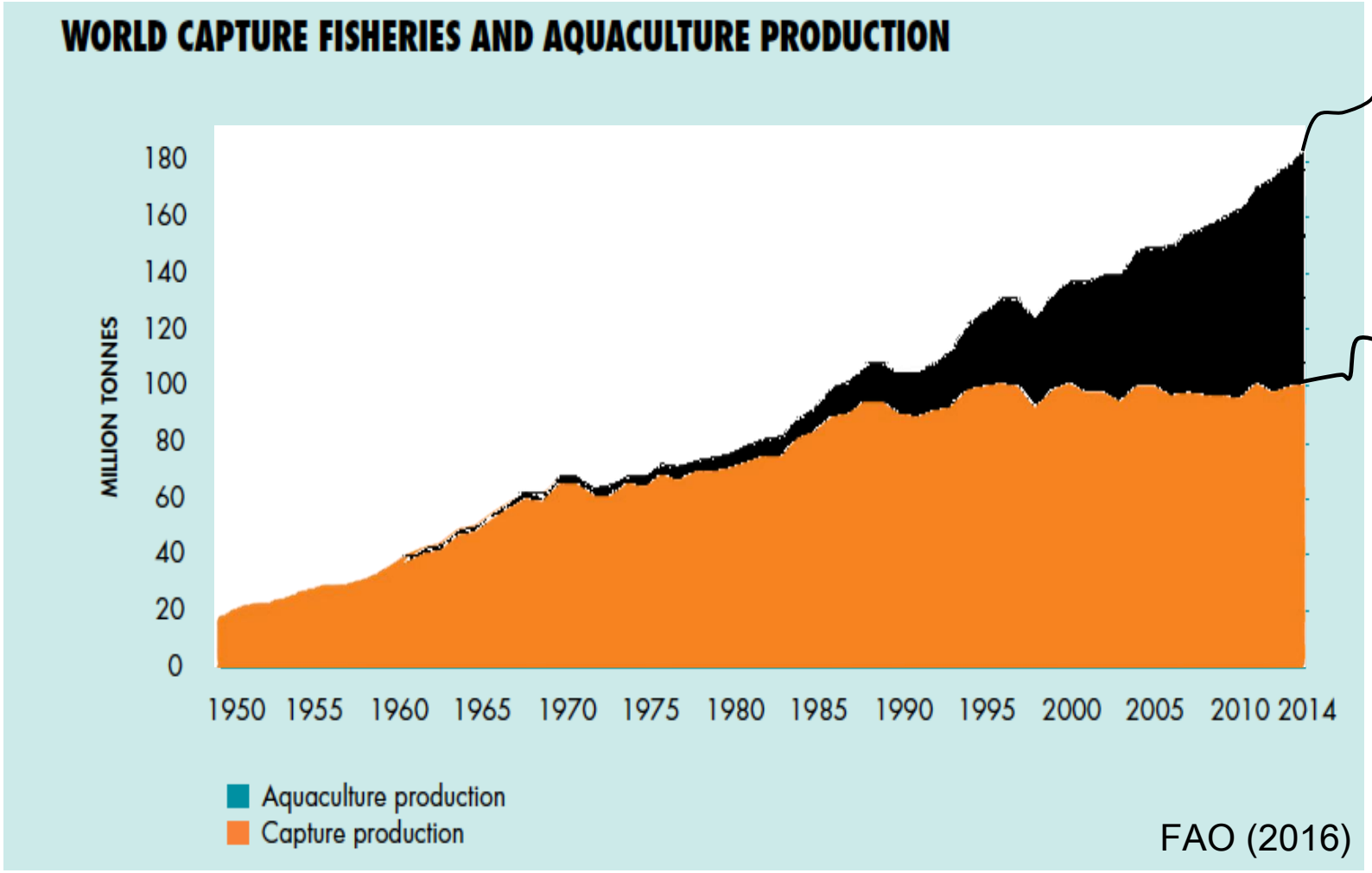
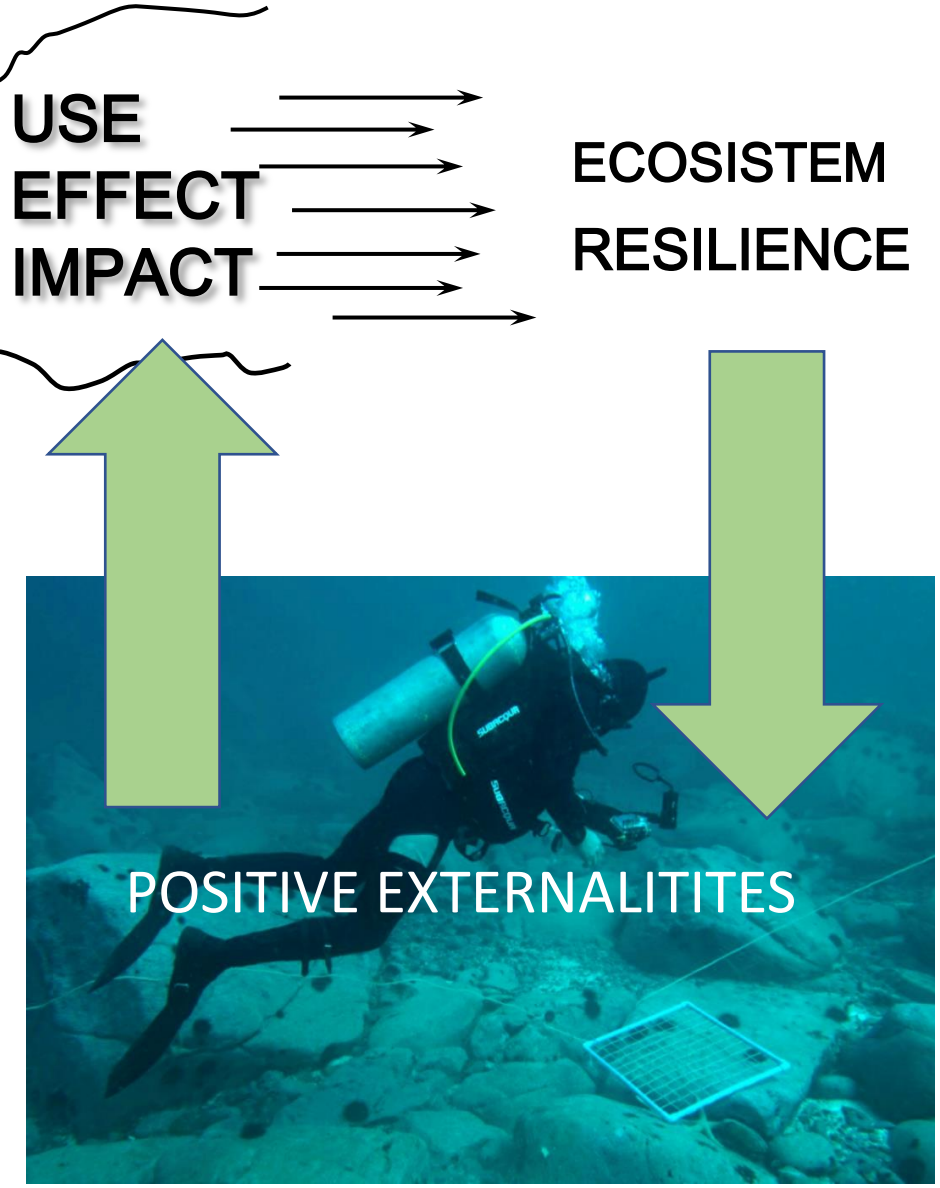
Emergent habitats and opportunities for stocking of targeted species

luis.henriquez@ifop.cl

DRC – IFOP


WORLD CAPTURE FISHERIES AND AQUACULTURE PRODUCTION
MILLION TONNES
180
160
140
120
100
80
60
40
20
0
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2014
Aquaculture production
Capture production

FAO (2016)

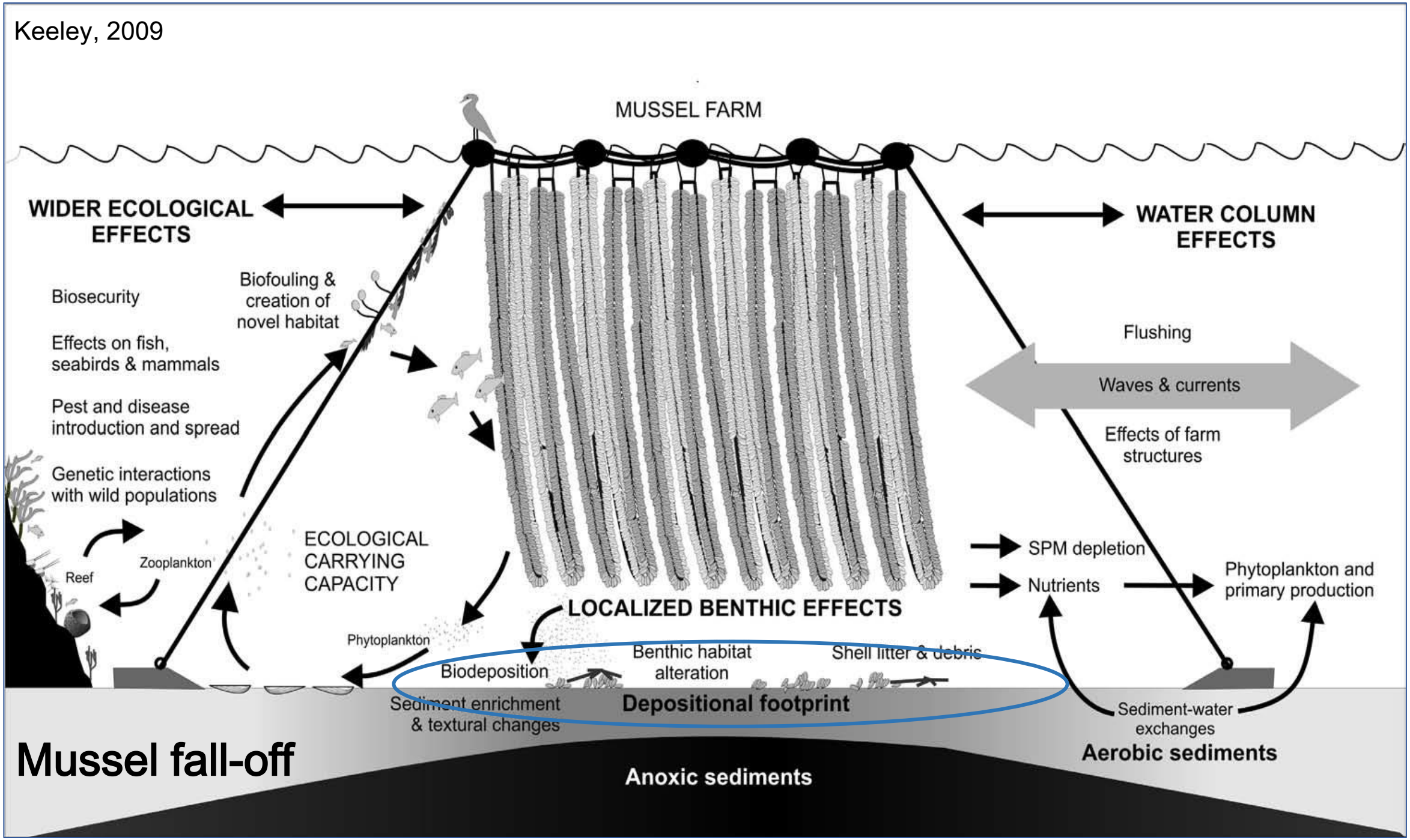

USE
EFFECT
IMPACT
ECOSISTEM
RESILIENCE
POSITIVE EXTERNALITITES

CHILE,
Top producer of mussels

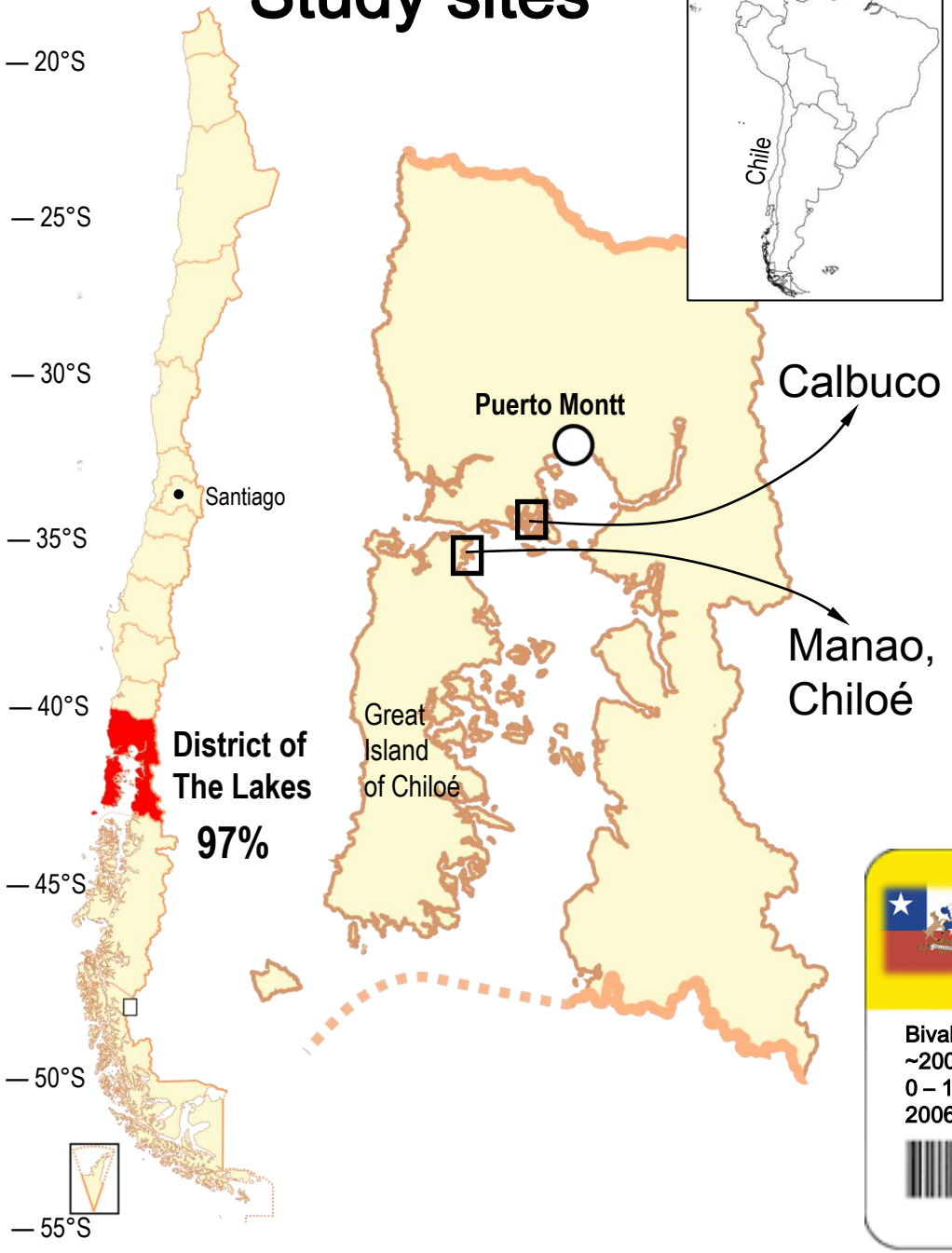

Achao, Chiloé


Quellón, Chiloé

Keeley, 2009


MUSSEL FARM
WIDER ECOLOGICAL EFFECTS
WATER COLUMN EFFECTS
Biosecurity
Biofouling & creation of novel habitat
Effects on fish, seabirds & mammals
Pest and disease introduction and spread
Genetic interactions with wild populations
Flushing
Waves & currents
Effects of farm structures
Reef
Zooplankton
ECOLOGICAL CARRYING CAPACITY
SPM depletion
Nutrients
Phytoplankton and primary production
LOCALIZED BENTHIC EFFECTS
Phytoplankton
Biodeposition
Benthic habitat alteration
Shell litter & debris
Sediment enrichment & textural changes
Depositional footprint
Sediment-water exchanges
Aerobic sediments
Anoxic sediments
Mussel fall-off

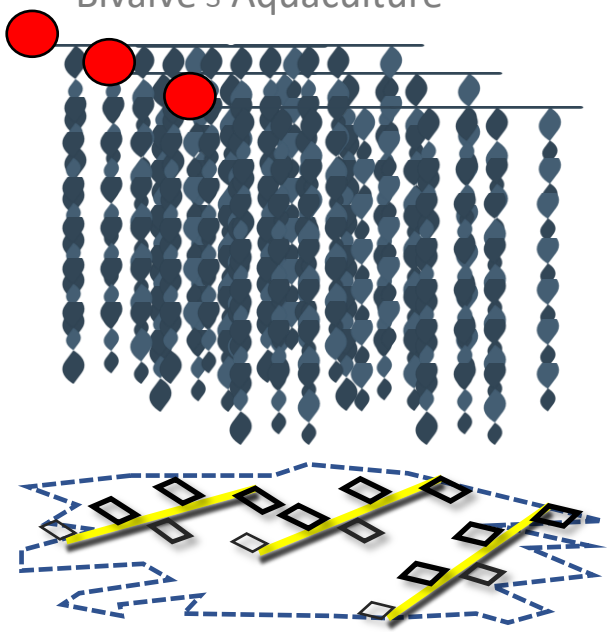
Study sites



Sampling layout

2 sites Small-Scale

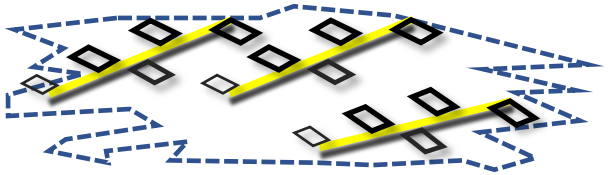
Bivalve's Aquaculture



X 2

2 reference sites

~200 m culture facilities



X 2

Experiment layout

- Treatment: beneath aquaculture facilities vs. “Reference” sites
- 3 replicated 30m transects/ five quadrats

Community structure

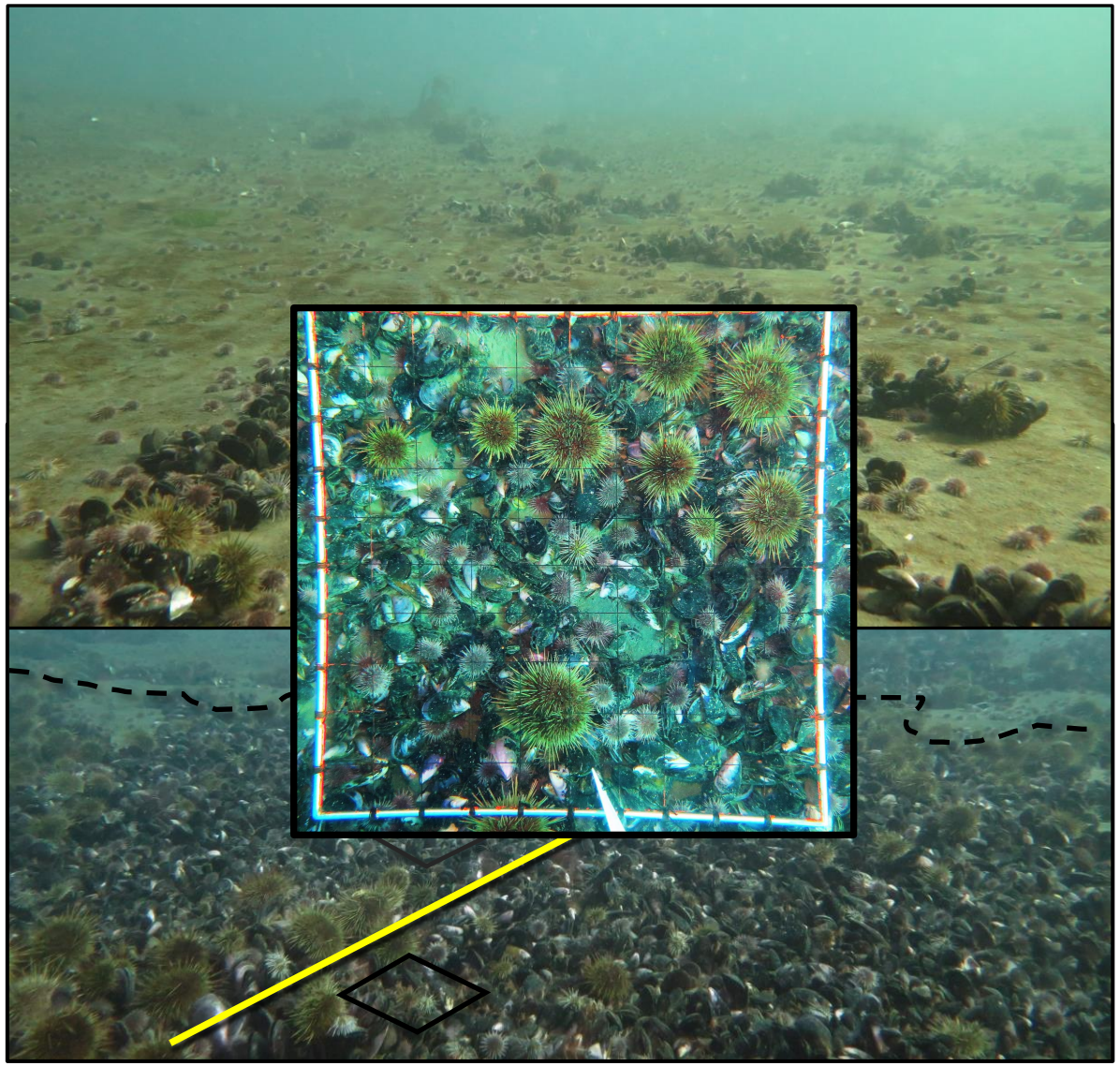
- Primary/ secondary substrate composition - % of cover
- Sessile invertebrates - % of cover
- Macroalgae - % of cover
- Mobile invertebrates – number
- ID of all benthic species

Biodiversity indicators

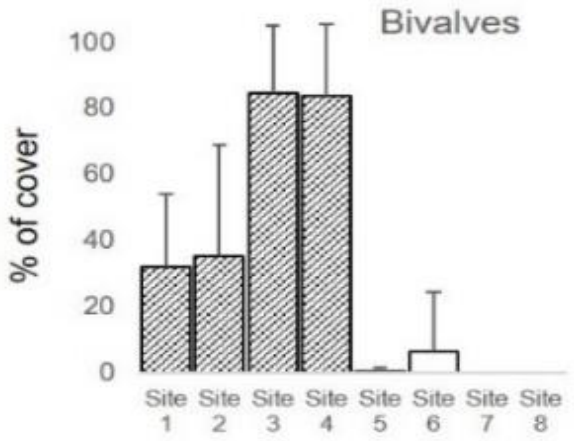
- Richness
- Evenness

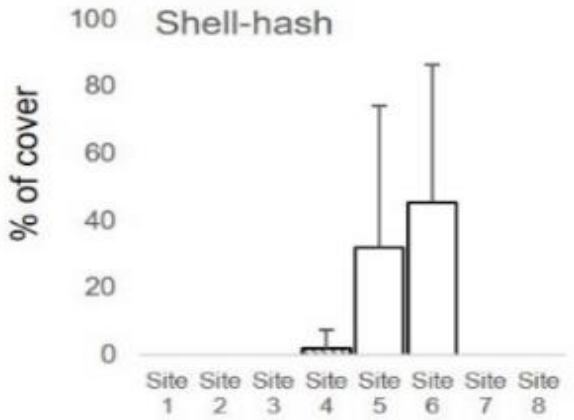
Community structure patterns: Principal Component Ordination (PCO).
Location vs. dispersion effects hypothesis: PERMANOVA and PERMDISP

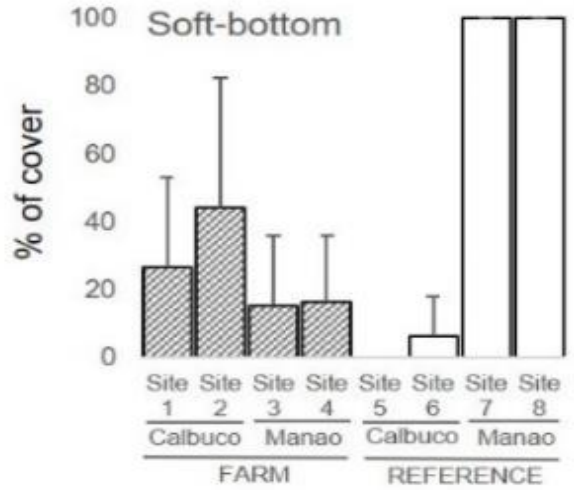
Treatment → Under the culture vs outside the culture (Fixed)
Sites(Treatment) (Random)
Error (i.e., quads.)
Hypothesis tests on univariate data (Biodiversity indicators) with GLM

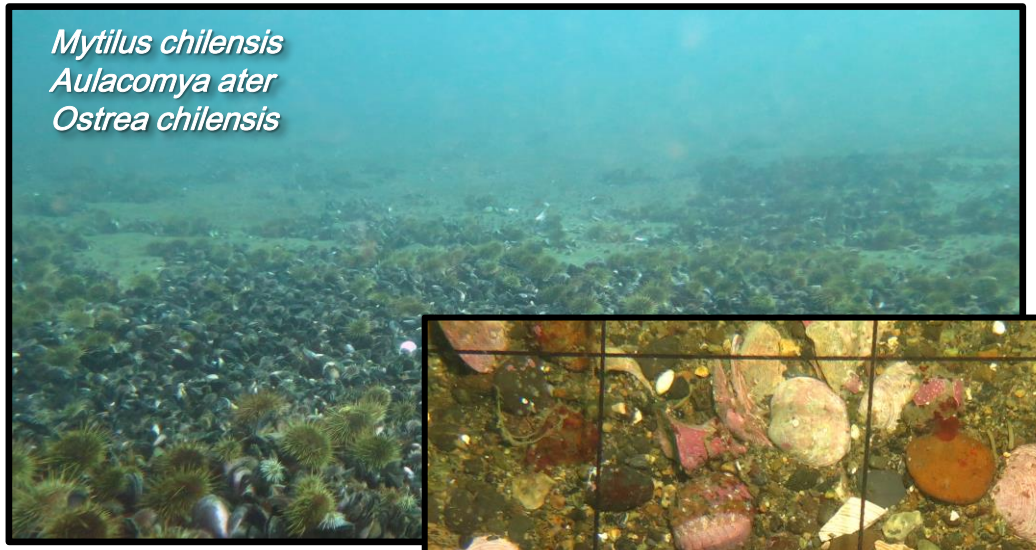


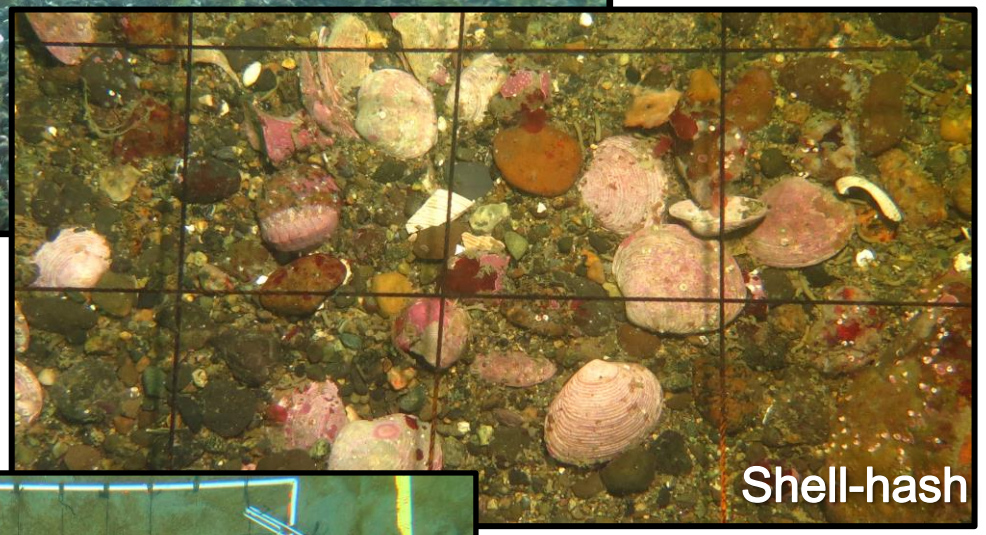
Bottom composition

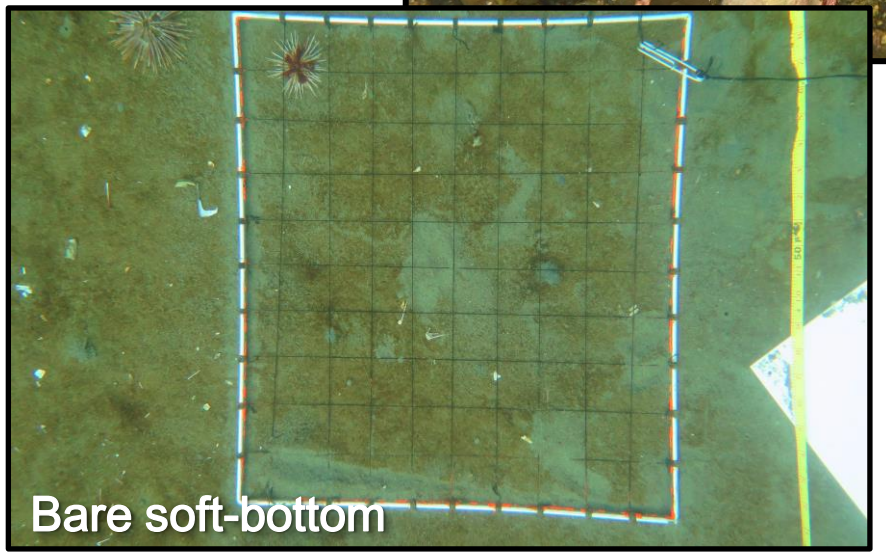




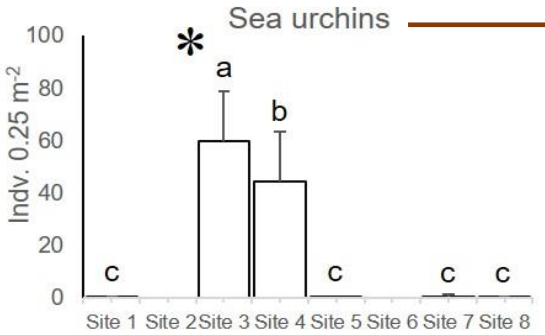


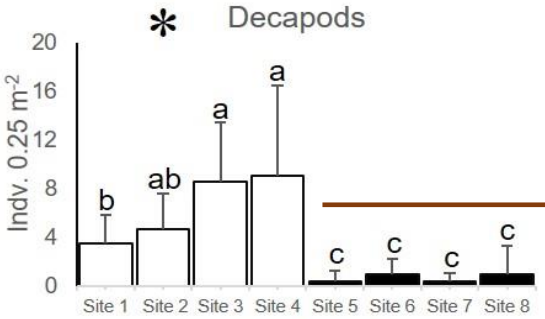


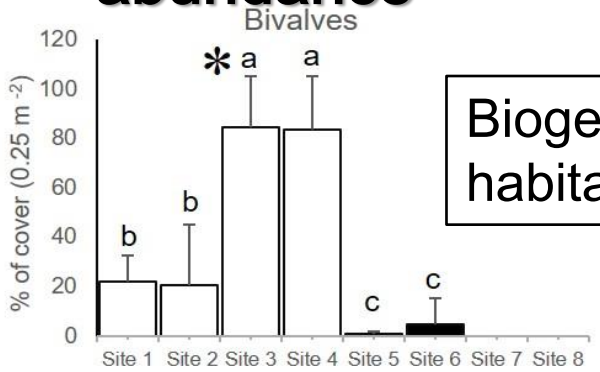




Invertebrates and Macrophytes abundance



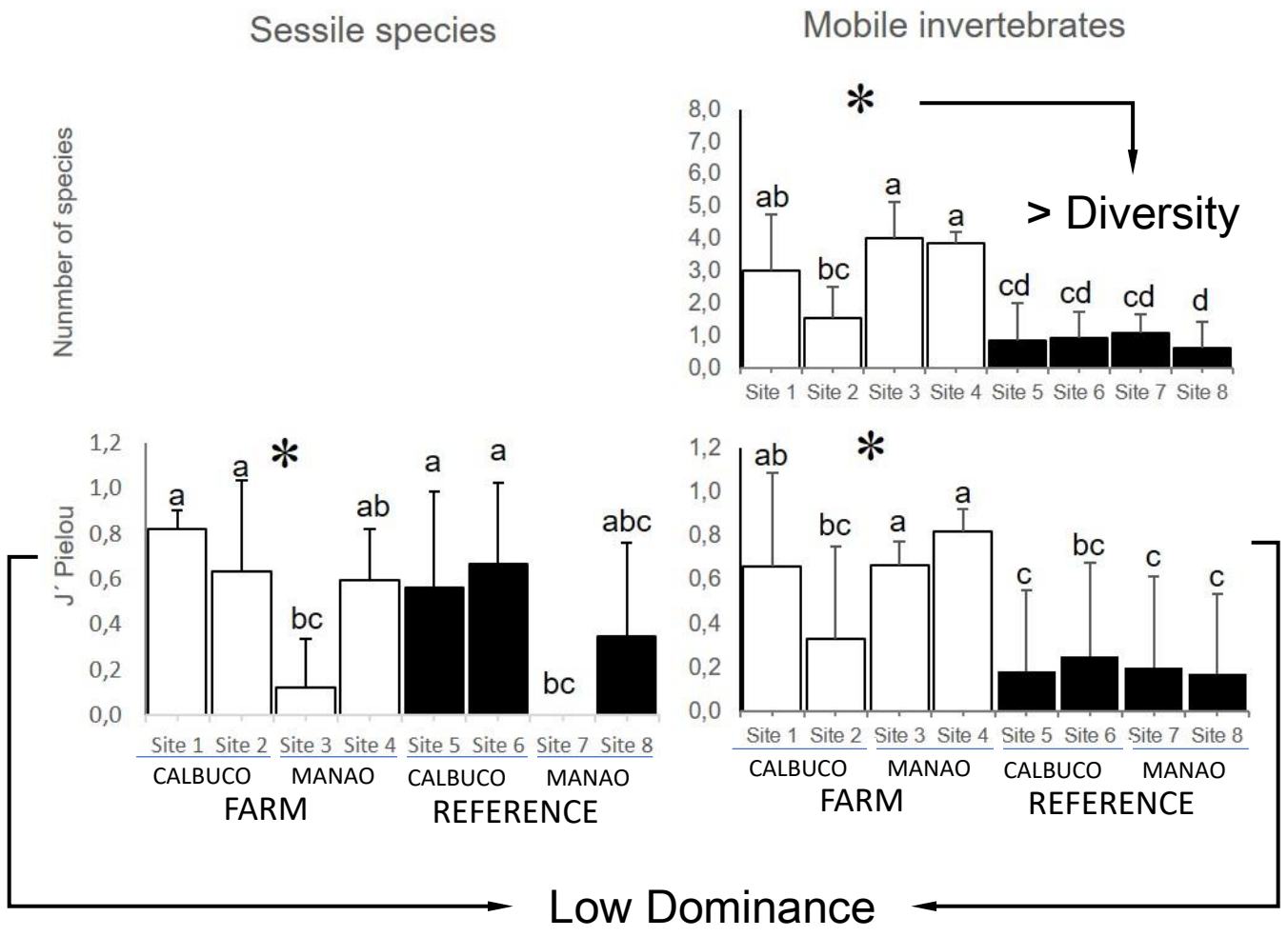




Biogenic habitat

"Generalists"

Richness and Dominance



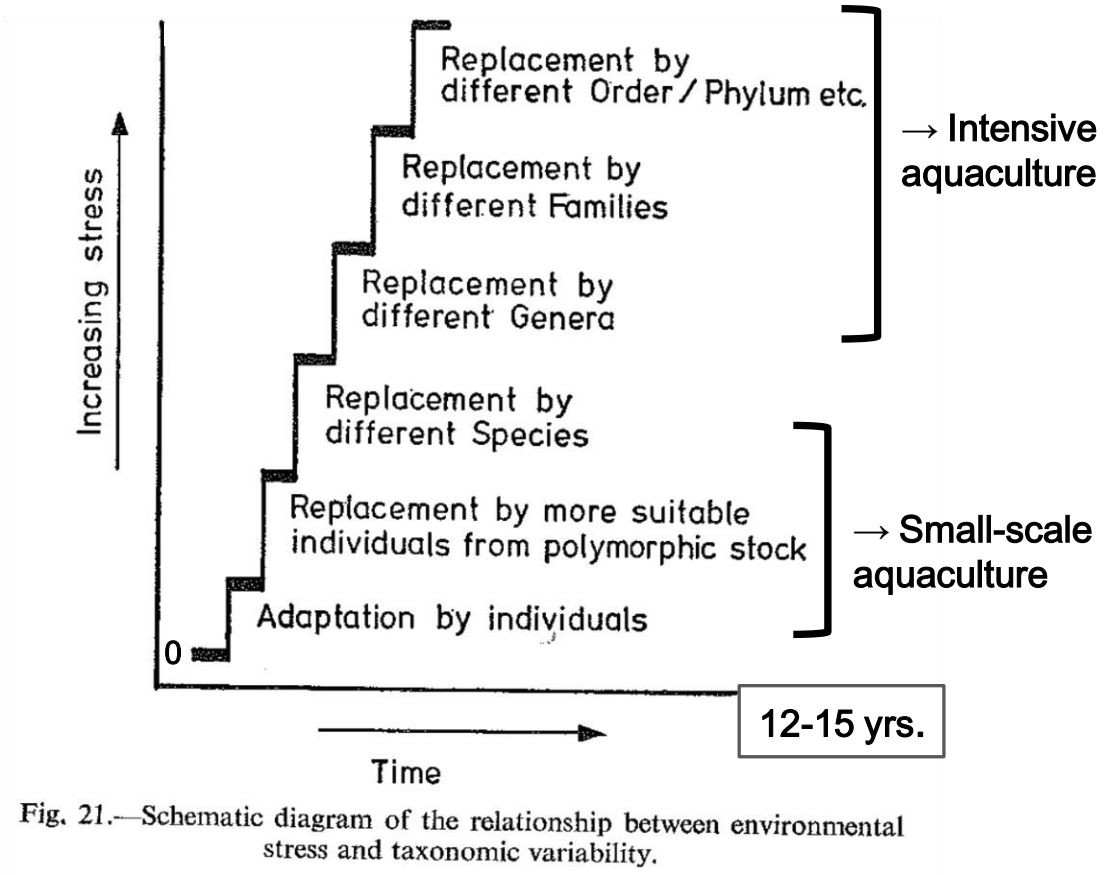


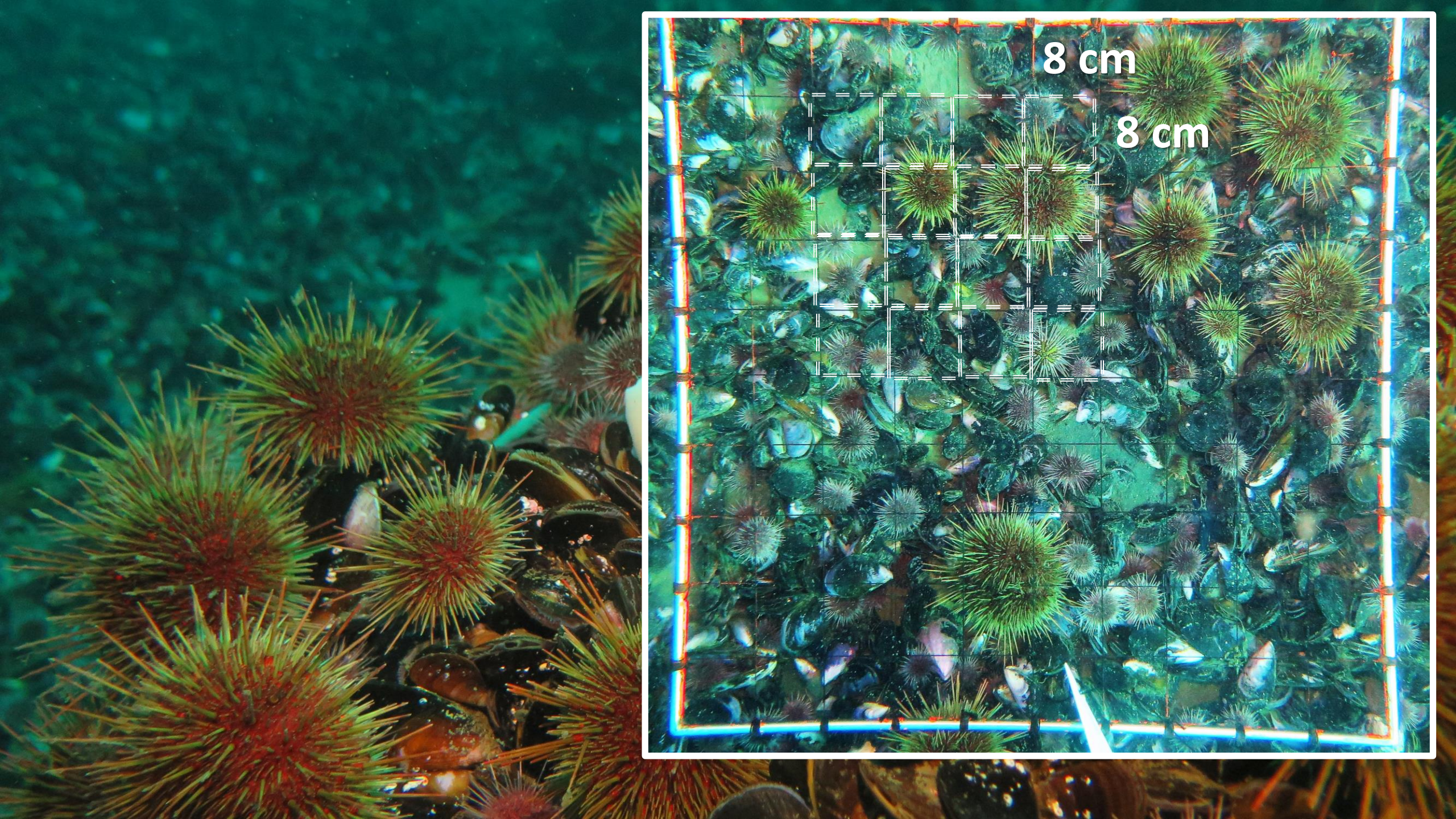
Fig. 21.—Schematic diagram of the relationship between environmental stress and taxonomic variability.

Pearson & Rosenberg (1978)

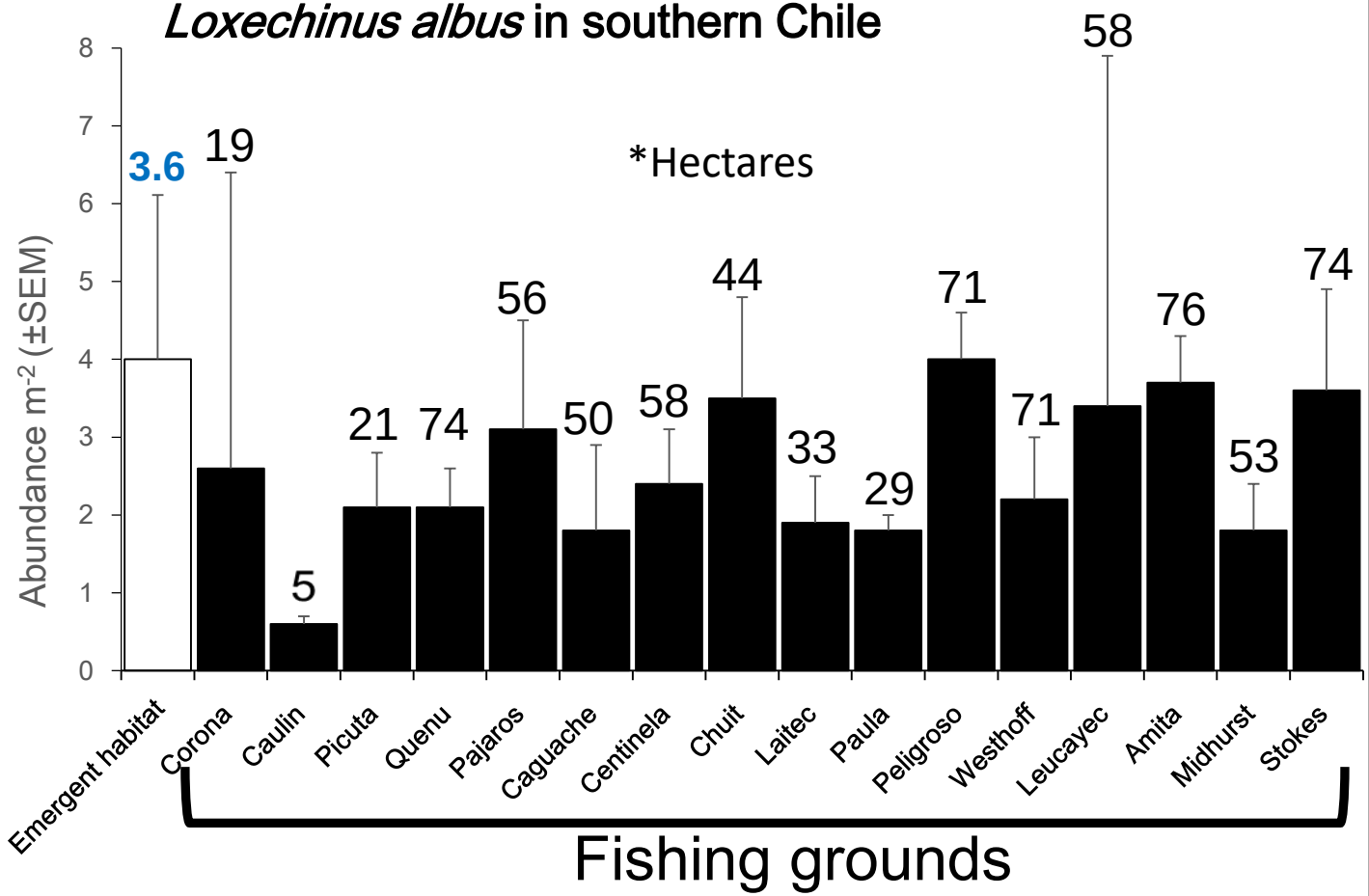
SIMPER Analysis	Taxon	Phyllum	**Ecological function**	Similarity Contribution (%)	Mean abundance (0.25 m^{-2})
Mobile/individual invertebrates					
FARM	*Munida subrugosa*	*Crustacea*	**P-DF**	57.64	4.36
Mean similarity	*Arbacia dufresnii*	*Echinodermata*	**O**	15.4	0.78
28.76%	*Pseudechinus magellanicus*	*Echinodermata*	**O**	15.03	0.61
	Loxechinus albus	*Echinodermata*	**H**	3.78	0.27
REFERENCE	*Chaetopterus pedicelatus*	*Annelida*	**SF SS**	35.83	0.19
Mean similarity	*Arbacia dufresnii*	*Echinodermata*	**O**	19.98	0.03
6.59%	*Ganeria flaklandica*	*Echinodermata*	**P**	17.95	0.15
	Munida subrugosa	*Crustacea*	**P DF**	11.02	0.09
	Anthothoe Chilensis	*Cnidaria*	**SF**	4.99	0.09
	Venus antiqua	*Mollusca*	**SF SD**	4.09	0.07
Agreggated/ colonial species					
FARM	*Mytilus chilensis*	*Mollusca*	**HF SF**	**74.42**	5.74
Mean similarity	*Aulacomya ater*	*Mollusca*	**HF SF**	**13.53**	1.79
42.13%	*Halichondria prostata*	*Porifera*	**HF SF**	**5.25**	1.18
REFERENCE	*Halichondria prostata*	*Porifera*	**HF SF**	44.82	0.89
Mean similarity	*Leucatis nuda*	*Porifera*	**HF SF**	24.42	0.36
5.42%	*Didemnum studeri*	*Chordata*	**SF**	18.35	0.56
Sessile/ colonial invertebrates (*)					
FARM	*M. pyrifera*	*Heterokontophyta*	**HF SS**	**38.98**	1.61
Mean similarity	*Halichondria prostata*	*Porifera*	**HF SF**	**34.51**	1.18
9.84%	*Leucatis nuda*	*Porifera*	**HF SF**	**14.53**	0.69
	Pyura chilensis	*Chordata*	**SF**	3.98	0.44
REFERENCE	*Chaetopterus pedicelatus*	*Annelida*	**SF SS**	45.87	0.75
Mean similarity	*Leftofauchea chiloensis*	*Rhodophyta*	—	17.02	0.72
9.60%	*Halichondria prostata*	*Porifera*	**HF SF**	15.31	0.89
	M. pyrifera	*Heterokontophyta*	**HF SS**	6.74	0.59
	Didemnum studeri	*Chordata*	**SF**	5.77	0.56

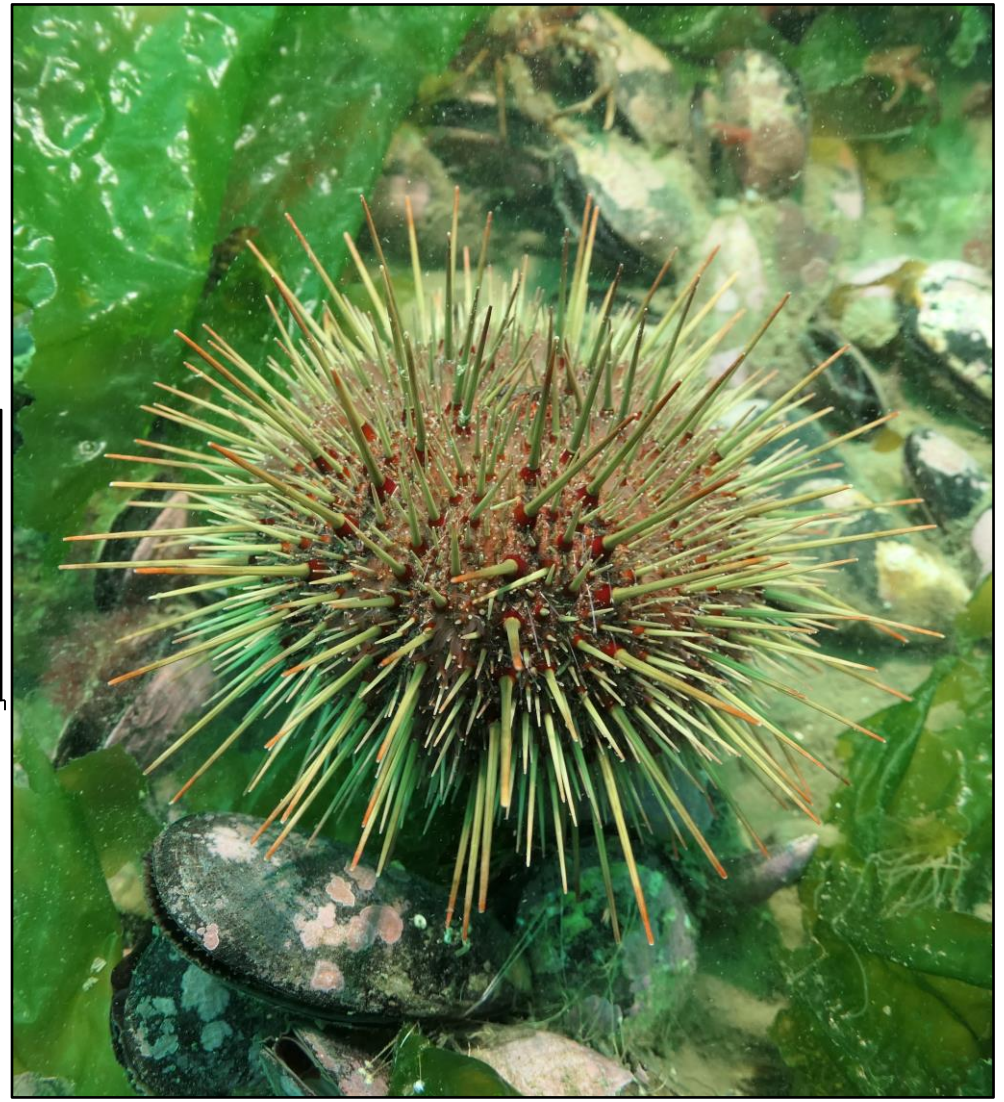
Ecological Function Characterization

P: Predator
DF: Deposit feeder
O: Omnivore
H: Herbivore
SF: Suspension Feeder
SS: Sediment Stabiliser
SD: Substrate destabiliser
HF: Habitat-forming


8 cm
8 cm

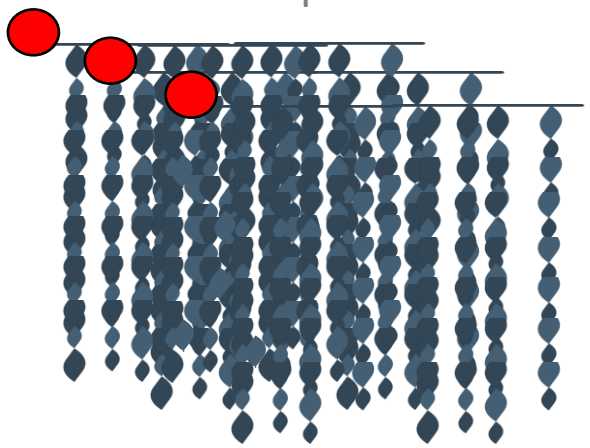
Open access fishing grounds vs Emergent habitat for *Loxechinus albus* in southern Chile

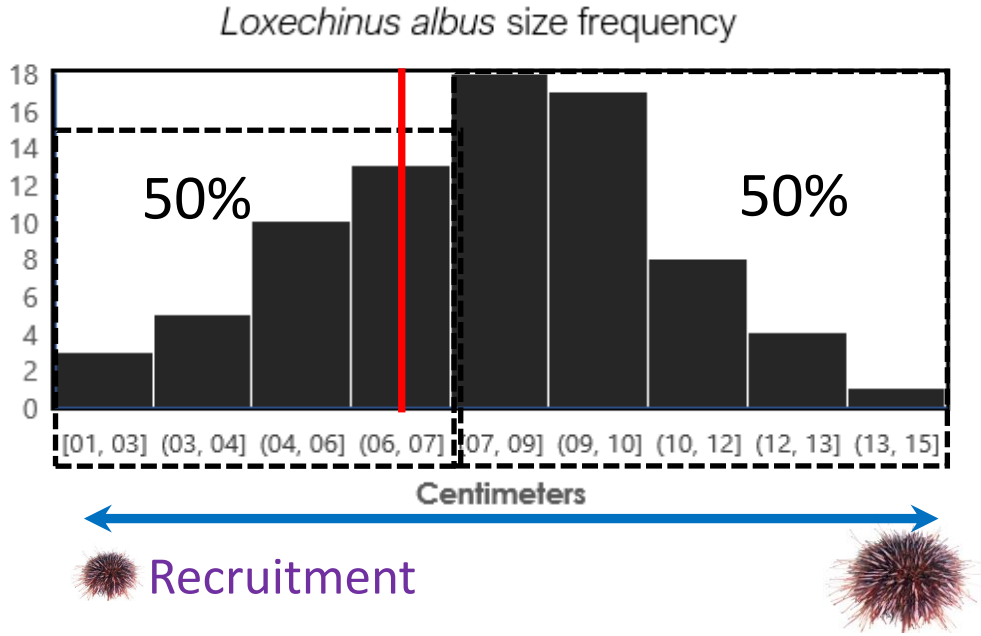




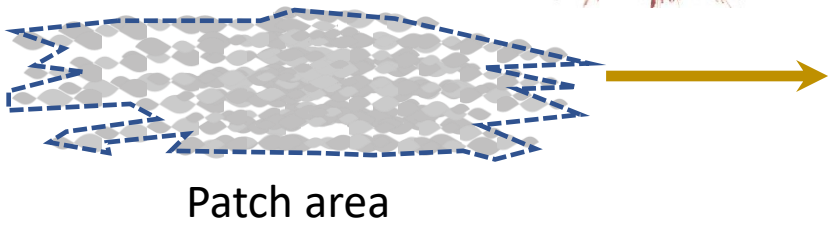
MANAO Small-Scale

Bivalve's Aquaculture



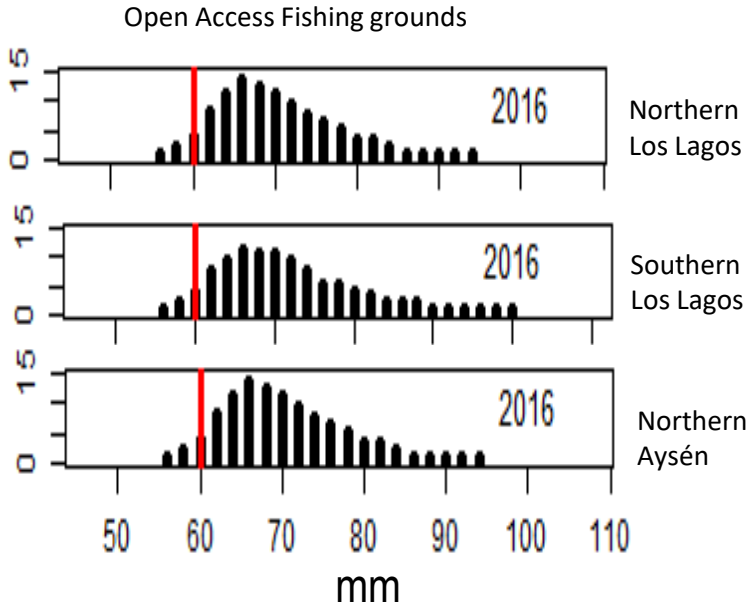


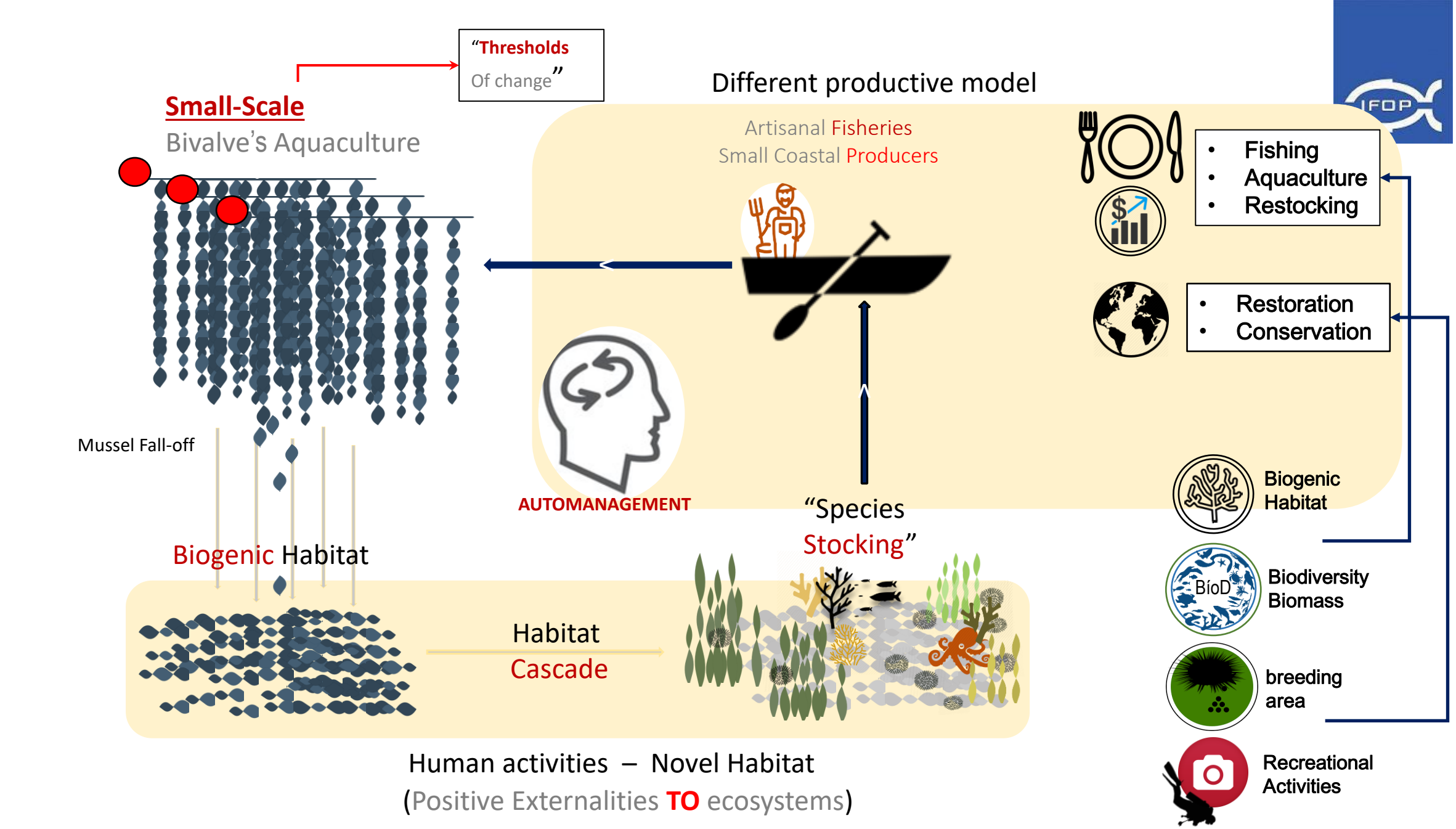
Loxechinus Albus $$$$



Patch area

- 3.6 ha
- All size classes
- ~272,000 seaurchins
- U$ 14,000 (100%)
- ~163,452 (60%)
- U$ 8,400 (60%)




"Thresholds
Of change"
Small-Scale
Bivalve's Aquaculture
Different productive model
Artisanal Fisheries
Small Coastal Producers
Fishing
Aquaculture
Restocking
Restoration
Conservation
Mussel Fall-off
AUTOMANAGEMENT
"Species
Stocking"
Biogenic Habitat
Habitat
Cascade
Biogenic
Habitat
BíoD
Biodiversity
Biomass
breeding
area
Recreational
Activities
Human activities – Novel Habitat
(Positive Externalities TO ecosystems)

Emerging habitats produced from aquaculture

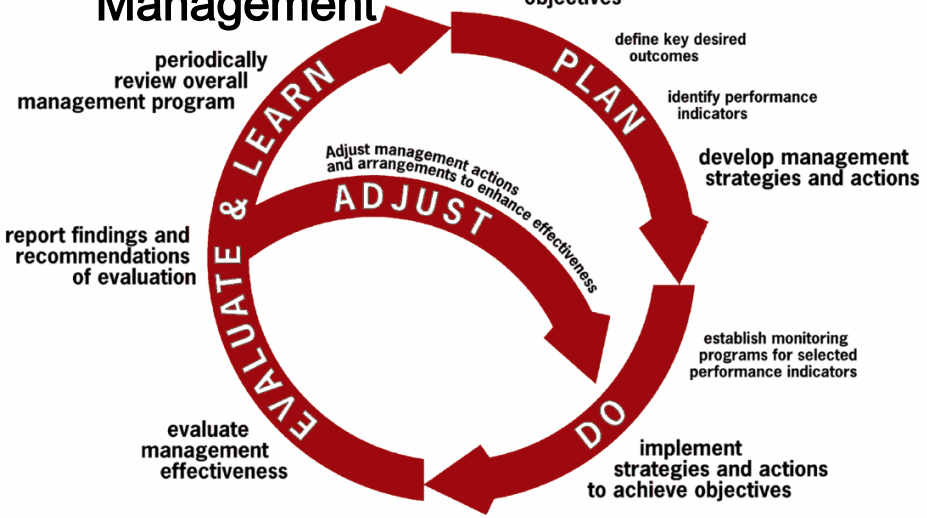
Emerging productive model for aquaculture

Agriculture

Small-Scale Aquaculture

Income diversification

Adaptive Management (Wardrop, 2016)



Novel Policies

Final Remarks

- SSBA can trigger HABITAT CASCADES promoting NOVEL HABITAT, this produces positive externalities for ecosystem and humans
- Stocking of targeted spp. can AID LOCAL FISHERIES
- REDUCED SIZE of farms is KEY to not ruin the ecosystem functionality
- Site-specific CURRENT REGIMES are KEY to avoid negative effects
- AUTOMANAGEMENT is KEY for farmers
- Novel habitats will require NOVEL LOCAL REGULATIONS not shaped by large-scale processes

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Services to ecosystem promoted by small-scale aquaculture of bivalves and emergent socio-ecological implications

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Morphology and density of mussels on natural and aquaculture structure habitats: implications for sea duck predators

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Patches of the mussel *Mytilus* sp. are islands of high biodiversity in subtidal sediment habitats in the Baltic Sea

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Contribution of mussel fall-off from aquaculture to wild lobster *Homarus americanus* diets

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