EGU26 GENERAL ASSEMBLY

Coastal resilience and island habitability in coral reef islands: A case study of Lakshadweep Islands

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This presentation participates in OSPP
EGU
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Introduction

Low–lying coral islands - rising sea levels & climate change. Erosion and submergence – land loss –present a considerable **risk to island habitability** - ***India is among the high-risk countries.***
The island's response to inundation – **both site-specific & global.**
The northern and western Indian Ocean - anomalous warming– **Lakshadweep at high risk**
Lakshadweep Archipelago – 36 islands – 10 inhabited.
Elevation – 0.5 – 6m.
Population – 64, 345 (2011 Census)

1) to identify regions of erosion v/s accretion from 2003–2022
2) to identify various causal mechanisms responsible for shoreline morphological variations

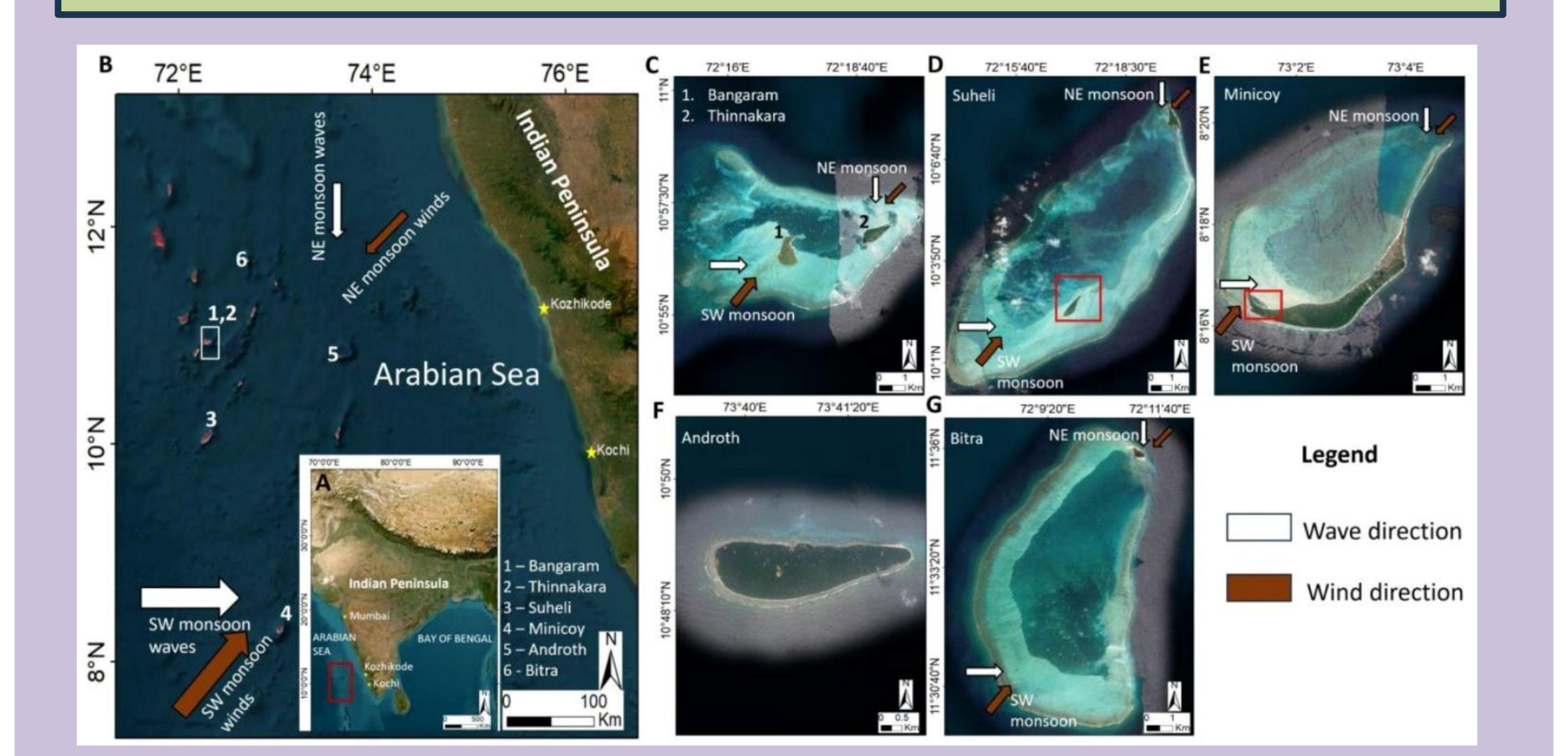


Fig 1: (A) Map of India with the location of the Lakshadweep Archipelago. (B) Map of Lakshadweep. The arrow marks depict the local prevailing wind directions during the SW and NE monsoon. (C–G) Satellite images of the islands in this study along with the hydrodynamic conditions depicted for each island during the SW and NE monsoon seasons. (C) Bangaram (1) and Thinnakara (2). (D) Suheli. (E) Minicoy. (F) Androth. (G) Bitra.

Methodology

Island	Uninhabited Inhabited	Size	Years Studied
Thinnakara	U	0.63	2003,2007,2011,2014, 2016,2017,2022
Suheli	U	0.38	2004,2006,2009,2014, 2016,2020,2021
Bangaram	U	0.62	2003,2005,2007,2011, 2015,2017,2018,2022
Bitra	I	0.17	2004,2007,2014,2017, 2022
Minicoy	I	4.8	2007,2014,2016,2018, 2019,2021
Androth	I	4.9	2011,2014,2015,2021

Satellite geomorphological studies obtained from CNES/Airbus (0.3 – 0.7m resolution).
All images collected post – monsoon (October – January)
Upto 3% variation – stable (Kench et al., 2018)

Shoreline Morphological Variations

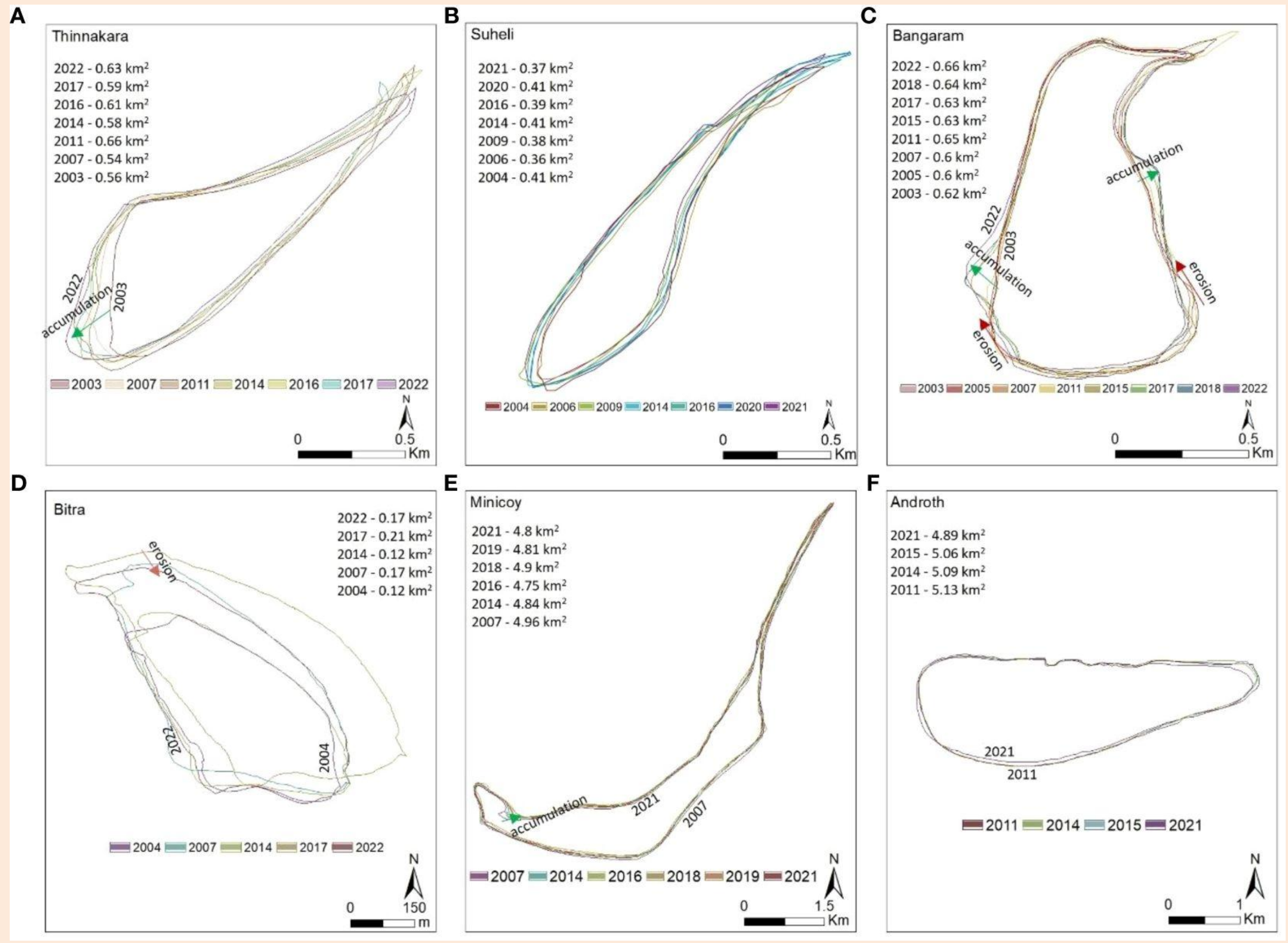
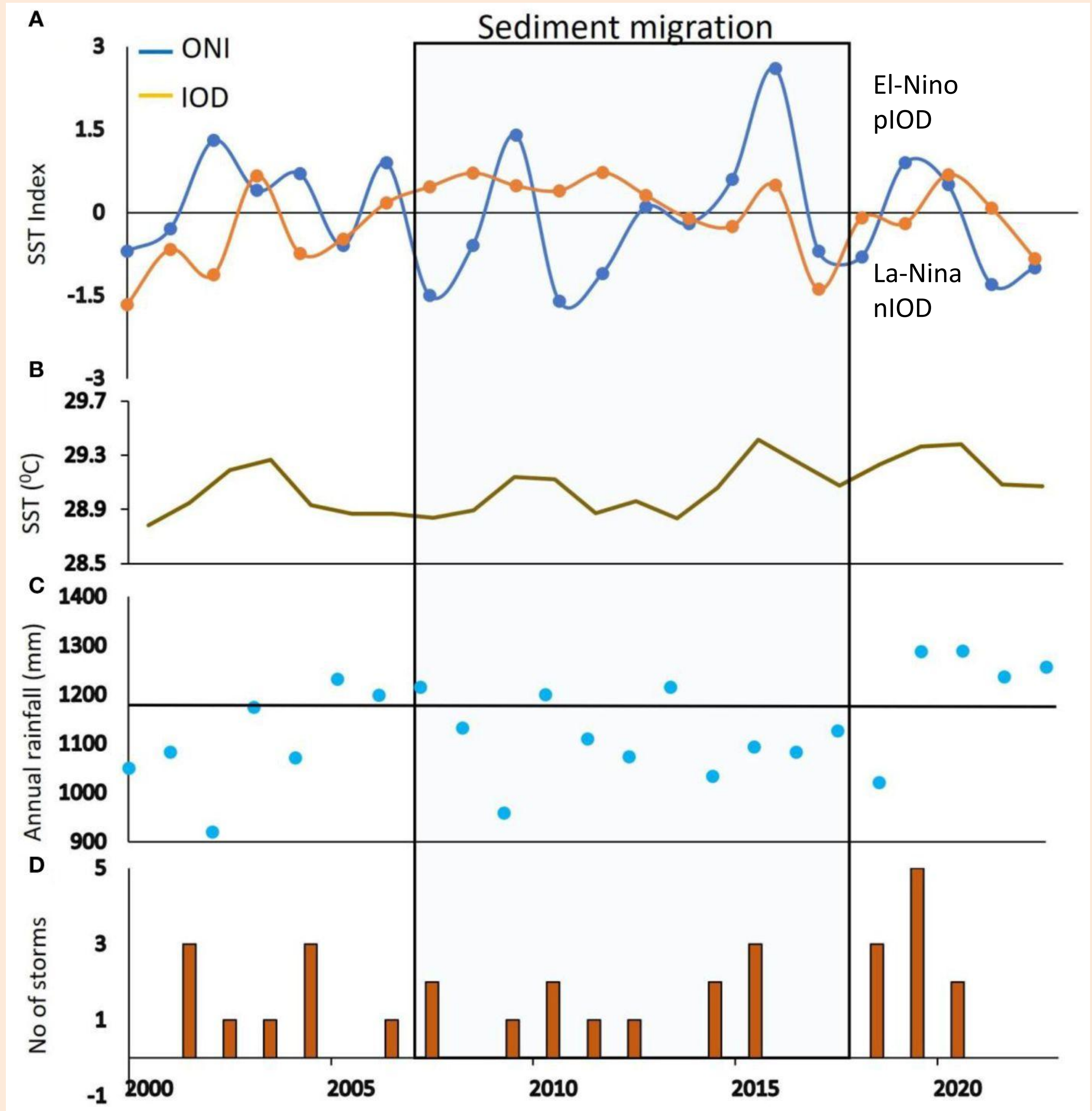


Fig 2: Shoreline morphological variations from 2003 – 2022; along with changes in area.



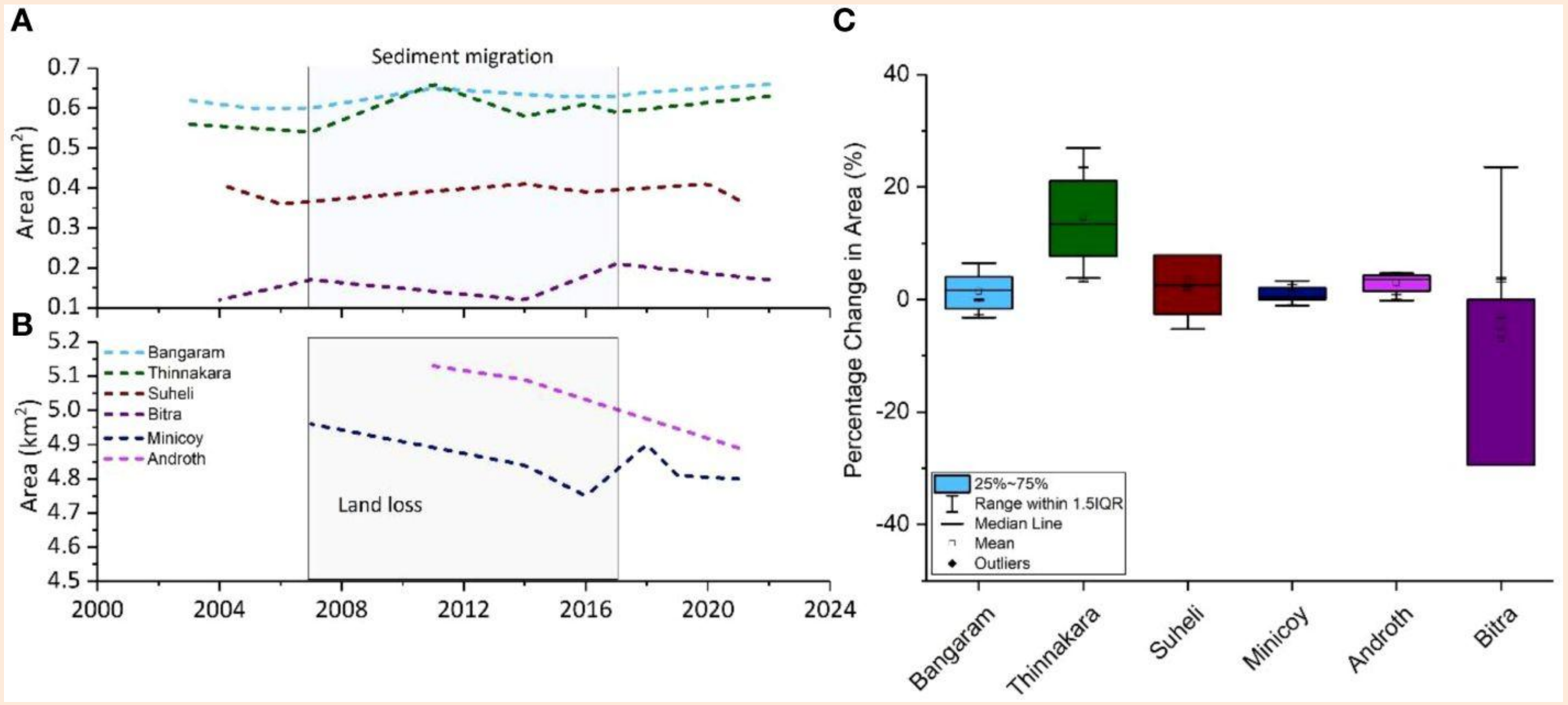


Fig 3: (A) Variation in absolute area with time for the small islands. The rectangle depicts the timeline with the greatest extent of change for the small islands. (B) Variation in absolute area v/s time for the large islands, with rectangle depicting overall land loss over time. (C) Percentage change with respect to island area for each island..

- Greatest extent of change for small islands – 2007 – 2017. Large islands – erosion through time.
- No particular variation in trend for inhabited/uninhabited small islands.
- Total percentage of change greater for smaller islands (upto 30%), however, this **stable** over time.
- Large islands – overall percentage <10% ; however; **constant land loss**.

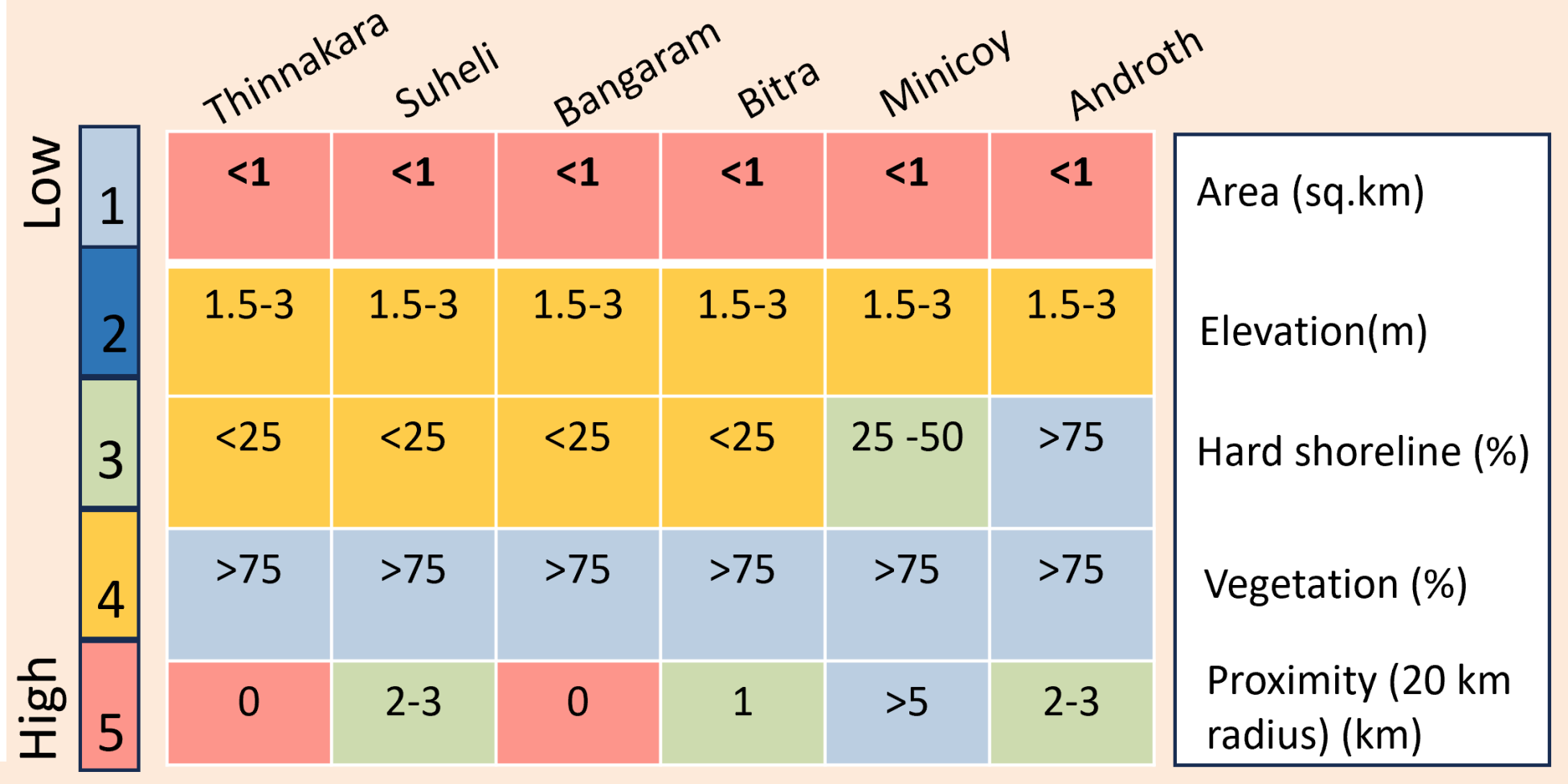
Ocean-atmospheric interactions – ***El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD)*** – variations in intensity and magnitude of monsoon over Indian Ocean.
El-Nino events – low rainfall intensities over Lakshadweep
La-Nina events – high rainfall over Lakshadweep
Positive IOD – Higher intensity of rainfall over Lakshadweep
Negative IOD – Lower intensity of rainfall over Lakshadweep

2003 – 2007 – ENSO amplitude not high; IOD consistently negative
2007 – 2016 – ENSO amplitude high – severe El – Nino; pIOD phases prominent – island size decreases
2016 – 2022 - Rainfall intensities increase – island growth and stabilization

However, no such changes for large islands – island morphology and presence of space – island growth → constant erosion with greater monsoon intensities.

Anthropogenic factors – tetrapods –Bangaram, Minicoy & Androth
Bangaram – south of Island – erosion
Overall, erosion in areas of tetrapods – ***ineffectiveness of current coastal management systems***

Fig 4: (A) Graph illustrating the El Nino-La Nina Index (ONI) (blue) and the Indian Ocean Dipole Index (ODI) (orange). (B) Graph of average annual sea surface temperatures over the Arabian Sea (near Lakshadweep). (C) Annual rainfall over India from 2000 – 2022. (D) Histogram of the number of storms in the Arabian Sea (near Lakshadweep) from 2000 – 2022. The light blue shaded rectangle corresponds to the years with the greatest variation in shoreline morphology (migration of sediments).



	Thinnakara	Suheli	Bangaram	Bitra	Minicoy	Androth	
Low 1	<1	<1	<1	<1	<1	<1	Area (sq.km)
2	1.5-3	1.5-3	1.5-3	1.5-3	1.5-3	1.5-3	Elevation(m)
3	<25	<25	<25	<25	25 -50	>75	Hard shoreline (%)
4	>75	>75	>75	>75	>75	>75	Vegetation (%)
High 5	0	2-3	0	1	>5	2-3	Proximity (20 km radius) (km)

Resource risks for Lakshadweep based on island morphometrics
Small islands – Moderate to high risk
Large islands – Low to moderate risk
However, morphological variations driven by monsoon
→ Small islands – sediment migration – confined resource risks
→ Large islands – erosion – low risk

Fig 5: Resource risks for the islands modified from Fellowes et al., 2023. Since the climatic conditions are similar, these have been neglected.

Implications - Vulnerability

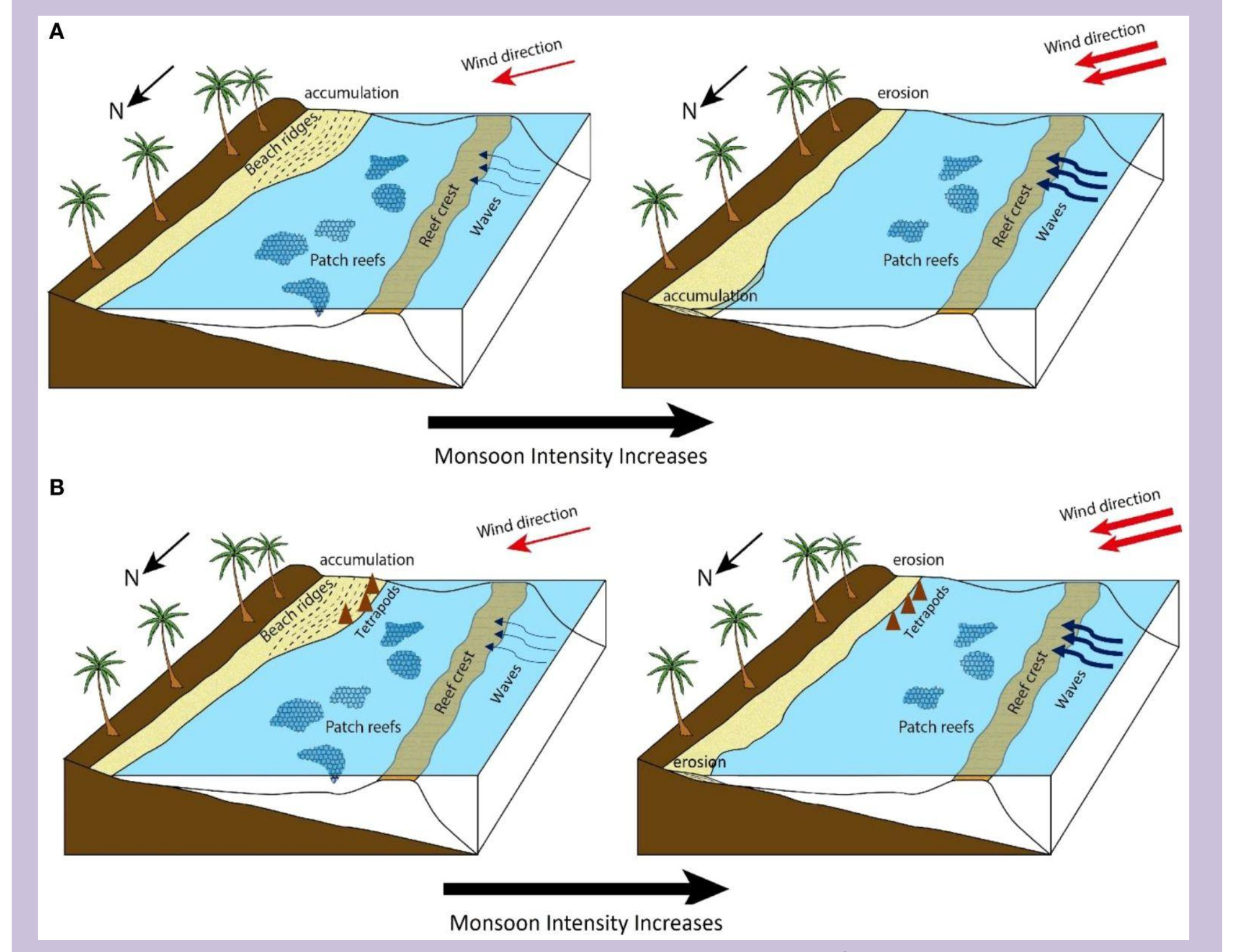


Fig 6: (A) The shoreline morphological variations for **smaller islands - preferential erosion (south) and accumulation (north)** with increase in monsoon intensities and coral abundance decreasing (ocean warming). (B) For **larger islands - erosion and land loss.** Additionally, the breakwaters have had no significant impact in protecting the coastline.

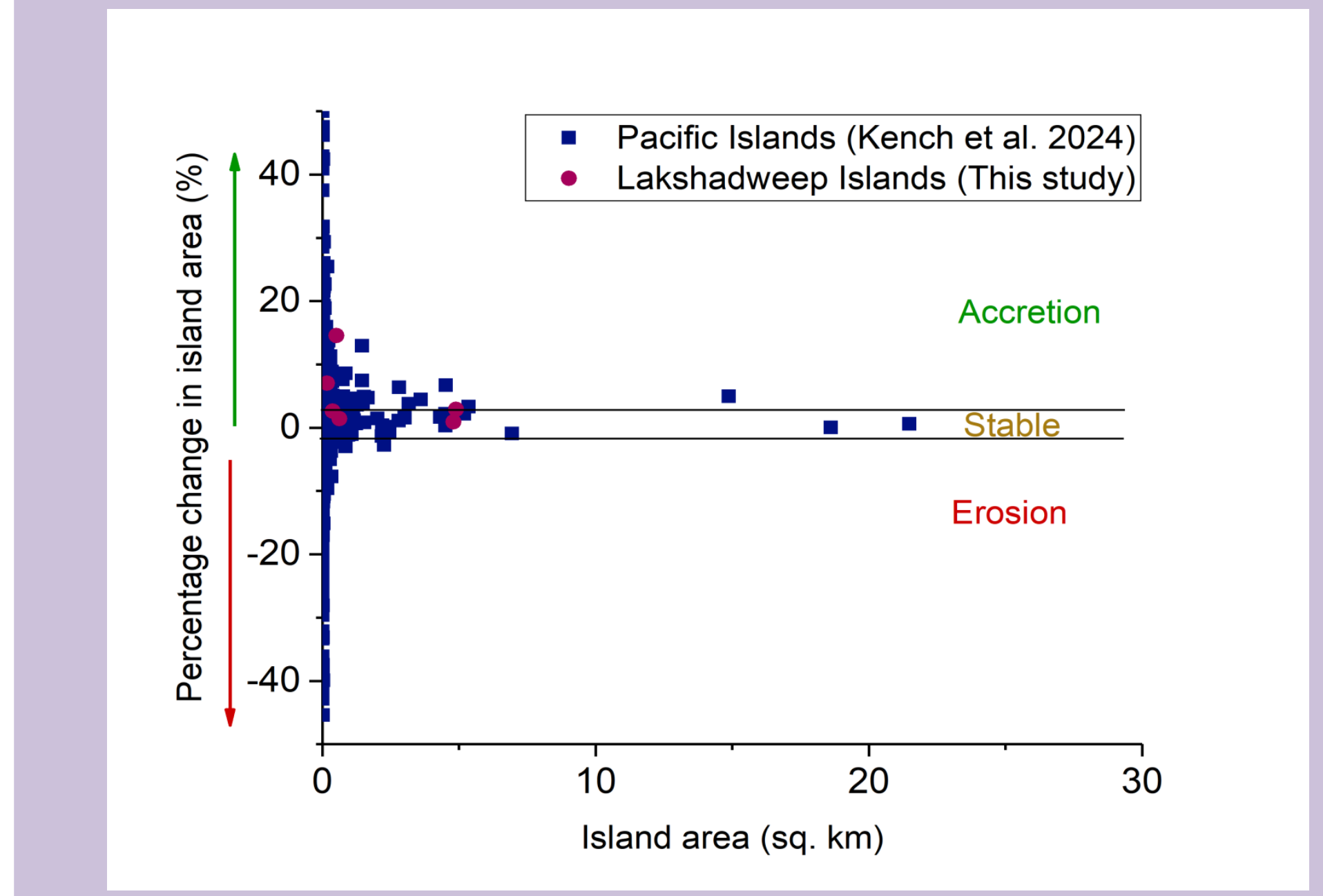


Fig 7: Comparison with Pacific carbonate islands show that the Lakshadweep Islands are **smaller in size, yet stable and or largely accreting** in decadal timescales. However, sediment migration presents resource risks.

Conclusion

Sediment transport and shoreline morphological variations – driven by monsoon – modulated by ENSO and IOD - implications in the scenario of varying monsoon intensities
Island vulnerability –
small islands – low to moderate risk – migration of sediments
Large islands – low – land loss (<5% percentage change)
Need to consider site-specific factors as response non-uniform.

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