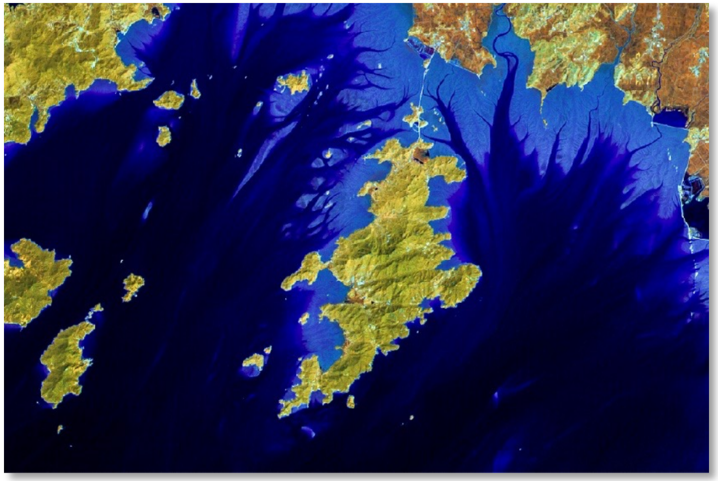
Monitoring coastal ecosystems from space



Dr Nicholas Murray

ARC Research Fellow & Senior Lecturer
Global Ecology Lab
Marine Data-Tech Hub

James Cook University, Australia

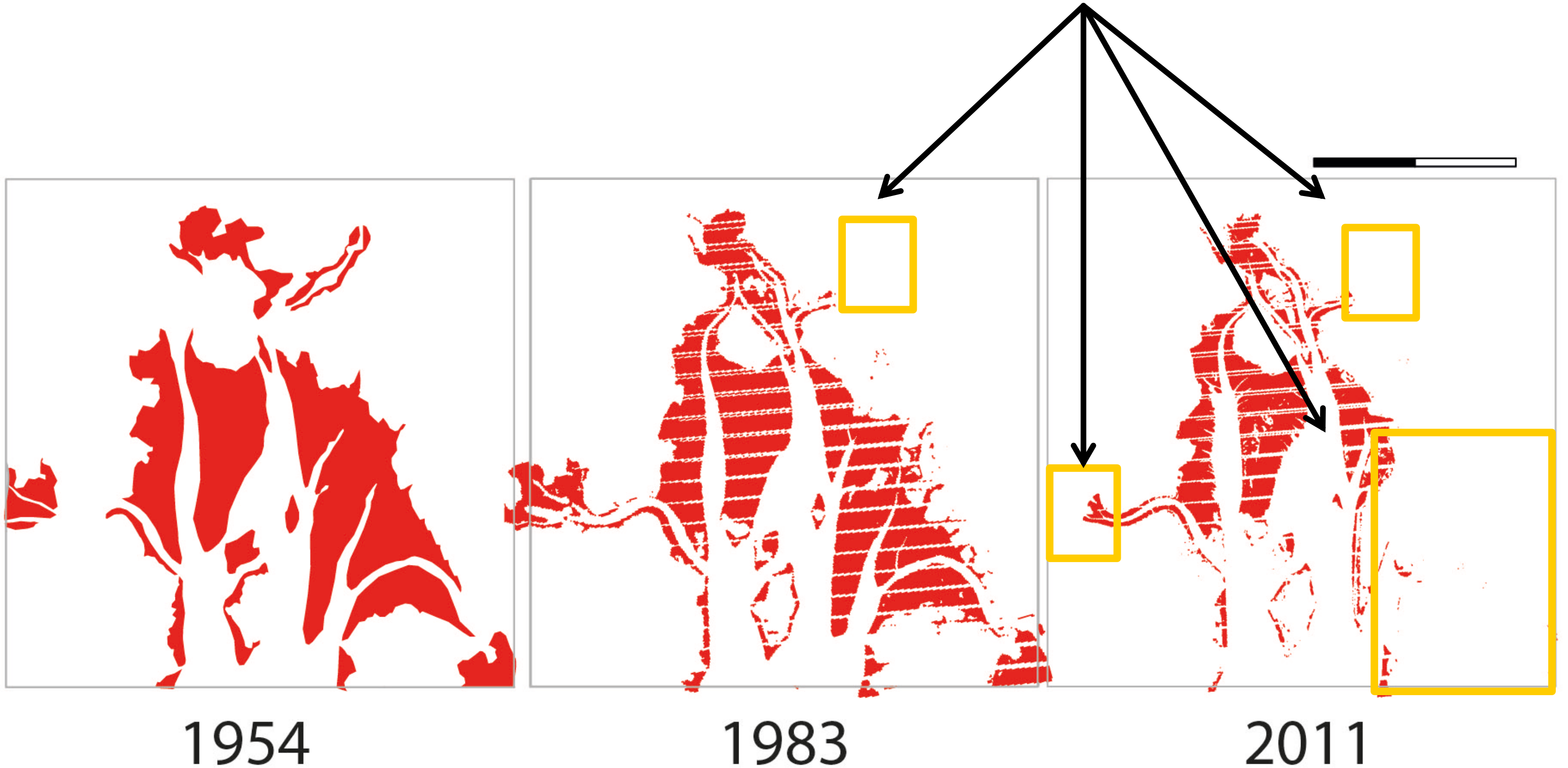
E: nicholas.murray@jcu.edu.au
W: https://www.globalecologylab.org

Bohai Bay, China 1976

Bohai Bay, China 2009

Tidal flats | time series

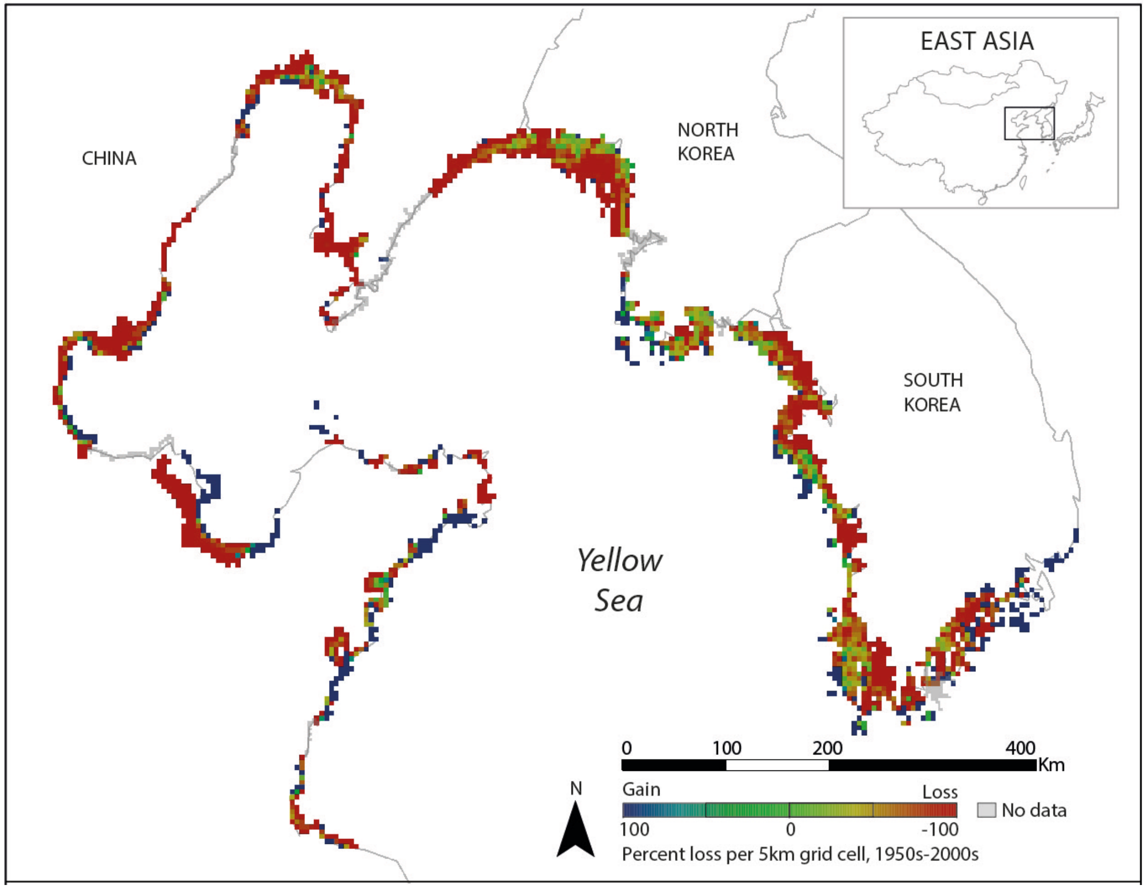
Large areas lost to reclamation, sea walls and aquaculture



historic map

remote sensing

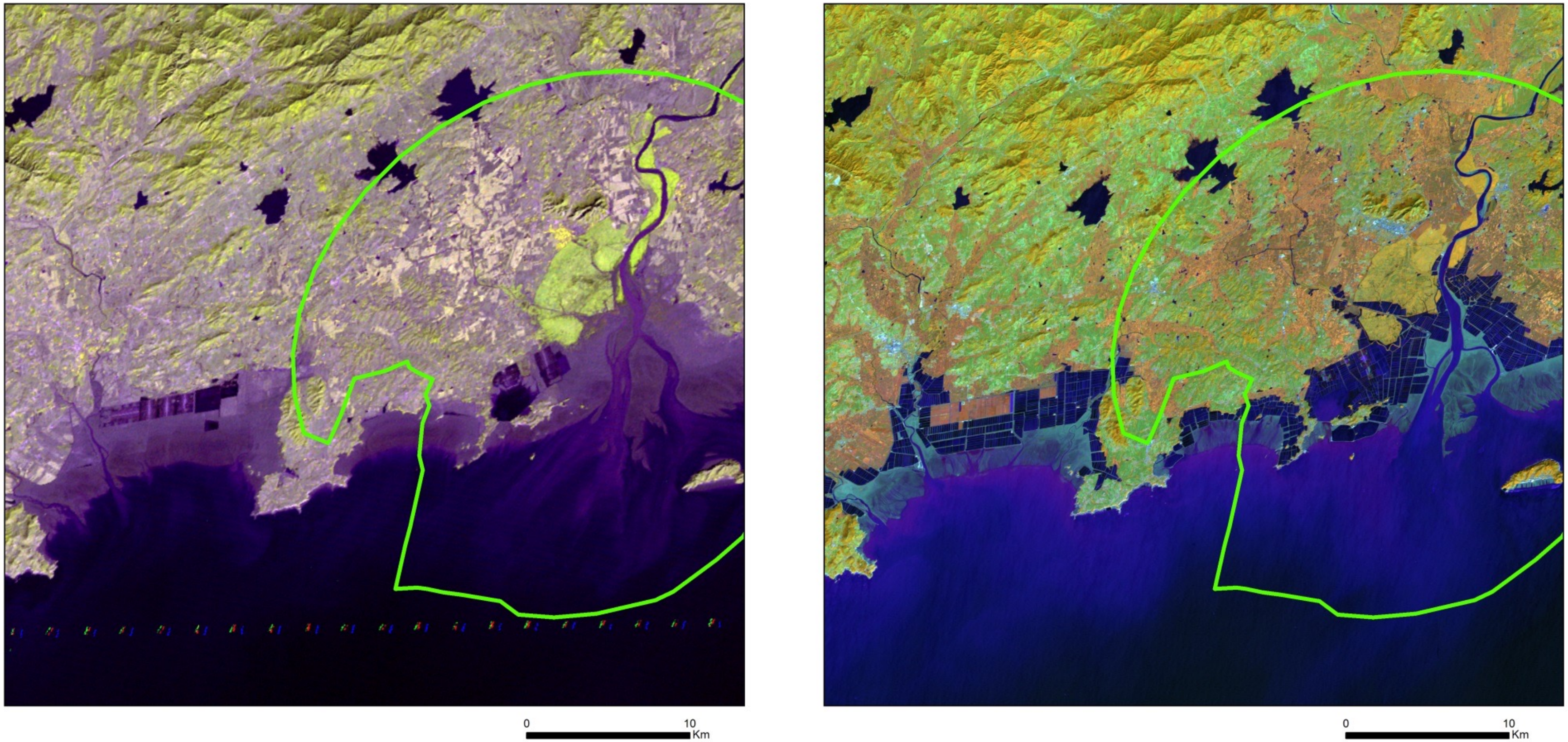
Tidal flats| Monitoring loss



Murray et al (2014) *Frontiers in Ecology and the Environment*

Protected areas | Nature reserves

19.2% of tidal flats *inside* protected areas
lost over last 30 years



Murray et al (2015) *J. Ornithology*

Global Tidal Flats Mapping Project (2016-2018)

What is the global distribution of tidal flats?

What is the status of tidal flats at the global-scale?

Global tidal flat change

Funded by Google to “develop global-scale remote sensing methods for mapping tidal mudflats”.

- Every Landsat satellite image since 1984 (707,528 images)
- Machine learning: data driven classification of each pixel
- 30 billion pixels * 56 predictors * 11 time steps
- 101 CPU core-years of computation on 22,000 machines (~ 25 years on a single computer)

Freely available data product: https://intertidal.app

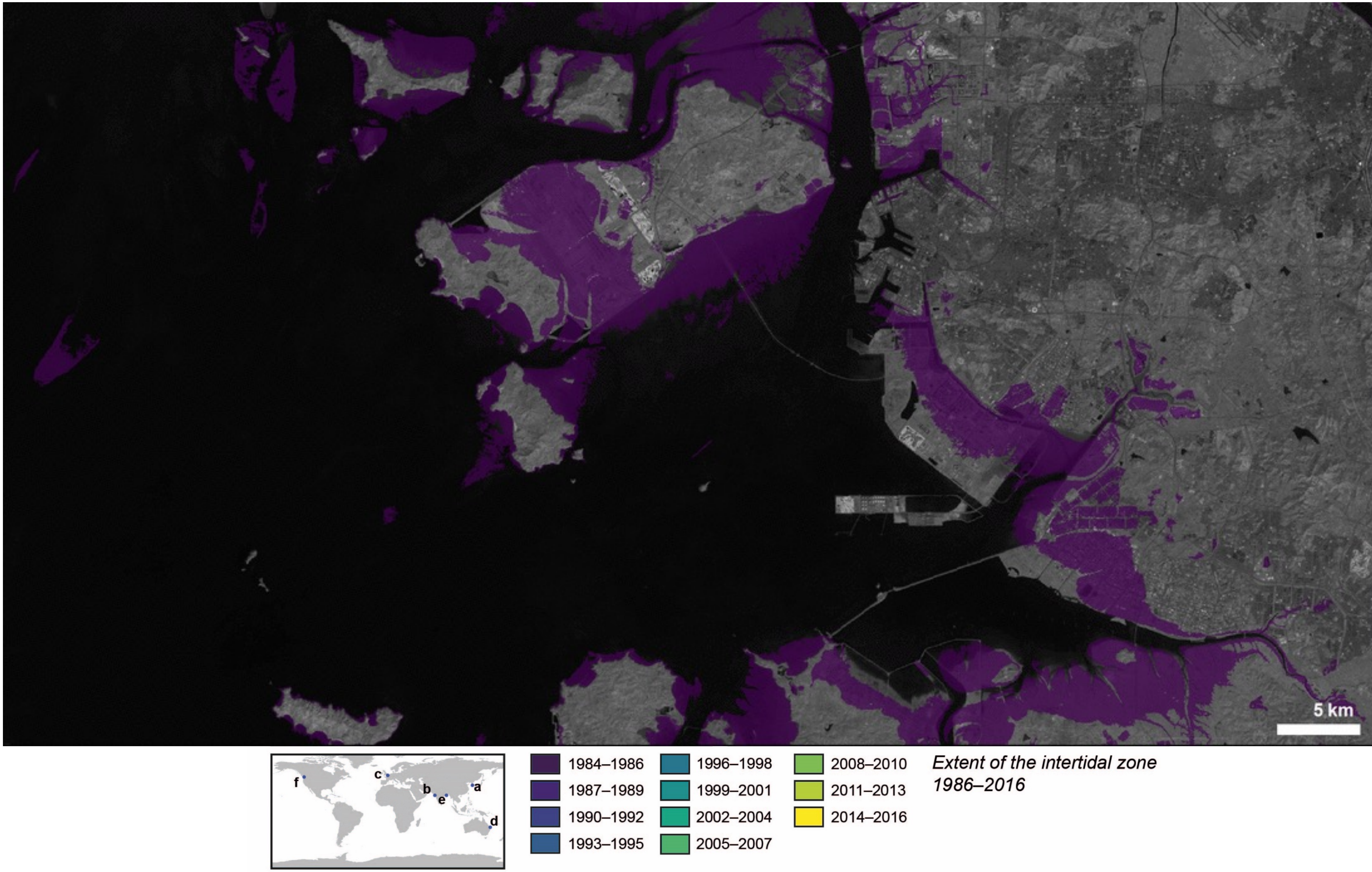
11 global maps @ 30m resolution (1984–2016)

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

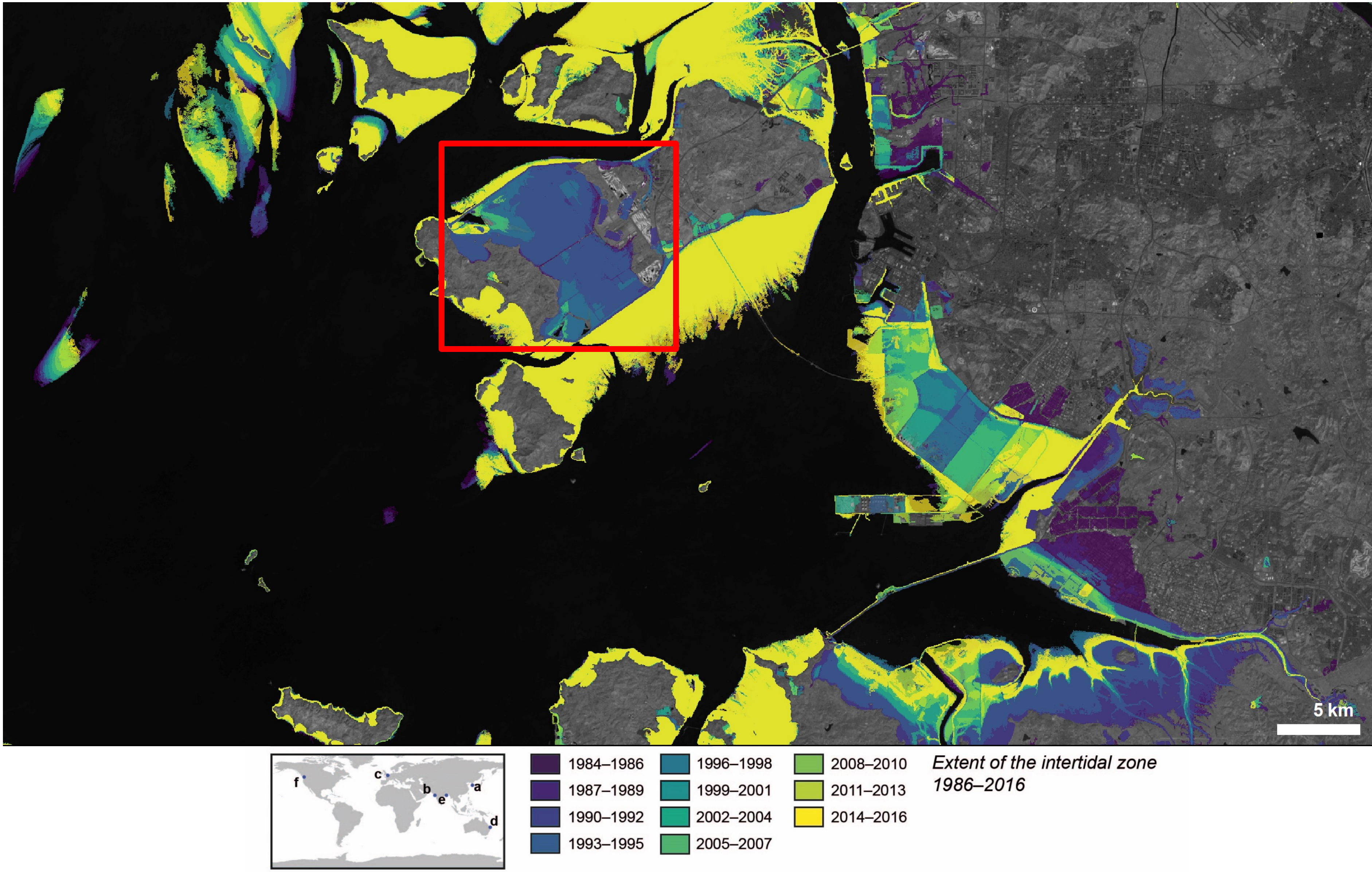
UNSW
AUSTRALIA

Murray et al (2019) The global distribution and trajectory of tidal flats. *Nature* 565, 222-225. | https://intertidal.app

Coastal reclamation | South Korea



Coastal reclamation | South Korea



Incheon Airport | South Korea

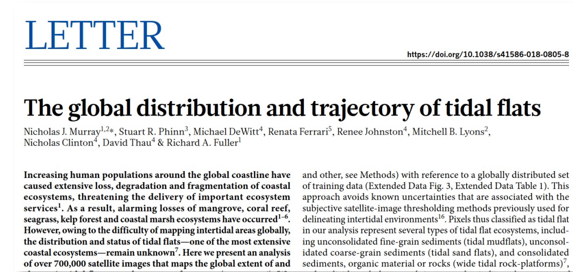
Global change in tidal flat extent

Where sufficient data enabled time-series analysis of extent:

- Significant decline in extent (1984-2016)

However:

- Only 16% of global coastline could be monitored due to lack of Landsat data
- Extensive transitions from tidal flat to mangrove and saltmarsh appear widespread.


LETTER

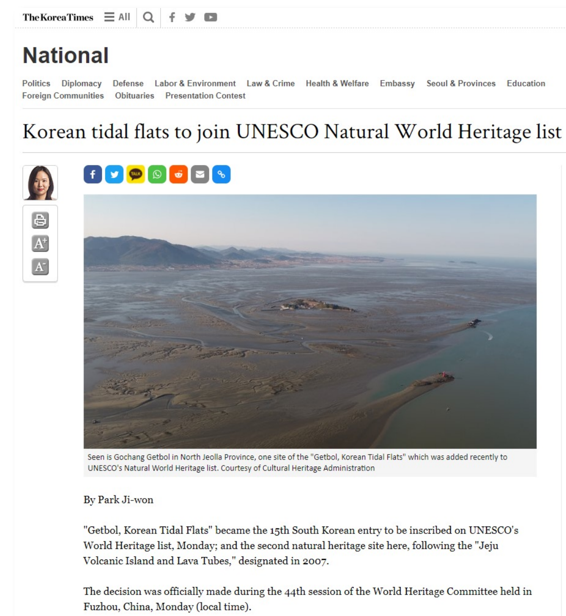
https://doi.org/10.1038/s41586-018-0805-8

The global distribution and trajectory of tidal flats

Nicholas J. Murray[1,2]*, Stuart R. Phinn[3], Michael DeWitt[4], Renata Ferrari[5], Renee Johnston[4], Mitchell B. Lyons[2], Nicholas Clinton[4], David Thau[4] & Richard A. Fuller[1]

Increasing human populations around the global coastline have caused extensive loss, degradation and fragmentation of coastal ecosystems, threatening the delivery of important ecosystem services[1]. As a result, alarming losses of mangrove, coral reef, seagrass, kelp forest and coastal marsh ecosystems have occurred[1–6]. However, owing to the difficulty of mapping intertidal areas globally, the distribution and status of tidal flats—one of the most extensive coastal ecosystems—remain unknown[7]. Here we present an analysis of over 700,000 satellite images that maps the global extent of and

and other, see Methods) with reference to a globally distributed set of training data (Extended Data Fig. 3, Extended Data Table 1). This approach avoids known uncertainties that are associated with the subjective satellite-image thresholding methods previously used for delineating intertidal environments[16]. Pixels thus classified as tidal flat in our analysis represent several types of tidal flat ecosystems, including unconsolidated fine-grain sediments (tidal mudflats), unconsolidated coarse-grain sediments (tidal sand flats), and consolidated sediments, organic material or rocks (wide tidal rock-platforms)[7],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Korean tidal flats to join UNESCO Natural World Heritage list

Seen is Gochang Getbol in North Jeolla Province, one site of the "Getbol, Korean Tidal Flats" which was added recently to UNESCO's Natural World Heritage list. Courtesy of Cultural Heritage Administration

By Park Ji-won

"Getbol, Korean Tidal Flats" became the 15th South Korean entry to be inscribed on UNESCO's World Heritage list, Monday; and the second natural heritage site here, following the "Jeju Volcanic Island and Lava Tubes," designated in 2007.

The decision was officially made during the 44th session of the World Heritage Committee held in Fuzhou, China, Monday (local time).

Global Intertidal Change (2019-2022)

Assessing risks to coastal ecosystems with new earth observation models

Overarching aim:

- Develop an operational system for monitoring losses and gains of saltmarsh, mangroves and tidal flat ecosystems at the global scale

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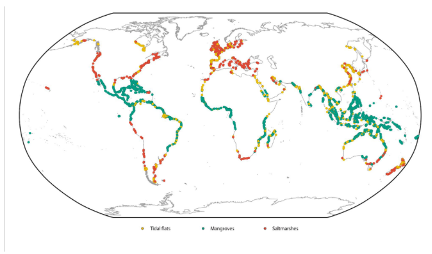
UNIVERSITY OF CAMBRIDGE
The Nature Conservancy
Australian Government
Australian Research Council

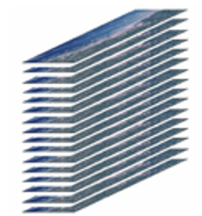
Remote sensing pipeline

Training Data



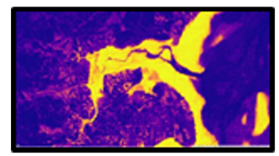
- 62,137 training data points (pixels)
- >500 hours image interpretation time

Predictor layers



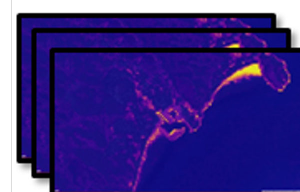
- 1.1 million satellite images
- 85 global data layers @ 30m resolution
- ~300 days compute time

Stacked machine learning classifiers

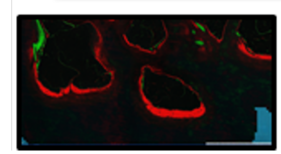


Time-series monitoring products

Type



QA



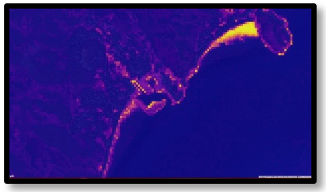
Loss/gain layers

Massive cloud-based parallel computing

Stacked machine-learning classifiers

At each time-step (7 time steps, 1999 – 2019) we run
3 random forest pixel classifiers:

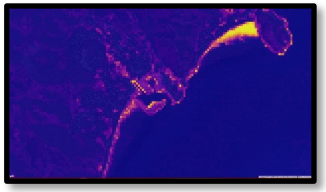
1. Occurrence: Distribution of all intertidal ecosystem types



Stacked machine-learning classifiers

At each time-step (7 time steps, 1999 – 2019) we run 3 random forest pixel classifiers:

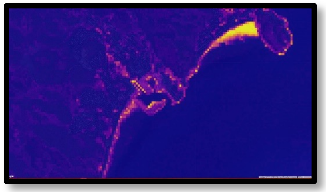
1. Occurrence: Distribution of all intertidal ecosystem types
2. Type: Each confirmed intertidal ecosystem pixel classified to ecosystem type (saltmarsh, mangrove, tidal flat)

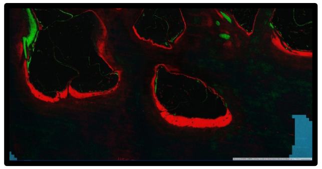


Stacked machine-learning classifiers

At each time-step (7 time steps, 1999 – 2019) we run 3 random forest pixel classifiers:

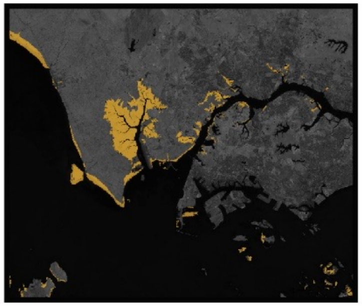
1. Occurrence: Distribution of all intertidal ecosystem types
2. Type: Each confirmed intertidal ecosystem pixel classified to ecosystem type (saltmarsh, mangrove, tidal flat)
3. Change: Any pixels that have changed is classified as lost or gained, identified by ecosystem type, and year of change is determined.
   - Additional training data:
     - loss
     - gain
     - no change





Global Intertidal Change Data

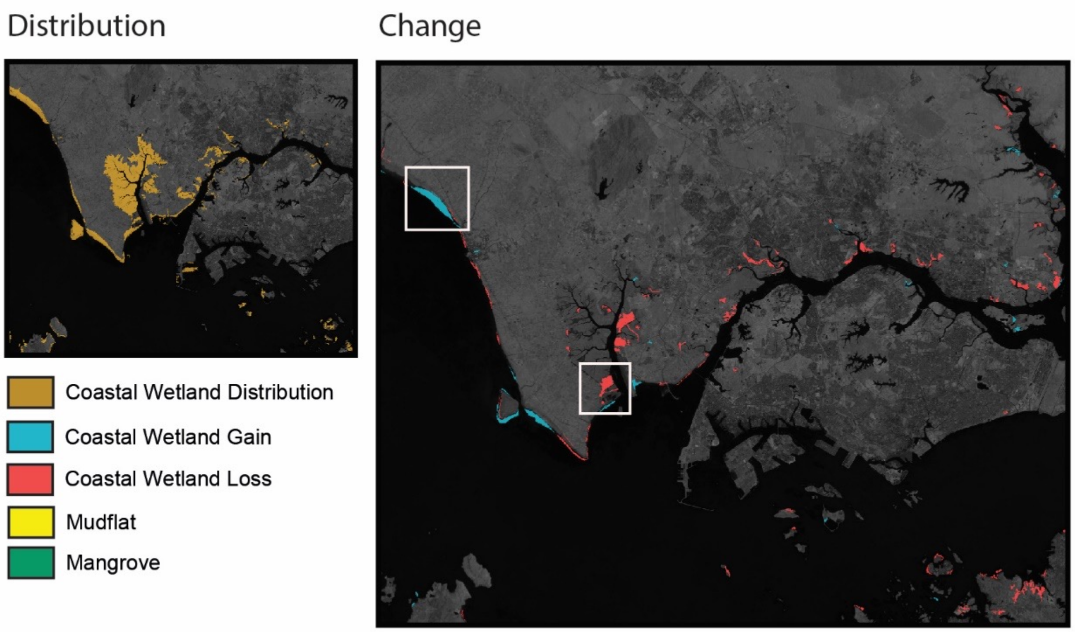
Distribution



Coastal Wetland Distribution
Coastal Wetland Gain
Coastal Wetland Loss
Mudflat
Mangrove

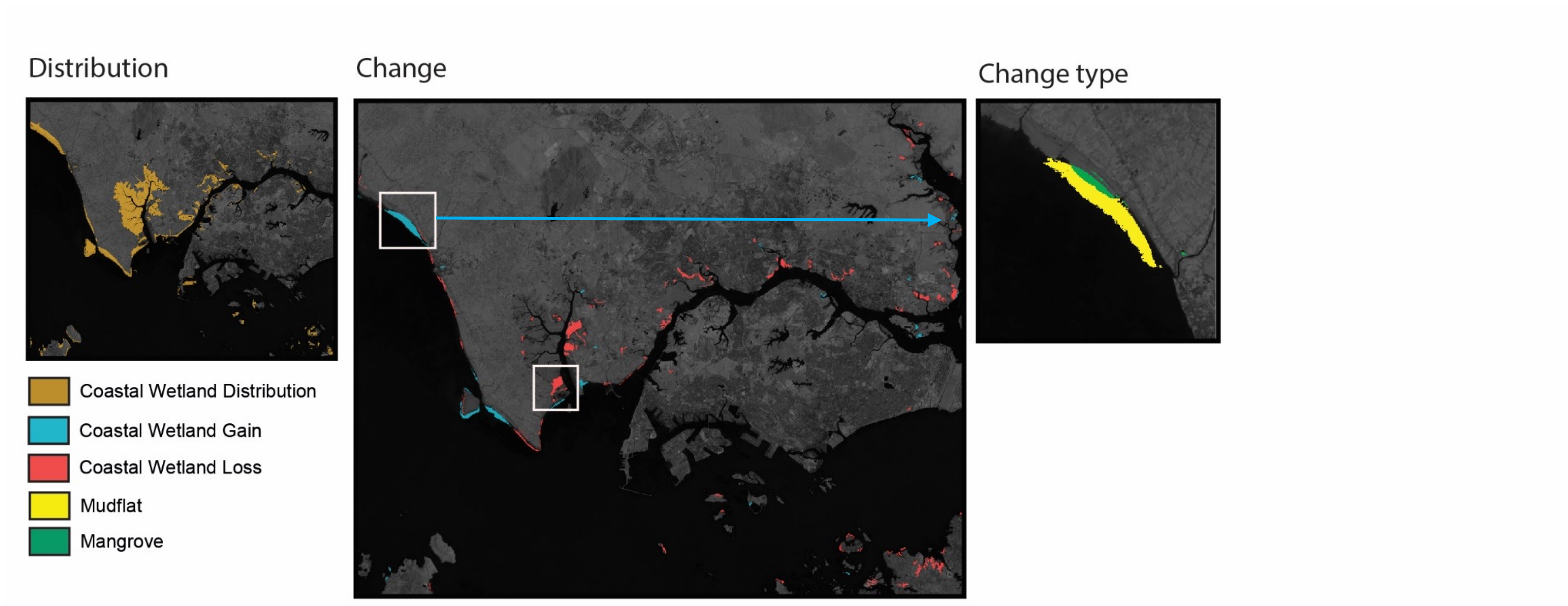
Global Intertidal Change Data

2019



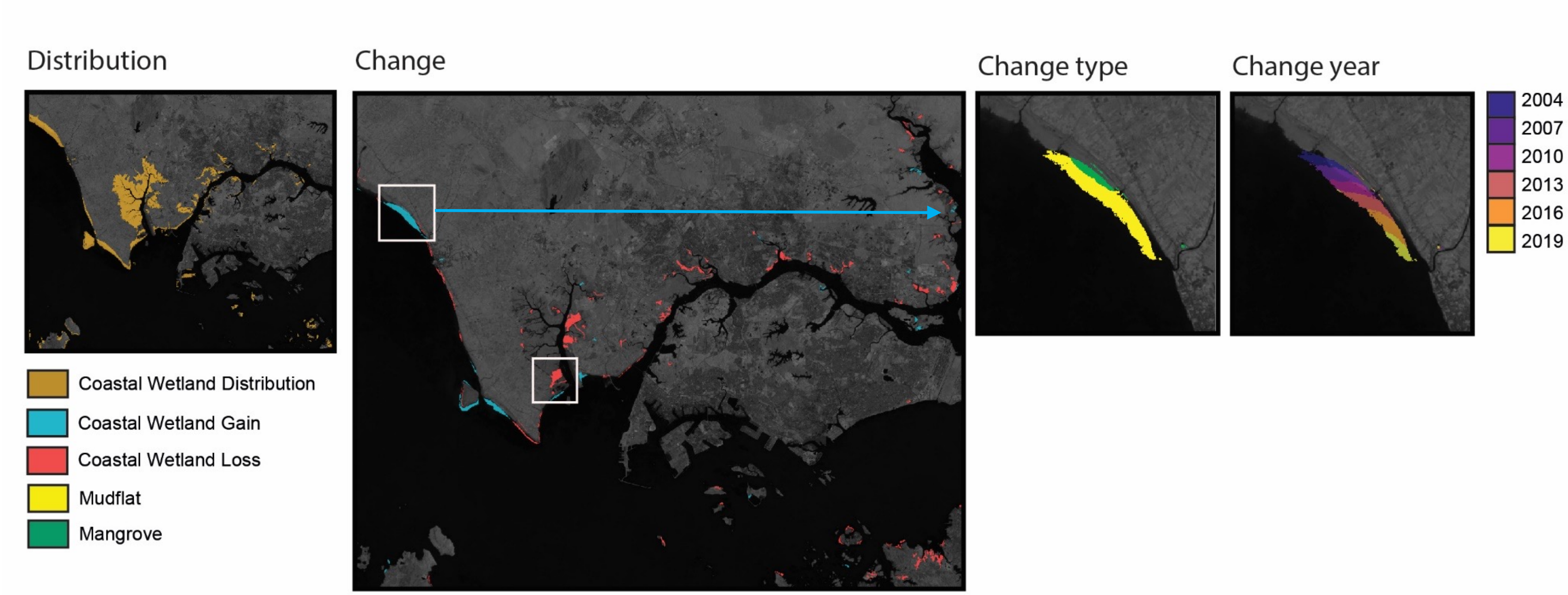
Global Intertidal Change Data

Gain: occurs now but not in 1999



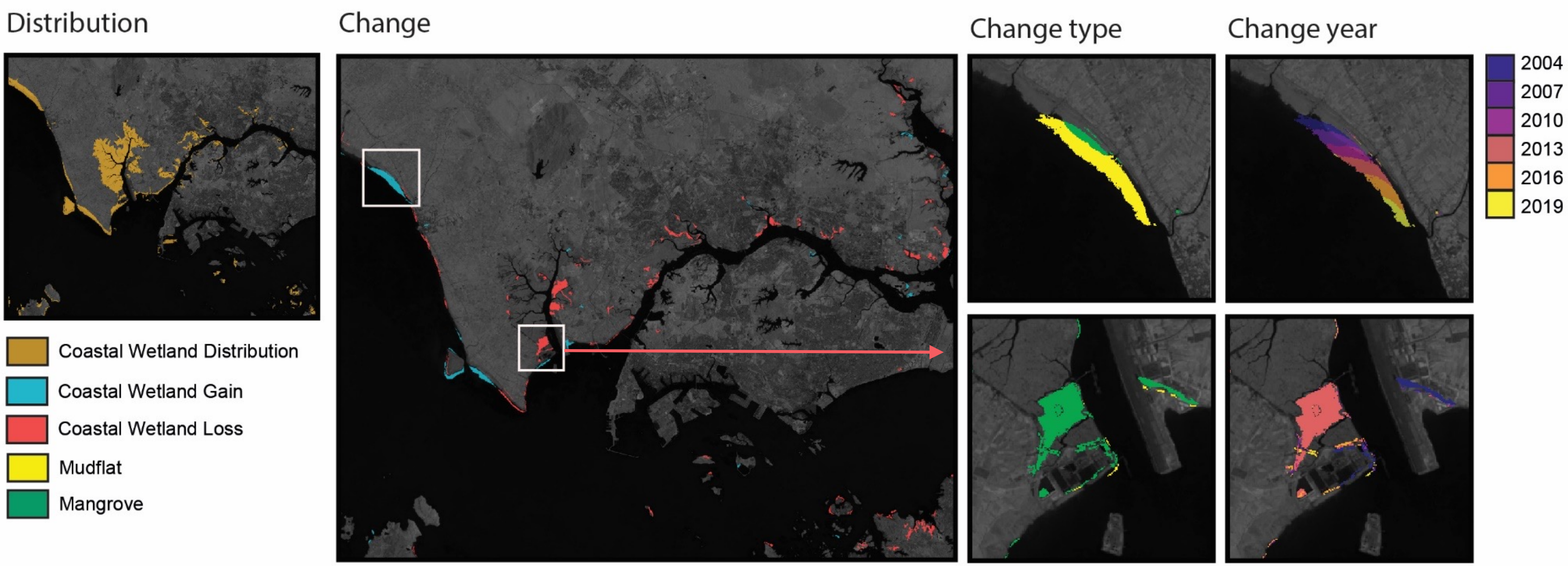
Global Intertidal Change Data

Gain: occurs now but not in 1999



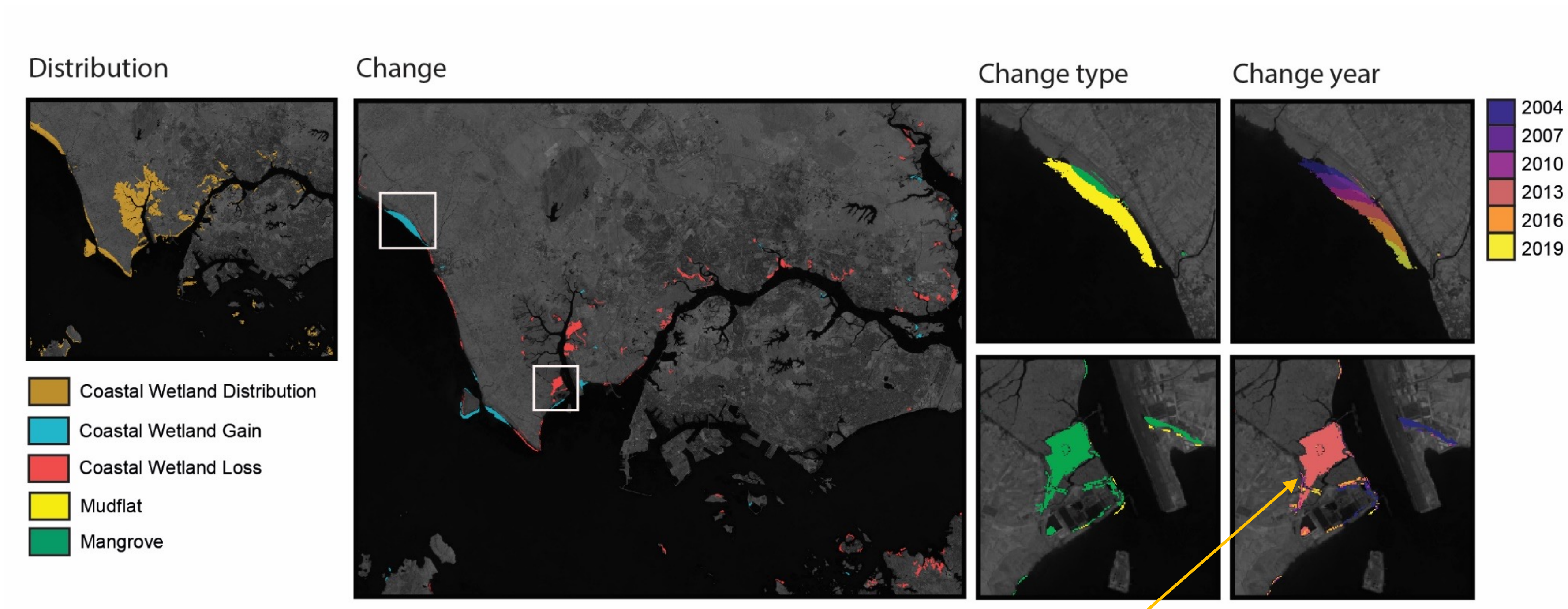
Global Intertidal Change Data

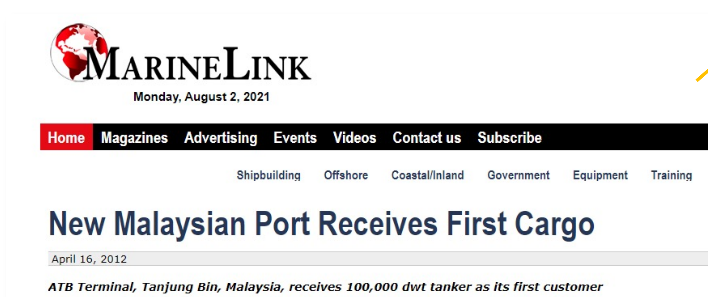
Loss: does not occur now but did in 1999



Global Intertidal Change Data

Loss: does not occur now but did in 1999





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Shipbuilding Offshore Coastal/Inland Government Equipment Training

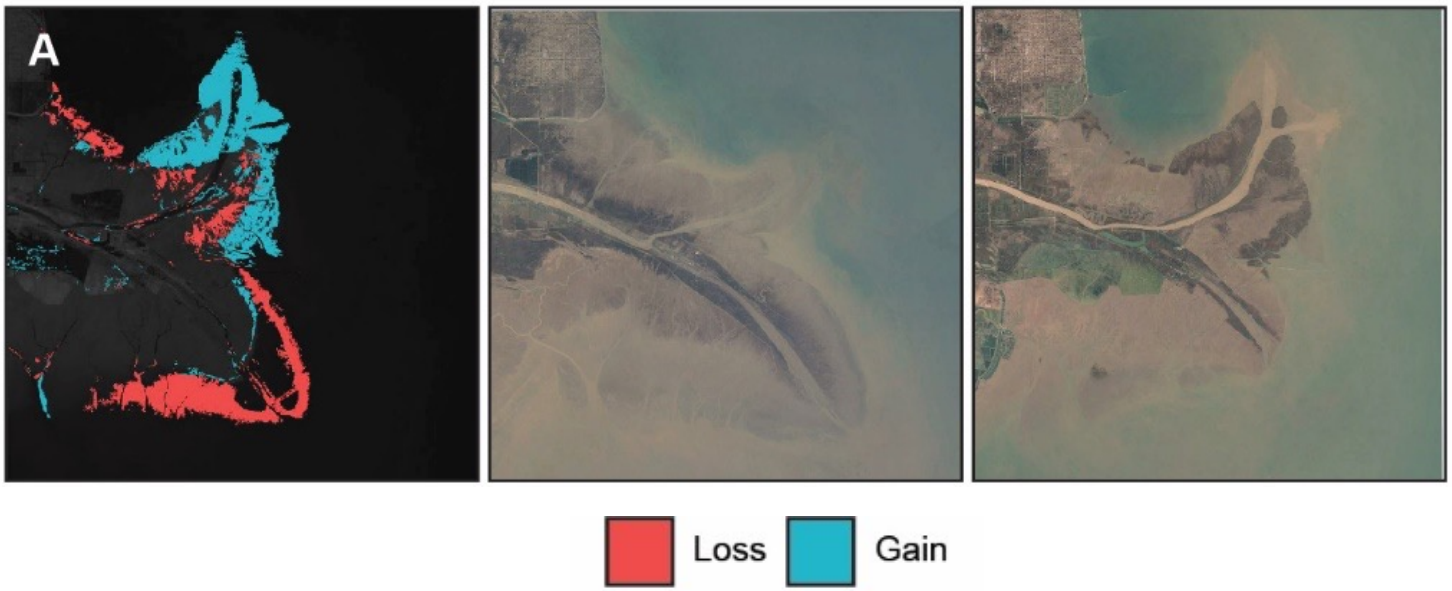
New Malaysian Port Receives First Cargo

April 16, 2012

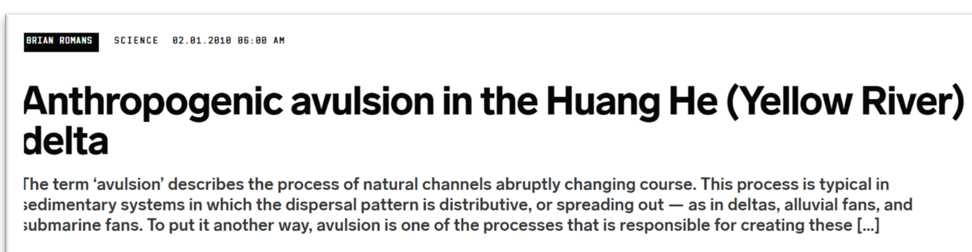
ATB Terminal, Tanjung Bin, Malaysia, receives 100,000 dwt tanker as its first customer

Huang He (Yellow River) | Delta change

Change product 1999 image 2019 image



1996: Southern channel blocked



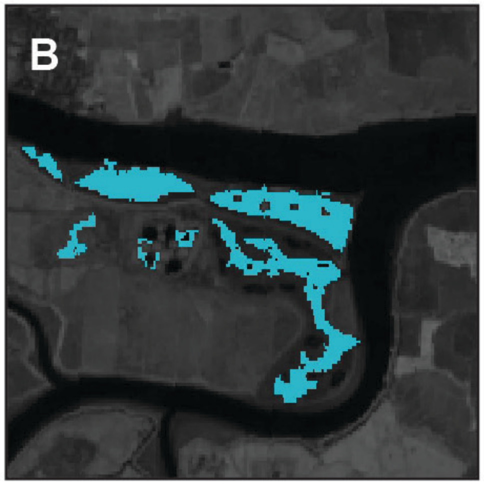
BRIAN ROMANS SCIENCE 02.01.2018 06:00 AM

Anthropogenic avulsion in the Huang He (Yellow River) delta

The term 'avulsion' describes the process of natural channels abruptly changing course. This process is typical in sedimentary systems in which the dispersal pattern is distributive, or spreading out — as in deltas, alluvial fans, and submarine fans. To put it another way, avulsion is one of the processes that is responsible for creating these [...]

Wallasea, UK | Coastal restoration

Change product

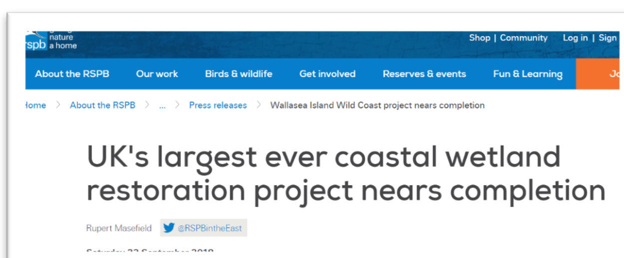


1999 image

2019 image

Loss Gain

2018: Restoration project completed



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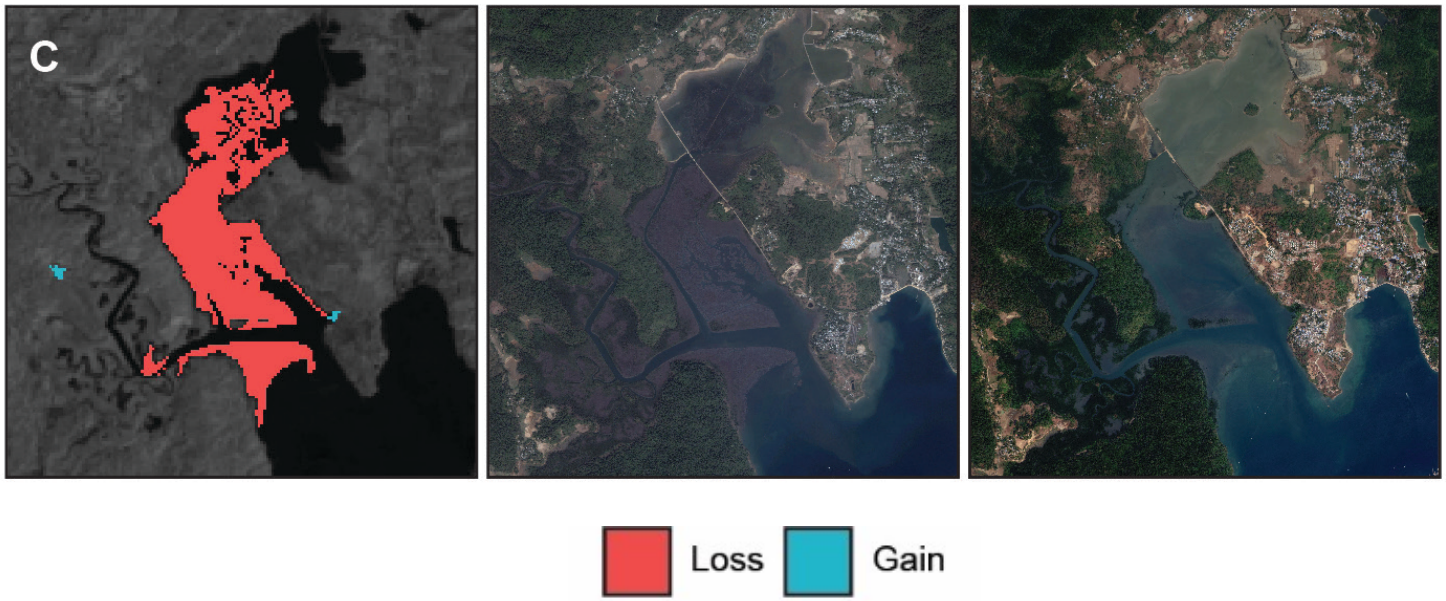
UK's largest ever coastal wetland restoration project nears completion

Rupert Masefield @RSPBintheEast

Nicobar Islands | Tectonic subsidence

Change product | 2005 image | 2019 image



2004: Magnitude 9.1 earthquake led to >2m tectonic subsidence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To search, type and hit enter.

Mongabay Series: India's Iconic Landscapes

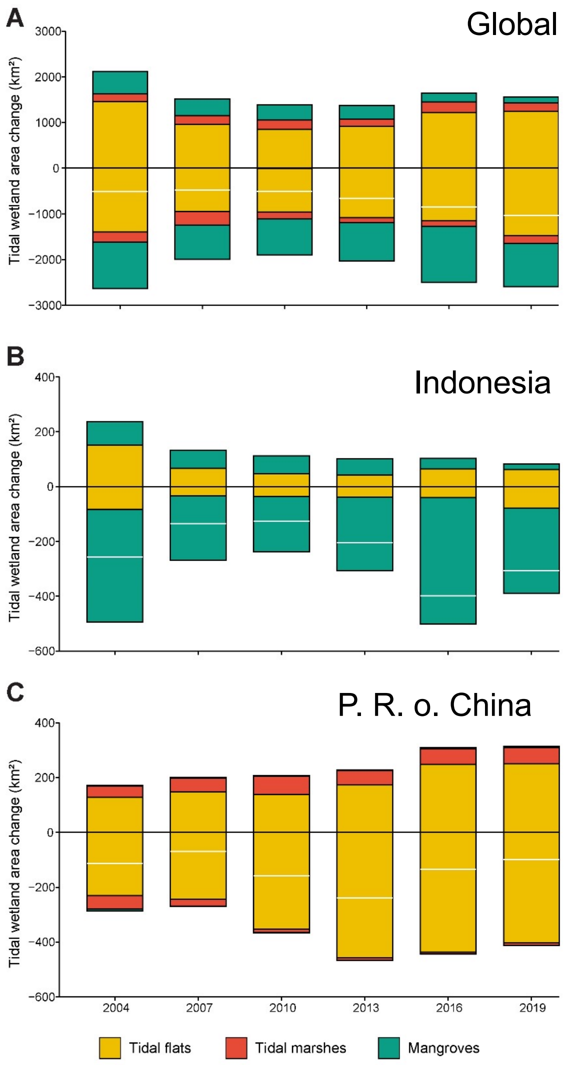
Indian Ocean tsunami: Nicobar Islands lost 97 percent of mangrove cover, uncov-

Future work and opportunities

Global intertidal change allows long-term monitoring of coastal wetland change at the site / region / national / global scale.

Future work will focus on:

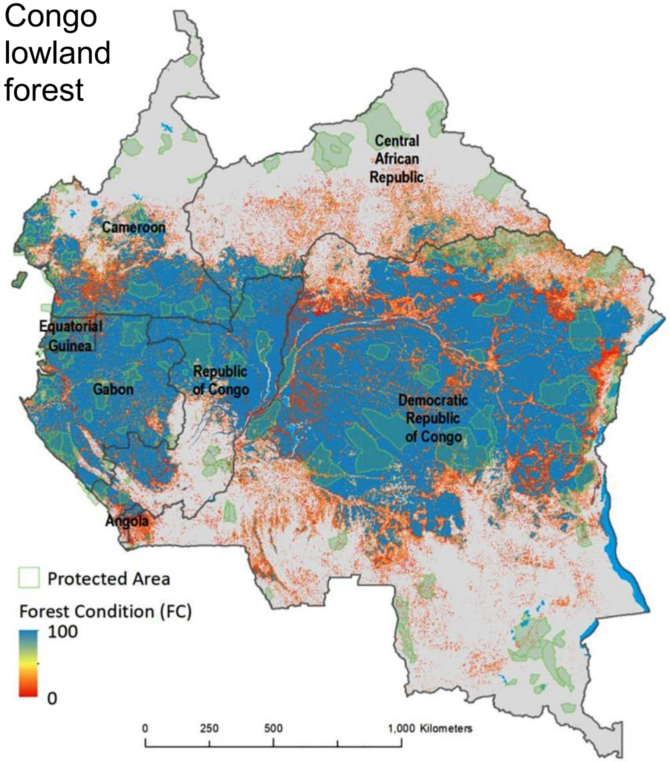
- Monitoring ecosystem degradation
- Informing findings from long-term bird population monitoring
- Developing an alert system (monthly)
- Feeding into advanced simulation models to assess the future risk of loss
- Identifying local and global drivers of change



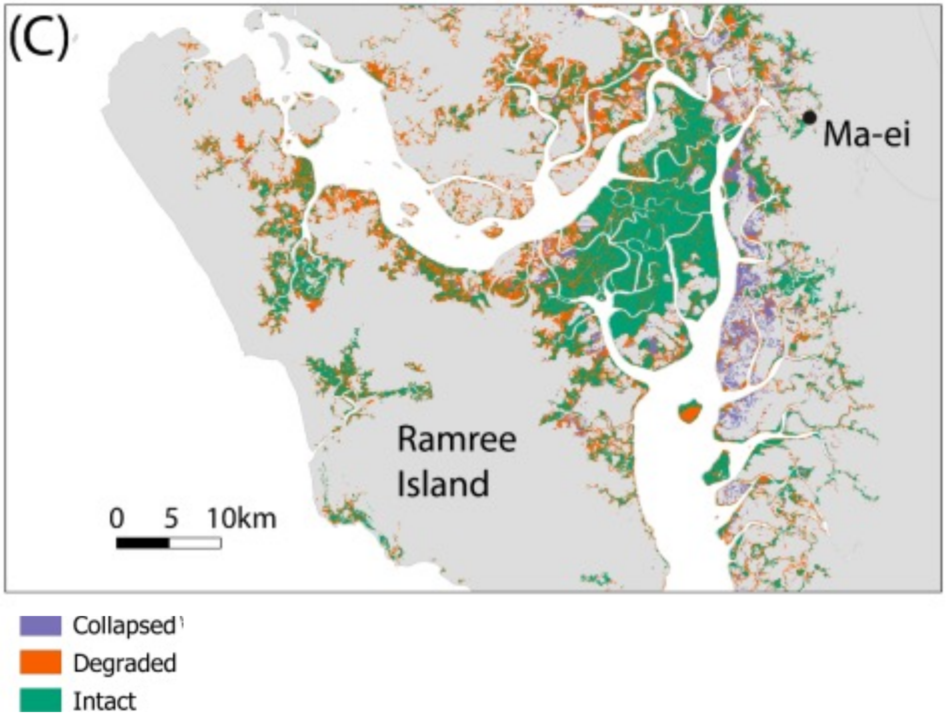
Remote sensing wetland degradation

Large-scale ecosystem degradation models informed by satellite data are continually advancing

Congo lowland forest



Myanmar mangroves



Integrating with population models

Using site-based estimates of change to inform models of shorebird population collapse

- Monitor wetland loss and degradation from space
- Inform population models and projections of shorebirds

The University of Queensland
Australia

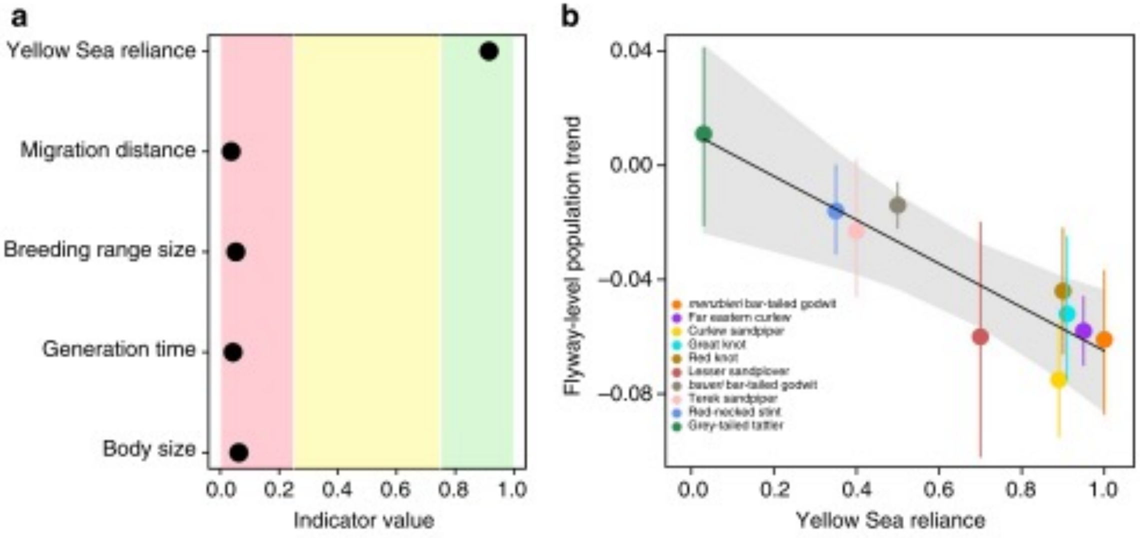
nature COMMUNICATIONS

ARTICLE

Received 12 Apr 2016 | Accepted 9 Feb 2017 | Published 13 Apr 2017 DOI: 10.1038/ncomms14895 OPEN

Rapid population decline in migratory shorebirds relying on Yellow Sea tidal mudflats as stopover sites

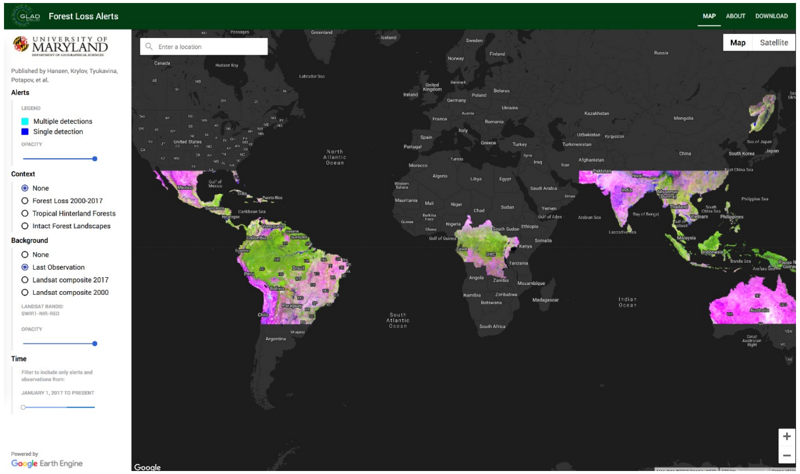
Colin E. Studds[1,2,3], Bruce E. Kendall[4], Nicholas J. Murray[1,5], Howard B. Wilson[1], Danny I. Rogers[6], Robert S. Clemens[1], Ken Gosbell[7], Chris J. Hassell[8], Rosalind Jessop[9], David S. Melville[10], David A. Milton[11], Clive D.T. Minton[7], Hugh P. Possingham[1,12], Adrian C. Riegen[13], Phil Straw[14], Eric J. Woehler[15] & Richard A. Fuller[1]



Alert systems for conservation

Reducing time-lags between satellite data observations and conservation action

- Research on tropical forests suggests that up to a 20% reduction in the probability of deforestation are achieved if alert systems are available




Trends in
Ecology & Evolution

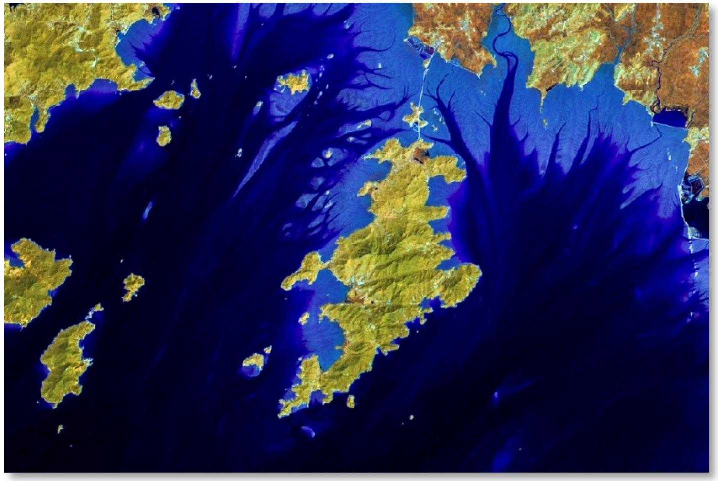
Forum

Data Freshness in Ecology and Conservation

Nicholas J. Murray[1,6,*,@]
Emma V. Kennedy,[2,5]
Jorge G. Álvarez-Romero,[3] and
Mitchell B. Lyons[4]

Evolving capabilities in environmental data collection, sharing, and processing, are enabling unprecedented use of data from a wide range of sources. Yet data freshness, an important quality dimension associated with the age of data, is a poorly reported aspect of data quality that can lead to additional uncertainty in research findings.

Monitoring coastal ecosystems from space



Dr Nicholas Murray
ARC Research Fellow
Senior Lecturer
James Cook University, Australia

E: nicholas.murray@jcu.edu.au
W: https://www.globalecologylab.org