International Virtual Course

Department of Oceanography, Institut Teknologi Bandung

IMPACTS OF CLIMATE CHANGE ON VEGETATION COVER

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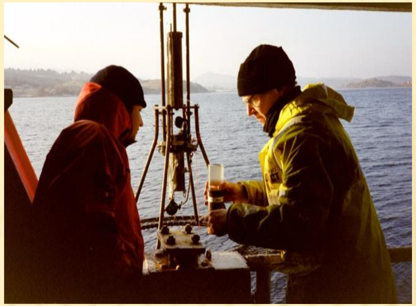
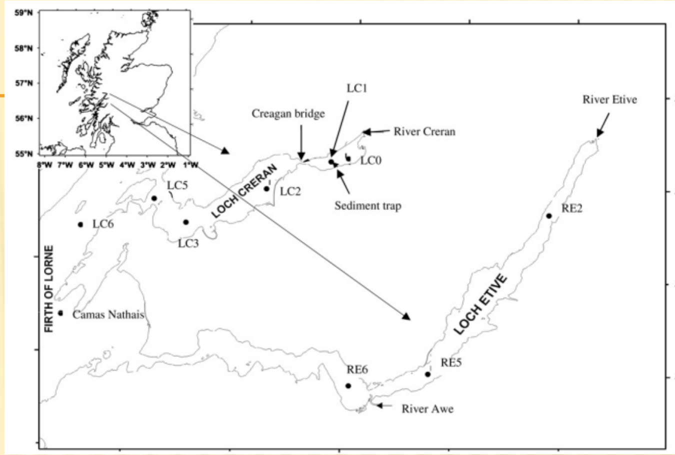
24 November 2020

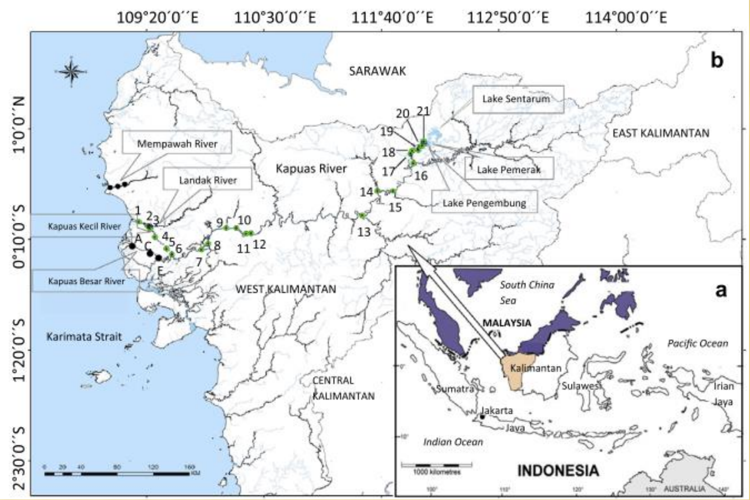
CONTENTS

SOME PREVIOUS WORKS

- Biomonitoring of heavy metals in molluscs in rivers in Sarawak, UNIMAS
- Sedimentary organic matter in Lochs Creran & Etive; Dunstaffnage 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

CONSEQUENCES


Heat stress and bleaching — the loss of symbiotic algae — killed many corals in Australia's Great Barrier Reef after the 2016 crisis.

ECOLOGY

Great Barrier Reef saw huge losses from 2016 heatwave

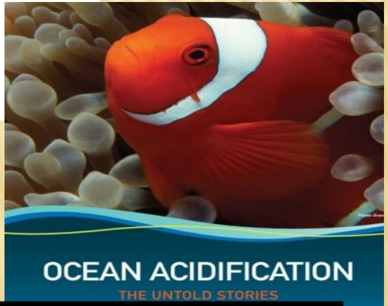
Local Extinction of Bull Kelp (*Durvillaea* spp.) Due to a Marine Heatwave

Mads S. Thomsen[1,2*], Luca Mondardini[1], Tommaso Alestra[1], Shawn Gerrity[1], Lei Paul M. South[4], Stacie A. Lilley[1] and David R. Schiel[1]

Community-Level Actions that Can Address Ocean Acidification

Sarah R. Cooley *, C. Ryan Ono, Sage Melcer and Julia Roberson

Ocean Acidification Program, Ocean Conservancy, Washington, DC, USA

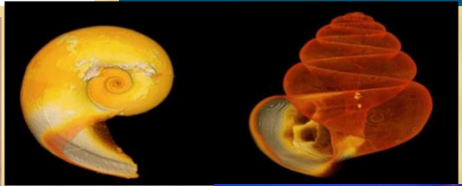


Hypoxia in the world ocean as recorded in the historical data set

DANIEL KAMYKOWSKI* 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.



Climate change

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

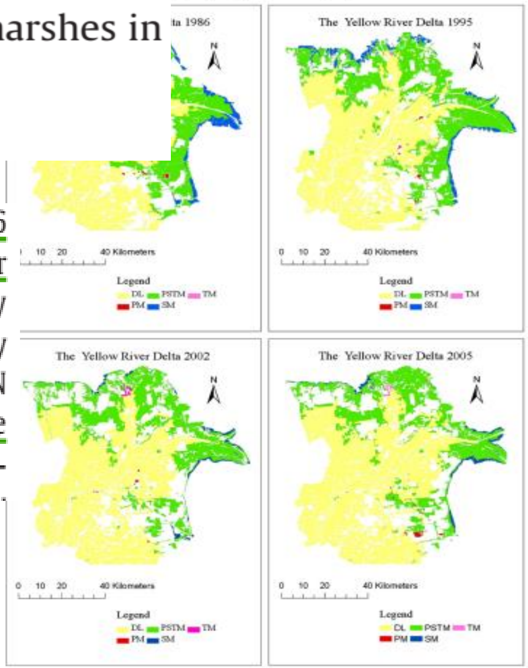
SOME STUDIES THAT DETERMINE VEGETATION CHANGES

Remote sensing

Two-decade wetland cultivation and its effects on soil properties in salt marshes in the Yellow River Delta, China

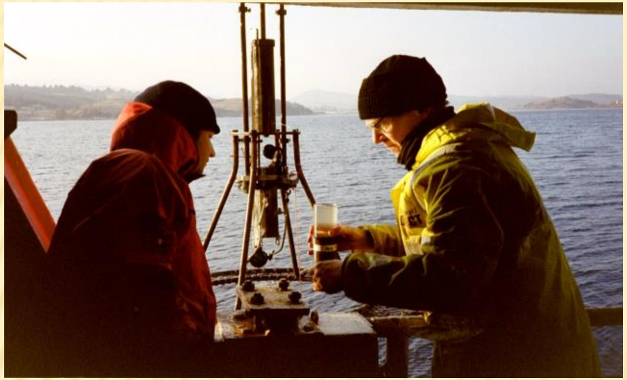
Laibin Huang [a], Junhong Bai [a,*], Bin Chen [a], Kejiang Zhang [b], Chen Huang [a], Peipei Liu [a]

marshes (PSTMs). The total area of marsh wetland was reduced by 65.09 km^2 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 NO_3^--N between different land-use types (P<0.05). After the conversions from marsh wetlands to dry lands, bulk density, pH, salinity and NH_4^+-N decreased slightly, while a significant increase in NO_3^--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 dur-

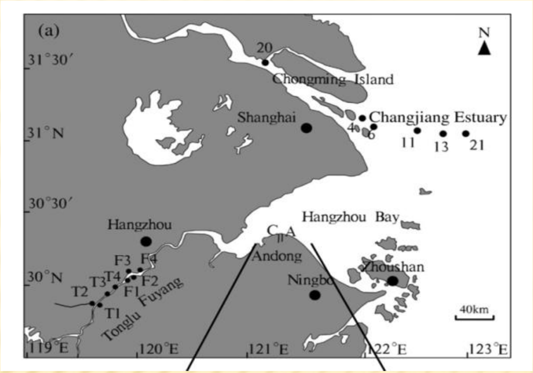


ges in the Yellow River Delta in 1986, 1995, 2000, and 2005. SM — *Suaeda salsa* marsh; PSTM — *Phragmites australis–Suaeda salsa–Ta*
lis marsh; TM — *Tamarix chinensis* marsh; DL — dry land.

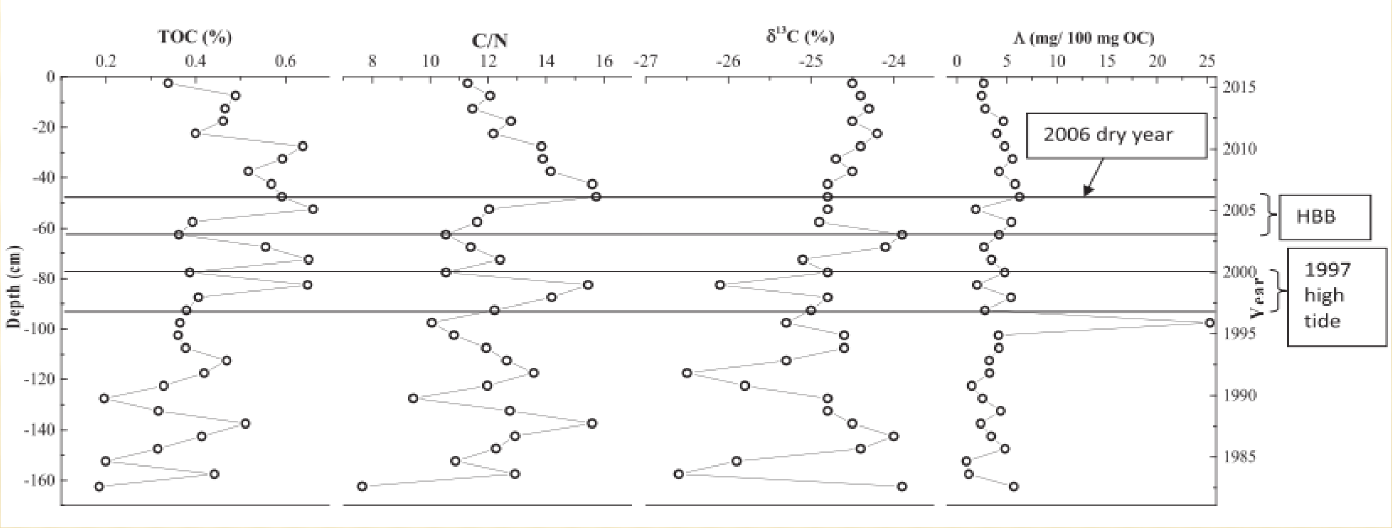
Sediment cores



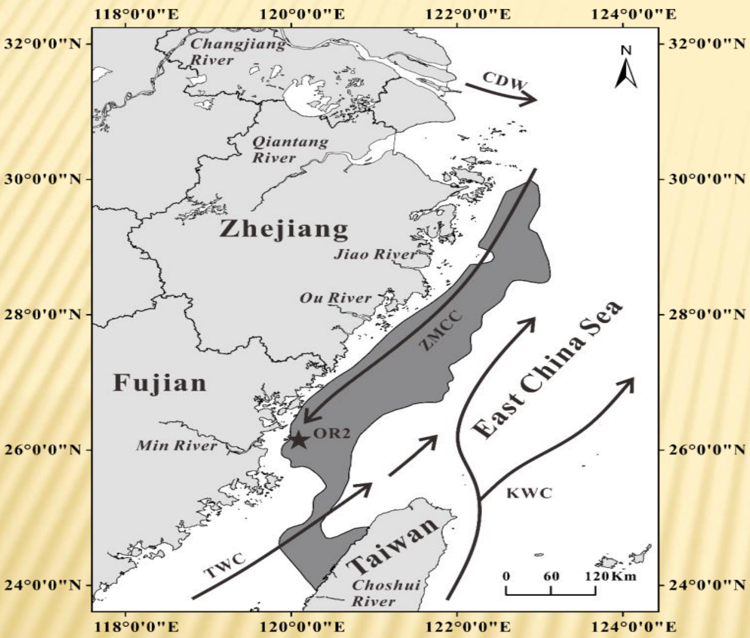
~ Andong salt marsh ~

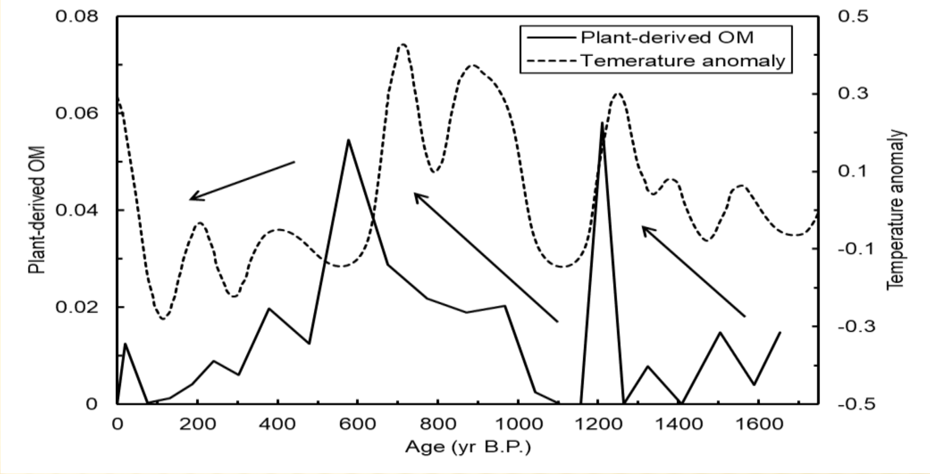


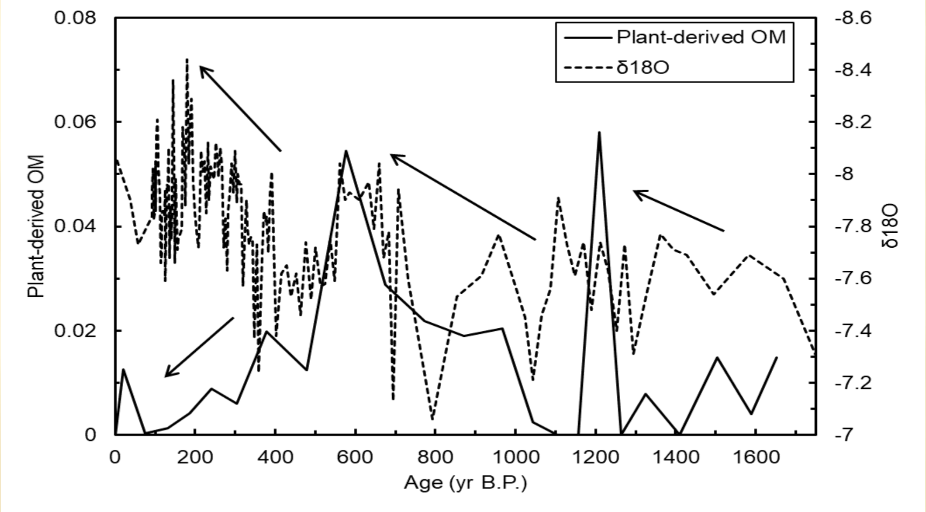
- Terrestrial plants have higher C/N ratios (above 23.3) than phytoplankton (ranging from 4.7 to 11.7)
- C3 photosynthetic plants have relatively more depleted $\delta^{13}C$ values (-22‰ to -35‰) than algae and phytoplankton materials (-12‰ to -23‰; Meyers 1994)
- Lignin as biomarker for terrestrial organic matter



~ Min River estuary ~







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. TREITZ[2] and DAVID M. ATKINSON[2]

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, Ingibjörg Svala Jónsdóttir, Kristine Bakke Westergaard, James P. Lawler, Mora Aronsson, Bruce Bennett, Hans Gardfjell, Starri Heiðmarsson, Laerke Stewart, Signe Normand

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

Karel Prach · Jiří Košnar · Jitka Klimešová · Martin Hais

2,042 × 521 m. The mapping carried out in 2008 did not reveal any changes in vegetation, since a previous study in 1936–1937, that could be attributed to climate change. We

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

Climat

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. Pearson[1]*, Steven J. Phillips[2], Michael M. Loranty[3,4], Pieter S. A. Beck[3], Theodoros Damoulas[5], Sarah J. Knight[1,6†] and Scott J. Goetz[3]

of vegetation across the Arctic. We predict that at least half of vegetated areas will shift to a different physiognomic class, and woody cover will increase by as much as 52%. By incorporating observed relationships between vegetation and albedo, evapotranspiration and biomass, we show that vegetation distribution shifts will result in an overall positive feedback to climate that is likely to cause greater warming than has previously been predicted. Such extensive changes to Arctic vegetation will have implications for climate, wildlife and ecosystem services.

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

Daan Blok[1], Gabriela Schaepman-Strub[2], Harm Bartholomeus[3], Monique M P D Heijmans[1], Trofim C Maximov[4] and …nk Berendse[1]

- Arctic fires
- Increased atmospheric CO_2

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

M. Syndonia Bret-Harte[1], Michelle C. Mack[2], Gaius R. Shaver[3], Diane C. Huebner[1], Miriam Johnston[3], Camilo A. Mojica[2], Camila Pizano[2] and Julia A. Reiskind[2]

Arctic tundra fires: natural variability and responses to climate change

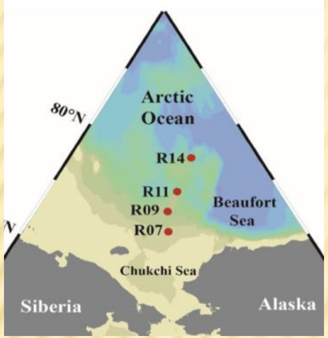
Feng Sheng Hu[1,2,3*], Philip E Higuera[4], Paul Duffy[5], Melissa L Chipman[3], Adrian V Rocha[6], Adam M Young[7], Ryan Kelly[8,9], and Michael C Dietze[9]

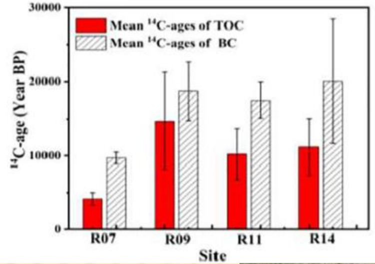
Changes in Arctic vegetation amplify high-latitude warming through the greenhouse effect

Abigail L. Swann[a,1], Inez Y. Fung[a], Samuel Levis[b], Gordon B. Bonan[b], and Scott C. Doney[c]

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. Wickland[2]

terrestrial to aquatic C transfer. We conclude that decreased DOC export, relative to total summer through autumn Q, results from increased flow path, residence time, and microbial mineralization of DOC in the soil active layer and groundwater. Counter to current predictions, we argue that continued warming could result in decreased DOC export to the Bering Sea and Arctic Ocean by major subarctic and arctic rivers, due to increased respiration of organic C on land. **Citation:** Striegl, R. G., G. R. Aiken, M. M. Dornblaser, P. A. Raymond, and K. P. Wickland (2005), A

ture [*Meentemeyer*, 1978]. More importantly, permafrost melting will result in increased hydraulic residence of soil water DOC and in rerouting of DOC into shallow groundwater, allowing for increased microbial mineralization and decreased riverine export of the terrestrially derived DOC (Warming II, Figure 1c). Although the extent of permafrost melting is not well documented throughout the Yukon basin,

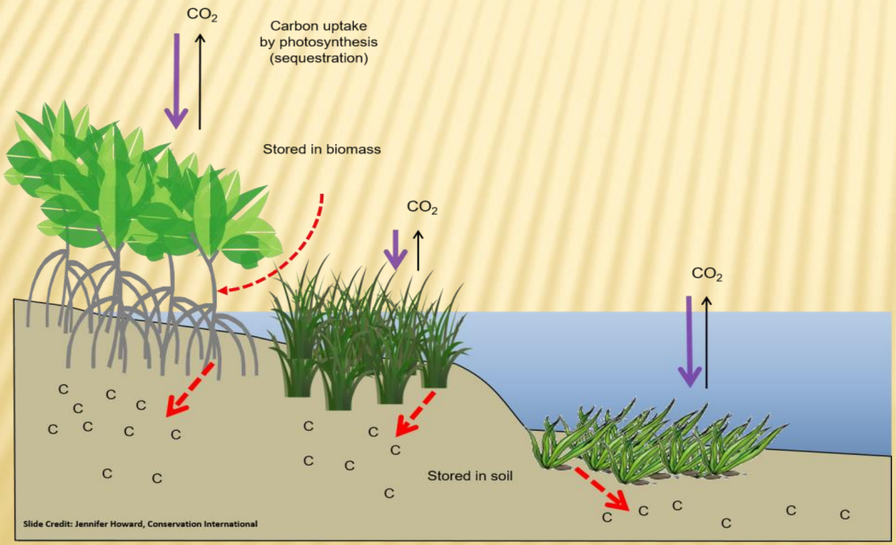
The Arctic Ocean carbon sink

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

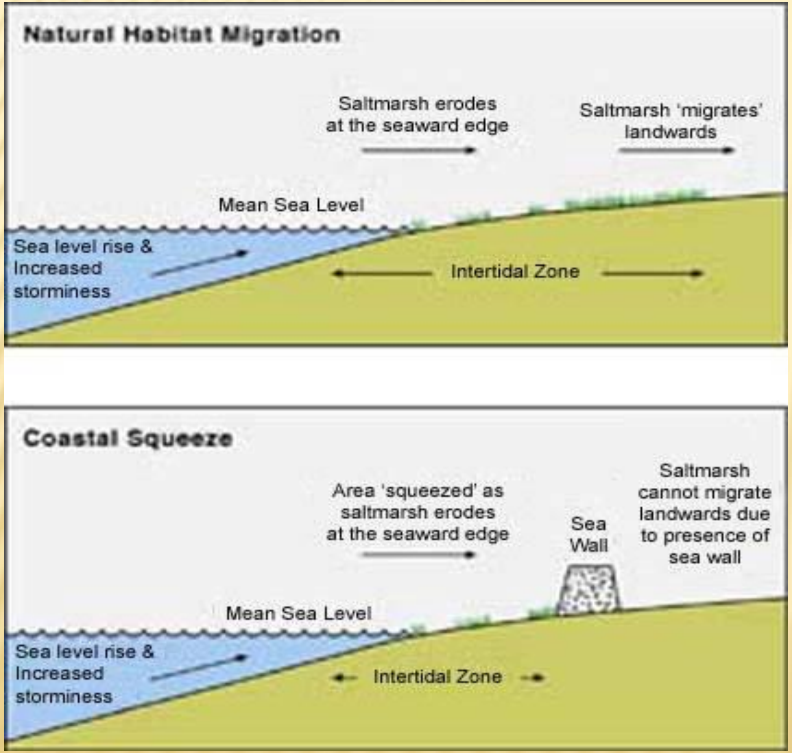
to infer the sources of interior transport implied that this export is primarily due to the sinking and remineralisation of organic matter, highlighting the importance of the biological pump. Furthermore, we qualitatively show that the present day Arctic Ocean is accumulating anthropogenic carbon beneath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

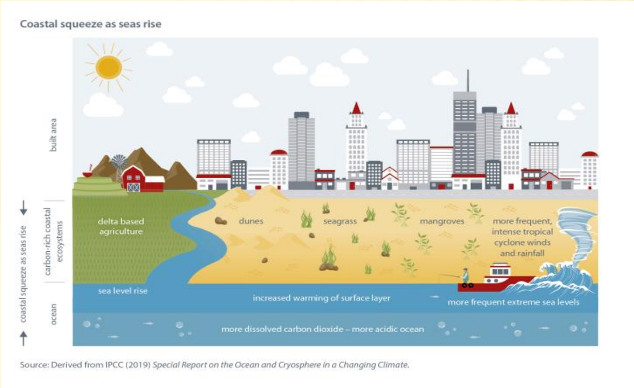
2. SALT MARSH

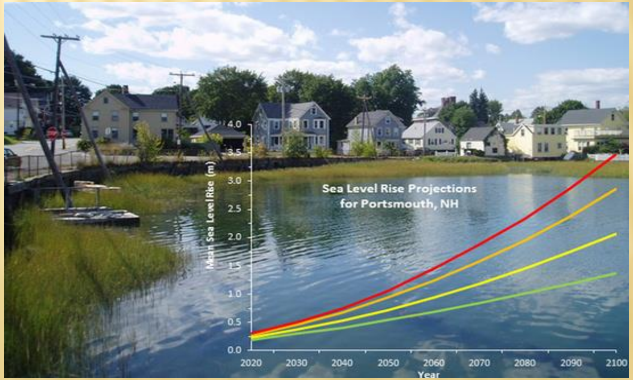
- Sediment transport
- Wave; tide
- Hurricane deliver sediment to salt marsh



- Their distribution and productivity are determined by sea level and space available for sediment accumulation







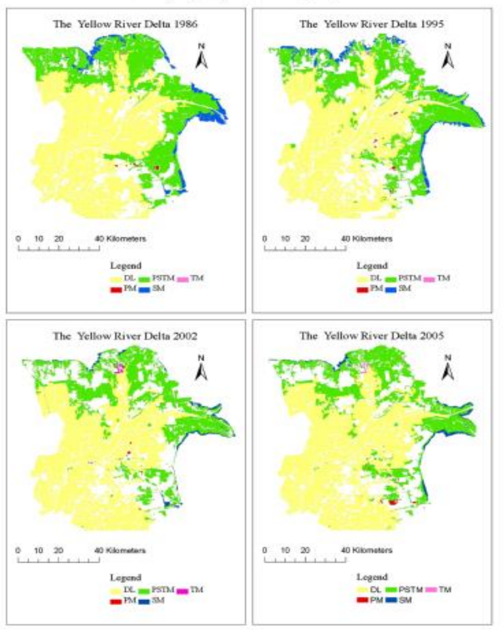
SOME STUDIES THAT DETERMINE WHETHER SALT MARSHES ARE CARBON SINK OR SOURCE

REMOTE SENSING

Two-decade wetland cultivation and its effects on soil properties in salt marshes in the Yellow River Delta, China

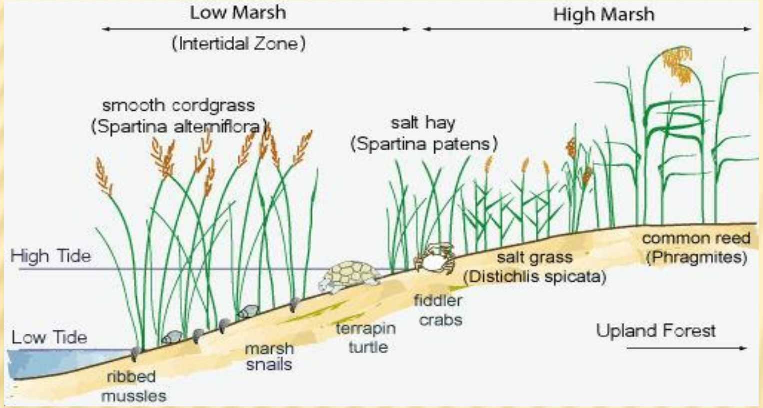
Laibin Huang [a], Junhong Bai [a,*], Bin Chen [a], Kejiang Zhang [b], Chen Huang [a], Peipei Liu [a]

marshes (PSTMs). The total area of marsh wetland was reduced by 65.09 km^2 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 NO_3^--N between different land-use types ($P<0.05$). After the conversions from marsh wetlands to dry lands, bulk density, pH, salinity and NH_4^+-N decreased slightly, while a significant increase in NO_3^--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 dur-



Classification mapping of salt marsh vegetation by flexible monthly NDVI time-series using Landsat imagery

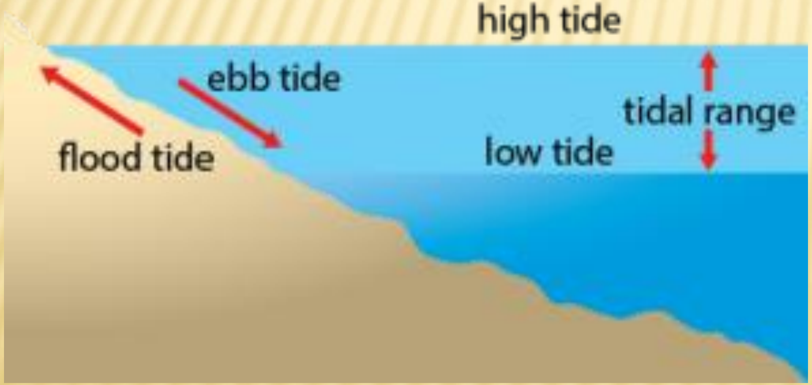
Chao Sun[a,b,*,1], Sergio Fagherazzi[b], Yongxue Liu[c,**]



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^2) is more than twice the conversion to vegetation communities typical of high elevations (18.3 km^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

estuarine waters. From average P and Si tidal fluxes analysis, both salt marshes act as a sink during high productivity period (May and July) and as a source, supplying estuarine water during low productivity period (November and March).

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.

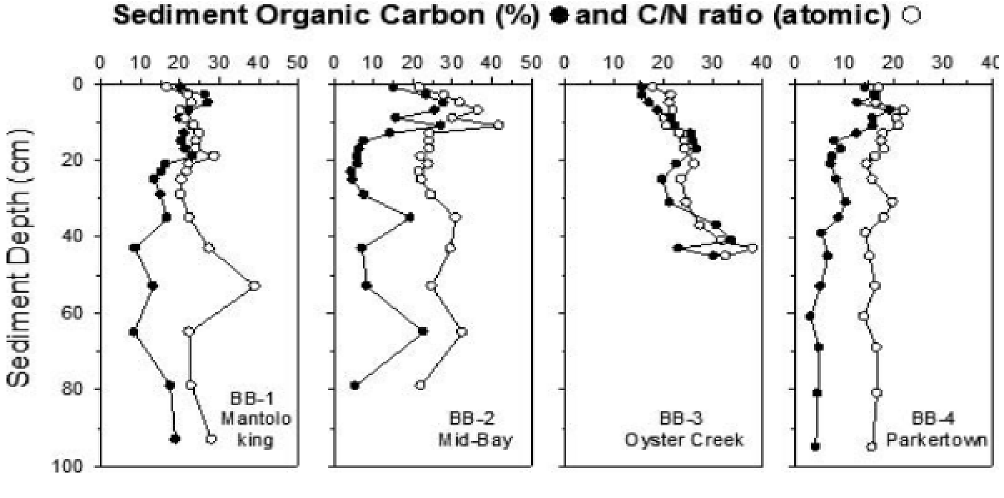
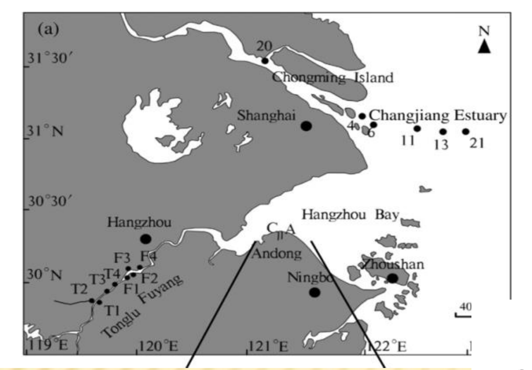


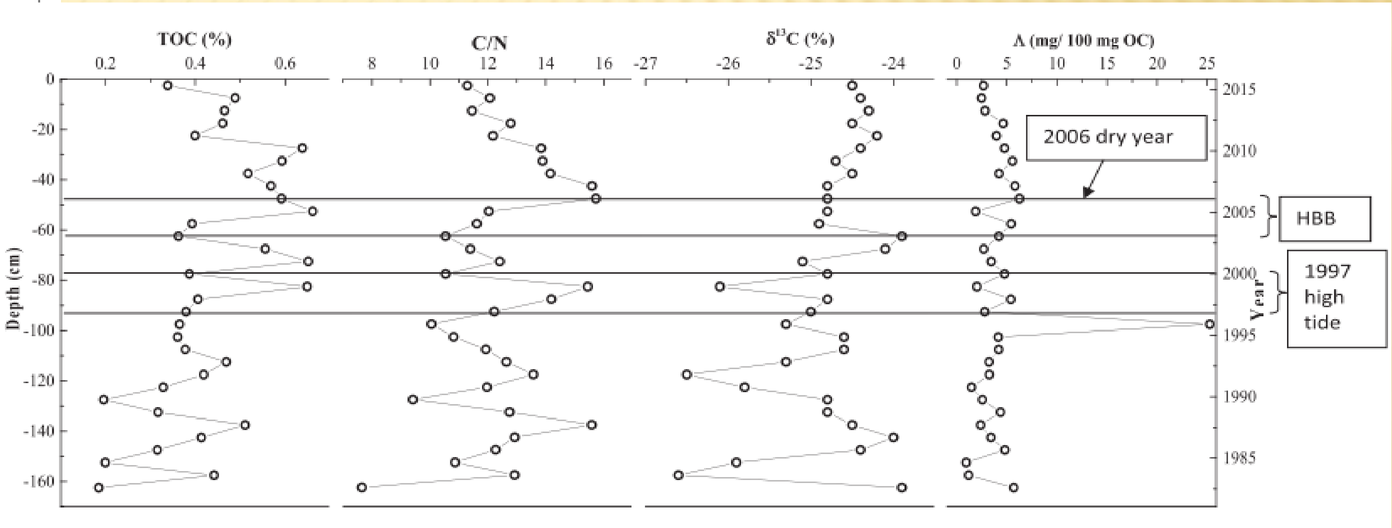
Figure 3. Sediment organic carbon and C:N ratio at four different coring sites in the marshes of Barnegat Bay.

~ Andong salt marsh ~



Impacts of human activity and extreme weather events on sedimentary organic matter in the Andong salt marsh, Hangzhou Bay, China

Pei Sun Loh[a,*], Long-Xiu Cheng[a], Hong-Wei Yuan[a], Lin Yang[a], Zhang-Hua Lou[a], Ai-Min Jin[a], Xue-Gang Chen[a], Yu-Shih Lin[b], Chen-Tung Arthur Chen[b]



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[a], Zongming Wang[a,*], Yuanzhi Zhang[b,c,**], Dehua Mao[a], Chao Wang[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

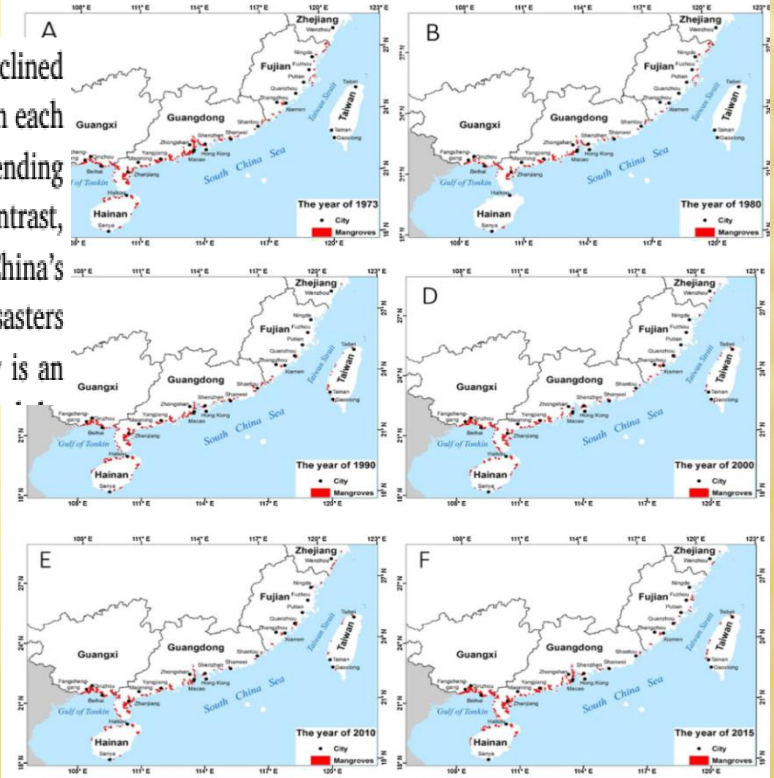
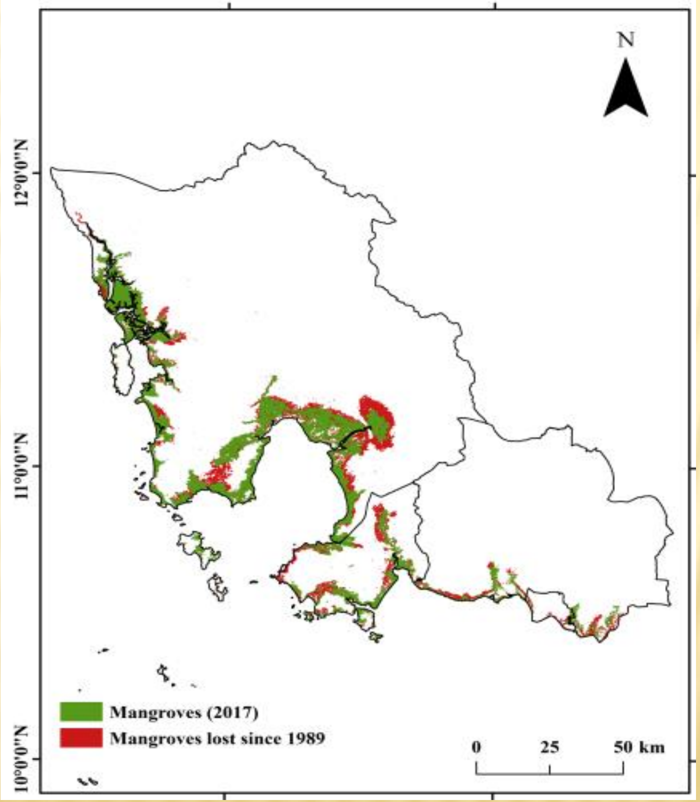


Fig. 2. Distribution of mangrove forests along the coast of China from 1973 to 2015.

Mangrove forests of Cambodia: Recent changes and future threats

Bijeesh Kozhikkodan Veettil[a], Ngo Xuan Quang[b,c,*]

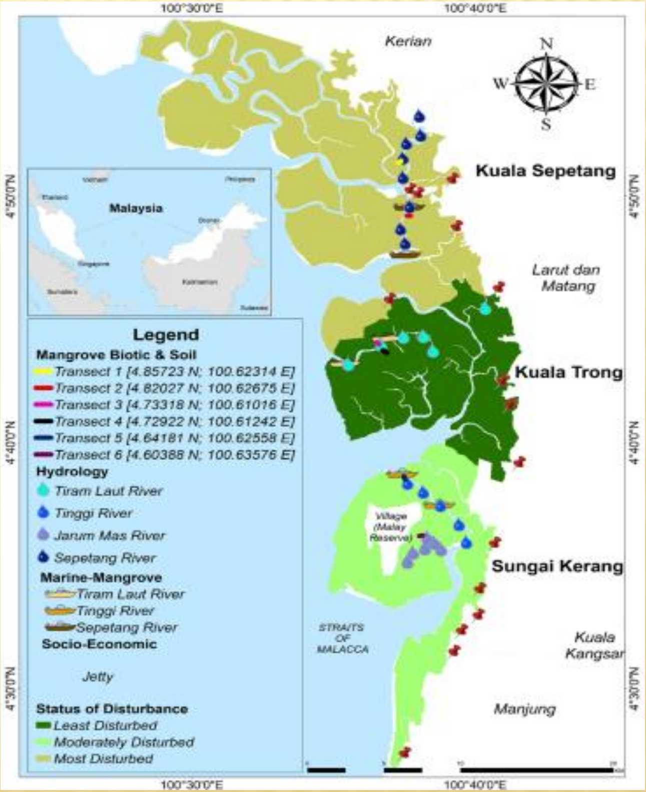


this study, decadal changes in mangrove forests along the Cambodian coastline were analysed using satellite data (Landsat series). Overall loss of mangrove forests between 1989 and 2017 has been estimated as 42% (1415 ha/year) in the four coastal provinces of Cambodia (Koh Kong, Kampot, Preah Sihanoukville, 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

I. Faridah-Hanum[a,*], Fatimah M. Yusoff[b,d], A. Fitrianto[c], Nuruddin A. Ainuddin[a,e], Seca Gandaseca[a,e], S. Zaiton[e,g], K. Norizah[a,e], S. Nurhidayu[a,e], M.K. Roslan[a], Khalid R. Hakeem[f], I. Shamsuddin[a], Ismail Adnan[a], A.G. Awang Noor[a], A.R.S. Balqis[d], P.P. Rhyma[a], I. Siti Aminah[a], F. Hilaluddin[d], R. Fatin[a], N.Z.N. Harun[a]

Index ($MQIS_4$) and Mangrove-Socio-economic Index ($MQIS_5$). 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,*,1], Armando A. Apan [a,b], Tek Narayan Maraseni [a], Severino G. Salmo III [c]

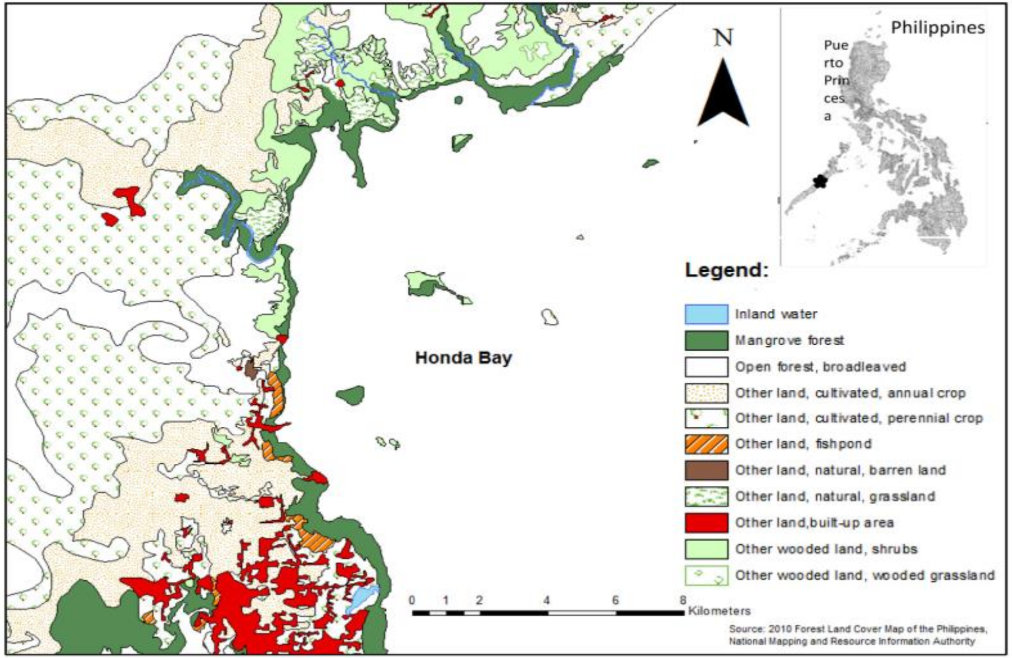


Table 5
Biomass stock densities (Mg $ha^{-1} \pm$ SE) of mangroves and other land uses in Honda Bay, Palawan, Philippines.

Land use/site	AGB	BGB	DWB
Closed canopy mangrove			
Bacungan	89.66 ± 15	43.25 ± 6	6.44 ± 1
Santa Cruz	103.29 ± 8	48.42 ± 3	6.03 ± 1
Salvacion	106.20 ± 20	58.67 ± 14	13.26 ± 3
Mean	**99.72** ± **5**	**50.11** ± **4**	**8.58** ± **2**
Open canopy mangrove			
Tagburos 1	13.20 ± 6	6.72 ± 3	2.45 ± 1
Santa Lourdes	37.49 ± 14	22.01 ± 10	13.13 ± 2
San Jose 1	31.65 ± 8	16.68 ± 5	5.22 ± 2
Mean	**27.44** ± **7**	**15.13** ± **5**	**6.93** ± **3**
Abandoned aquaculture pond			
San Jose 2	0	0	0
Tagburos 2	0	0	0
Tagburos 3	0.11 ± 0	0.08 ± 0	0.07 ± 0
Mean	**0.04** ± **0**	**0.03** ± **0**	**0.02** ± **0**
Coconut plantation			
Tagburos 4/**mean**	**11.36** ± **3**	**0.60** ± **0**	**0**

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 Veettil[a], Ngo Xuan Quang[b,c,*], Ngo Thi Thu Trang[d]

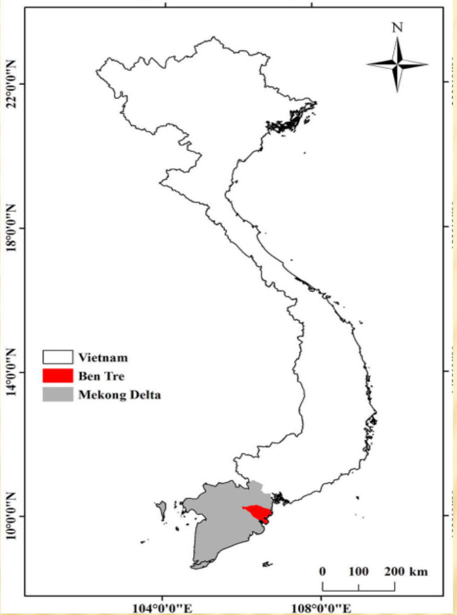


Table 2
District-wise changes in mangrove coverage in Ben Tre (1998–2015).

Year	Mangrove vegetation (km^2)			
	Binh Dai	Ba Tri	Thanh Phu	Total
1998	28.58	12.54	48.9	90
2006	23	12.27	30.93	66.2
2015	14.46	8.36	19.88	42.7

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

Year	Rice crops (km^2)				Aquaculture (km^2)			
	Binh Dai	Ba Tri	Thanh Phu	Total	Binh Dai	Ba Tri	Thanh Phu	Total
2000	171.35	186.77	172.69	530.81	57.6	21.4	71.3	150.3
2006	138.7	183.05	88.98	410.73	93.5	24.2	159.5	277.2
2015	103.41	171.49	88.37	363.27	148.8	24	157.2	330

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

Land cover/Land use[a]	Current area (km^2)	1 m sea level rise		2 m sea level rise	
		Area flooded (km^2)	Area flooded (%)	Area flooded (km^2)	Area flooded (%)
Mangrove forests	42.7	19.3	45.2	25.3	59.2
Rice crops	363.27	342.27	60.9	416.29	74.1
Aquaculture ponds	330	214.7	65	267.5	89.2
Total provincial area including water bodies	2272.4	1045.4	46	1352	59.5

[a] LULC in 2015 taken as latest.

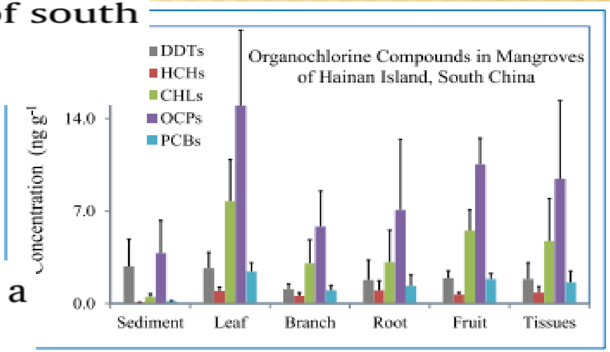
Effects of mangrove rehabilitation on density of *Scylla* spp. (mud crabs) in Kuala Langsa, Aceh, Indonesia

Mariah Ulfa [a,b], Kou Ikejima [a,*], Erny Poedjirahajoe [b], Lies Rahayu Wijayanti Faida [b], Moehar Maraghiy Harahap [b]

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

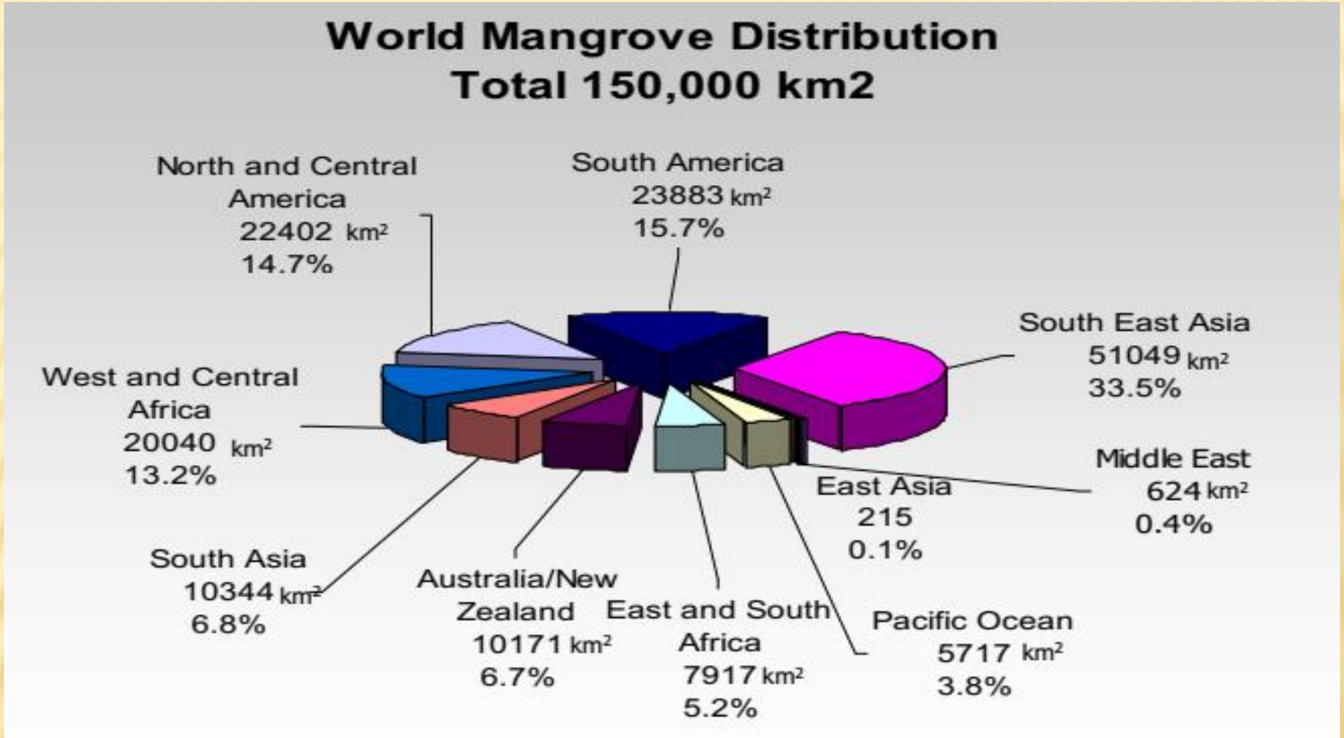
Yao-Wen Qiu [a, *], Han-Lin Qiu [c], Gan Zhang [b], Jun Li [b]



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

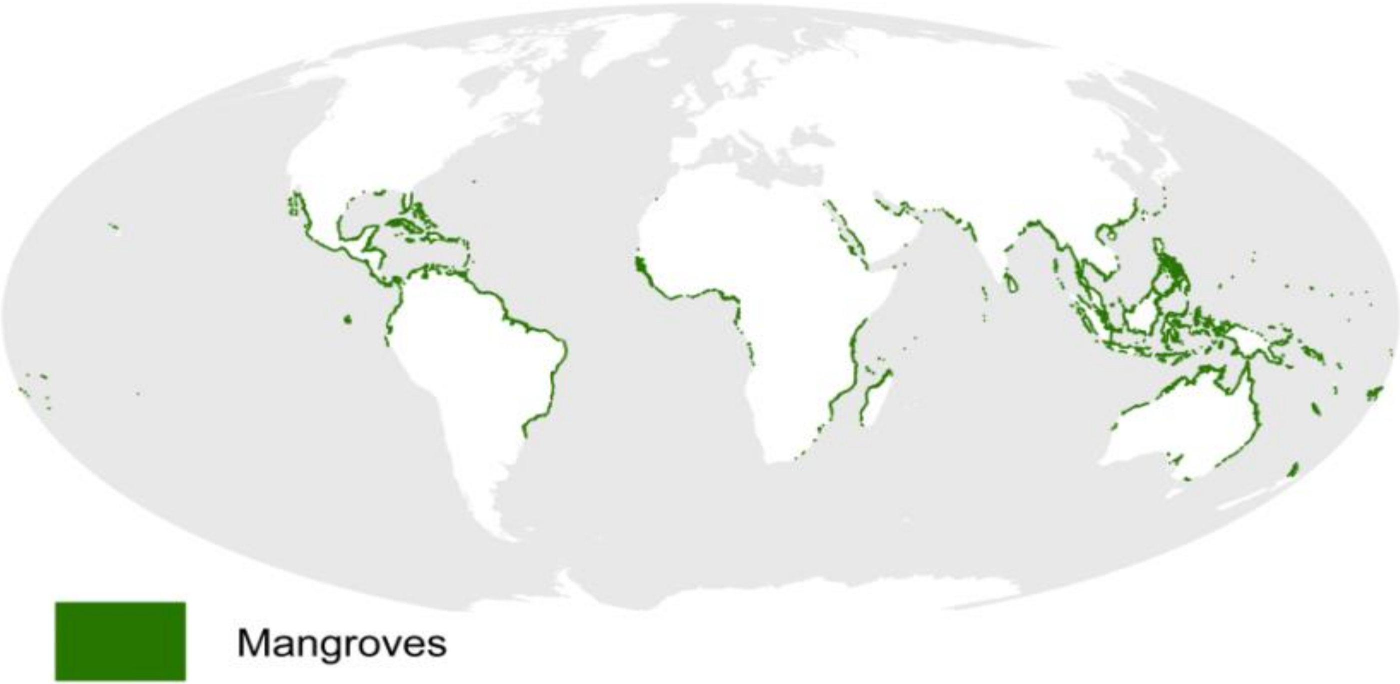
Jun Deng[a,b], Peiyong Guo[a,b,*], Xiaoyan Zhang[c], Xiaobiao Shen[d], Haitao Su[a,b], Yuxuan Zhang[a,b], Yanmei Wu[a,b], Cheng Xu[a,b]

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's Atlas of Mangroves

Global Distribution of Mangroves USGS (2011)



DISTRIBUTION

- 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 !

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