The effects of land subsidence and uplift on intertidal mollusks following the Great East Japan Earthquake

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Effects of the 2011

on marine life and residents

- Rapid impacts by liquefaction and tsunamis
- Short and Long-term effects by land subsidence and uplift
- Effects of man-made structures
- Concept of tsunami disaster prevention in Japan and in the world

Introduction

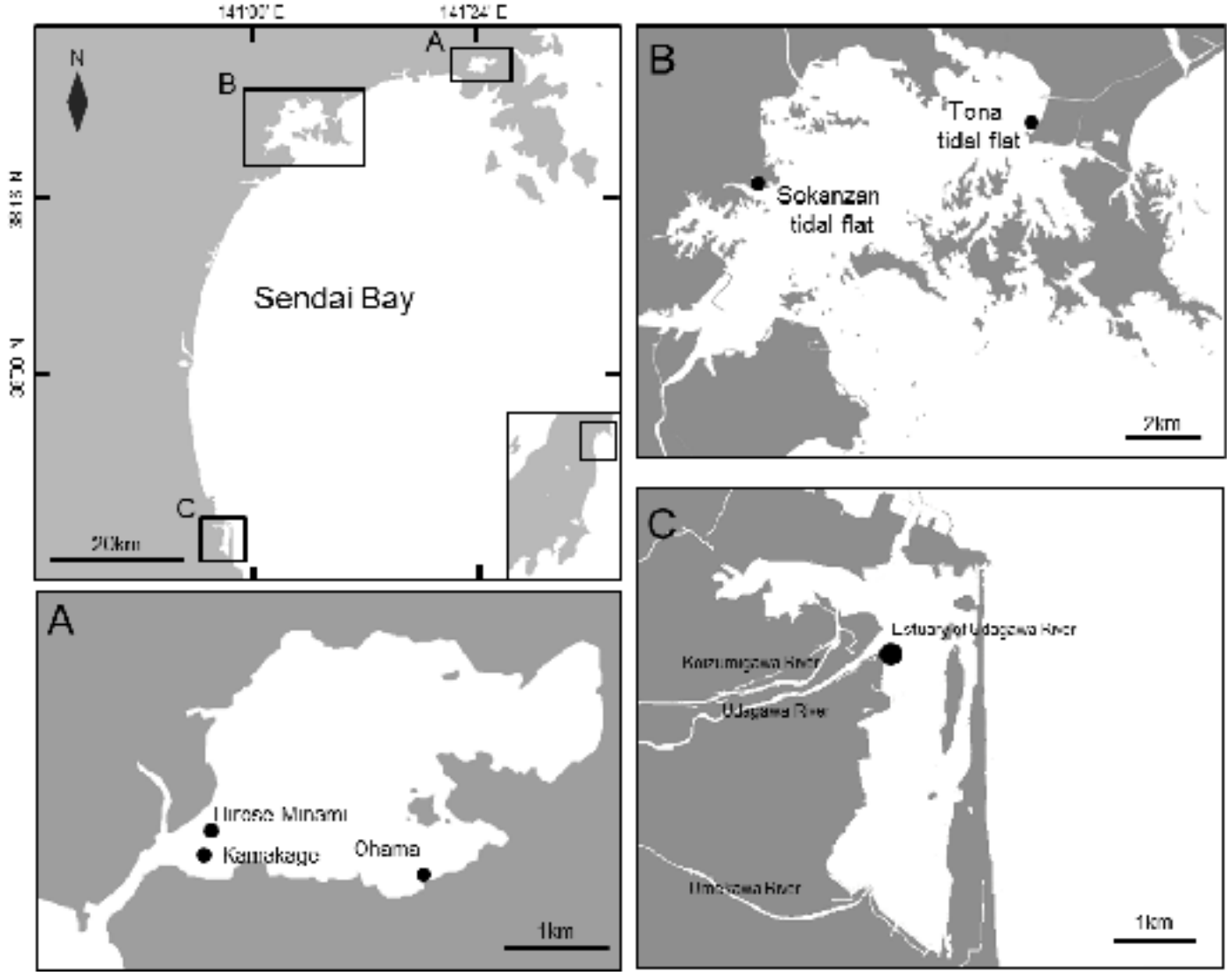
The 2011 Great East Japan Earthquake

March 11th 2011
Magnitude 9.0
Huge tsunamis

short-term effects :
liquefaction and tsunamis

long-term effects :
land subsidence and uplift

Study area

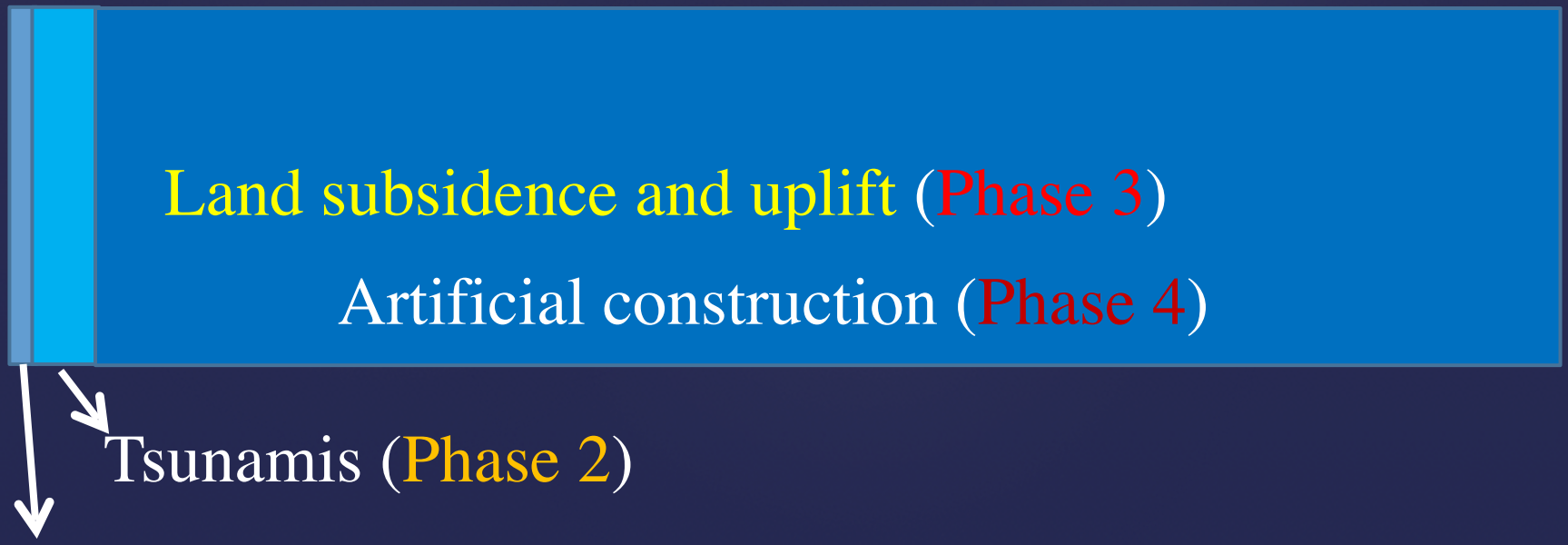


Maps showing the location of the study area in Sendai Bay, Japan, and the locations of (A) Mangoku-ura Lagoon, (B) Matsushima Bay and (C) Matsukawa-ura Lagoon.

Introduction

The 2011 Great East Japan Earthquake

Impact of the earthquake (time series)



Phase 1: earthquake and liquefaction

Sanbanze tidal flat in Tokyo Bay in Apr 2011

Cracks in the ground

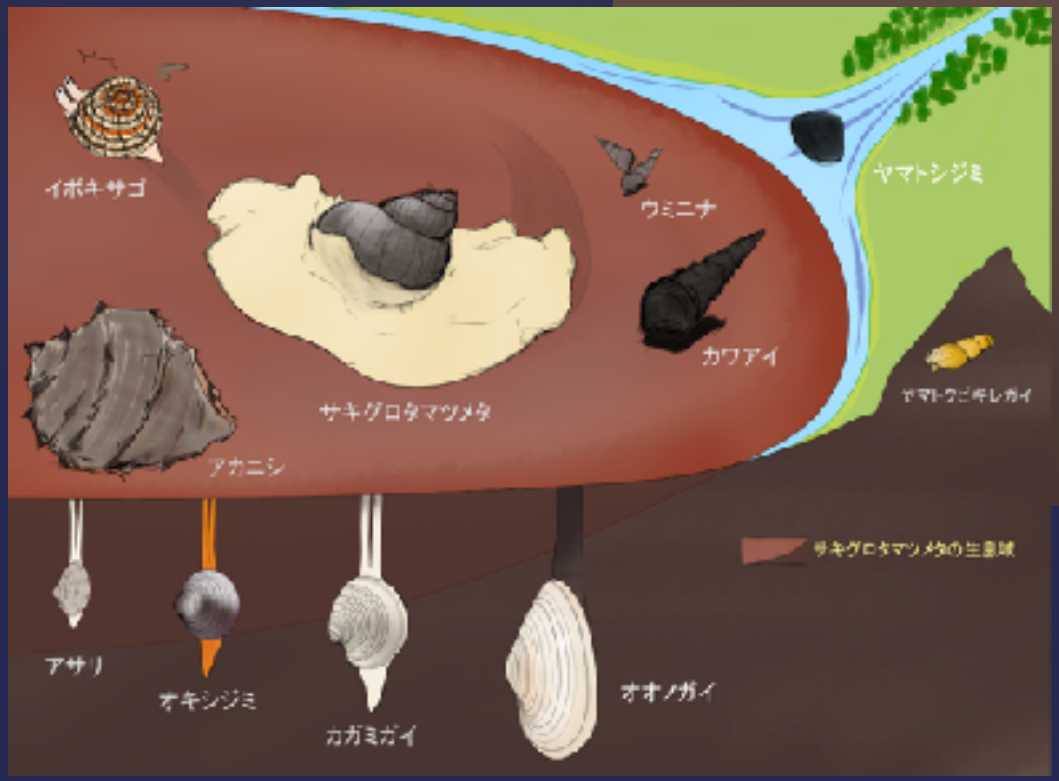
Liquefaction induced by earthquake shaking occurred just after the earthquake

Sand boils that erupted in tidal flat caused by liquefaction

before arrival of the first tsunami

Phase 1: earthquake and liquefaction

Before liquefaction and tsunami



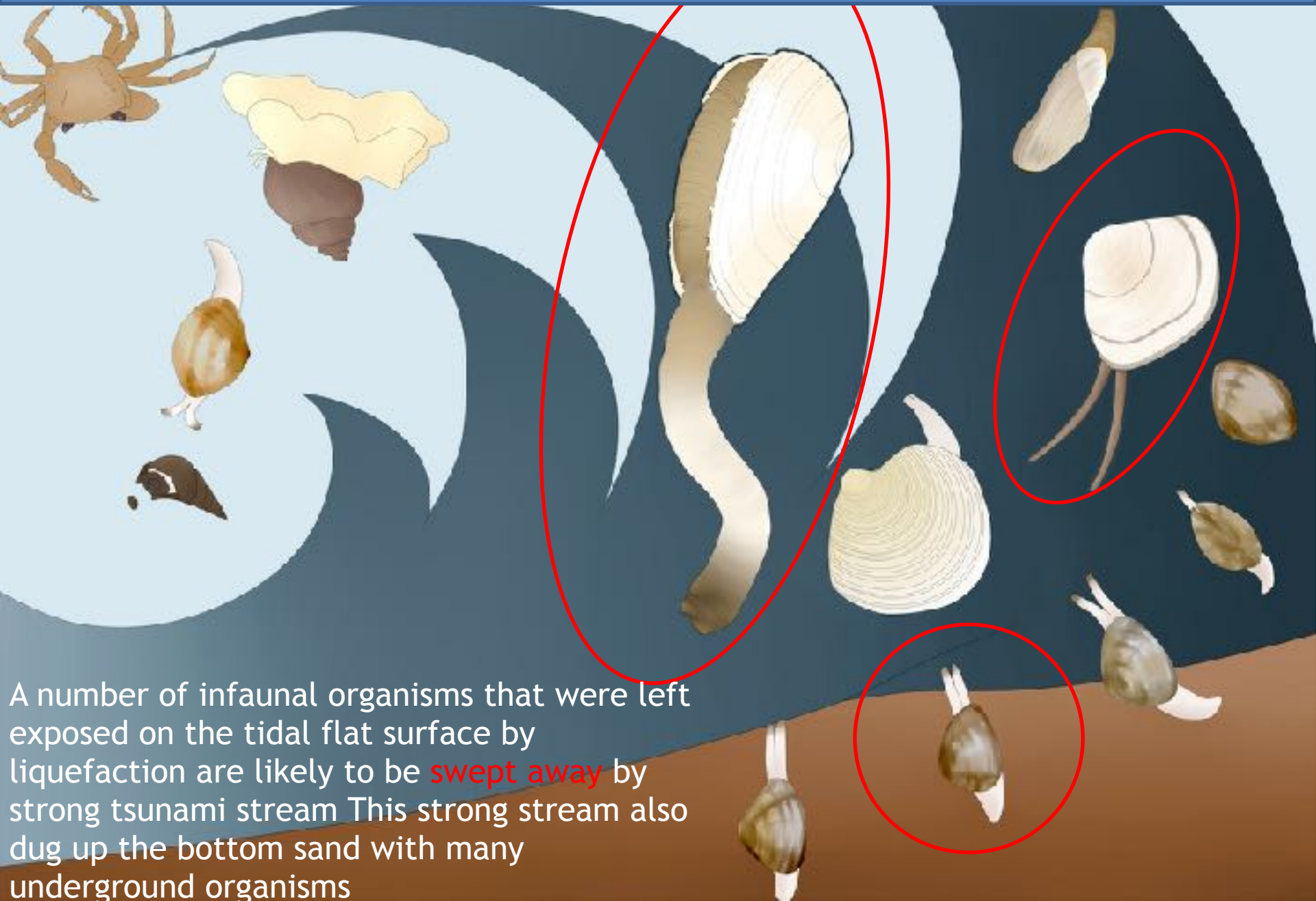
Phase 1: earthquake and liquefaction

Tidal flats before the tsunami was coming

It is likely that these bivalves were pushed out from the deep sediments by these jets of water, leaving many of the bivalves that live submerged in the sediments exposed on the tidal flat surface prior to the arrival of the tsunamis.

This figure was made on the basis of the testimony of witnesses

Phase 2: subsequent tsunamis



A number of infaunal organisms that were left exposed on the tidal flat surface by liquefaction are likely to be swept away by strong tsunami stream This strong stream also dug up the bottom sand with many underground organisms

Phase 2: subsequent tsunamis

Dispersion of benthic organisms

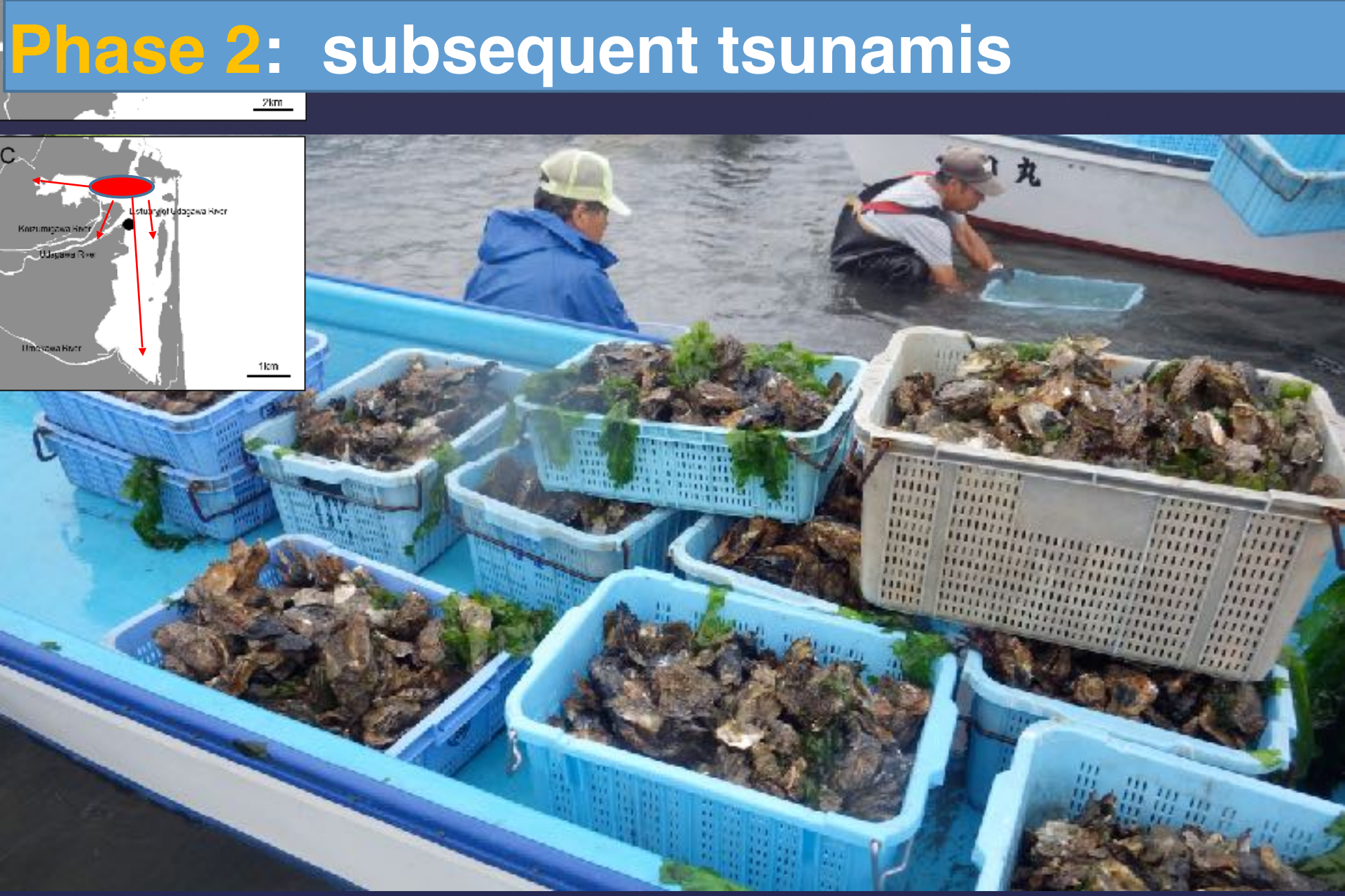
Earthquakes with tsunamis have occurred in ~500 year cycles along the Pacific coast of northern Japan (Okoshi 2015) and may have contributed to the creation of new habitats for sessile organisms such as the oyster (Okoshi 2016).

Before tsunami (2009)

After tsunami (2016)

Okoshi K. 2015. Impact of repeating massive earthquakes on intertidal mollusk community in Japan. In: Ceccaldi H-J, Hénocque Y, Koike Y, Komatsu T, Stora G, Tusseau-Vuillemin M-H (Eds). Marine Productivity: Perturbations and Resilience of Socio-ecosystems. Springer, pp 55–62. ISBN 978-3-319-13877-0, ISBN 978-3-319-13878-7 (eBook) DOI 10.1007/978-3-319-13878-7_6

Phase 2: subsequent tsunamis



Work to remove the oyster that has spread to the clam fishery field（Aug 2014）

Bivalves damaged in Matsukawa-ura tidal flats from the 2011 earthquake, where uoyancy caused by soil liquefaction pushed up many underground organisms includin
Mya arenaria oonogai ●and *Macoma contaculata*●

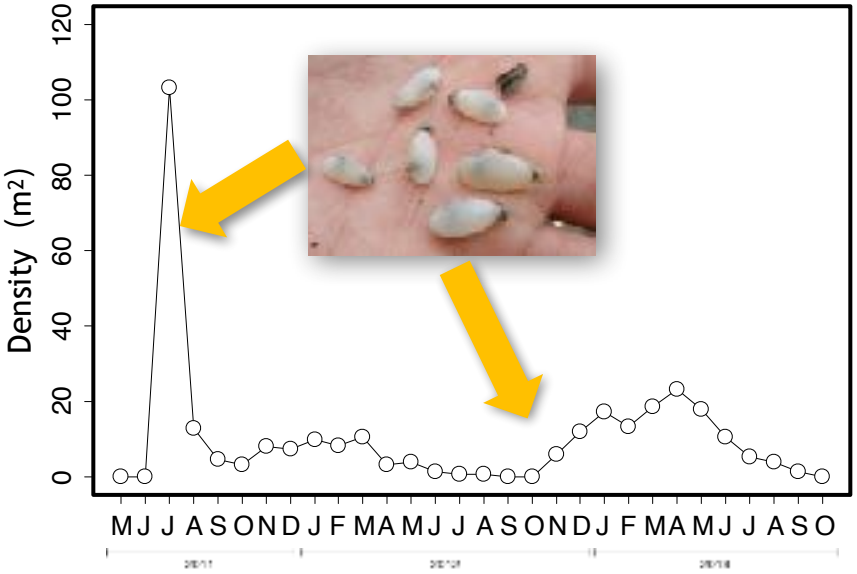
6 April, 2011 in Matsukawa-ura Inlet, Fukushim

Differences in the recovery process

＜Dig out mollusks that lived in deep ＞

Mya arenaria oonogai

Annual juvenile recruitment



Macoma contacrata

No juvenile recruitment

Differences in the recovery process

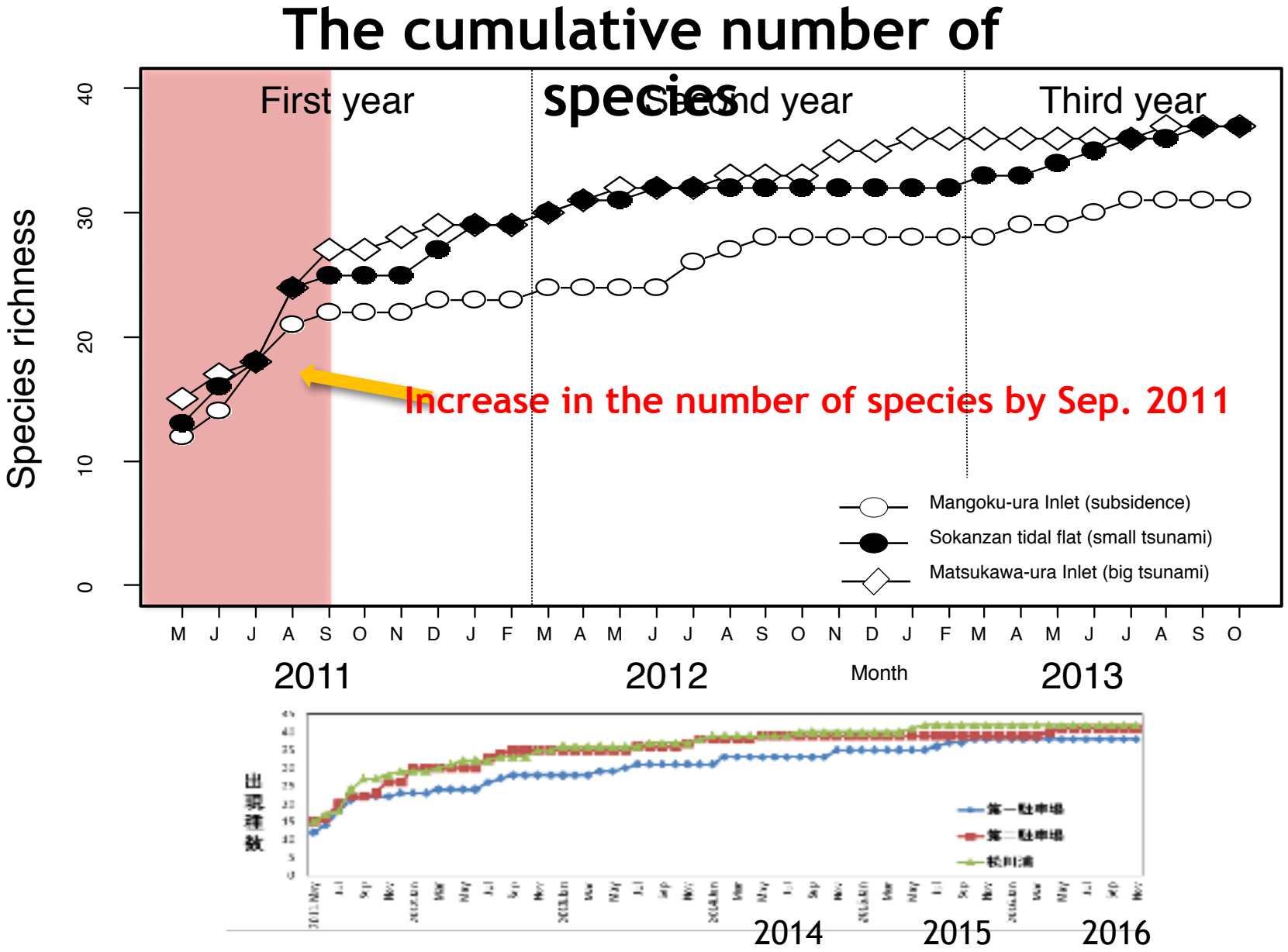
< Dig out mollusks that lived in deep >

	Mya arenaria oonogai	*Macoma contacrata*
		
	Annual juvenile recruitment	No juvenile recruitment
Life cycle	Annual spawning (Kinoshita 2002)	The spawning once every few years (Tanabe & Arimura 1987)

Macoma contaculata haven't recovered since the tsunami

We can not be grasped in a few years to recover post-quake situation!

Changes in the number of species observed after the tsunami

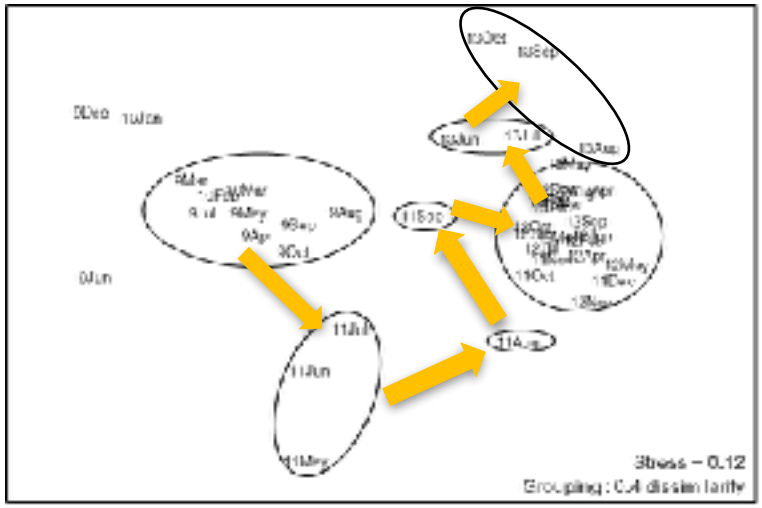


Changes in community structure after the tsunami

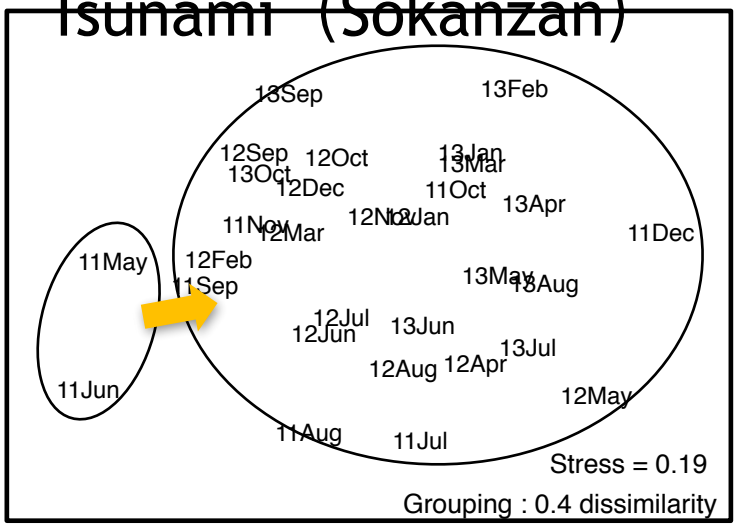
nMDS analysis

The result of (a) cluster analyses and (b) nonmetric multidimensional scaling (nMDS) based on Bray- Curtis dissimilarity index of density data (Number of individuals （/m²） /month)

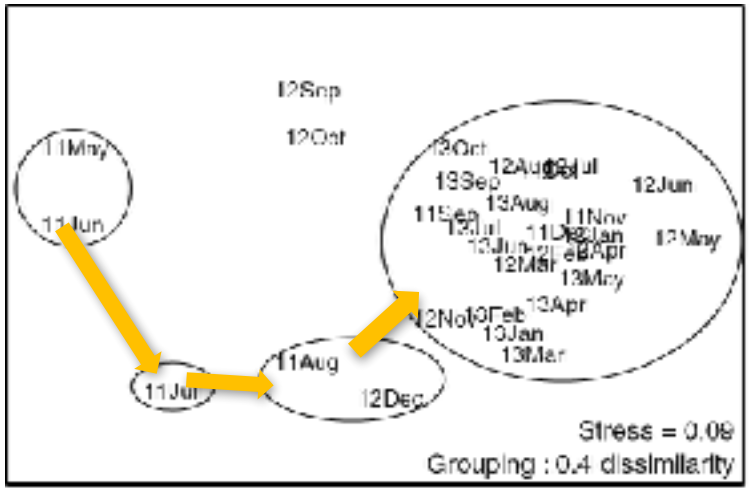
Subsidence （Mangoku)



Small Tsunami （Sokanzan)



Big Tsunami （Matsukawa)



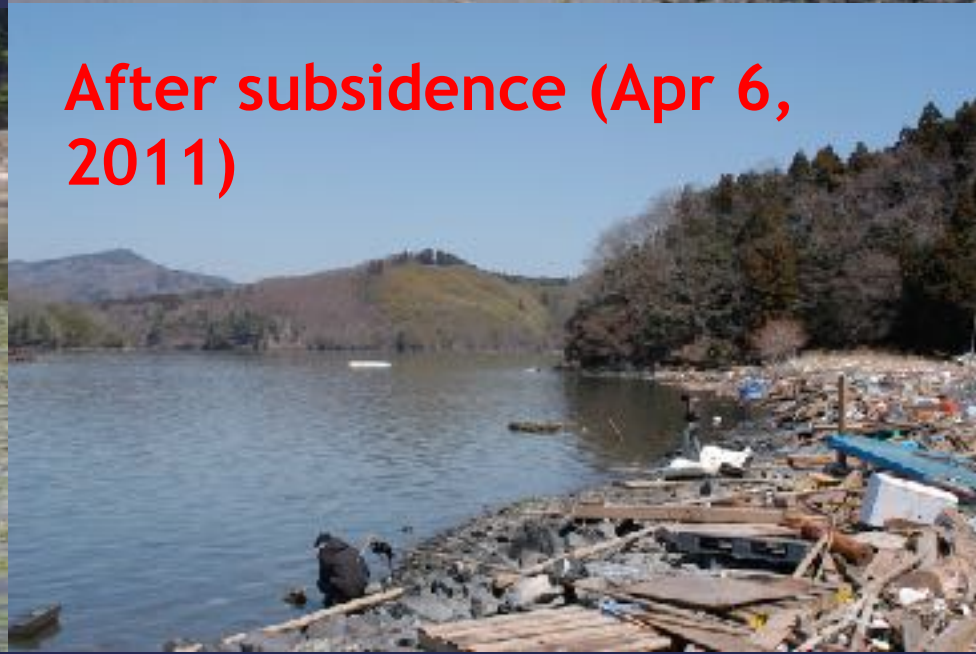
Phase 3: land subsidence

Mangoku-ura Lagoon
80cm subsidence

All pictures taken at the time of maximum low tide

Before subsidence (2009)

After subsidence (Apr 6, 2011)



Changes in habitat

Cedar trees withered and immersed in seawater

Oysters and barnacles attached to the roots of cedar

Effect by land subsidence

Short-term effect- Migration of mollusks

Parts of mollusks are moving at place that was “land” before, due to seawater level rose as land subsidence (changing habitat)

Lomg-term effect -Community change

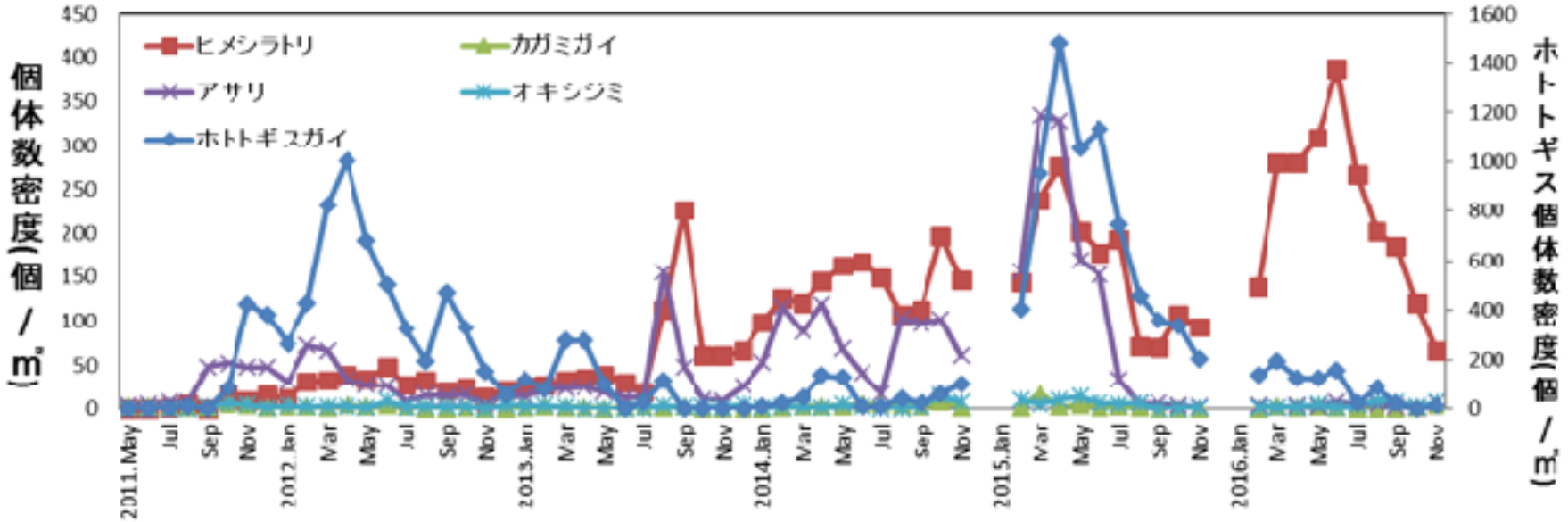


図13　万石浦第一駐車場地先の二枚貝優占種の個体数変動

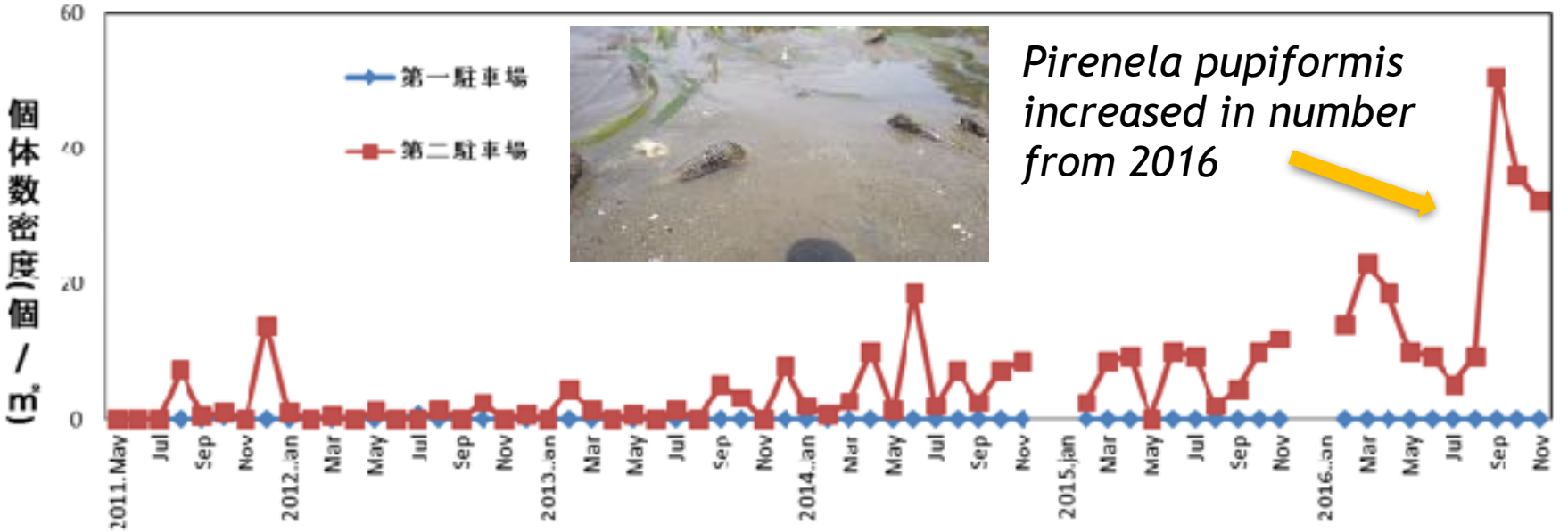
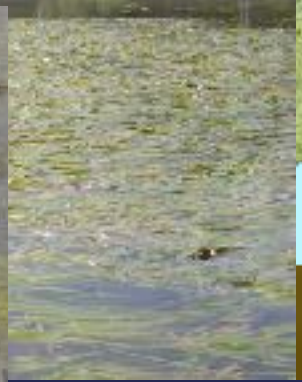


Fig. Population density of *Pirenela pupiformis* from May 2011 to Nov. 2016 in Mangoku-ura

Phase 3: land subsidence

Mangoku-ura Lagoon
80cm subsidence

Arcuatula senhousia



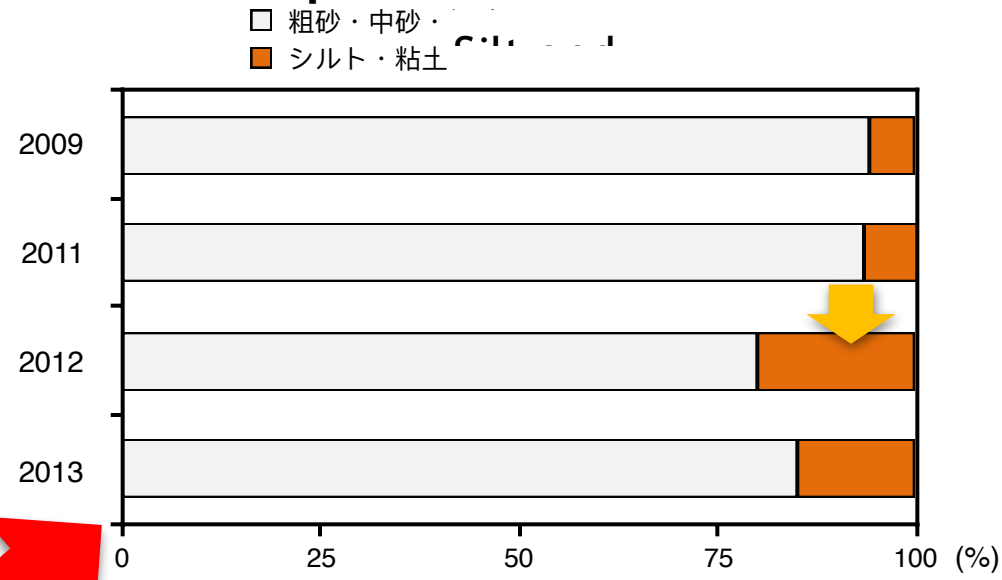
Changes in bottom sediment due to subsidence in Mangoku-ura lagoon

Arcuatula senhousia

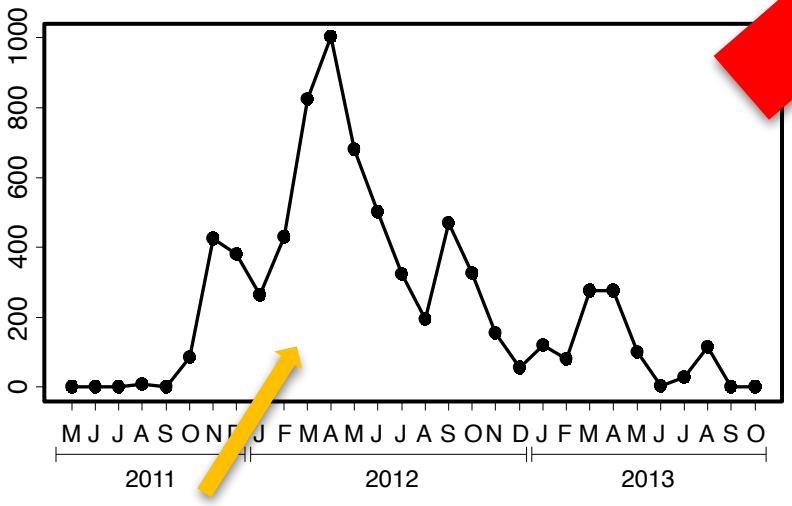
Opportunistic species, High density, covered bottom with byssal mats.

(Yamamuro et al. 2000; Buschbaum et al. 2009)

＜Composition of silt contents ＞

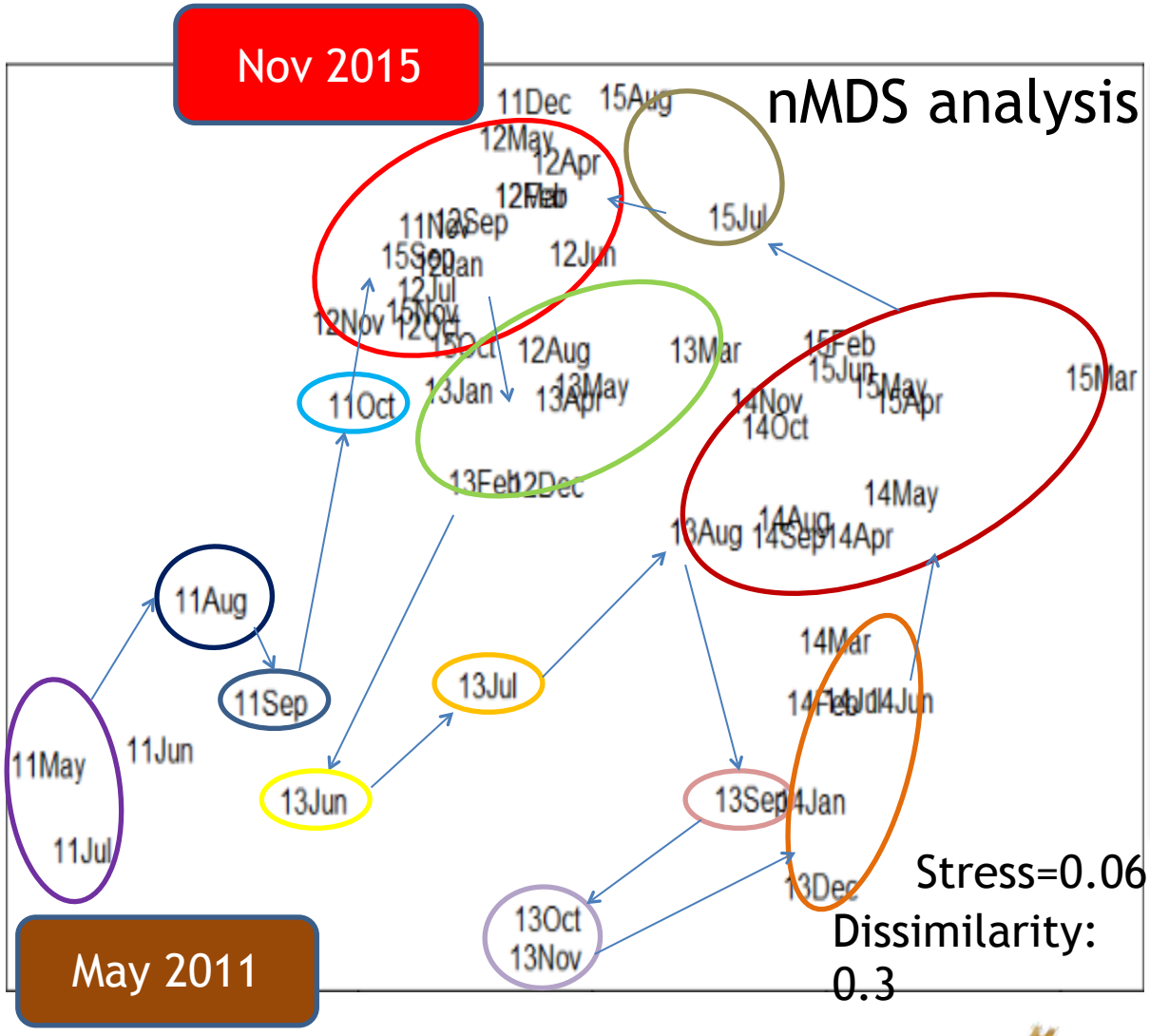


Change in the number of *A. senhousia* (m~~2~~)



Increase in number in2012

Changes in community structure in Mangoku



Changed to silty and muddy

The dominant species has been changed from species that prefer sandy bottom environments (R. philippinarum) to those prefer muddy bottom systems (M. incongrua and C. angustus) owing to the increase in the silt content of the sediment.

Species composition and abundance of bivalves changed every year, indicating that the bivalve community was compositionally

We kept observing the rock from 201 until now

From Okoshi(2016)

K. Okoshi. 2016. The Effects of Liquefaction, Tsunami, and Land Subsidence on Intertidal Mollusks Following the Great East Japan Earthquake. In: J. Urabe & T. Nakashizuka (Eds). Ecological impacts of tsunamis on coastal ecosystems: Lessons from the Great East Japan Earthquake. Springer pp.165-178.
DOI 10.1007/978-4-431-56448-5, ISBN 978-4-431-56446-1, ISBN 978-4-431-56448-5 (eBook)

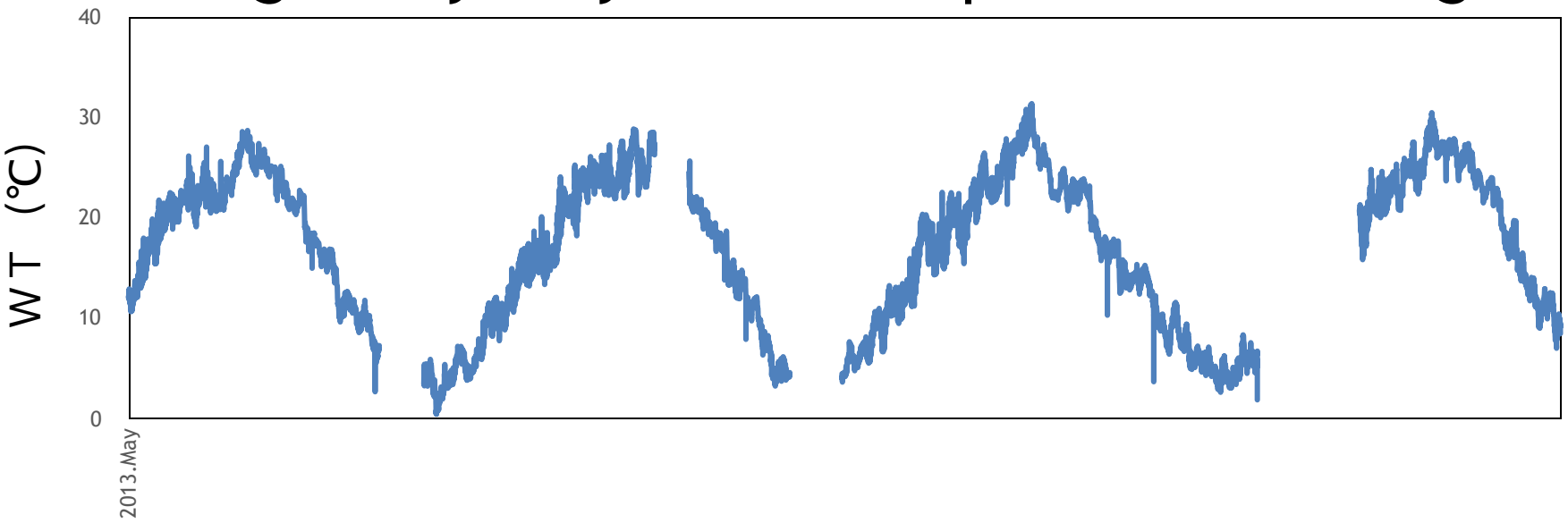

2011
2012
2013
2014
2015

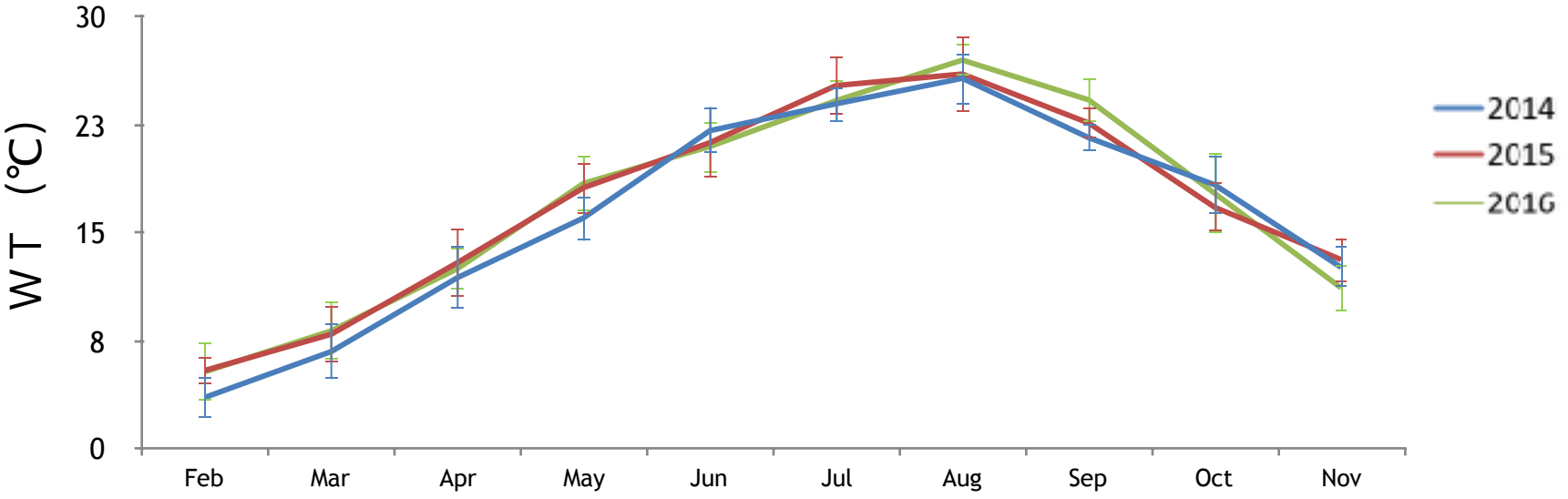

Aug. 2016


High tide


Low tide

Changes in yearly water temperature in Mangoku-ur





Ground uplift Map from March 2011 to Feb. 2017 (in cm)

From the Geographical Survey Institute, Japan (2017)

Effect by uplift?

Short-term effect- Migration of mollusks

Parts of mollusks are moving at place that was “land” before, due to seawater level rose as land subsidence (changing habitat)

Lomg-term effect -Change from subsidence to uplift

A gradual community change

Effects of the 2011

on marine life and residents

- Rapid impacts by liquefaction and tsunamis
- Short and Long-term effects by land subsidence and uplift
- **Effects of man-made structures**
- Concept of tsunami disaster prevention in Japan and in the world

Phase 4: Artificial structure

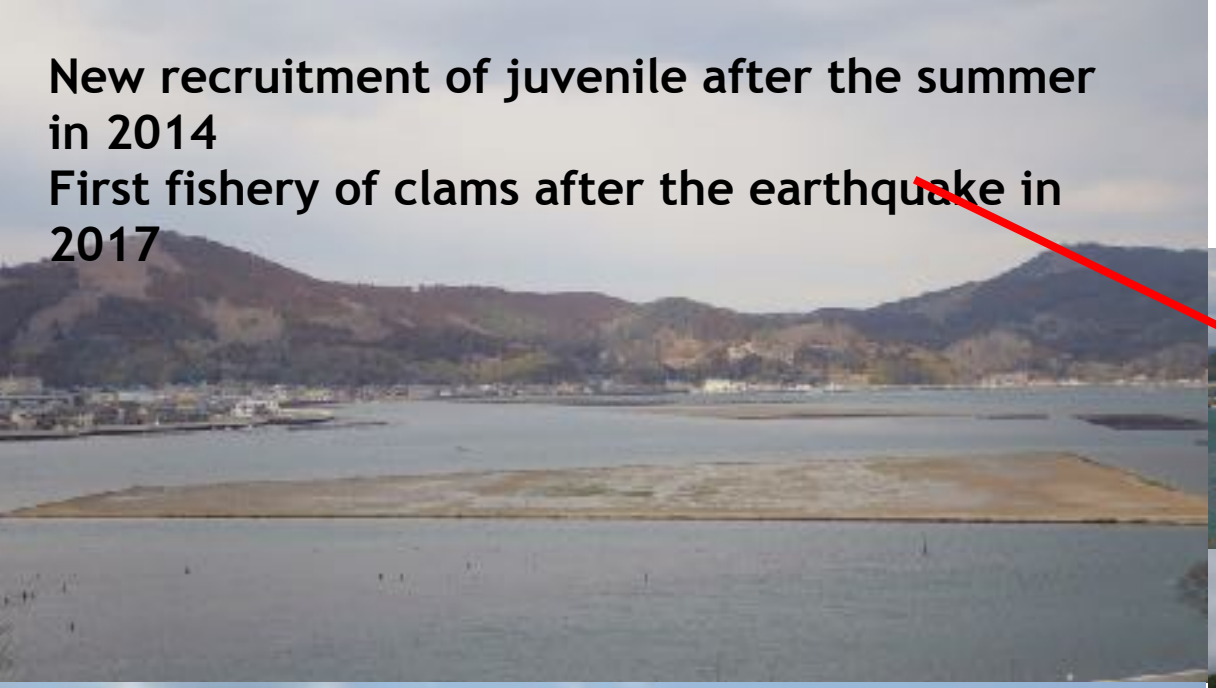
Destruction by the tsunami

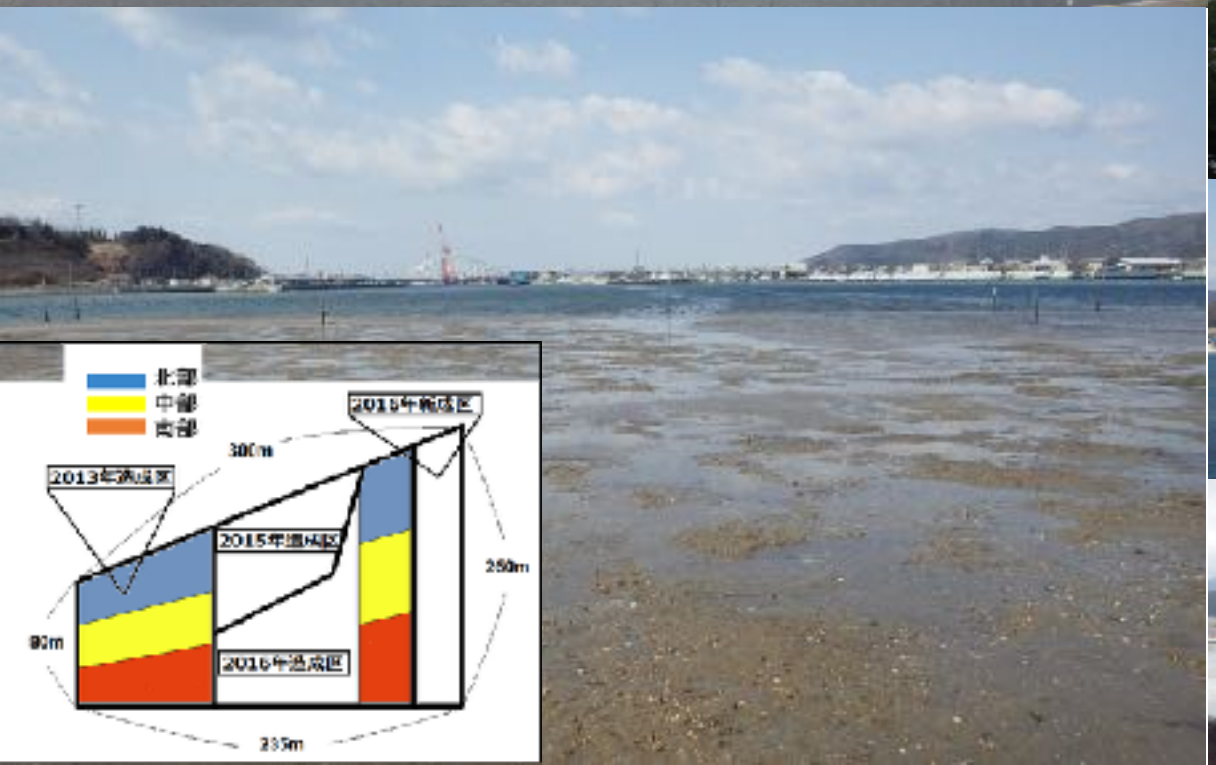
80cm subsidence after the earthquake

Construction of new and higher seawalls and artificial tidal flats

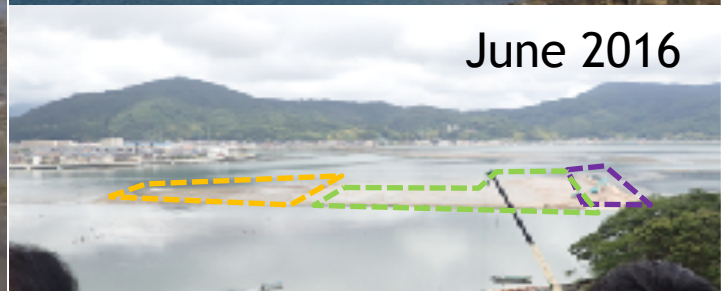
A&B: Artificial tidal flats made by mountain sediment in Mangoku-ura Inlet. C: Turbidity appear when stir the sand

New recruitment of juvenile after the summer in 2014
First fishery of clams after the earthquake in 2017





Start sand putting in 2013



Top articles of local newspapers

First fishery of clams after the earthquake

in May 2017

First shipment of clam

Tsunami seawall with a trapezoidal section

Decrease of tidal area and change of bottom sediment

The tideland area was landfilled with a width of 30 m

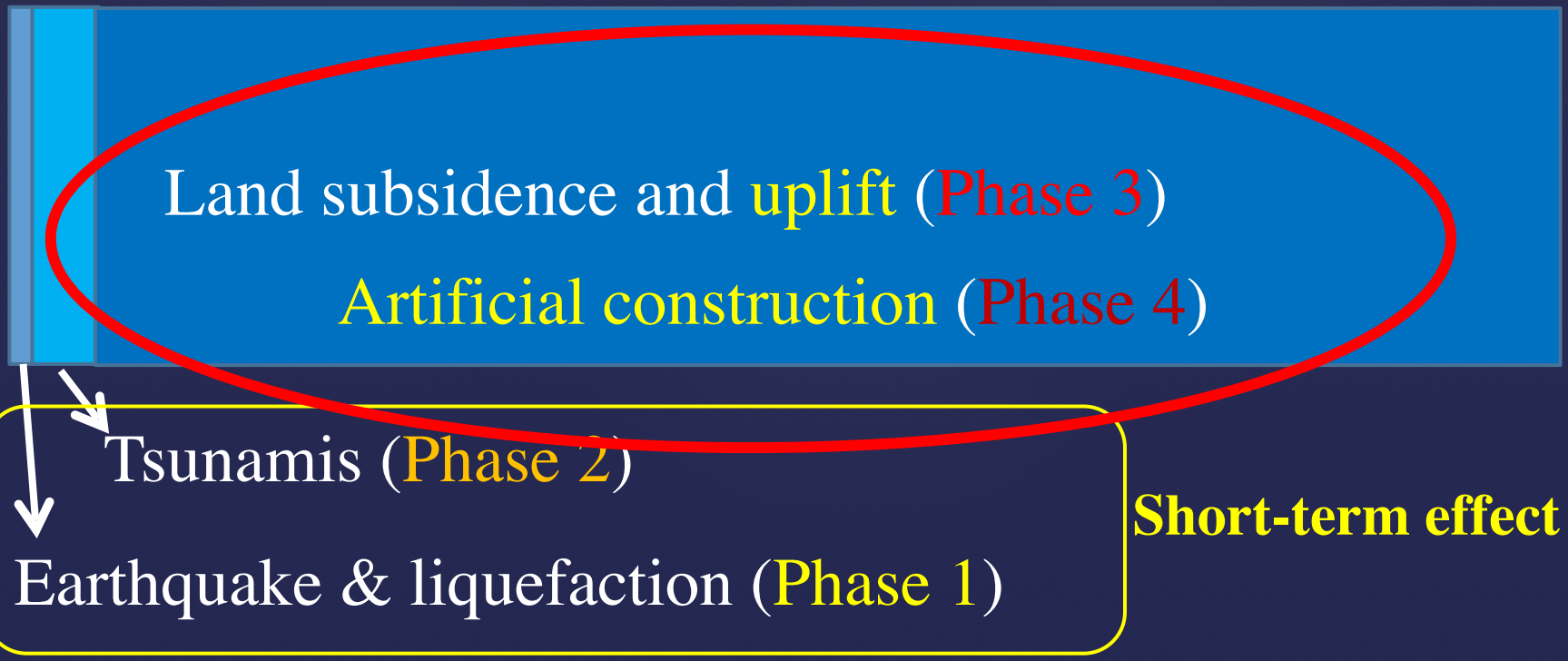
Tanohata , Iwate Pref. in Oct. 2017


Taro Kanko Hotel
Resident area
Industrial area
Outside of tsunami seawall

Conclusion

The 2011 Great East Japan Earthquake

Research of mega earthquake (time series)



Conclusion in marine life

We have to clarify・・・

（2）long-term effect which may explain continuous changes in population with land subsidence, uplift and artificial structure

Effects of the 2011

on marine life and residents

- Rapid impacts by liquefaction and tsunamis
- Short and Long-term effects by land subsidence and uplift
- Effects of man-made structures
- **Concept of tsunami disaster prevention in Japan and in the world**

Japan - Thailand Joint Workshop

on

Ecosystem Disturbances by Natural Disasters such as Earthquakes and Tsunamis

(June 15~17, 2017)

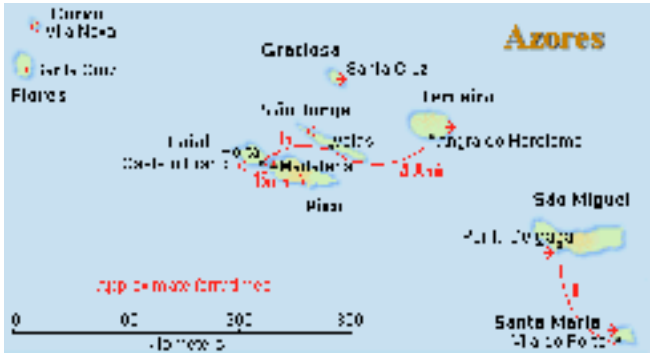

ANDAMAN SEA


BAAN NAM KEM TSUNAMI MEMORIAL PARK

Tsunami evacuation oar

Monuments made for the victims of th

Historical tsunami in the Azores archipelago (Portugal)

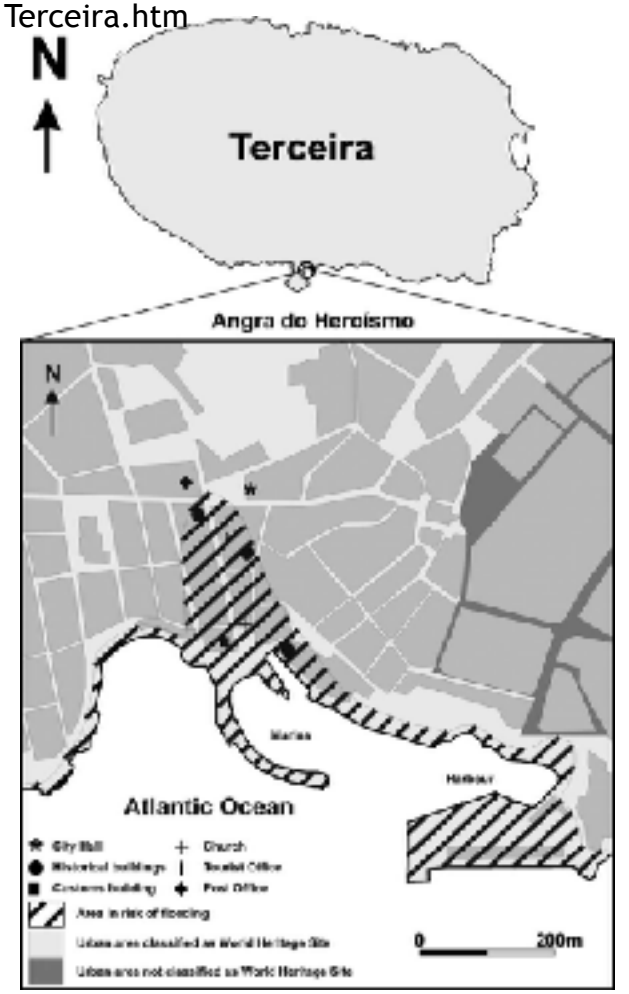


http://www.ewpnet.com/azores/Terceira.htm

C. Andrade a, P. Borges b, M.C. Freitas a
a Centro e Departamento de Geologia da Universidade de Lisboa, Bloco C-6 3° Piso, Campo Grande, 1749-016 Lisboa, Portugal
b Departamento de Geociências da Universidade dos Açores, Rua da Mãe de Deus, Apartado 1422, 9501-801 Ponta Delgada, Portugal

Journal of Volcanology and Geothermal Research 156 (2006) 172-185

Because of its exposed northern mid-Atlantic location, morphology and plate-tectonics setting, the Azores Archipelago is highly vulnerable to tsunami hazards associated with landslides and seismic or volcanic triggers, local or distal. Critical examination of available data – written accounts and geologic evidence – indicates that, since the settlement of the archipelago in the 15th century, at least 23 tsunami have struck Azorean coastal zones. Most of the recorded tsunami are generated by earthquakes. The highest known run-up (11–15 m) was recorded on 1 November 17[illegible] Terceira Island.



Ponta Delgada, Azores
in Portugal, July 2013

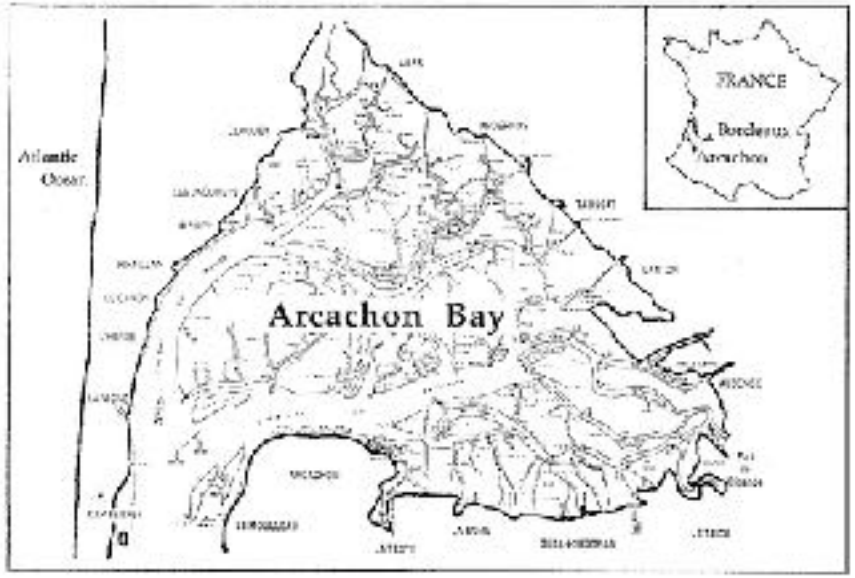


Fig.3 Map of Arcachon, France

Études sur la formation de coquilles d'huîtres

Okoshi et al. 1987. Characteristics of shell chamber formation between the two local races in the Japanese oyster, *Crassostrea gigas*
Aquaculture 67, 313-320.

Okoshi et al. 1992. Proceedings of the Tecno-0cean'92 International Symposium pp. 727-734.
Okoshi. 1992. Observations concernant la coexistence d'activites diverses sur le **bassin d'Arcachon. Colloque Bordeaux** Aquaculture 1992 Publication N° 33 17—20

Fig.4 Arcachon Bay. Various activities are being conducted in Arcachon Bay. Major ones of them are oyster culture and sight-seeing industry centering on leisure boats. a:Seaside villa. b:Marina. c:Dune de Pyla, the largest sand dune in Europe. d:Teich Ornithological Park. e:Oyster farm. f:Spat (Seed oyster) collectors, curved tiles coated with plaster. g:Oyster fishing boats. h:Oyster farming community. The basins in which the oysters are fattened prior to sale (Cujan-Mestras).

http://au-jardin-francais.com/

http://au-jardin-francais.com/

http://au-jardin-francais.com/

http://www.club-t.com/hokkaido/special/island/

Do you know the difference?


一部が欠けた名所「なべつる岩」――幹線道路・重要農業島嶼は壊滅、土砂崩れなどで通行不能の箇所が数多くできた。
島のシンボル「なべつる岩」も地震により、頂上の一部が崩落したが、何とか原型をとどめた。

Coastline of Okushiri Island, Hokkaido Japan. A: Natural coast. Coastal vegetation is continuous until the beach. B: Coast which are divided by the tsunami seawalls with some vegetation on the shore. C: Huge seawalls. There is no vegetation at all on the shore. (Okeshi, 2015)

The magnitude 7.7 earthquake occurred in 1993 near the Okushiri Island in southwest-off Hokkaido, northern Japan

Pour demain plein de lumière

Run up the stairs

24 years since the tsunami disaster

Nobody is here !

DAVOS SENDAI

WORLD BOSAI FORUM

IDRC 2017 in SENDAI

International Disaster and Risk Conference 2017, Sendai, JAPAN

世界防災フォーラム／防災ダボス会議@仙台

International Disaster and Risk Conference 2017 in Sendai, Japan

What is our choice for the next generation?

FORUM

IDRC 2017 in SENDAI

International Disaster and Risk Conference 2017, Sendai, JAPAN

世界防災フォーラム／防災ダボス会議@仙台

International Disaster and Risk Conference 2017 in Sendai, Japan

Acknowledgements

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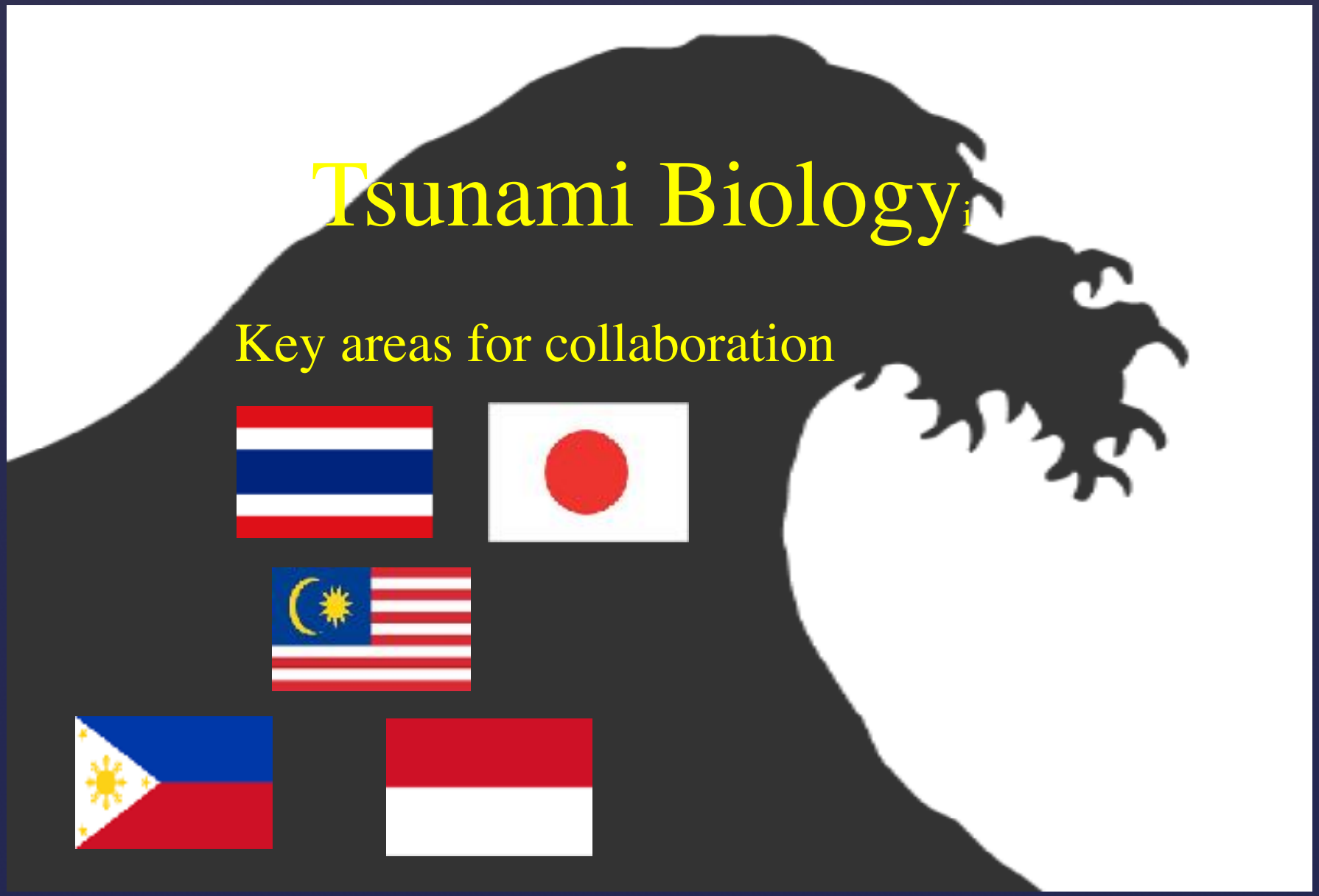
Impact of repeating massive earthquakes on coastal marine life in Asia



Phase 1: earthquake and liquefaction

Liquefaction induced by earthquake shaking occurred just after the earthquake before arrival of the first tsunami

Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking. The water spurted from the cracks, which looked like a jet of water. (just after the earthquake, March 11, 2011)

の経済紙

900億円

の関心も

二月にか

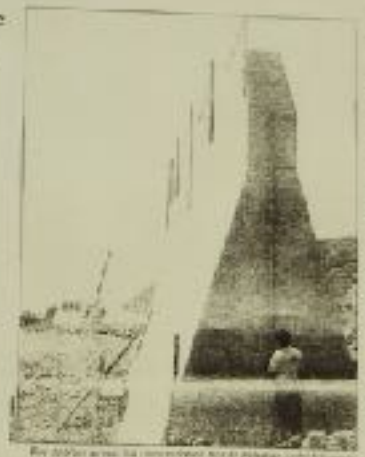
ヨーク・

ス転ル

ORIZONS

ÎLE QUI SE BAT CONTRE LES VAGUES

Okushiri, petite île du Japon victime d'un tsunami en 1993, a mis au point un système perfectionné de protection contre les raz de marée. Toute la population est mobilisée



ÎLE QU

CONTRE L

Okushiri, petite île du Japon victime d'un tsunami en 1993, a mis au point un système perfectionné de protection contre les raz de marée. Toute la population est mobilisée

Old seawall, just after the earthquake (2011)

New seawall (2016)

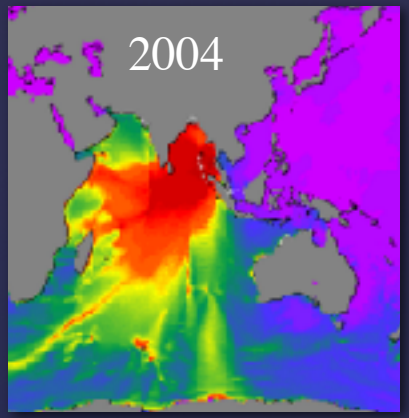
Position of the old seawall edge

Old seawall, just after the earthquake (2011)

New seawa

Tidal flat area was greatly reduced due to the influence of land subsidence and tsunami seawall construction

Tsunami & Marine Life in Asia



http://www.ngdc.noaa.gov/spotlight/tsunami/image/pmelmaxcomputedamplitude.gif

Tropical zone

13 years

Prof. Chavanich
and her collaborators

Temperate zone
(Rias coast)
6 years

Prof. Sato-Okoshi
Prof. Okoshi
Dr. Abe
Mr. Suzuki

organized by K. Okoshi and S.A. Chavanich at World Congress of Malacology 2016 held in Penang, Malaysia