047	.012	.012
.11	**1.001**	1.00	.763	.763	.436	.436	.356	.356	.102	.102	.505	.505	.524	.421	.138	.085	.047	.012	.012
.13	**1.000**	.991	.762	.762	.431	.431	.356	.356	.098	.098	.508	.508	.526	.421	.138	.083	.047	.012	.012
.15	**1.000**	.982	.761	.761	.425	.425	.357	.357	.094	.094	.511	.511	.528	.420	.138	.081	.047	.012	.012
.17	**1.000**	.973	.759	.759	.421	.421	.358	.358	.090	.090	.513	.513	.530	.420	.138	.079	.047	.012	.012
.19	**1.000**	.964	.757	.757	.416	.416	.358	.358	.087	.087	.516	.516	.532	.420	.138	.077	.047	.012	.012

Dominant eigenvalue tells us what happens around the equilibrium $(0, 0, 0, 0, ..., 0)$

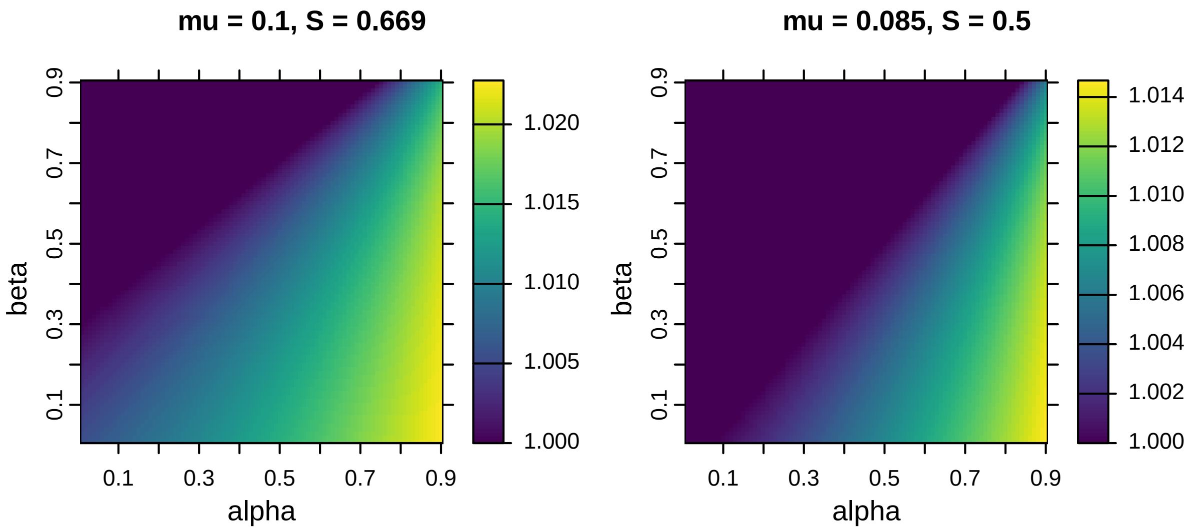
1. If dominant eigenvalue is greater than one, then the trivial equilibrium is unstable $\rightarrow$ population grows exponentially. **Dominant eigenvalue is the long-term growth rate**
2. If dominant eigenvalue is less than one, then the trivial equilibrium is stable $\rightarrow$ population is extinct.
3. If dominant eigenvalue is equal to one, the population can be constant or extinct.

Eigenvalues in function of parameters



1. Blue, green and yellow regions: exponential growth
2. Dark purple region: population constant or declining depending of the initial conditions

Eigenvalues in function of parameters



1. Blue, green and yellow regions: exponential growth
2. Dark purple region: population constant or declining depending of the initial conditions

Expected population vector in year t

- The expected population vector in year t is

$$\mathbf{z}_t = \underbrace{N_0}_{\substack{\text{initial}\\\text{mature}\\\text{population}}} \underbrace{\lambda_0}_{\substack{\text{dominant eigenvector}\\\text{stable age distribution}}} \prod_{i=1}^{t} \mathbf{L}_t,$$

where L_t is the Leslie matrix where the following parameters vary in time α_t, β_t, γ_t and μ_t and are to be estimated as N_0.

Sighting history $\mathbf{y}$

- From a catalogue of whales sighting and identification, we can obtain the history for each individual identified.
- $\mathbf{y}$ is the matrix of sighting history for one individual. Example on 10 years:

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

  - $(1, 0, 0)$ means that a whale is seen as a calf
  - $(0, 1, 0)$ means that a whale is seen with a calf
  - $(0, 0, 1)$ means that whale not seen or seen without a calf

Expected number of whales with sighting history $\mathbf{y}$

- Expected number of whales with sighting history $\mathbf{y}$:

$$\mathbb{E}(\mathbf{y}) = N_0\lambda_0 \underbrace{\prod_{t=1}^{T(y)} \mathbf{L}_t \langle y_{*,t}\mathbf{P}_t\rangle}_{\text{loop through history until first positive identification}} \underbrace{\prod_{t=T(y)}^{T_{\max}} \mathbf{Q}_t \langle y_{*,t}\mathbf{P}_t\rangle}_{\text{loop through rest of history}} \mathbf{1}$$

  where $\mathbf{Q}_t$ is the matrix $\mathbf{L}_t$ with transition probability from calving to calf equal to zero, P_t is the observation probability matrix, $y_{*,t}$ is one year of history

- The likelihood of the dataset is obtained by assuming that observed frequencies of each sighting history are Poisson distributed random variables with expectation $\mathbb{E}(\mathbf{y})$.
- The model is fitted by maximum likelihood.

Peel D, Jones LL, Evans K (2024). Subcomponent 3: Expanding utilisation of southern right whale datasets for estimation of national population parameters. Final Report.

Application: IPCoD

- Age classes could be grouped (example: age 2 to age 4 are pups, age 5 to age 14 are juveniles). Juveniles and pups would have survival rates.
- The matrix represents the vulnerable population
- Each age class must be divided into undisturbed individuals and disturbed individuals (due to noise, etc.)
- Parameters in the Leslie matrix are obtained from statistical distributions to simulate environmental stochasticity
- Expert elicitations would be used to determine effect of disturbance on survival and fertility

Harwood J, King S, Schick R, Donovan C, Booth C. (2013). A Protocol for Implementing the Interim Population Consequences of Disturbance (PCoD) Approach: Quantifying and Assessing the Effects of UK Offshore Renewable Energy Developments on Marine Mammal Populations. *Scottish Marine and Freshwater Science* 5. www.gov.scot/Resource

References and acknowledgements

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Thank you to Luke Llyod-Jones and David Peel for their help!

Shy Albatross population dynamics model

Robin Thomson and Geoff Tuck

CSIRO Environment

NESP workshop, Bass Strait Ecosystem and Offshore Renewable Energy

9-10 April 2025

Origin of our seabird model

- **Tuck, Polacheck, Croxall, Weimerskirch (2001)**
  - Modelling impact of fishery bycatch on Crozet and South Georgia Wandering Albatross
  - Deterministic, density dependant, age-structured
  - Longline fishing effort dataset 5x5° from IOTC, SPC, ICCAT, Australia, Japan, New Zealand
  - Tagging data from albatross

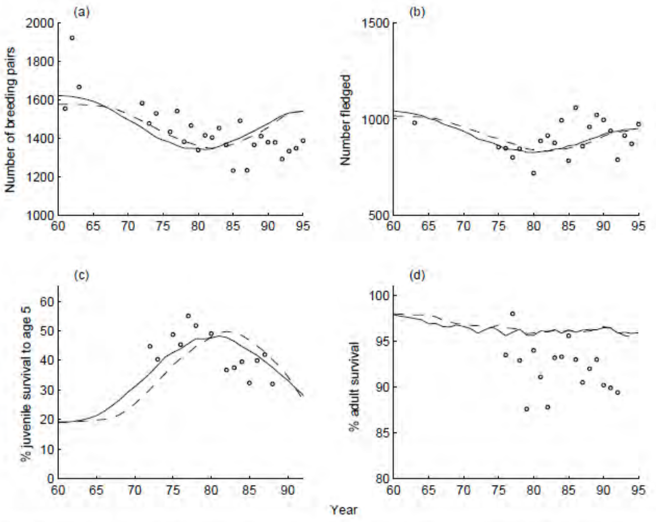


Fig. 7. The predicted (line) and observed (circle) values for (a) breeding pairs, (b) numbers fledged, (c) juvenile survival to age 5 and (d) adult survival for the Bird Island wandering albatross population. The solid line shows predicted trajectories when it is assumed that the albatrosses' spatial distribution is proportional to the Southern Ocean longline effort, while the dashed trajectories make the assumption that the albatrosses' spatial distribution is uniformly distributed across the Southern Ocean.

ICCAT application of model

- **Tuck et al (2011)**
  - ERA approach to 68 seabird populations
    - 22 were designated high priority across all risk scores, 41 across ≥1
    - Fisheries overlap investigated for 22 populations
    - 3 high priority albatross populations modelled
  - 5 x 5^{o} spatial pelagic longline fishing effort dataset

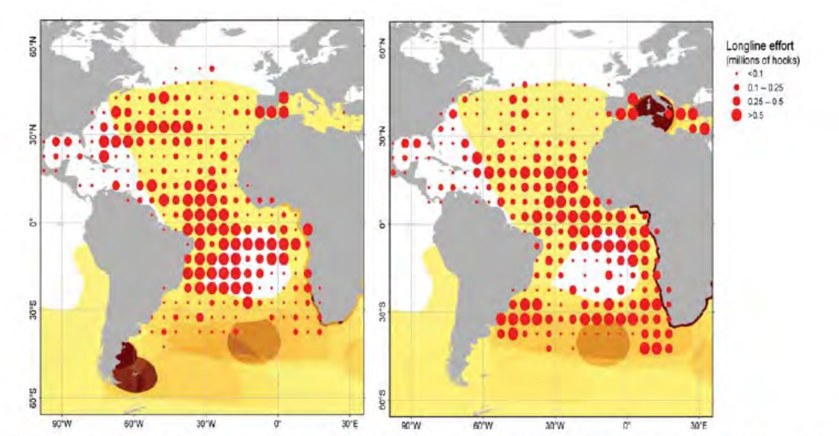


Figure 2. The overlap of ICCAT pelagic longline-fishing effort with the combined distribution of 22 populations (ten species) of seabird for the months January (left) and July (right). Longline fishing effort (millions of hooks) averaged over the years 2000 – 2005 is shown proportional to the diameter of the circle (see key). Contours of seabird density (numbers per degree square) give equal weight to each of the ten species and are illustrated as relative density. Darker shades (of brown) depict a greater density of birds.

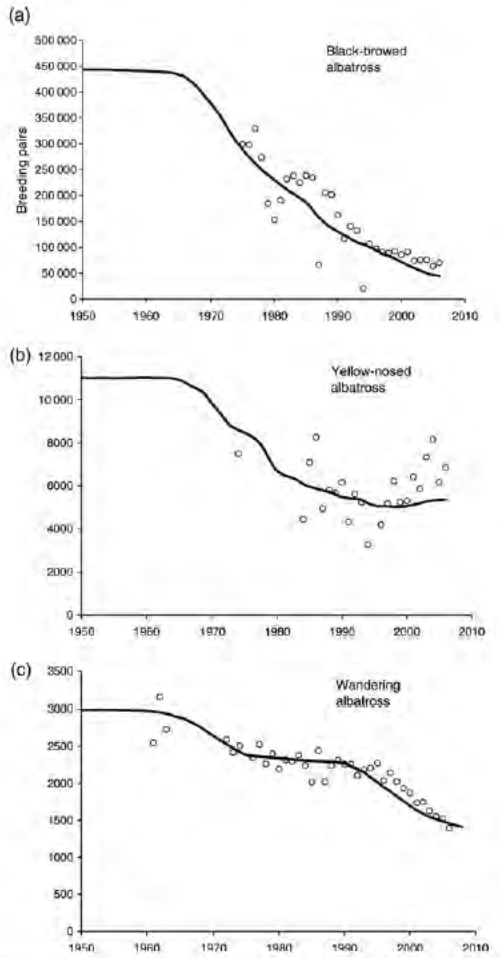


Figure 3. Model-estimated (line) and observed (points) numbers of breeding pairs for (a) the South Georgia black-browed albatross, (b) the Gough Island Atlantic yellow-nosed albatross, and (c) the South Georgia wandering albatross.

Crozet albatross

- **Tuck, Thomson et al (2015)**
  - Crozet Wandering Albatross: considered shy and bold behaviours
  - Fleets: pelagic longline fleet, fresh tuna

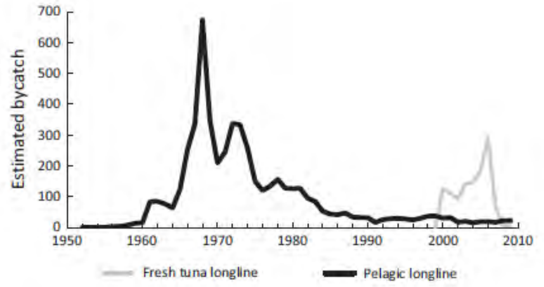
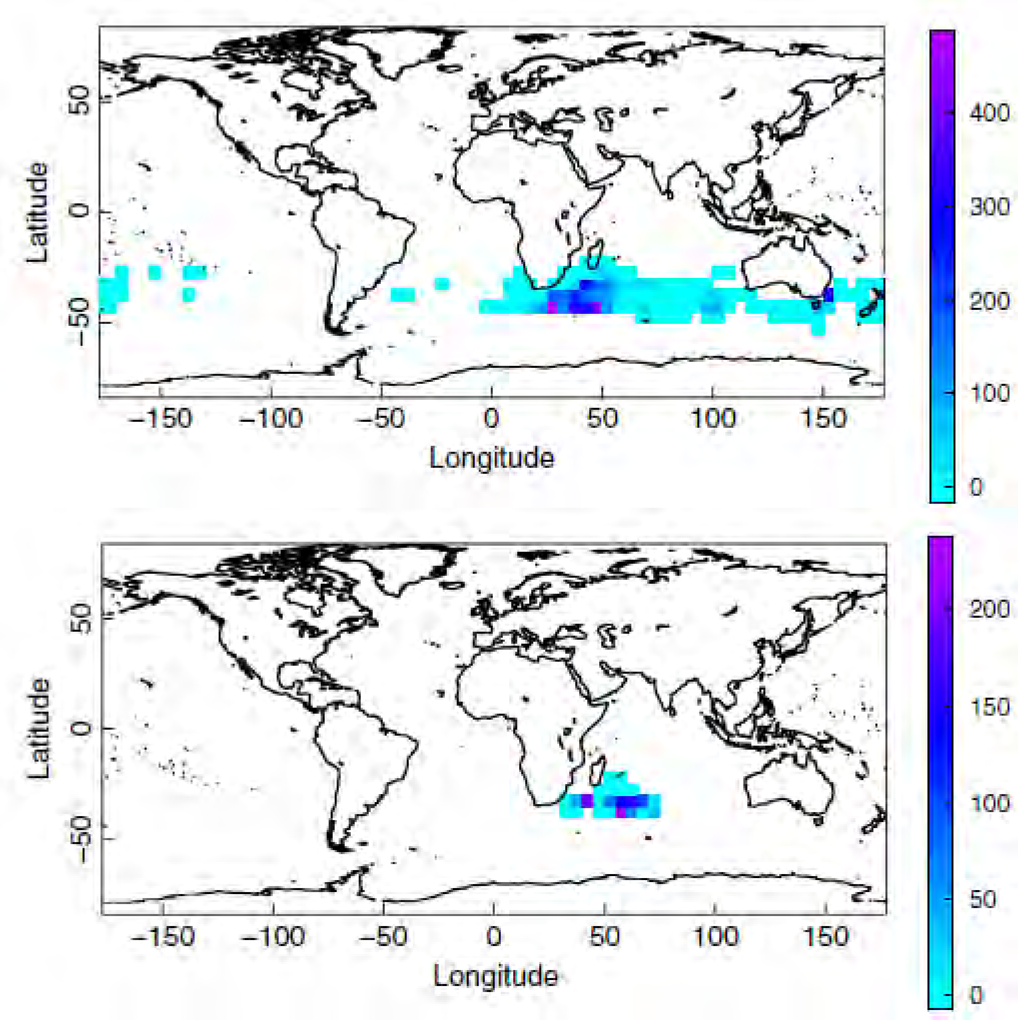


Fig. 7. The time series of model-predicted bycatch by super-fleet for the xFB model. Pelagic longline is an aggregation of all pelagic longline fleets except the Indian Ocean fresh tuna longline fleets.



Shy albatross; Giant Petrels

- **Thomson, Alderman, Tuck, Hobday (2015); Alderman, Tuck et al (2019)**
  - Impact of climate change; Impact of pests (eradication)
  - Local fishery dataset: pelagic and demersal longline, and trawl
  - Future climate scenarios for rainfall and days over 23^{o}C – future projections

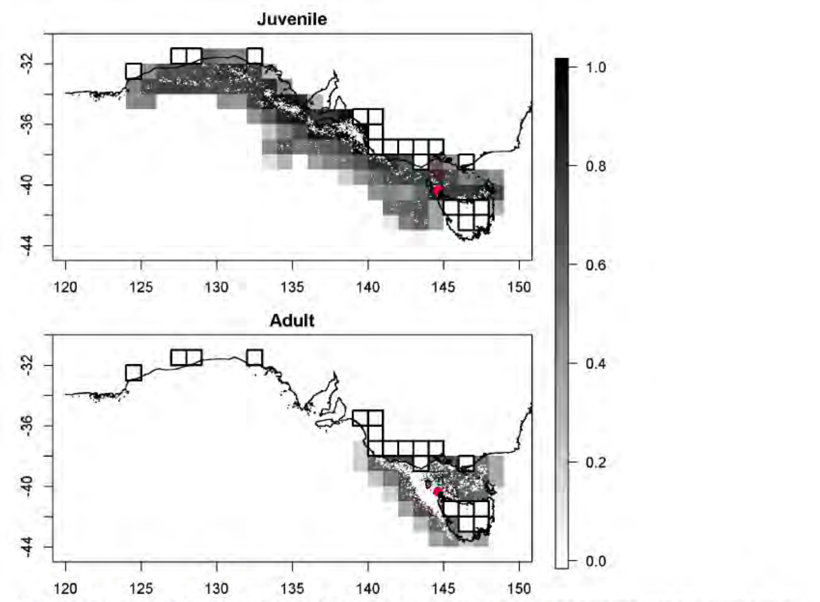


Fig 1. The foraging range for (A) 11 juvenile and (B) 55 adult shy albatrosses from the Albatross Island population. White dots show the locations returned from satellite transmitter (PTT) tracking devices and the colour scale shows percentage utilization calculated using the kernel density method. A 1 degree grid is imposed; black outlines indicate grid cells that have been excluded from the calculation because they substantially cover land. A red dot marks the location of Albatross Island.

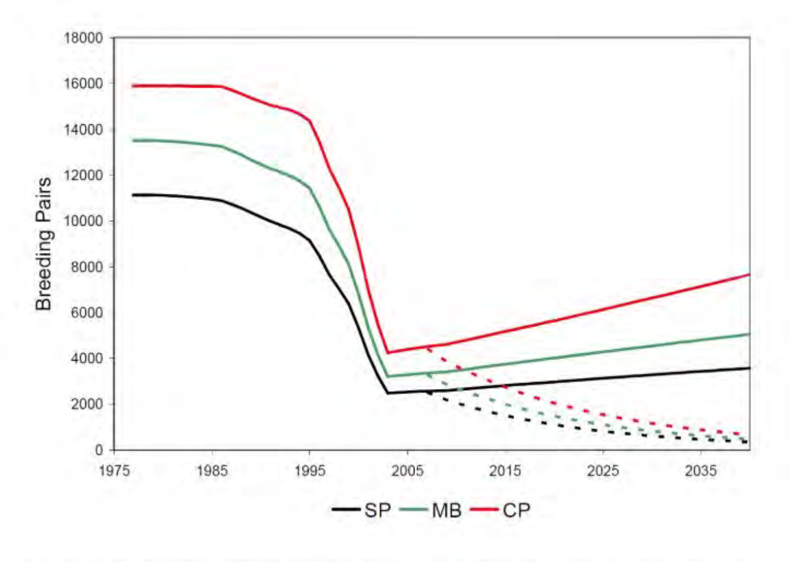


Figure 6.37 The estimated numbers of breeding pairs by colony projected into the future with fishing effort equal to that in 2006/07 (solid line) and 1999/00 (dashed line). This scenario assumes that the density (and therefore burrows) in 1977/78 is twice that estimated by Fullagar and Disney (1981). SP Stevens Point; MB Middle Beach; CP Clear Place; NB Neds Beach; LMBG Little Mutton-bird Ground; HB Hunter Bay.

Seabird model details

- **Population**
  - Stages: chicks, juveniles, adults (breeding, failed breeders, non-breeding)
    - Stage-specific, month-specific at-sea distributions
    - Stage-specific survival rates
  - Sex specific
  - Monthly time step (for at-sea distribution)
  - Density dependence acts on
    - chick survival (related to breeding population size)
    - juvenile survival (related to 1+ population size)

Seabird model details

- **Fisheries bycatch**
  - Spatial overlap between birds and fisheries
  - Each fleet has an estimated ‘catchability’, can be time blocked
  - Observed numbers of birds caught used to estimate parameters

Seabird model details

- **Environmental variables**
  - Chick mortality rate can be related to an environmental variable through a specified functional form with estimated parameters

Seabird model details

- **Response variables**
  - Numbers of breeding pairs
  - Numbers of chicks fledged
  - Annual adult survival rate
  - Annual juvenile survival rate
  - Bycatch observations

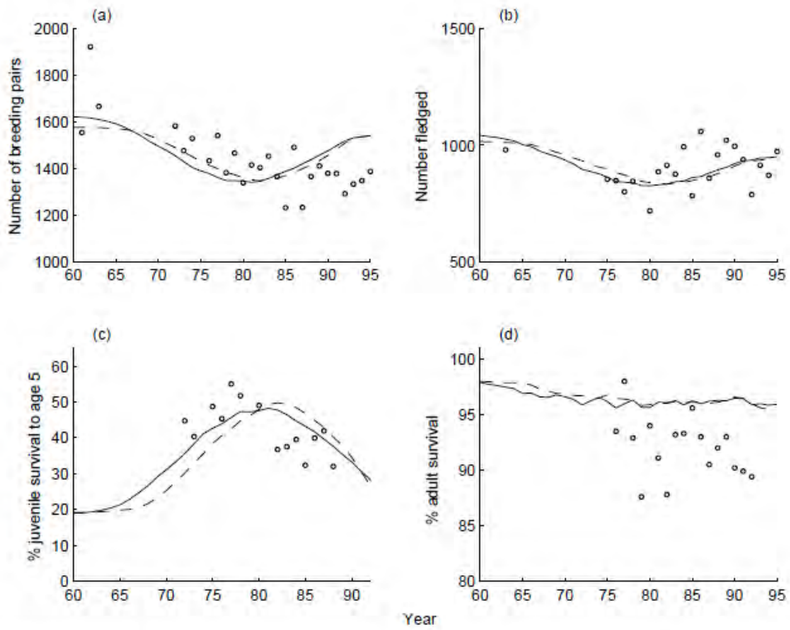


Fig. 7. The predicted (line) and observed (circle) values for (a) breeding pairs, (b) numbers fledged, (c) juvenile survival to age 5 and (d) adult survival for the Bird Island wandering albatross population. The solid line shows predicted trajectories when it is assumed that the albatrosses' spatial distribution is proportional to the Southern Ocean longline effort, while the dashed trajectories make the assumption that the albatrosses' spatial distribution is uniformly distributed across the Southern Ocean.

Seabird model and windfarms

- **Windfarm = Fishing fleet (stationary effort distribution)**
  - Seabird stage-based at-sea distribution overlaps with wind/fishing effort
  - Fit a model to existing data, then project into the future with windfarm
  - Windfarm ‘catchability’ or ‘bycatch’ must be assumed

- **Low data populations**
  - Assume parameters such as survival, density dependence, population size
  - OR use a less data demanding model / method

Thank you

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Marine and Coastal

National Environmental Science Program

Bass Strait Ecosystem and Offshore Renewable Energy

Day 2: Species distribution and offshore wind impact pathways

Population dynamics modelling: Priority shorebirds

- recruitment and survival monitoring
- movement behaviour

Toby Ross, Marcel Klaassen

DEAKIN UNIVERSITY

Marine and Coastal
National Environmental Science Program

Migratory shorebird populations: research for management and recovery

Project 4.17

UQ DEAKIN UNIVERSITY VWSG AWSG Australasian Wader Studies Group QLD WADER STUDY GROUP BirdMark

Shorebirds and the world

CMS

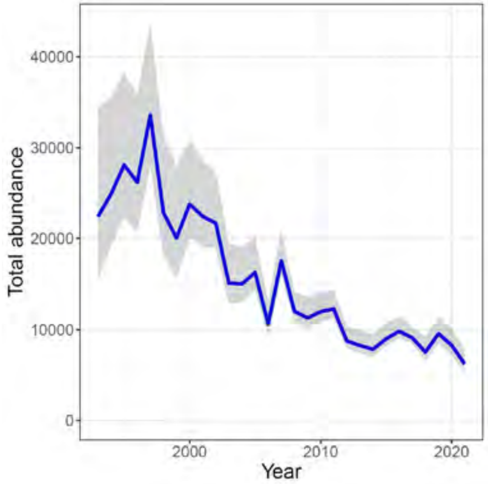
EAAFP


© Ken Gosbell

Birds in crisis

- Australia is home to ~37 species of migratory shorebirds
- Population declines in 3 decades prior to ~2015

Eastern Curlew Population Trend



From NESP Project 1.21
Australia's migratory shorebirds: Trends and prospects

The story so far…

- Populations of some species stabilising in recent years
- Not clear what contributed to the stabilisation
    - Improved survival?
    - Successful conservation efforts?

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AWSG
Australasian Wader Studies Group

QLD WADER STUDY GROUP

VWSG

BirdMark

Tagging · Tracking · Reporting

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WADER
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GROUP
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XHB

What have we done?

- 596,000 observations
- 80,564 individual birds
- ~50 years of data
- 12 species

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To what extent do non-breeding shorebirds in Australia exhibit site fidelity?

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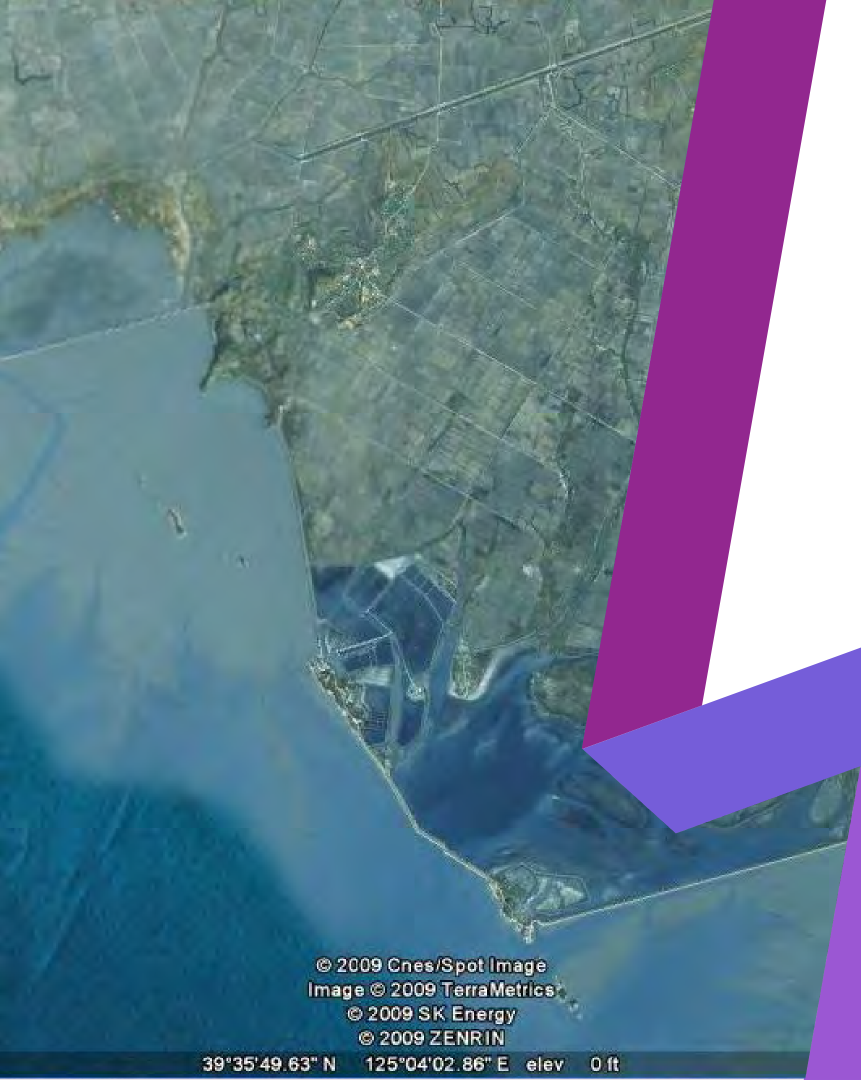


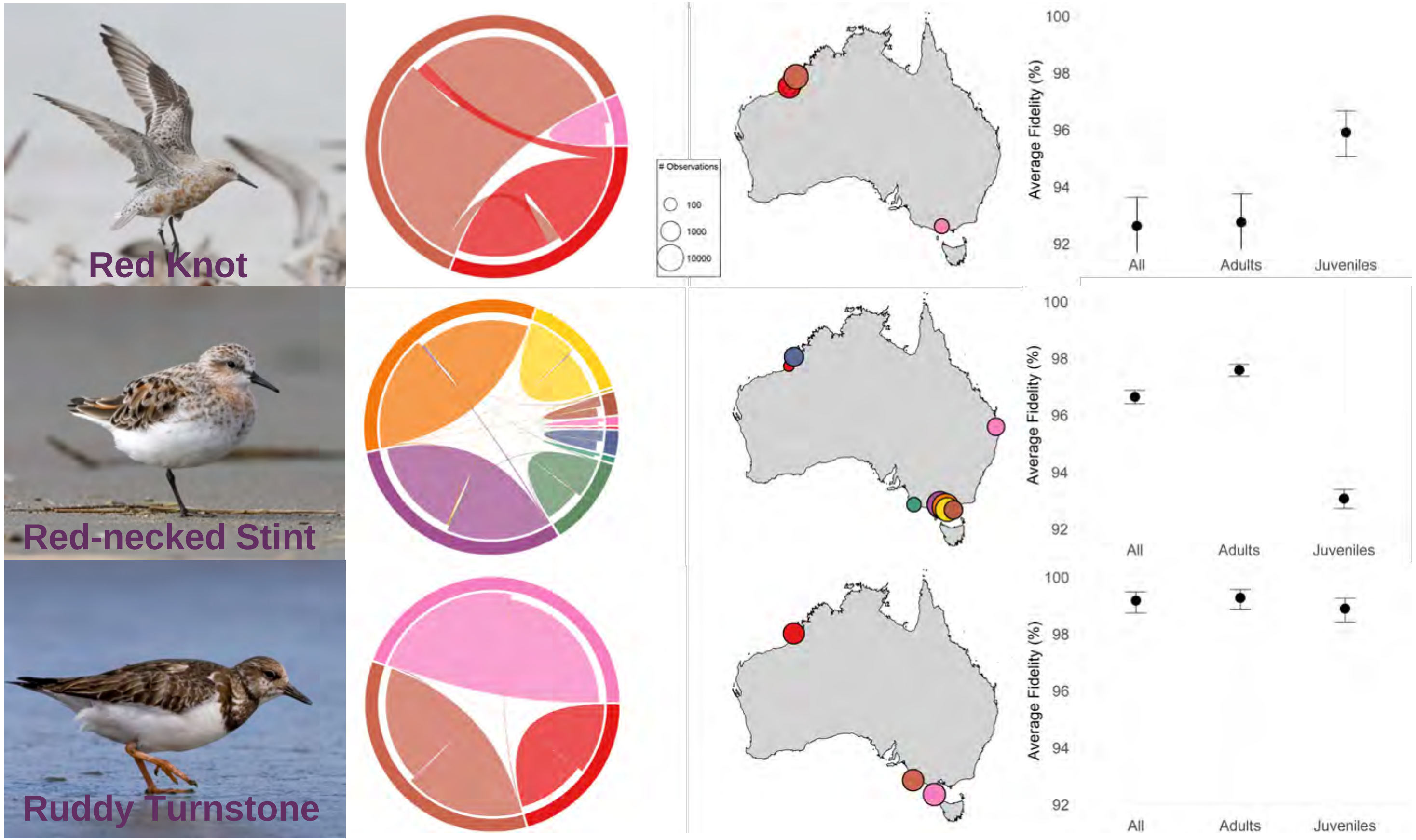
Site fidelity

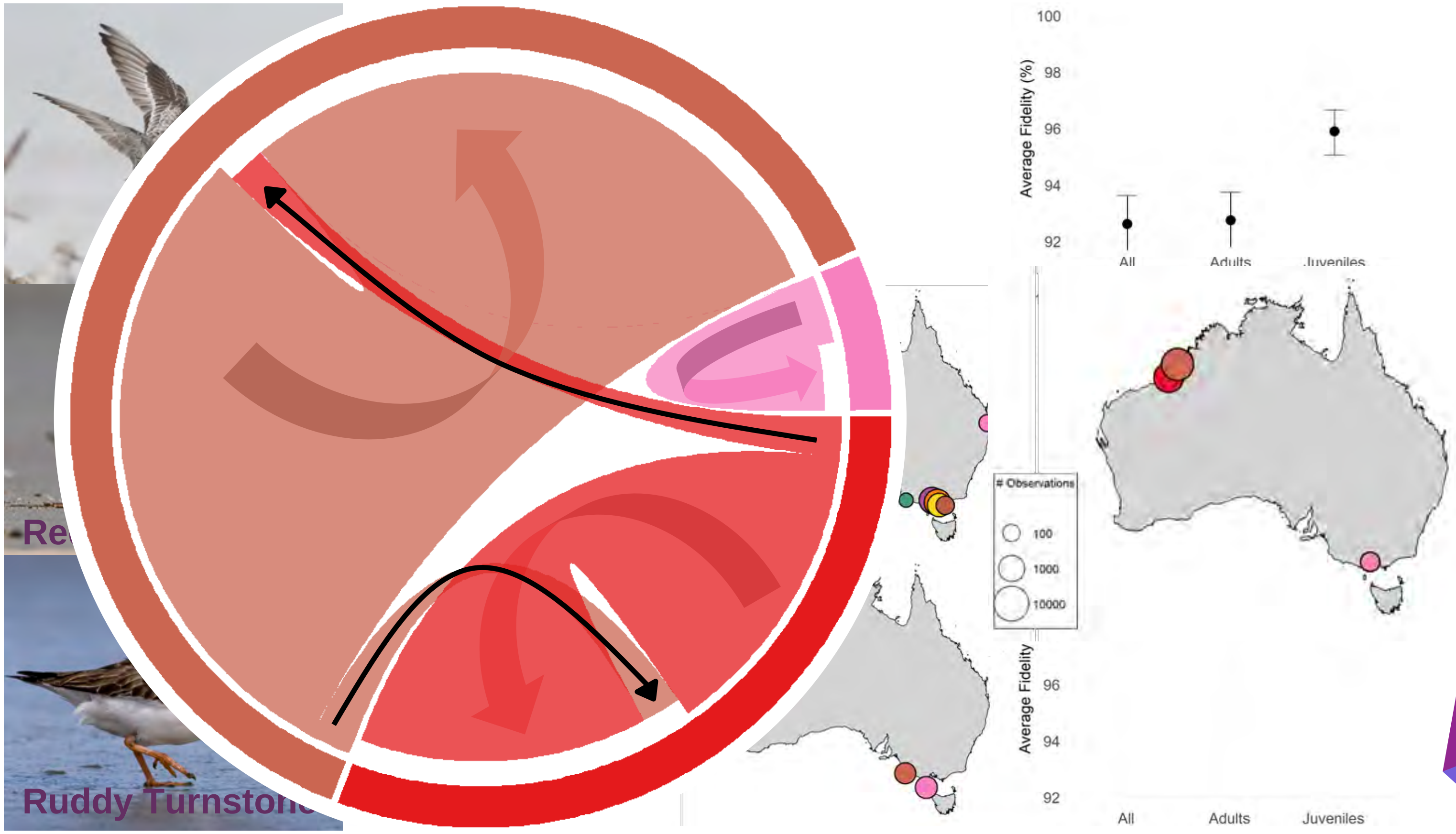
Good:

- Capitalise on prior knowledge
- Better exploit resources and avoid predation risks

Bad:

- Global change – tidal flat reclamation
- Unable to adapt?


Red Knot
Red-necked Stint
Ruddy Turnstone
Observations
100
1000
10000
Average Fidelity (%)
100
98
96
94
92
All
Adults
Juveniles


Ruddy Turnston
Average Fidelity (%)
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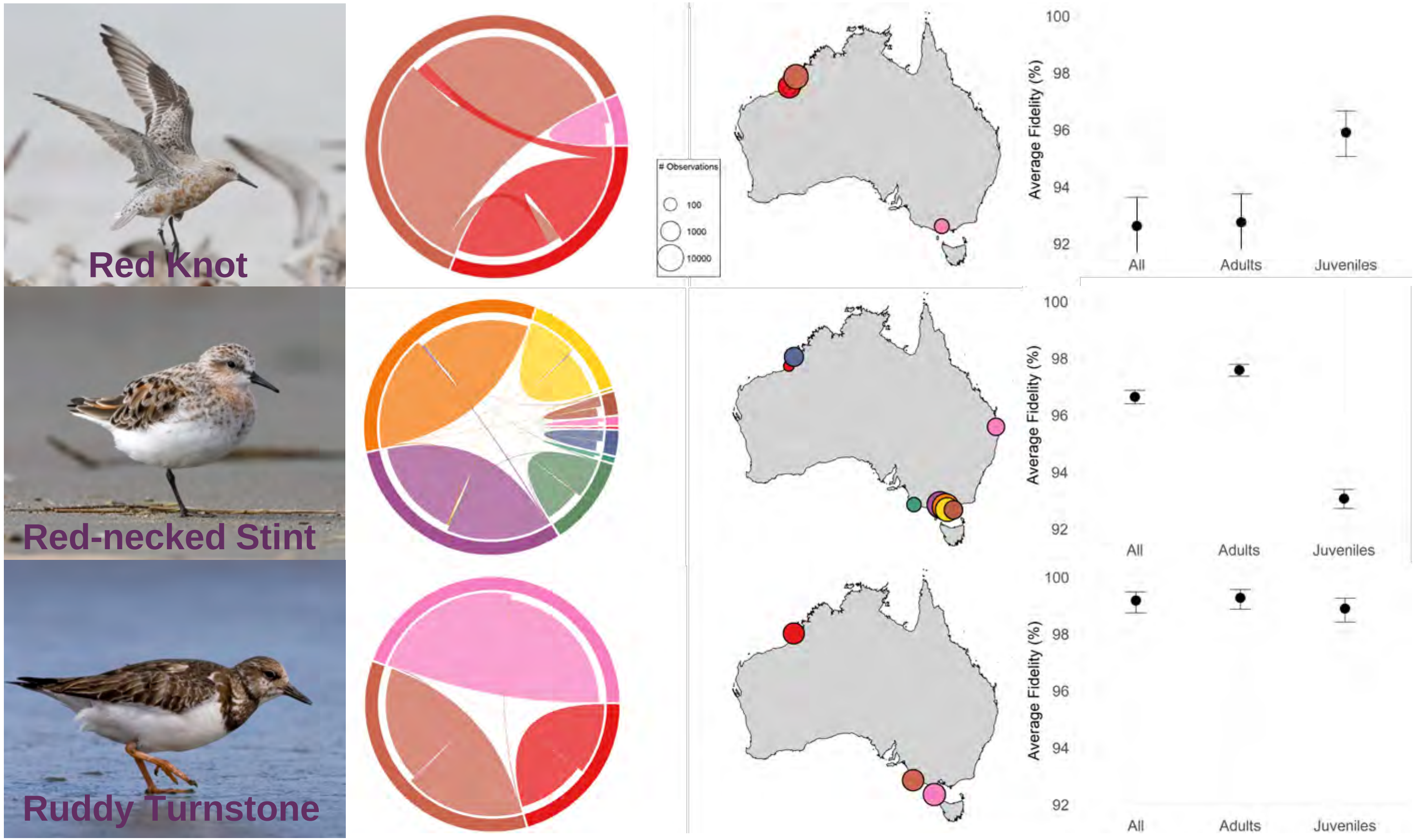

Red Knot
Red-necked Stint
Ruddy Turnstone
Observations
100
1000
10000
Average Fidelity (%)
100
98
96
94
92
All
Adults
Juveniles

Site Fidelity is high

- Knowledge is important to shorebirds

- Forcing birds to change may cost them

Shorebird survival and juvenile recruitment

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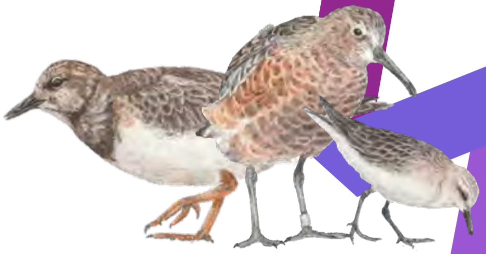
https://www.kuwaitbirds.
org/birds/ruddy -turnstone

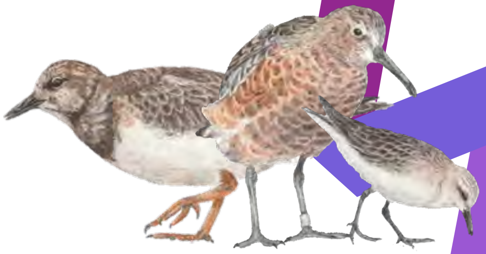
Survival modelling

- Using CJS models in JAGS to estimate:
  - Annual adult survival
  - Average juvenile survival
  - Recapture effort
    - Site specific
    - Method specific
- **Implement into annually updated dashboard for 12 species**

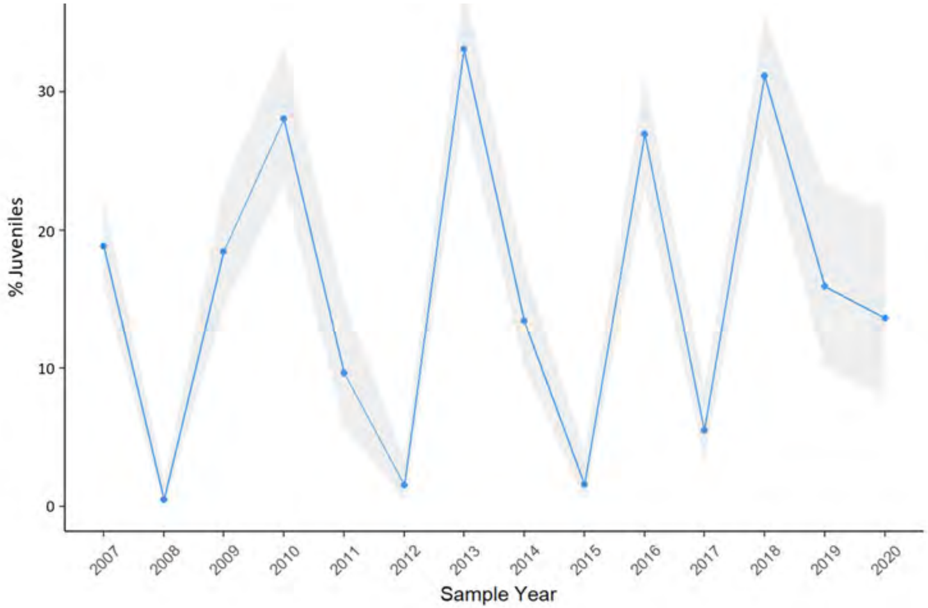


Juvenile recruitment

- Can indicate breeding success and recruitment; important aspect of population dynamics
- Calculated as the proportion of a bird population that are juveniles

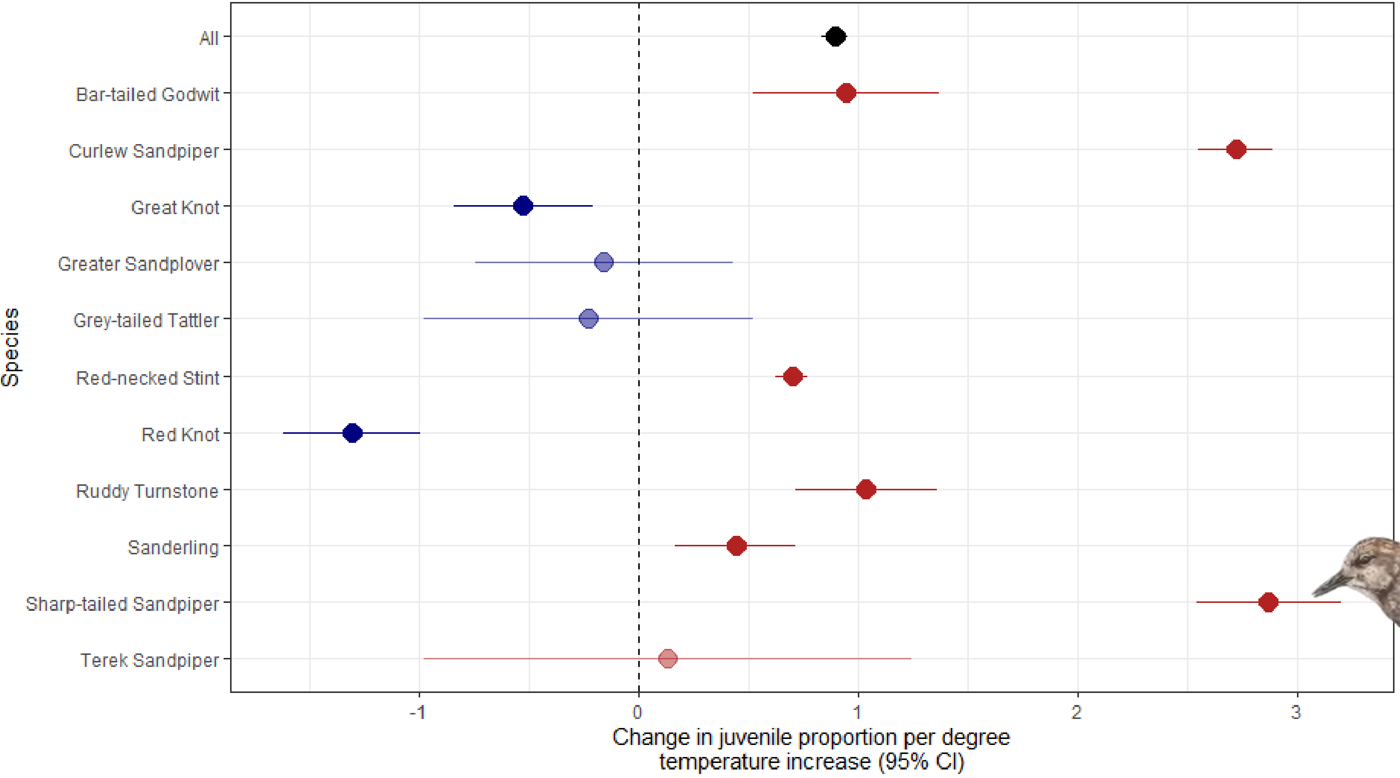


Juvenile recruitment



Ross et al. Sci. Tot. Env. (2024) 955

Juvenile proportions increase over time, with some variation between species



Dr Sara Ryding
Postdoctoral Researcher

Movement behaviour of shorebirds and offshore renewable energy

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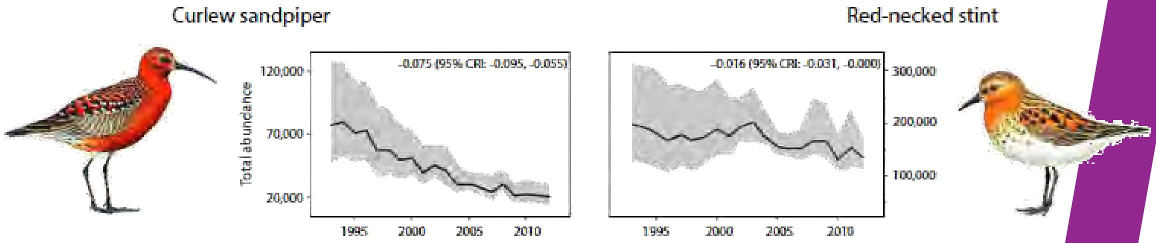
Caveats



- Is focus on priority species only warranted?
- Direct impacts of windfarms?
  - migratory movements

Caveats

- Is focus on priority species <u>only</u> warranted?
- Direct impacts of windfarms?
  - migratory movements
  - day-to-day movements
  - where (3D) do they go when?

developing an understanding

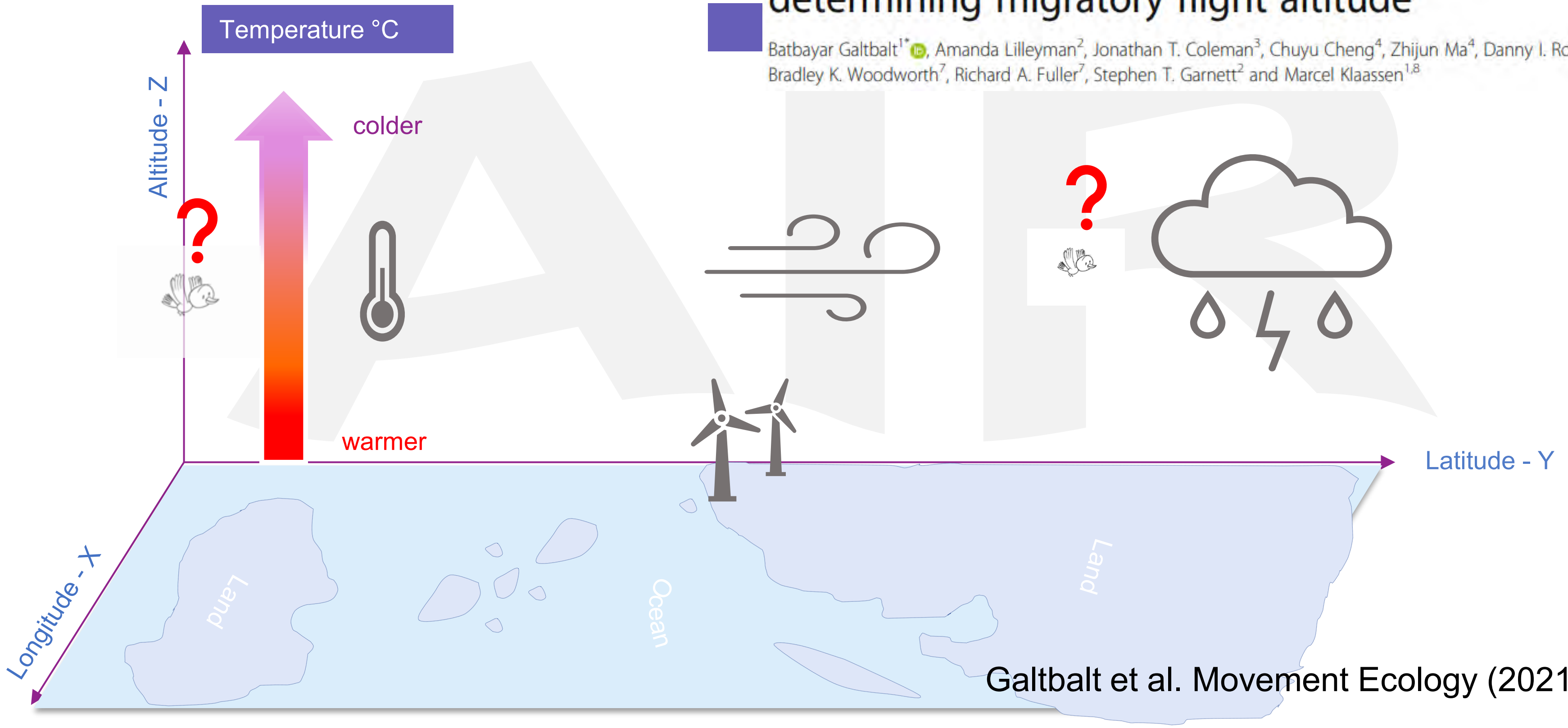

PNAS RESEARCH ARTICLE | ECOLOGY

Predicting resilience of migratory birds to environmental change

Simeon Lisovski[a,1], Bethany J. Hoye[b], Jesse R. Conklin[c], Phil F. Battley[d], Richard A. Fuller[e], Ken B. Gosbell[f], Marcel Klaassen[f,g], Chengfa Benjamin Lee[h,i], Nicholas J. Murray[j], and Silke Bauer[k,l,m,n]

Caveats

- where (3D) do they go when?




RESEARCH Open Access

Far eastern curlew and whimbrel prefer flying low - wind support and good visibility appear only secondary factors in determining migratory flight altitude

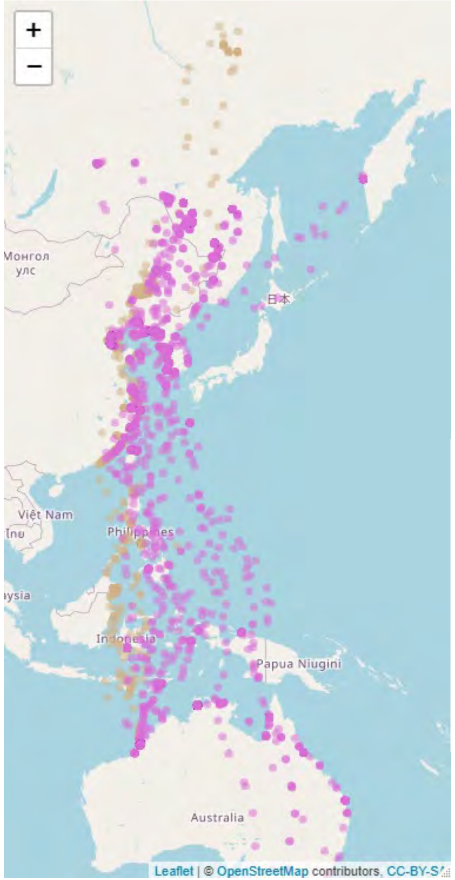
Batbayar Galtbalt[1*], Amanda Lilleyman[2], Jonathan T. Coleman[3], Chuyu Cheng[4], Zhijun Ma[4], Danny I. Rogers[5,6], Bradley K. Woodworth[7], Richard A. Fuller[7], Stephen T. Garnett[2] and Marcel Klaassen[1,8]

Galtbalt et al. Movement Ecology (2021) 9:32

Caveats

- where (3D) do they go when?

GPS-GSM tracking
by AWSG 2017-2019



@ RSPB

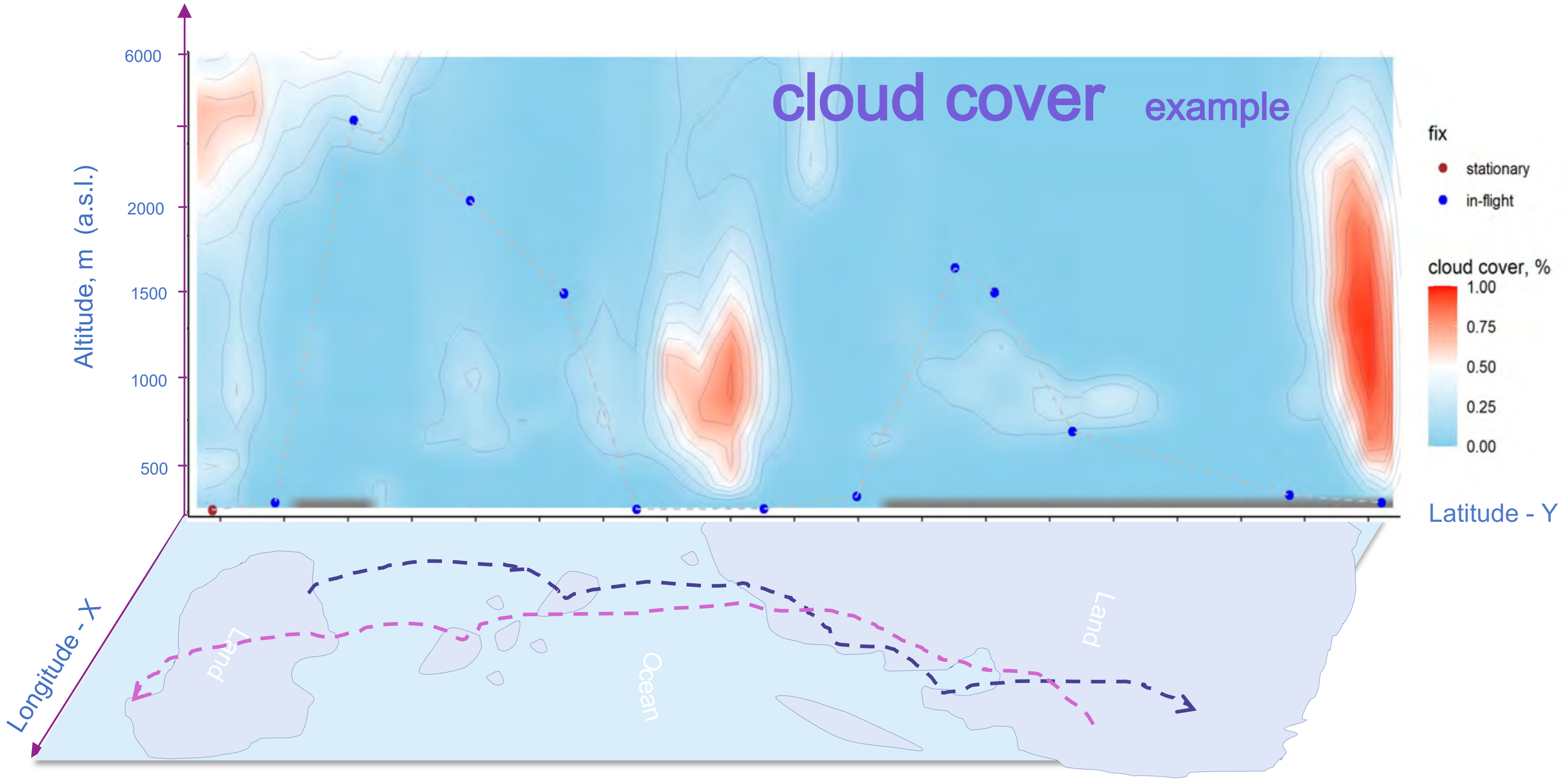
- Far-eastern curlew: 17 individuals

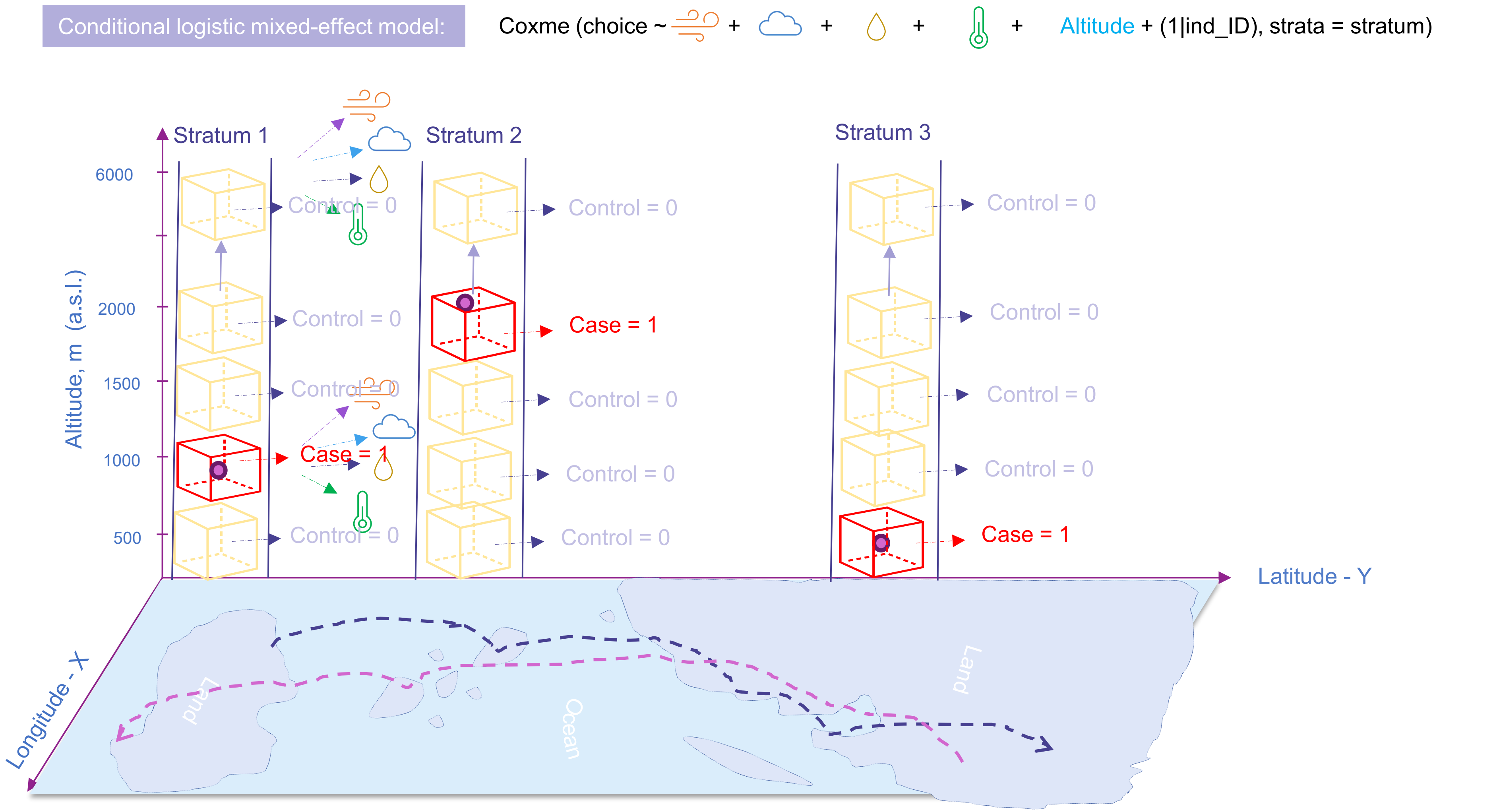
@ RSPB

- Whimbrel: 9 individuals

Caveats

- where (3D) do they go when?

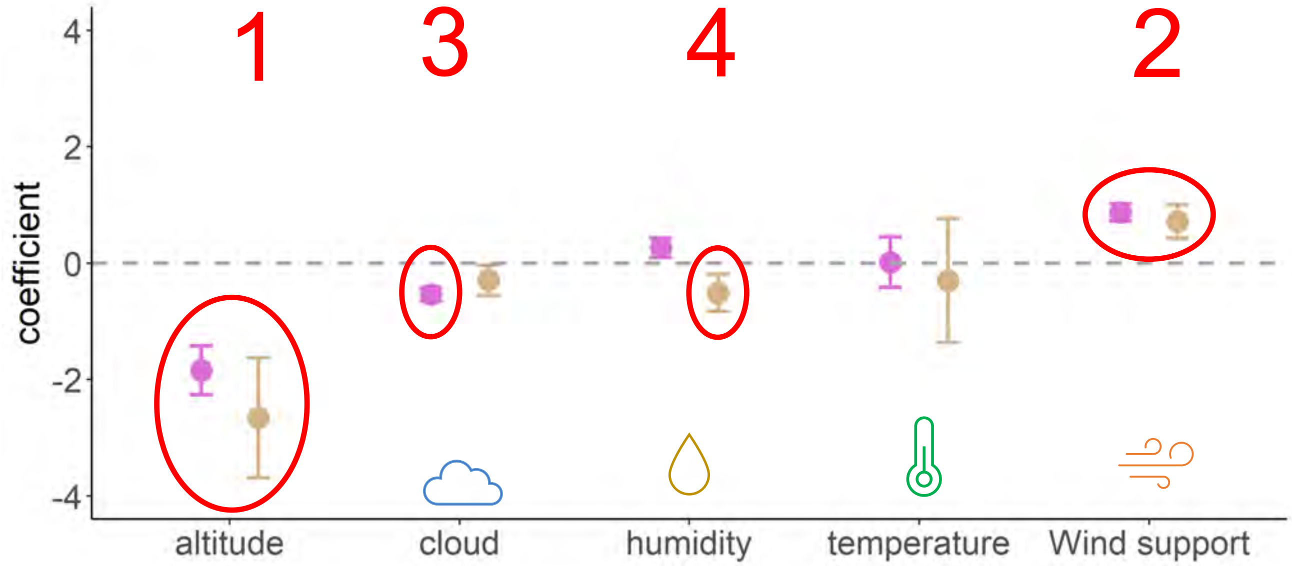




Conditional logistic mixed-effect model:
Coxme (choice ~ + + + + Altitude + (1|ind_ID), strata = stratum)
Stratum 1
Stratum 2
Stratum 3
Altitude, m (a.s.l.)
6000
2000
1500
1000
500
Control = 0
Control = 0
Control = 0
Case = 1
Control = 0
Control = 0
Case = 1
Control = 0
Control = 0
Control = 0
Control = 0
Control = 0
Control = 0
Control = 0
Case = 1
Latitude - Y
Longitude - X
Land
Ocean
Land

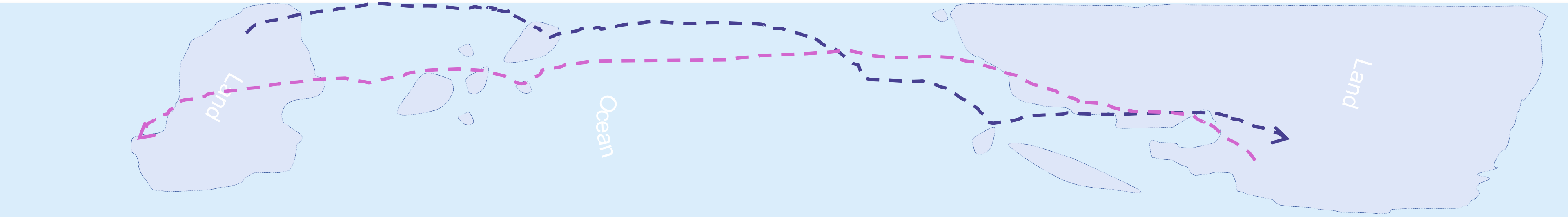
Caveats

- where (3D) do they go when?



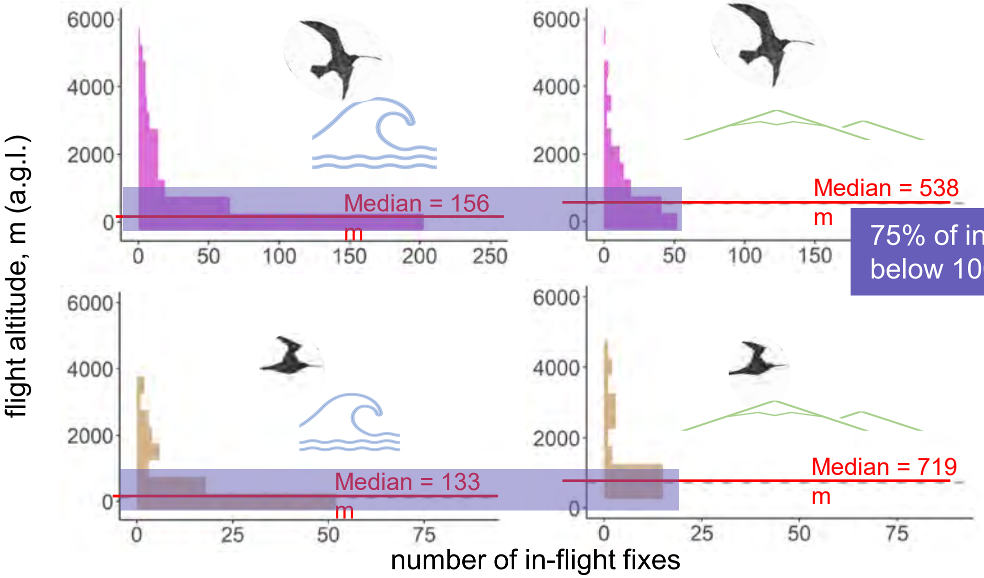
- Far-eastern curlew

- Whimbrel



Caveats

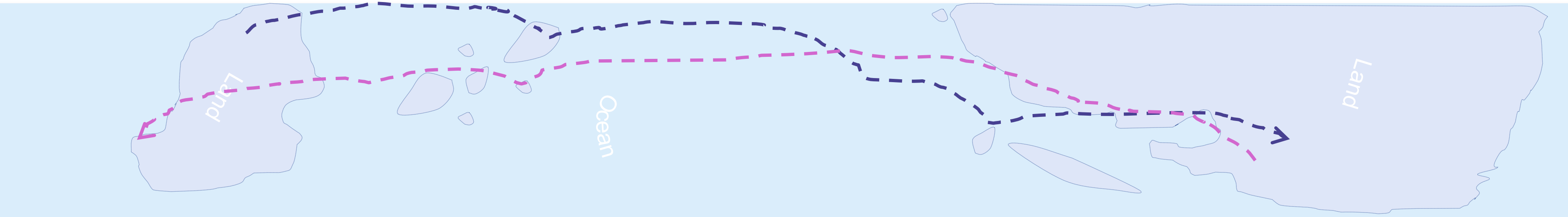
- where (3D) do they go when?



75% of in-flight fixes were below 1000 m a.g.l.

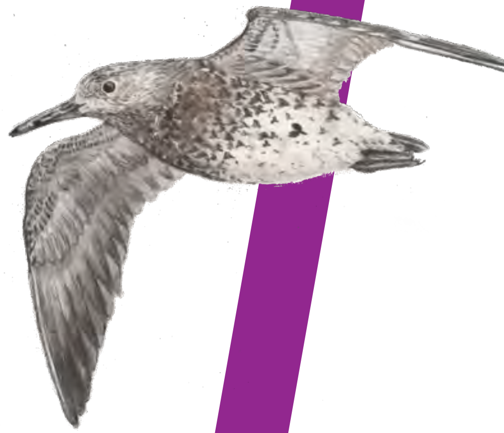
- Far-eastern curlew

- Whimbrel

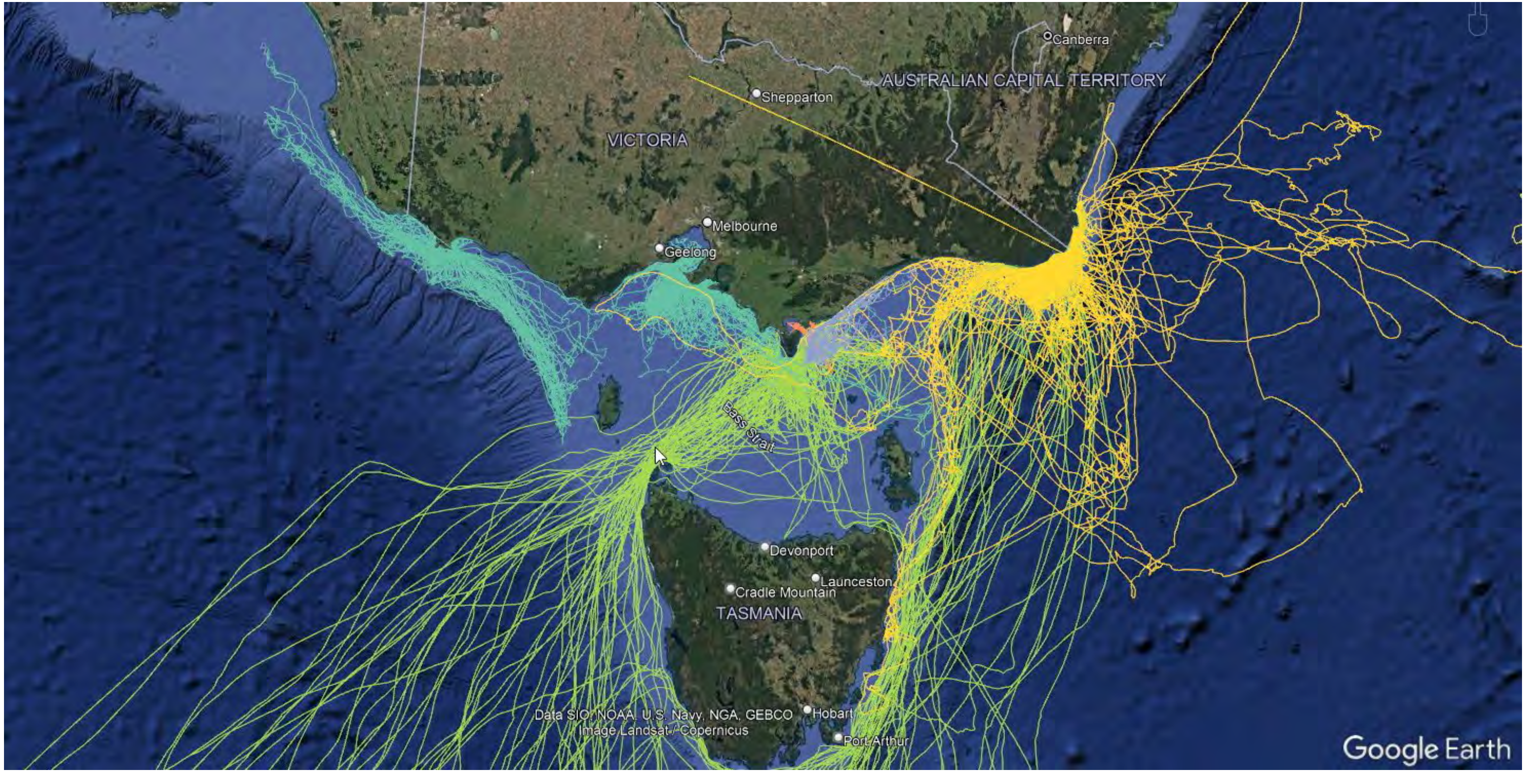


Caveats

- Is focus on priority species <u>only</u> warranted?
- Direct impacts of windfarms?
  - migratory movements
  - day-to-day movements
  - where (3D) do they go when
- Build real-time habitat suitability models
  - To guide planning
  - To develop mitigation strategies and operational models



… and still other Bass-strait species



summer 2023-2024: Australasian Gannet; Little Penguin; Wedge-tailed shearwater; Black-faced cormorant (data John Arnould)

To summarise

- There is good potential to monitor population dynamics of key shorebird species
- Movement behaviour observations and analyses for the development of real-time habitat suitability models

Thank you!

Toby Ross t.ross@deakin.edu.au
Marcel Klaassen marcel.klaassen@deakin.edu.au

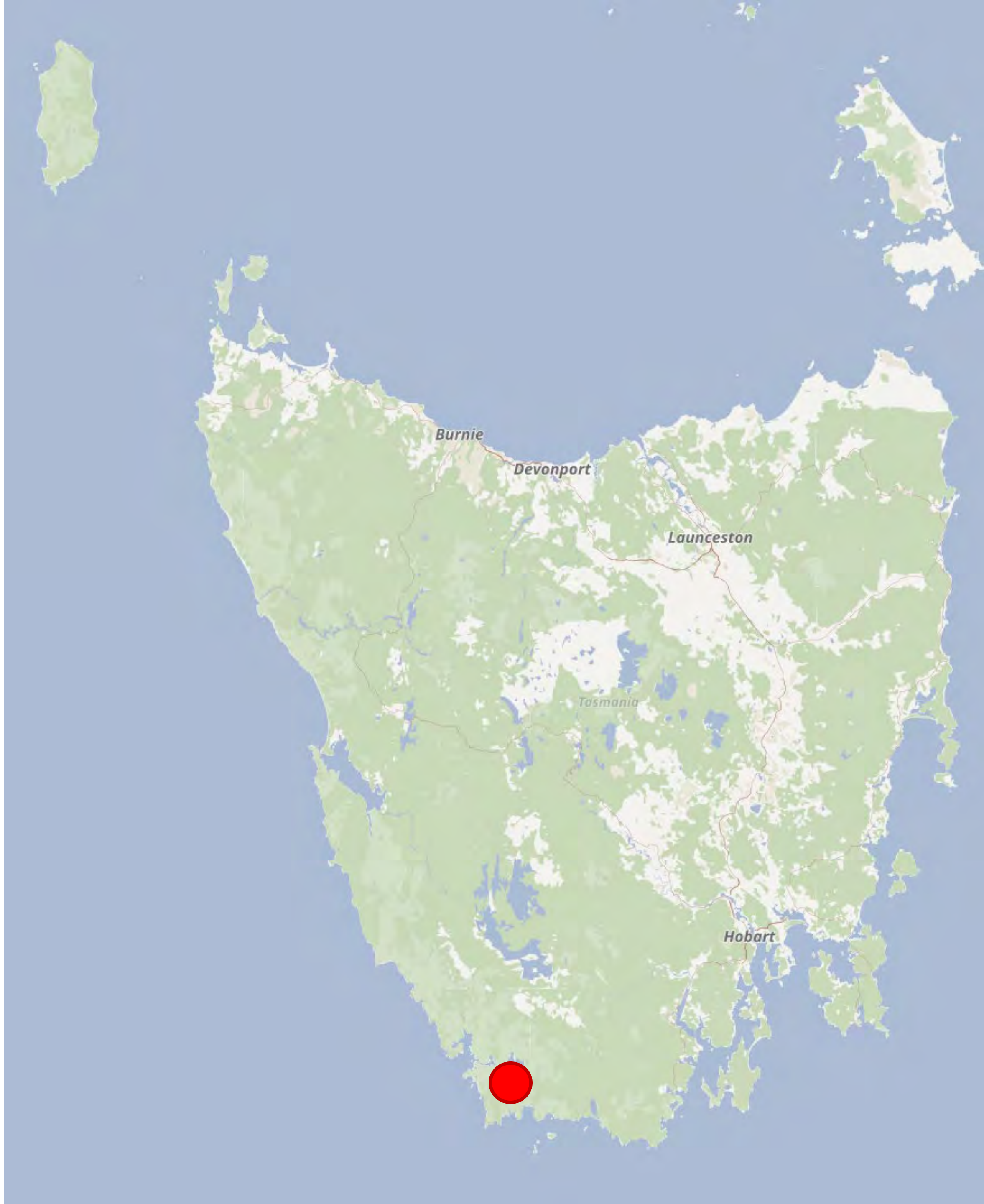
Population Viability Analysis: Orange-bellied parrots

Nick Beeton

CSIRO

Data sources

- Life history parameters (fecundity, mortality) largely determined by annual mark-recapture studies at Melaleuca TAS, run since 1979
- OBPs probably breed only at Melaleuca (Stojanovic et al. 2018), so can assume closed-population for breeding season

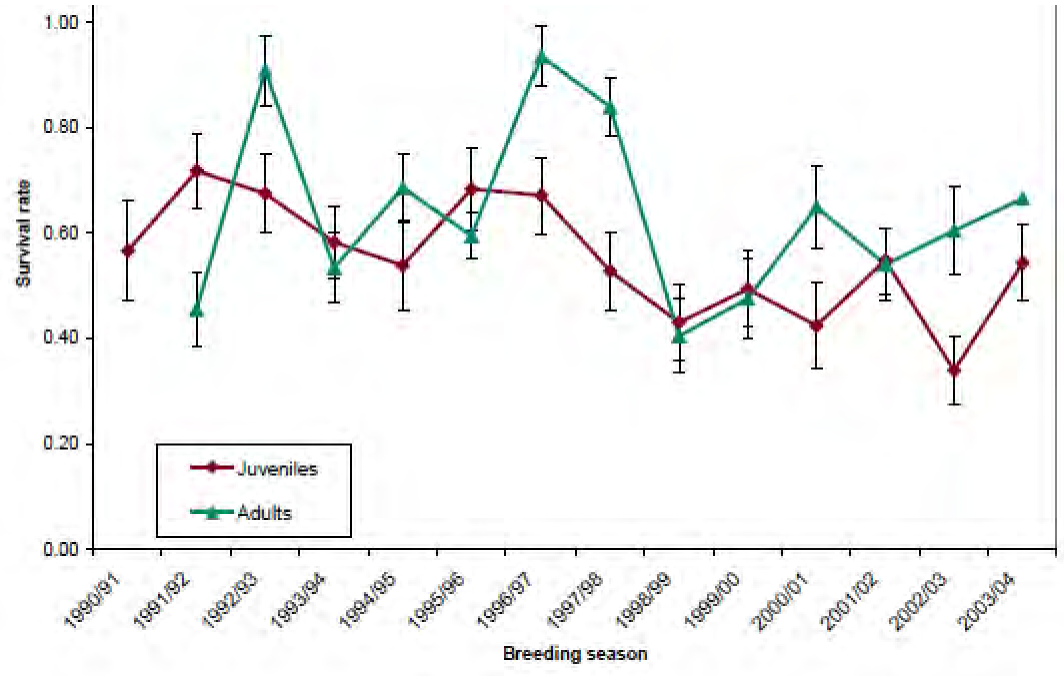


Holdsworth (2006; PhD thesis)

- Used data between 1993 to 2004
- Model selection by AICc used to determine time-dependence
- Best model selected had survival ϕ dependent on juvenile/adult status and year, capture probability p dependent on year

$$\phi_j(t)\ \phi_a(t)\ p(t)$$

- Fecundity measured 1.62 per female on average



Holdsworth, Dettmann & Baker (2011)

- Similar analysis using updated data to 2009, with same model selected $\phi_j(t)\ \phi_a(t)\ p(t)$

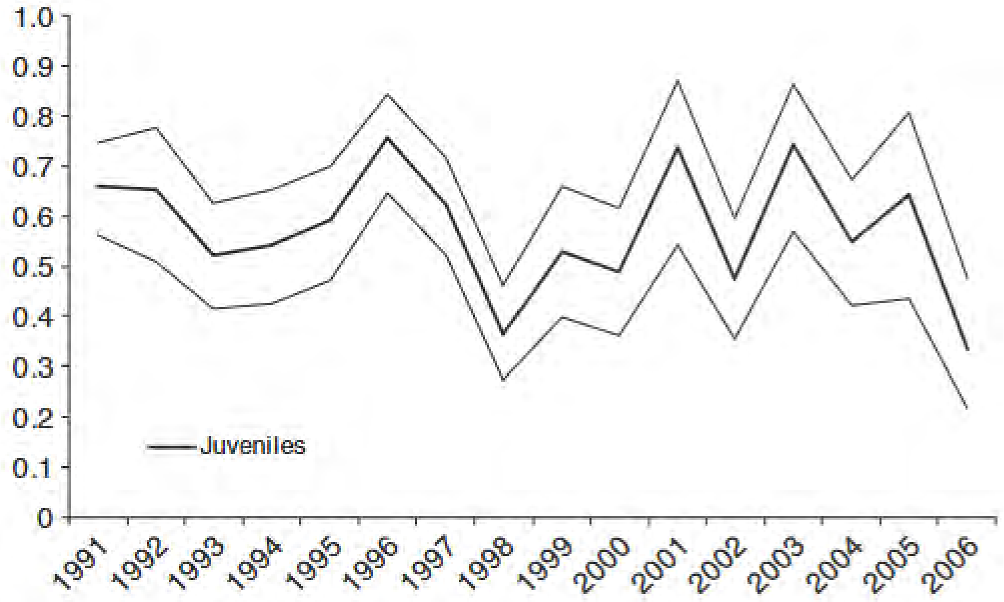


Fig. 1. Survival of juvenile Orange-bellied Parrots over time, with 95% confidence intervals, as estimated by Model 1. Survival values for years 2007 and 2008 could not be estimated.

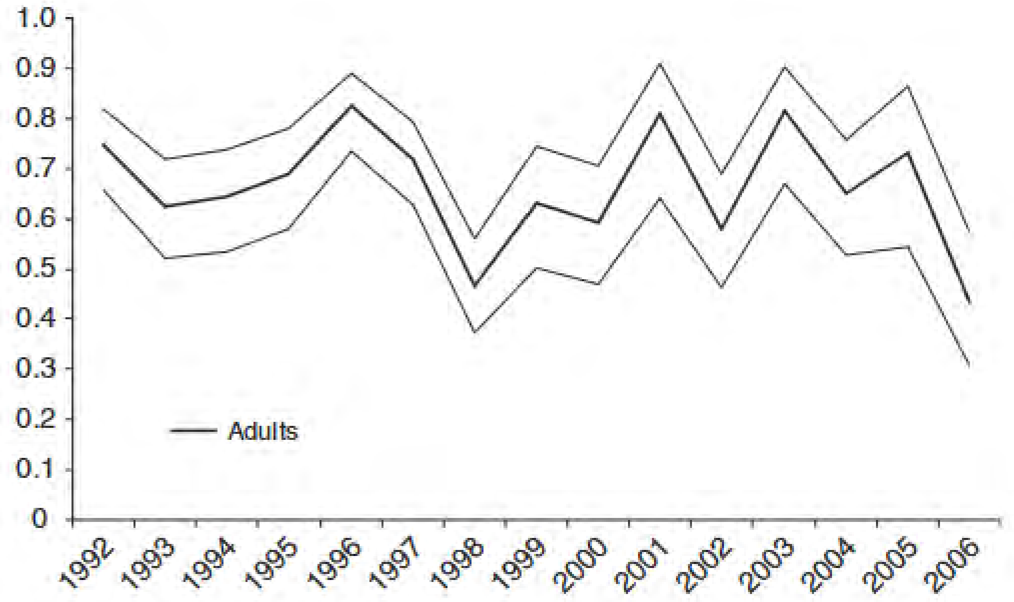
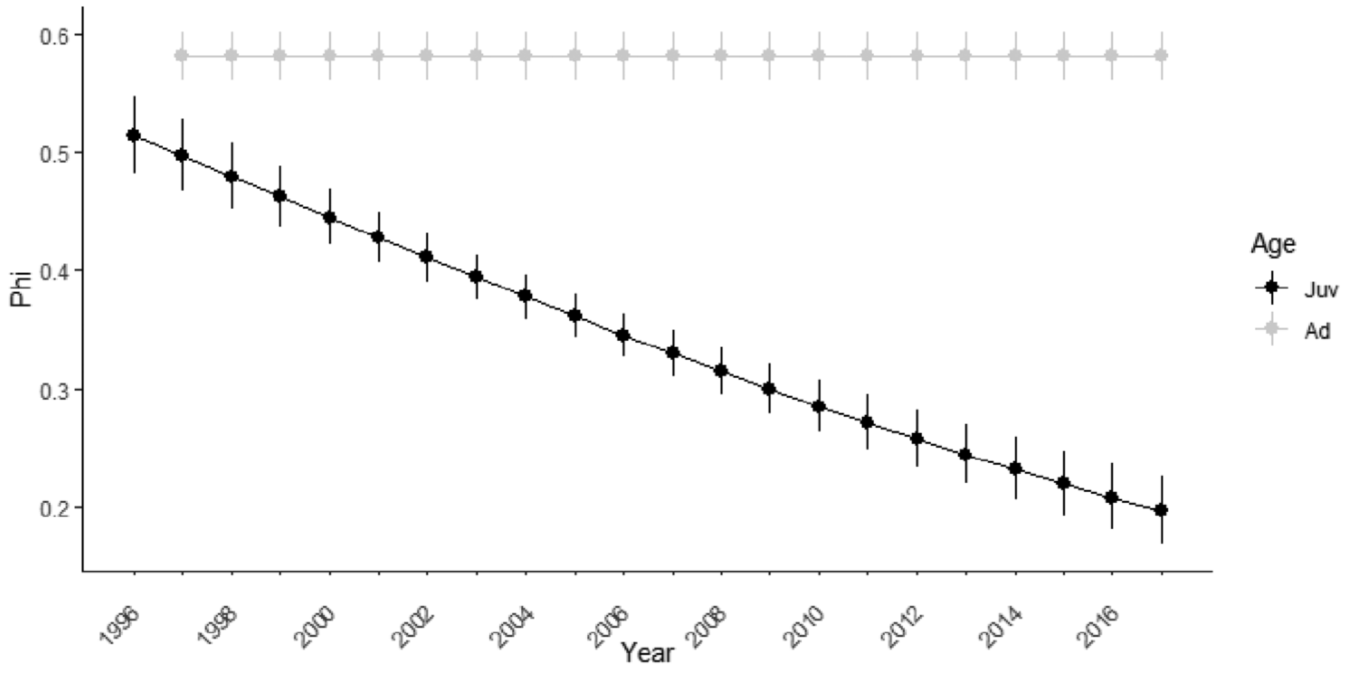


Fig. 2. Survival of adult Orange-bellied Parrots over time, with 95% confidence intervals, as estimated by Model 1. Survival values for years 2007 and 2008 could not be estimated.

Stojanovic et al. (2020)

- Used same data up to 2017
- After steep decline in 2010, a captive breeding program was introduced. Data was subset into 1995-2010 vs 2011-2017
- Not enough data for survival by year, so linear trend used instead
- Best model was

$$\phi_{\mathrm{j}}(t)\ \phi_{\mathrm{a}}(\cdot)\ p(\cdot)$$



Population Viability Analysis modelling

- PVA calculates probability of extinction in a given timeframe
- Used to evaluate management scenarios and/or perform sensitivity analyses on model parameters
- Uses stochastic modelling to simulate demographic stochasticity
- Randomly varies relevant parameters to simulate environmental stochasticity

Drechsler, Burgman & Menkhorst (1998)

- Survival modelled by
$$N_x(t+1) \sim \mathrm{Bin}\left(N_x(t), s_x\, f\big(N_x(t)\big)\right)$$
- Reproduction sampled from table
- Survival s_x and variability taken from 1991-1995 mark-recapture results
- Function f depends on "scramble" or "contest" competition at high densities

Table 2. Probability that a breeding pair raises a particular number of fledglings (M. Holdsworth, unpub. data)

Number of fledglings	1	2	3	4	5
Probability	0·10	0·05	0·05	0·15	0·20

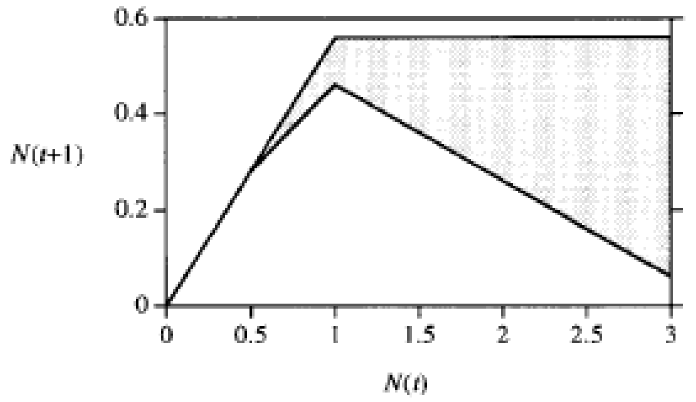
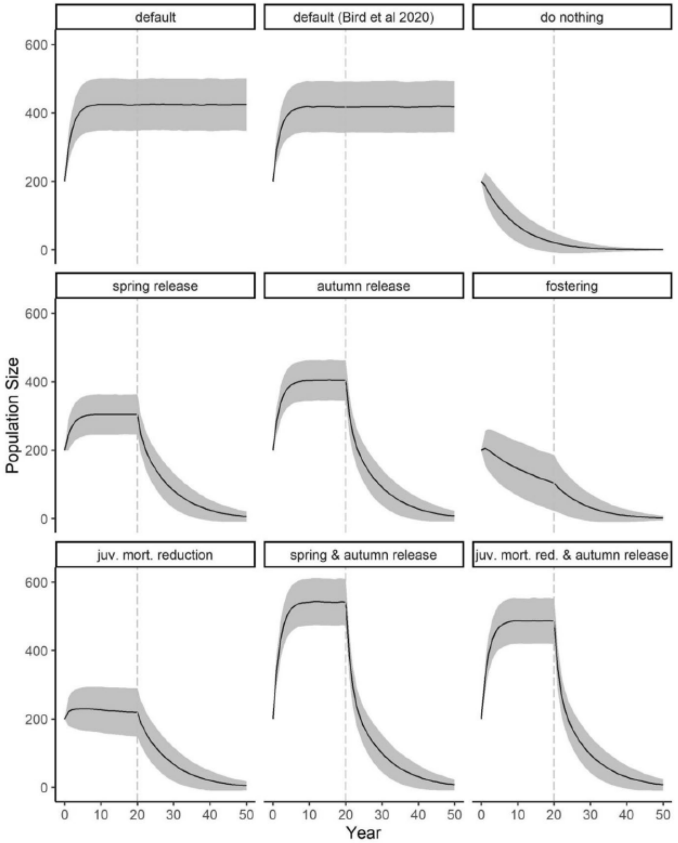


Fig. 1. Number of survivors, $N(t+1)$ as a function of the present number of individuals, $N(t)$ (demographic fluctuations neglected). $N(t)$ and $N(t+1)$ are measured in units of the winter capacity, K_w. For simplicity the numbers of juveniles and adults are assumed to be equal. The upper curve represents contest competition, the lower one represents scramble competition. Juvenile and adult survival rates are $s_j = 0{\cdot}49$, $s_a = 0{\cdot}63$, the scramble factor is $S = 0{\cdot}1$ and the 'scramble threshold' is $K = K_w/2$; K_w denotes the winter capacity. The shaded area between the two curves represents the additional mortality caused by scramble competition.

Stojanovic et al. (2023)

- Uses software platform VORTEX
- Juvenile mortality based on 2017 endpoint of linear trend (80%) in Stojanovic et al. (2020)
- Parametric stochasticity (+/- SD) not justified
- Results unsurprisingly show population unsustainable without continuous management



Main Components	Demographic Parameter	Values used	Justification
Inbreeding Depression	Lethal equivalents	0	Excluded because observed mortality rates in the wild population (Stojanovic et al. 2020c) already include potential lethal inbreeding effects.
Carrying capacity	Carrying capacity	1000±0 SD	Optimistic assumption to remove carrying capacity limits.
Reproductive System	Mating system	Monogamy	Social monogamy within a breeding season (Higgins 1999).
	Age range of first offspring and maximum age of reproduction – both sexes	First offspring = 1 year Maximum age = 11 years	Breeds at 1 year old after completing a migration (Higgins, 1999) and optimistic assumption that all birds that survive migration attempt to breed.
	Maximum lifespan	11	Longest-lived wild individual (Stojanovic et al. 2020c).
	Maximum number of broods per year	1	Short breeding season and only one recorded case of double-brooding in the wild (Stojanovic et al. 2018).
	Maximum number of progeny per year	6	Historical (Higgins, 1999) and contemporary sources (Stojanovic et al. 2020a).
	Sex ratio at birth (% males)	50%	Unpublished data from the contemporary population.
Reproductive Rates	Percentage adult females breeding	Formula: MIN(1:100/F)*100. Included 10% SD due to environmental variation	Formula limiting the number of breeding opportunities by the provisioning of 100 nest boxes (Stojanovic et al. 2018).
	Distribution of broods per year	100% have 1 brood	Evidence from the field (Troy and Lawrence 2021). Only one record of double brooding in the wild (Stojanovic et al. 2018).
	Number of offspring per female per brood	Mean of 3.5±1 SD. Scenarios that involved Fostering as an intervention had a mean brood size of 4.5 (Table 2)	Recent and historical data (Stojanovic et al. 2020a, Higgins, 1999). Fostering is possible (Stojanovic et al. 2018) but most broods can only be increased by the addition of one nestling (Stojanovic et al. 2020d).
Mortality Rates	Adult mortality rate	42% ± 2 SD (baseline for all models)	Based on survival estimates (Stojanovic et al. 2020c).
		49% ± 2 SD (only used for the 'Default (Bird et al. 2020)' scenario	Modelled estimate (Bird et al. 2020).
	Baseline juvenile mortality rates	49% ± 10 SD – (used only for the default scenario)	Based on survival estimates (Stojanovic et al. 2020c).
		80% ± 10 SD – (used as the baseline for all scenarios except the two default scenarios)	
Mate monopolization	Proportion of males in the breeding population	100%	Management efforts to rectify adult sex ratio biases (Troy and Lawrence 2021).
Initial population size	Initial population size	200	Historical population sizes (Stojanovic et al. 2020c).
	Stable age distribution, based on 100 individuals per sex		Based on automated calculations within VORTEX and set manually for each scenario.

Thoughts

- Scope for more robust analysis
- E.g. state space modelling
  - Requires access to raw mark-recapture data
  - Can incorporate measurement uncertainty
    - coefficient of linear trend in $\phi_j(t)$
    - interannual variability in ϕ_x, p etc
- Without raw data, limited to current assumptions
  - Point value estimates of e.g. ϕ_j
  - Stochastic effects less robust
- Carrying capacity unlikely to be an issue

Migration

- Radio tagging performed on 46 OBPs in 2024
- 12 birds detected after leaving Melaleuca (mostly 25 Mar - 8 Apr)
- Small subset of birds during a single season makes results hard to generalise
- Return data may help?

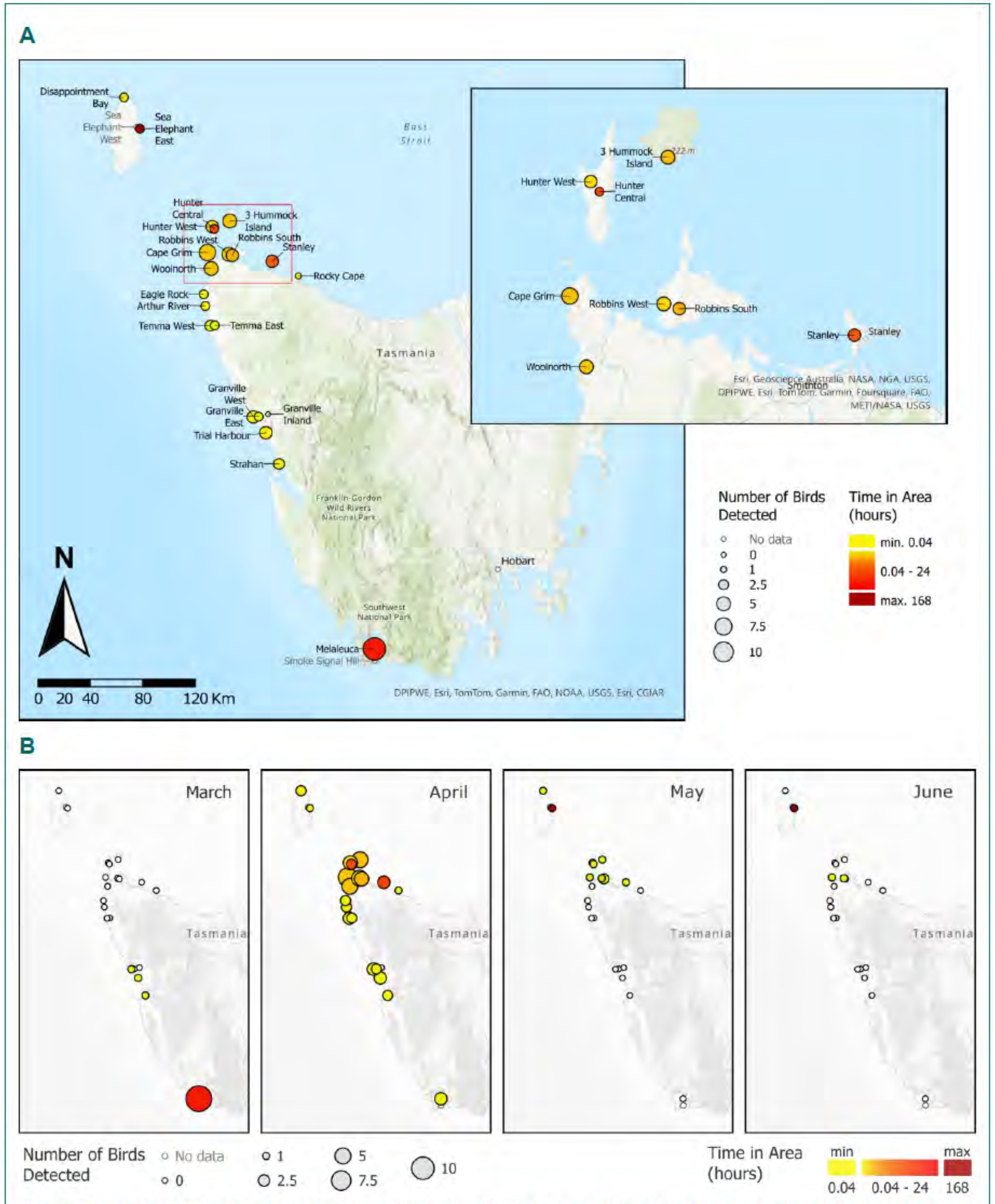
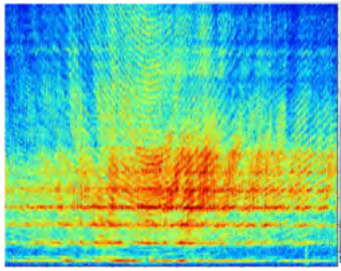
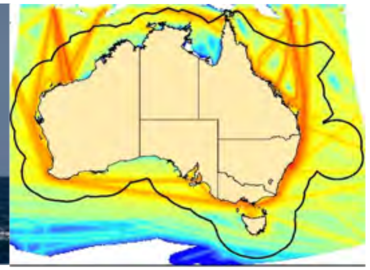


Figure 9 A. Map of OBP activity among receiver sites for the 12 birds detected outside of Melaleuca across Tasmania between March and June 2024. Inset map shows the section of the northwest region highlighted in red in the main map. Sites are scaled by the number of individual birds detected at that site (max 12 birds) and coloured by the average length of time each bird spent in range of the receiver at that site over the survey period. **B.** By month showing the northward trend in detections.

Marine and Coastal

National Environmental Science Program



Bass Strait Ecosystem and Offshore Renewable Energy:

Underwater Noise

Christine Erbe and Cristina Tollefsen

Centre for Marine Science and Technology (CMST)

Perth, WA

Curtin University

Sound propagates well in water (as opposed to light). Animals use sound passively (listening) and actively.

- Acoustic communication
  - Reproduction (e.g., male whale song; male fish sing on spawning grounds)
  - Rearing of young (e.g., mother-pup contact calls in seals)
  - Coordination of group behaviour (e.g., signature whistles of dolphins)

- Environmental sensing
- Predator detection
- Navigation (e.g., biosonar)
- Foraging, prey detection

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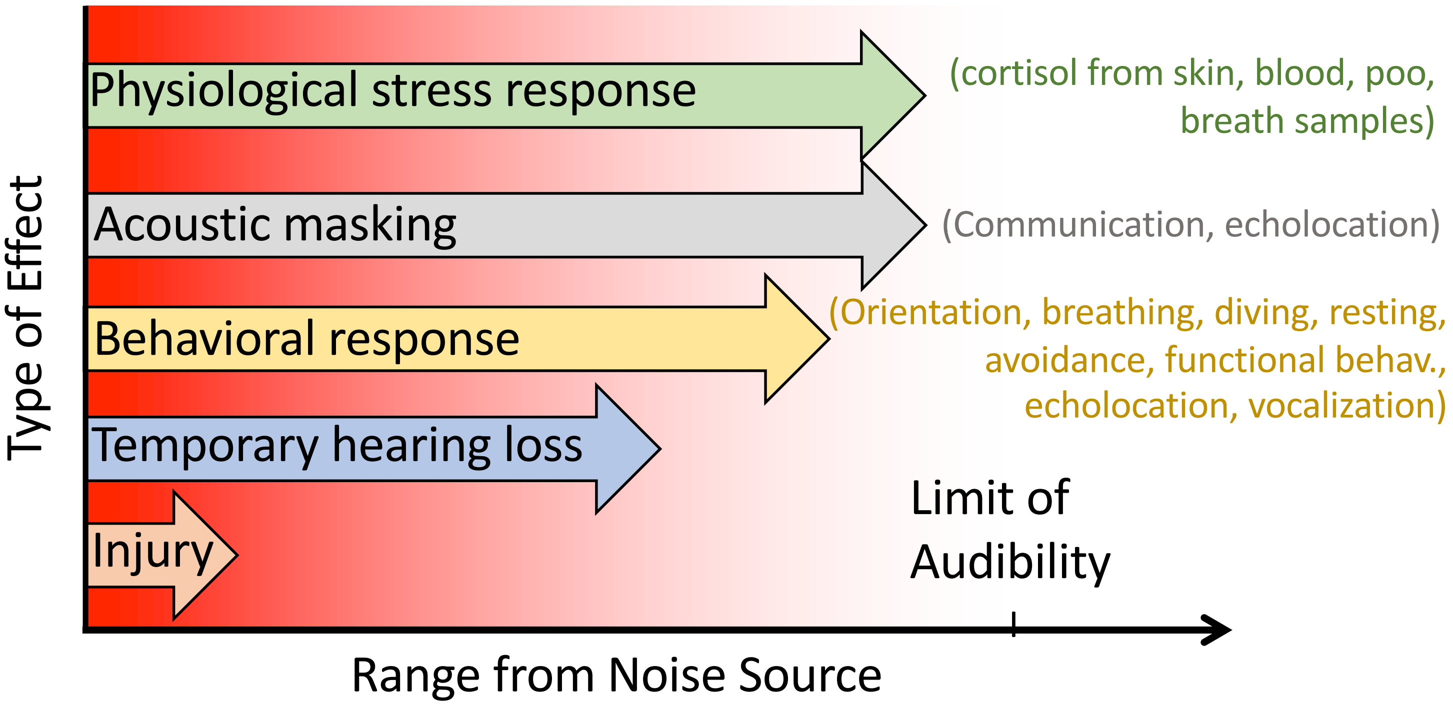
Effects of Noise on Marine Fauna



Erbe C et al. (2022) The effects of noise on animals. In: Erbe C, Thomas JA (eds) Exploring Animal Behavior Through Sound. Springer pp 459-506

Southall BL et al. (2007) Marine mammal noise exposure criteria: Initial scientific recommendations. Aquat Mamm 33 (4):411-521

Southall BL et al. (2019) Updated scientific recommendations for residual hearing effects. Aquat Mamm 45 (2):125-232

Southall BL et al. (2021) Assessing the Severity of Marine Mammal Behavioral Responses to Human Noise. Aquat Mamm 47 (5):421-464

Popper AN, Hawkins AD (2019) An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. J Fish Biol 94:692-713.

Popper AN et al. (2022) Offshore wind energy development: Research priorities for sound and vibration effects on fishes and aquatic invertebrates. J Acoust Soc Am 151 (1):205-215.

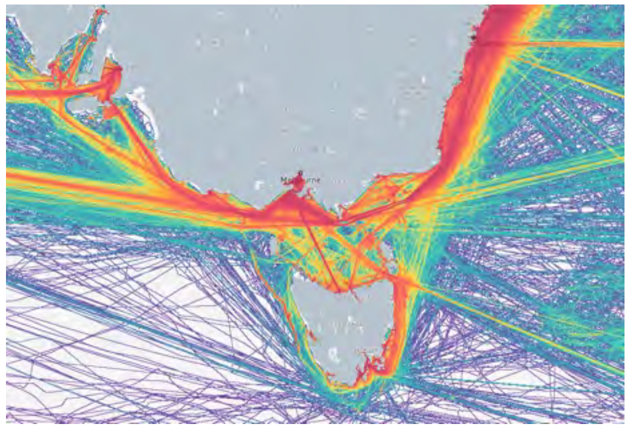
Noise sources related to offshore wind energy

https://www.windenergy.org.nz/offshore-wind/


Photo: Christine Erbe

<u>Construction phase:</u>
Pile driving / mooring
Increased vessel presence

Changes in vessel traffic ?



<u>Operation phase:</u>
Some noise from nacelle
and vibrations
Offshore substation


https://www.energy.vic.gov.au/renewable-energy/offshore-wind-energy

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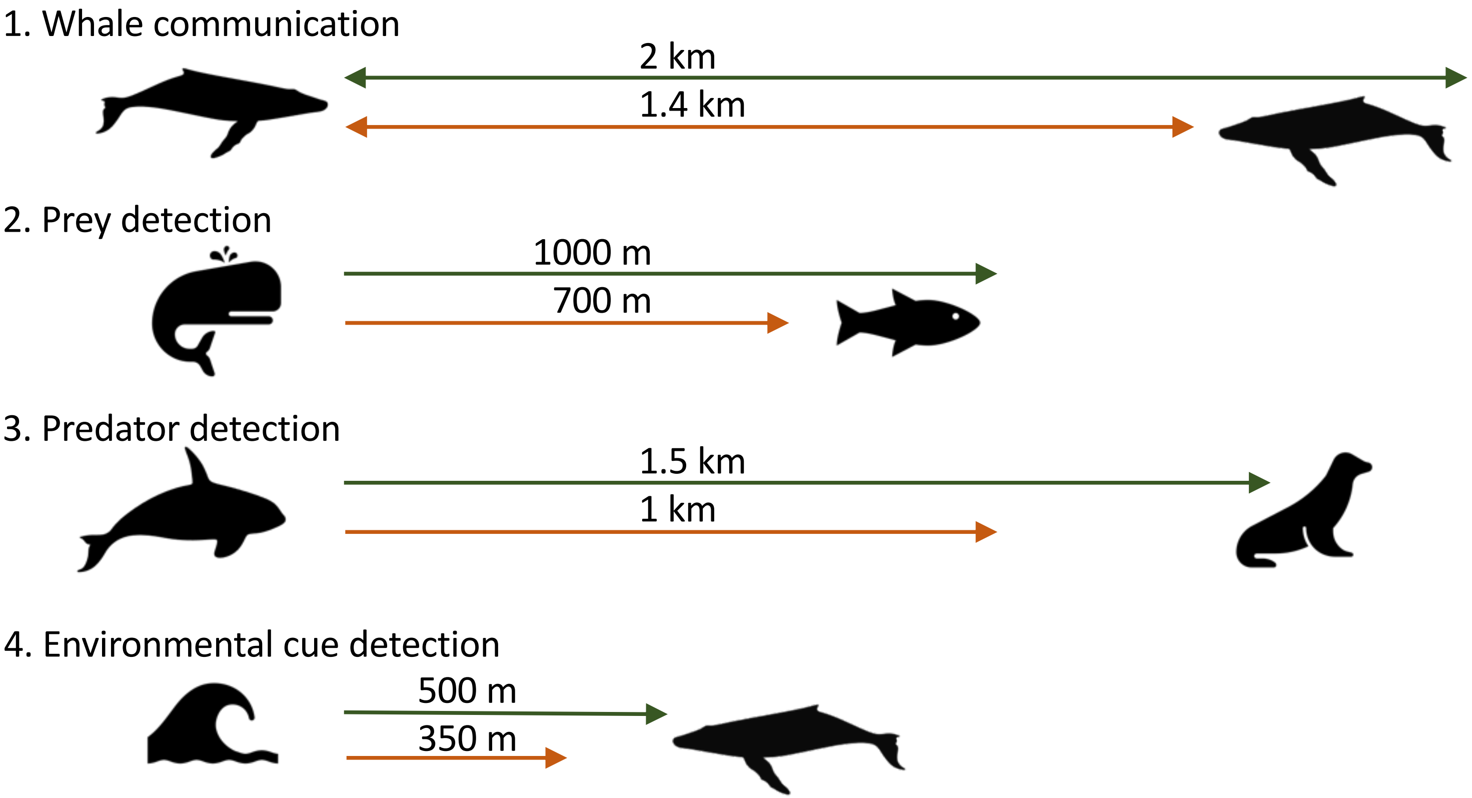
Implications of a 3 dB increase in ocean ambient noise:

In scenarios where hearing is ambient noise limited, the active acoustic space reduces to 70% because of masking



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Erbe C et al. (2016) Communication masking in marine mammals: A review and research strategy. Mar Pollut Bull 103:15-38

Ingredients for a noise model

Sources

- Source spectrum & level
- Physical properties
- Impulsive vs continuous
- Location & depth

Propagation through the environment

- Sound speed profile (T,S,d)
- Bottom geoacoustic properties
- Surface roughness

Receivers

- Location & depth
- Frequency sensitivity
- Response/impact metrics

Sources → Propagation through the environment → Receivers

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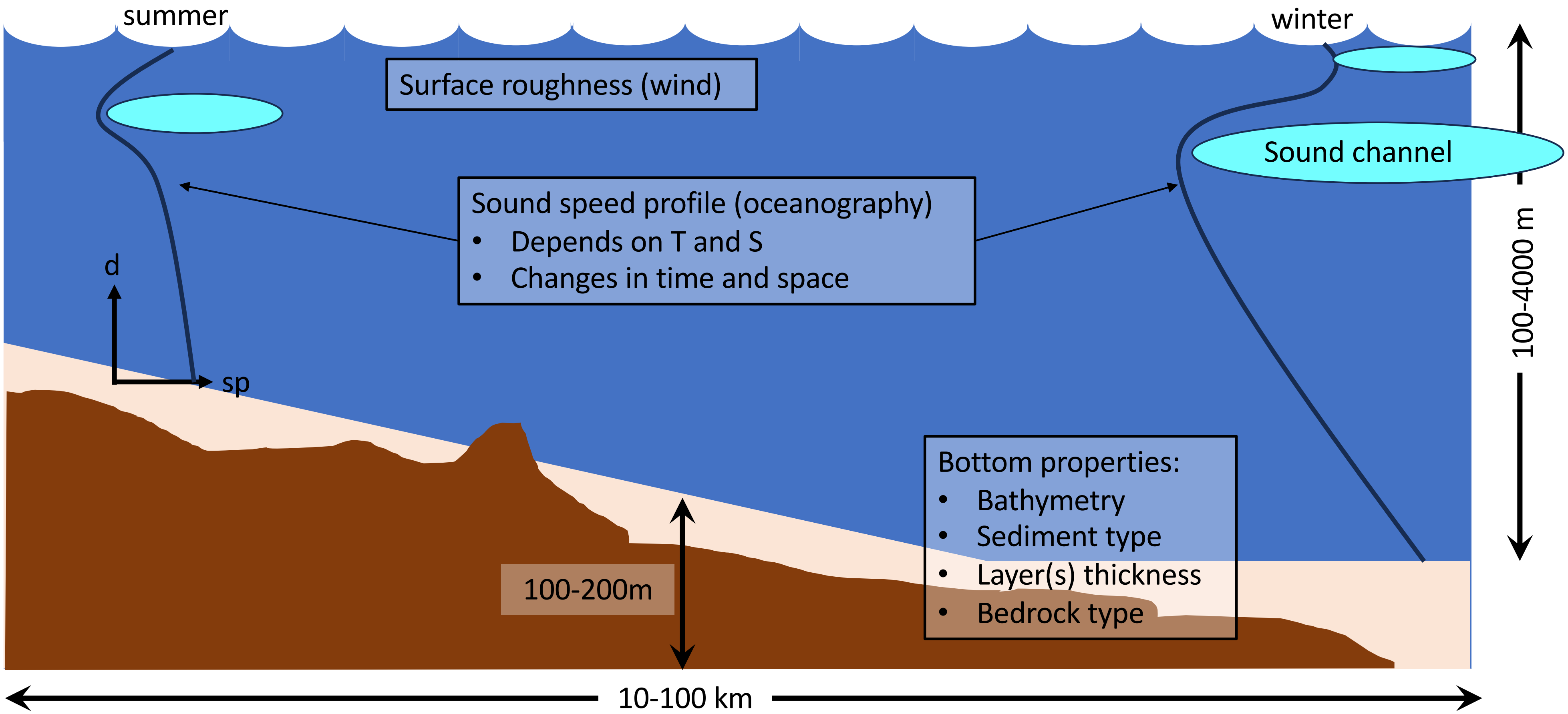
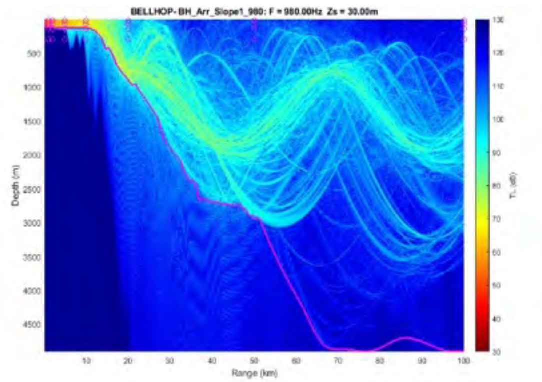
Propagation through the water

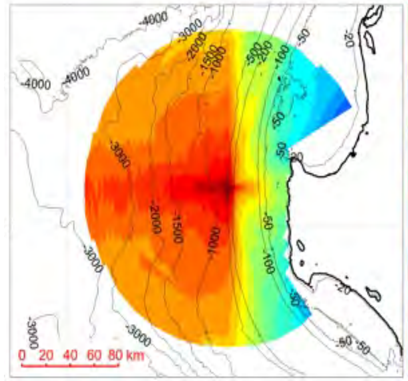
Your outputs are our inputs!

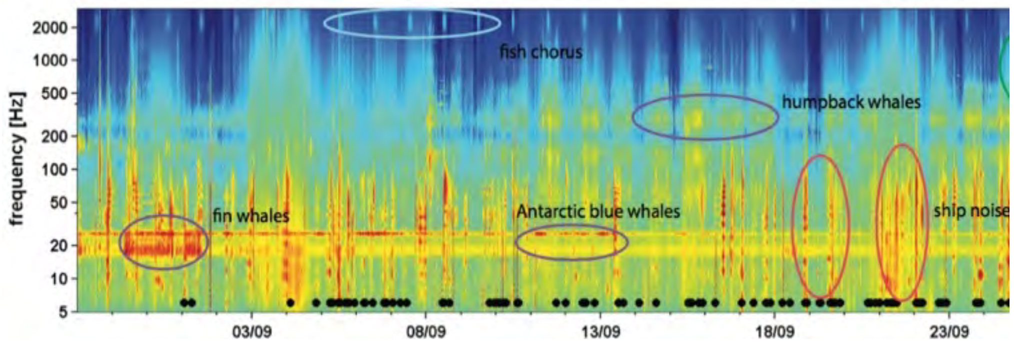


Project Objectives

1. Characterise the underwater sound propagation conditions in Bass Strait
2. Build a marine soundscape model that includes the dominant contributions of geophony (wind-driven noise), biophony (whale song, fish choruses), anthropophony (ships)
3. Validate the current model
4. Predict soundscape into the *far* future (add operating windfarms, consider changes in ship traffic, changes in ocean weather/climate?, changes in megafauna abundance and distribution?)
5. Model noise footprints from windfarm construction
6. Model noise exposures of whales







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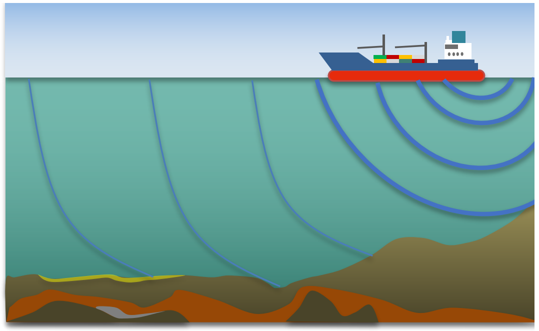
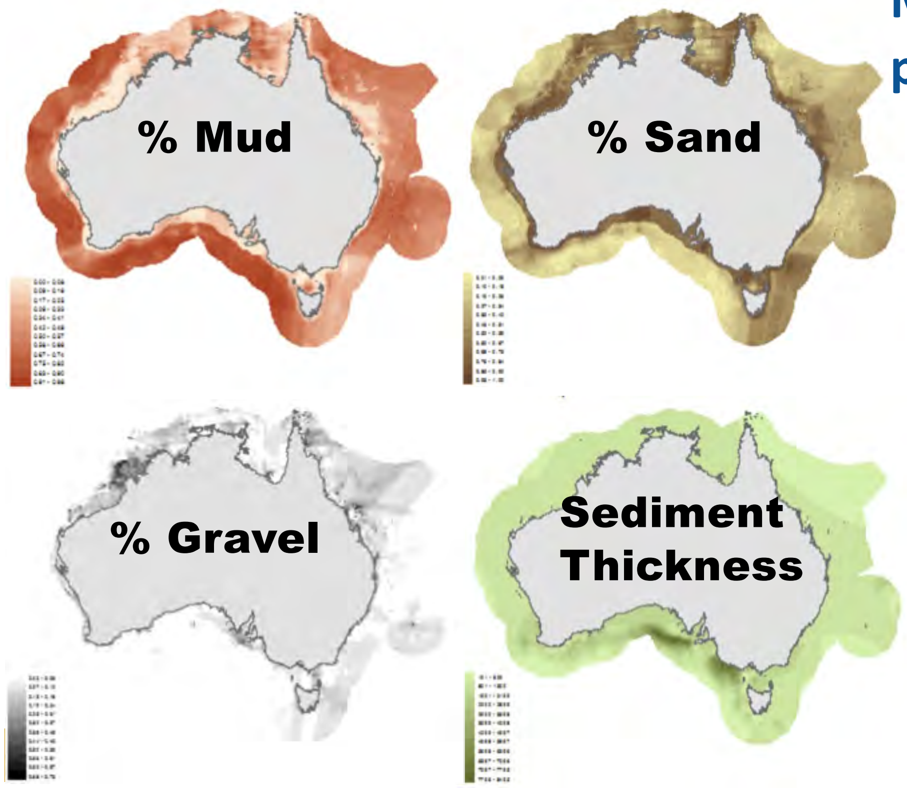
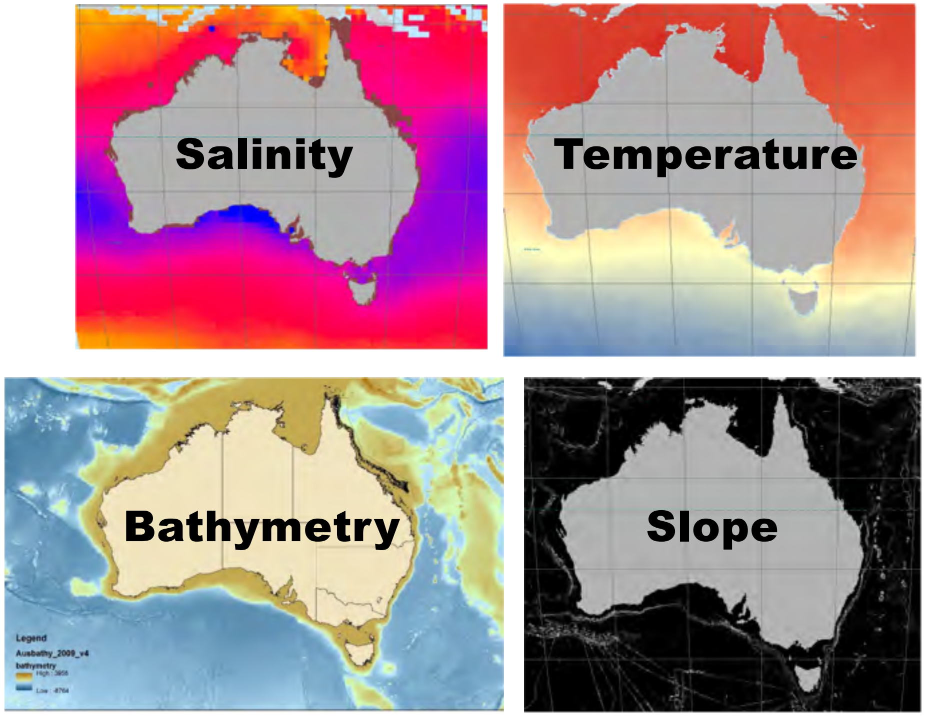
Project Objectives

1. Characterise the underwater sound propagation conditions in Bass Strait
   => ref. NESP Project E2, 2021



Metocean, seafloor and geological parameters affecting sound propagation

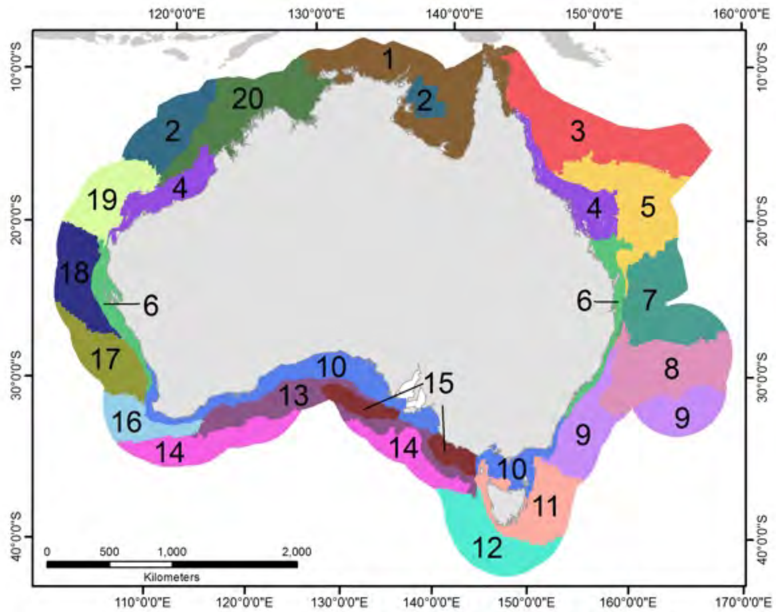


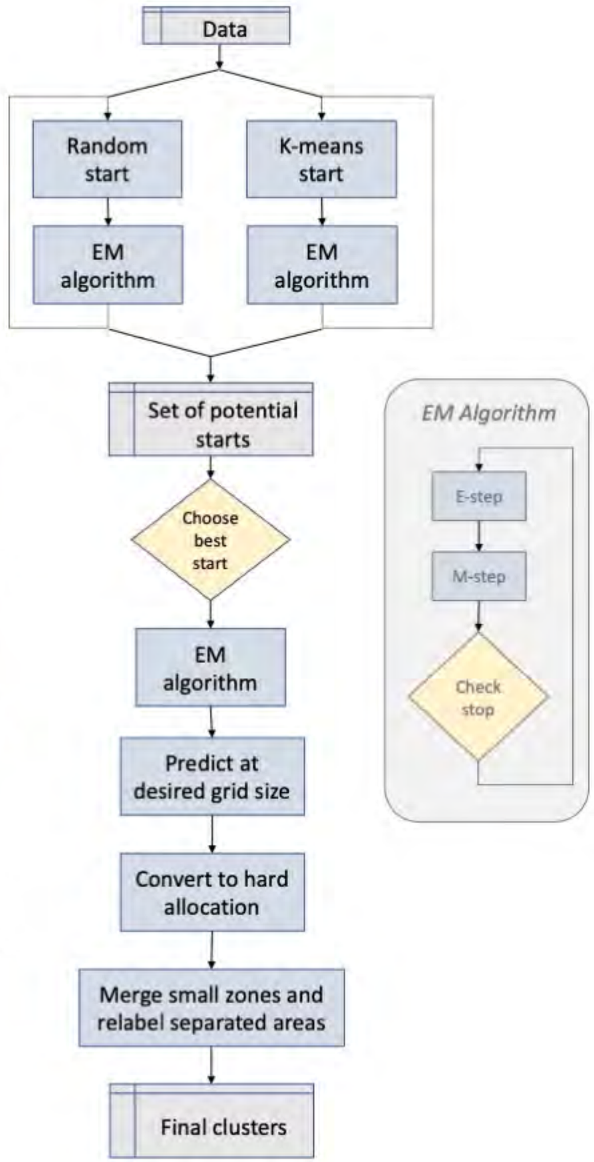


Project Objectives

1. Characterise the underwater sound propagation conditions in Bass Strait
   => ref. NESP Project E2, 2021

Zone	Name	Description
1	Northern Tropical Shelf	Hot northern zone, shallow water with low salinity. Borders appear to align with salinity change.
2	Muddy Tropical Shallow	Two areas of northern Australia, one offshore in the West and one in shallow water in the Gulf of Carpentaria. Their predominant features are a muddy sea bed, hot temperature, and low salinity.
3	Eastern Tropical 1	Excludes coastal waters but spans a range of depths. Separate from neighbouring Zone 5 to the South by water column sound speed profile. Zones 1- 3 and 20 have the steepest downward refracting gradients. An abrupt change in salinity defines the border with Zone 1.
4	Tropical Shelf	Exists on both coasts. Mostly shallow, sandy, coastal water. Hot temperature, medium salinity.
5	Eastern Tropical 2	Geoacoustic parameters drive the border with Zone 4, hydroacoustic parameters (i.e., sound speed profiles) drive the borders with Zones 3 and 7.
6	Sub-Tropical to Temperate Shelf	Exists on both coasts. Warm, shallow, sandy.
7	Eastern Sub-Tropical Deep	Inner bound at continental shelf. Hydroacoustic parameters drive the separation from Zone 8.
8	Eastern Temperate Deep 1	Inner bound at continental shelf. High sea surface salinity. Less downward refracting than Zone 7.
9	Eastern Temperate Deep 2	Inner bound at continental shelf. High salinity. Less downward refracting than Zone 8.
10	Southern Temperate Shelf	Shallow water bounded by the continental slope. High salinity. Sandy seafloor.
11	Southern Cold	Covers shallow coastal Tasmania but also extends to deep water South-East of Tasmania. Cold water with a strong surface duct in July.
12	Southern Cold Deep	Most southerly zone. Cold. Less saline surface water than Zone 11. The least sound-focussing sound speed profiles.
13	Great Australian Bight Temperate Deep 1	Southern, cold, deep. Inner bound at continental shelf. Shallower yet thicker sediment than Zone 14.
14	Great Australian Bight Temperate Deep 2	Southern, cold, deep.
15	Southern Thick Sediment	An area (2 locations) between Zones 10 and 13 with very high sediment thickness.
16	Western Temperate Deep 1	Offshore with a sandy, shallower band resulting in different seabed acoustic properties from neighbouring Zones 14 and 17. Sound speed gradients at 40-1000m different from neighbouring zones. Inner bound at continental shelf.
17	Western Temperate Deep 2	Inner bound at continental shelf. Cooler and more saline than Zone 18 to the North.
18	Western Sub-Tropical Deep	Offshore, warm. Inner bound at continental shelf.
19	Western Tropical Offshore	Warm-hot. Downward refracting July profile. Inner bound at continental shelf. Shallower than Zone 2 to the North and Zone 18 to the South.
20	Western Tropical Shelf	Shallow water. Wide, sandy continental shelf. Hot sea surface; strongly downward refracting.





5 km grid => 500 m grid

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Erbe C, Peel D, Smith JN, Schoeman RP (2021) Marine acoustic zones of Australia. J Mar Sci Eng 9 (3):340.

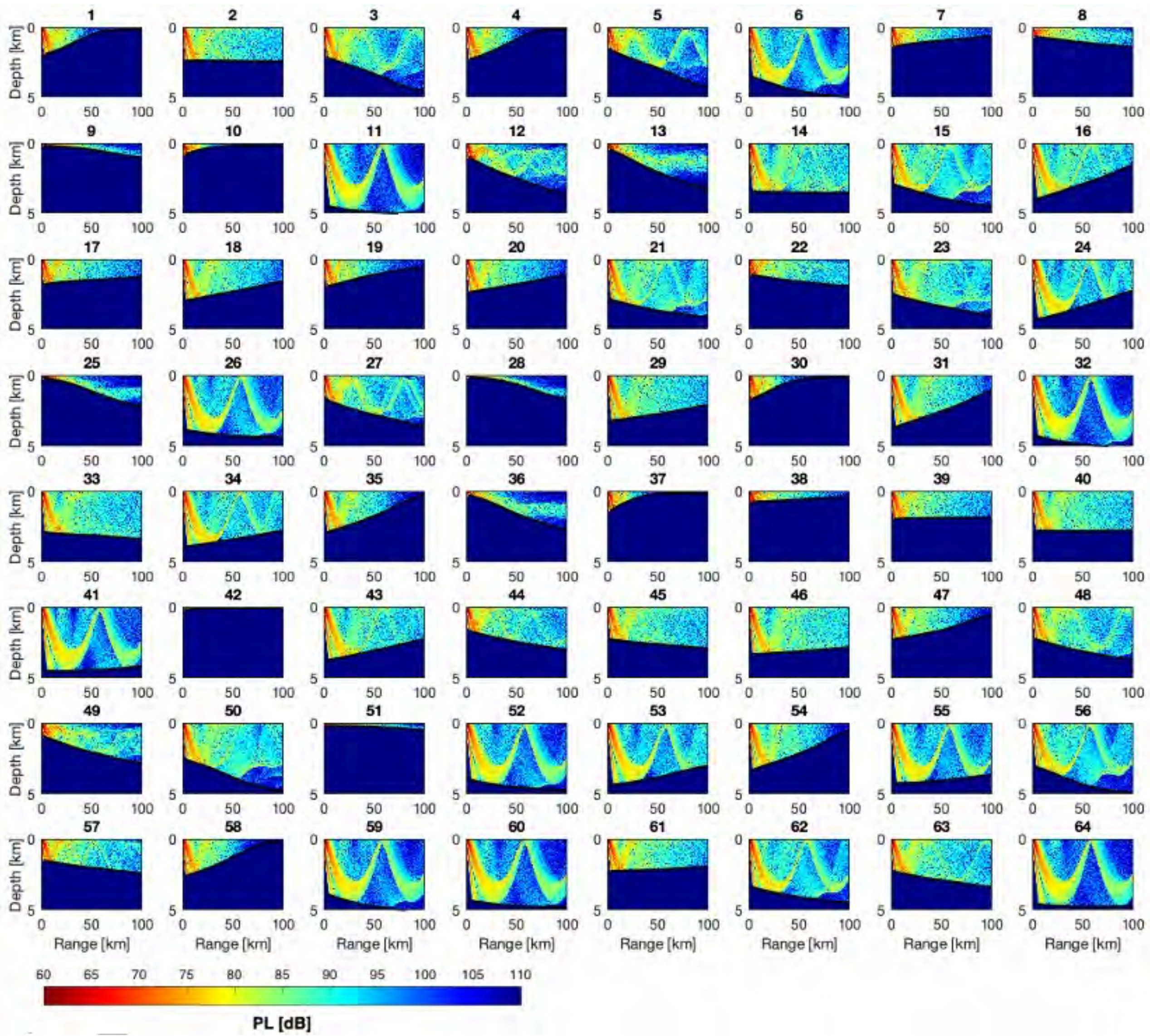
Project Objectives

1. Characterise the underwater sound propagation conditions in Bass Strait
   => ref. NESP Project E2, 2021

Machine Learning to cluster sound-propagation transects.

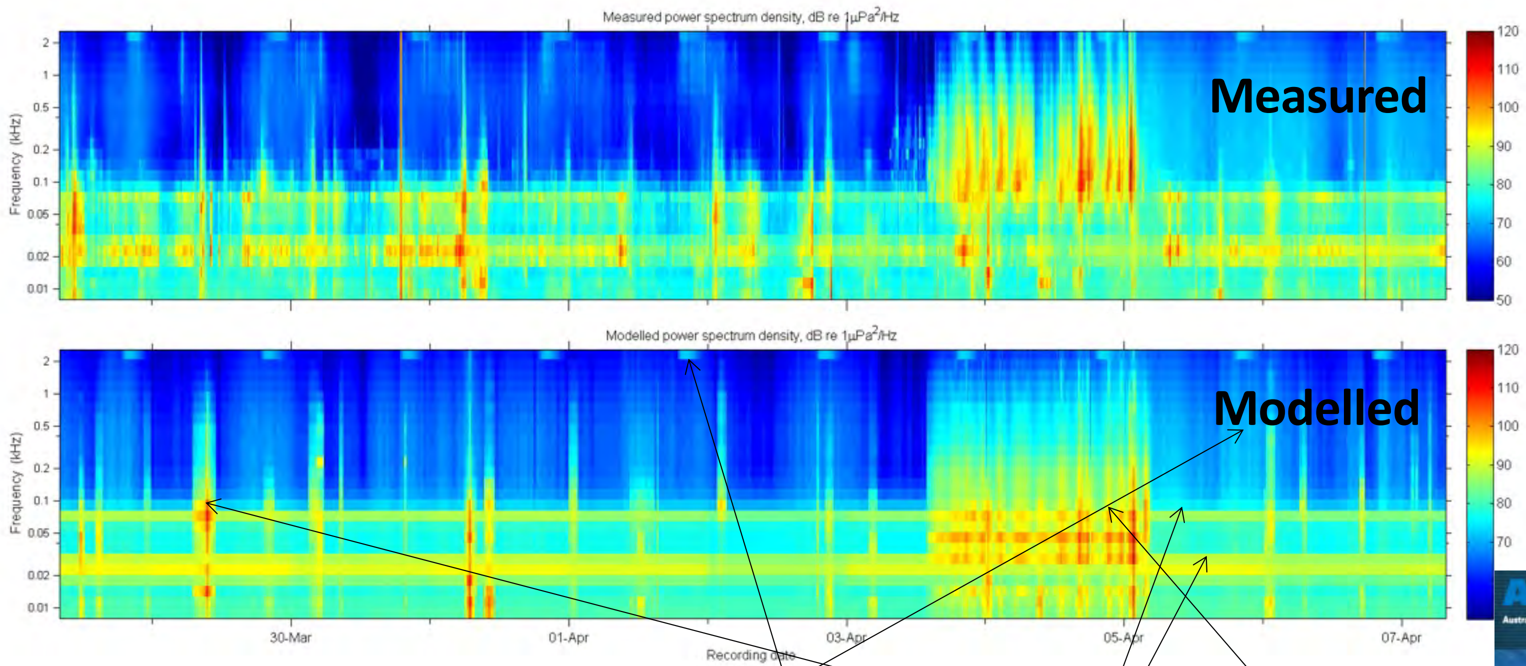
Model propagation loss as a function of range and depth, along 64 cluster centroids per acoustic zone.

=> Reduces the need to model every sound source and every receiver at every point in space and time to a look-up of propagation loss.



Project Objectives

2. Build a marine soundscape model that includes the dominant contributions of geophony (wind-driven noise), biophony (whale song, fish choruses), anthropophony (ships)



Ex. Perth Canyon
16 years of IMOS
Passive acoustic observatories

$$SL = 10\log\left[SL_B(f) + 10^{SL_W(f,t)/10} + 10^{SL_F(f,t)/10} + 10^{SL_{PBW}(f,t)/10} + 10^{SL_S(f,t)/10}\right]$$

Baseline Wind Fish Whales Ships

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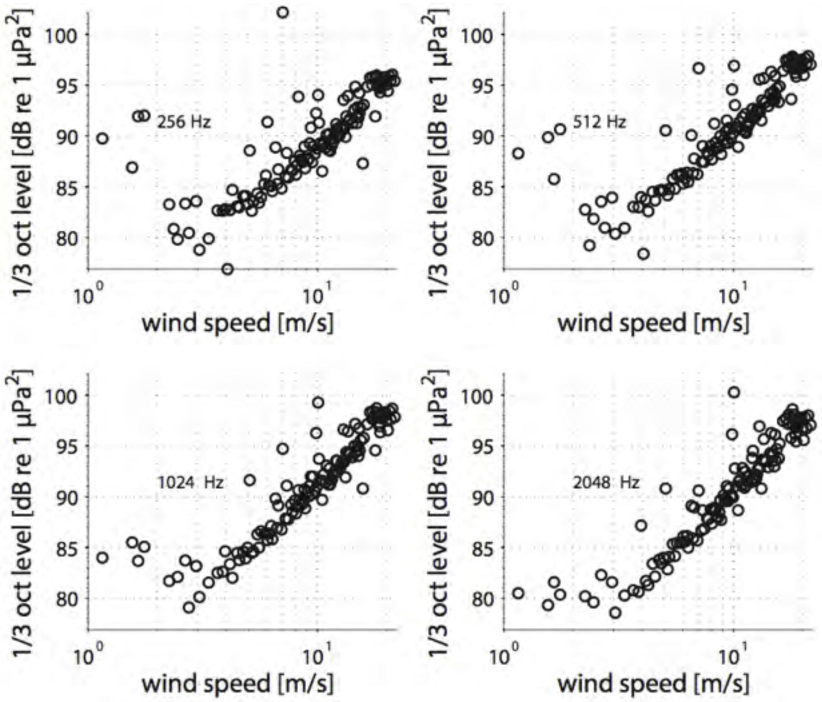
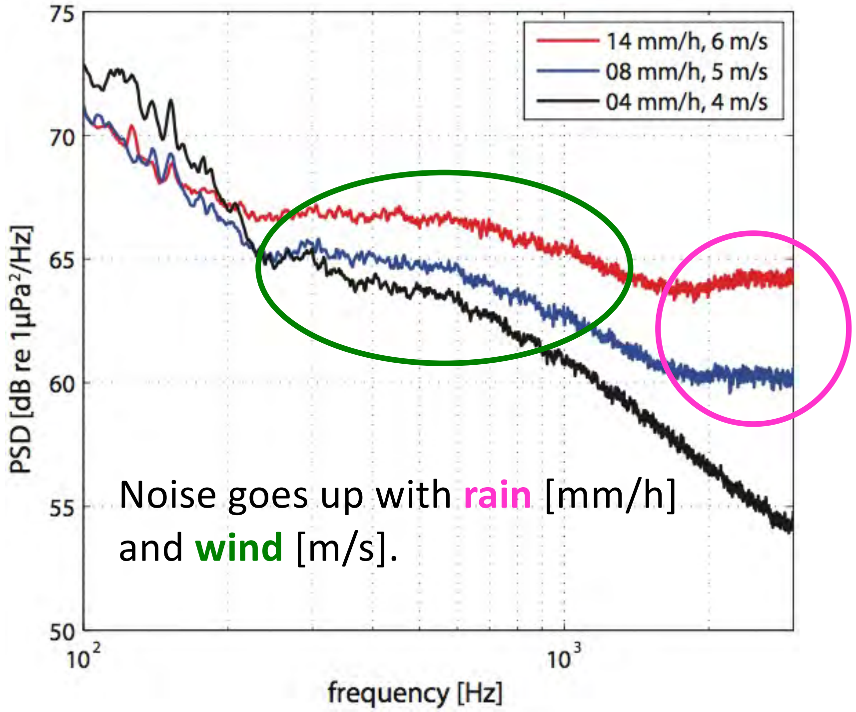
Offshore Weather: Wind, Rain, Hail, Snow

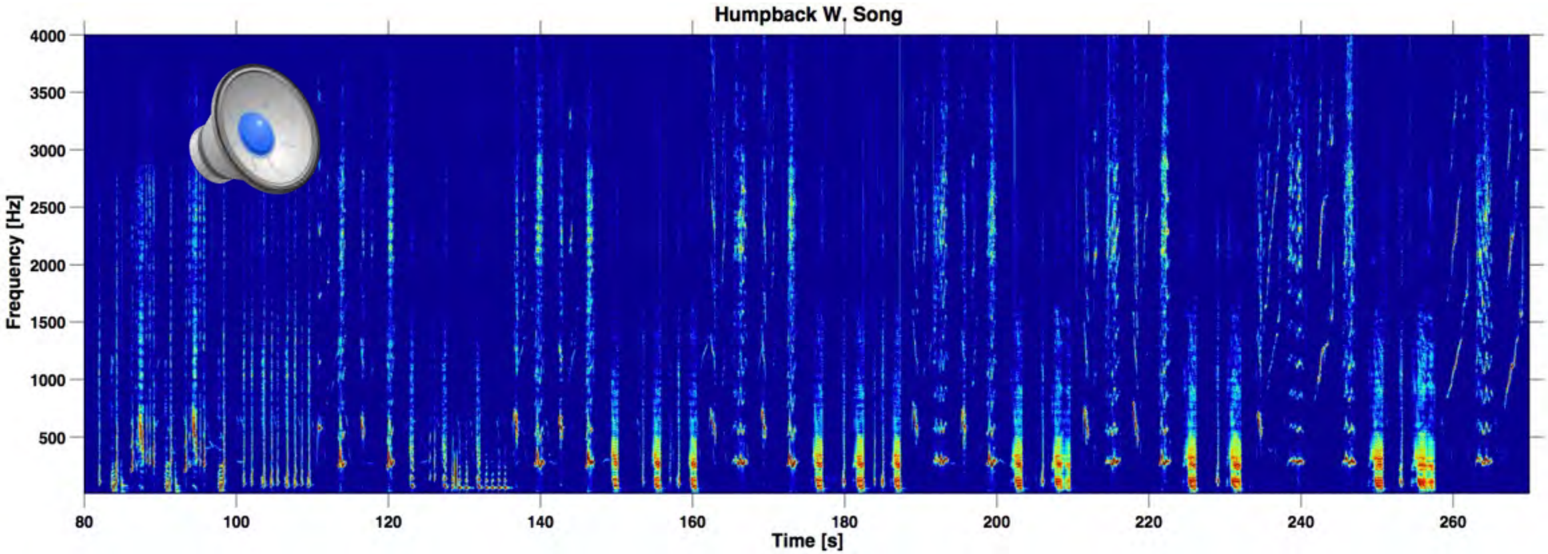




Erbe C et al. (2015) The marine soundscape of the Perth Canyon. Prog Oceanogr 137:38-51

Humpback Whales, Minke Whales, Killer Whales, …

Nils: https://commons.wikimedia.org/wiki/File:Balaenoptera_acutorostrata_2901229.jpg



Compiled by Miles Parsons

Fish Sounds

Mulloway
(*Argyrosomus japonicus*)

Westralian dhufish
(*Glaucosoma hebraicum*)

Black jewfish
(*Protonibea diacanthus*)

Terapontids: possibly
Fourlined trumpeter
Barred grunter

Unidentified fish calls

Western rock lobster
(Panulirus cygnus)

Orbiculate batfish
(*Platax orbicularis*)

Myctophids:
e.g. Lanternfish

Images: Roger Swainston
Photo: Rokuc Groenweld

Parsons, M.J.G. et al. 2014 In situ calls of Western Australian dhufish (*Glaucosoma hebraicum*) Acoust Austral 42(1): 31-35

Parsons, M.J.G., McCauley, R.D., and Mackie, M.C., 2013 Characterisation of mulloway advertisement sounds, Acoust Austral 41(3): 196-201

Parsons, M.J.G. et al. 2013 Sound production by the West Australian dhufish (*Glaucosoma hebraicum*). J Acoust Soc Am 134(4): 2701-2709

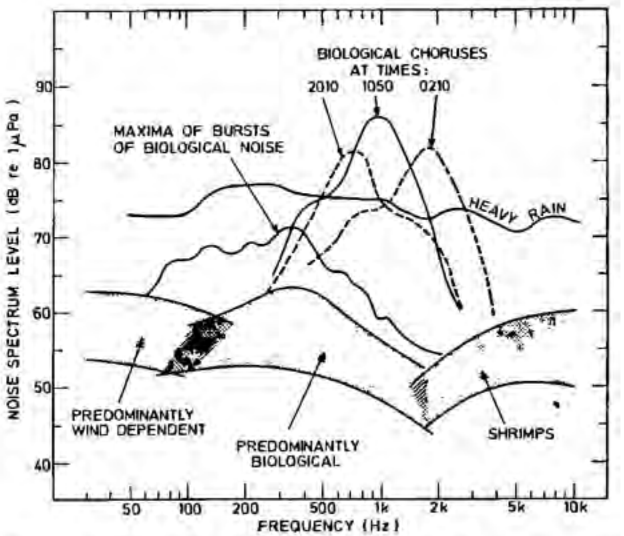
Parsons, M.J.G., McCauley, R.D., and Thomas, F., 2013, Sound of fish calls off Cape Naturaliste, Western Australia, Acoust Austral 41(1):58-63.

Parsons, M.J.G. et al. 2012, *In situ* source levels of mulloway (*Argyrosomus japonicus*) calls, J Acoust Soc Am 132(5):3559-68

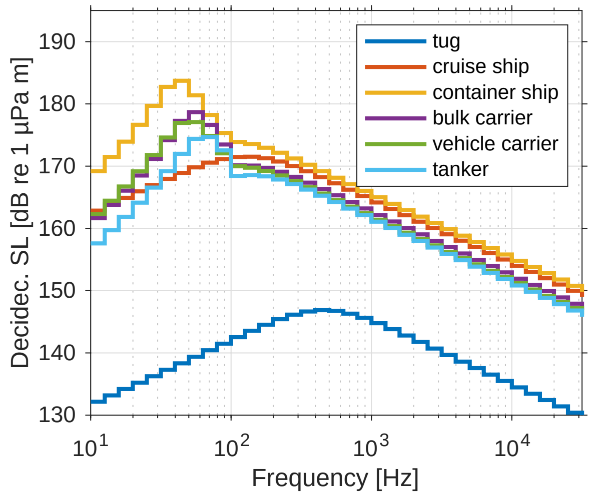
Project Objectives

2. Build a marine soundscape model that includes the dominant contributions of geophony (wind-driven noise), biophony (whale song, fish choruses), anthropophony (ships)

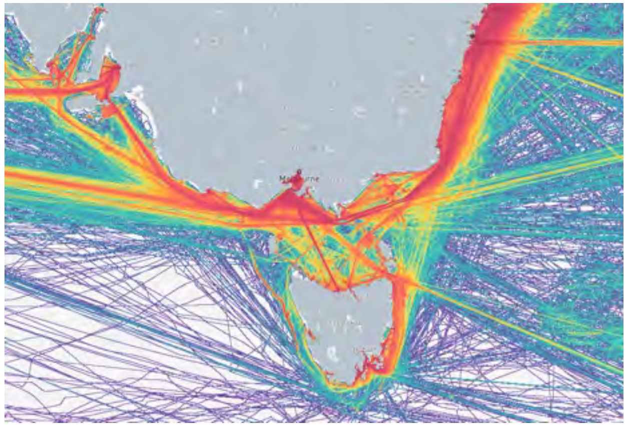
=> Input data needed (wind measurements/hindcast, megafauna abundance, ship logs/AIS)



Cato DH (1980) Some unusual sounds of apparent biological origin responsible for sustained background noise in the Timor Sea. J Acoust Soc Am 68 (4):1056-1060



MacGillivray A, de Jong C (2021) A reference spectrum model for estimating source levels of marine shipping based on Automated Identification System data. J Mar Sci Eng 9 (4):369

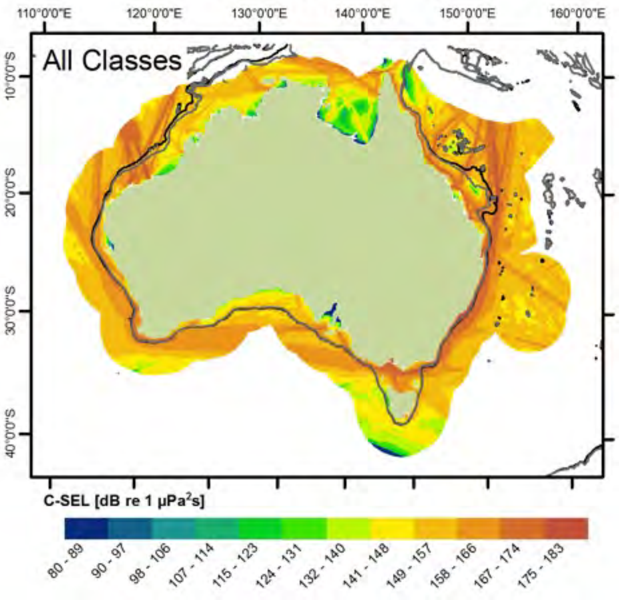


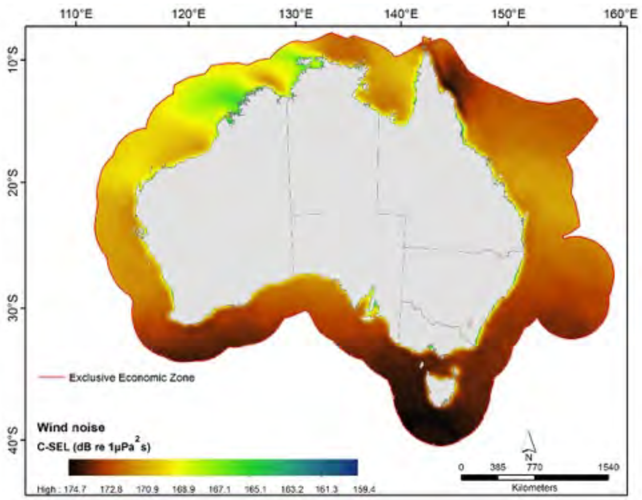
Marinetraffic.com

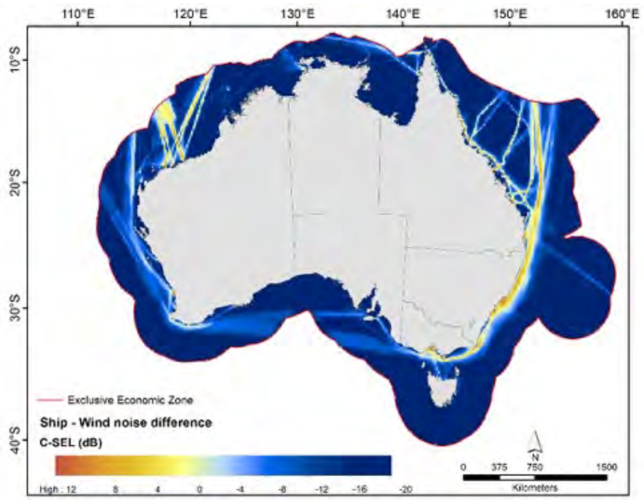
Curtin University

Project Objectives

Erbe C, Schoeman RP, Peel D, Smith JN (2021) It often howls more than it chugs: Wind versus ship noise under water in Australia's maritime regions. J Mar Sci Eng 9 (5):472







NESP E2, 2021

Ship Noise

Wind Noise

Ship – Wind Noise

3. Validate the current model

=> with in situ recordings from the modelled year

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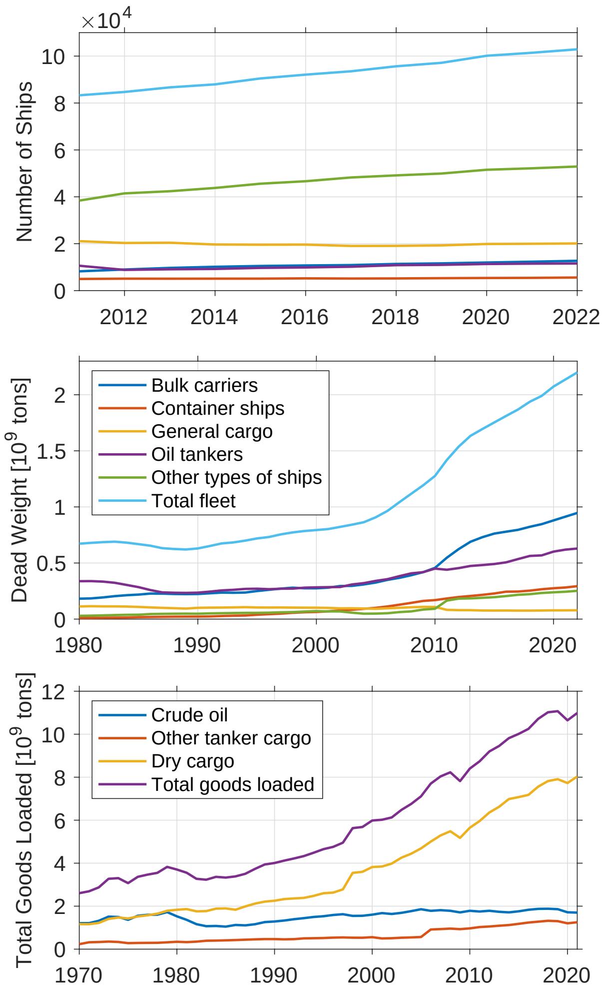
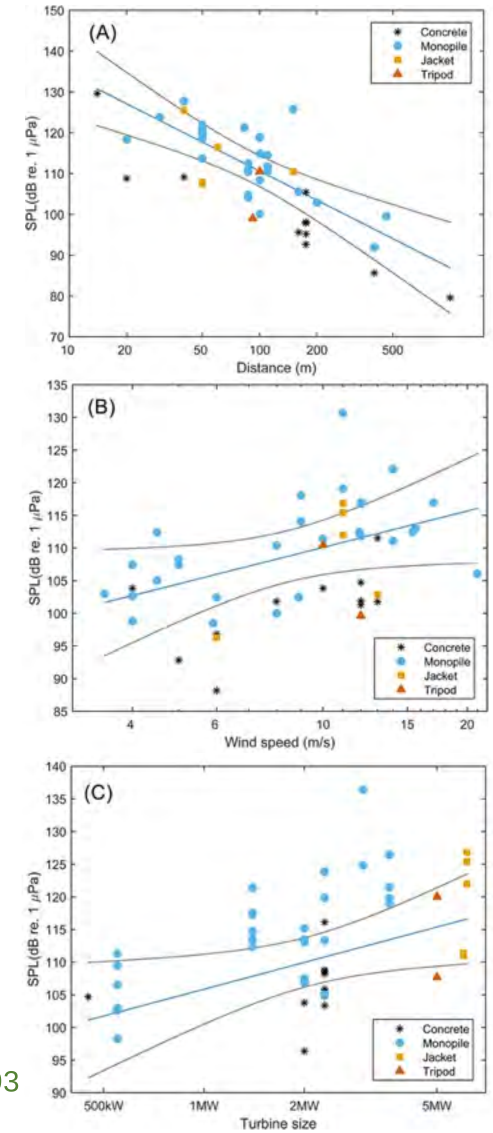
Project Objectives

4. Predict soundscape into the *far* future

- add operating windfarms
- consider changes in ship traffic
- changes in ocean weather/climate?
- changes in megafauna abundance and distribution?

=> Inputs from other NESP projects





Tougaard J et al. (2020) How loud is the underwater noise from operating offshore wind turbines? J Acoust Soc Am 148 (5):2885-2893

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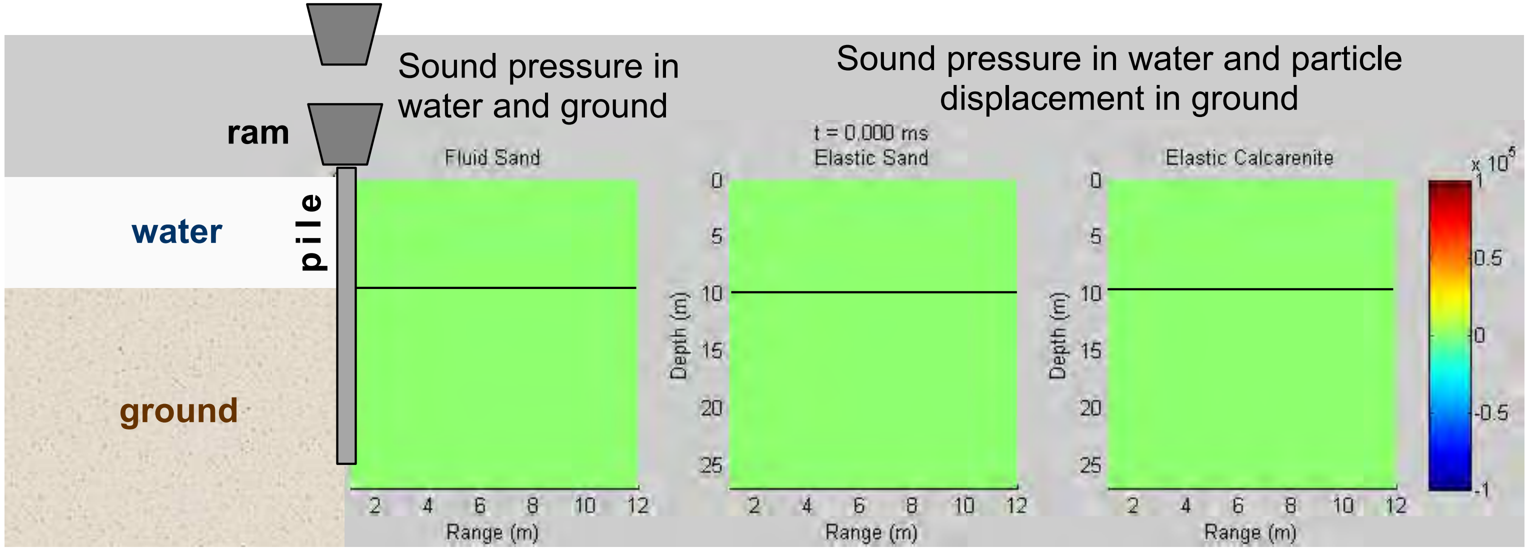
Project Objectives

5. Model noise footprints from windfarm construction



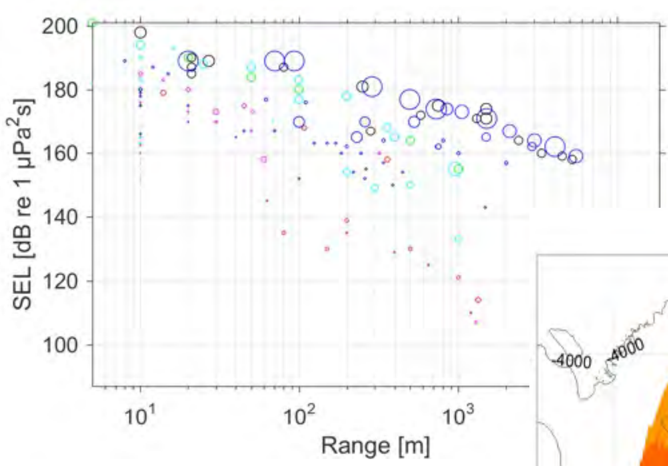
Wilkes DR, Gourlay TP, Gavrilov AN (2016) Numerical modeling of radiated sound for impact pile driving in offshore environments. IEEE J Ocean Eng 41 (4):1072-1078

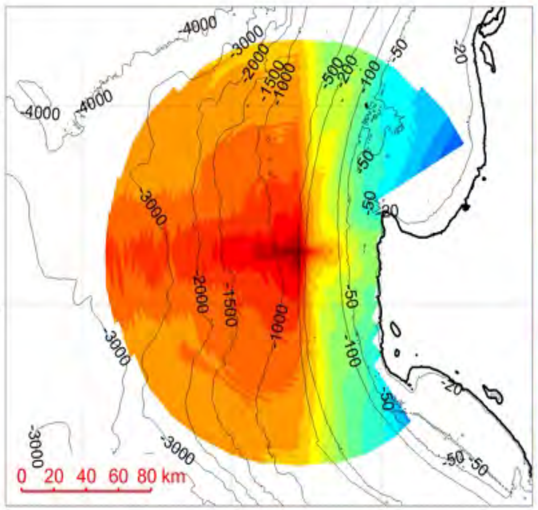
Curtin University

Project Objectives

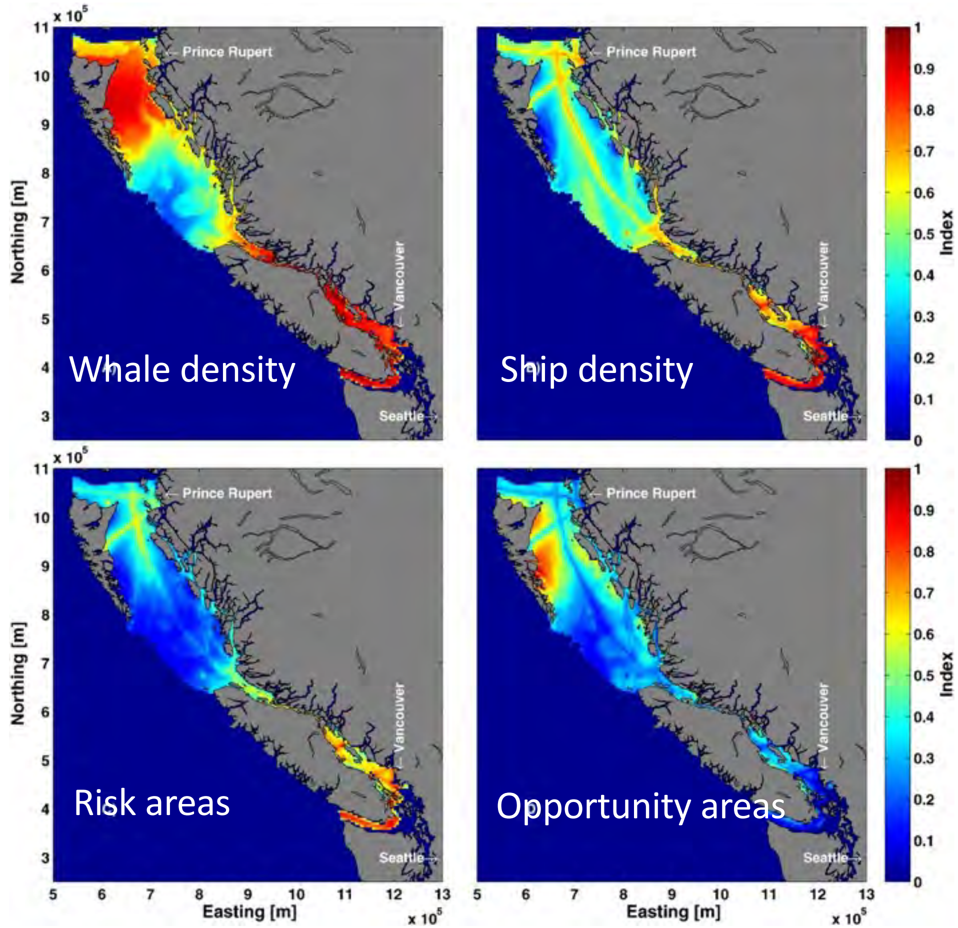
Williams R, Erbe C, Ashe E, Clark CW (2015) Quiet(er) marine protected areas. Mar Pollut Bull 100 (1):154-161

5. Model noise footprints from windfarm construction
6. Model noise exposures of whales





Regions of Risk vs Regions of Opportunity



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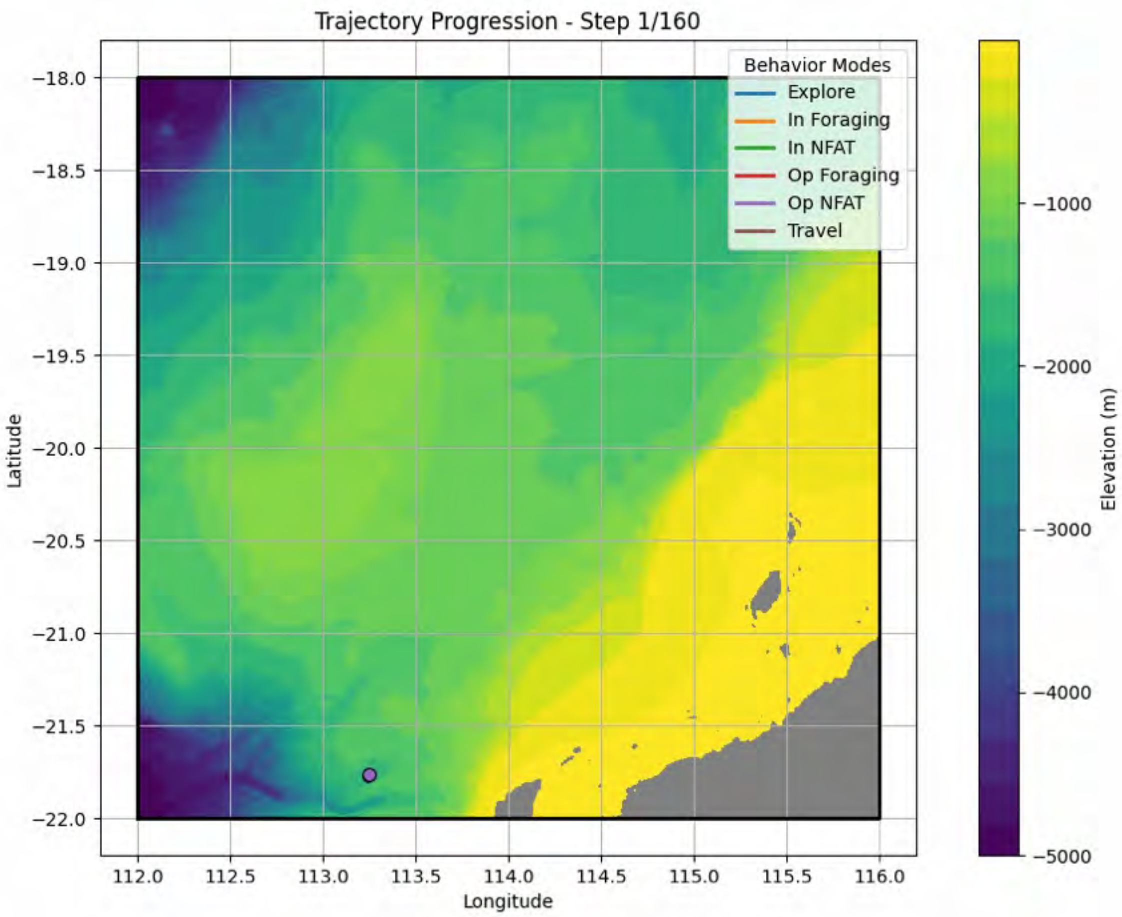
- # animals or % population potentially exposed above thresholds
- # animals or % population potentially disturbed foraging
- …



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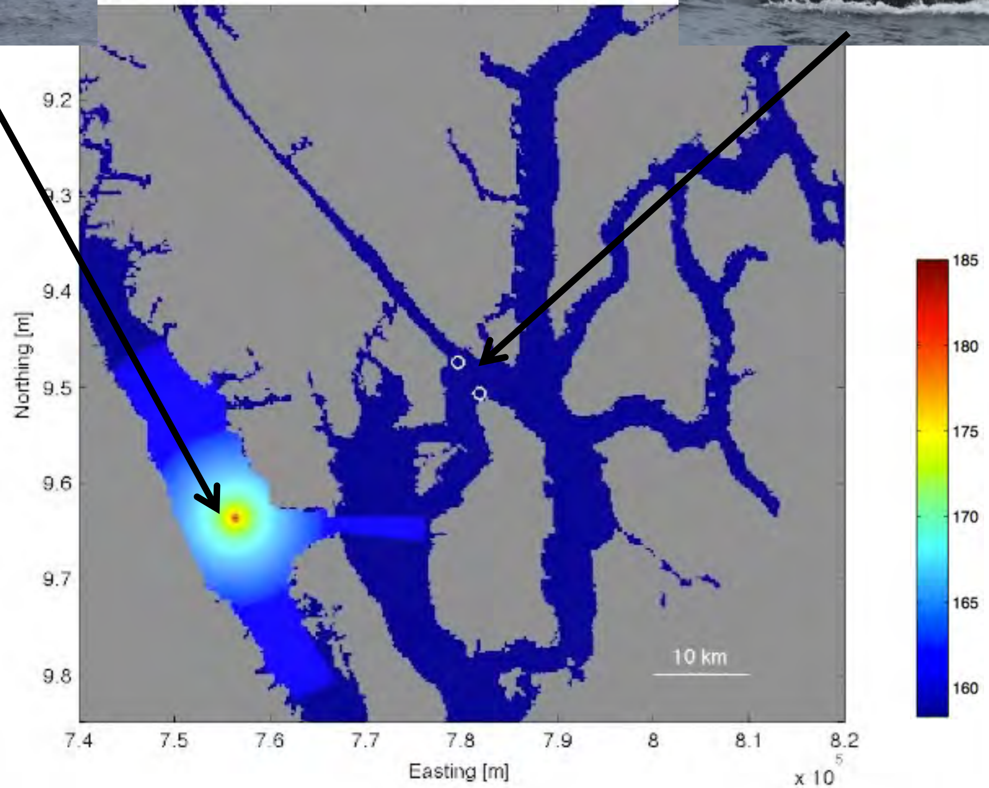
Thank You !

Masking

Erbe et al. (2012) J Acoust Soc Am 132: 423-428



Noise level dB re 1µPa

killer whales talking --- 1 ship approaching

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Using iPCoD to estimate impacts of OWF development on blue whales & southern right whales

interim
Population
Consequence
of
Disturbance

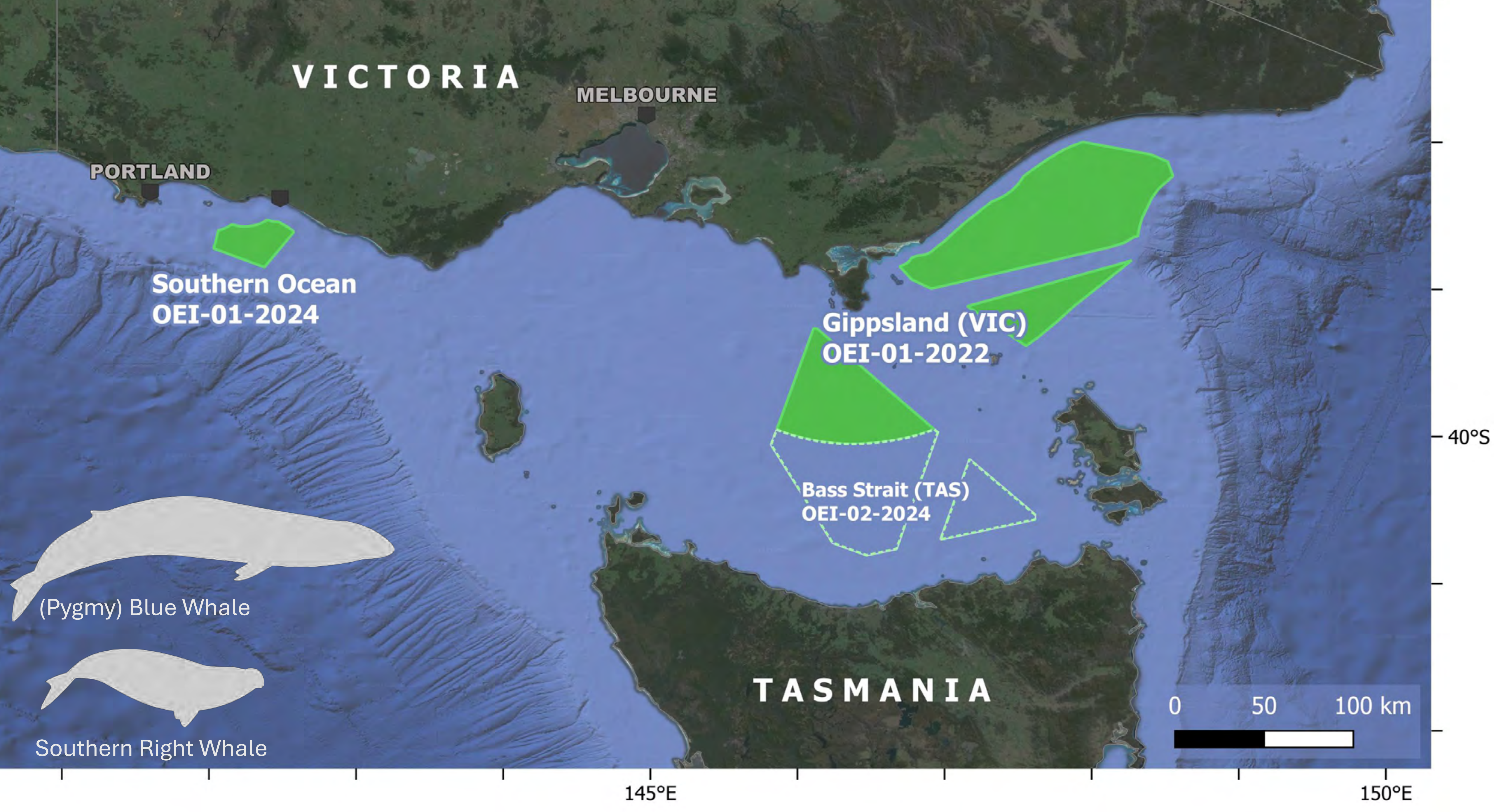
The University of Queensland
Australia

Cetacean Ecology Group

Bec Dunlop

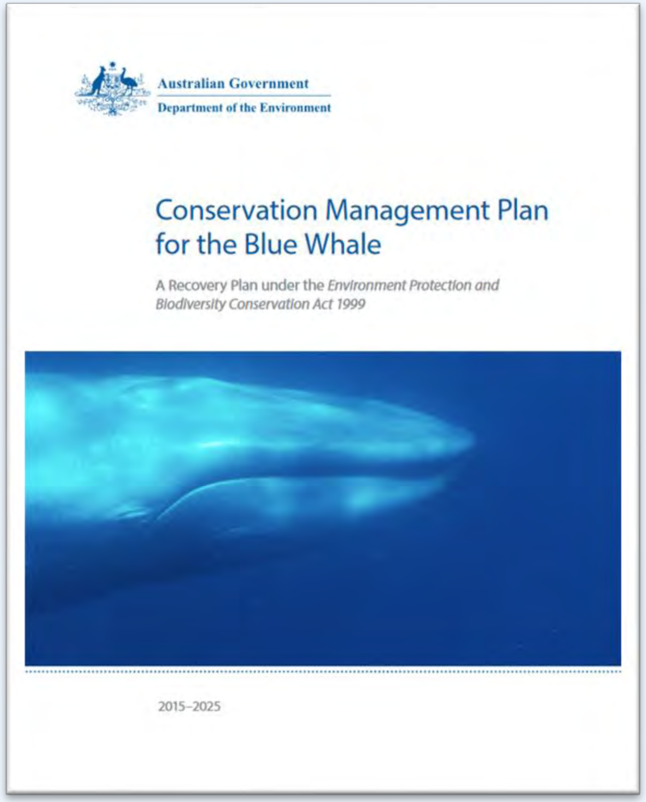
Sophia Volzke

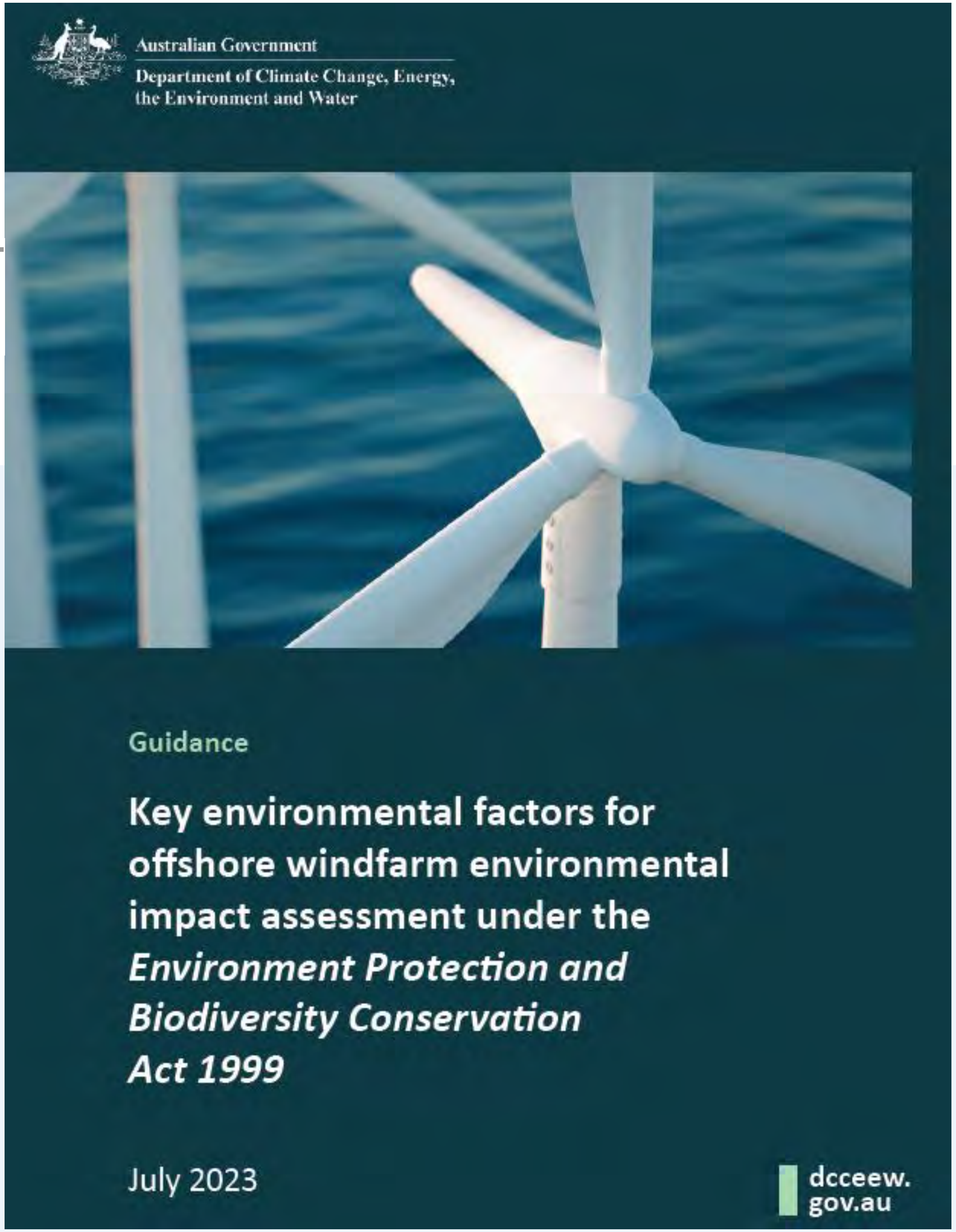
Marine and Coastal
National Environmental Science Program

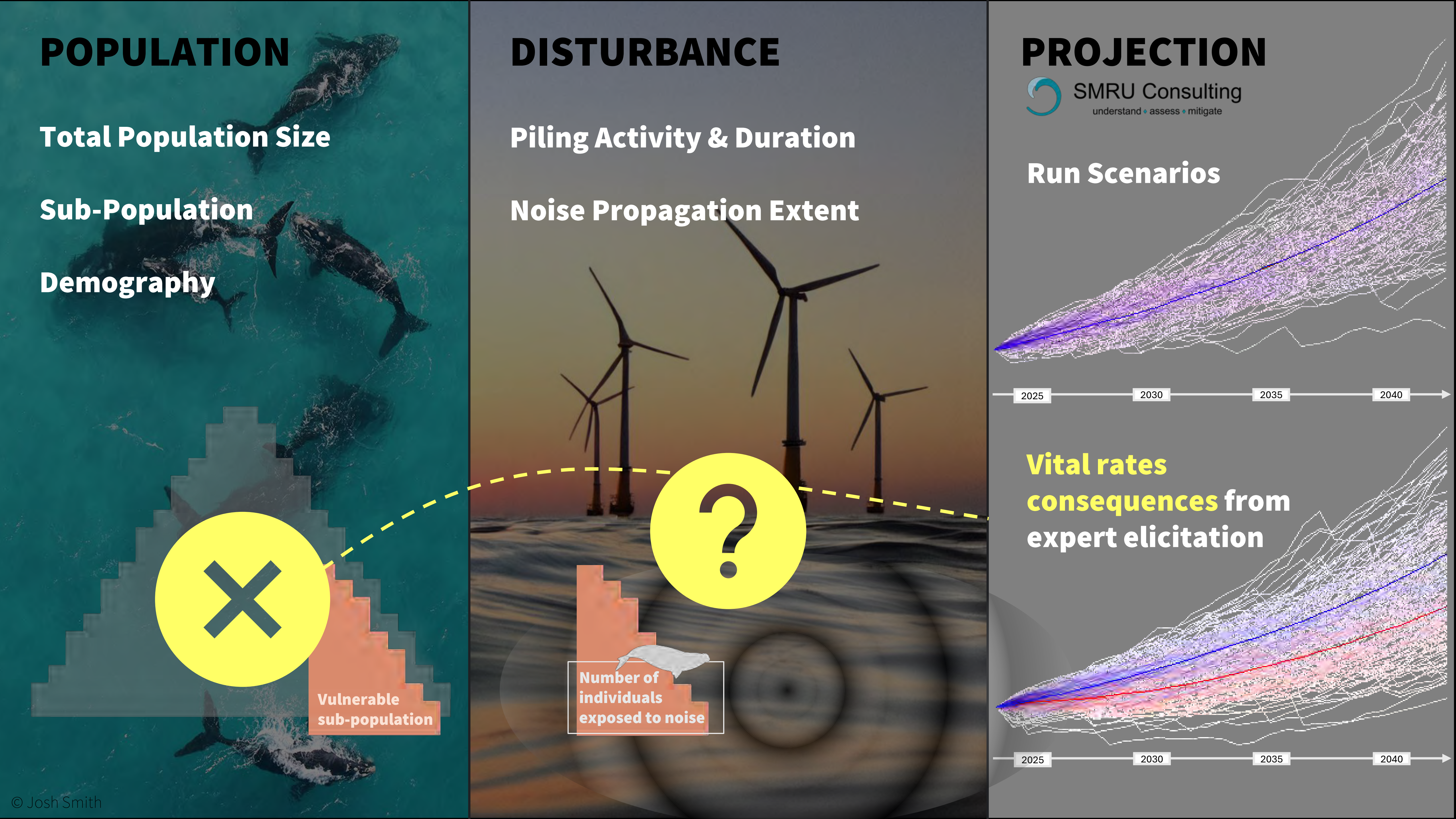

VICTORIA
MELBOURNE
PORTLAND
Southern Ocean
OEI-01-2024
Gippsland (VIC)
OEI-01-2022
Bass Strait (TAS)
OEI-02-2024
(Pygmy) Blue Whale
Southern Right Whale
TASMANIA
0
50
100 km
40°S
145°E
150°E

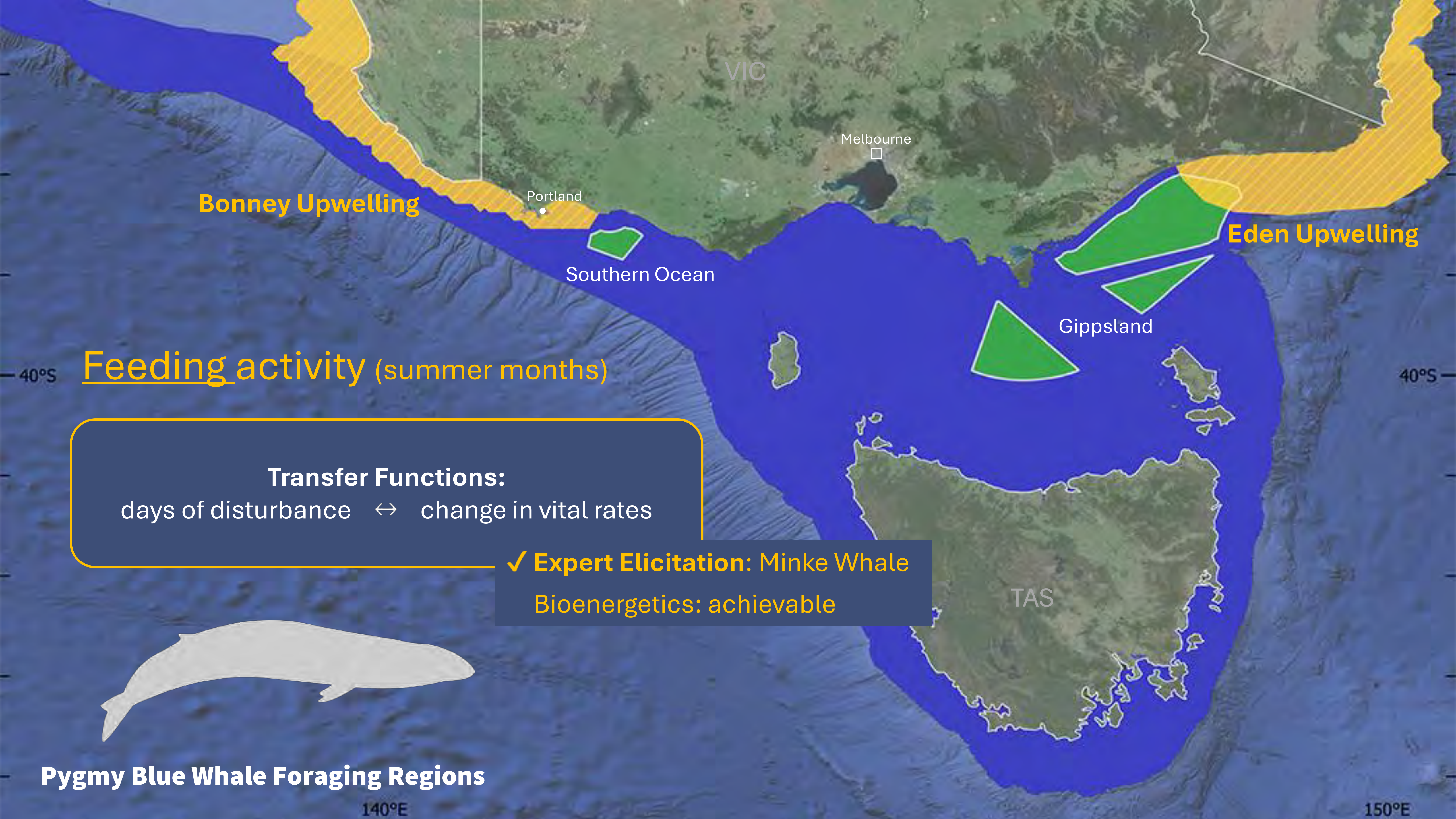
Risk to threatened species

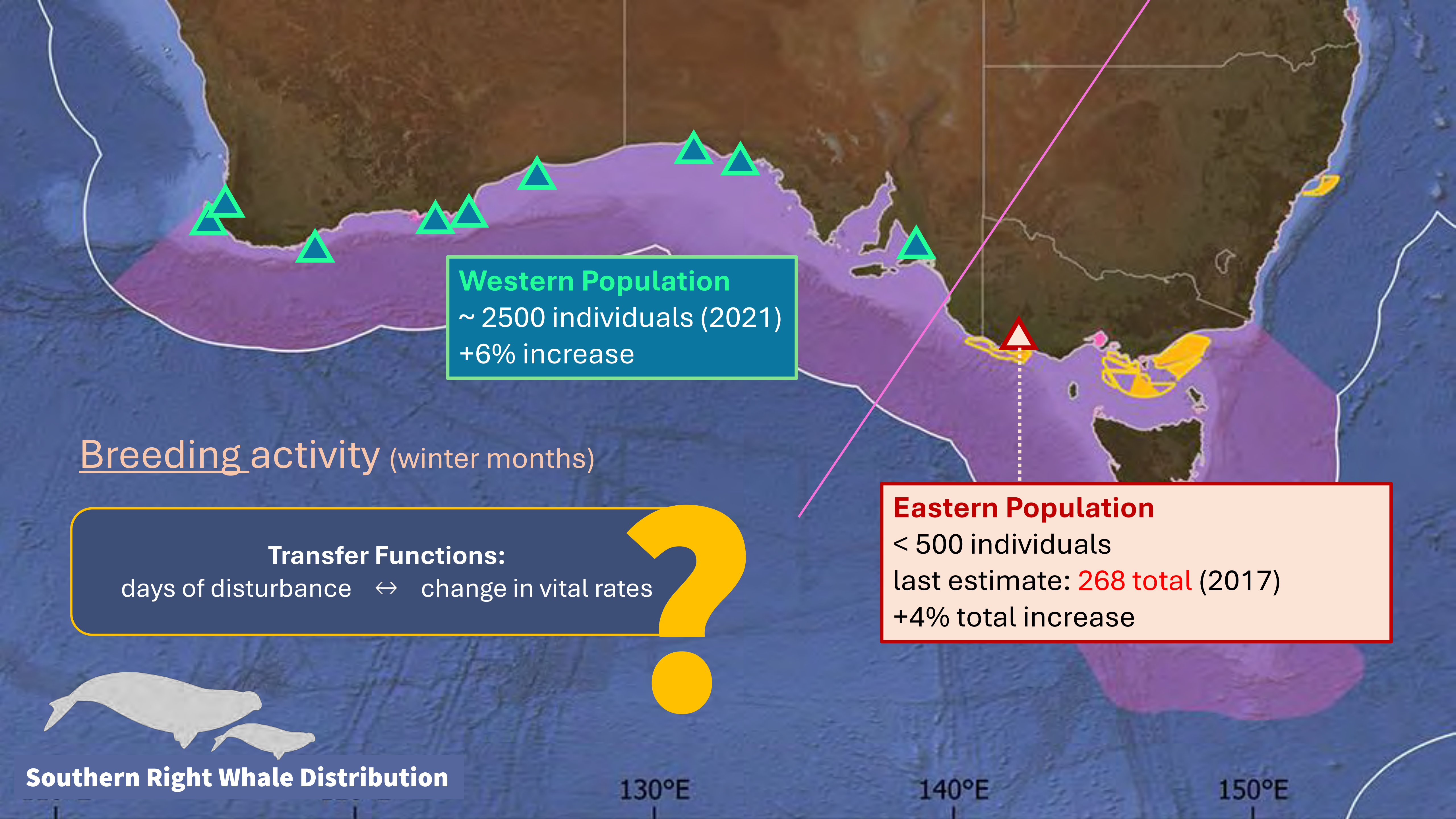
The Challenge: Making Defensible Regulatory Decisions When Faced with Scientific Uncertainty






POPULATION
Total Population Size
Sub-Population
Demography
Vulnerable sub-population
© Josh Smith
DISTURBANCE
Piling Activity & Duration
Noise Propagation Extent
?
Number of individuals exposed to noise
PROJECTION
SMRU Consulting
understand • assess • mitigate
Run Scenarios
2025
2030
2035
2040
Vital rates consequences from expert elicitation
2025
2030
2035
2040


VIC
Melbourne
Portland
Bonney Upwelling
Southern Ocean
Eden Upwelling
Gippsland
40°S
40°S
Feeding activity (summer months)
Transfer Functions:
days of disturbance ↔ change in vital rates
✓ Expert Elicitation: Minke Whale
Bioenergetics: achievable
TAS
Pygmy Blue Whale Foraging Regions
140°E
150°E


Western Population
~ 2500 individuals (2021)
+6% increase
Breeding activity (winter months)
Transfer Functions:
days of disturbance ↔ change in vital rates
?
Eastern Population
< 500 individuals
last estimate: 268 total (2017)
+4% total increase
Southern Right Whale Distribution
130°E
140°E
150°E

Historic Whaling Data

- Dawbin 1986

Plate I. Right whale hunting off Twofold Bay, N.S.W. from an original painting by Oswald Brierly held by the National Library, Canberra.

REP. INT. WHAL. COMMN (SPECIAL ISSUE 10)

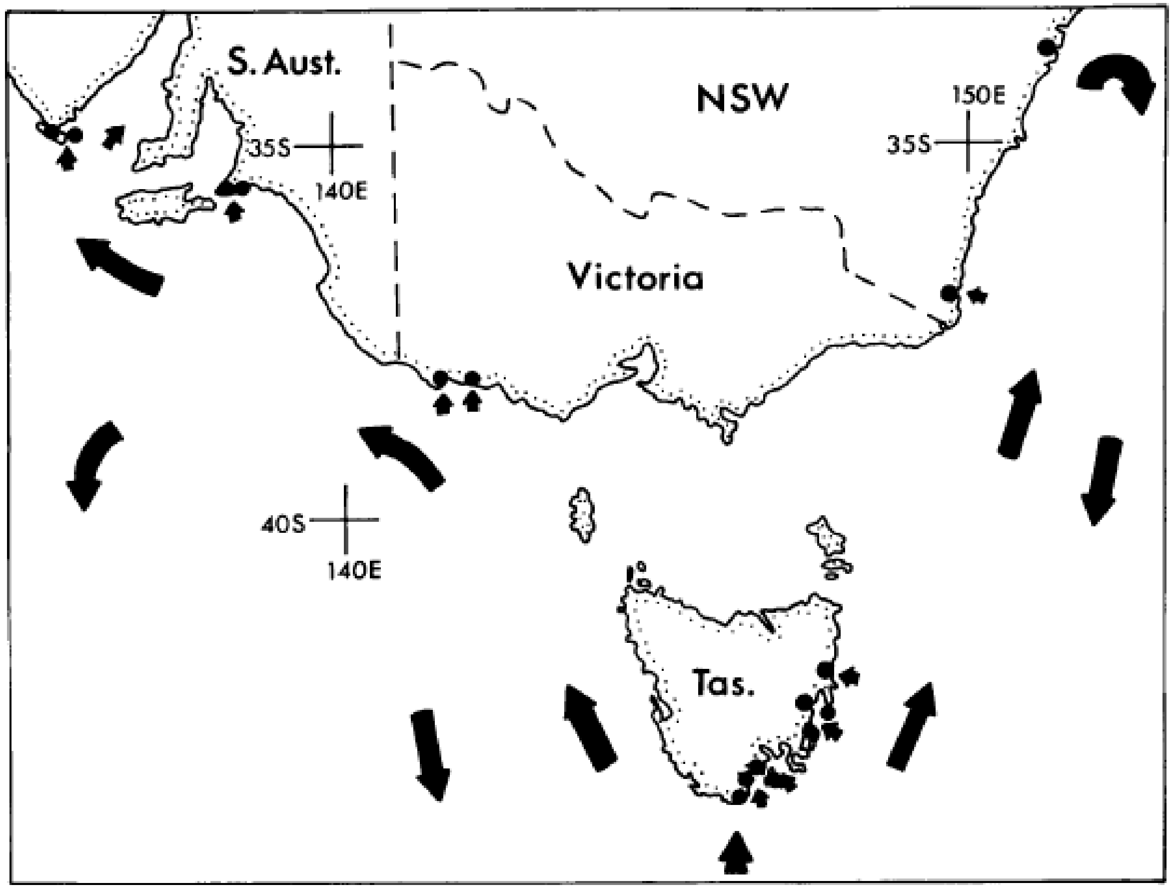
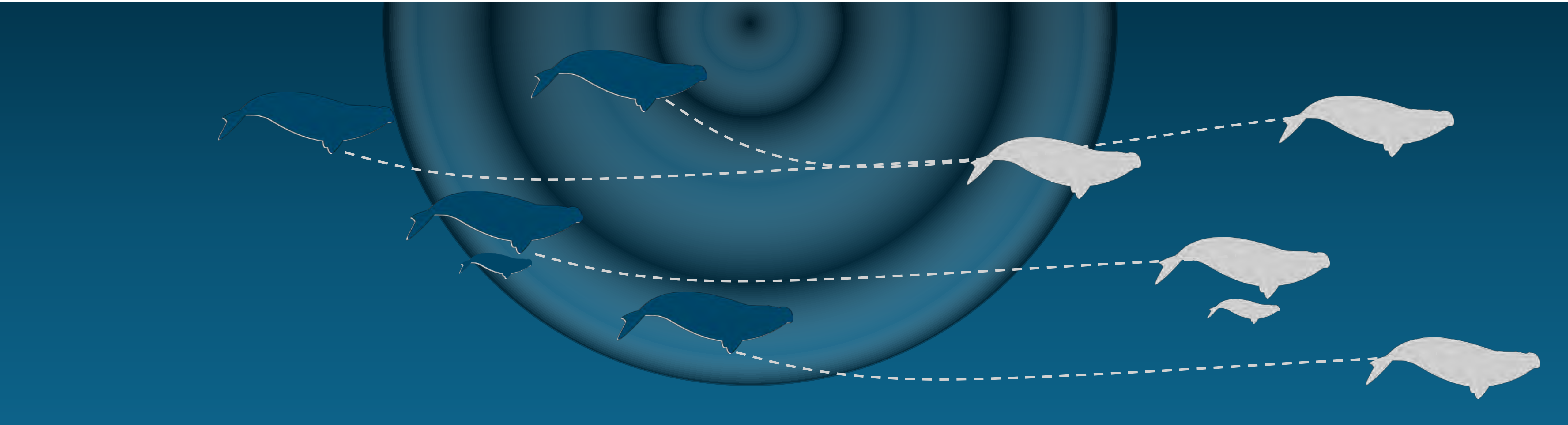


Fig. 1. Southeastern Australian sites of the main shore stations for right whaling during the 19th Century. Large arrows indicate the overall trend in whale movements and small arrows indicate the main movements of cows to calve near sheltered bays.

How many individuals are exposed to the disturbance and for how long?

What's the maximum abundance / worst case scenario ?

Is there a detectable effect if ALL individuals are exposed to noise?



Using iPCoD to estimate impacts of OWF development on blue whales & southern right whales

interim
Population
Consequence
of
Disturbance

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Cetacean Ecology Group

Bec Dunlop

s.volzke@uq.edu.au

Sophia Volzke

Marine and Coastal

National Environmental Science Program

Australian Government

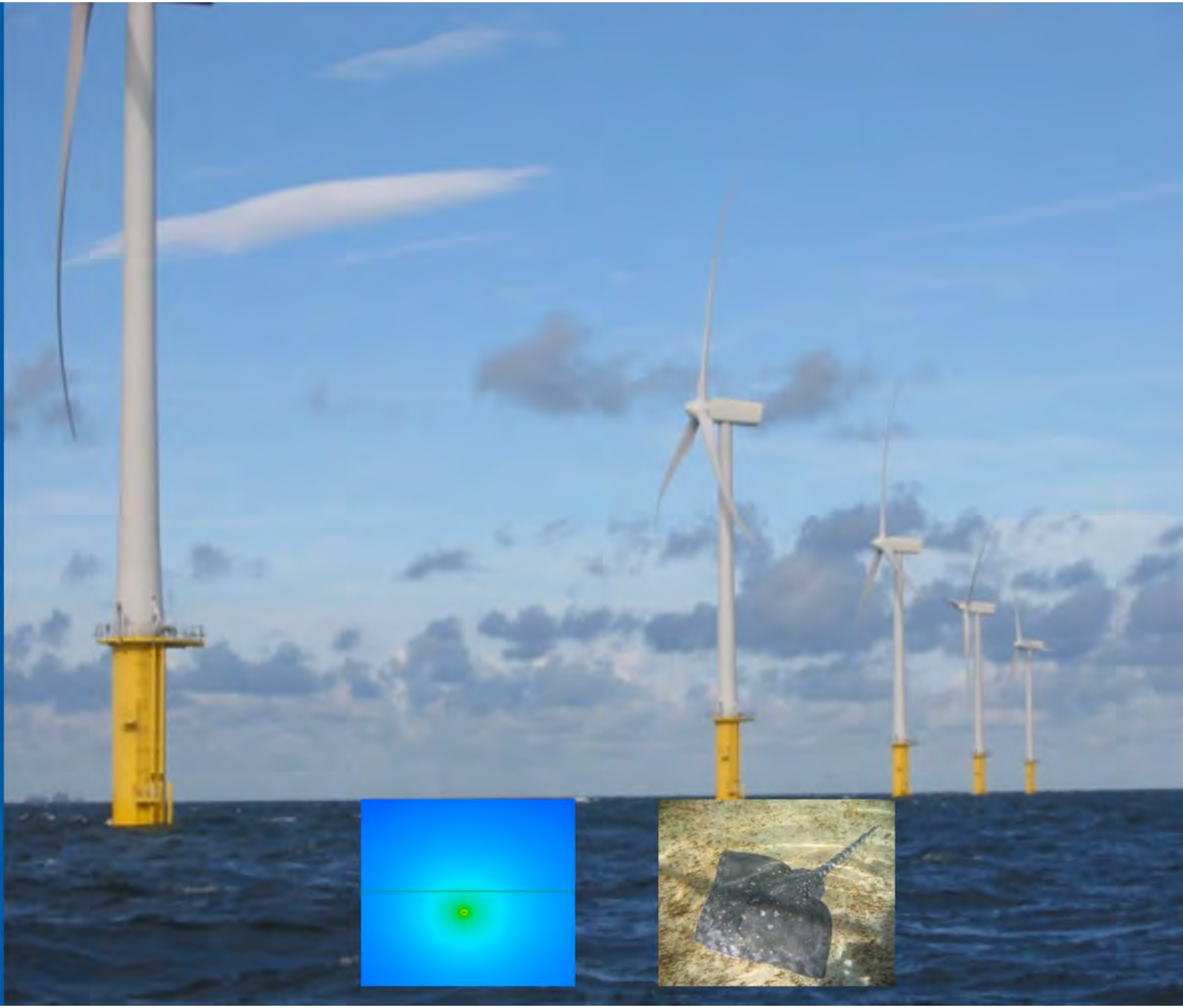
Australian Institute of Marine Science

Andrew B Gill PhD FRSB

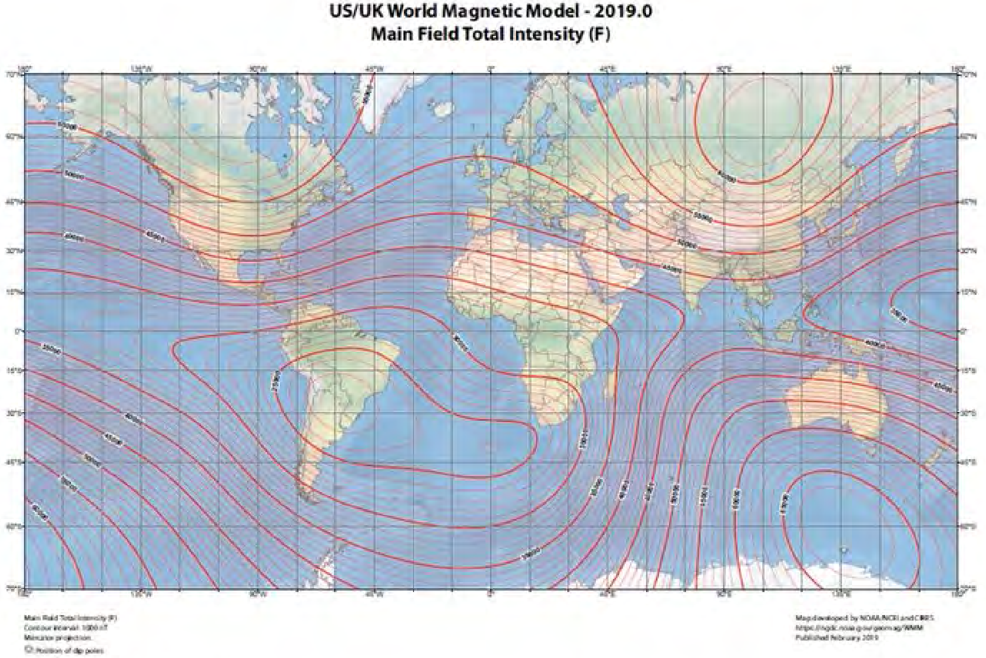
Senior Scientist Offshore Renewables

Australian Institute of Marine Science

Collaborators: Dianne McLean, AIMS



Natural electromagnetic fields



NOAA, NCEI, 2019

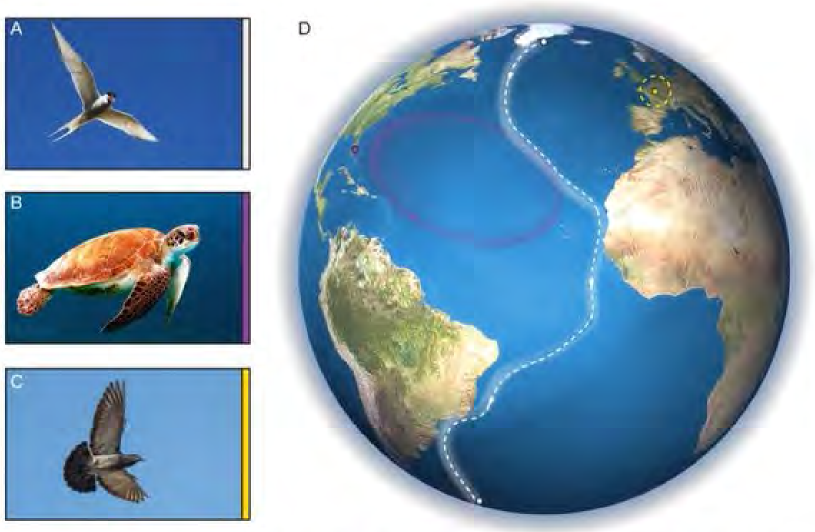
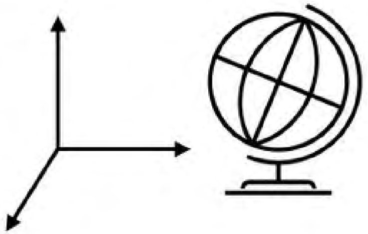


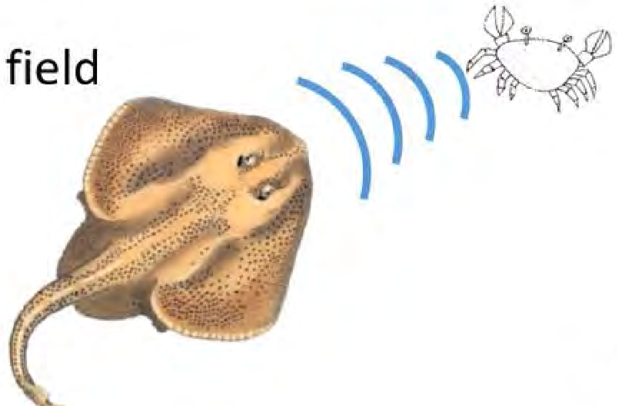
Image Source: Nordmann et al., 2017

- Geomagnetic field
- c.a. 25 – 65 μT

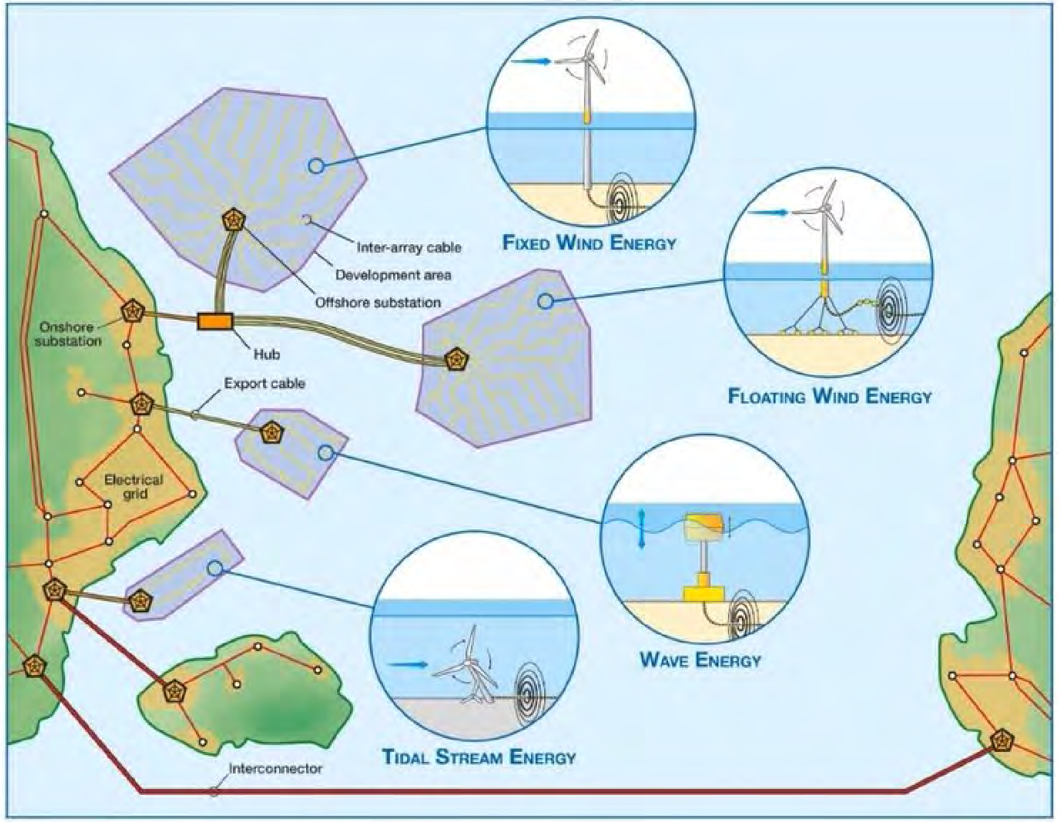


Also in the sea:

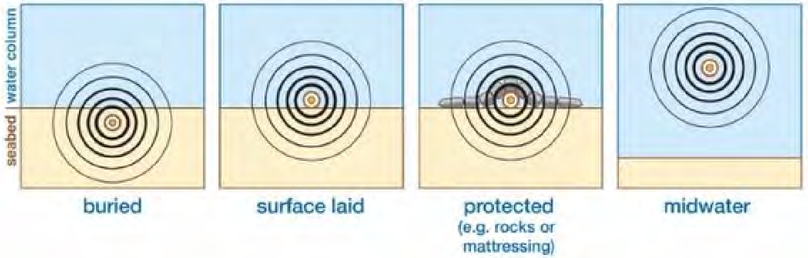
- Motionally induced electric field
- Weak bioelectric fields



Sources of Electromagnetic Fields (EMF) from Subsea Electricity Transmission

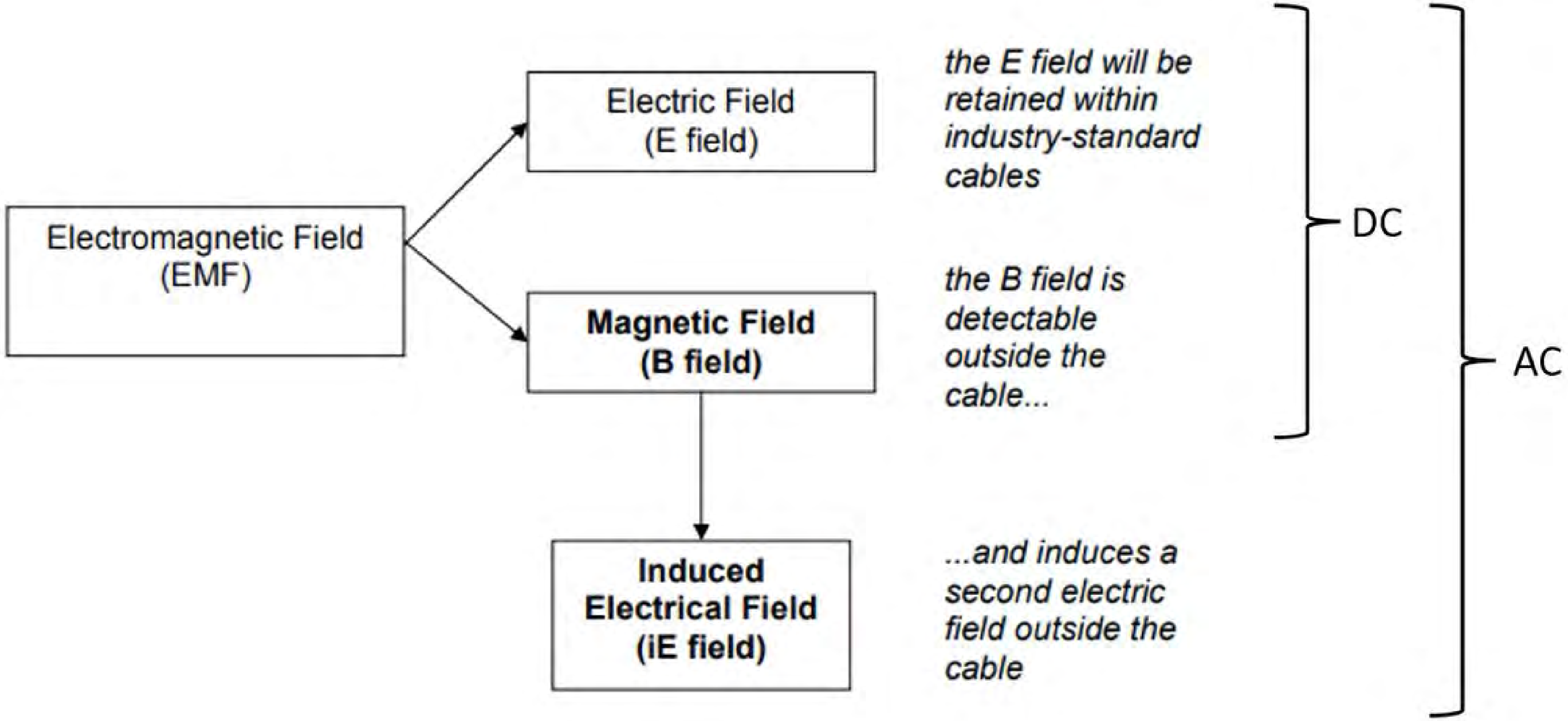


Position of Cables in the Coastal and Marine Environment



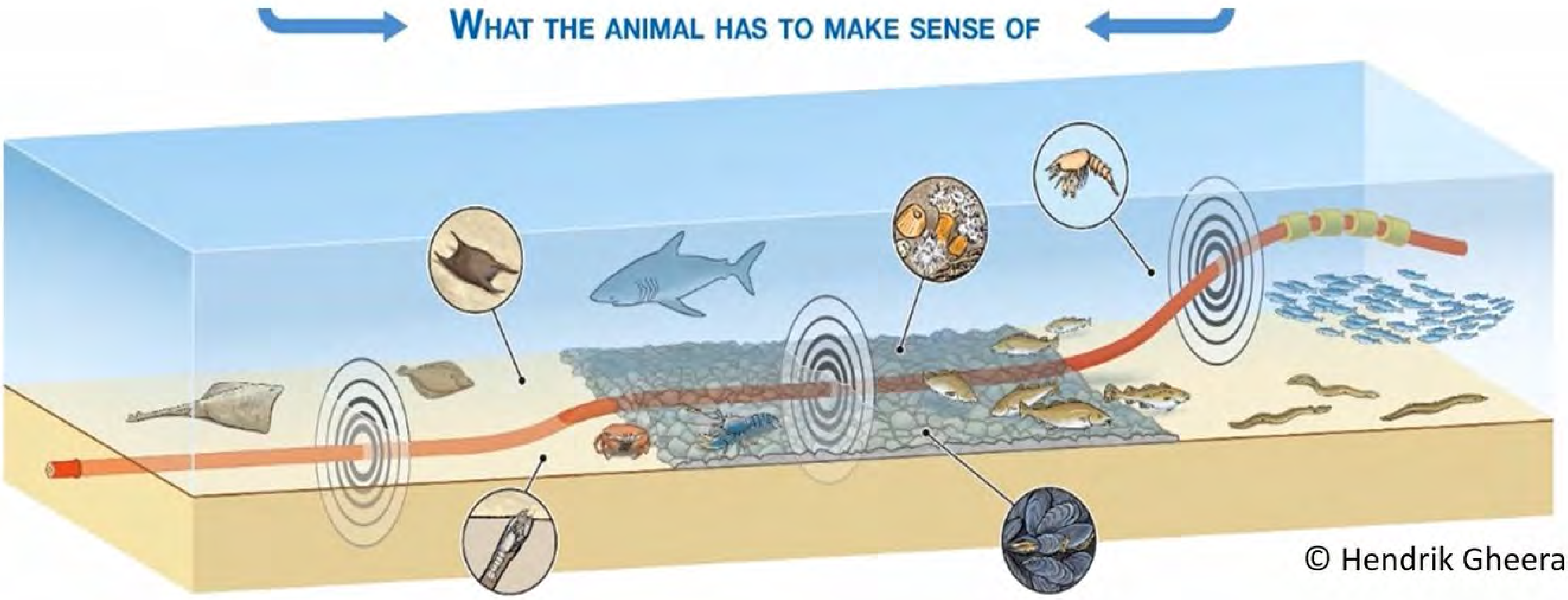
Introduction to Cable EMFs . . .

. . . in the marine environment

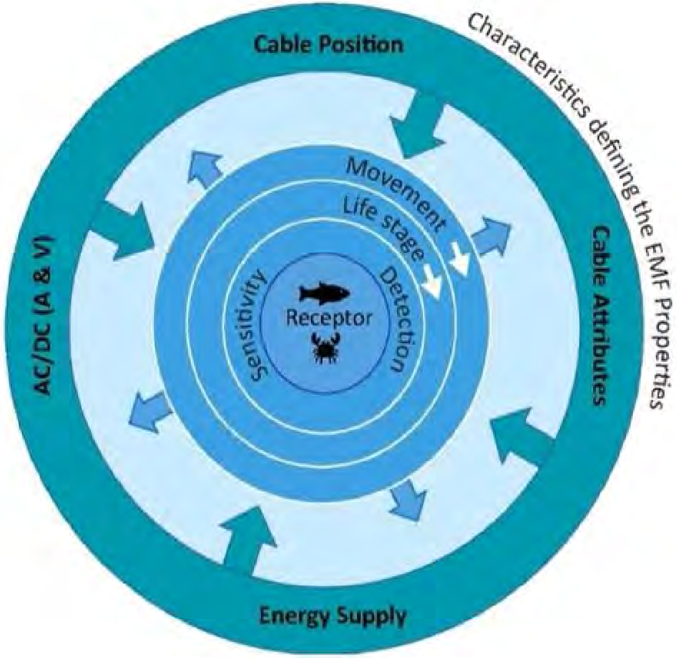


Above: emissions from the cable
These will interact with the local environment

Adapted from Cowrie 1.5, 2005


WHAT THE ANIMAL HAS TO MAKE SENSE OF

Taking a fish-eye view of EMFs

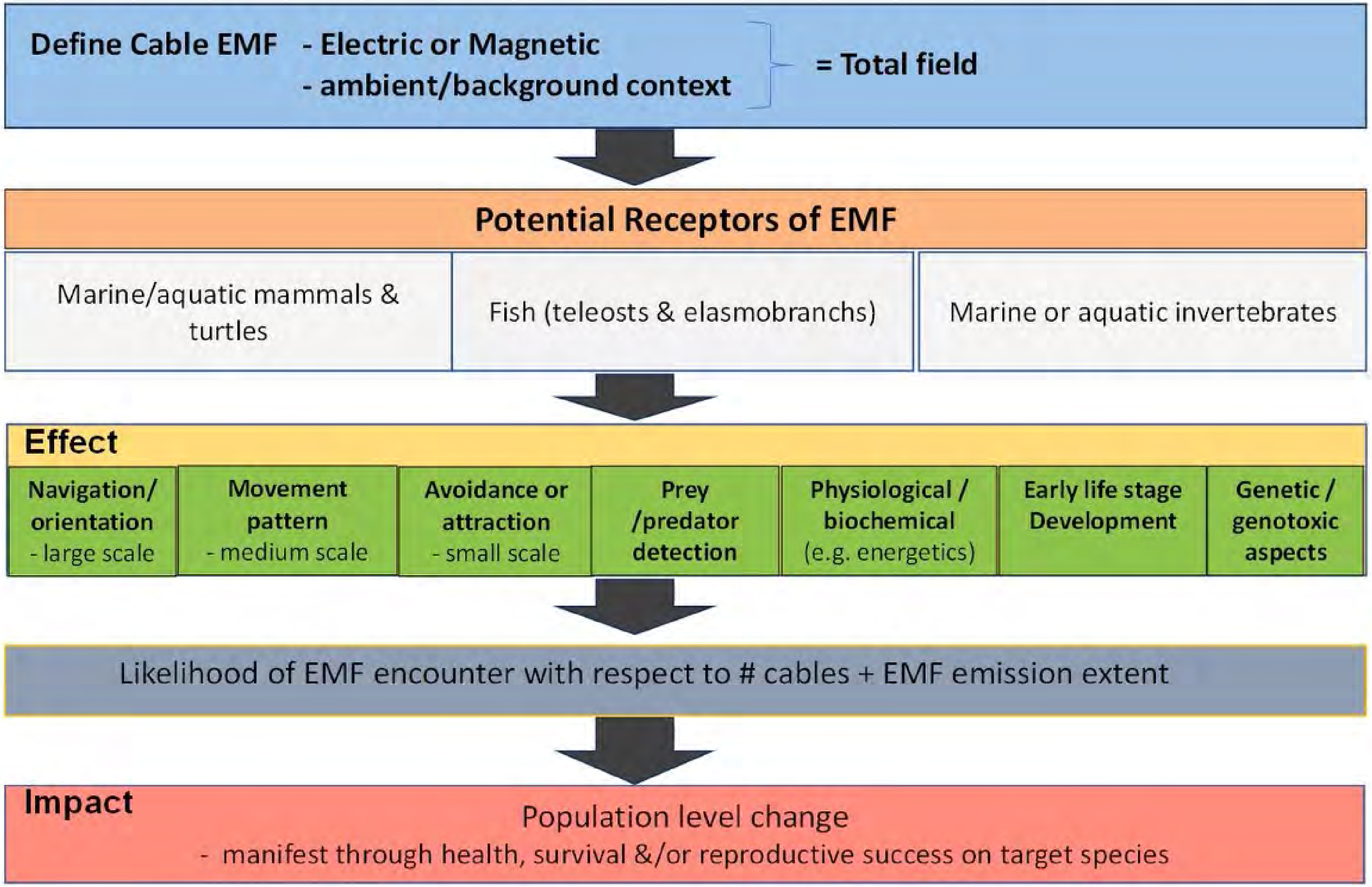


Adapted from Hutchison, Secor & Gill 2020, Oceanography

Take the vantage point of the receptive species:

- Their position in space and time
- How they perceive their sensory environment
- Which cues are important at that time
- Cable characteristics which influence the EMF

Framework for Assessing EMFs effects and likelihood of encounter to determine impacts



Offshore Wind Evidence + Change Programme

FLOWERS – Floating Offshore Wind Environmental Response to Stressors

Sept 22 – Apr 25

Andrew B. Gill
Strategic lead - Offshore and Marine Renewable Energy, Cefas

<u>The team</u>:

Cefas

- Marieke Desender, Brian Kneafsey, Emma Storey & Nic Terry

Scottish Government

- Marine Directorate: Kirsty Wright and Matt Newton
- Offshore Wind Directorate : Zoe Hutchison

Many thanks to:
- Offshore Transmission Operators (OFTOs)
- OWF operators
- National Grid

THE CROWN ESTATE | Cefas | marine scotland

EMF Work Package

Aim

Method to assess encounter rate between sensitive species and EMF environment associated with dynamic cables.

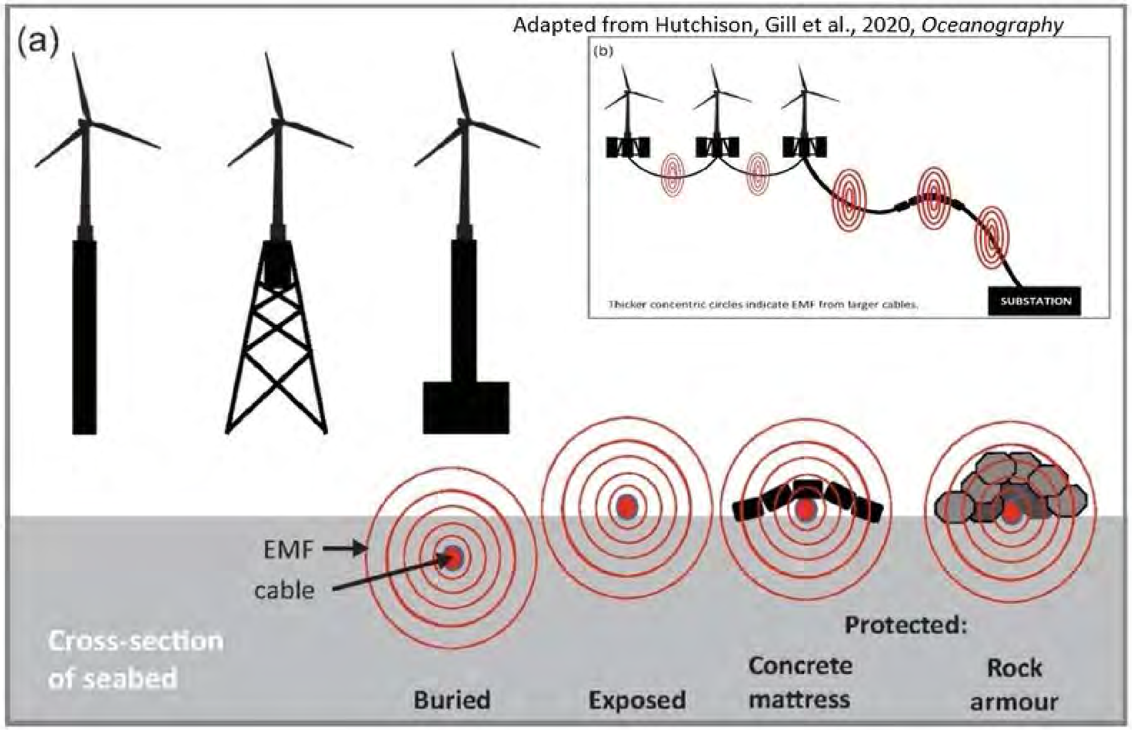
Objectives

1) Define the EMF environment associated with subsea power Cables

2) Verification of EMF model parameters through field data collection,

3) Estimation of the spatial (and temporal) overlap between selected sensitive species and cabling routes

4) Development of a version 1 method to estimate the likelihood of species encounter as a proxy to inform the potential risk of EMF to target species.

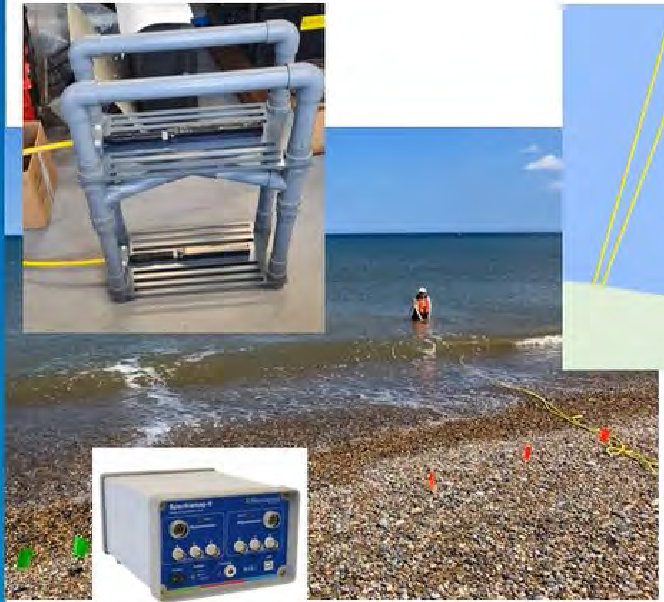


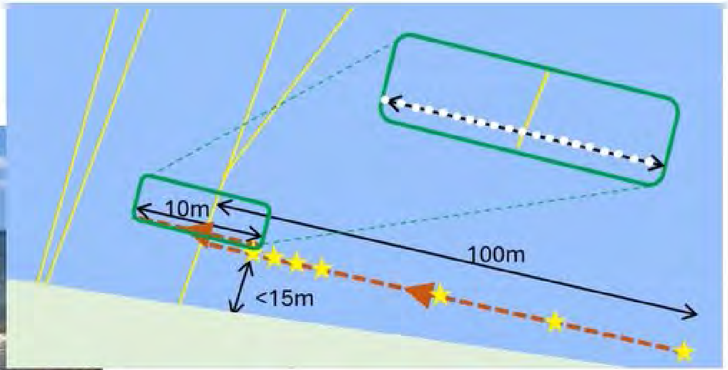
Field site locations

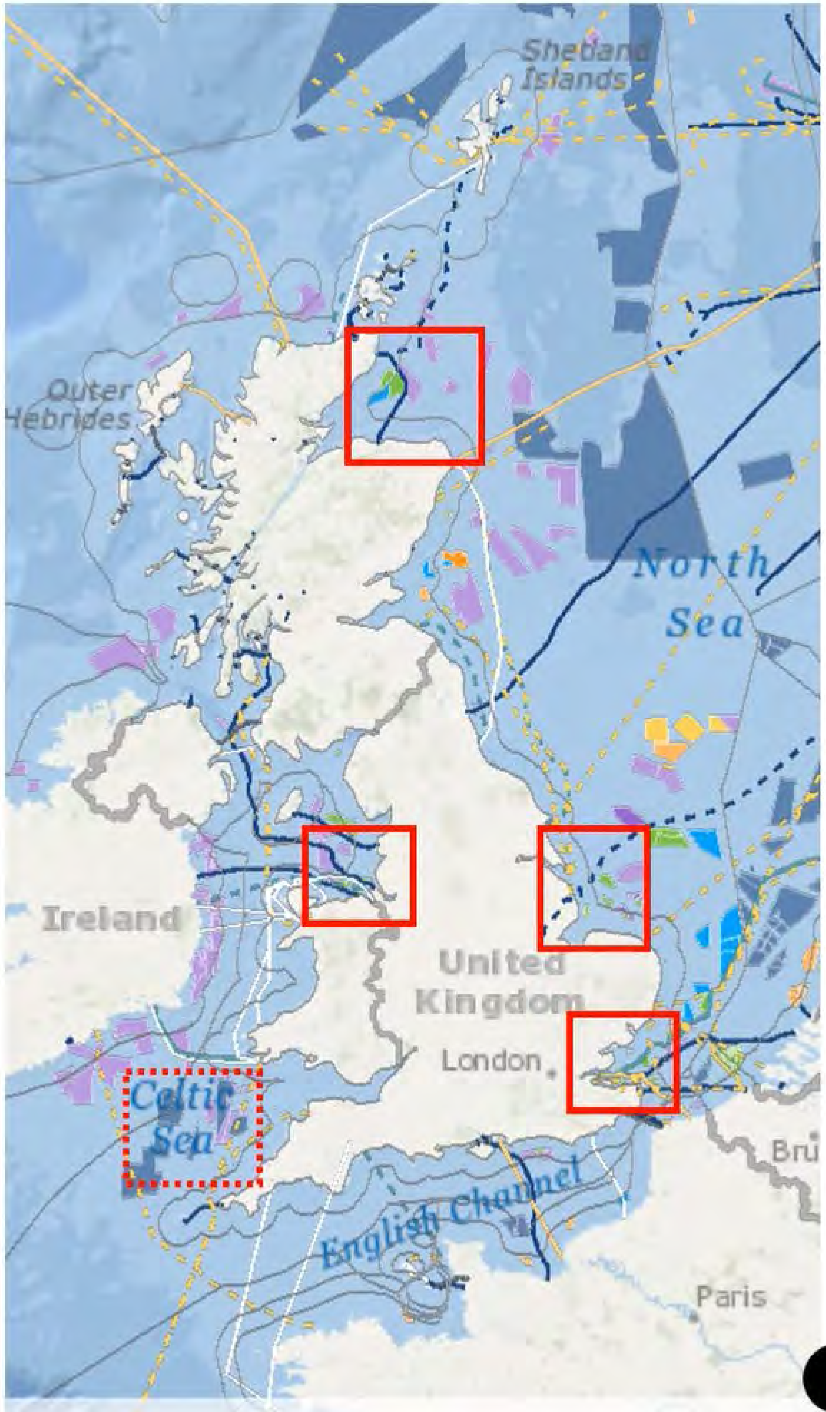
Site surveys with magnetometers at operational cables

High Voltage power cables

- AC (OWFs) x 12 cables
- DC (Interconnector) x 2 cables





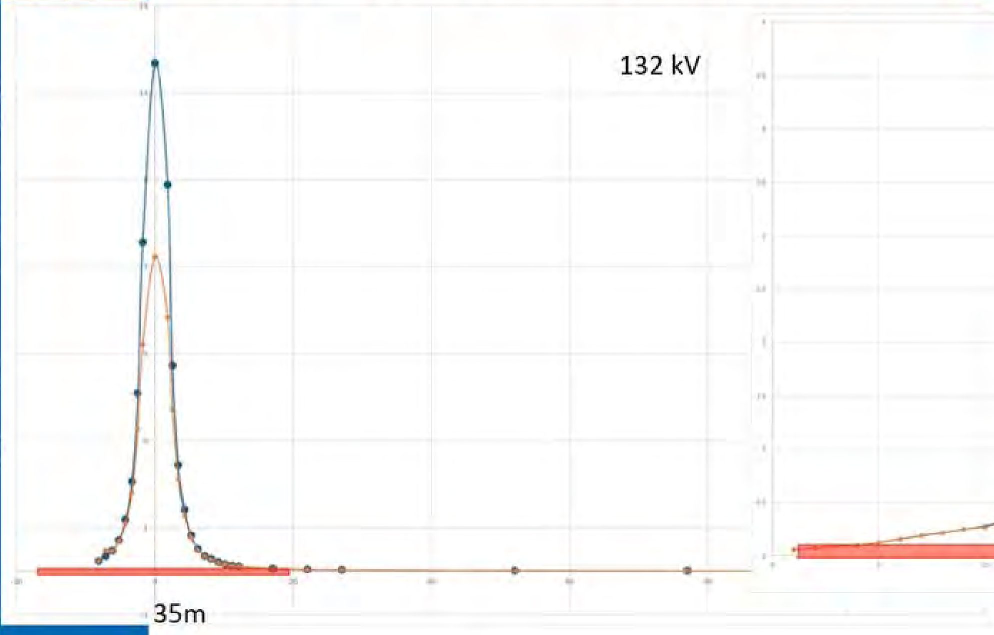


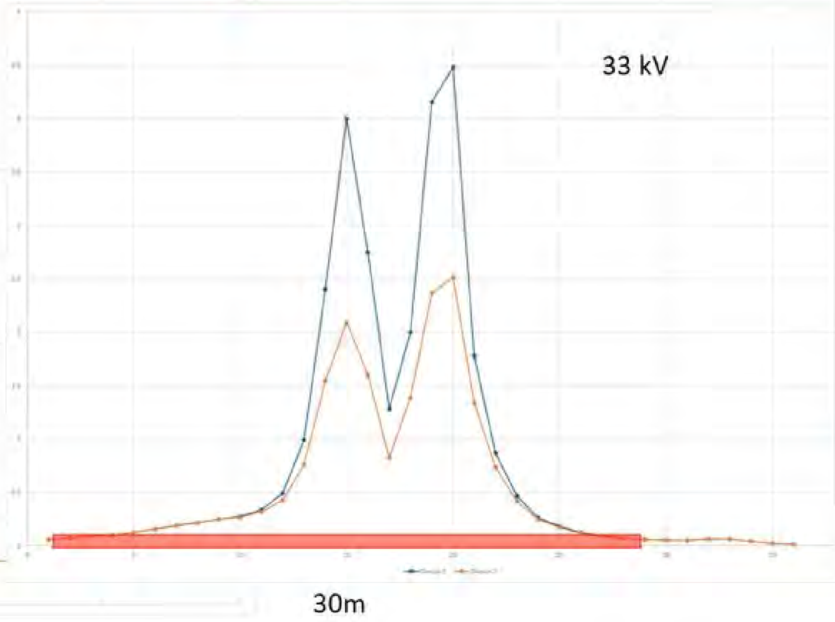
Australian Government

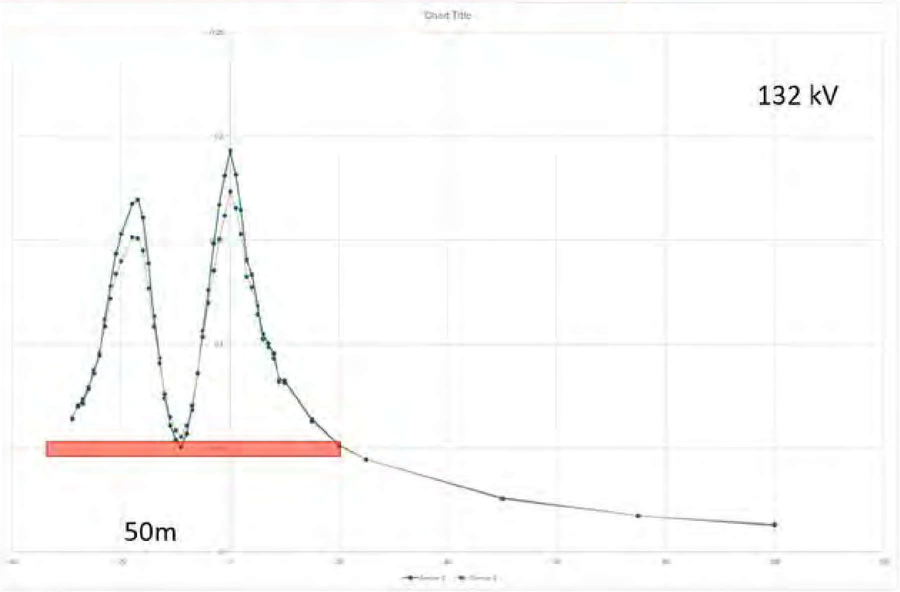
Australian Institute of Marine Science

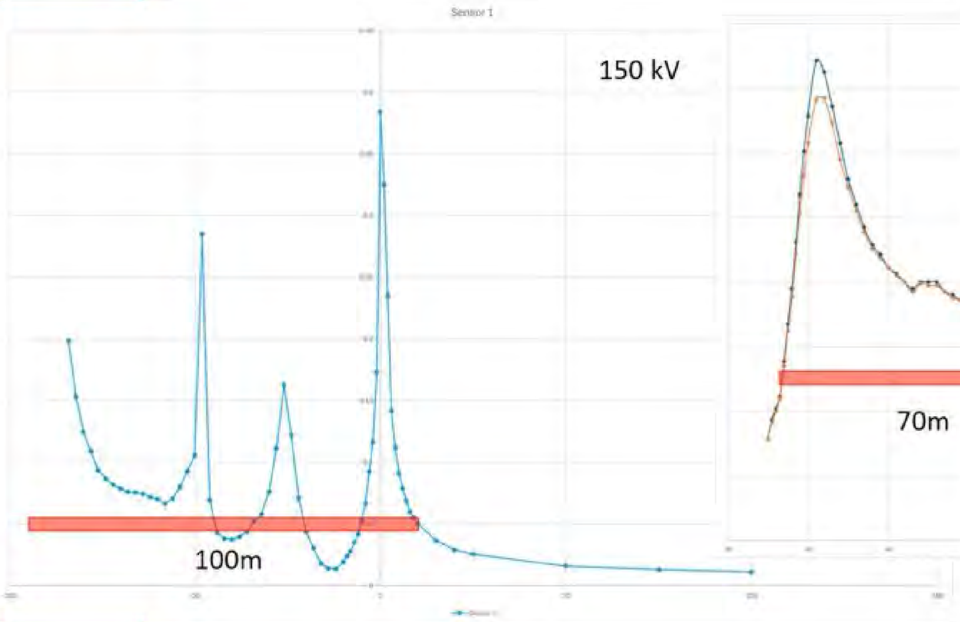
EMF Measurements

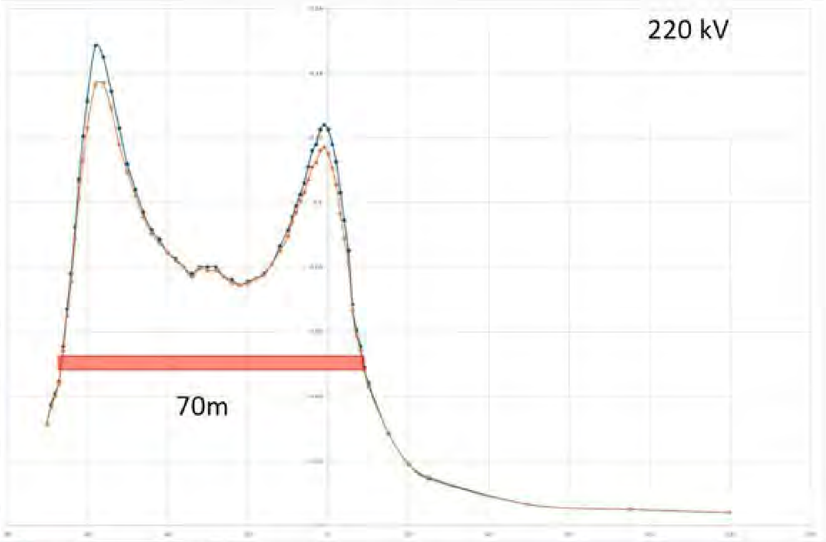
<u>*NOTE: indicative examples from preliminary results HVAC*</u>







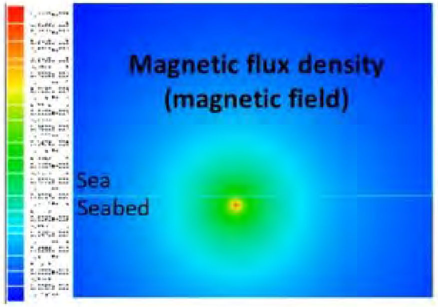




- Intensities magnetic field we measured ranged from :
  - 0.15 –11.7 microTesla at 1.5-2 m (estimates) for HVAC cables
  - Within the range of know detection of different taxa (*note: data limited)*

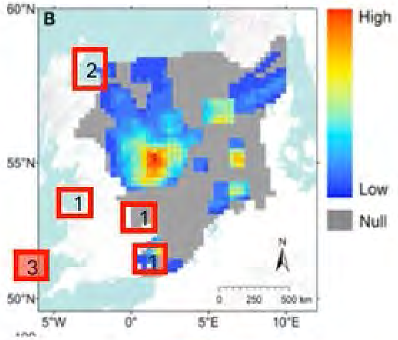
Standardised approach to determining likelihood of overlap between species occurrence and subsea cable routes

- Step-by-Step framework to assess likelihood of encounter of species w.r.t. to cable EMF



Cable characteristics, modelling + measurements

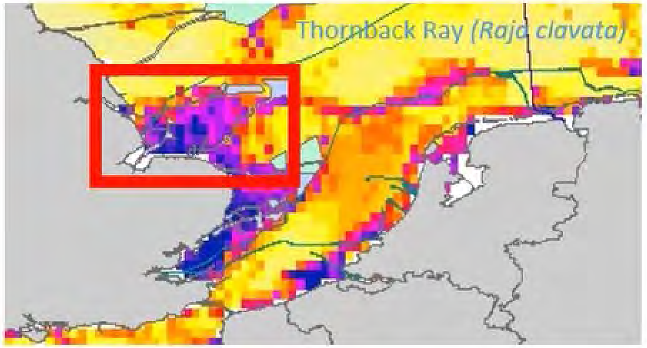
EMF environment



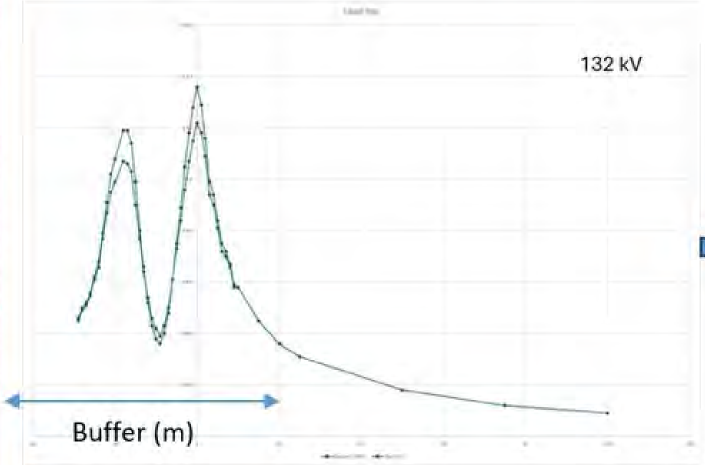
Species distribution (2D spatial) + depth and temporal where available

Likelihood of encounter of species w.r.t. to cable EMF

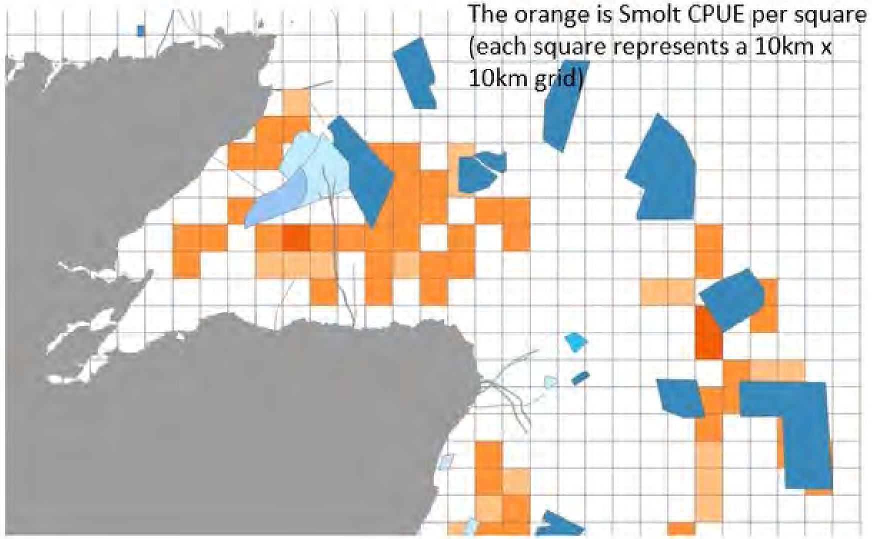
(+ confidence category: low, med, high)

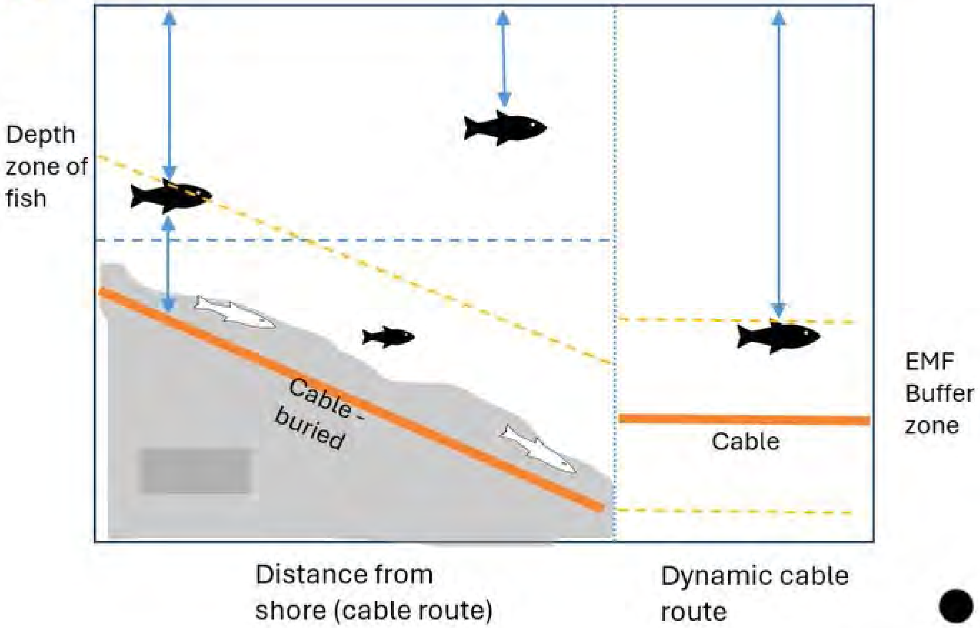


Outputs and Evidence needs



Cable Buffer zone (m)





Receptors

- Habitat use (i.e. depth aspect)
- Life stage association with habitat zones

Pressures

- Cable EMF extent and variability (during year and seasons)
- Data availability from transmission operators

- Timing of occurrence v EMF variability

THANKS to:
All colleagues working on EMF
Scottish Government; University Rhode Island; FOI – Swedish Defence Agency; Cranfield University; Liverpool University; EPRI
Witteveen+Bos, WaterProof, Bureau Waardenburg-Netherlands;
Funders: EPRI, BOEM, USA; EC, Europe; COWRIE, OWEC UK;

Thanks

&

Very happy to talk further :

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