IMPACTS OF CLIMATE CHANGE ON VEGETATION COVER

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24 November 2020
Previous works
Climate change - causes & consequences
Determination of Vegetation Change
Impacts of climate change on vegetation cover
  # Arctic
  # Salt marshes
  # Mangroves
# Biomonitorting of heavy metals in molluscs in rivers in Sarawak, UNIMAS

# Sedimentary organic matter in Lochs Creran & Etive; Dunstaffnag Marine Laboratory

# Sedimentary organic matter along Kapuas River; NSYSU

# Sedimentary phosphorus species in Lakes Simcoe and Winnipeg; York University
# Changjiang Estuary, Qiantang River and Hangzhou Bay

# Salt marsh south in Hangzhou Bay and Zhoushan

# Zhoushan coastal area
CLIMATE CHANGE
CAUSES
Great Barrier Reef saw huge losses from 2016 heatwave

Local Extinction of Bull Kelp (Durvillaea spp.) Due to a Marine Heatwave

Mads S. Thomsen1,2, Luca Mondardini1, Tommaso Alestra1, Shawn Gerrity1, Le Paul M. South4, Stacie A. Lilley1 and David R. Schiel1

Community-Level Actions that Can Address Ocean Acidification

Sarah R. Cooley1, C. Ryan Ono, Sage Melcer and Julia Roberson
Ocean Acidification Program, Ocean Conservancy, Washington, DC, USA

Hypoxia in the world ocean as recorded in the historical data set

Daniel Kamyrkowsk1 and Sara-Joan Zentara*

Massive Phytoplankton Blooms Under Arctic Sea Ice

Kevin R. Arrigo,* Donald K. Perovich, Robert S. Pickart, Zachary W. Brown, Gert L. van Dijken, Kate E. Lowry, Matthew M. Mills, Molly A. Palmer, William M.

Increasing shrub abundance in the Arctic

The warming of the Alaskan Arctic during the past 150 years1 has accelerated over the last three decades2 and is
SOME STUDIES THAT DETERMINE VEGETATION CHANGES
Two-decade wetland cultivation and its effects on soil properties in salt marshes in the Yellow River Delta, China

Laibin Huang a, Junhong Bai a,b, Bin Chen a, Kejiang Zhang b, Chen Huang a, Peipei Liu a

marshes (PSTM). The total area of marsh wetland was reduced by 65.09 km² during the period from 1986 to 2005, and these conversions might be attributed to a combination of farming, oil exploration and water extraction, as well as soil salinization. Significant differences were observed in bulk density, pH, salinity and NO₃⁻-N between different land-use types (P<0.05). After the conversions from marsh wetlands to dry lands, bulk density, pH, salinity and NH₄⁺-N decreased slightly, while a significant increase in NO₃⁻-N, TN (total nitrogen), and AP (available phosphorus) (P<0.05) was observed. The more loss of soil nutrient storage also occurred after the maximal area conversion from PSTM to dry lands compared to other conversions during the study period. The storage of soil organic matter, NH₄⁺-N and total phosphorus decreased greatly.
# Sediment cores #
- Terrestrial plants have higher C/N ratios (above 23.3) than phytoplankton (ranging from 4.7 to 11.7).
- C3 photosynthetic plants have relatively more depleted δ¹³C values (-22‰ to -35‰) than algae and phytoplankton materials (-12‰ to -23‰; Meyers 1994).
- Lignin as biomarker for terrestrial organic matter.
IMPACT OF CLIMATE CHANGE ON VEGETATION COVER
1. ARCTIC

- The Arctic plant communities are sensitive to warming
- Arctic vegetation distribution controlled by climate, especially summer temperature
- Summer temperature has been increasing

Remote Sensing of Arctic Vegetation: Relations between the NDVI, Spatial Resolution and Vegetation Cover on Boothia Peninsula, Nunavut

GITA J. LAIDLER,¹ PAUL M. TREITZ² and DAVID M. ATKINSON²

Status and trends in Arctic vegetation: Evidence from experimental warming and long-term monitoring

Anne D. Bjorkman, Mariana García Criado, Isla H. Myers-Smith, Virve Ravolainen, Ingiþög Svala Jónsdóttir, Kristine Bakke Westergaard, James P. Lawler, Mora Aronsson, Bruce Bennett, Hans Gardfjell, Starri Helmarsson, Laerke Stewart, Signe Normand

High Arctic vegetation after 70 years: a repeated analysis from Svalbard

Karel Prach · Jiří Košnar · Jitka Klimešová · Martin Hais

Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI

Martha K. Raynolds a,*, Josefino C. Comiso b,1, Donald A. Walker a,2, David Verbyla
Affect species composition, ecosystem productivity
Deciduous ecosystem is expanding
Shrub extended farther north
Greening of tundra

Matthew Sturm*, Charles Racine†, Kenneth Tape‡

Increasing shrub abundance in the Arctic

The warming of the Alaskan Arctic during the past 150 years\(^1\) has accelerated over the last three decades\(^2\) and is expected to increase vegetation productivity in tundra if shrubs become more abundant\(^3,4\); indeed, this transition may already be under way according to local plot studies\(^5\) and remote sensing\(^6\). Here we present evi-
Enhanced transpiration

Land surface albedo change: decrease summer albedo

Overall positive feedback: greater warming

Shifts in Arctic vegetation and associated feedbacks under climate change

Richard G. Pearson¹*, Steven J. Phillips², Michael M. Loranty³,⁴, Pieter S. A. Beck³, Theodoros Damoulas⁵, Sarah J. Knight¹,⁶, and Scott J. Goetz³

The response of Arctic vegetation to the summer climate: relation between shrub cover, NDVI, surface albedo and temperature

Daan Blok¹, Gabriela Schaepe-Müller, Harm Bartholomeus¹, M. P. de Hoffmans¹, Trofin C Maximov¹ and Erik Berendse¹
Arctic fires

Increased atmospheric CO₂

The response of Arctic vegetation and soils following an unusually severe tundra fire

M. Syndonia Bret-Harte¹, Michelle C. Mack², Gaius R. Shaver³, Diane C. Huebner¹, Miriam Johnston³, Camilo A. Mojica², Camila Pizano² and Julia A. Reiskind²

Arctic tundra fires: natural variability and responses to climate change

Feng Sheng Hu¹,²,³, Philip E Higuera⁴, Paul Duffy⁵, Melissa L Chipman³, Adrian V Rocha⁶, Adam M Young⁷, Ryan Kelly³,⁸ and Michael C Dietze⁹

Changes in Arctic vegetation amplify high-latitude warming through the greenhouse effect

Abigail L. Swann¹, Inez Y. Fung¹, Samuel Levis⁵, Gordon B. Bonan⁶, and Scott C. Doney⁷
Sources and sink of black carbon in Arctic Ocean sediments

Peng Ren a, Yanguang Liu b,c, Xuefa Shi b, Shuwen Sun d, Di Fan d, Xuchen Wang

A decrease in discharge-normalized DOC export by the Yukon River during summer through autumn

Robert G. Striegl,1 George R. Aiken,2 Mark M. Dornblaser,2 Peter A. Raymond,3 and Kimberly P. Wickland2

The Arctic Ocean carbon sink

G.A. MacGilchrist a, A.C. Naveira Garabato a, T. Tsubouchi b, S. Bacon b, S. Torres-Valdés b, K. Azetsu-Scott c

to infer the sources of interior transport implied that this export is primarily due to the sinking and remineralisation of organic matter, highlighting the importance of the biological pump. Furthermore, we qualitatively show that the present day Arctic Ocean is accumulating anthropogenic carbon beneath the mixed layer, imported in Atlantic Water.
2. SALT MARSH

- Sediment transport
- Wave; tide
- Hurricane deliver sediment to salt marsh
Their distribution and productivity are determined by sea level and space available for sediment accumulation.
SOME STUDIES THAT DETERMINE WHETHER SALT MARSHES ARE CARBON SINK OR SOURCE
Two-decade wetland cultivation and its effects on soil properties in salt marshes in the Yellow River Delta, China

Laibin Huang a, Junhong Bai a,*, Bin Chen a, Kejiang Zhang b, Chen Huang a, Peipei Liu a

marshes (PSTMs). The total area of marsh wetland was reduced by 65.09 km² during the period from 1986 to 2005, and these conversions might be attributed to a combination of farming, oil exploration and water extraction, as well as soil salinization. Significant differences were observed in bulk density, pH, salinity and NO₃⁻-N between different land-use types (P<0.05). After the conversions from marsh wetlands to dry lands, bulk density, pH, salinity and NH₄⁺-N decreased slightly, while a significant increase in NO₃⁻-N, TN (total nitrogen), and AP (available phosphorus) (P<0.05) was observed. The more loss of soil nutrient storage also occurred after the maximal area conversion from PSTMs to dry lands compared to other conversions during the study period. The stores of soil organic matter, NH₄⁺-N and total phosphorus decreased greatly.
Classification mapping of salt marsh vegetation by flexible monthly NDVI time-series using Landsat imagery

Chao Sun\textsuperscript{a,b,*,1}, Sergio Fagherazzi\textsuperscript{b}, Yongxue Liu\textsuperscript{c,**}

Salt marshes are deemed as one of the most dynamic and valuable ecosystems on Earth. Recently, salt marsh deterioration and loss have become widespread because of anthropogenic stressors and sea level rise. Long-term acquisition of spatial information on salt marsh vegetation communities is thus critical to detect the general evolutionary trend of marsh ecosystems before irreversible change occurs. Medium resolution imagery organized in inter-annual time series has been proven suitable for large-scale mapping of salt marsh vegetation. For long-term monitoring purpose, the challenge still lies in developing time series based on data with sparse and uneven temporal distribution. This paper proposes a flexible Monthly NDVI Time-Series (MNTS) approach to achieve multi-temporal classification maps of salt marsh vegetation communities in the Virginia Coast Reserve, USA, by utilizing all viable Landsat TM/ETM + images during the period 1984–2011. Salt marsh vegetation communities are identified on a reference MNTS spanning 12 months with an overall accuracy of 0.898, approximately 0.107 higher than classifications using single images. Utilizing a flexible selection process based on the reference MNTS, a significant inverse hyperbolic relationship emerges between overall accuracy and average length of the time series. Based on these results, eight classification maps with average accuracy of 0.844 and time interval of 2–5 years are acquired. A spatio-temporal analysis of the maps indicates that the upper low marsh vegetation community has diminished by 19.4% in the study period, with a recent acceleration of losses. The conversion of marsh area to vegetation communities typical of low elevations (37.7 km\textsuperscript{2}) is more than twice the conversion to vegetation communities typical of high elevations (18.3 km\textsuperscript{2}), suggesting that salt marsh ecosystems at the Virginia Coast Reserve are affected by sea level rise.
# Fluxes measurement #

☆ Ebb tide (E) = sea level falls; water flows away; water recede; water level falls
☆ Flood tide (F) = tidal current is flowing inland; water level is rising
☆ $M_E > M_F$: this indicates the marsh is a source or is releasing materials to the bay
☆ $M_F > M_E$: this indicates the marsh is a sink or is absorbing materials.
Seasonal nutrient fluxes variability of northern salt marshes: examples from the lower St. Lawrence Estuary

Patrick Poulin · Émilien Pelletier · Vladimir G. Koutitonski · Urs Neumeier

Factors controlling sediment and nutrient fluxes in a small microtidal salt marsh within the Venice Lagoon

Bonometto A.*, Feola A., Rampazzo F., Gion C., Berto D., Ponis E., Boscolo Brusà R.

Fluxes were assessed by coupling field data with the calculated discharges. The salt marsh filtering function was related to the inflow matter concentrations and tidal amplitude. When high suspended solid and nutrient concentrations enter the salt marsh, accumulation processes prevail on release. In contrast, in the case of low concentrations and high tidal excursion, the salt marsh functions as a nutrient and sediment source. During all campaigns, the nitrogen removal function was more effective within the intertidal vegetated areas. Sediment release was the dominant process in the outermost creek, whereas sedimentation prevailed in the inner area of the salt marsh because of the attenuation of hydrodynamic forcing during tide propagation.
Sediment cores

Tidal Marsh Record of Nutrient Loadings in Barnegat Bay, New Jersey

David J. Velinsky†*, Bhanu Paudel†, Thomas J. Belton†, and Christopher K. Sommerfield§

Sequester approximately 79 ± 11% of N and 54 ± 34% of P entering the Bay from upland sources; thus, these marshes perform an important ecosystem service in the form of nutrient sequestration. Marsh accretion rates at the coring sites fall at, to just below, rates of relative sea-level rise recorded by nearby tide gauges. These relatively low rates of accretion render the marsh vulnerable to inundation should the rate of sea-level rise accelerate in the future.

Figure 3. Sediment organic carbon and C:N ratio at four different coring sites in the marshes of Barnegat Bay.
Impacts of human activity and extreme weather events on sedimentary organic matter in the Andong salt marsh, Hangzhou Bay, China

Pei Sun Loh\textsuperscript{a,\ast}, Long-Xiu Cheng\textsuperscript{a}, Hong-Wei Yuan\textsuperscript{a}, Lin Yang\textsuperscript{a}, Zhang-Hua Lou\textsuperscript{a}, Ai-Min Jin\textsuperscript{a}, Xue-Gang Chen\textsuperscript{a}, Yu-Shih Lin\textsuperscript{b}, Chen-Tung Arthur Chen\textsuperscript{b}

\textsuperscript{a}Hangzhou University, Hangzhou, China; \textsuperscript{b}University of Delaware, Newark, USA

\textsuperscript{\ast}Corresponding author. E-mail: sunlohn@zju.edu.cn
3. MANGROVES

- Important carbon reservoir
- Regulators of nutrients and pollutants
- Provide food, medicine, fuel, home to animals, protect coastal zone
- Threats: deforestation, farming, land use, erosion; pollution, climate change
Monitoring loss and recovery of mangrove forests during 42 years: The achievements of mangrove conservation in China

Mingming Jia\textsuperscript{a}, Zongming Wang\textsuperscript{a,\ast}, Yuanzhi Zhang\textsuperscript{b,c,\ast\ast}, Dehua Mao\textsuperscript{a}, Chao Wang\textsuperscript{d}

... after the establishment of the reserves. Results showed that: 1) on the national scale, mangrove forests declined from 48,801 ha to 18,702 ha between 1973 and 2000, then partially recovered to 22,419 ha in 2015; 2) in each reserve, the areal extent of mangrove forests increased immediately after the reserve was established. Depending on our analysis, in the early time, agricultural reclamation caused the loss of mangrove forests; in contrast, recently, protection and reforestation actions prompt to mangrove forest restoration greatly. Because of China’s conservation efforts, since 2000, direct destruction by human beings has rarely happened, and natural disasters and the existing artificial seawalls have become major threats to mangrove forest in China. This study is an...
Mangrove forests of Cambodia: Recent changes and future threats

Bijeesh Kozhikkodan Veettil\textsuperscript{a}, Ngo Xuan Quang\textsuperscript{b,c,*}

In this study, decadal changes in mangrove forests along the Cambodian coastline were analysed using satellite data (Landsat series). Overall loss of mangrove forests between 1989 and 2017 has been estimated as 42% (1415 ha/year) in the four coastal provinces of Cambodia (Koh Kong, Kampot, Preah Sihanoukville, and Kep). Individual losses of mangrove areas in Koh Kong, Kampot, Sihanoukville and Kep during the study period were 39\%, 45\%, 52\% and 34\%, respectively. Three main causes of mangrove forest destruction in Cambodia (salt farming, charcoal production and shrimp farming) have been perceived based on the literature review.
Development of a comprehensive mangrove quality index (MQI) in Matang Mangrove: Assessing mangrove ecosystem health


Index ($MQI_s^4$) and Mangrove-Socio-economic Index ($MQI_S^5$). Using Principle Component Analysis, ten variables representing all the five categories were selected to formulate the overall MQI. They are aboveground biomass, crab abundance, soil carbon, soil nitrogen, number of phytoplankton species, number of diatom species, dissolved oxygen, turbidity, education level, and time spent fishing. We developed the overall MQI based on the total score obtained from each category. The health status of mangroves is ranked from 1 to 5 viz. 1 (worst), 2 (bad), 3 (moderate), 4 (good), 5 (excellent). In the Matang Mangrove, the health status of the least disturbed area
Tree biomass quantity, carbon stock and canopy correlates in mangrove forest and land uses that replaced mangroves in Honda Bay, Philippines

Jose Alan A. Castillo a, b, d, e, f, Armando A. Apan a, b, Tek Narayan Maraseni a, Severino G. Salmo III c

Table 5
Biomass stock densities (Mg ha⁻¹ ± SE) of mangroves and other land uses in Honda Bay, Palawan, Philippines.

<table>
<thead>
<tr>
<th>Land use/site</th>
<th>AGB</th>
<th>BGB</th>
<th>DWB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed canopy mangrove</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacungan</td>
<td>89.66 ± 15</td>
<td>43.25 ± 6</td>
<td>6.44 ± 1</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>103.29 ± 8</td>
<td>48.42 ± 3</td>
<td>6.03 ± 1</td>
</tr>
<tr>
<td>Salvacion</td>
<td>106.20 ± 20</td>
<td>58.67 ± 14</td>
<td>13.25 ± 3</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>99.72 ± 5</strong></td>
<td><strong>50.11 ± 4</strong></td>
<td><strong>8.58 ± 2</strong></td>
</tr>
<tr>
<td>Open canopy mangrove</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tagburos 1</td>
<td>13.20 ± 6</td>
<td>6.72 ± 3</td>
<td>2.45 ± 1</td>
</tr>
<tr>
<td>Santa Lourdes</td>
<td>37.49 ± 14</td>
<td>22.01 ± 10</td>
<td>13.13 ± 2</td>
</tr>
<tr>
<td>San Jose 1</td>
<td>31.65 ± 8</td>
<td>16.68 ± 5</td>
<td>5.22 ± 2</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>27.44 ± 7</strong></td>
<td><strong>15.13 ± 5</strong></td>
<td><strong>6.93 ± 3</strong></td>
</tr>
<tr>
<td>Abandoned aquaculture pond</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Jose 2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tagburos 2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tagburos 3</td>
<td>0.11 ± 0</td>
<td>0.08 ± 0</td>
<td>0.07 ± 0</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>0.04 ± 0</strong></td>
<td><strong>0.03 ± 0</strong></td>
<td><strong>0.02 ± 0</strong></td>
</tr>
<tr>
<td>Coconut plantation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tagburos 4/mean</td>
<td><strong>11.36 ± 3</strong></td>
<td><strong>0.60 ± 0</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

AGB = aboveground biomass  BGB = belowground biomass  DWB = downed woody debris biomass.  
Biomass of Abandoned salt pond and Cleared mangrove are zero and not included in the table.

Changes in mangrove vegetation, aquaculture and paddy cultivation in the Mekong Delta: A study from Ben Tre Province, southern Vietnam

Bijeesh Kozhikkodan Veetil\textsuperscript{a}, Ngo Xuan Quang\textsuperscript{b,c,e}, Ngo Thi Thu Trang\textsuperscript{d}

Table 2

<table>
<thead>
<tr>
<th>Year</th>
<th>Binh Dai vegetation (km\textsuperscript{2})</th>
<th>Ba Tri</th>
<th>Thanh Phu</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>28.58</td>
<td>12.54</td>
<td>48.9</td>
<td>90</td>
</tr>
<tr>
<td>2006</td>
<td>23</td>
<td>12.27</td>
<td>30.93</td>
<td>66.2</td>
</tr>
<tr>
<td>2015</td>
<td>14.46</td>
<td>8.36</td>
<td>19.88</td>
<td>42.7</td>
</tr>
</tbody>
</table>

Table 3
District-wise area changes in rice crops and aquaculture ponds in the coastal districts.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice crops (km\textsuperscript{2})</th>
<th>Aquaculture (km\textsuperscript{3})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Binh Dai</td>
<td>Ba Tri</td>
</tr>
<tr>
<td>2000</td>
<td>171.35</td>
<td>186.77</td>
</tr>
<tr>
<td>2006</td>
<td>138.7</td>
<td>183.05</td>
</tr>
<tr>
<td>2015</td>
<td>103.41</td>
<td>171.49</td>
</tr>
</tbody>
</table>

Table 4
Predictions of various LULC changes in Ben Tre Province after 1 m and 2 m rise in the current sea level.

<table>
<thead>
<tr>
<th>Land cover/Land use\textsuperscript{a}</th>
<th>Current area (km\textsuperscript{2})</th>
<th>1 m sea level rise</th>
<th>2 m sea level rise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area flooded (km\textsuperscript{2})</td>
<td>Area flooded (%)</td>
<td>Area flooded (km\textsuperscript{2})</td>
</tr>
<tr>
<td>Mangrove forests</td>
<td>42.7</td>
<td>19.3</td>
<td>45.2</td>
</tr>
<tr>
<td>Rice crops</td>
<td>363.27</td>
<td>342.27</td>
<td>60.9</td>
</tr>
<tr>
<td>Aquaculture ponds</td>
<td>330</td>
<td>214.7</td>
<td>65</td>
</tr>
<tr>
<td>Total provincial area including water bodies</td>
<td>2272.4</td>
<td>1045.4</td>
<td>46</td>
</tr>
</tbody>
</table>

\textsuperscript{a} LULC in 2015 taken as latest.
Effects of mangrove rehabilitation on density of *Scylla* spp. (mud crabs) in Kuala Langsa, Aceh, Indonesia

Mariah Ulfa, Kou Ikejima, Erny Poedjirahajoe, Lies Rahayu Wijayanti Faida, Moehar Maraghiy Harahap

of mud crab density (with positive correlation); a weak, positive correlation was also apparent for tree height and DO. Results support the view that mangrove rehabilitation enhances densities of mud crabs. Manipulative experimentation is required to determine the mechanisms of the ecology of mangrove ecosystems affect mud crab populations.

Bioaccumulation and cycling of organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in three mangrove reserves of south China

Yao-Wen Qiu, Han-Lin Qiu, Gan Zhang, Jun Li

An evaluation on the bioavailability of heavy metals in the sediments from a restored mangrove forest in the Jinjiang Estuary, Fujian, China

Jun Deng, Peiyong Gao, Xiaoyan Zhang, Xiaobiao Shen, Haitao Su, Yuxuan Zhang, Yanmei Wu, Cheng Xu

...to heavy metal ions in the restored regions compared to the mudflat (control group). The conclusions were also similar when taking TOC concentrations into account. Mangrove wetland restoration has significant effects on the bioavailability of heavy metals in sediments. According to the thresholds for metal toxicity on benthic organisms in sediments, Pb, Cu and Ni had potential adverse effects on benthic organisms in this restored wetland.
World Mangrove Distribution
Total 150,000 km²

- South East Asia: 510.49 km², 33.5%
- South America: 23,883 km², 15.7%
- East Asia: 215 km², 0.1%
- Middle East: 624 km², 0.4%
- Pacific Ocean: 5,717 km², 3.8%
- East and South Africa: 7,917 km², 5.2%
- Australia/New Zealand: 10,171 km², 6.7%
- West and Central Africa: 20,040 km², 13.2%
- North and Central America: 22,402 km², 14.7%
Global Distribution of Mangroves USGS (2011)
Mostly occupy intertidal and shallow water environments

**Mangroves** occur in 118 countries worldwide, but ~75% of the total coverage is located in 15 countries, *with 23% found in Indonesia alone*

Mangroves declined at 1-3% during second half of 20th century due to aquaculture, land use change and land reclamation

Since 21st century, mangrove loss rates are 0.16-0.39%/year: due to changes in aquaculture and *conservation efforts*
THANK YOU!
REFERENCES

Thomsen et al. 2019. Local extinction of bull kelp (Duvillaea spp.) due to a marine heatwave. Frontiers in Marine Science 6, 84.