Geographic Citizen Science in Marine Management

A spatial analysis case study | Jervis Bay, NSW

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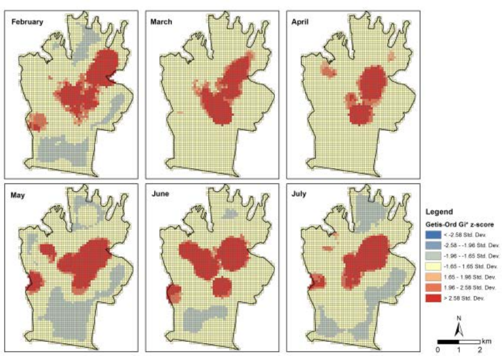
GEOCOASTAL RESEARCH GROUP

VGI and Citizen Science Projects

- **Graffiti project** – defining the identity of urban environments

Amuse, aka Amews, in Surry Hills, Sydney (Jam Project)



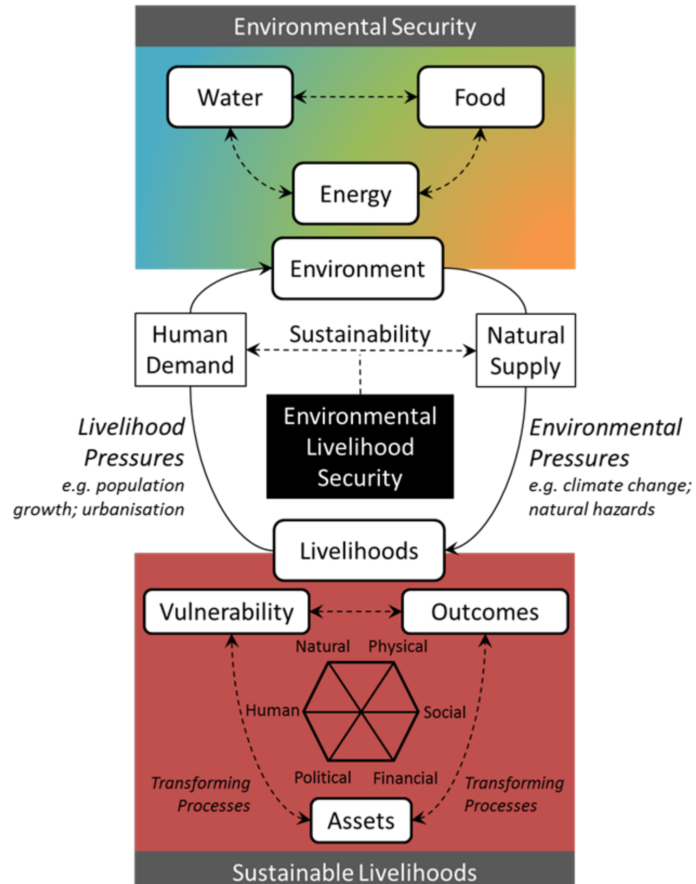
- **Bushfire preparation** – foster community engagement and building disaster resilience

PhD Billy Haworth

www.billyhaworth.com

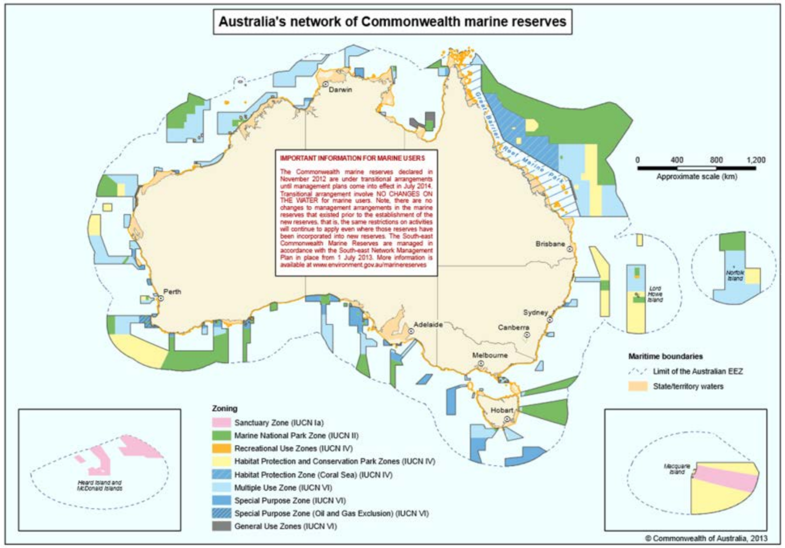
- Climate Change Adaptation in Post-Disaster Recovery Processes

- Geospatial Information for Assessing Environmental Livelihood Security: South Pacific



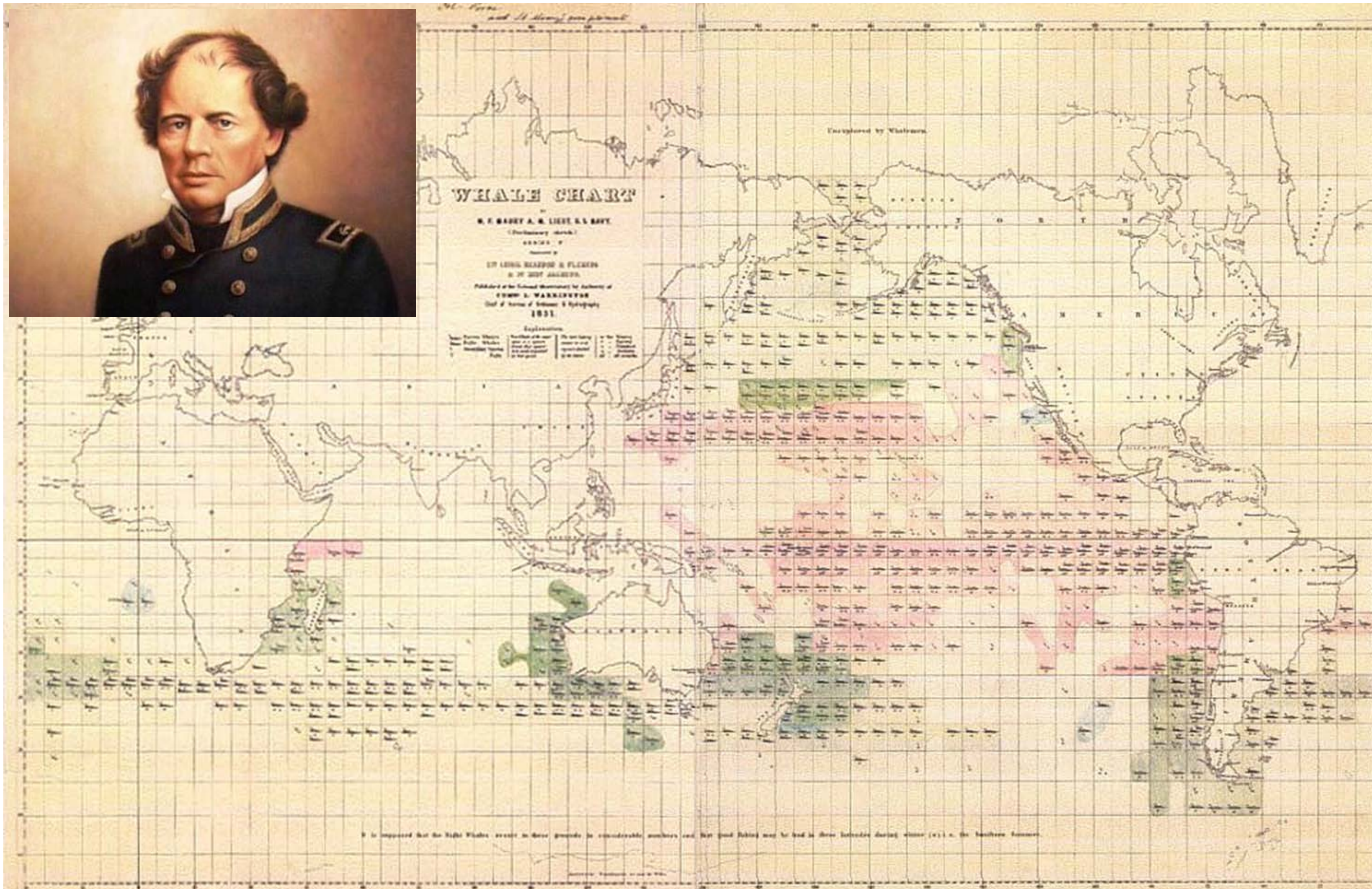
Spatial patterns and uncertainty

- Broad scale distributions patterns requires extensive monitoring data
- Challenged by logistical constraints
- Citizen Science – engaging non-specialist volunteers in collection of data for scientific enquiry (Bhattacharjee, 2005; Silverton, 2009)
- Achieves geographical reach needed to address spatial ecological questions at scales relevant to species migration patterns



[Source: Scott Sheehan]

Matthew Maury's – Whale chart



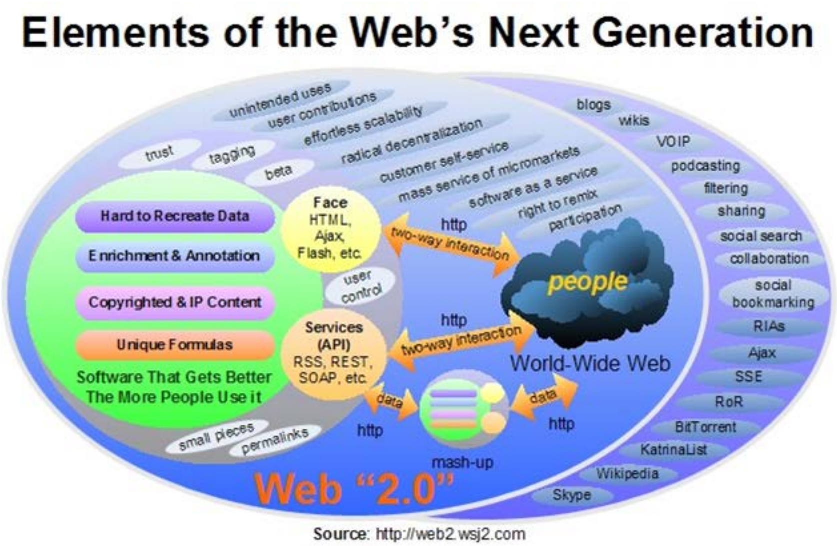
Volunteered Geographic Information

- Geographical citizen science is used to refer to projects in which the collection of locational information is integral to the study (Haklay, 2013; Elwood et al., 2012)

- VGI phenomenon involves the acquisition and dissemination of geographic information through the voluntary activity of individuals or groups (Elwood et al., 2012)

[Source: http://www.geocrowd.eu/workshop_2012/]

Challenge traditional scientific practices…



- Web 2.0
- Increase in user generated content (UGC) disseminated via the internet
- Proliferation of locational-acquisition devices
- Facilitate large-scale citizen science initiatives but also challenges traditional scientific practices…

Levels of engagement

Haklay (2013) – knowledge building through engagement

Level 4 ‘Extreme Citizen Science’

- Collaborative science – problem definition, data collection and analysis

Level 3 ‘Participatory science’

- Participation in problem definition and data collection

Level 2 ‘Distributed Intelligence’

- Citizens as basic interpreters
- Volunteered thinking

Level 1 ‘Crowdsourcing’

- Citizens as sensors
- Volunteered computing

climateprediction.net
the world's largest climate modelling experiment for the 21st century

[Haklay, M., 2013, Citizen Science and Volunteered Geographic Information – overview and typology of participation.]

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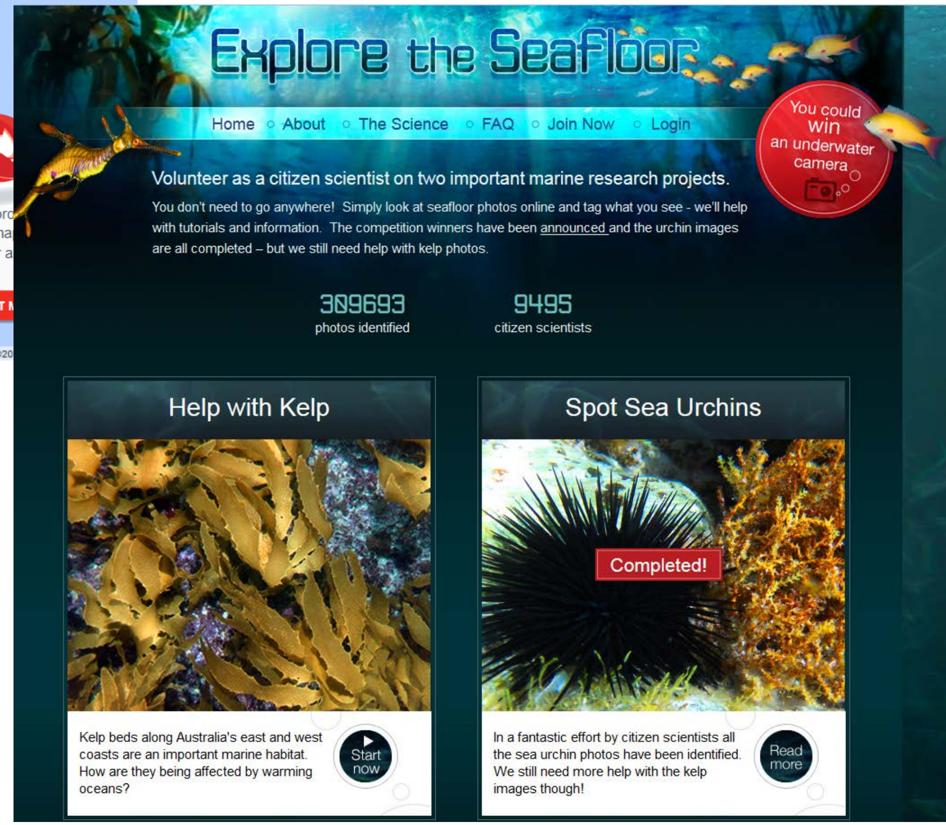
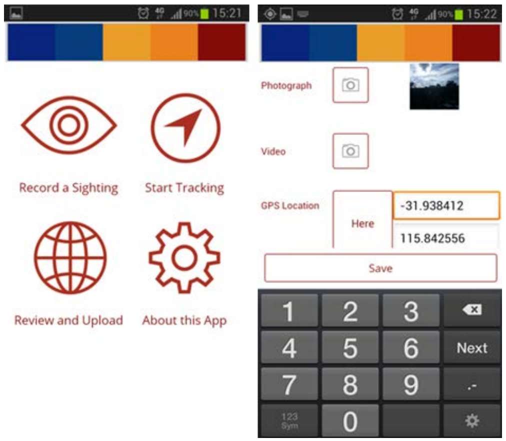
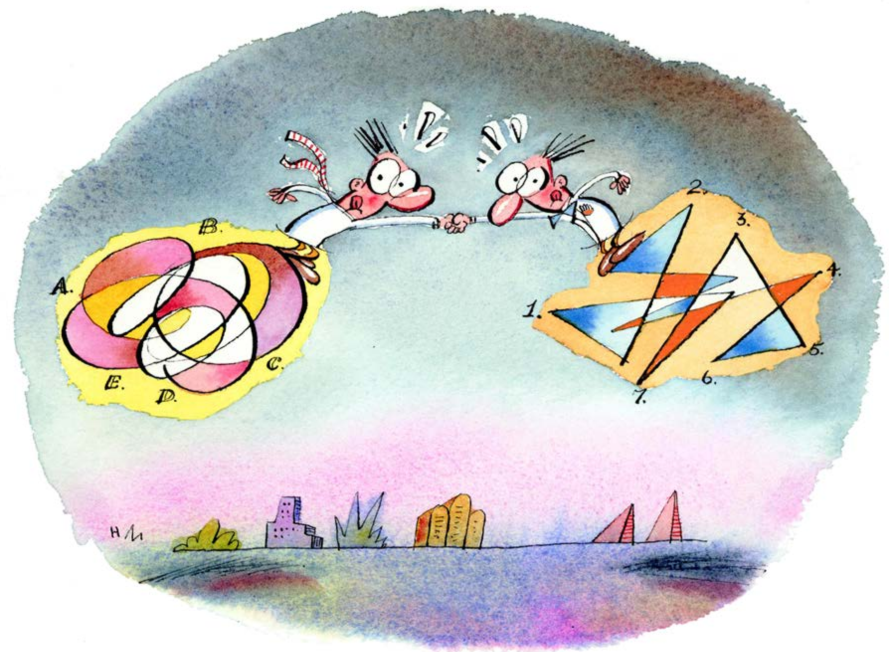


Persuasive technologies to useful research collaborations…



[Source: http://mucru.org/our-research/research-projects/citizen-science-coastal-walkabout/]

[Source: Scott Sheehan, Marine Mammal Research]



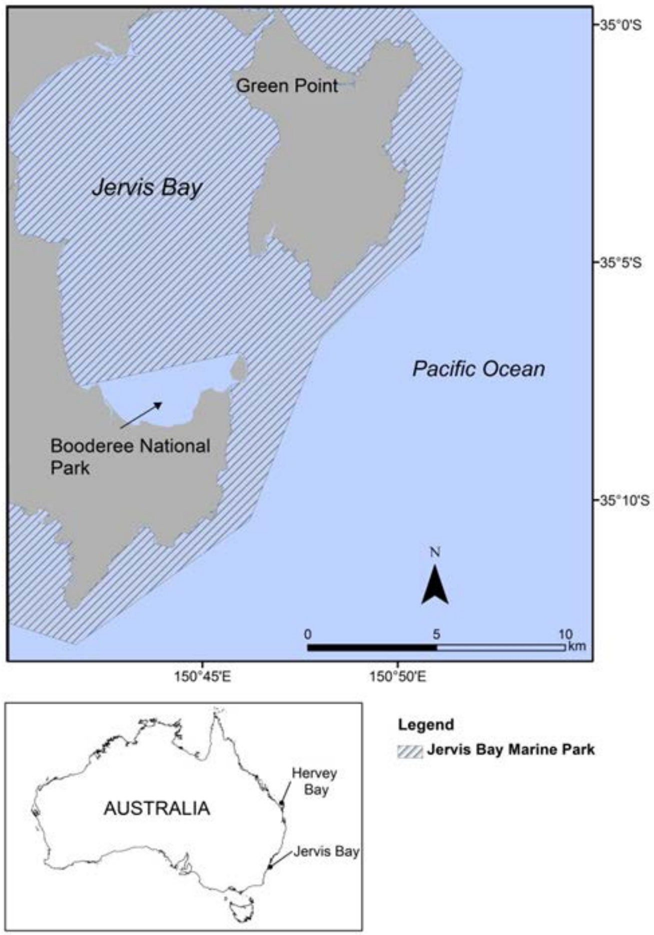
[Source: Hal Mayforth, http://sciencecareers.sciencemag.org/career_magazine]

Challenges…

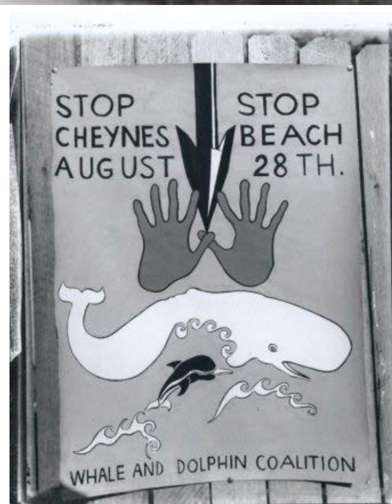
- Acceptance dependent on recognition of inherent bias
  - Robustness of volunteer-collected data
  - Lack of standardised collection procedures
  - Inadequate evaluation of the validity of these data for the intended study
- Surveillance rather than targeted monitoring
- Opportunistic sampling methods often adopted in volunteer-tourism based marine surveys

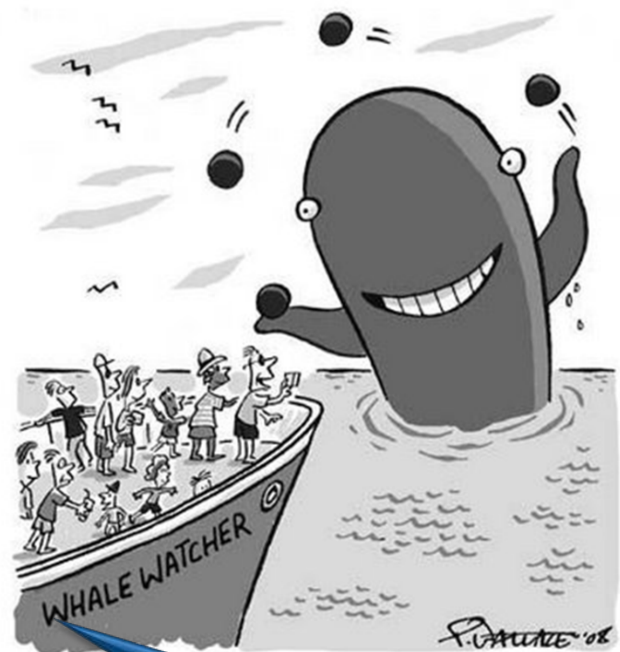
[Source: Scott Sheehan, Marine Mammal Research]

Case study: Distribution patterns of migrating humpback whales



Near extinction

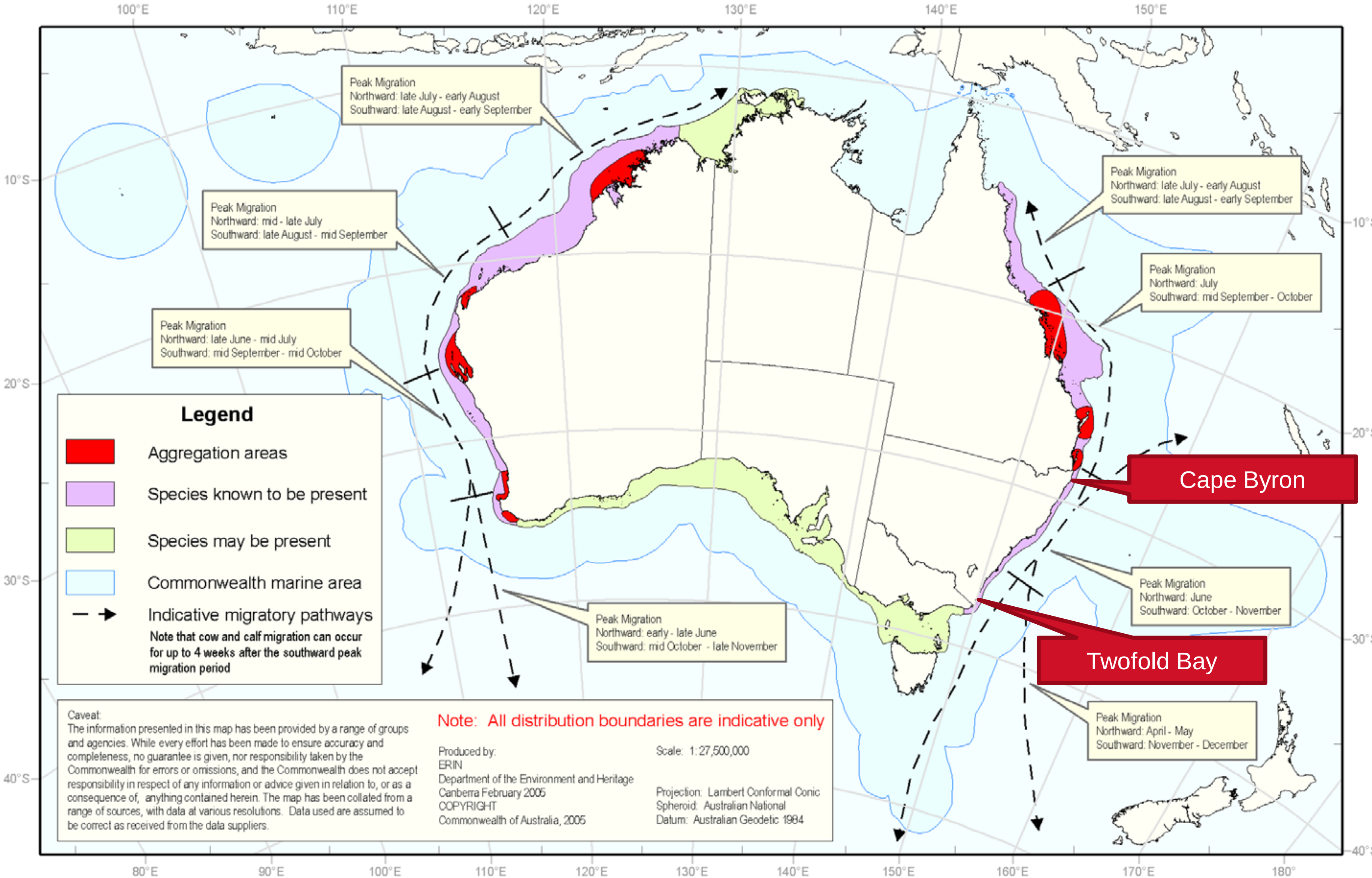




Anti whaling protest poster designed by Peter Wright (© 1977—Jonny Lewis Collection)

Geographic Citizen Science Platform

Figure 1: Distribution, migration and recognised aggregation areas of the humpback whale



East Australian Humpback Whale

Mother-calf pair, Jervis Bay

- High levels of maternally directed philopatry
- Mother-calf pairs show a significant preference for warm, shallow water and sheltered embayments relative to other group types
- Calf's experience may influence subsequent habitat choices
- Need to identify critical resting sites along migration path
- Interconnectivity of coastal areas has implications for reserve design

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- To establish spatial clusters of mother-calf observations within Jervis Bay relative to other whale groups during mid to late austral spring.

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Geographic citizen science data

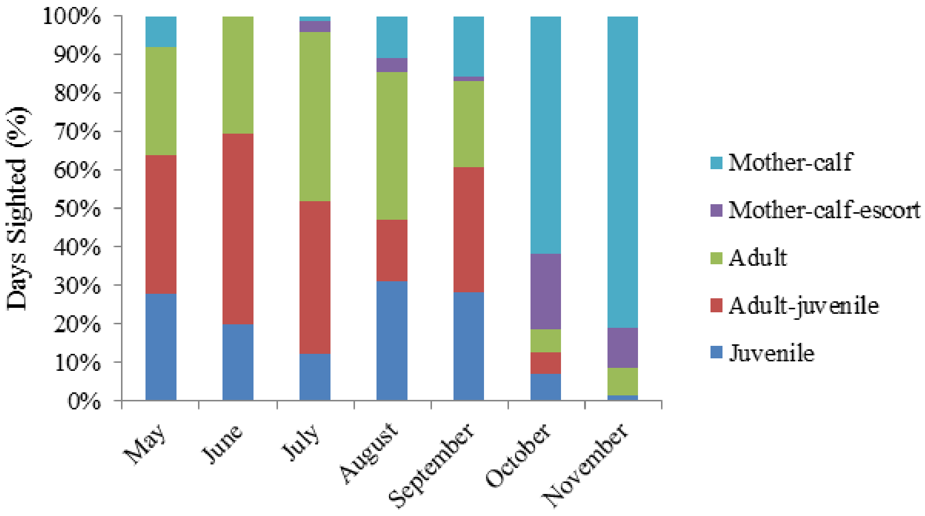
Volunteer collected data – commercial whale-watch platform

- What are the constraints?
- Standardisation of sampling effort difficult particularly if survey design requires flexibility

- Spatial sampling bias
- Observer error
- Positional offset

- Different spatial configurations of errors may result in either the underestimation or overestimation of a cluster

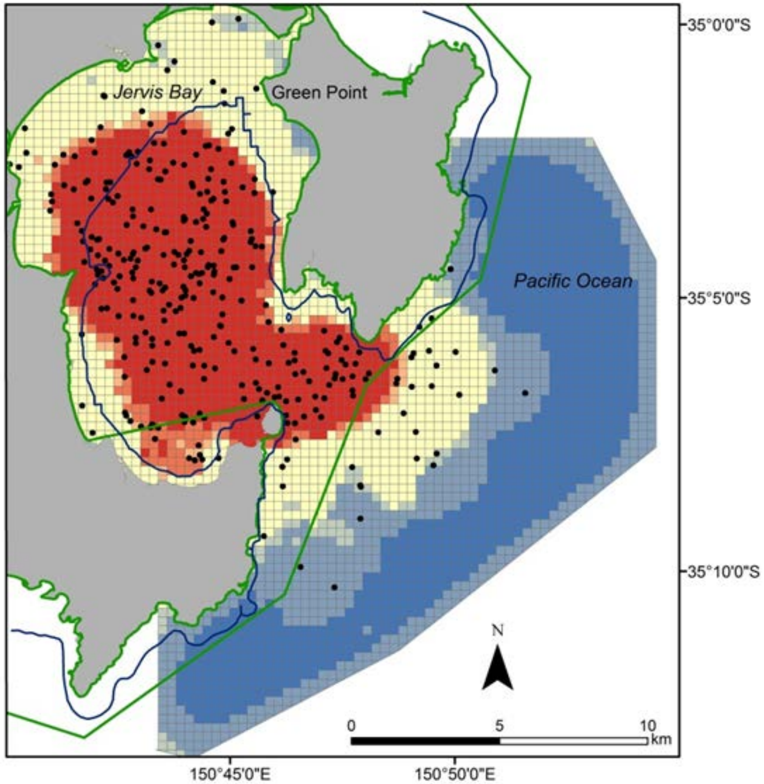
Spatial cluster analysis



Proportion of days in which each whale group composition was sighted per month between 2007 and 2010.

- Moran's I and G_i^* statistics
- Lag distance d = 2000 m
- False discovery rate (FDR)
- Randomisation tests in which sample data was randomly rearranged to examine impact of potential bias on spatial cluster detection

Mother-calf groups



Non mother-calf groups

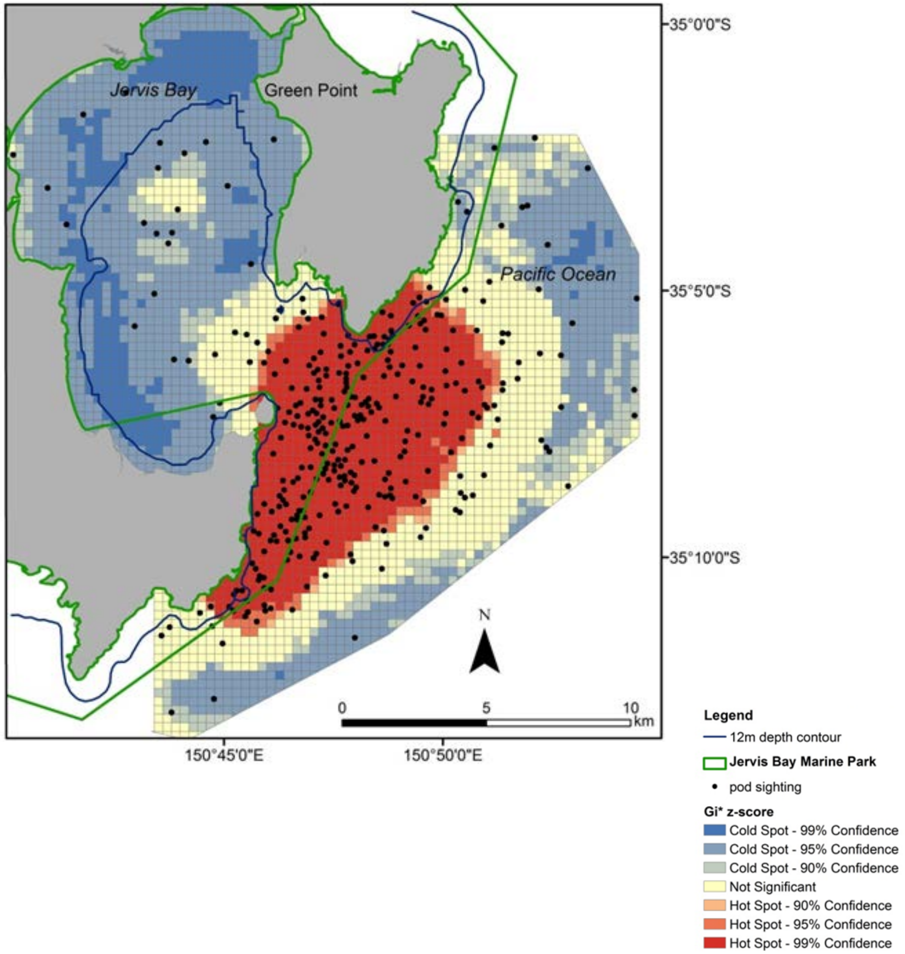


Table 2. Comparative global Moran's *I* results for mother-calf pod and non-calf pod sightings using data randomly adjusted for spatial sampling, positional offset and pod composition observation error (100 random samples).

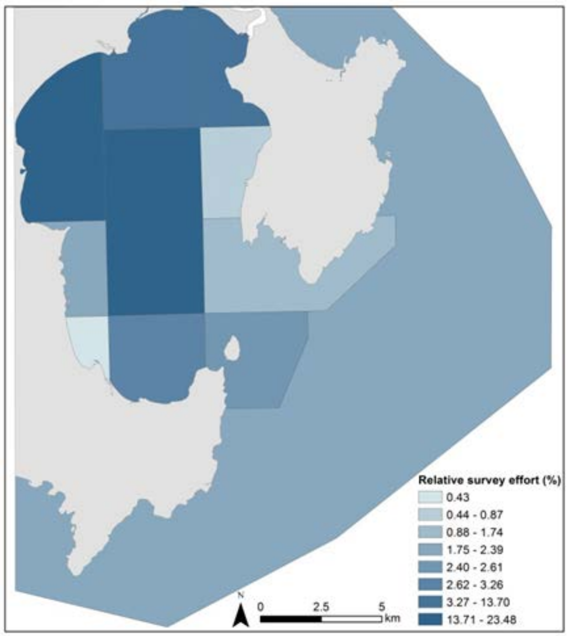
	Non-calf groups			Mother-calf groups		
	Moran's I	STD	p value	Moran's I	STD	p value
Unadjusted	0.1793		<0.001	0.1401		<0.001
Adjusted for spatial sampling effort	0.1797	0.0012	<0.001	0.1148	0.0029	<0.001
Offset distance						
50 m	0.1787	0.0028	<0.001	0.1376	0.0029	<0.001
100 m	0.1740	0.0049	<0.001	0.1399	0.0028	<0.001
150 m	0.1712	0.0062	<0.001	0.1400	0.0033	<0.001
200 m	0.1682	0.0049	<0.001	0.1387	0.0043	<0.001
250 m	0.1651	0.0058	<0.001	0.1364	0.0052	<0.001
300 m	0.1636	0.0061	<0.001	0.1380	0.0046	<0.001
Observation error						
2%	0.1732	0.0034	<0.001	0.1350	0.030	<0.001
5%	0.1654	0.0058	<0.001	0.1286	0.040	<0.001
10%	0.1503	0.0071	<0.001	0.1168	0.062	<0.001
15%	0.1377	0.0083	<0.001	0.1072	0.0057	<0.001
20%	0.1264	0.0084	<0.001	0.0983	0.0061	<0.001
25%	0.1146	0.0095	<0.001	0.0928	0.0065	<0.001

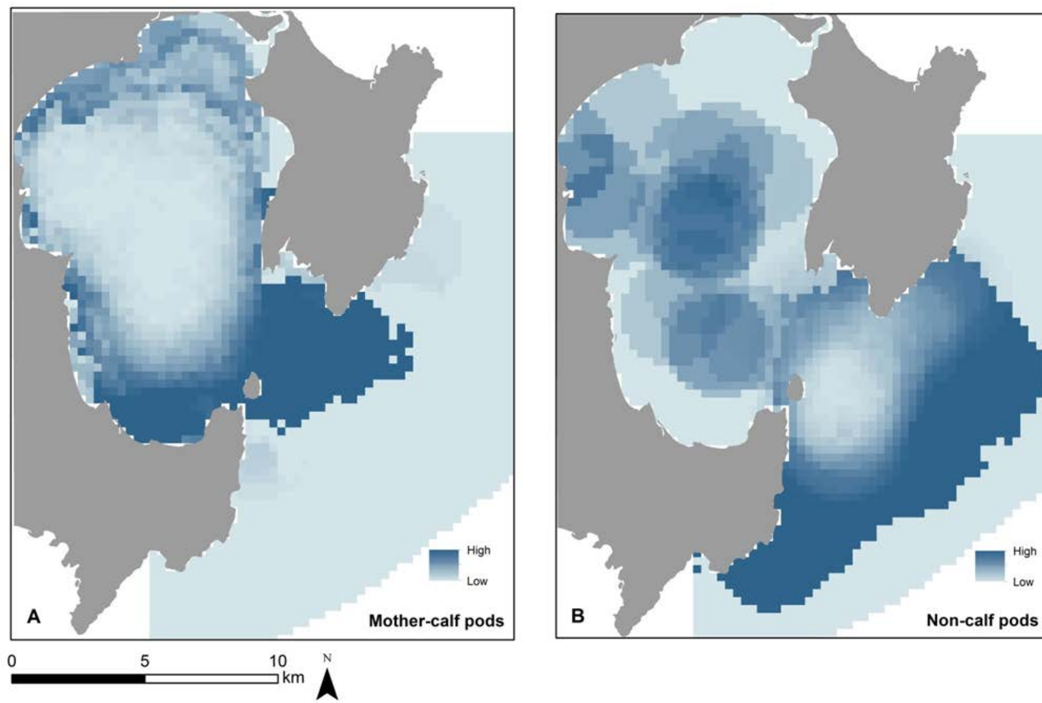
Table 3. Testing of the G_i^* statistic with sample data adjusted for potential bias in sampling effort, observer error and positional offset (100 random samples).

Pod	Unadjusted (%)	Adjusted for sampling effort (%)	Observer Error (%)						Positional Offset (%)					
			2%	5%	10%	15%	20%	25%	50 m	100 m	150 m	200 m	250 m	300 m
Mother-calf (N = 3548)														
G_i^*														
Accept null	25.6	27.3	23.9	25.1	27.0	28.4	29.5	30.0	25.7	25.4	25.4	25.5	25.8	25.6
Reject null	74.4	72.7	76.1	74.9	73.0	71.6	70.5	70.0	74.3	74.6	74.6	74.5	74.2	74.4
Positive cluster - 99% CL	23.0	22.7	23.9	23.5	23.0	22.6	22.3	22.2	23.0	23.1	23.0	23.0	22.7	22.9
Positive cluster - 95% CL	3.3	3.6	2.9	3.0	3.0	3.2	3.4	3.7	3.2	3.2	3.2	3.2	3.3	3.2
Positive cluster - 90% CL	1.4	1.4	1.2	1.5	1.7	1.9	2.0	2.1	1.4	1.4	1.4	1.3	1.4	1.4
Negative cluster - 99% CL	25.0	17.7	31.5	30.1	27.5	25.7	23.4	22.4	24.5	25.8	25.4	24.9	23.5	24.0
Negative cluster - 95% CL	18.7	23.1	12.4	12.6	13.1	13.3	14.4	14.4	18.9	17.8	18.3	18.7	19.9	19.6
Negative cluster - 90% CL	3.0	4.2	4.1	4.3	4.6	4.8	5.1	5.2	3.3	3.3	3.3	3.3	3.3	3.3
Non-calf (N = 3548)														
G_i^*														
Accept null	21.1	21.0	23.6	26.5	32.4	36.9	40.7	42.5	21.7	22.4	22.7	23.0	23.5	23.7
Reject null	78.9	79.0	76.4	73.5	67.6	63.1	59.3	57.5	78.3	77.6	77.3	77.0	76.5	76.3
Positive cluster - 99% CL	19.4	19.4	19.0	18.5	17.7	17.0	16.3	15.8	19.1	18.9	18.7	18.6	18.6	18.5
Positive cluster - 95% CL	2.1	2.2	2.3	2.4	2.5	2.5	2.6	3.0	2.3	2.4	2.6	2.5	2.5	2.5
Positive cluster - 90% CL	1.0	1.1	1.0	1.0	1.1	1.3	1.6	2.0	0.9	0.9	1.0	1.1	1.1	1.1
Negative cluster - 99% CL	10.6	10.6	6.2	4.3	2.6	2.1	1.6	1.3	8.4	6.0	5.3	4.3	3.6	3.2
Negative cluster - 95% CL	35.0	36.6	36.4	34.0	28.2	24.6	22.6	21.4	36.6	36.8	36.0	35.3	35.2	35.2
Negative cluster - 90% CL	10.8	9.2	11.6	13.2	15.5	15.7	14.7	14.1	10.9	12.6	13.6	15.2	15.6	15.8

Positional error within 300 m had minimal impact on the Global Moran's I and G_i^* statistics

Potential for under or over representation

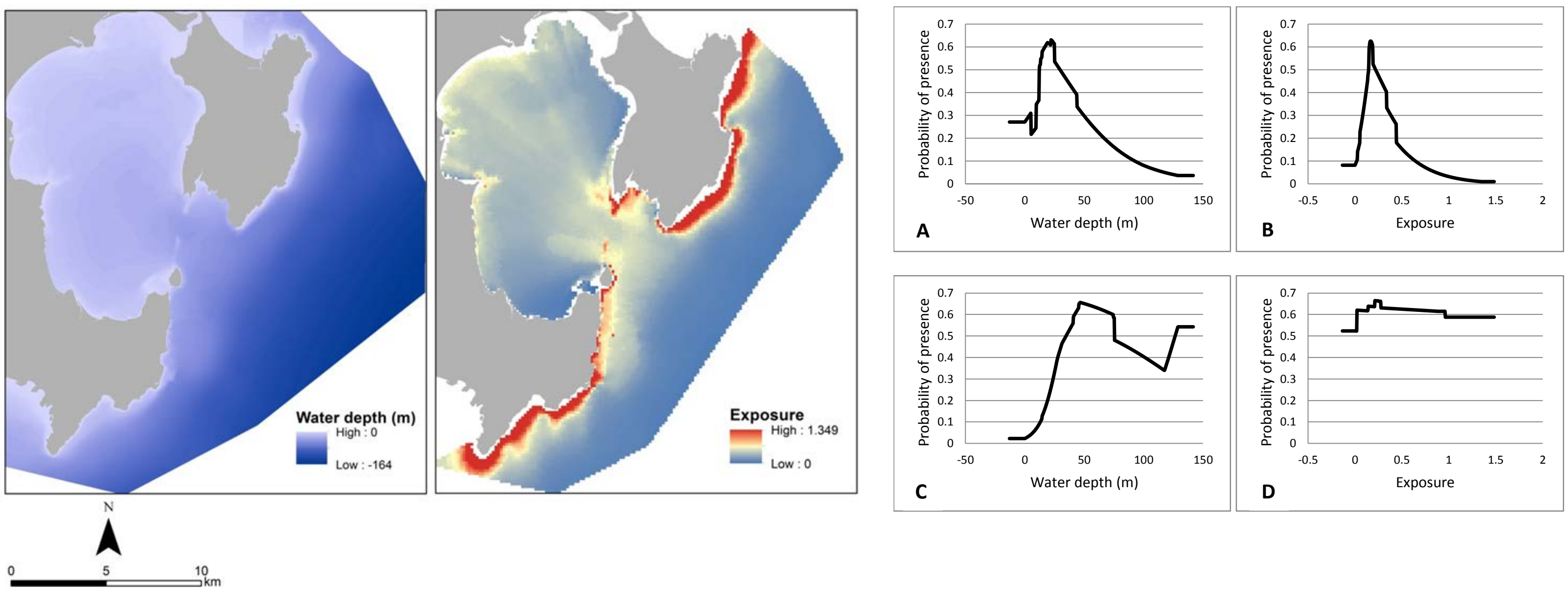




Relative sampling effort

Proportion of randomly adjusted samples whose test values exceeded the original test value (G_i^* statistic)

Depth and exposure preference



Response curves showing the relationship between probability of calf-pod occurrence and depth (A) and exposure (B), and non-calf pod and depth (C) and exposure (D). The shape of the curve shows change in logistic prediction for each variable while the other variable is kept at the mean sample value.

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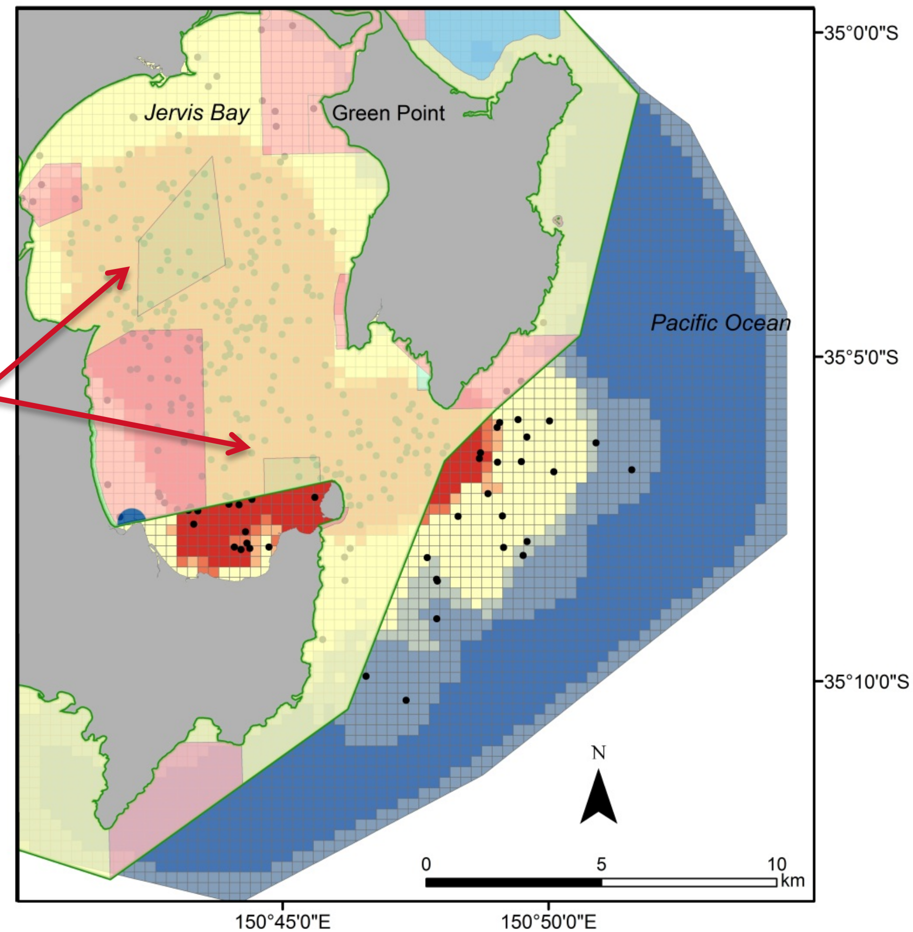
Purse Seining & Lift Netting



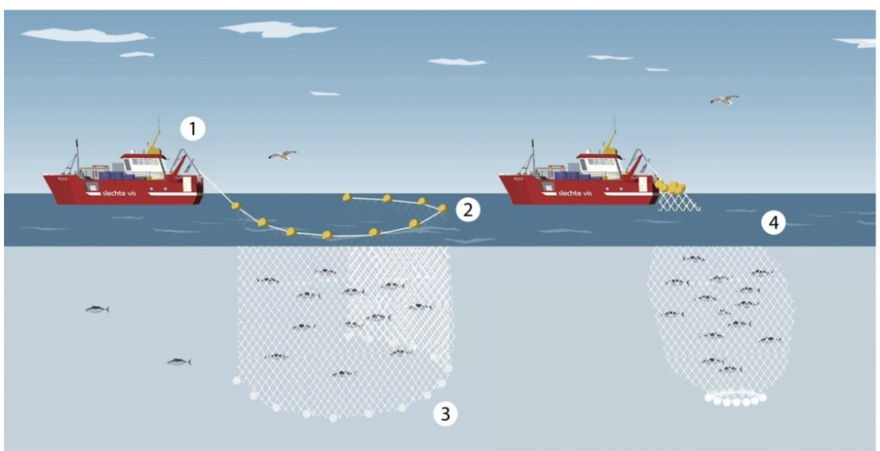
Legend

- group sighting

Zone Plan

Zone

- General Use Zone
- Habitat Protection Zone
- Habitat Protection Zone (Purse Seining & Lift Netting)
- Habitat Protection Zone (Seasonal Anchoring Zone)
- Habitat Protection Zone (Spearfishing Prohibited)
- Sanctuary Zone
- Sanctuary Zone (Designated Anchoring Area)
- Special Purpose Zone



1. The fishing vessel surrounds a school of fish 2. Floats 3. Weights 4. The bottom of the net is brought together and then hauled on-board

[Source: Goodfishbadfish Sustainable Seafood, 2013]

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Findings

› Local indicators of spatial clustering were more susceptible to both observational errors and spatial sampling bias.

› Cluster confirmed despite introduced observer bias

› With increased populations range has begun to expand beyond traditional migratory routes, ‘spill over’ particularly important to mother-calf groups

› Changing habitat usage trends have implications for Marine Protected Area management – citizen engagement with policy decisions

Considerations

- Longitudinal studies over wide geographic regions
- Observer bias can be reduced through in-field training and observer experience
- Open Tools - mechanism s for determining and communicating uncertainty
- Participant involvement beyond passive sensors to cognitive engagement in scientific problem

- **Bruce, E**., Albright, L., Sheehan, S. and Blewitt, M. (2014) Distribution patterns of migrating humpback whales (*Megaptera novaengliae*) in Jervis Bay, Australia: A spatial analysis using geographical citizen science data, *Applied Geography,* 54: 83-95. doi:10.1016/j.apgeog.2014.06.014
- Haworth, B. and **Bruce, E.** (2015). A Review of Volunteered Geographic Information for Disaster Management, *Geography Compass*, 9(5): 237-250, DOI: 10.1111/gec3.12213.
- Biggs EM, **Bruce E**, Boruff B, Duncan JMA, Duce S, Haworth BJ, Horsley J, Curnow J, Neef A, McNeill K, Pauli N, Van Ogtrop F, Imanari Y, (2015). Sustainable development and the water-energy-food nexus: a perspective on livelihoods. *Environmental Science and Policy* doi:10.1016/j.envsci.2015.08.002

- **Climate Change Adaptation in Post-Disaster Recovery Processes**
- http://www.climatechangeplus.net/

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