A breakdown of habitat isolation among coastal fish by an artificial habitat modification

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Hybridization

Photo by T. Abe

deforestation

soil contamination

fragmentation

Habitat alteration by human activities

eutrophication

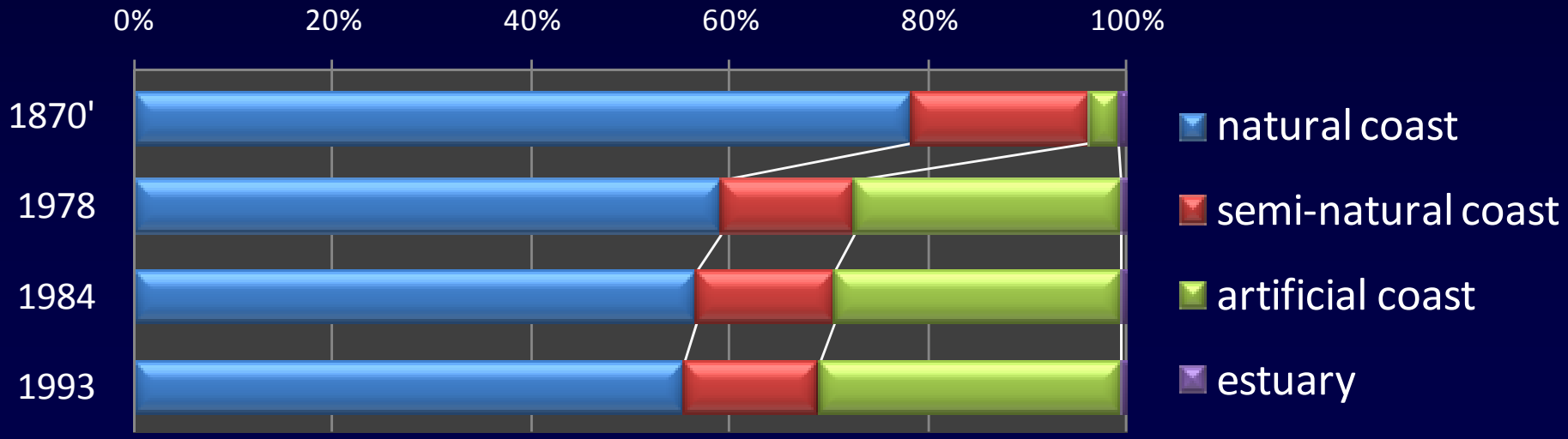
water pollution

desertification

Coastal area is not an exception…

Artificial modification of coast line are very common in Japan.

Transition of coastal line of each category in Japan



(Ministry of the Environment of Japan, Nature Conservation Bureau)

Artificialization of coast line cause serious influence on marine ecosystems.

Decrement of seaweed bed

Artificialization

shore protection

reclamation

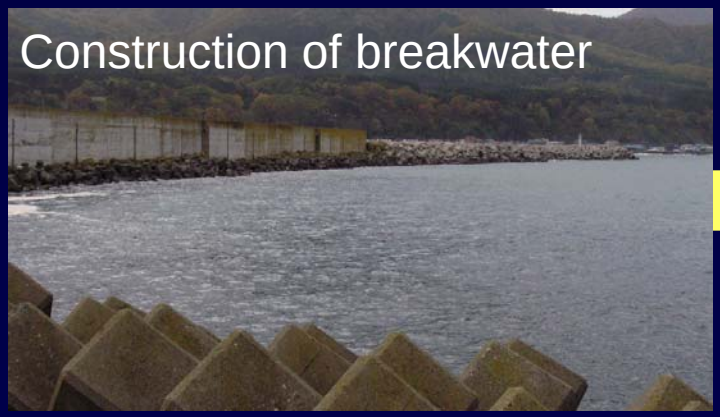
artificial construction

…etc.

suitable habitat for growing, feeding, shelter, and reproduction

Extinction of local population

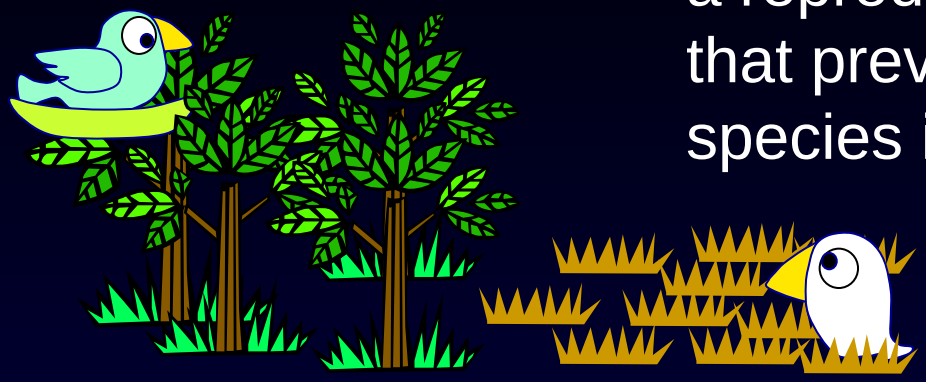
Today's topic



Breakdown of habitat isolation

Hybridization between naturally isolated species

Habitat Isolation



a reproductive isolating mechanism that prevents gene exchange among species in different habitats

- **maggot fly *Phagoletis pompnella*** (Forbes & Feder, 2006)

apple-infesting host race
V.S.
hawthorn-infesting host race

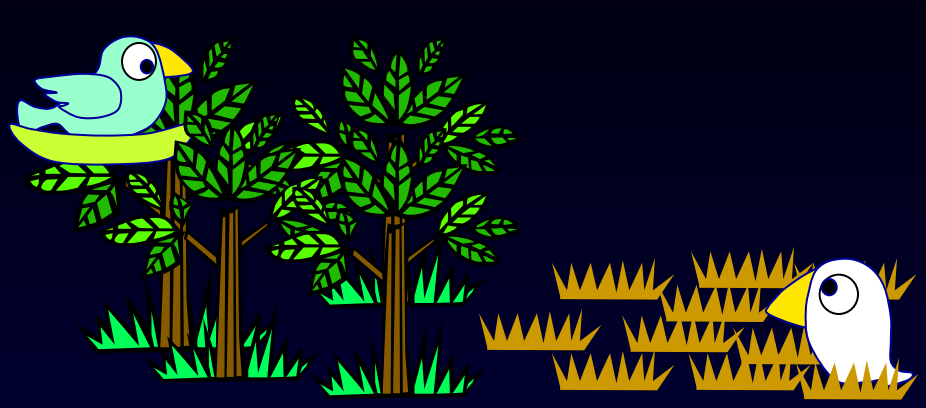
→distinguish each host plat by olfactory and visual fruit cues

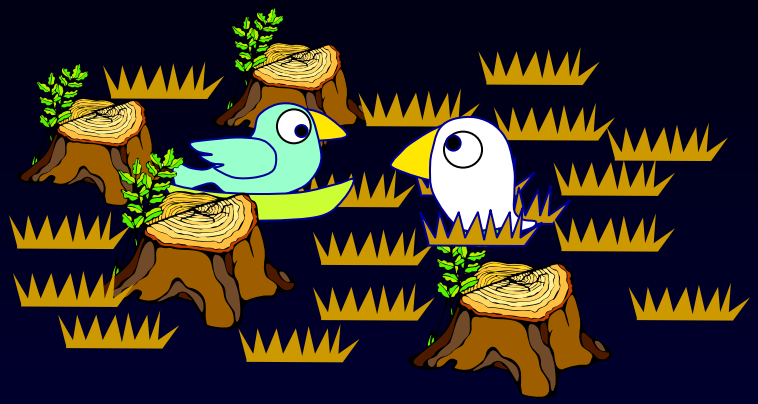
- ***Heliconius* butterflies** (Estrand & Jiggins, 2002)

H. melpemene inhabit open secondary forest
V.S.
H. cydno inhabit closed-canopy forest

→difference of microhabitat contribute to pre-mating isolation

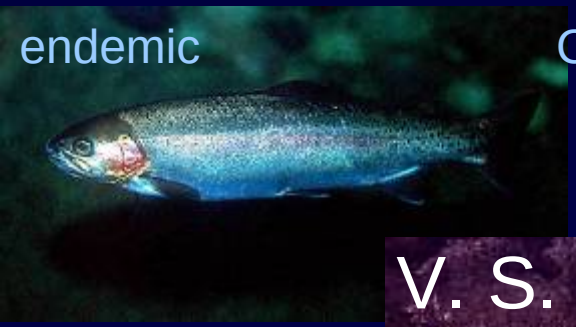
Habitat Isolation → can be disrupted by artificial modifications of habitat





Such human-cased hybridization sometimes lead to extinctions of local population.

Well known example is species introduction.



Cutthroat Trout

V. S.

Rainbow Trout

introduced

grey duck

V. S.

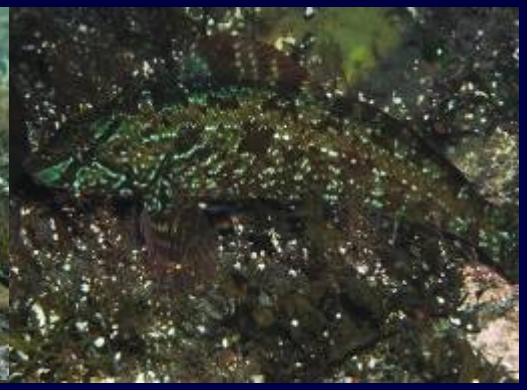
mallard ducks

introduced

greenling (*Hexagrammos* generic species)

Hexagrammos otakii

H. agrammus



H. octogrammus

Coastal benthic fish

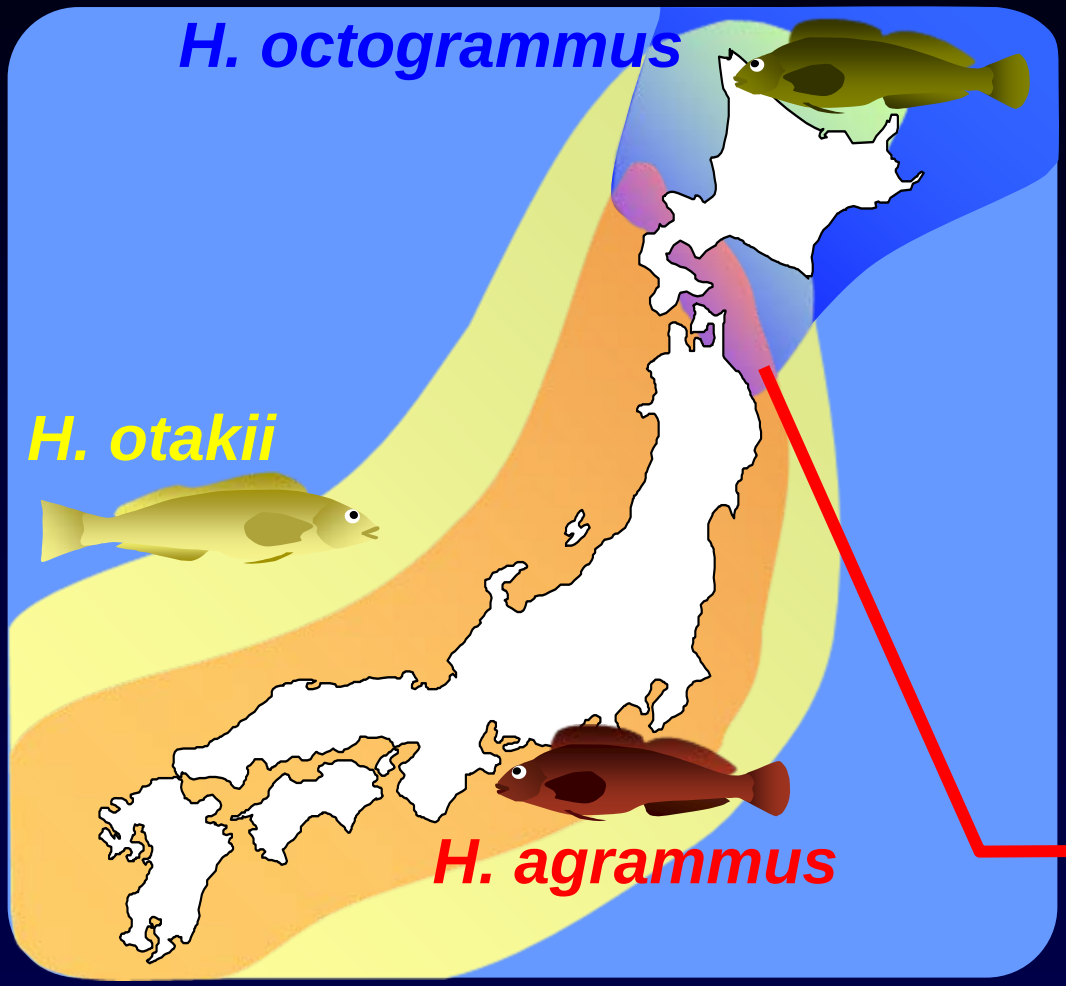
Commons species in North Pacific

Males establish breeding territories during breeding season.

Females visit males' territories and spawn egg masses on substrates.

Egg masses deposited by multiple females are cared for by territorial males until hatching.

Hybridization among three *Hexagrammos* species

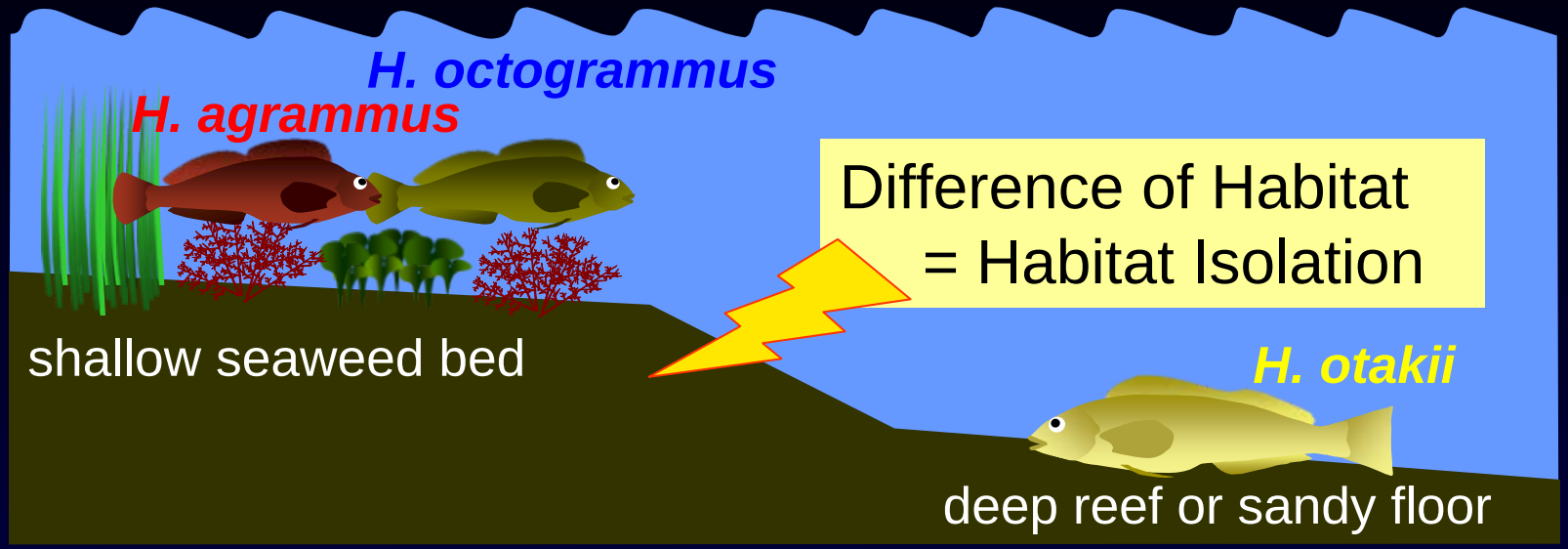


A boreal species
(***H. octogrammus***)
and
two temperate species
(***H. otakii*** & ***H. agrammus***)
secondary came into
contact
after glacial age

Hybrid Zone

Hybridization among three *Hexagrammos* species

Habitat use of three *Hexagrammos* species



H. agrammus x *H. octogrammus*

(has been reported since 1970's)

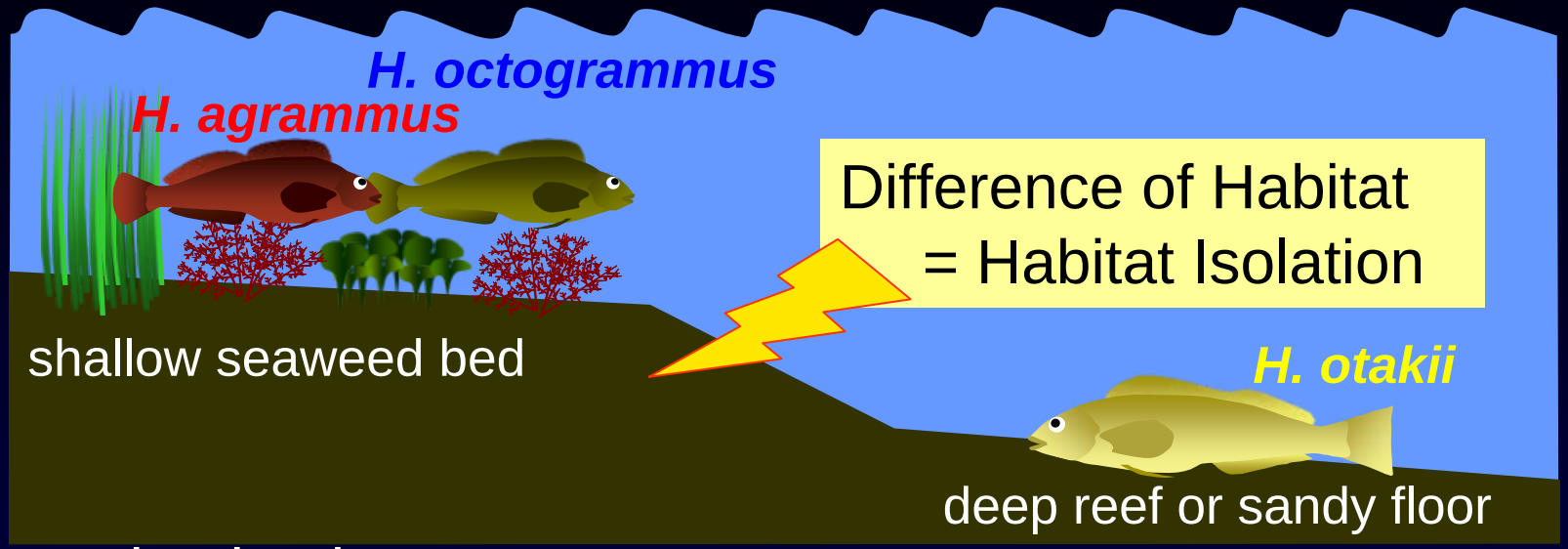
H. otakii x *H. octogrammus*

(first reported in 2001)

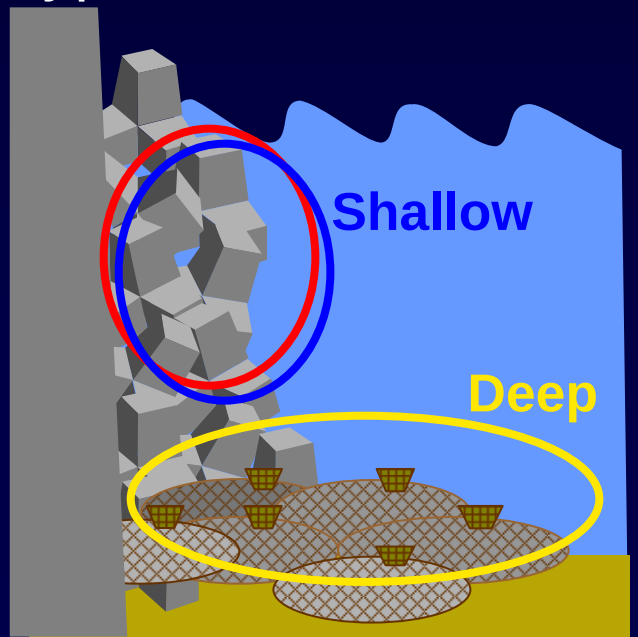
Why ! ?

Hybridization among three *Hexagrammos* species

Habitat use of three *Hexagrammos* species

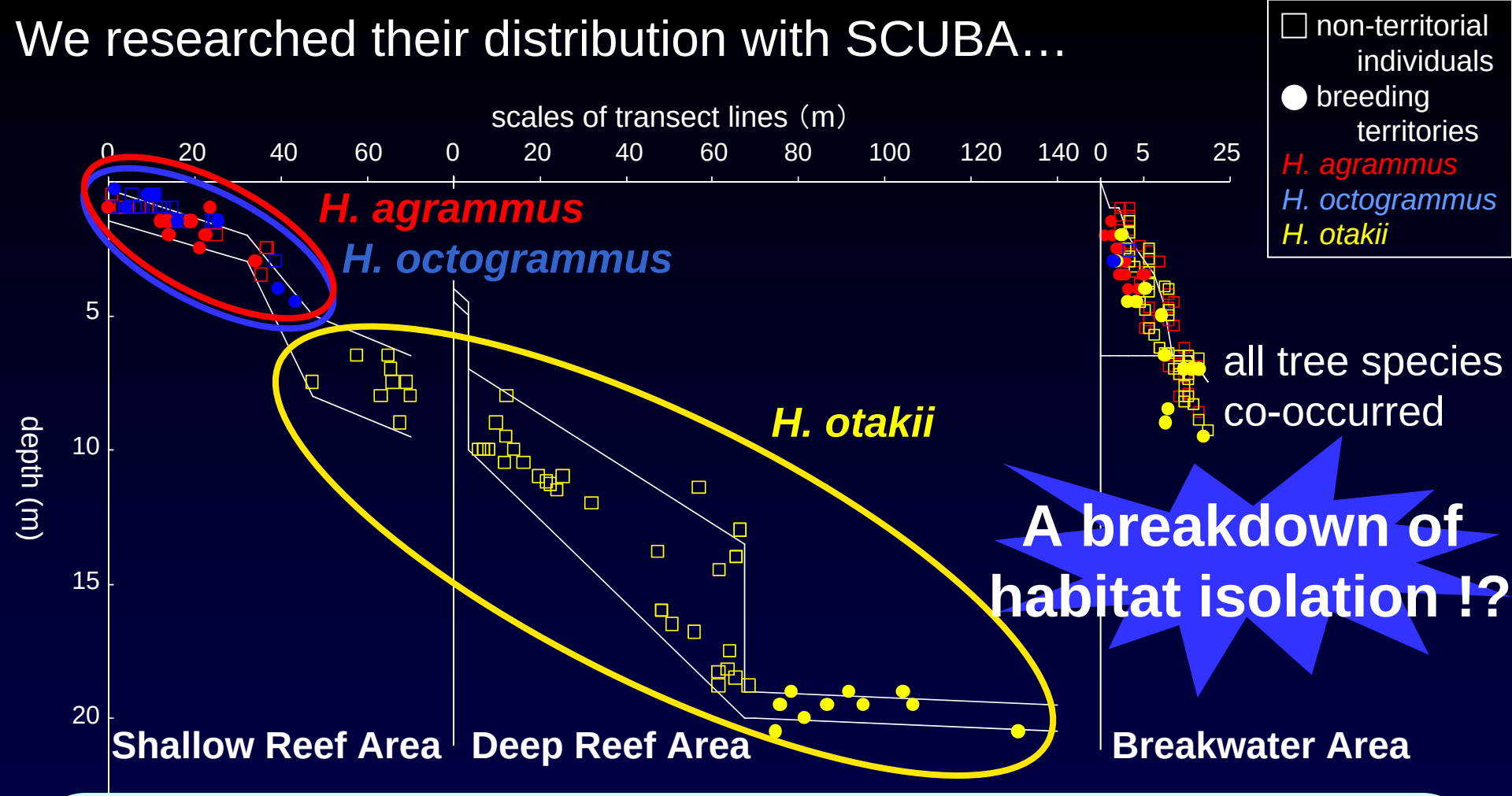


We hypothesized…



Man-made construction such as breakwater would approximate shallow and deep environment owing to its steep sloops, allowing naturally isolated shallow and deep species to breed in same area.

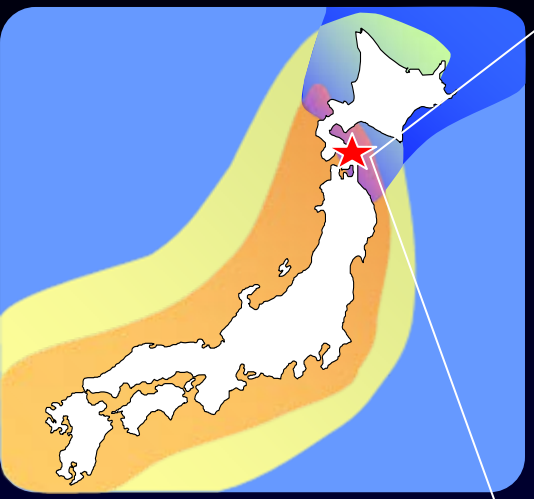
We researched their distribution with SCUBA…

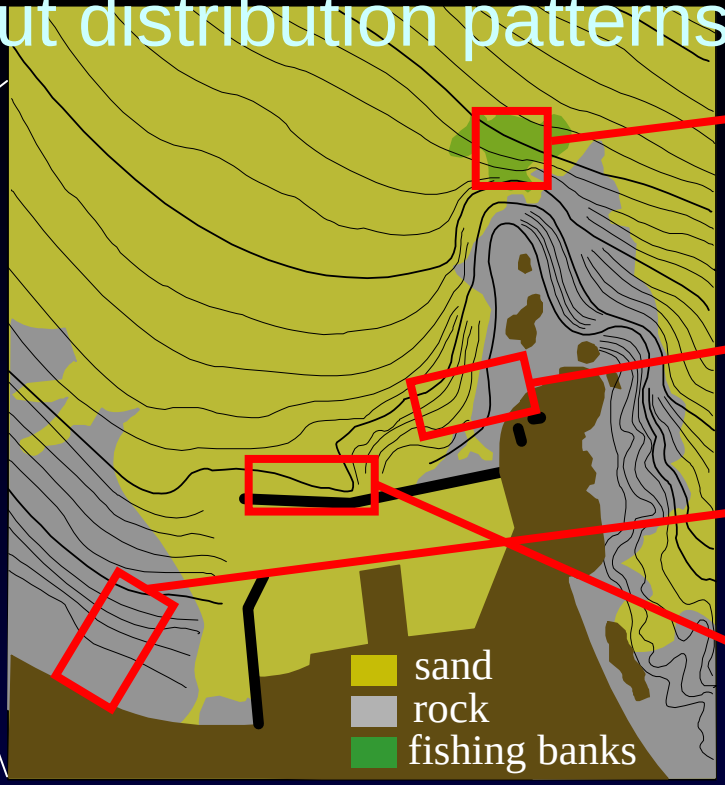


Question:

1. **What is the factor that make their natural distribution segregated?**
   (What cause habitat isolation?)
2. **Why all three species co-occurred in Breakwater area?**
   (What is the breakdown mechanism?)

Research about distribution patterns and habitat use



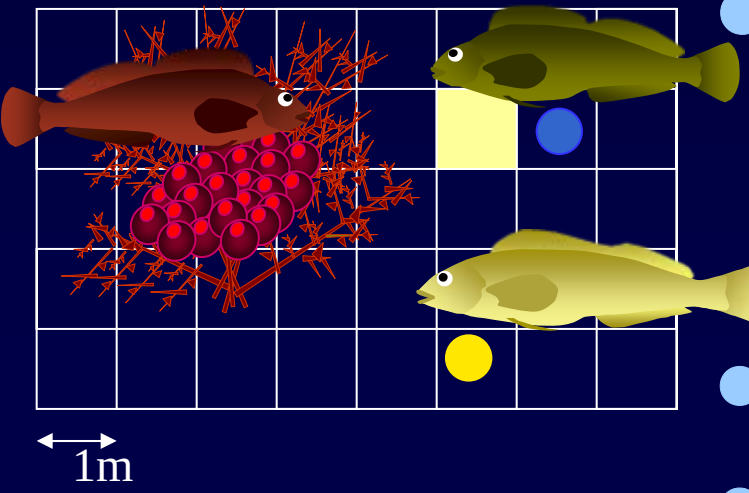


Sandy Area
(with fishing banks)
depth: 19-21m, 30 × 50m

Natural Reef 1
depth: 0-9m, 20 × 70m

Natural Reef 2
depth: 0-5m, 20 × 70m

Breakwater Area
depth: 0-11m, 25 × 70m



- **Habitat characteristic**
  - **depth**
  - **bottom materials** (rock, sand, boulder, fishing banks, tetrapods, net)
  - **vegetation** (small algae, macroalgae, surfgrass, bryozoans, net knot, bare)
- **Distribution of *Hexagrammos* fish** (non-territorial and territorial)
- **Spawning substrates**

1. **What is the factor that make their natural distribution segregated?**

➡ Which environmental factor most influence the distribution patterns of *Hexagrammos* species?

A series of Maltinomial log-liner models

dependent variables:
species occurred in given compartment

a.) non-territorial individuals

Model	independent variables	AIC
Model 1	β_0 + β_1 (depth) + β_2 (bottom) + β_3 (vegetation)	**424**
Model 2	β_0 + β_1 (bottom) + β_2 (vegetation)	455
Model 3	β_0 + β_1 (depth) + β_2 (vegetation)	489
Model 4	β_0 + β_1 (depth) + β_2 (bottom)	440
Model 5	β_0 + β_1 (depth)	545
Model 6	β_0 + β_1 (bottom)	509
Model 7	β_0 + β_1 (vegetation)	527

The distributions of non-territorial individuals might **NOT** be determined by any particular factors.

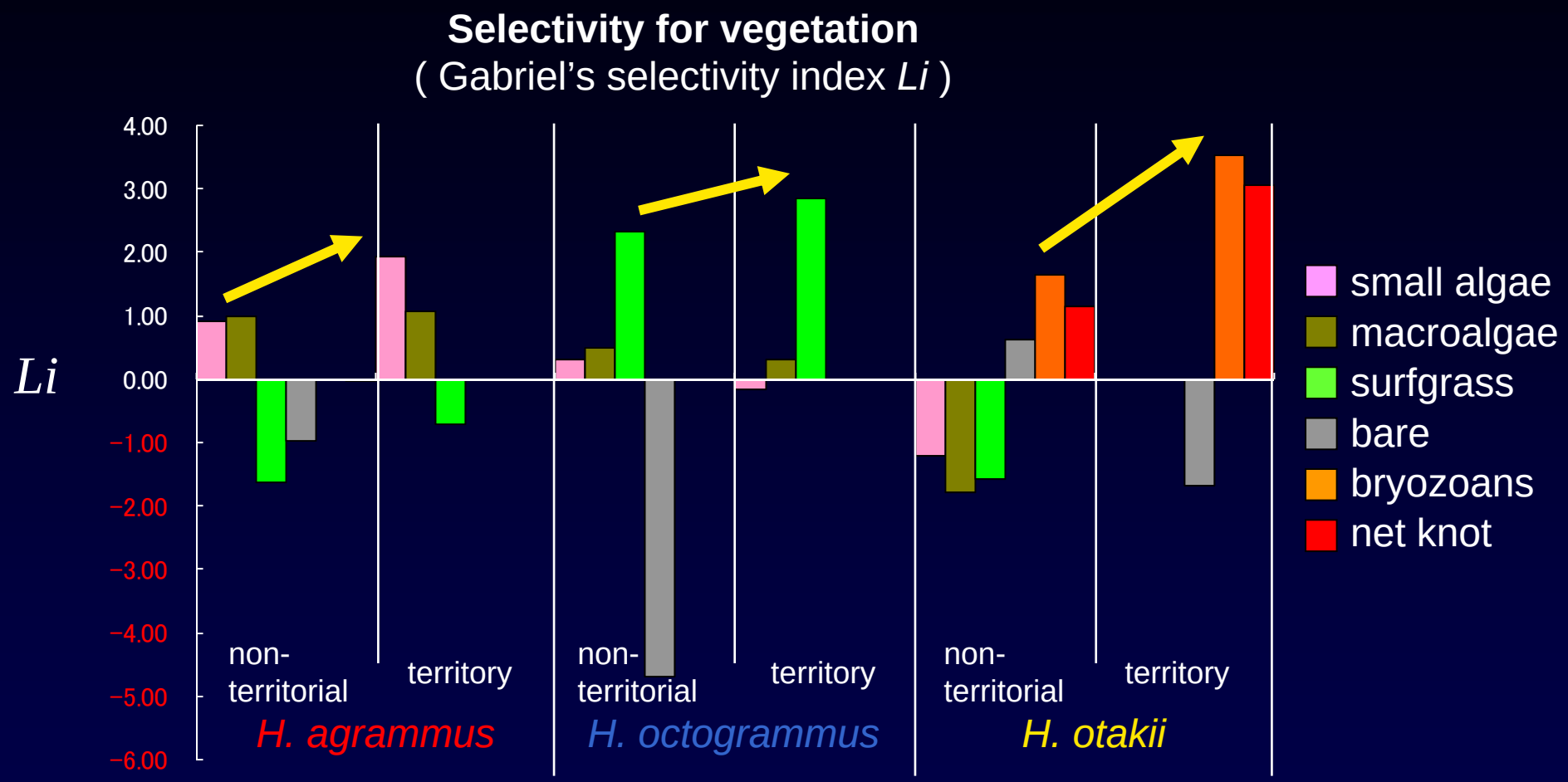
b.) territories

Model	independent variables	AIC
Model 1	β_0 + β_1 (depth) + β_2 (bottom) + β_3 (vegetation)	100
Model 2	β_0 + β_1 (bottom) + β_2 (vegetation)	97
Model 3	β_0 + β_1 (depth) + β_2 (vegetation)	97
Model 4	β_0 + β_1 (depth) + β_2 (bottom)	109
Model 5	β_0 + β_1 (depth)	110
Model 6	β_0 + β_1 (bottom)	129
Model 7	β_0 + β_1 (vegetation)	**95**

The distributions of territories were well explained by **vegetation**.

1. **What is the factor that make their natural distribution segregated?**

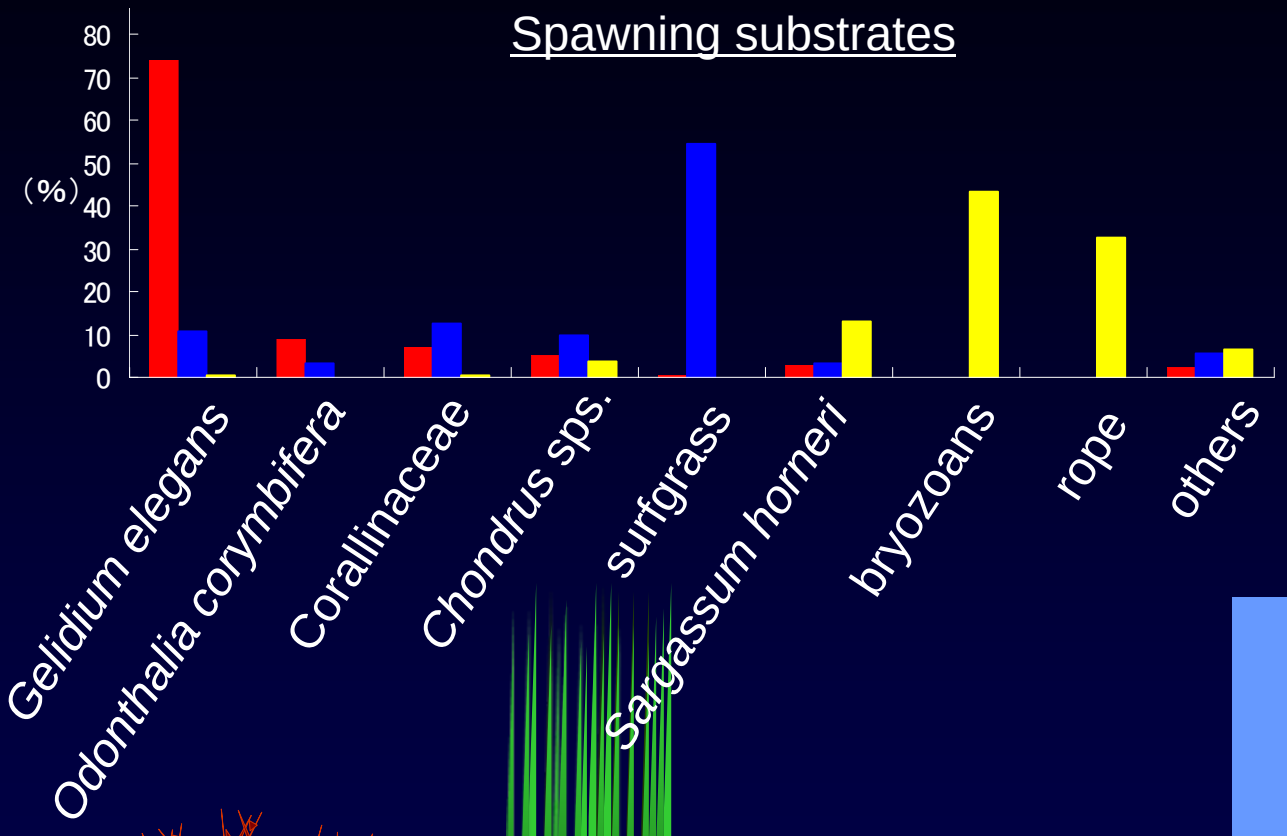
➡ What vegetation does each *Hexagrammos* species prefer?



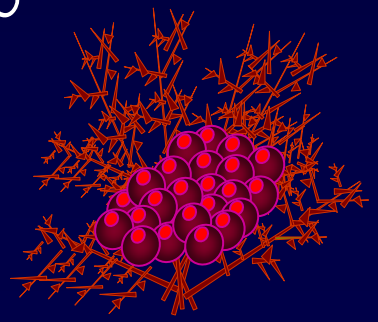
- Each species showed different preference for vegetation.
- Selectivity for preferred vegetation of territory were higher than that of non-territorial individuals.

1. **What is the factor that make their natural distribution separated?**

➡ Why the selectivity for vegetation were higher as to territory?

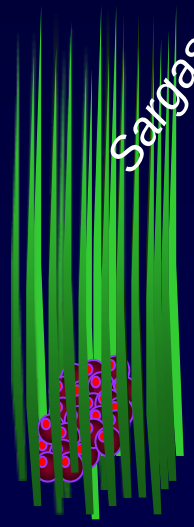


(No. of egg masses)
- *H. agrammus* (N=428)
- *H. octogrammus* (N=261)
- *H. otakii* (N=362)



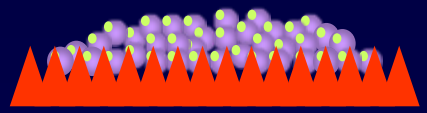
Gelidium elegans

H. agrammus



surfgrass

H. octogrammus



bryozoans / rope

H. otakii

Three species use different spawning substrates

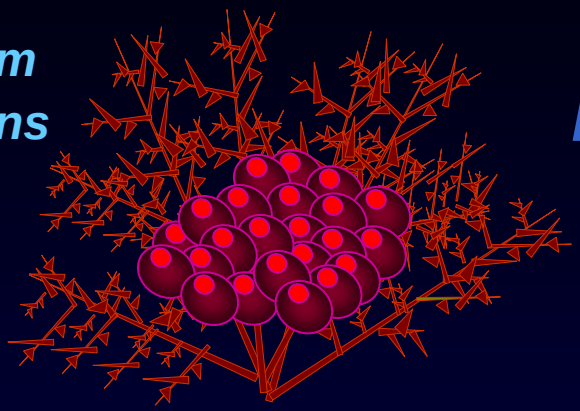
⬇

Distribution of territories might be influenced by the distribution of spawning substrates !?

1. **What is the factor that make their natural distribution segregated?**

➡ Why spawning substrates are different among three species?

Gelidium elegans

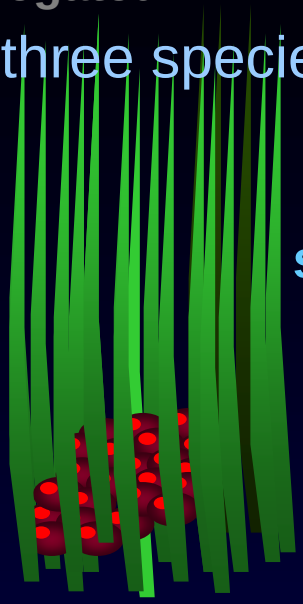


H. agrammus
H. octogrammus

⇩

very viscous egg masses

⇩



surfgrass

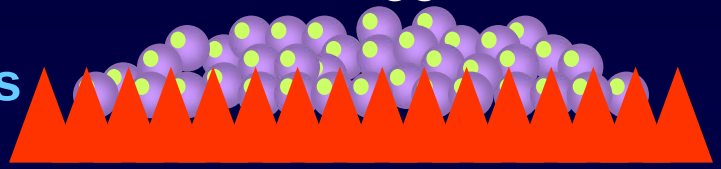
wrapped up with seaweed branches, shaping into globular masses

H. otakii

⇩

less viscous egg masses

bryozoans



pressed over rugged materials, shaping into platy masses

Males might select suitable substrates according to the property of egg masses

2. **Why all three species co-occurred in Breakwater area?**

➡ How is the environment of Breakwater area like?

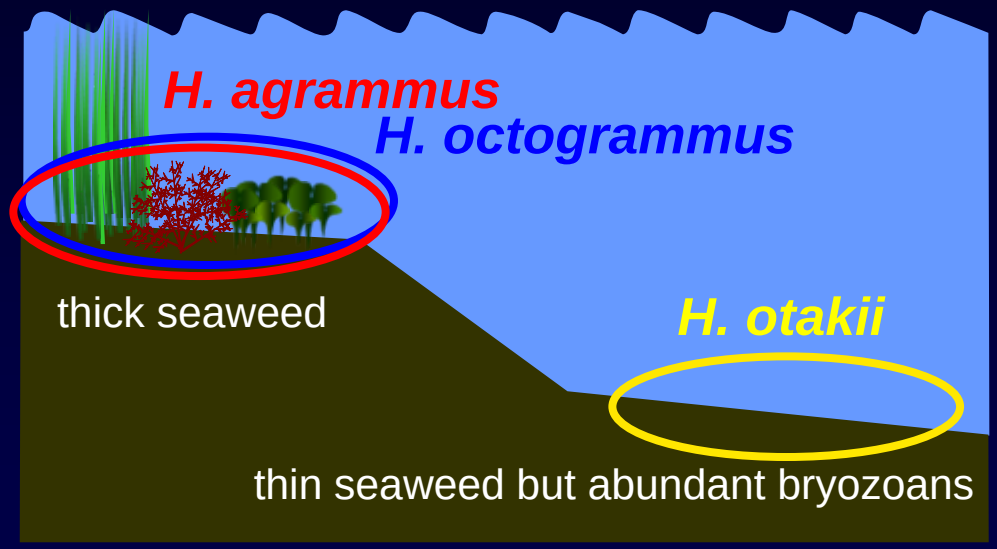
The distribution of territories were well explained by **vegetation**.

↓

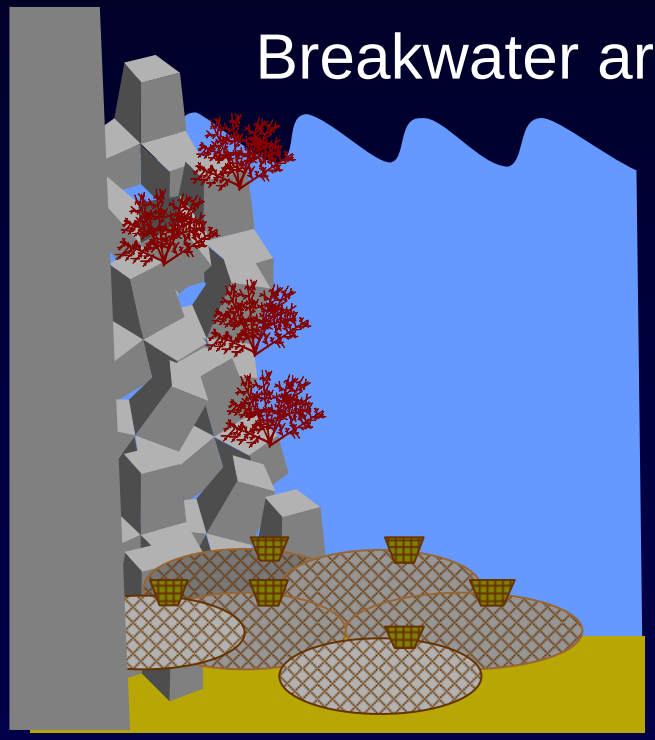
co-occurrence of three *Hexagrammos* species

= **co-occurrence of different vegetation**

Natural reef



Breakwater area



2. **Why all three species co-occurred in Breakwater area?**

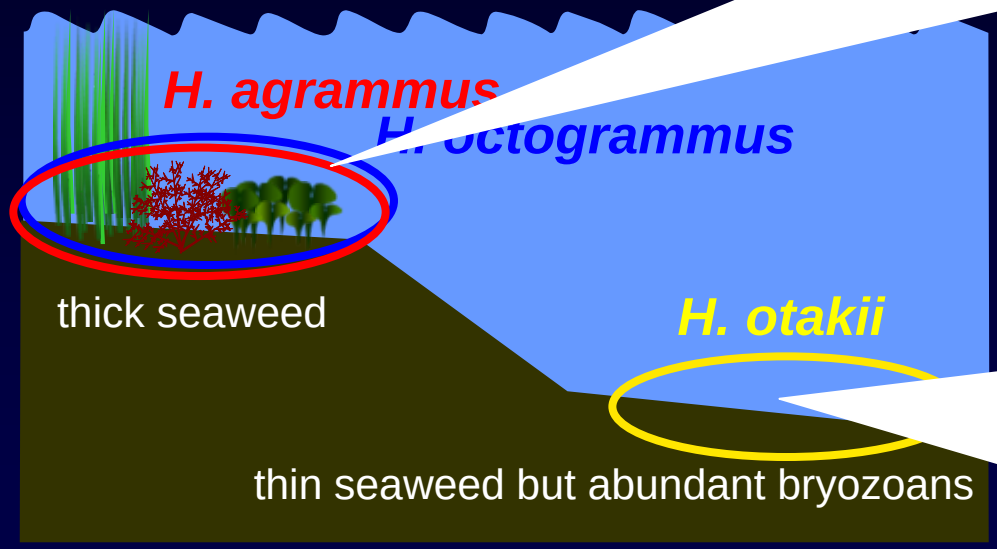
How is the environment of Breakwa

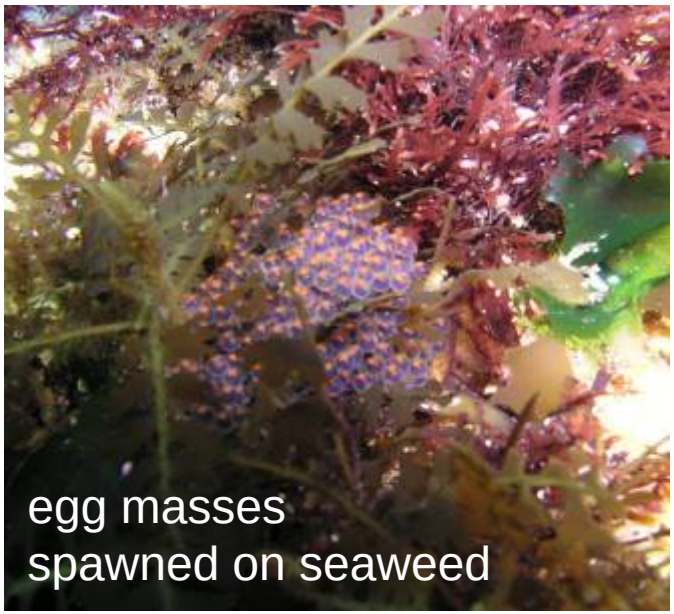
The distribution of territories were w

co-occurrence of three *Hex*

= co-occurrence of diff

Natural reef





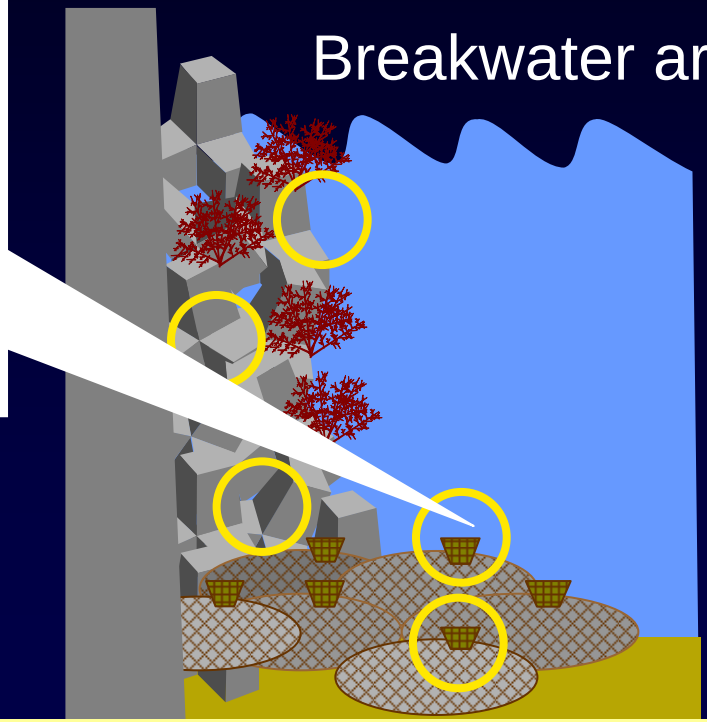
water area?

ater area like?

ell explained by **vegetation**.

xagrammos species

ferent vegetation



Steep slope and complex structure of tetrapods create heterogeneous environment in which **shallow and deep environment coexist**.

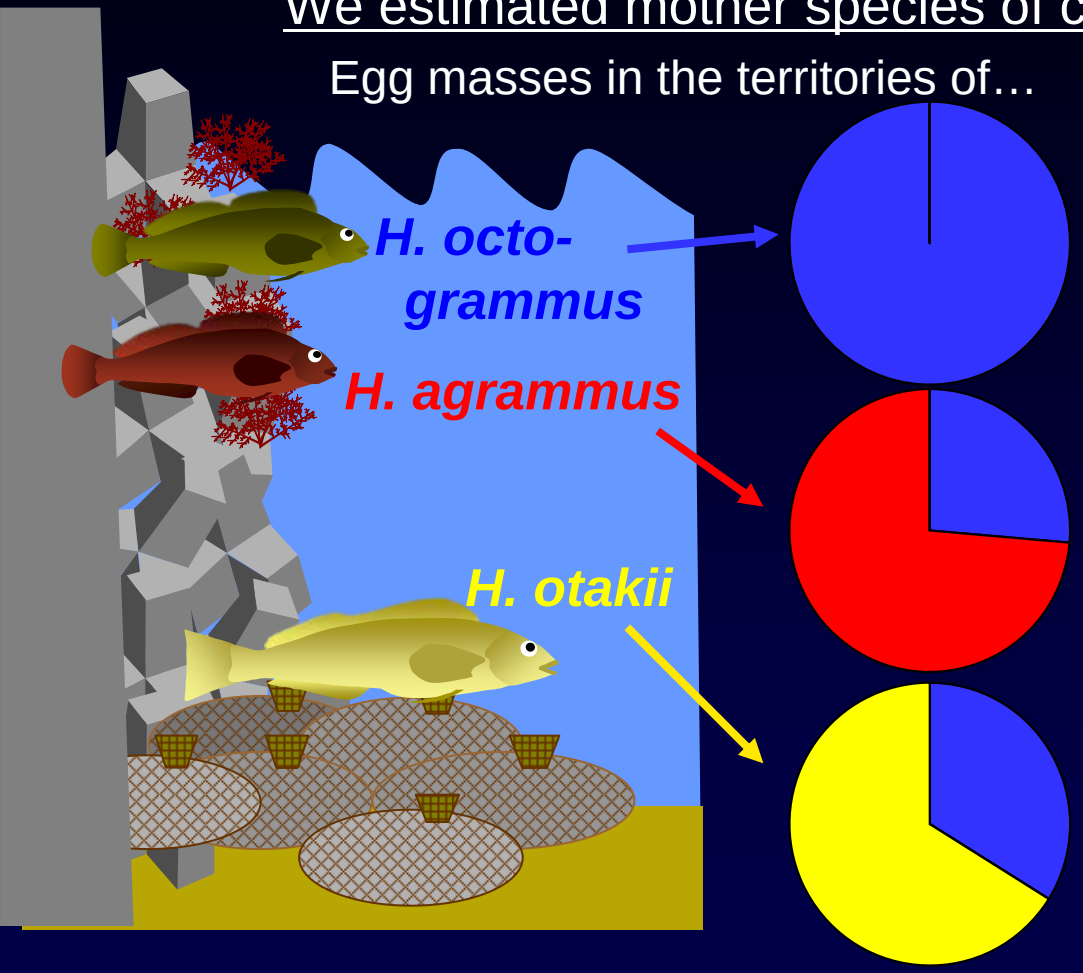
egg masses spawned on net knod

Hybridization occurred in Breakwater area

Male's breeding territories of three species were observed in Breakwater area.

We estimated mother species of cared egg masses with mtDNA.

Egg masses in the territories of…



mtDNA
(estimated female)
- *H. octogrammus*
- *H. agrammus*
- *H. otakii*

The territories of *H. agrammus* and *H. otakii* contained many egg masses probably spawned by *H. octogrammus* females.

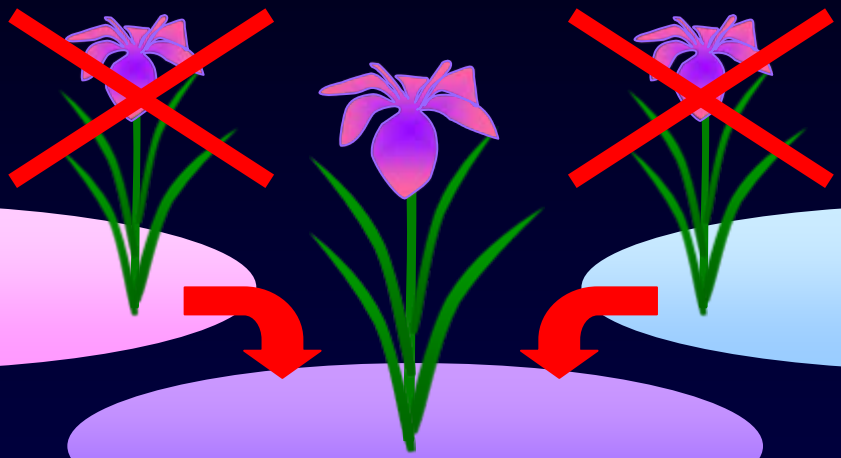
Unidirectional hybridization occurred in artificial habitat.

H. octogrammus and *H. otakii* are at a risk of human-caused hybridization by the breakdown of habitat isolation.

Mechanisms of breakdown of habitat isolation through habitat modification by human activity

● Hybridization of Habitat

Iris fulva



Iris hexagona

habitat A

habitat B

new intermediate habitat

● Habitat loss

Phoxinus tennesseensis

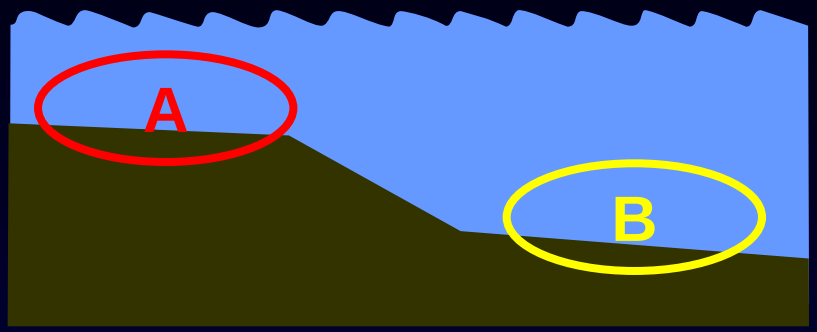
Semotilus atromaculatus

habitat A

habitat B

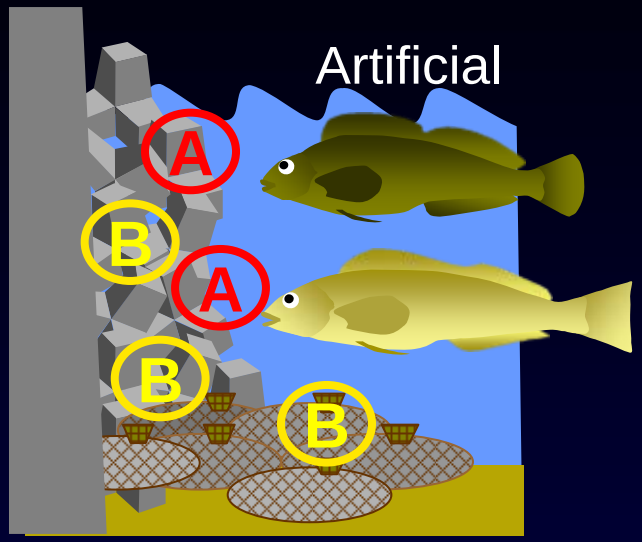
New breakdown mechanism “Habitat coexistence”

Natural



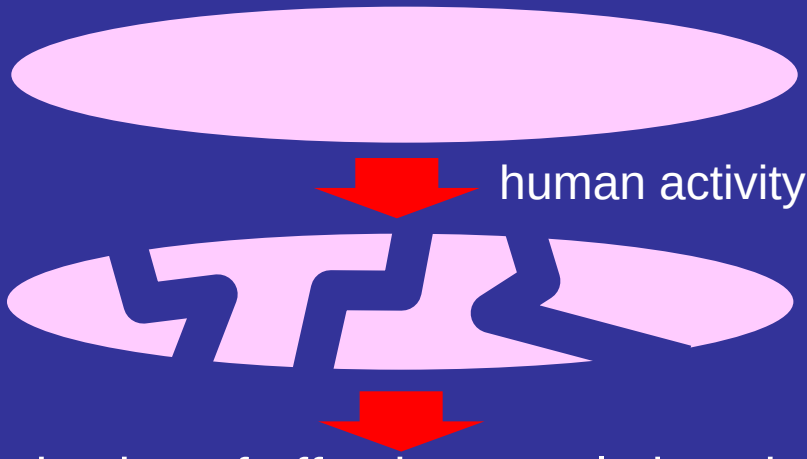
approximate heterogeneous environment

Artificial



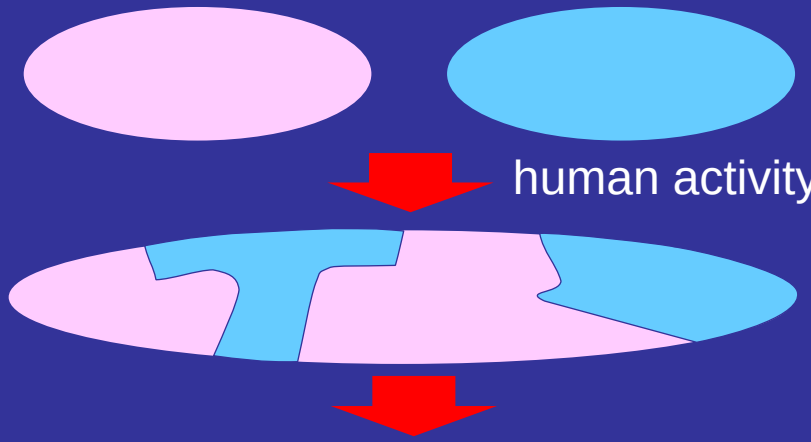
mosaic habitat

Habitat fragmentation



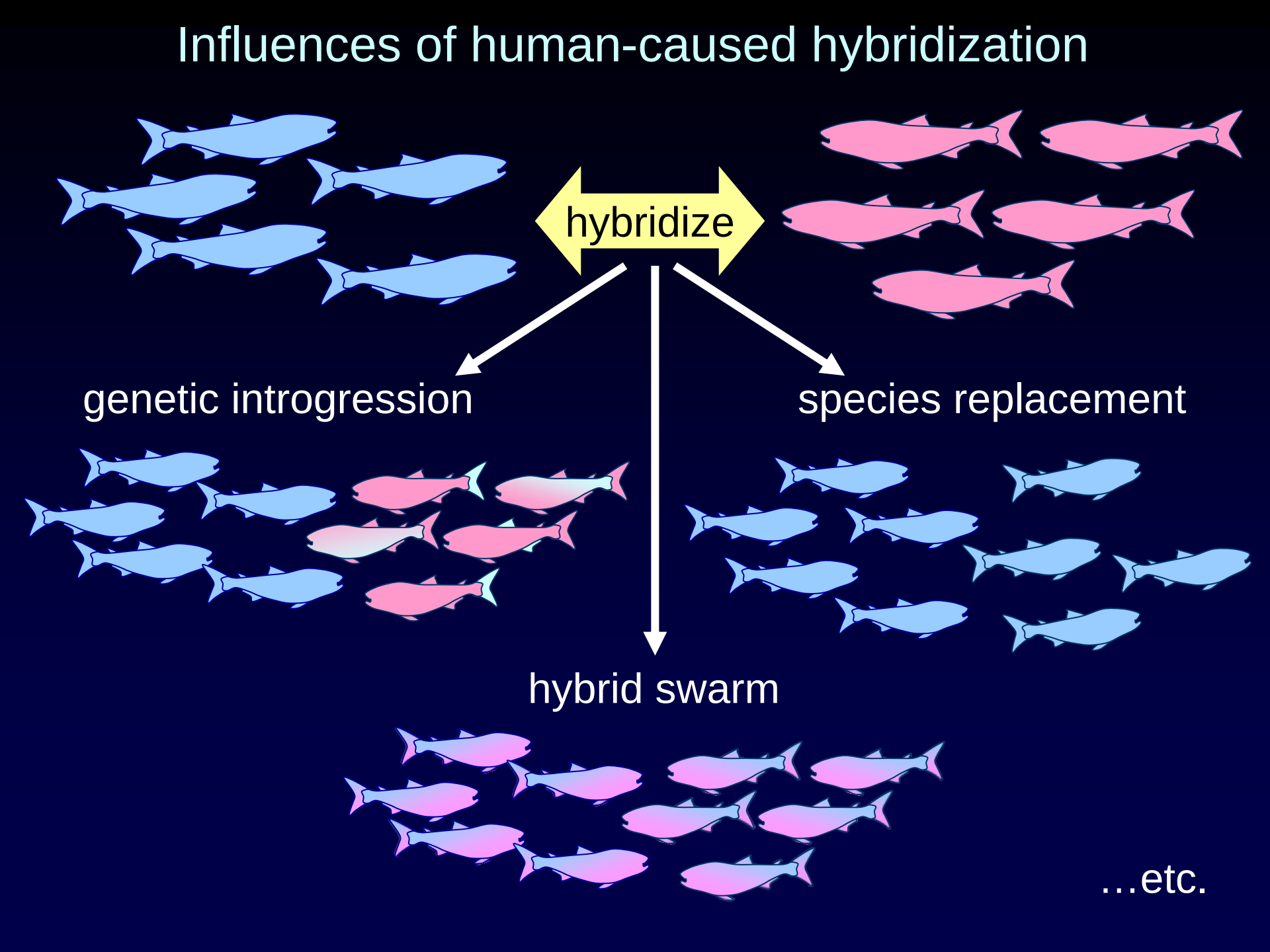
reduction of effective population size

Habitat coexistence



hybridization

Influences of human-caused hybridization



To quantify the influence of breakdown of habitat isolation by artificial habitat modifications…

We need to simulate the dynamics of genetic population structure within hybrid zone.

Further study requires …

- Frequency of annual hybridization
- Survival rate of hybrid offspring
- Proportion of genetic introgression
- Relation between a degree of habitat modification and a rate of hybridization

Thank you for your attention!

I could would like to acknowledge the people listed here.

- My supervisor, **Prof. Hiroyuki Munehara**
  for his continuous encouragement and consistent guidance
- **Prof. Yasunori Sakurai** & **Prof. Yutaka Watanuki**
  for their helpful discussions and valuable advice
- **Dr. Takashi Yanagimoto**
  for his invaluable technical support of DNA analysis
- identification of seaweed
  Prof. Yasui, Dr. Kawagoe
- identification of bryozoans
  Prof. Mawatari
- support of diving research
  Mr. Kiyoshi Nomura, Mrs. Yoko Uozumi, Mrs. Naomi Yamamoto
- our lab members for their helpful support and precious discussion
  Dr. Satoshi Awata, Dr. Yoko Iwata, Dr. Takuzo Abe, Noriko Nagai, Noriyoshi Sato, Sumiko Yasukochi, Tomoki Yahata, Yoshiki Tanaka, Toru Nakamura, Tomoyuki Futamura, Kotaro Terano