Fine-scale analysis of drifting Fish Aggregation Device (dFAD) beaching events in the Seychelles Archipelago, Indian Ocean

Presenting: Isla MacMillan

Authors: Isla MacMillan, Martin Attrill, Taha Imzilen, Christophe Lett, Simon Walmsley, Clarus Chu, David M. Kaplan

UNIVERSITY OF PLYMOUTH

WWF

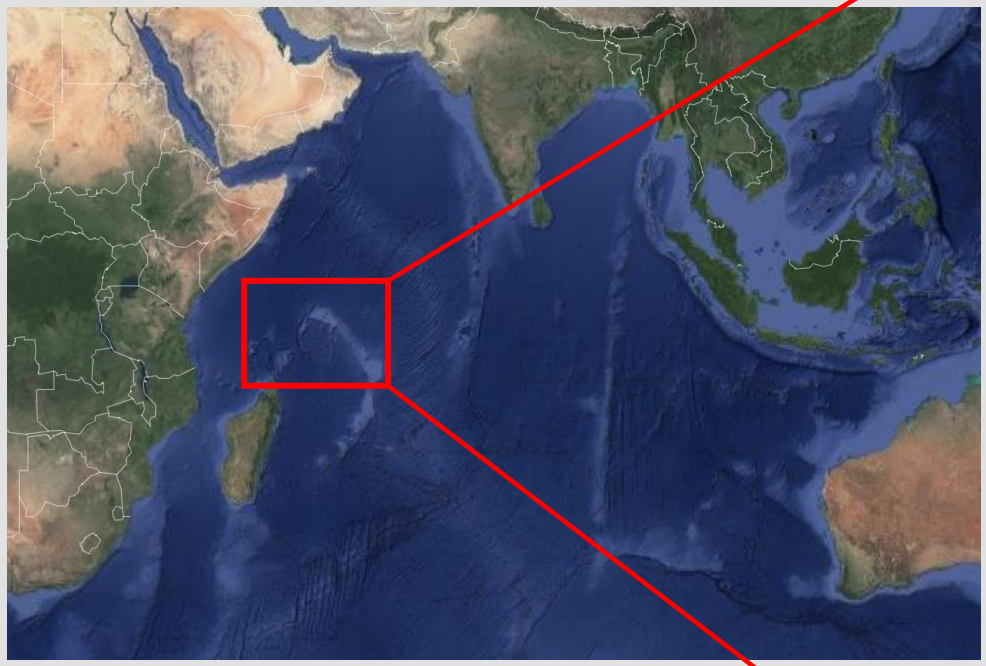
Institut de Recherche pour le Développement FRANCE

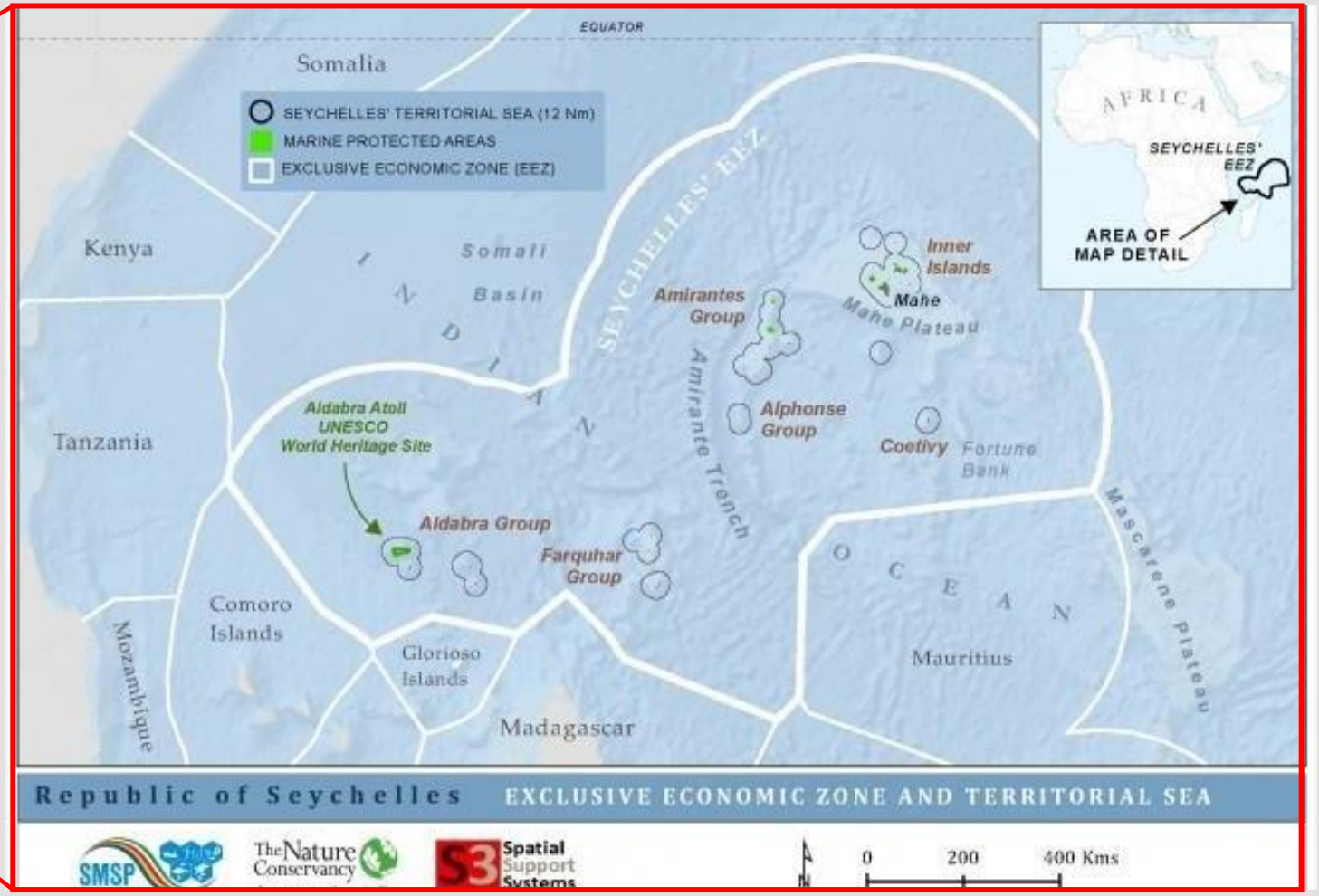
Beaching events

‘Beaching event’ definition:

Any extended period over which a deployed dFAD is uncharacteristically motionless, which is presumably due to entanglement of the dFADs subsurface structure with the ocean bottom

Republic of Seychelles, Indian Ocean





Figures (above and right). Indian Ocean (above) depicting the location of the Seychelles (right).

Seychelles, Indian Ocean

- Biodiversity hotpot supporting high levels of fish and coral species richness and biomass
- Ecosystem services provided by these habitats are integral to human health and prosperity within the Seychelles
- Many protective designations –UNESCO World Heritage Site, Aldabra Atoll

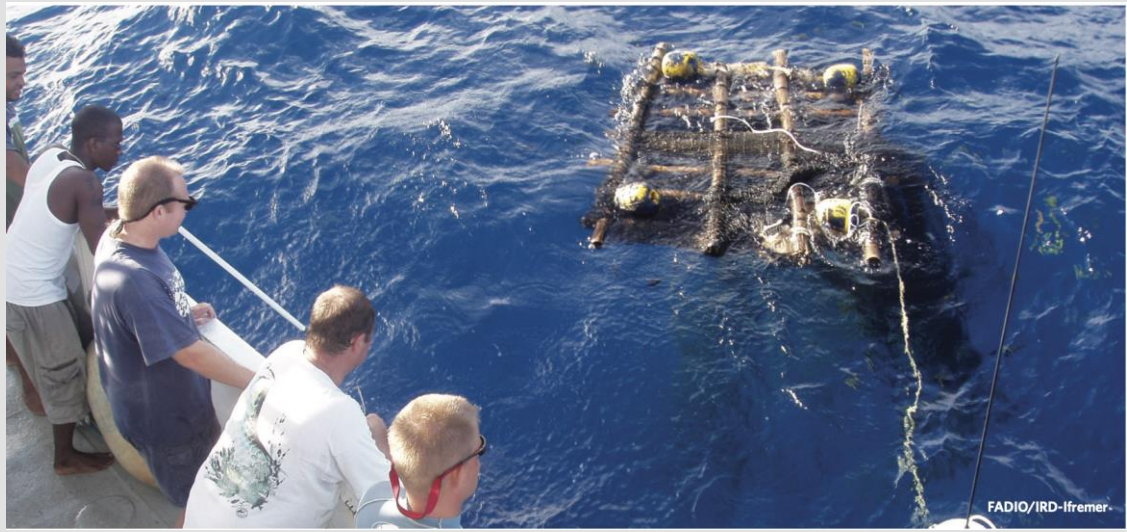
Seychelles tuna Purse Seine (PS) industry

Seychelles and dFAD use

- *Important fishing ground*
- *Canneries and fishing licenses are significant source of income for Seychelles economy*
- *dFADs capture skipjack, less sensitive to overexploitation comparative to yellowfin*
- *Lowest edible biomass to CO_2 output*

However,

- *Globally, ~120,000 dFADs deployed annually*
- *~15-20% result in beaching events (Moreno et al., 2020; Imzilen et al., 2020)*
- *No legal obligation to collect deployed dFADs*
- *Where do dFADs end up?*



Project Overview

Beachings were assessed as a function of –

- *Intra- and interannual trends and seasonality*
- *Water depth and distance from land*
- *Fine scale benthic habitat class assessment*
- *Rebeaching*

To produce –

- *Comprehensive map of beaching events*
- *Accumulation zones and at-risk regions and habitats*
- *Information for future management and policy considerations*

Beaching event identification

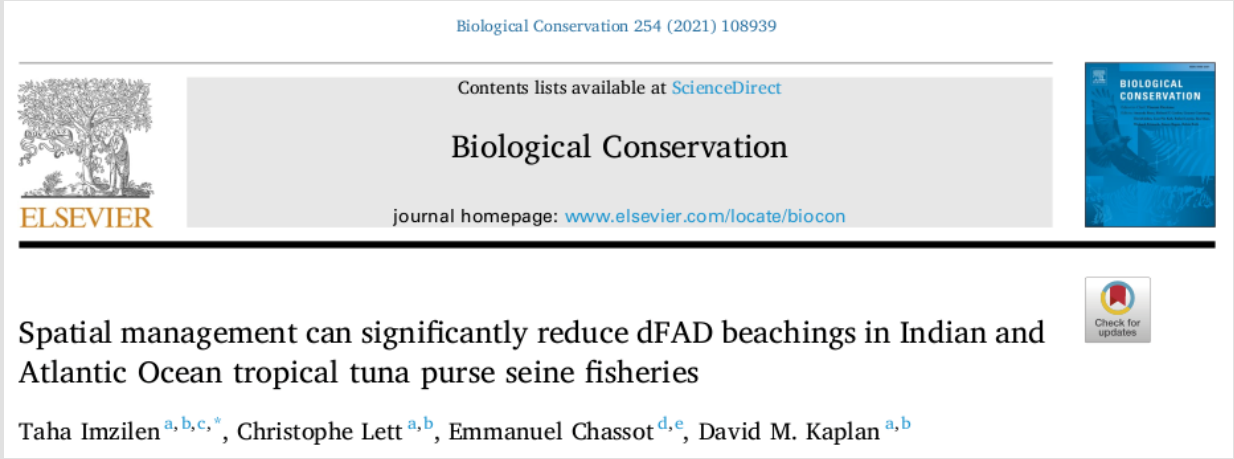
Initial identification by IRD -

- *Uncharacteristically slow movement over extended time period*
- *Two later positions were within 200m of original event*

Only beaching events that met following conditions were further analysed -

- *≤ 10km from major port*
- *Emitting continuous location 3 days prior to event*
- *≥90% of positions by an individual buoy met time and distance criteria above*

Resulted in *3,760* identified beaching events.



Biological Conservation 254 (2021) 108939

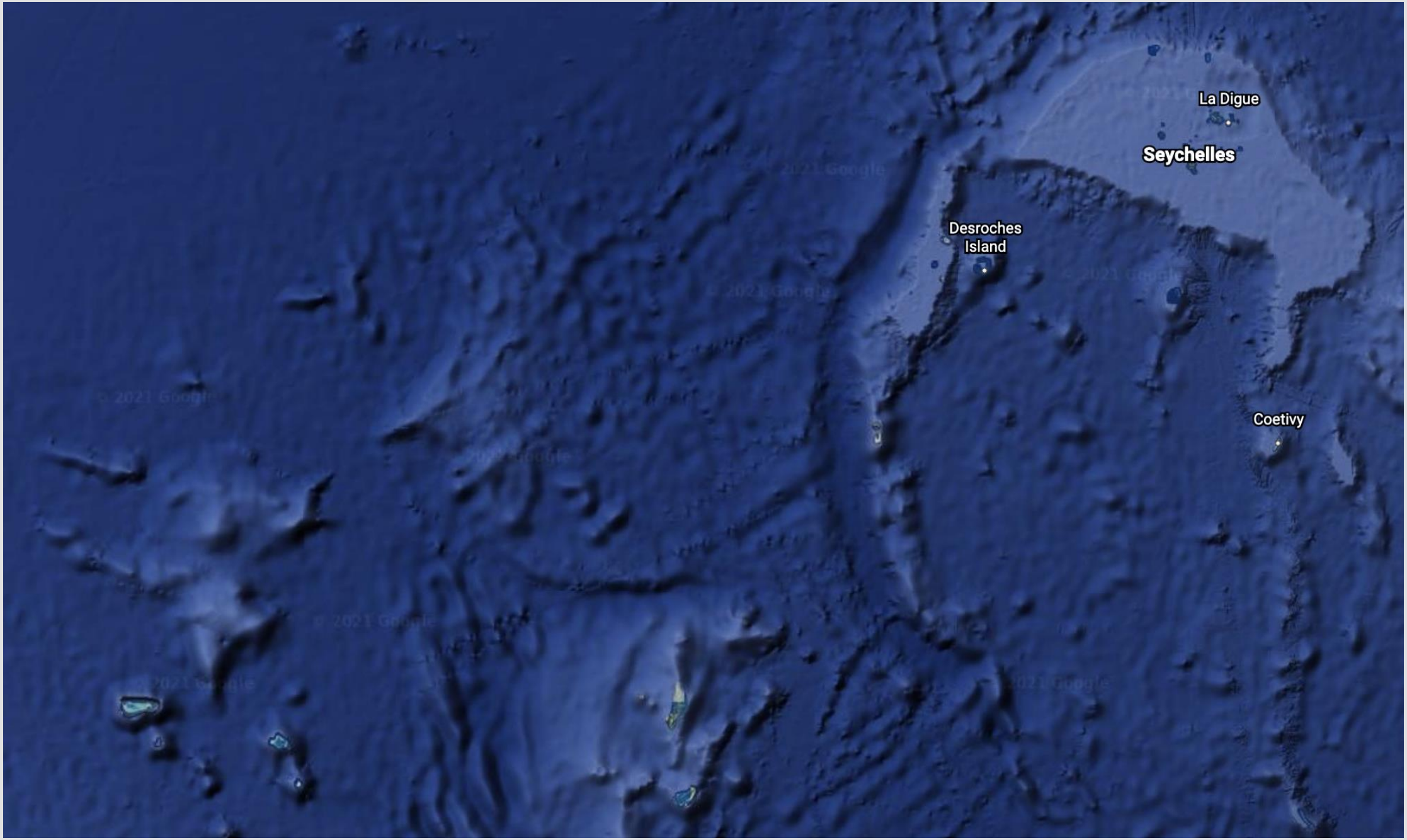
Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Spatial management can significantly reduce dFAD beachings in Indian and Atlantic Ocean tropical tuna purse seine fisheries

Taha Imzilen [a,b,c,*], Christophe Lett [a,b], Emmanuel Chassot [d,e], David M. Kaplan [a,b]


La Digue
Seychelles
Desroches Island
Coetivy

Methods and Results

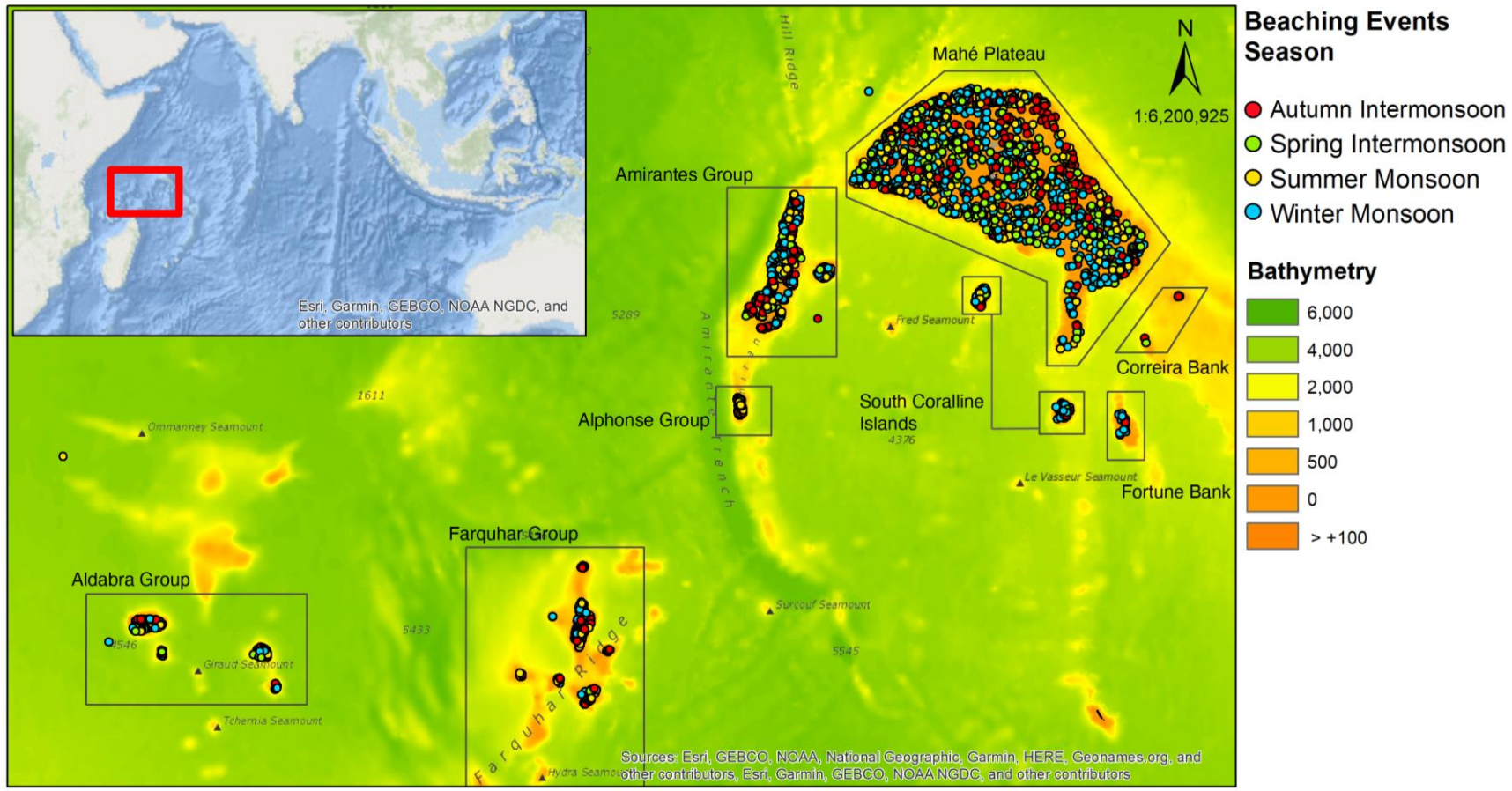


Figure (above). Extent of beaching events across the Seychelles Archipelago, coordinated to season of event and displaying bathymetry of the area. Inset: Location of the Republic of Seychelles within the Indian Ocean.

Beaching events

- 8 island groups
- 3,760 identified events
- Seasonal context
- Bathymetry of region

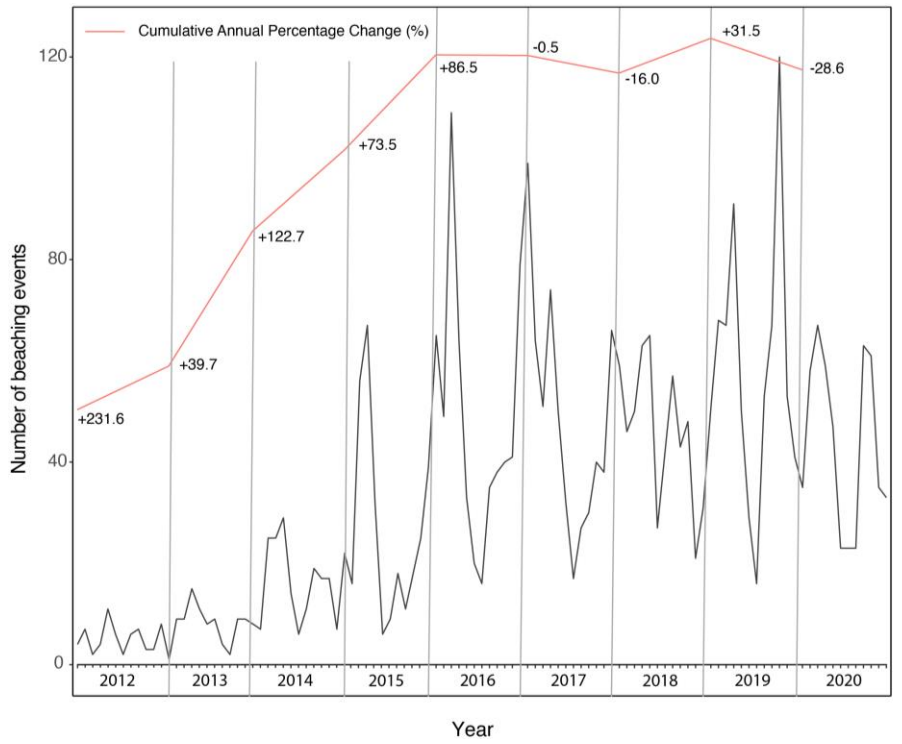
Intra- and interannual trends

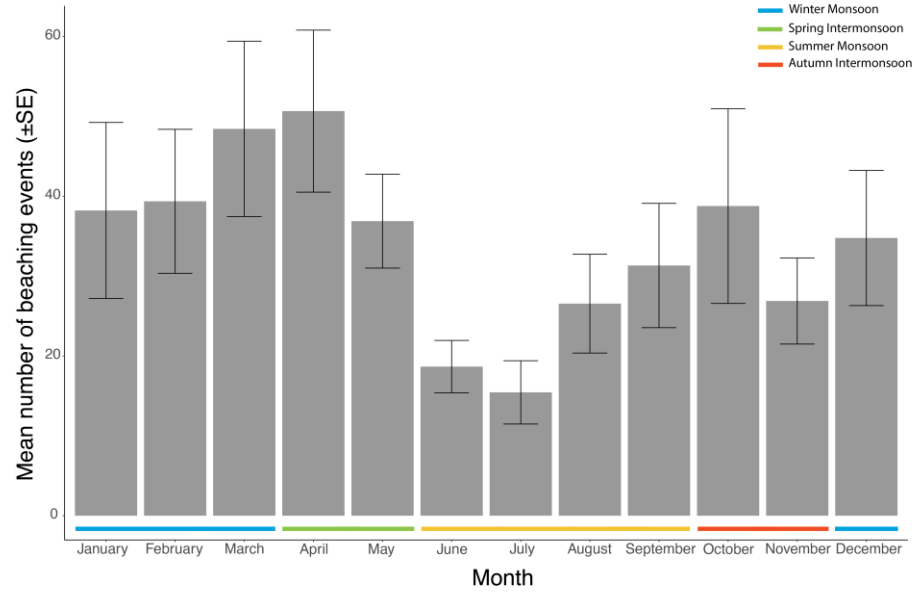
Interannual trends present

- *Exponential increase of beaching events between 2012-2016.*
- *Increased density of active purse seiners around Seychelles*

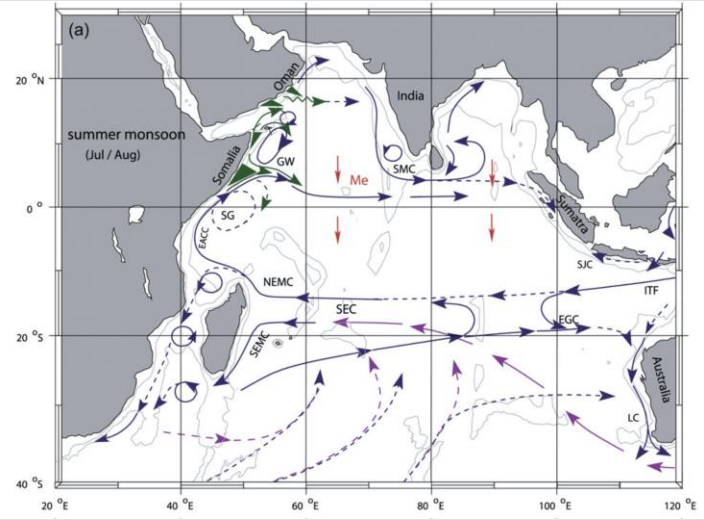
Intra-annual variation indicated influence of seasonality

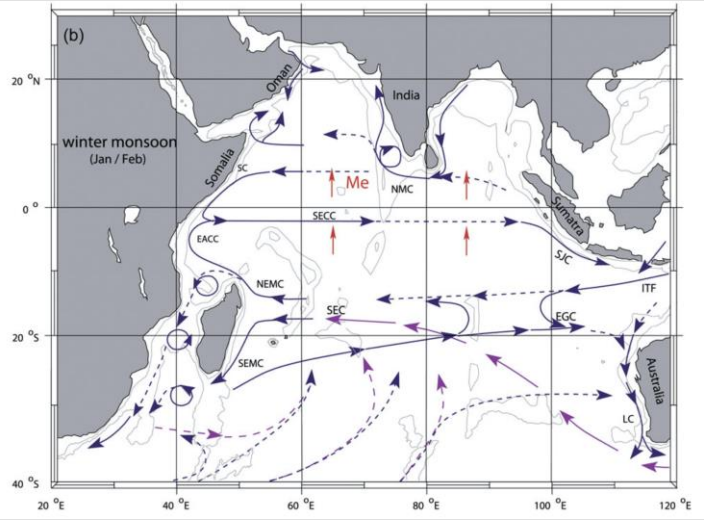
- *Seasonality more marked after 2015, greatest proportion of beaching events occurred within winter monsoon (43.4%), spring intermonsoon (21%), summer monsoon (20%) and autumn intermonsoon (15.6%).*





Seasonal variability driven by NE and SW monsoon regimes





Figures (a & b) schematic depicting circulatory differences derived from Indian Ocean monsoon regime. *Source Kaplan et al., (2015).*

Beaching events were grouped according to the four regimes that affect hydrography in the region;

Southeast monsoon (SE trade winds >20knots, dry and cool climate)

- Spring intermonsoon (April – May)
- Summer monsoon (June – September)

Northwest monsoon (lighter winds <10knots, rainy season, warmer climate)

- Autumn intermonsoon (October - November)
- Winter monsoon (December – March)

Seasonality

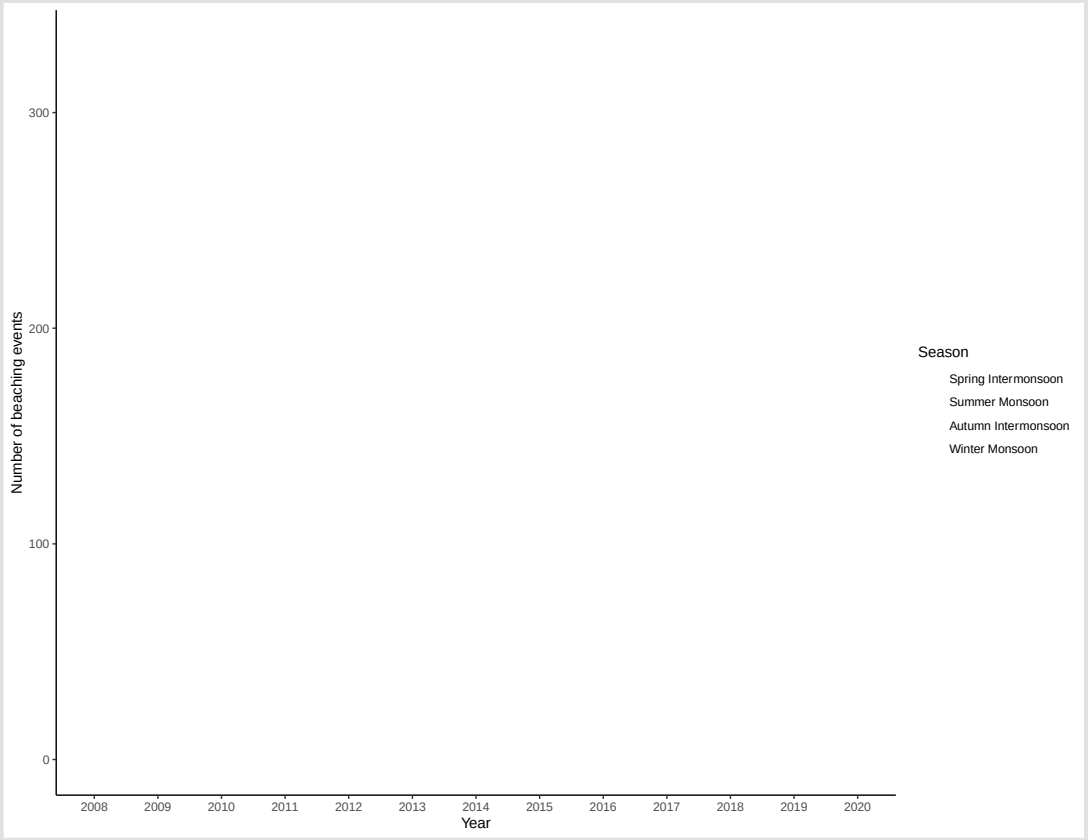


Figure (Left). Number of beaching events that occurred seasonally (2008-2017).

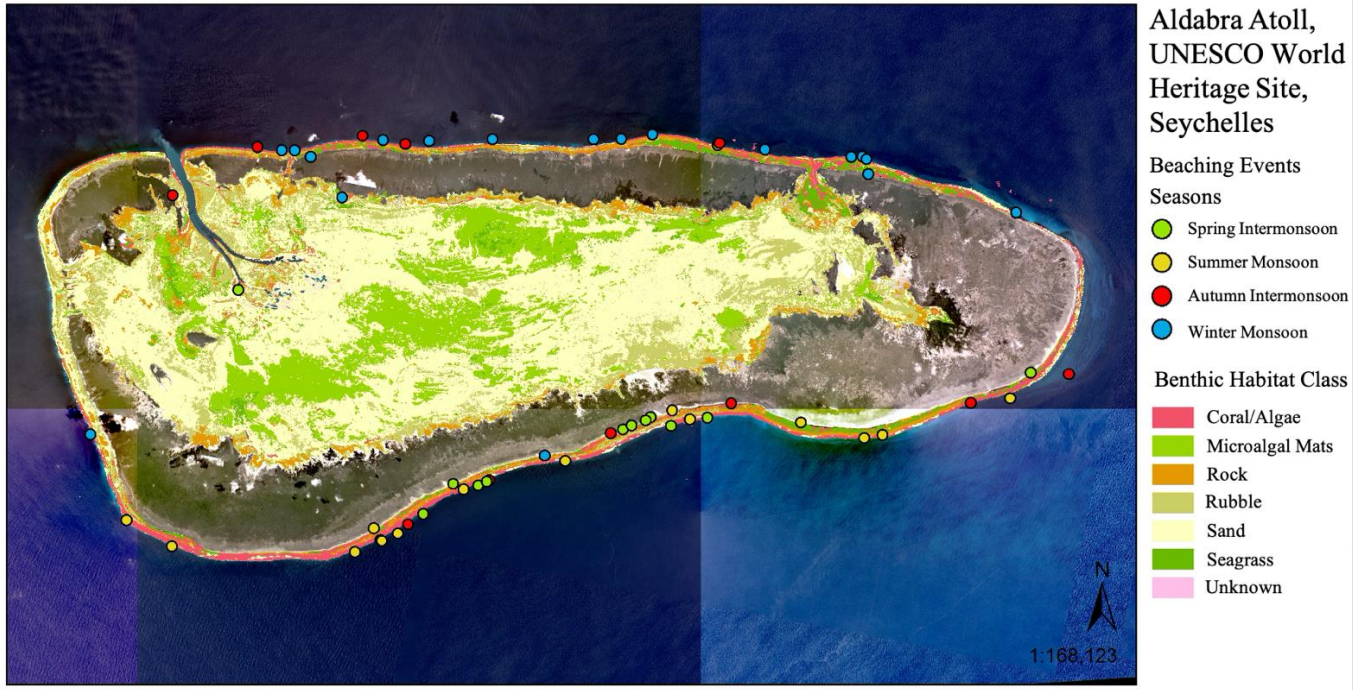
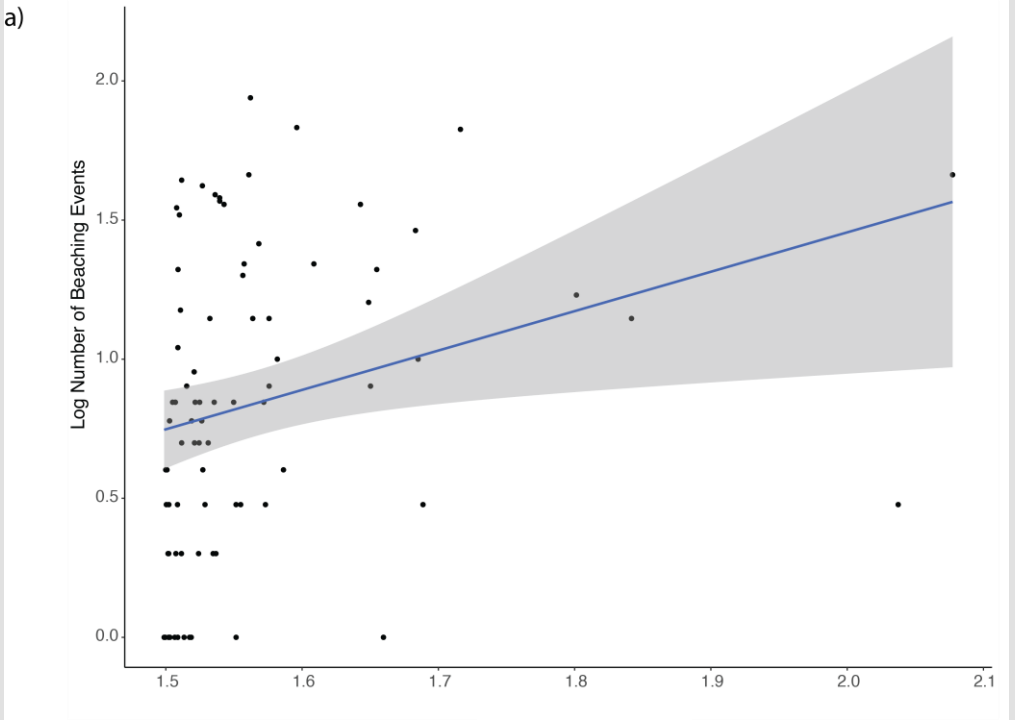
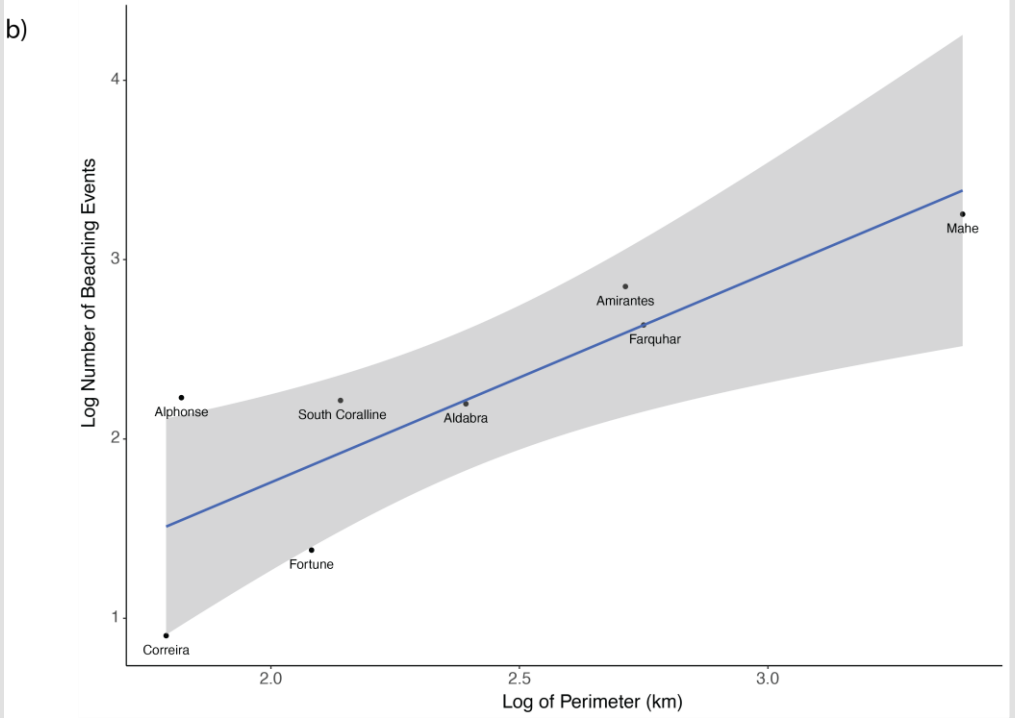


Figure (Right). Benthic habitat composition of Aldabra Atoll, UNESCO World Heritage Site. Benthic habitat adapted from Allen Coral Atlas.

Beaching events per island and island group





- Significant relationship between the number of beaching events and island size.
- High amount of unexplained variance suggested island size is not sole factor influencing beaching event locations within the archipelago
- Large proportion of most impacted islands were the smallest
- However, linear relationship with beaching events and island group size indicates clear driver of distribution

Figure (top). Relationship between log number of beaching events and log perimeter (km) of (a) islands and (b) island groups within the Seychelles (2008-2020). Figure (bottom).

Vulnerability Index

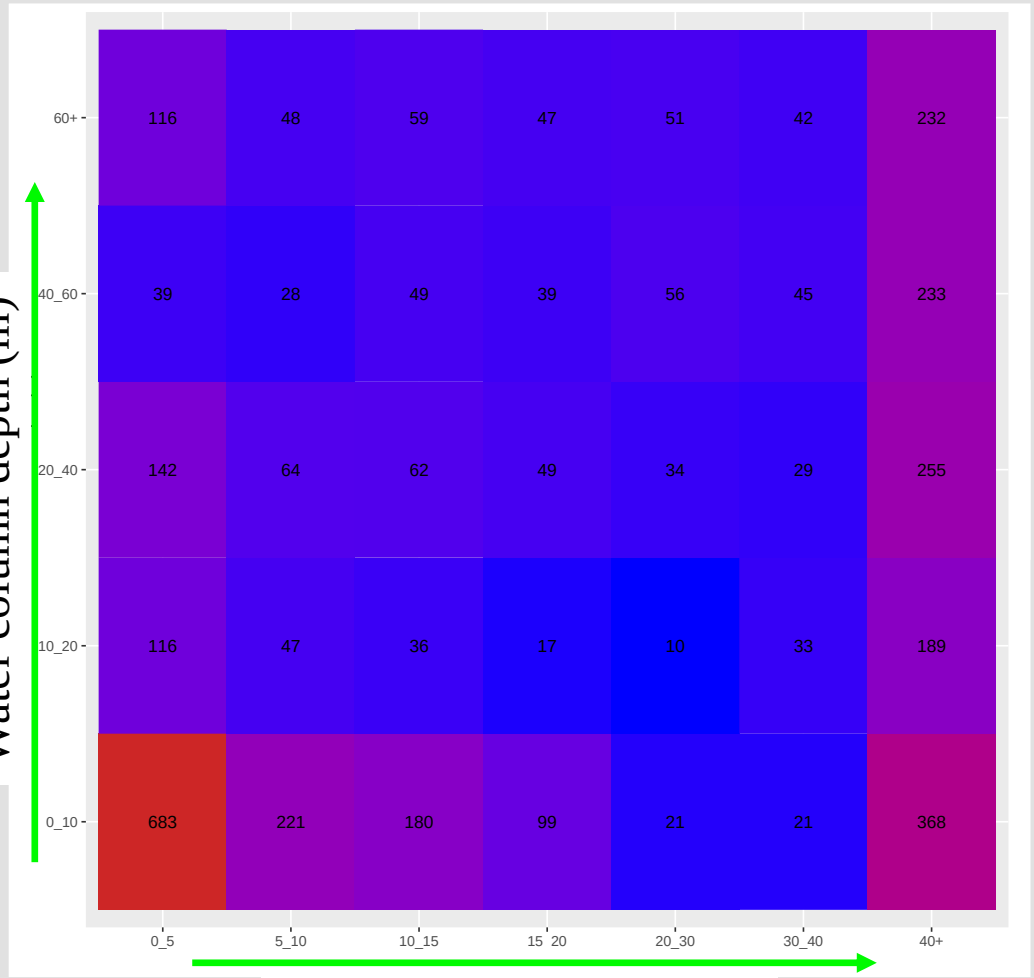


Figure (left). Depth and Distance Vulnerability index. High number of beaching events indicated in red, low number of beaching events indicated in blue. Green arrows denote increasing water depth (m) and increasing distance from shore (km).

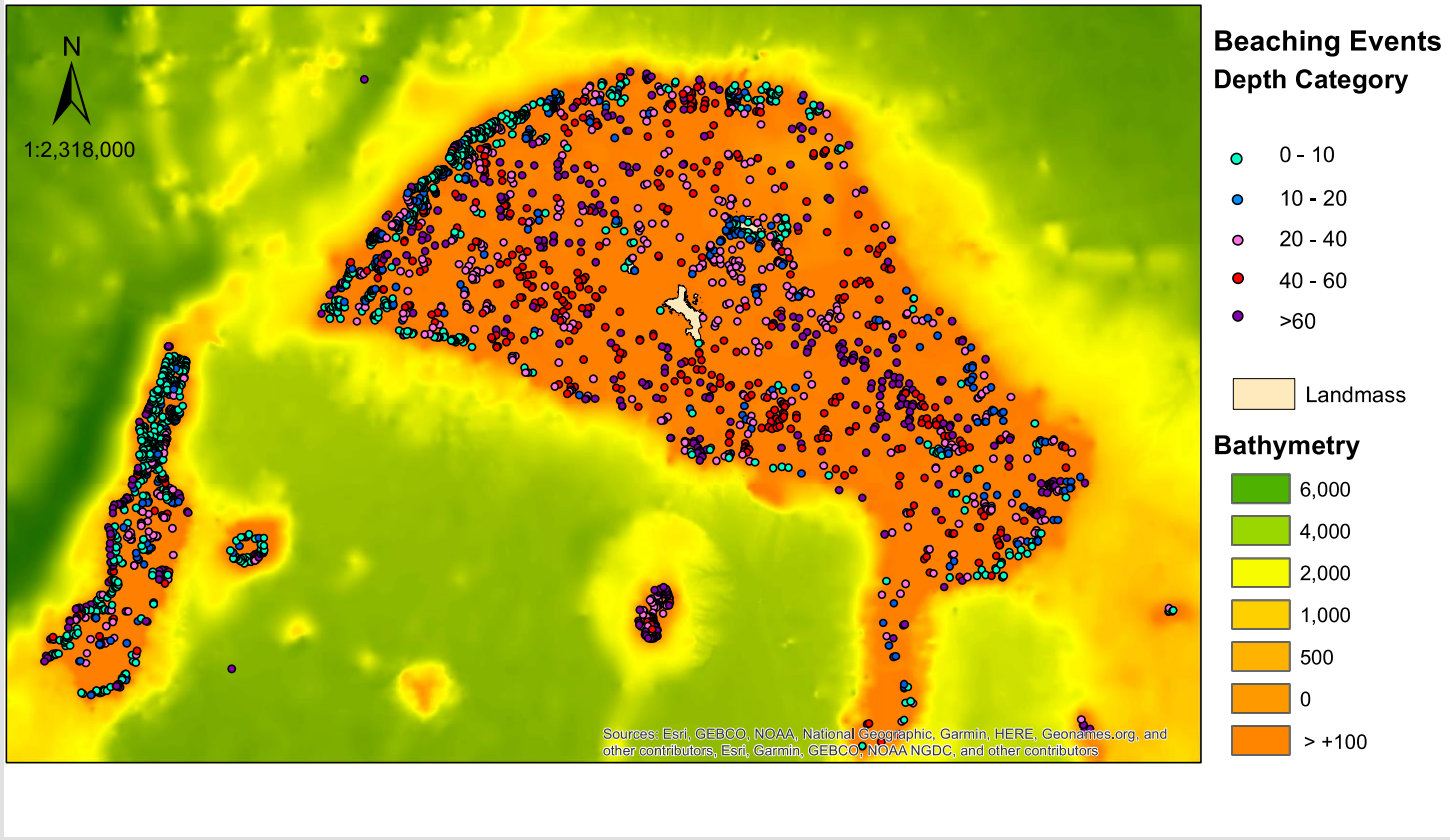
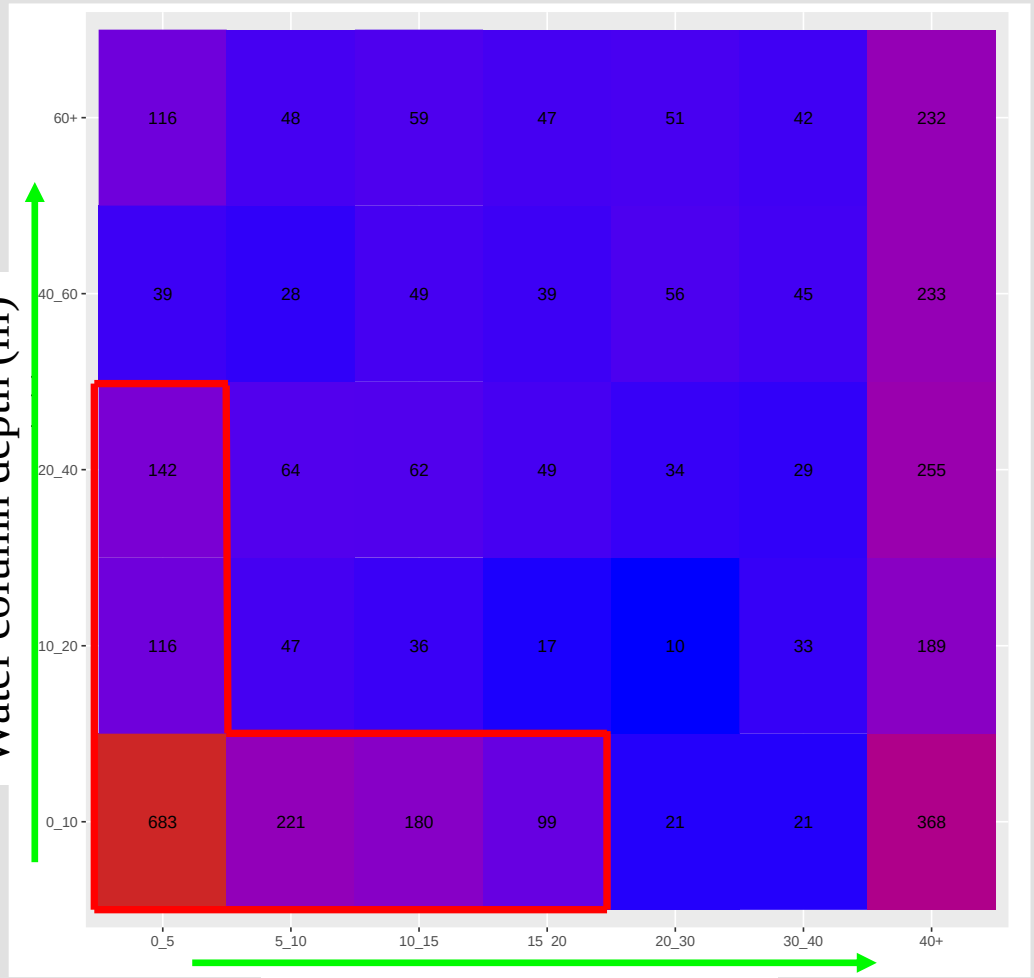


Figure (right). Beaching events by depth category across the Mahé Plateau, Amirantes Bank, including Correira and Fortune Banks.

Vulnerability Index



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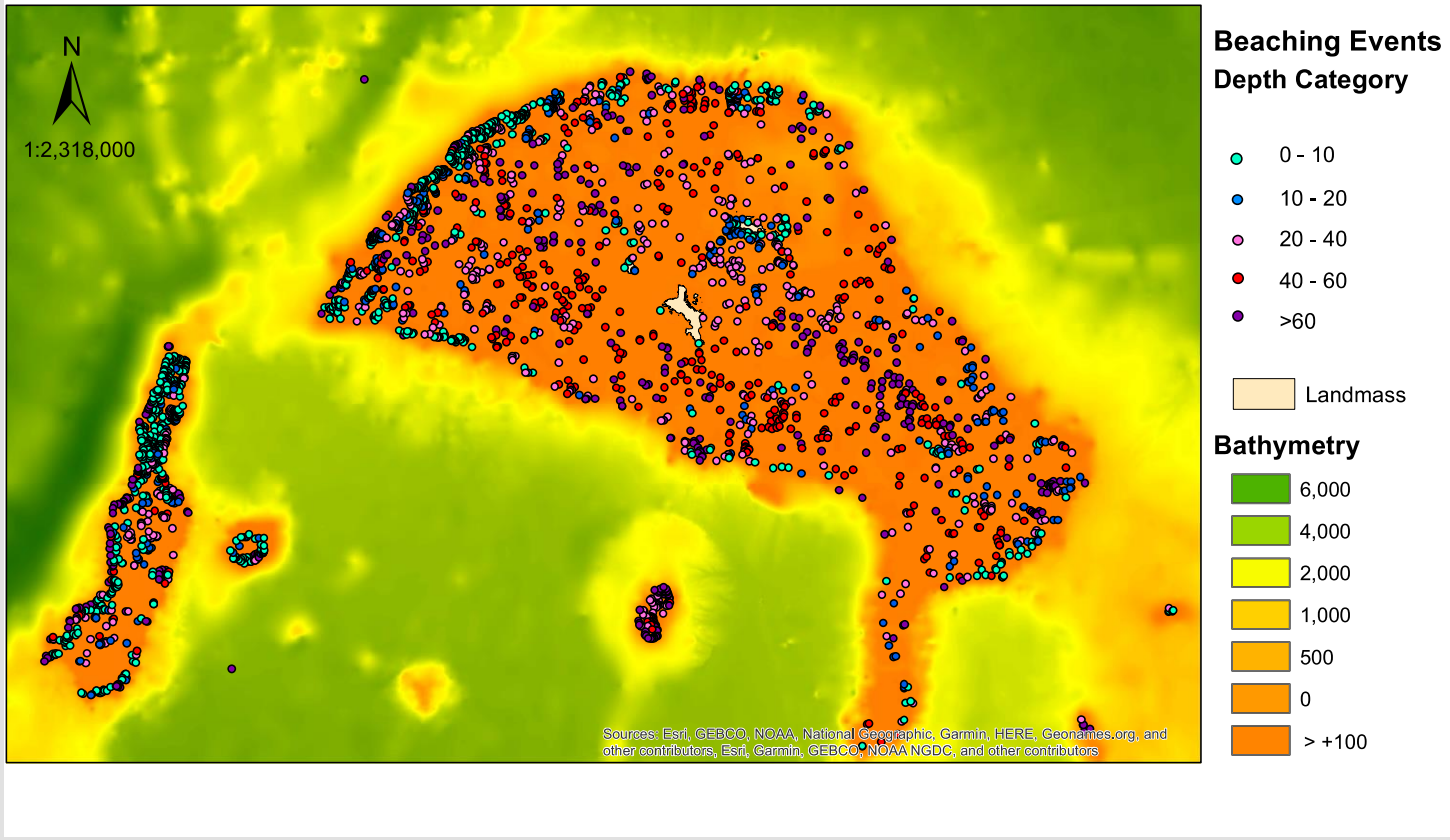

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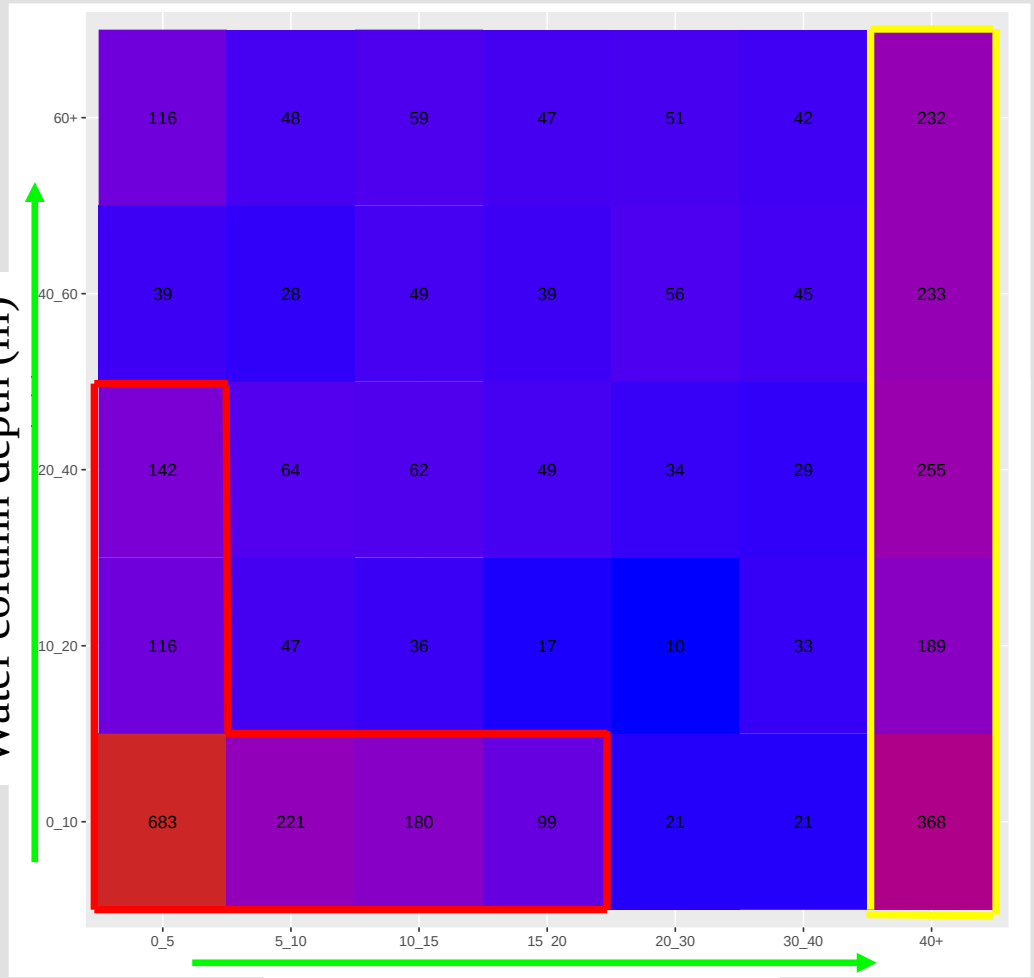
Vulnerability Index



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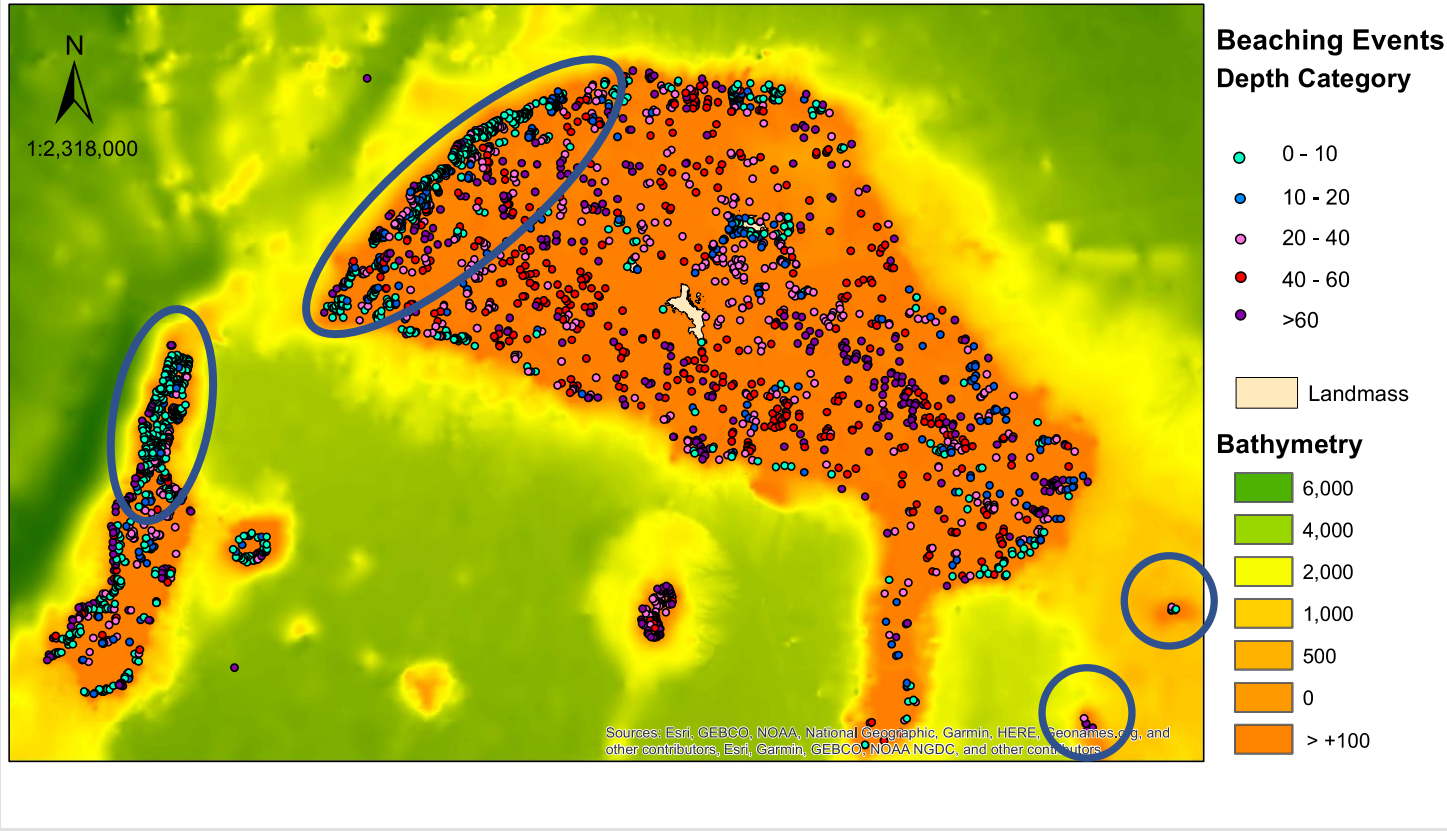

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Rebeaching events

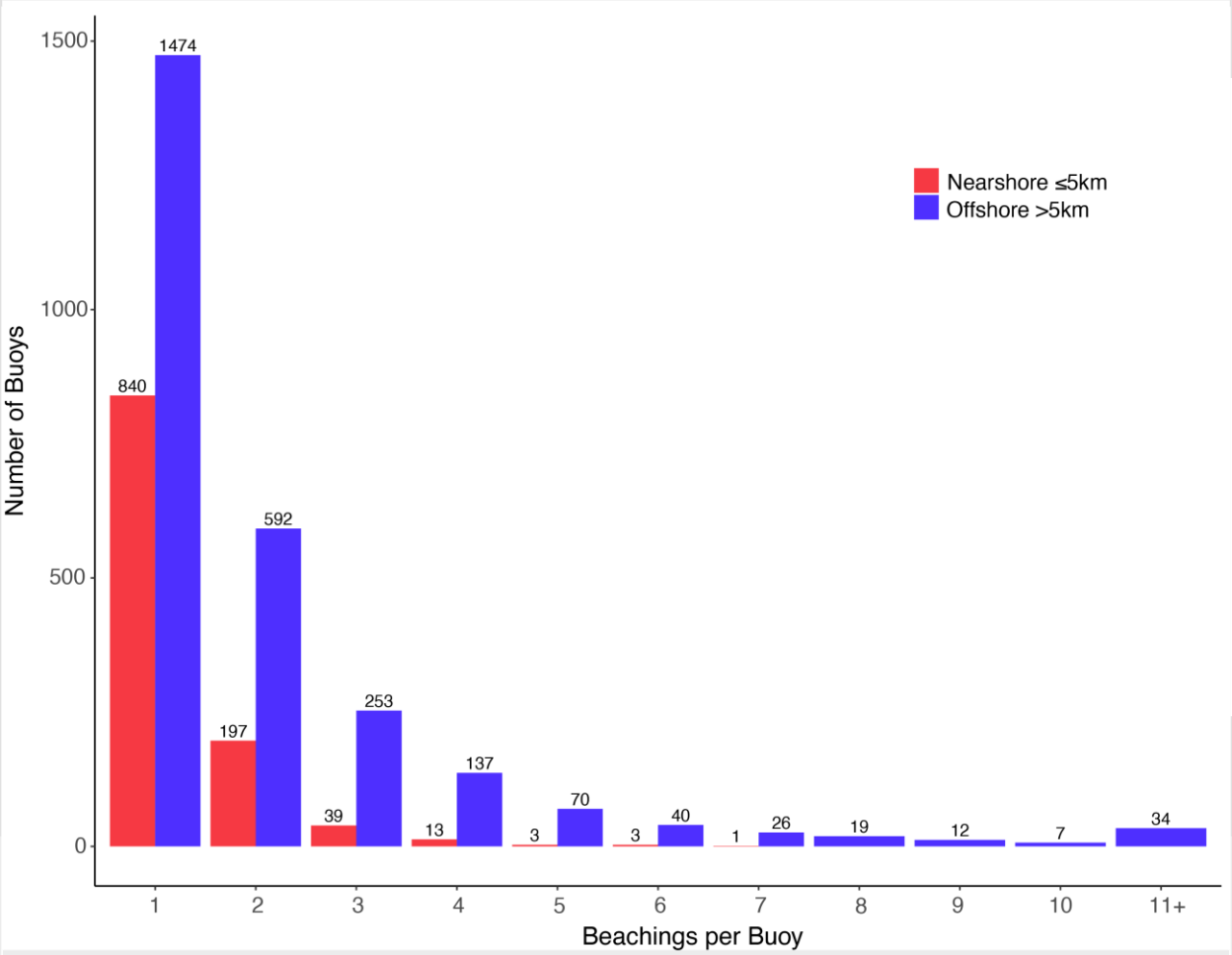


Figure (left). Number of uniquely identified drifting Fish Aggregation Devices (dFADs) that recorded single to multiple beaching/ rebeaching events, comparing nearshore (≤ 5km from shore) and offshore (>5km from shore).

- 3,960 beaching events caused by 2,314 uniquely identified dFADs
- 38.5% of identified beaching events were rebeaching events
- One dFAD rebeached a total of 35 times over a period of 11 months and 8 days.
- The consequences of dFAD beaching events cannot be delimited to one singular event but rather to a series of events, which occurred over an extended area.

Benthic Habitat

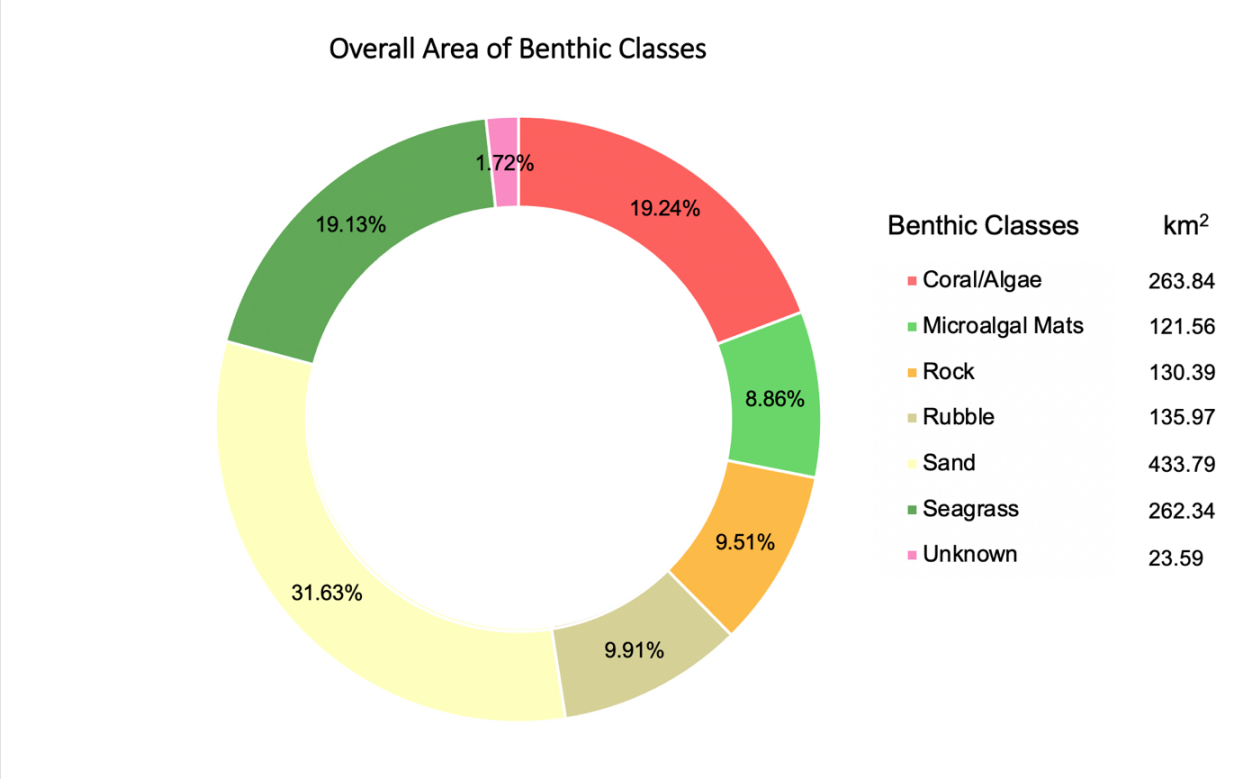


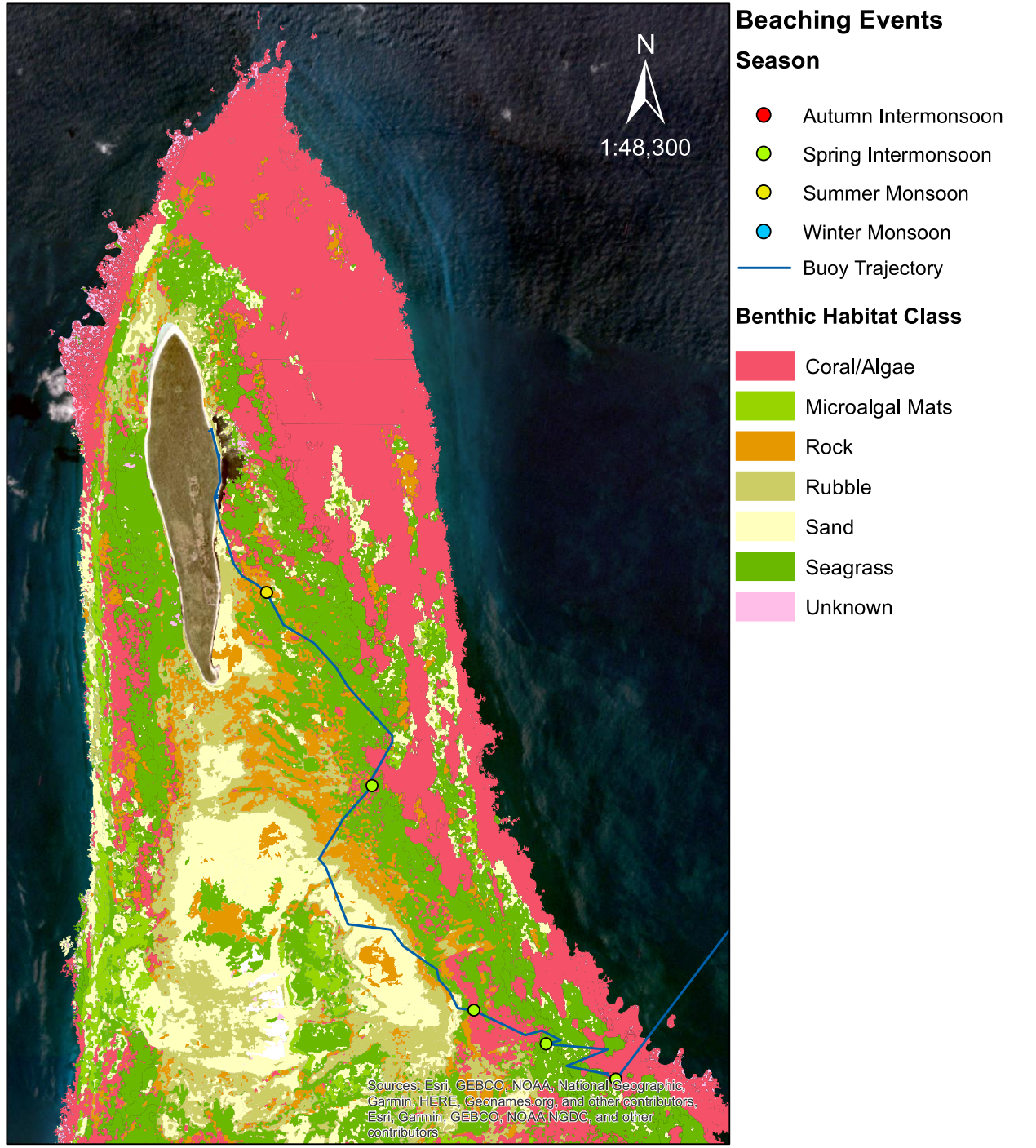
Figure (left). Overall area (% cover and km^2) of benthic habitat classes mapped by Allen Coral Atlas across entire Seychelles Archipelago.

Benthic Habitat Class	Mapped area of each benthic habitat class (km^2)	Total number of beaching events per benthic habitat class	Ratio of the number of beachings to the area of habitat class
Coral/Algae	263.84 (19.24%)	247 (36.6%)	1.9
Microalgal Mats	121.56 (8.86%)	28 (4.2%)	0.5
Rock	130.39 (9.51%)	78 (11.6%)	1.2
Rubble	135.97 (9.91%)	63 (9.3%)	0.9
Sand	433.79 (31.63%)	126 (18.7%)	0.6
Seagrass	262.34 (19.13%)	132 (19.6%)	1

Table (right). Number of beaching events per benthic habitat class (n = 674).

Rebeaching events at Providence Island

- Beaching events of single dFAD (Figure right; green dots) with actual trajectory of travel (blue line)
- Subsurface structure of dFADs up to 80m in length
- Likely dragged through the variety of benthic habitats between beachings.
- dFADs potentially causing damage over a wider area than has previously been considered.



The cost of clean-up

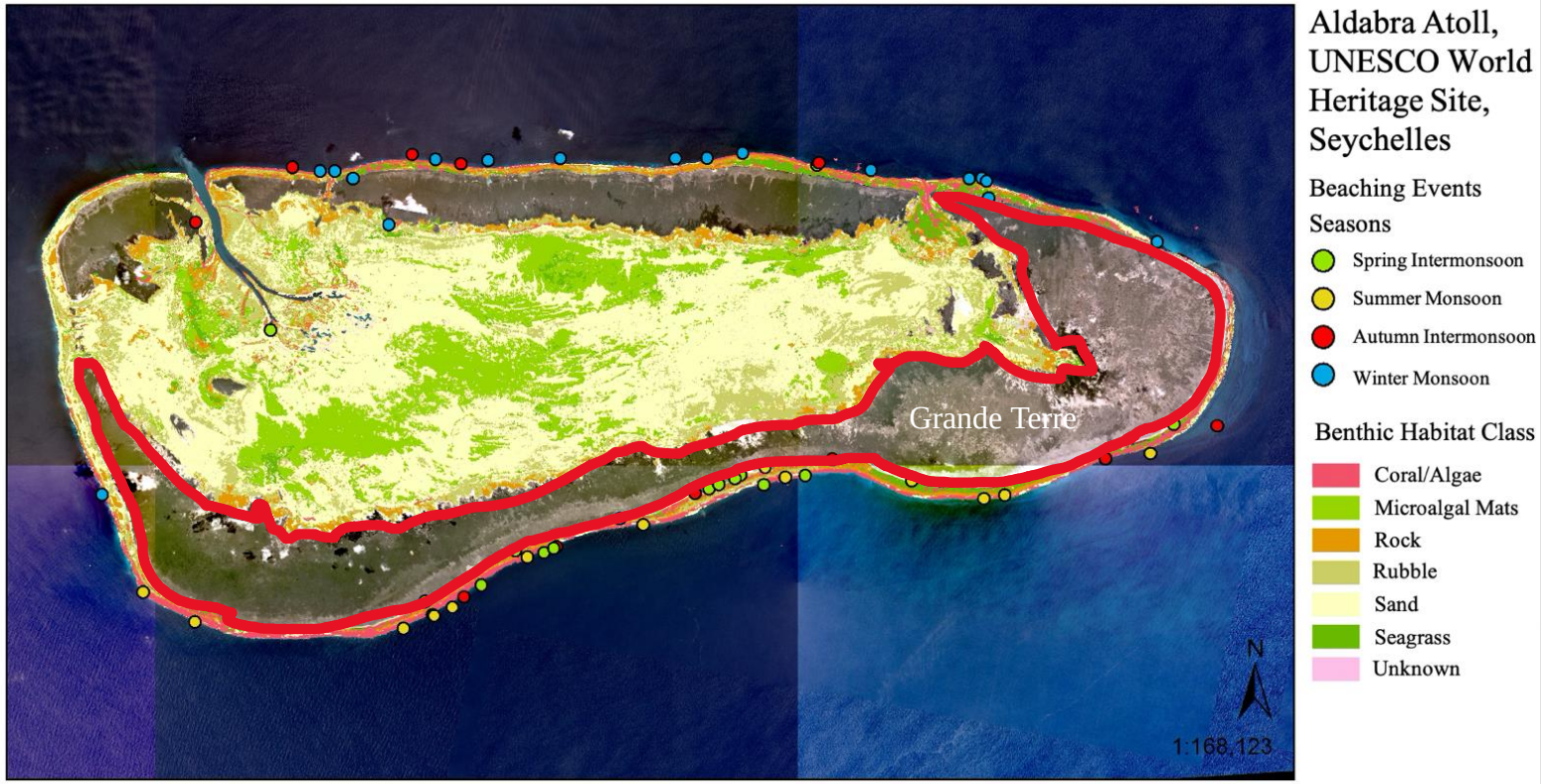


Figure (above). Benthic habitat composition of Aldabra Atoll, UNESCO World Heritage Site, including locations of dFAD beaching events within a seasonal context (2010-2020). Benthic habitat adapted from Allen Coral Atlas.

- Seychelles Island Foundation conducted clean-up operation on at Grande Terre island (Burt *et al*., 2020)
- 26.5 tonnes of marine plastic litter collected in 5 weeks
- Included 13 dFADs
- Remaining litter estimated to be 513.4 tonnes
- Fishing related items contributed ~83%
- Clean-up of entire island of Grande Terre estimated to be US$4.68 million

Alphonse Island Group

- St François, small island (area), was most impacted island
- In 2015, 40 beached dFADs were removed as part of a scientific study from the surrounding marine environment of St François (Balderson & Martin, 2015).
- Seven of the 40 dFADs retrieved from St François were within extremely close proximities (<0.12 km) to the dFAD beaching events within the present study.
- Offers a promising validation of the conditions implemented to identify beaching events within this study
- this method may be an effective tool in estimating the non-effective fishing effort that is derived from FADs drifting out of the fishing grounds

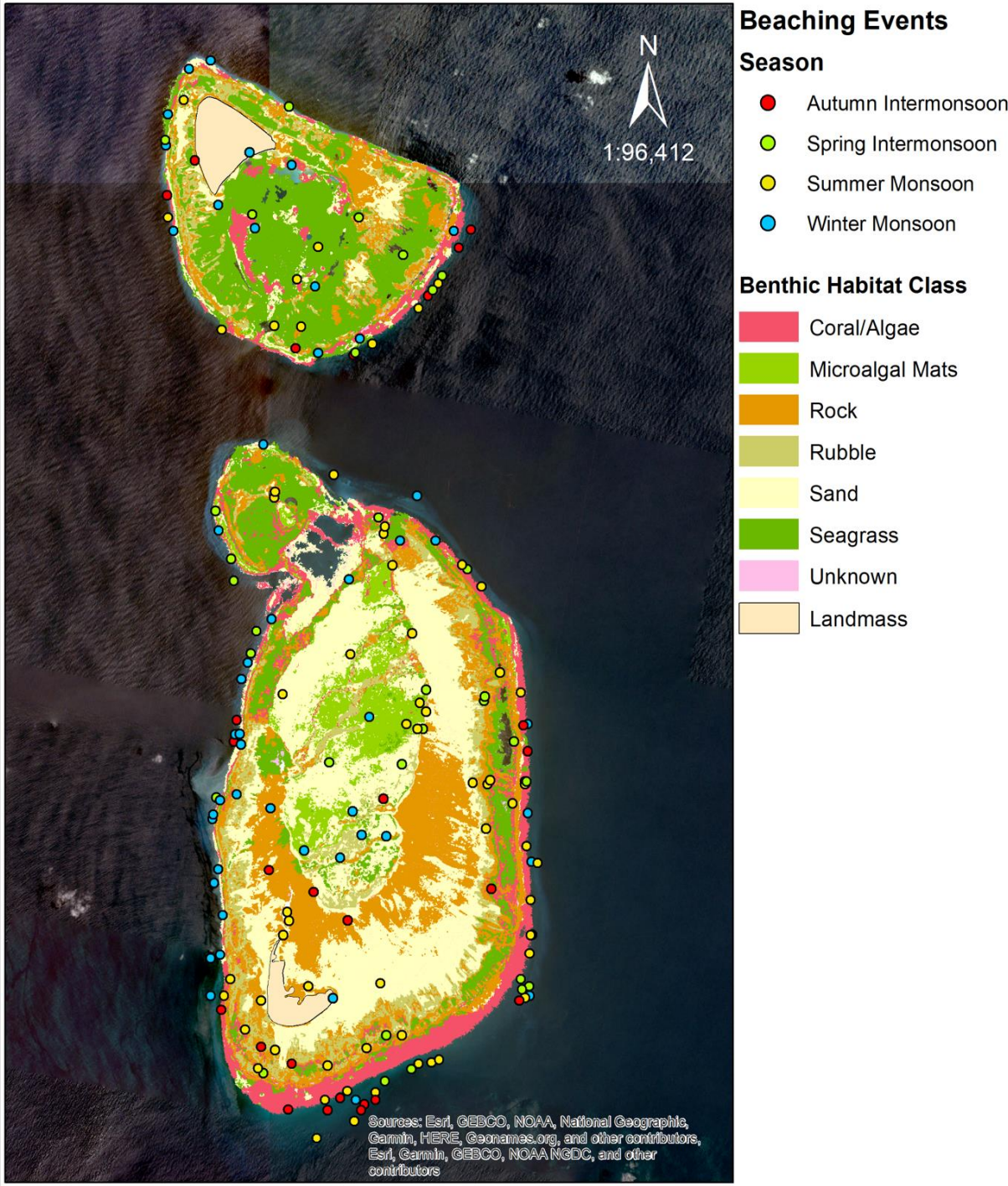


Figure (right). Benthic habitat map of the Alphonse Group (North to South: Alphonse, Bijoutier and St François, whereby Alphonse has an area of 1.71km^2 and the Alphonse Group has a total area of 19km^2, including reef flat and lagoon. Comparatively, Mahé is recorded to be 157.3km^2) including the locations of dFAD beaching events within a seasonal context (2008-2020). Benthic habitat adapted from Allen Coral Atlas.

Conclusion

- Stable rate since 2016 indicating seasonality; Winter season most important since 2016;
- Area contained in 100m isobath decent overall predictor of beaching rate;
- Rebeachings are a regular occurrence, particularly in shallow water and offshore areas, spreading impacts;
- Corals/Algae receive far more beachings than one would expect based on area.

Thank you for listening, any questions?

Acknowledgments

We are grateful to University of Plymouth for funding this research. Thanks to the Allen Coral Atlas (ACA) for providing open-source fine resolution benthic habitat mapping. We would also like to thank Pierre-André Adam, Head of Science and Projects at the Island Conservation Society, for providing the sample of FAD data from Alphonse Group which allowed direct comparisons of our beachings and those reported in Balderson and Martin (2015).

We thank Laurent Floch and other members of the Pelagic Ecosystem Observatory (Ob7) of the MARBEC laboratory for data preparation and management. We also thank the three French tuna companies, Compagnie Française du Thon Océanique (CFTO), SAPMER and Via Océan, for making their dFAD tracking data available without which this study would not have been possible.

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