Effects of coastal seascape diversity on the associated fish production

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Focus on Landscape/seascape structure

Seascape ecology is now on the verge of entering main stream of marine ecology (Hooper et al. 2005, Duffy 2006, Pittman 2011)

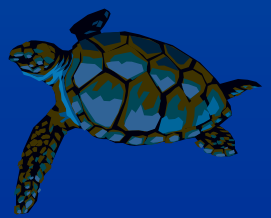
The interests in seascape ecology are originally derived from:

(1) Allochthonous input (spatial subsidy)

Bustamante et al. 1995, Bustamante & Branch 1995, 1996, Polis 1996, Polis and Strong , Hori 2006, Hori 2008, Thottathil 2008, Spiller et al. 2010 etc.)

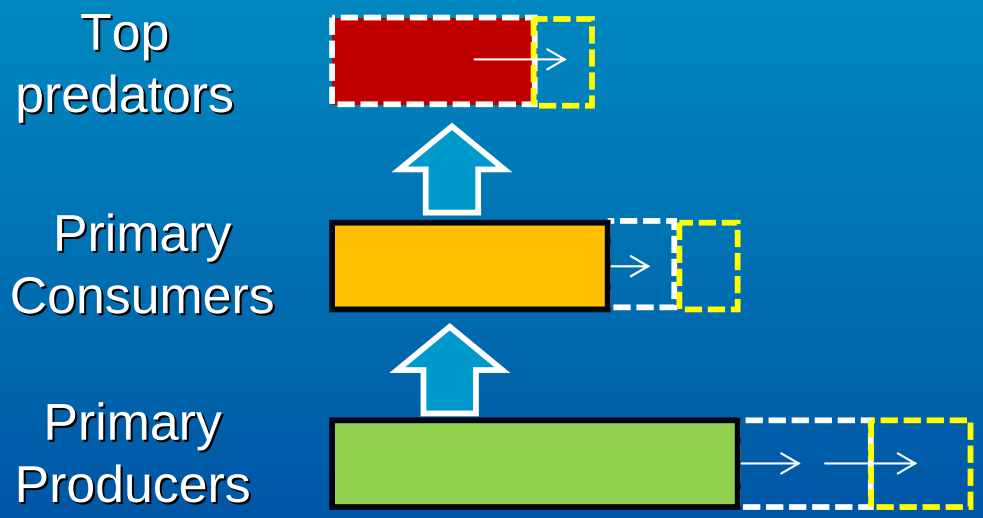
(2) Multiple habitat use by the organisms in higher trophic levels

Robbins & Bell 1994, Micheli & Peterson 1999, Hovel & Lipcius 2001, Pittman et al. 2007, Hori et al. 2009, Oliver et al. 2011, Hitt et al. 2011, Pittman et al. 2011)



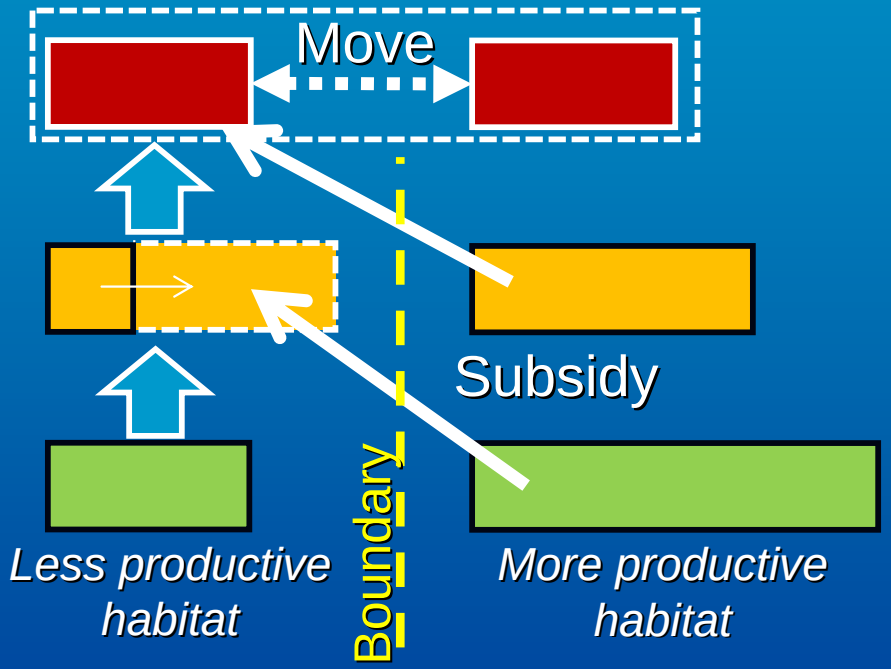
(1) Allochthonous input (Spatial subsidy)

The influx of nutrients, detritus and organic materials from a donor (more productive) ecosystem to a recipient (less productive) ecosystem is called “allochthonous input”,



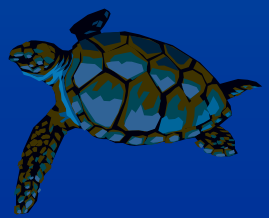
Traditional ecosystem theory (food web)

(Hairston et al. 1960, MacArthur 1972, Pianka 1978, Oksanen et al. 1989)

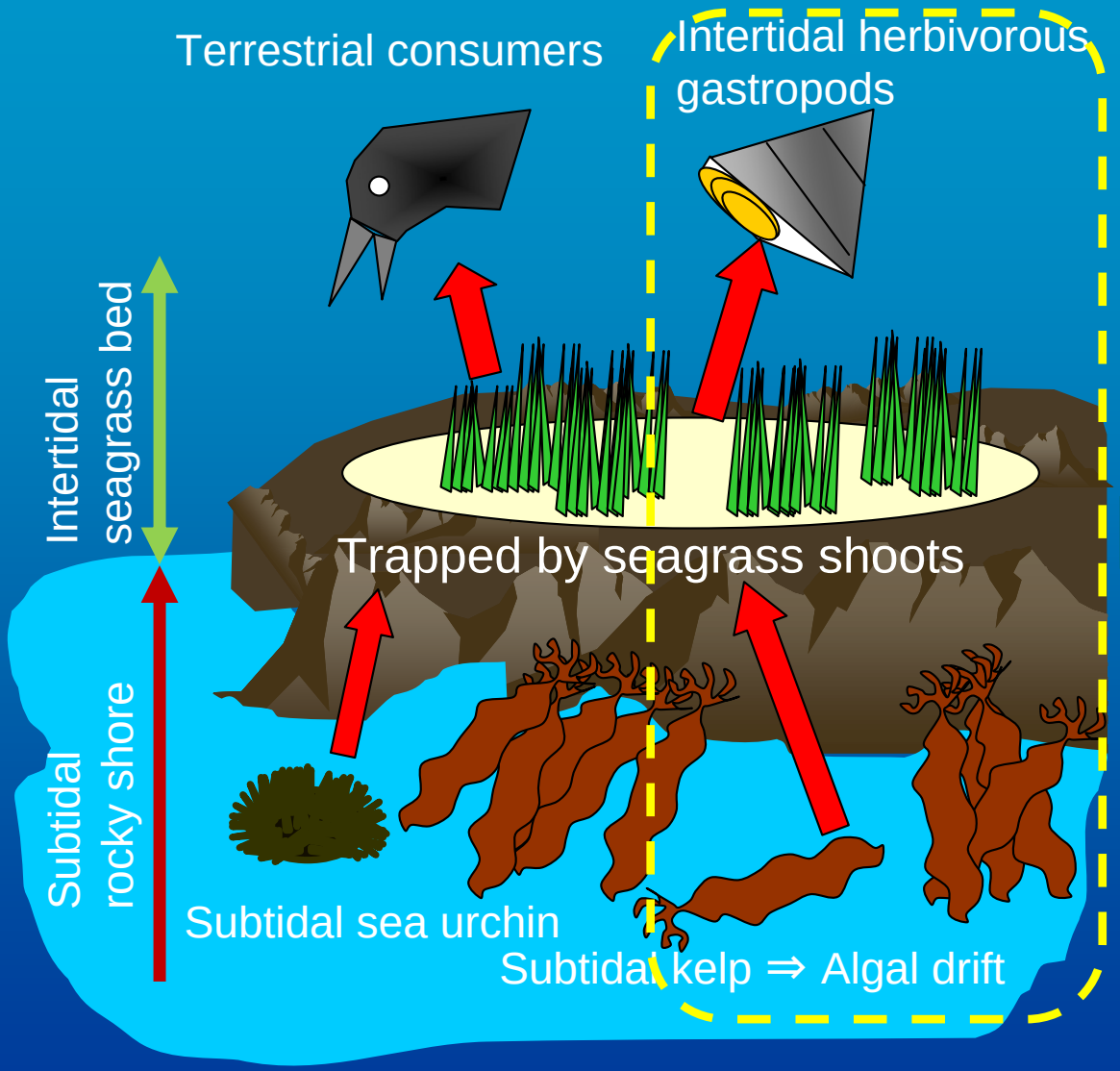


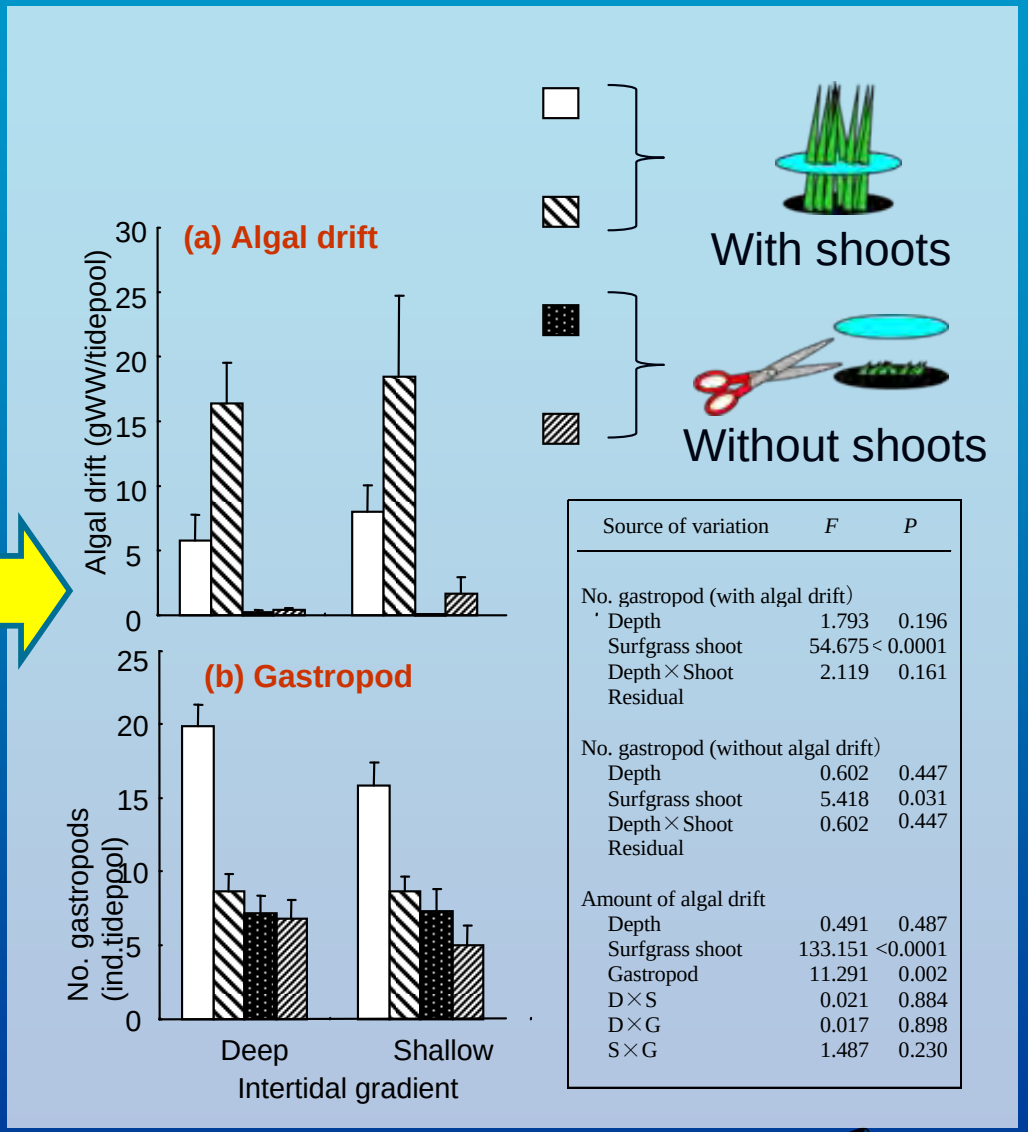
Refined ecosystemTheory

(Polis & Strong 1996)



(1) Allochthonous input (Spatial subsidy)





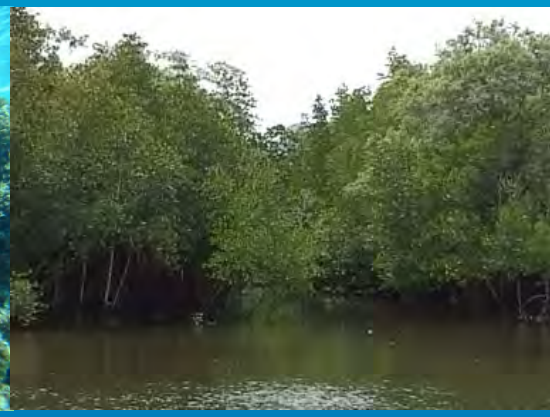
Source of variation	*F*	*P*
No. gastropod (with algal drift)		
Depth	1.793	0.196
Surfgrass shoot	54.675	< 0.0001
Depth × Shoot	2.119	0.161
Residual		
No. gastropod (without algal drift)		
Depth	0.602	0.447
Surfgrass shoot	5.418	0.031
Depth × Shoot	0.602	0.447
Residual		
Amount of algal drift		
Depth	0.491	0.487
Surfgrass shoot	133.151	<0.0001
Gastropod	11.291	0.002
D × S	0.021	0.884
D × G	0.017	0.898
S × G	1.487	0.230

Intertidal (seagrass associated) food web was regulated by subtidal (Rocky shore) production

(Hori 2006: *MEPS*)

(2) Multiple habitat use in coastal ecosystem

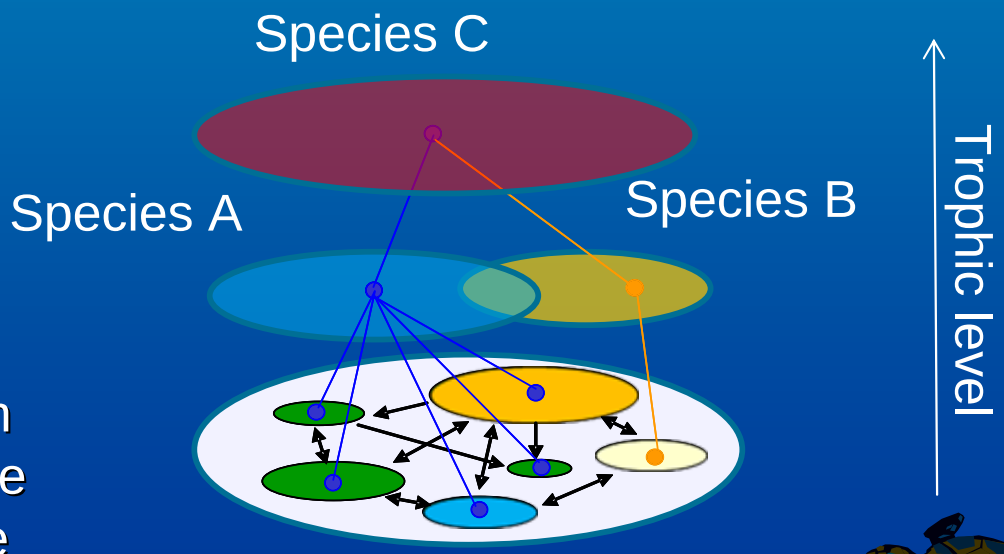




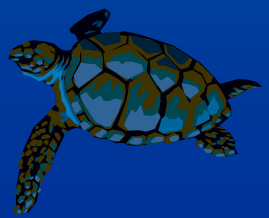
- Coastal ecosystems are characterized by the prominence of foundation species such as seagrass beds, mangrove forest, coral reefs and kelp/sargassum beds.

- The associated organisms such as fish and large invertebrates normally have wide spatial distribution and use these multiple foundation species in their life cycles.

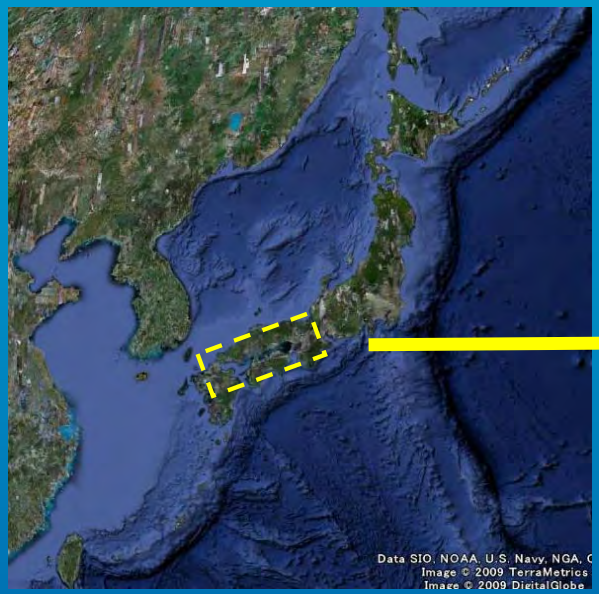
- Now it is recognized that spatial distribution and composition of foundation species have effect on the production and diversity of the associated organisms
  (Hooper et al.. 2005, Duffy et al. 2006, Pittman et al. 2011)

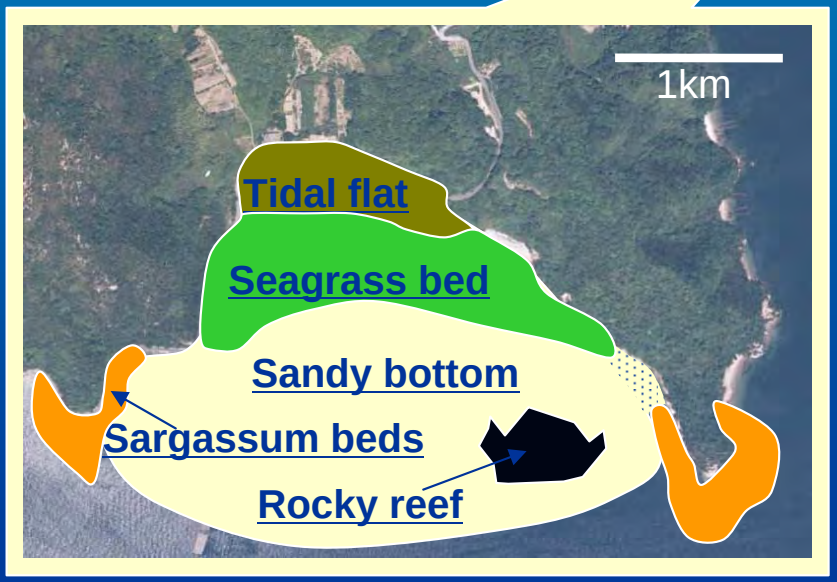


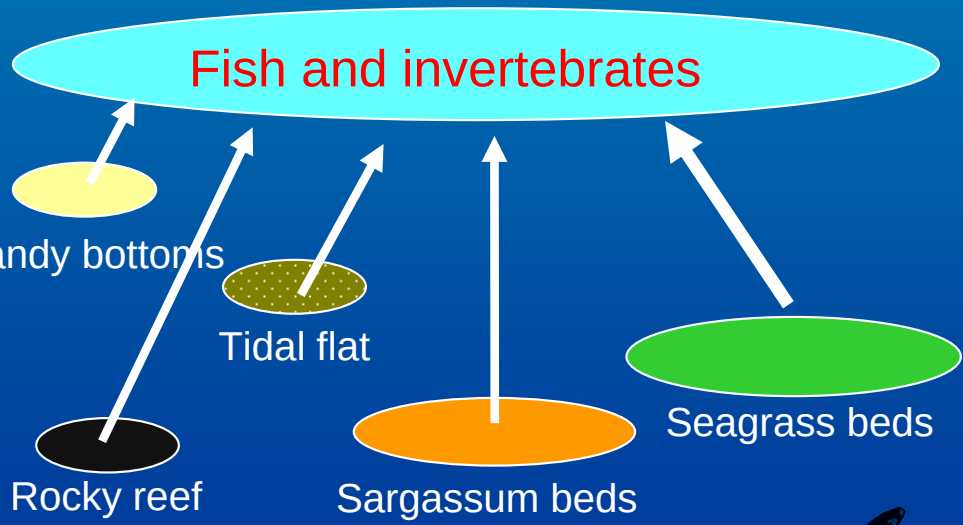
Spatial distribution of foundation species

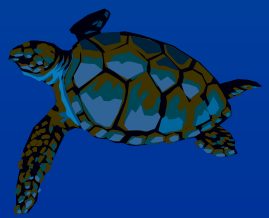


Seto Inland Sea, Japan





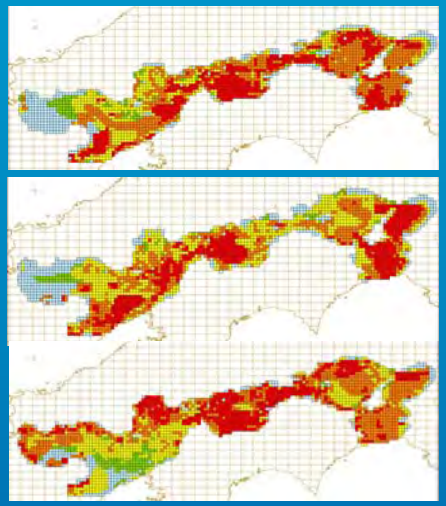




Macrohyte habitats are important to secondary production in Setio inland Sea

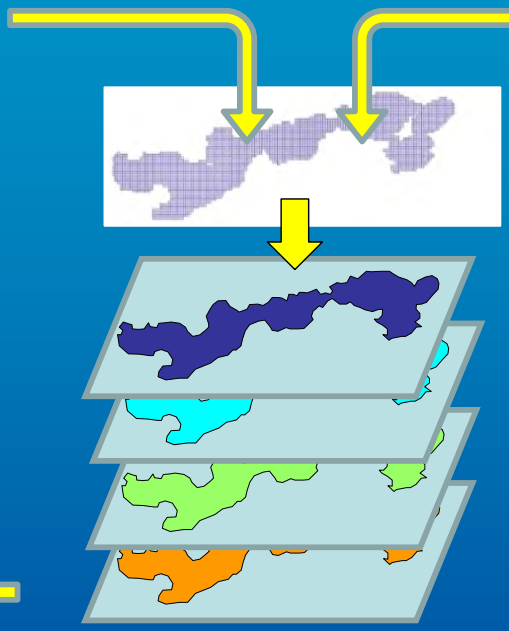
Our Approach in Seto Inland Sea:

Spatial analyses to estimate suitable seascape structure for fish specie

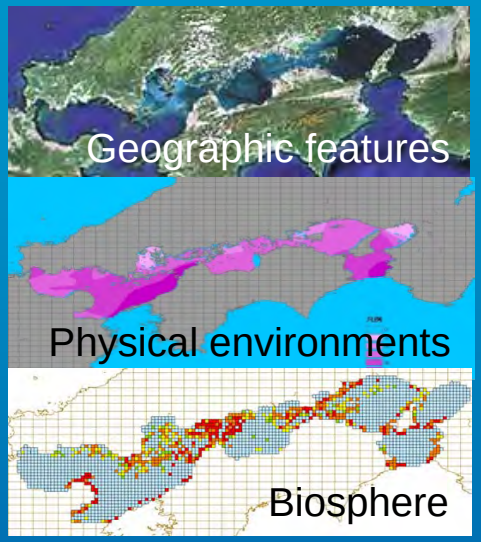


Spatial distribution of annual fishery catch of each species

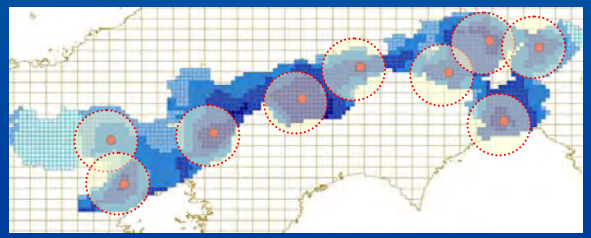
(1) Formalizing these information on GIS



Raster-formatted data files

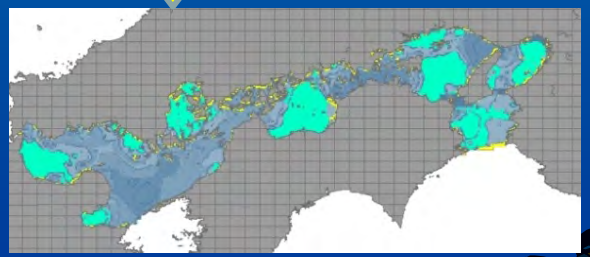


Spatial data on coastal environments



(2) Generalized-linear modeling for spatial analysis using spatial autocorrelation & a buffering method

(3) Selection of suitable environments by the model



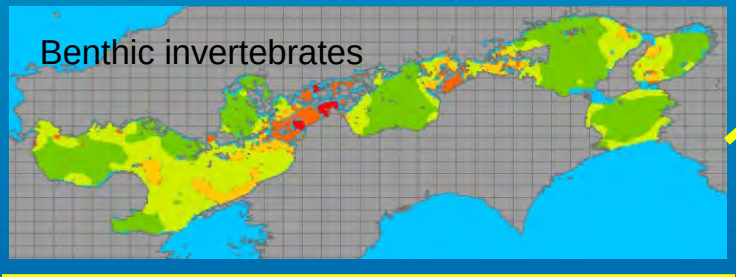
(4) Extracting the area with the suitable seascape structure

Results of modeling and extracting the seascape structure

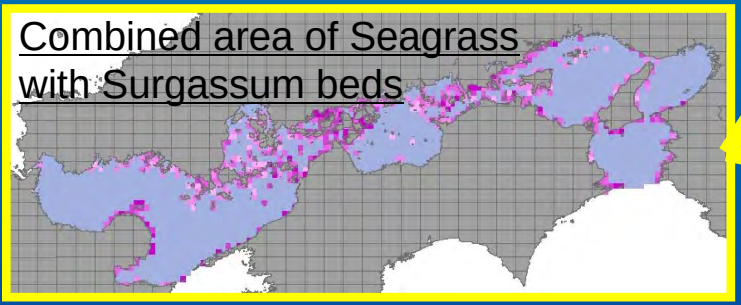
Major effective factors on fish species

Depth

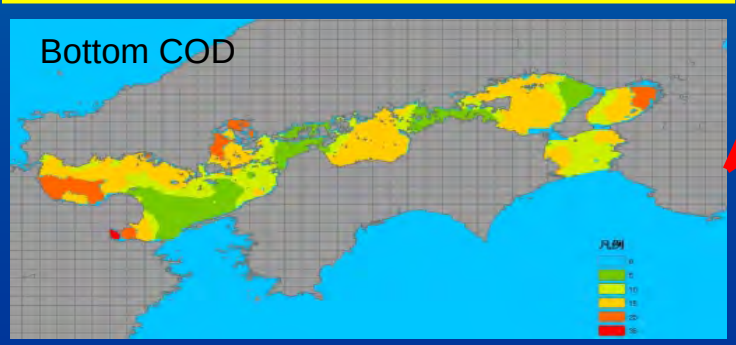
Benthic invertebrates



Combined area of Seagrass with Surgassum beds



Bottom COD



Correlation strength

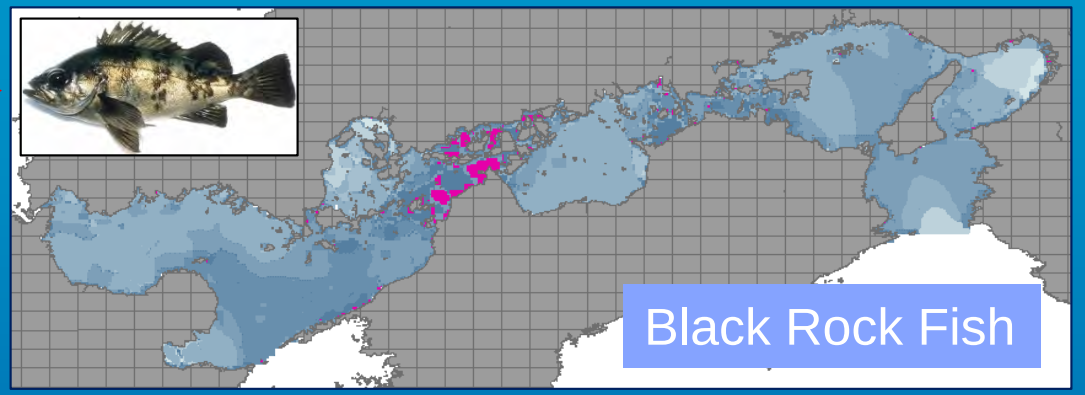
Negative

Positive

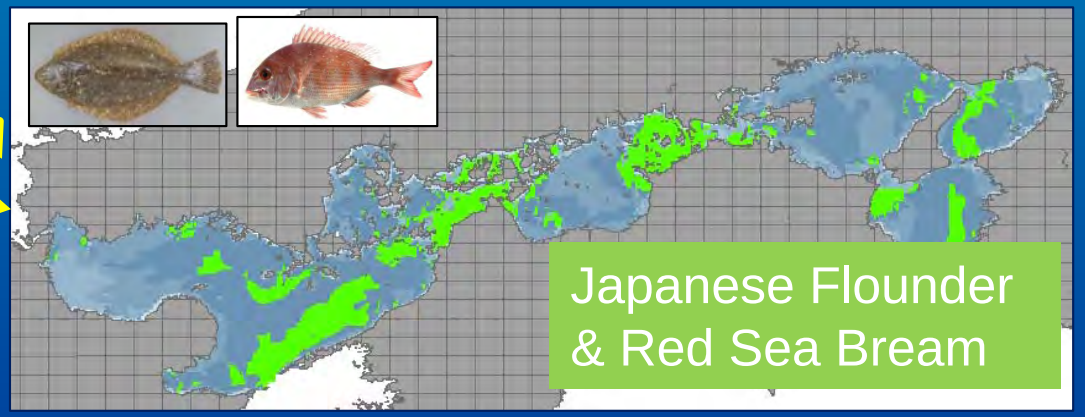
Relative weak

Other factors

The Most Suitable Areas (MSA) for each fish

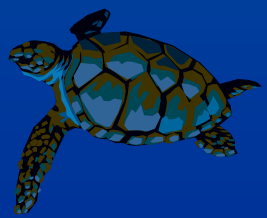


Black Rock Fish



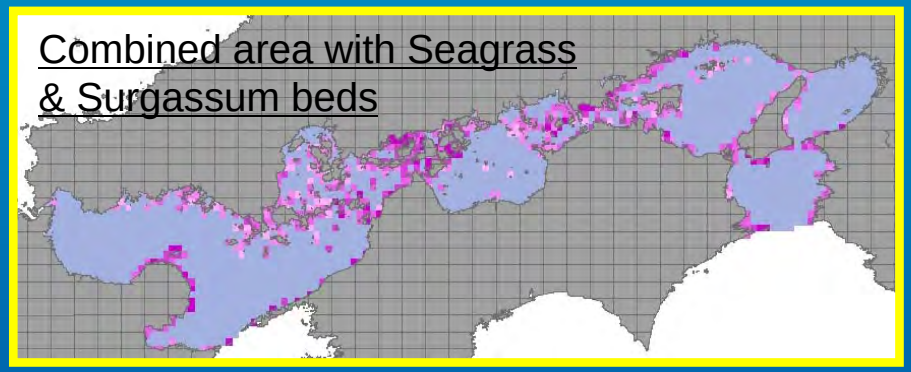
Japanese Flounder & Red Sea Bream

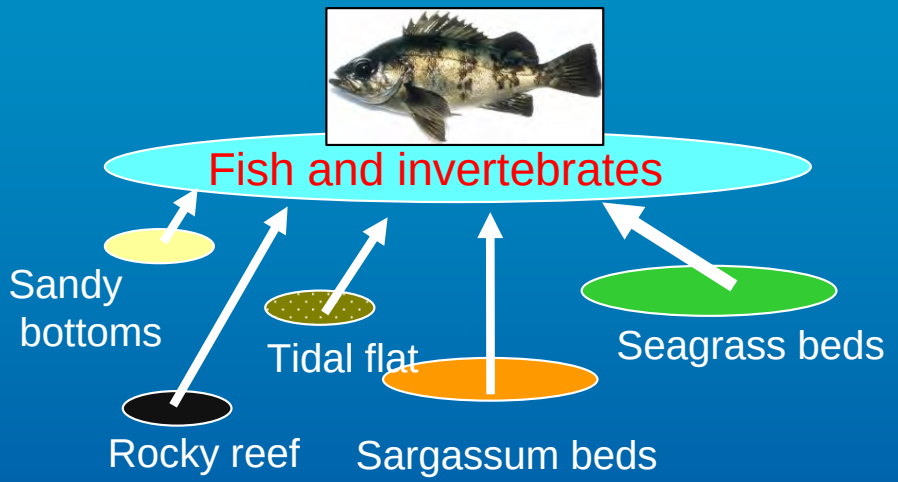
Combined area of seagrass with sargassum beds is the most effective factor on fish production



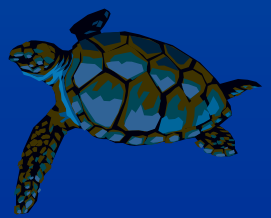
Question

How mixed seascape structure of seagrass and sargassum vegetation enhance fish production?



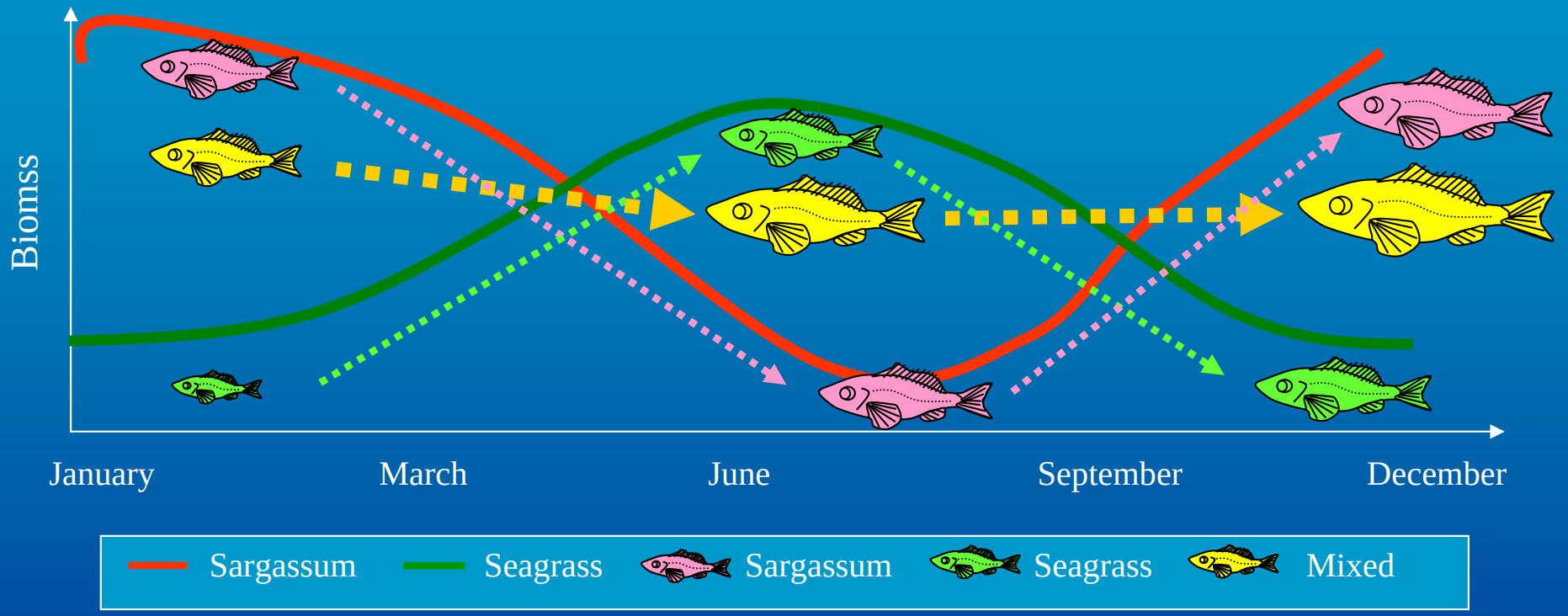


To demonstrate the ecosystem functions of the marine macrophytes in coastal seascape structure, mesocosm experiment for black rock fish growth was conducted by manipulating seagrass and surgassam vegetations



Hypothesis

Why the Mixed vegetative habitats enhance fish production?

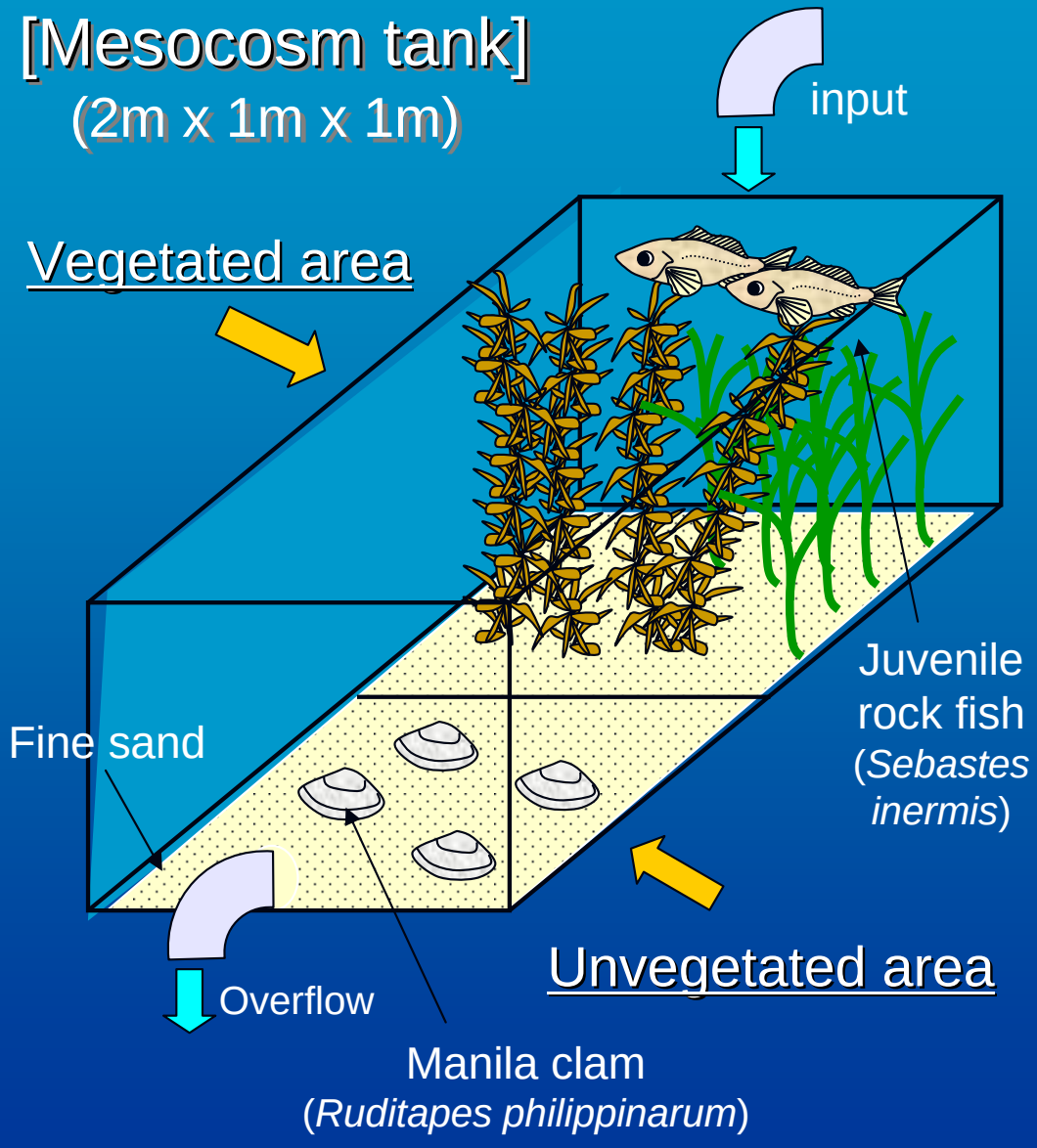


Clear difference in seasonal growth pattern between seagrass and sargassum vagetation

The sescape with mixed vegetation can maintain vegetation structure and food resource for rock fish through a year

Materials and Methods

[Mesocosm tank]
(2m x 1m x 1m)



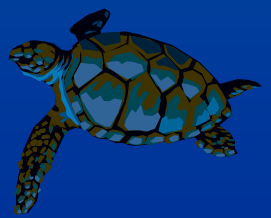
Vegetation & benthic community

Seagrass (*Zostera marina*) and sargassum (*Sargassum patens*) with the associated community were transplanted form the field

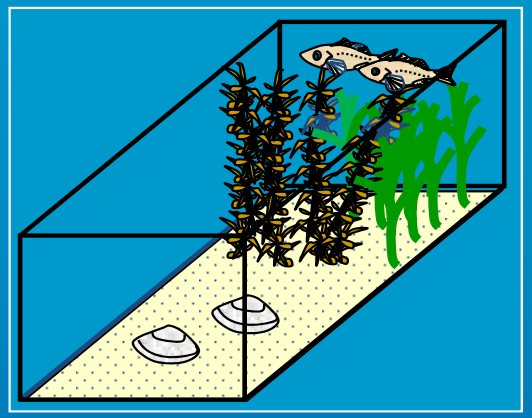
Seagrass and sargassum vegetations were the same biomass and shoot density as the average of Hiroshima Bay

Rock fish and bivalve:

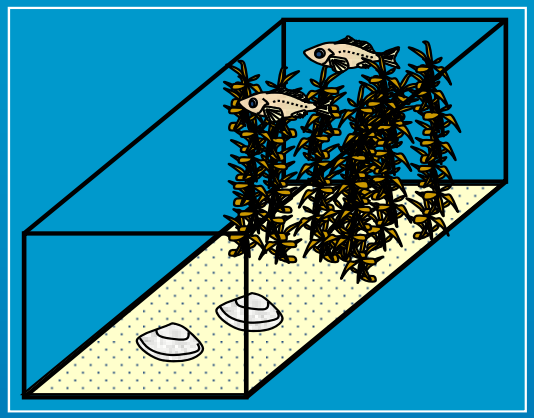
Manila clams as an indicator to check appearance of POM derived from adjacent vegetation



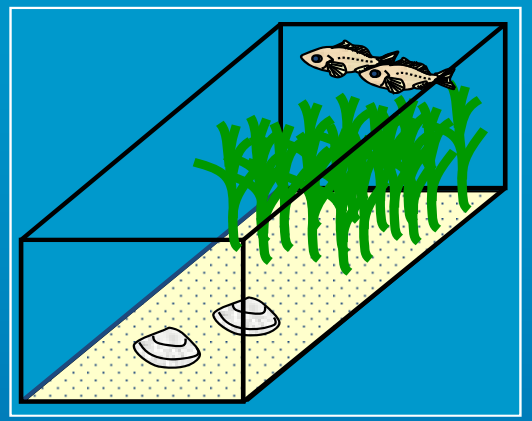
Summary of Experimental Design



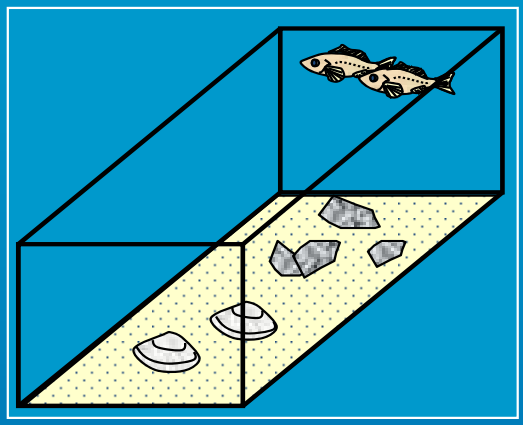
Treatment 1



Treatment 2



Treatment 3



Treatment 4

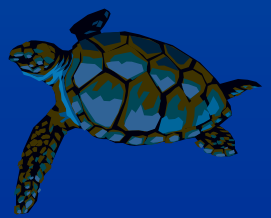
High — Seascape diversity — Low

Treatment 1: <u>Seagrass and sargassum (mixed) vegetation</u> ➡ <u>Control</u>

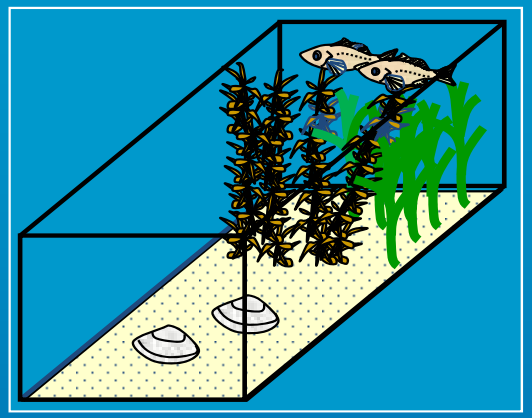
Treatment 2: <u>Sargassum vegetation</u>
(Seagrass - removed)

Treatment 3: <u>Seagrass vegetation</u>
(Sargassum - removed)

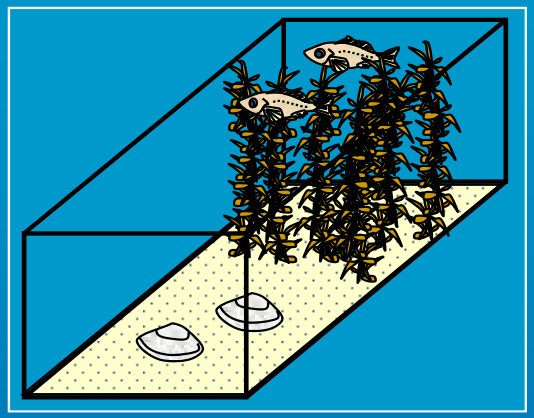
Treatment 4: <u>No vegetation</u>
(Both seagrass and sargassum - removed)



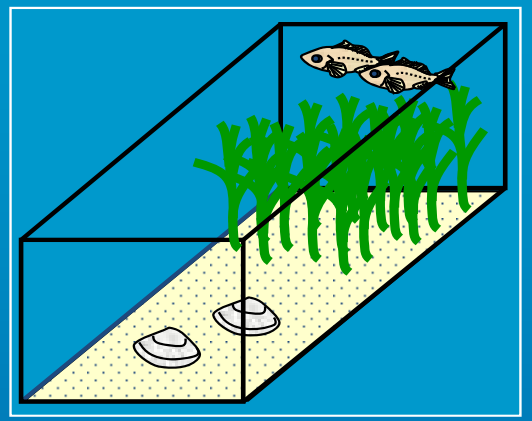
Summary of Experimental Design



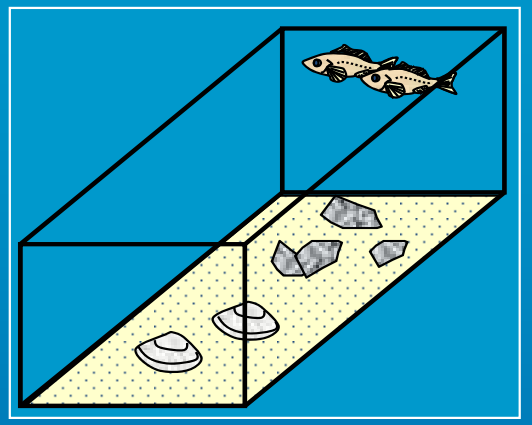
Treatment 1



Treatment 2



Treatment 3



Treatment 4

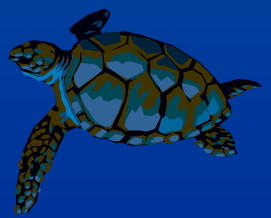
High — Seascape diversity — Low

Duration: One year without feed

12 tanks total

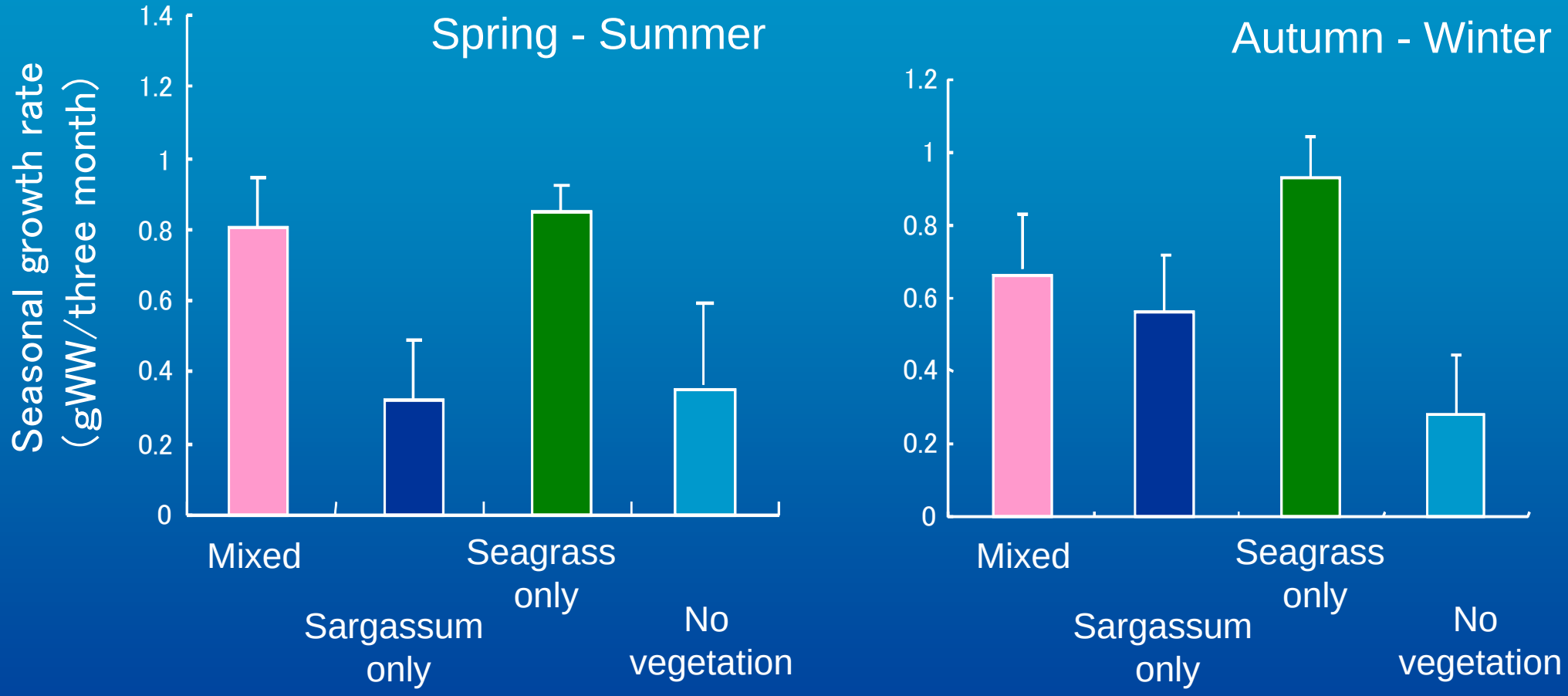
Measurement of the fish and bivalve growth

Analyses of carbon and nitrogen stable isotope composition

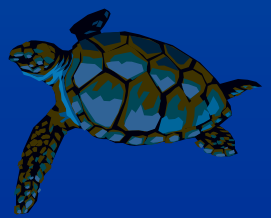


Results

Difference in seasonal growth of bivalve among treatments

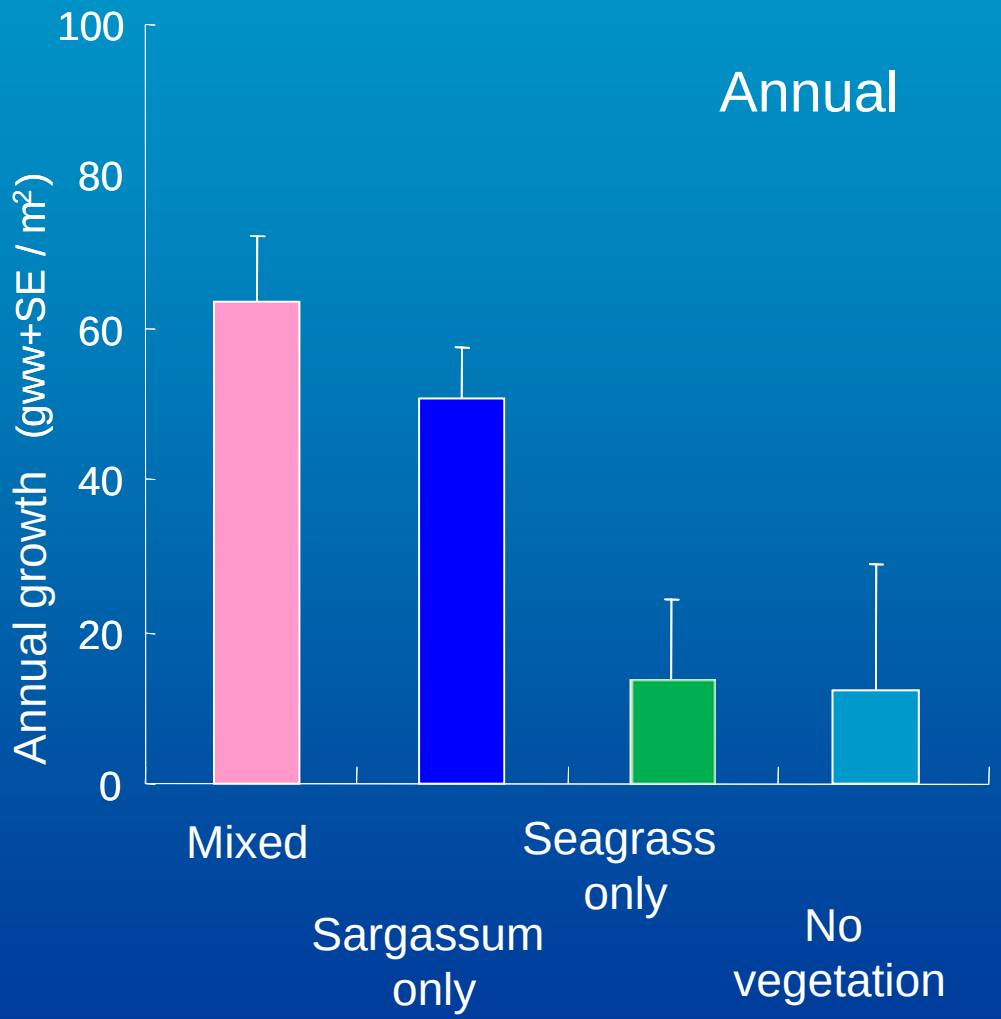


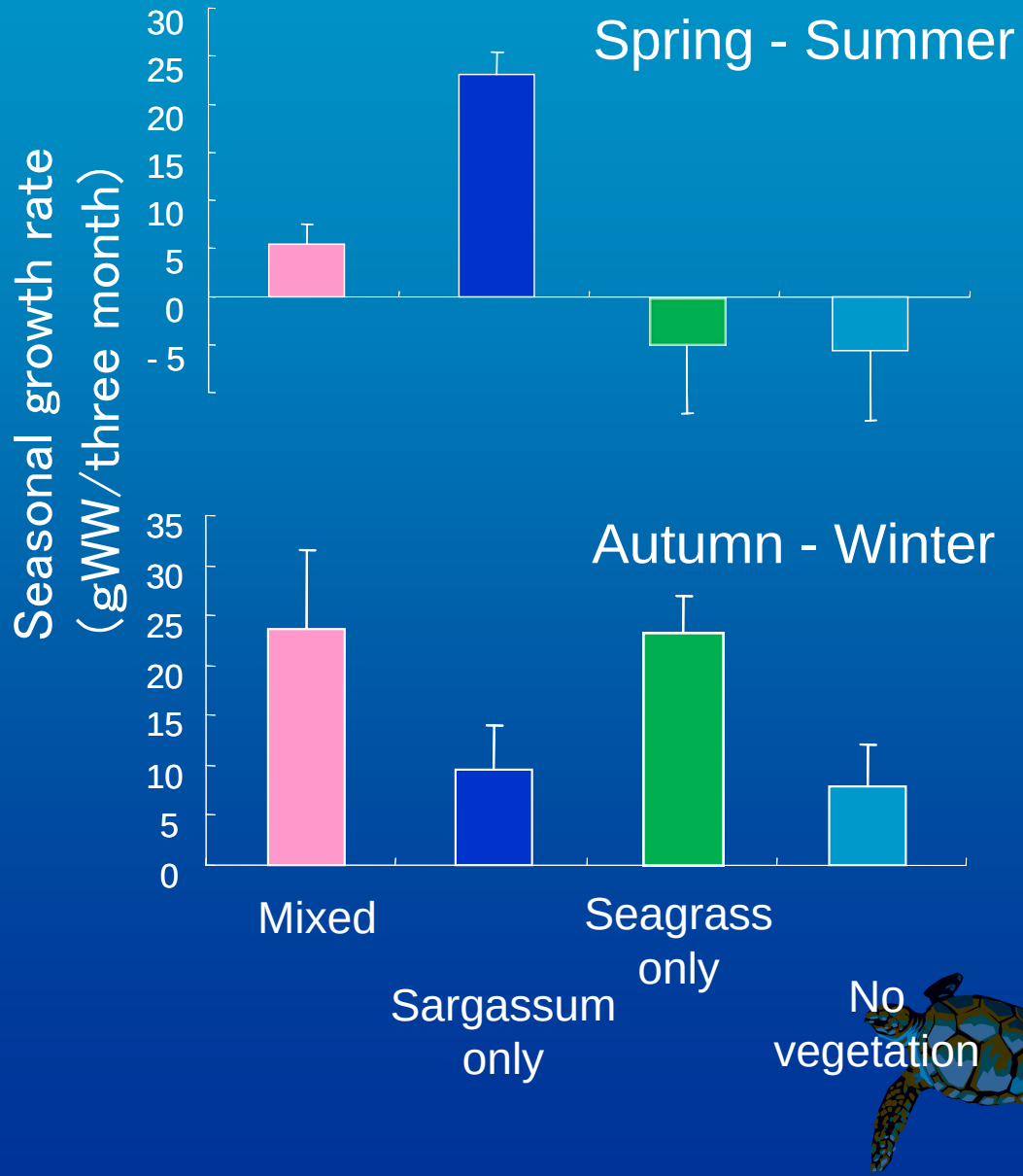
Seagrass habitat may supply more POM to the adjacent habitat than other habitats



Results

Difference in seasonal/annual growth of rock fish





The beginning of the experiment

After one year

Mixed

Sargassum only

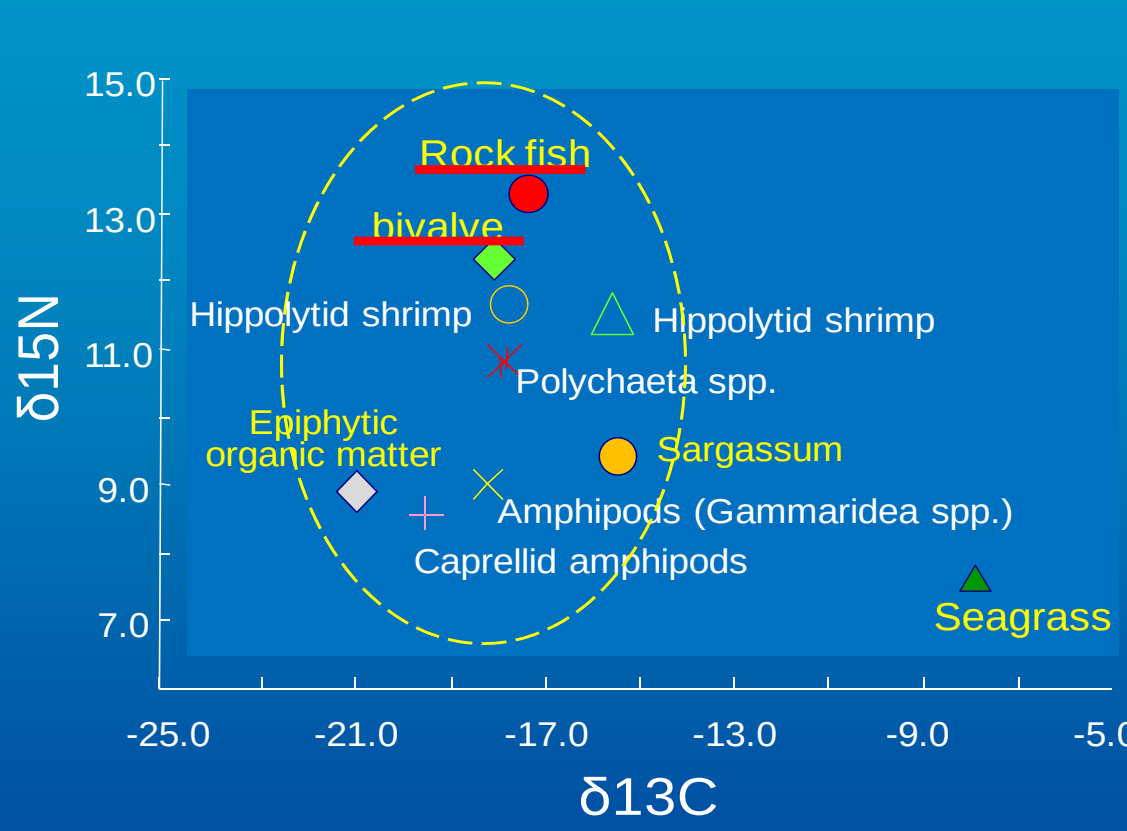
Seagrass only

No vegetation

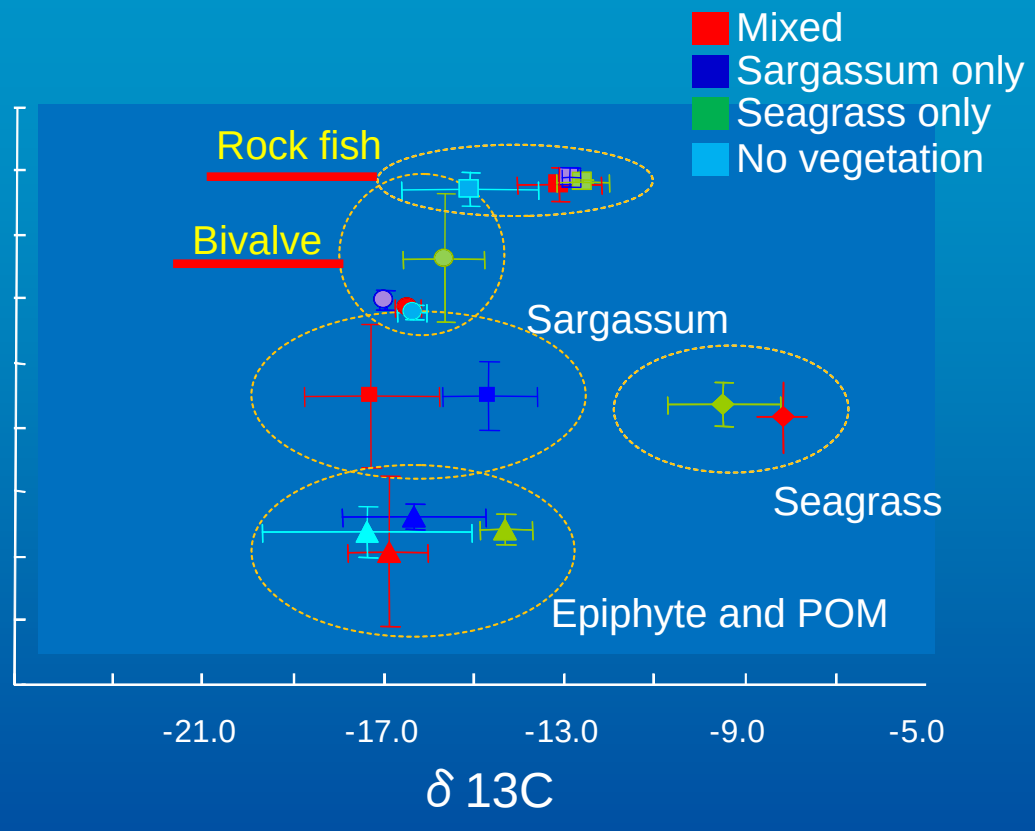
high Seascape diversity Low

Results

Stable isotope composition of mesocosm community



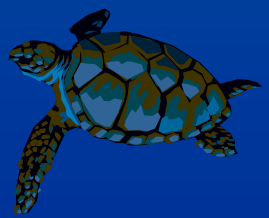
At the beginning of the experiment



After one year

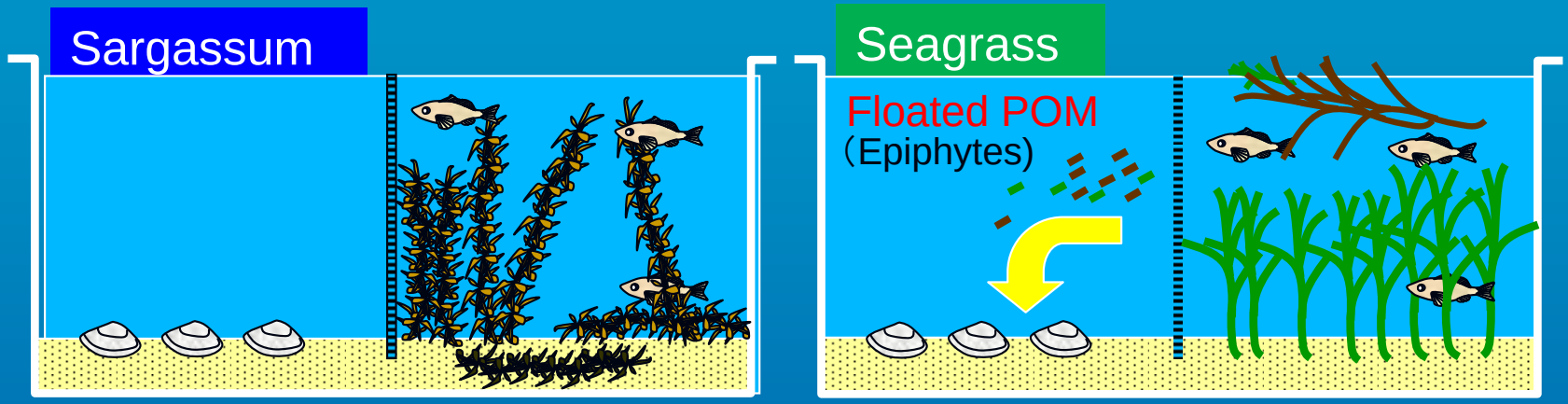
Difference in the stable isotope composition among treatments was not significant

The stable isotope composition of both rockfish and bivalve had little changed during the experiment



Discussion

Possible processes through food chains



Detritus derived from the fragment settled in the bottom

Floated epiphytes and detritus derived from the fragment

In the treatments with sargassum vegetation

Sargassum vegetation → Deposit/Detritus → Invertebrates → Rock fish

The stable isotope composition suggested that rock fish and invertebrates did not assimilate sargassum fragments

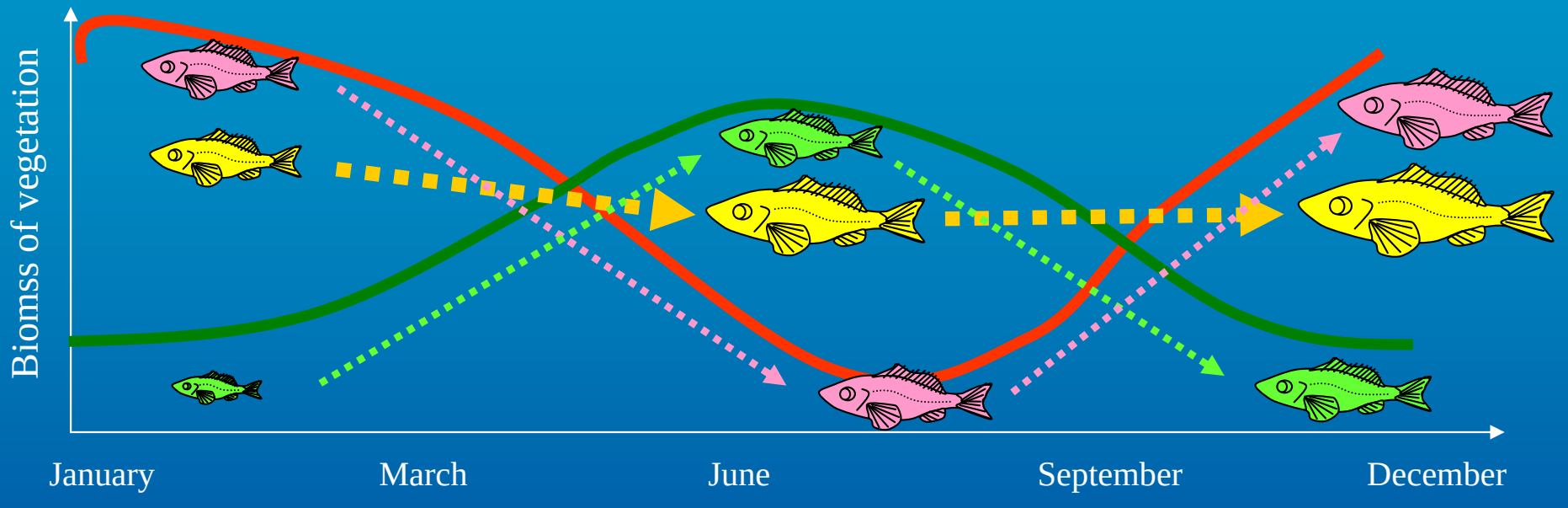
In the treatments with Seagrass vegetation

Seagrass vegetation → Epiphytes/POM → Bivalve
→ Invertebrates → Rock fish (Seasonal)

The stable isotope composition suggested that rock fish and invertebrates did not assimilate seagrass fragments

Discussion

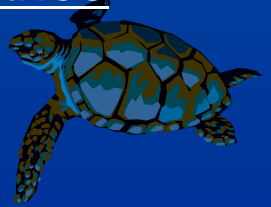
Why the mixed seascape enhanced fish production?



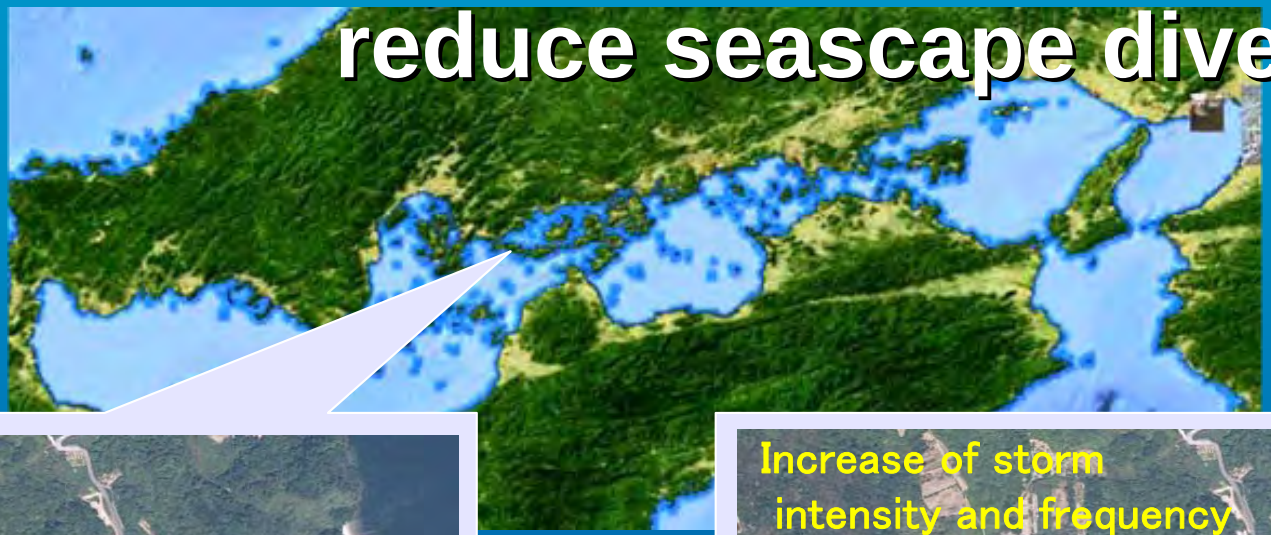
The habitat with mixed vegetation can maintatin vegetation structure and resource production through a year, so that it would be the most efficient for fish production

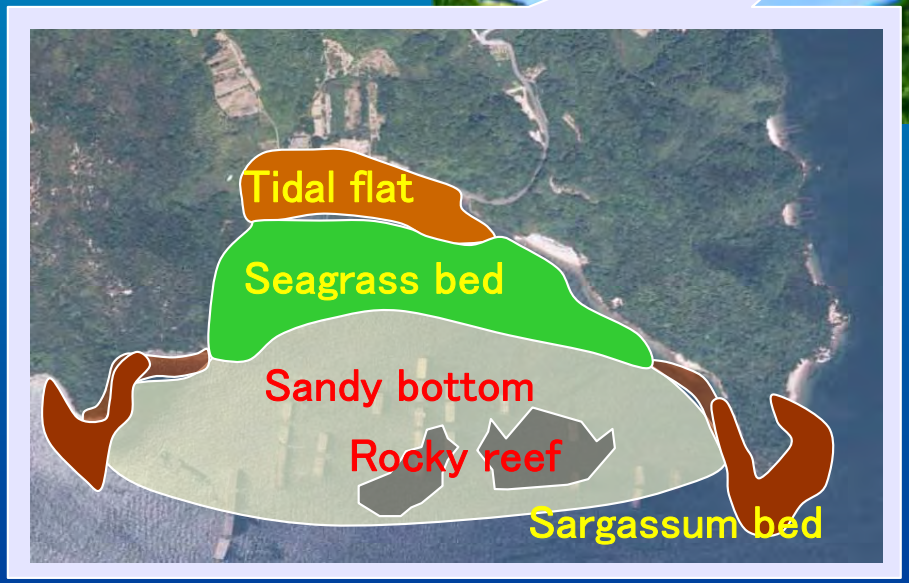
Conclusion:

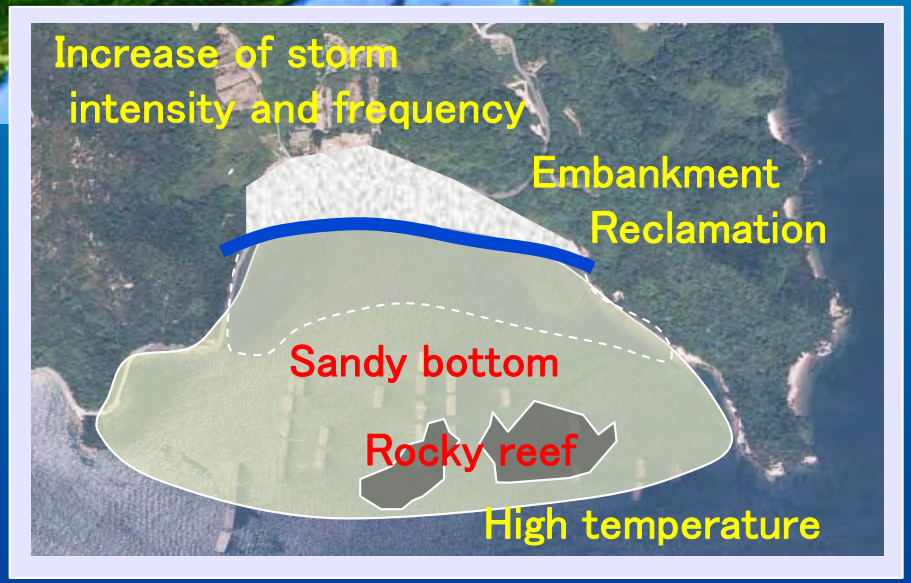
Spatial and temporal niche complementarity by seascape diversity enhance secondary production ⇒ True!



Further focus:
Climate change and artificial exploitation reduce seascape diversity

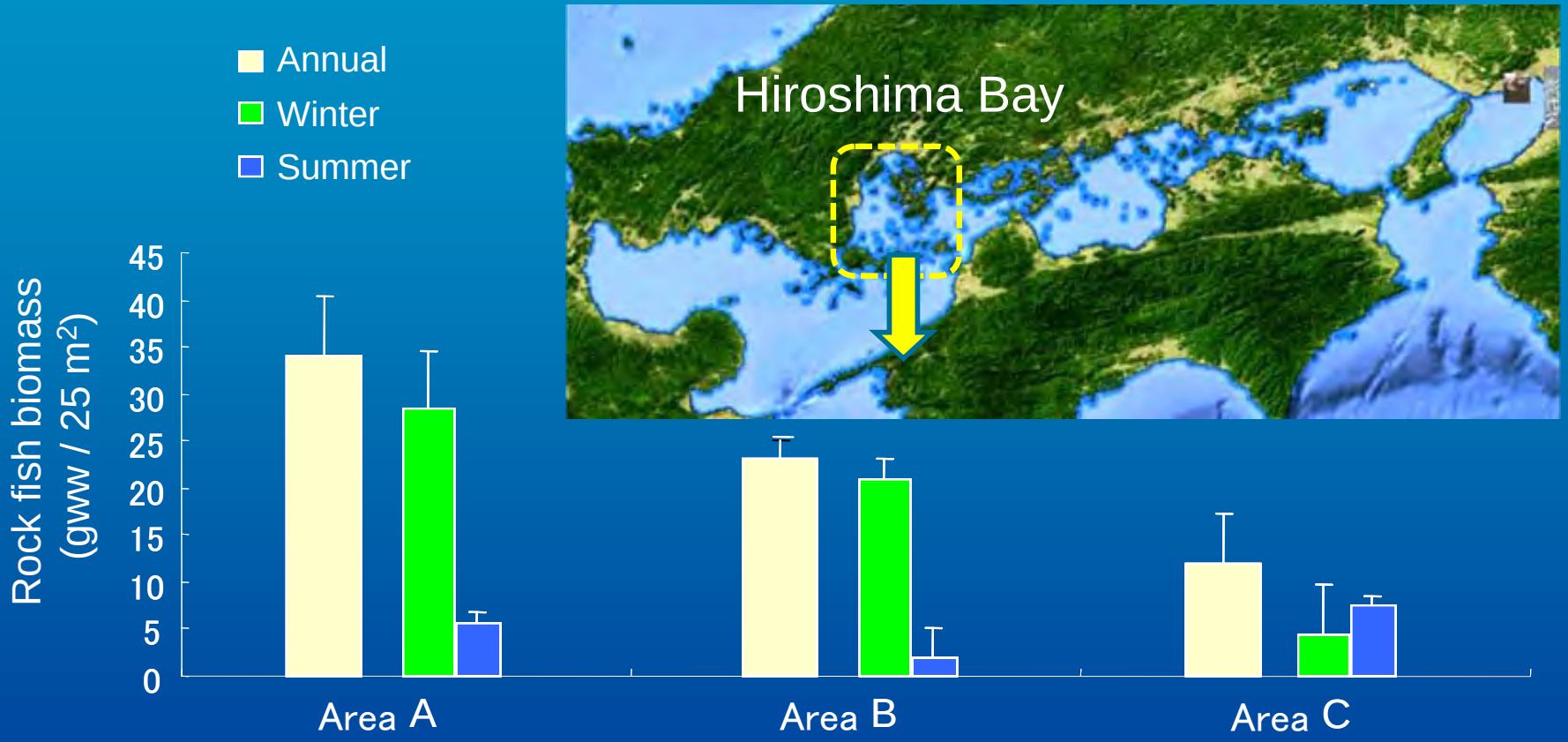




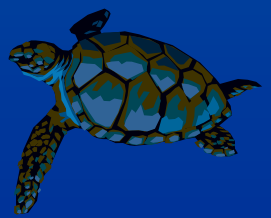


Seto inland sea is now exposed to serious climate change (warming) and artificial exploitation which have some negative effects on seascape structure and diversity (FRA 2010).

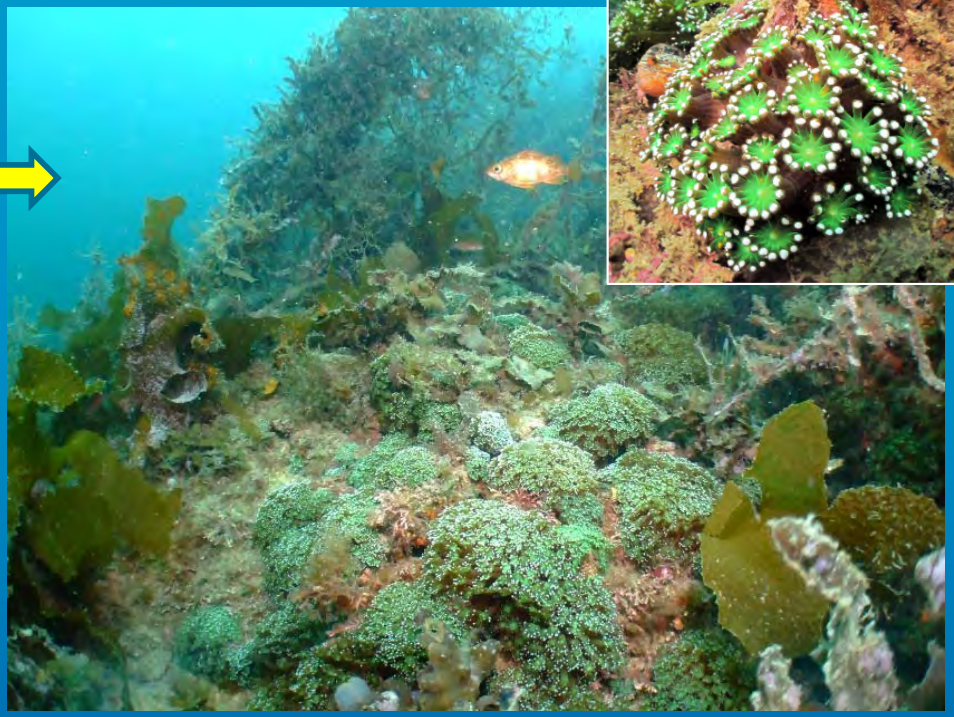
Loss of macrophyte habitats affects fish production?



	Area A	Area B	Area C
Seagrass bed	Good	Disappeared	Disappeared
Sargassum bed	Good	Good	Disappeared
Other vegetation	Good	Good	Disappeared
Tidal flat	Good	Good	Good



高知県水産試験場HPより



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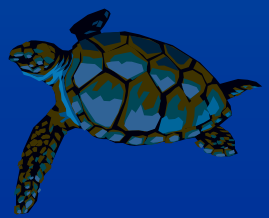
Sargassum and other macroalgal vegetation have been displaced by corals and/or coralline algae

Herbivorous fish and invertebrates come from southern region have decreased seagrass and macroalgal vegetation

Presumably because of environmental change (warming) in Seto Inland Sea?



Seascape ecology is an effective tool to identify and restore “Where and How?”

Thank you for your attention

Black rock fish juveniles in a Sargassum bed of Seto Inland Sea