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Geomorphodynamic stability of lands in intertidal zones

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Background

Sandbars: Important roles in coastal land stability and habitats

Persistent sandbars remained "enigma"

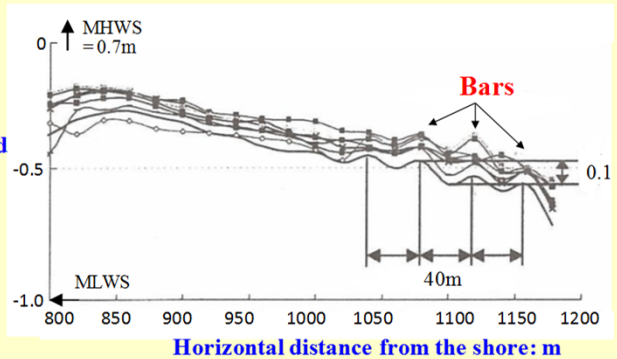
Sassa and Watabe (GRL, 2009) showed for the first time that such persistent nature manifests itself due to the feedback between the suction-dynamics induced cyclic contraction, strength gain and sediment transport and morphology

Purpose

To apply and clarify this new principle on morphodynamic stability by performing integrated observations/surveys and analyses of morphological and geoenvironmental changes as well as species diversity and geostratigraphy variations in the artifically created sandbars in Tokyo bay, Japan

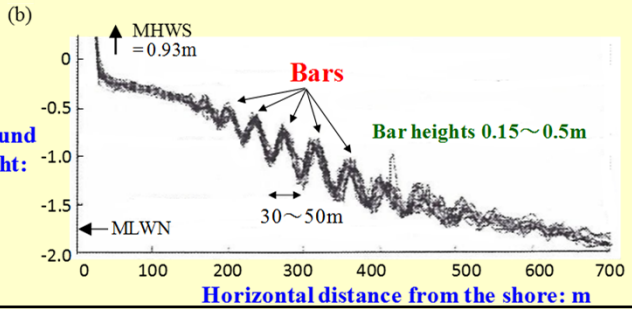
A novel engineering framework for achieving both biodiversity and morphodynamic stability in intertidal zones.

The morphodynamic stability of intertidal zones



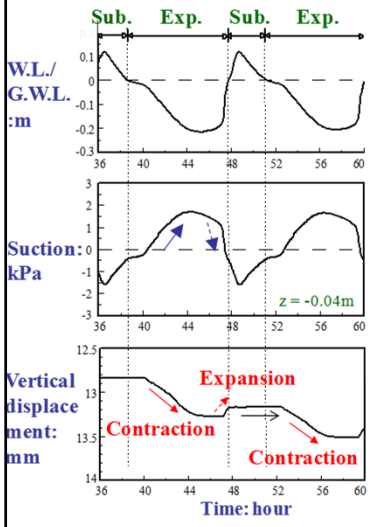
Banzu intertidal flat from 1995 to 2000 (Furukawa et al., 2000)

Occasional arrival of storms and typhoons



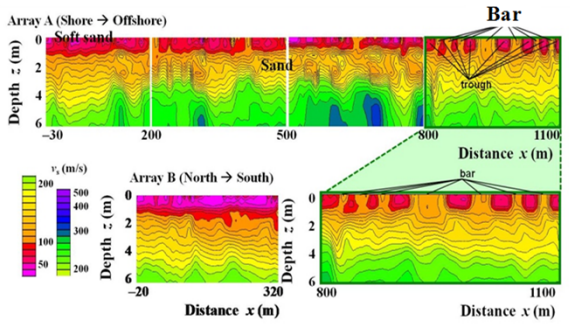
Okoshiki beach from 2003 to 2005 (Yamada and Kobayashi, 2007)

The suction dynamics effects: Geophysical evidence

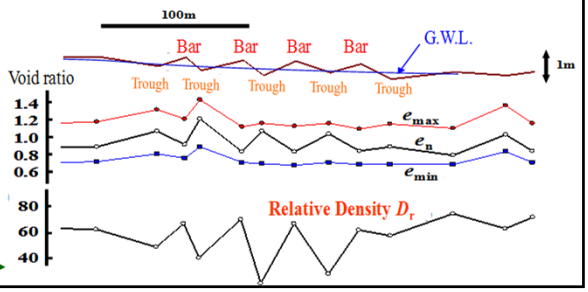


Results from model flat experiments
Suction-induced cyclic elastoplastic contraction

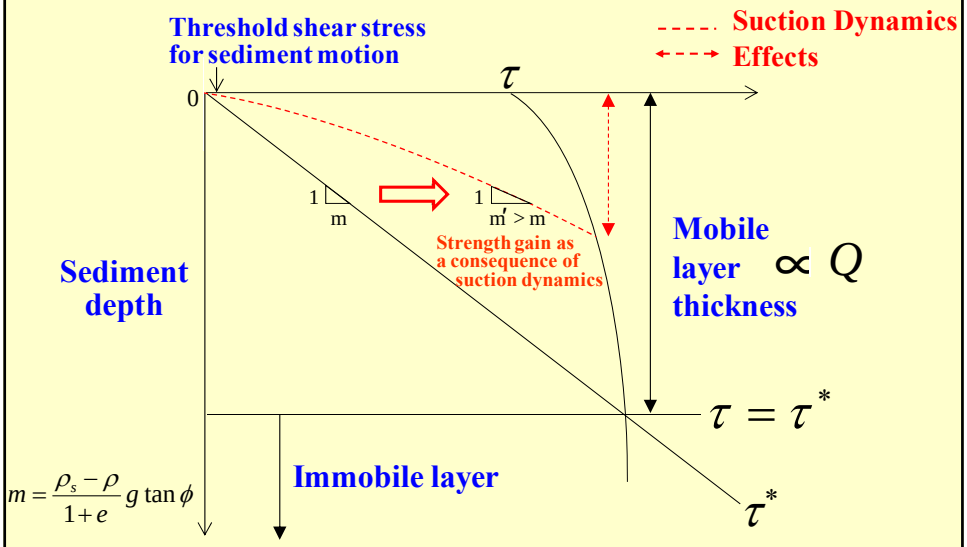
Results from in-situ sediment sampling and physical soil tests



Results from MASW (Multichannel Analysis of Surface Waves)
Sassa & Watabe, JGR(2007); Watabe & Sassa, MG(2008)



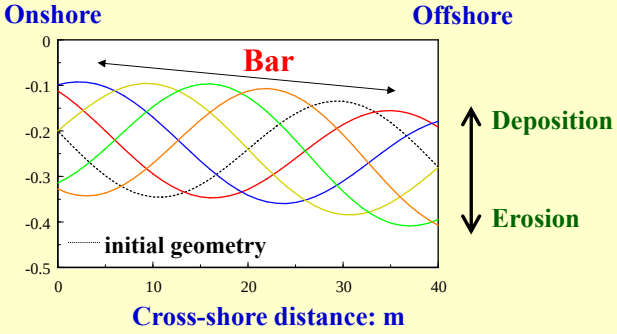
Sketch showing sediment transport rate Q as functions of both shear stress τ and shear strength τ^* of sediment



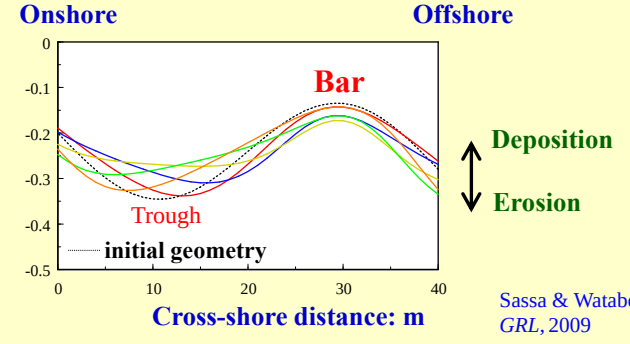
In the current perspectives, shear strength is fixed in space and time !

Here g : earth's gravity, ρ : mass density of fluid, ρ_s : mass density of sediment particles, e : void ratio of sediment, ϕ : internal friction angle of sediment.

(a) Without the effects of suction dynamics



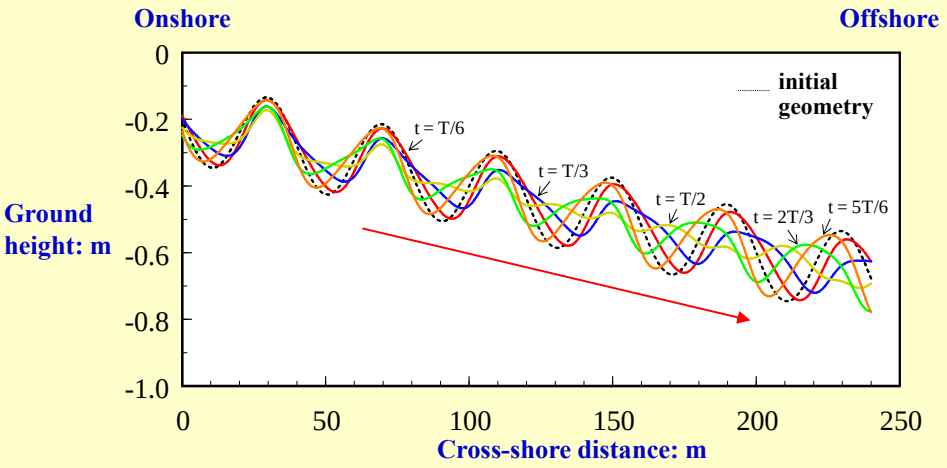
(b) With the effects of suction dynamics



Persistent nature appears !

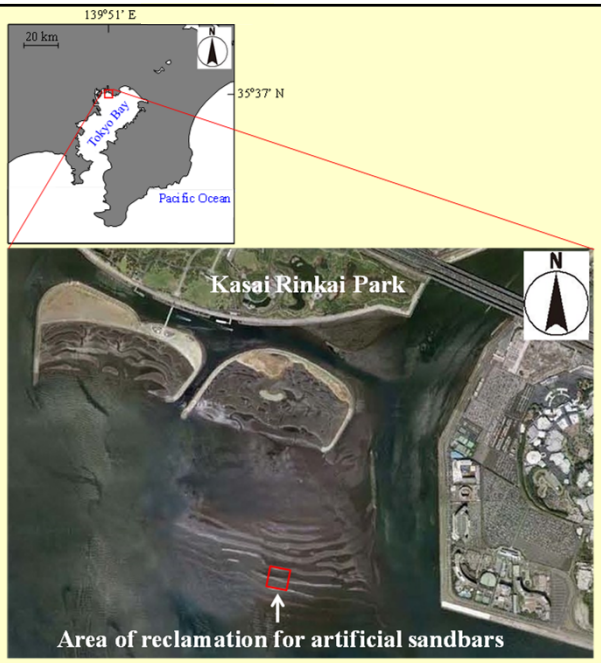
Sassa & Watabe, *GRL*, 2009

Results of analysis showing the transformation of bar behaviour in the offshore direction

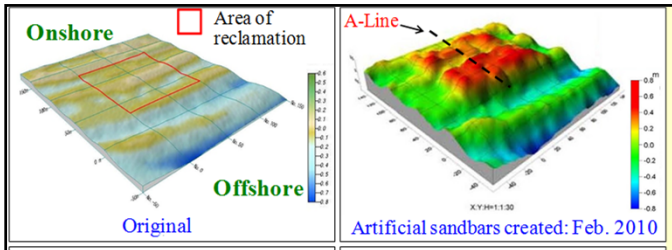


Decreasing effects of suction dynamics in the offshore direction

→ **Sequence of processes of bar generation, migration and development and decay at the offshore fronts !**



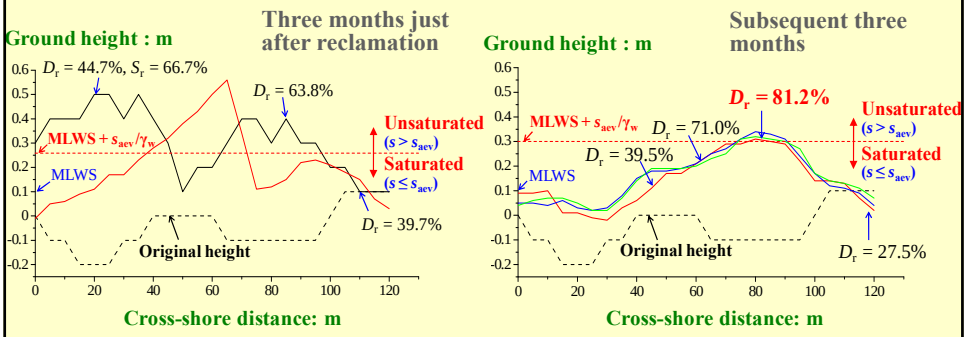
Location of artificially created sandbars in Tokyo Bay, Japan



Integrated observations/surveys, laboratory tests and analysis of artificially created sandbars

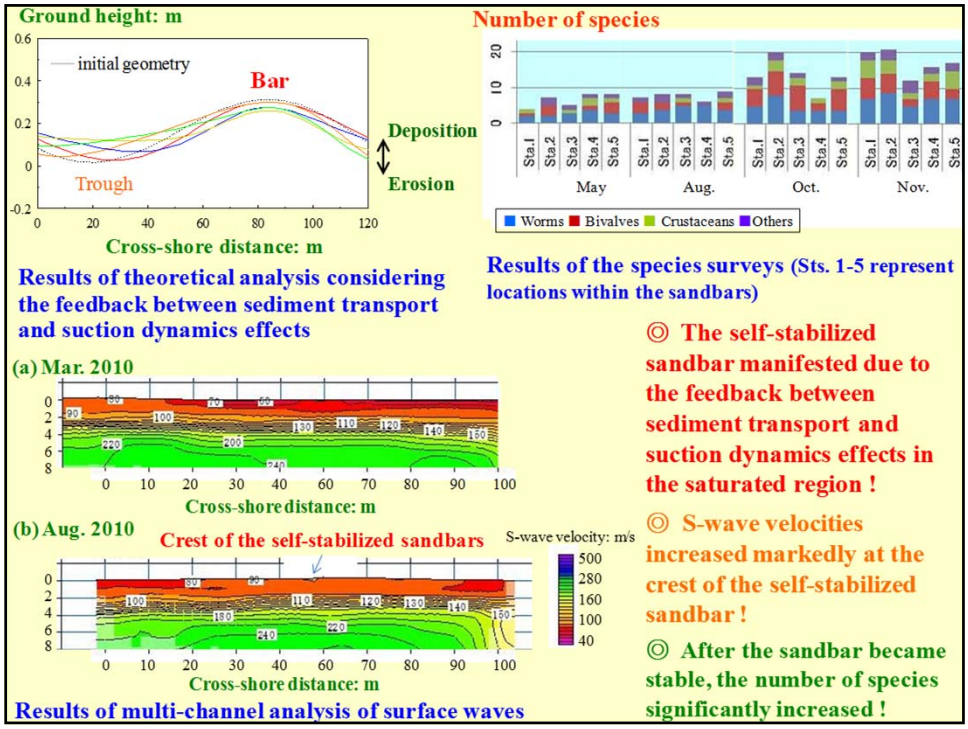
- ◎ **Morphodynamics**
- ◎ **Species distributions**
- ◎ **Geoenvironmental dynamics**
- ◎ **Multi-channel analysis of surface waves for the geo-stratigraphy**
- ◎ **Theoretical analysis of morphodynamics considering the suction-dynamics effects**

Results of the integrated analyses of the field observations/surveys and laboratory tests on the linkage between morphological and geoenvironmental changes of the artificially created sandbars



In the unsaturated regions during the exposure periods, the suction-dynamics induced **compaction was marginal**, thus the sediments remained looser with increasing ground heights. As a result, **the sandbars moved dynamically in the cross-shore direction.**

By contrast, after the bar crest reached an **essentially saturated region,** the suction-dynamics induced **compaction became pronounced** and the surface shear strength increased beyond three-fold magnitudes. As a consequence, **the morphological changes due to repeated erosion and deposition became markedly suppressed, yielding the distinctly stable sandbars !**



On the basis of the above results and discussions,
an optimal design of reclamation height *H* and sand layer thickness *D* by which to expect such self-stabilized sandbar may be obtained as

$$H = MLWS + \frac{S_{aev}}{\gamma_w} \quad (1) \qquad D = H - H_{org} \quad (2)$$

where MLWS represents the mean low water spring and H_{org} represents the original ground height before reclamation.

When the reclamation height exceeds the above ground height, the surficial sediments can become unsaturated. This means that the suction-dynamics effects may be less pronounced and marginal under such situations. By contrast, when the reclamation height is set at or near below the above ground height, the surficial sediments remain saturated throughout the course of the tides, and thus we can expect
the maximum impact of the suction dynamics effects on erosion, giving rise to the manifestation of such self-stabilized sandbars.

Summary

A comprehensive set of the field observations and surveys, laboratory soil tests and analyses for the artificially created sandbars in Tokyo Bay, Japan, in order to clarify our recently found mechanism of the morphodynamic stability of intertidal sandbars.

The results clearly demonstrated that in the morphodynamic processes where the sediments moved from the unsaturated zone to the saturated zone, namely, where the suction-dynamics induced sediment compaction and associated increase in the surface shear strength became pronounced, **the self-stabilization of the intertidal sandbars manifested owing to the impact of the suction dynamics effects on erosion.**

On the basis of these results, we proposed an optimal design of such dynamically stable sandbars. Our findings can be used widely for the creation and maintanance of such morphological features, which are often crucial for disaster reduction, as well as for conservation and restoration of habitats with diverse biological activity.