



Macroalgae cultivation in Korea/Asia with emphasis on emerging technology trends

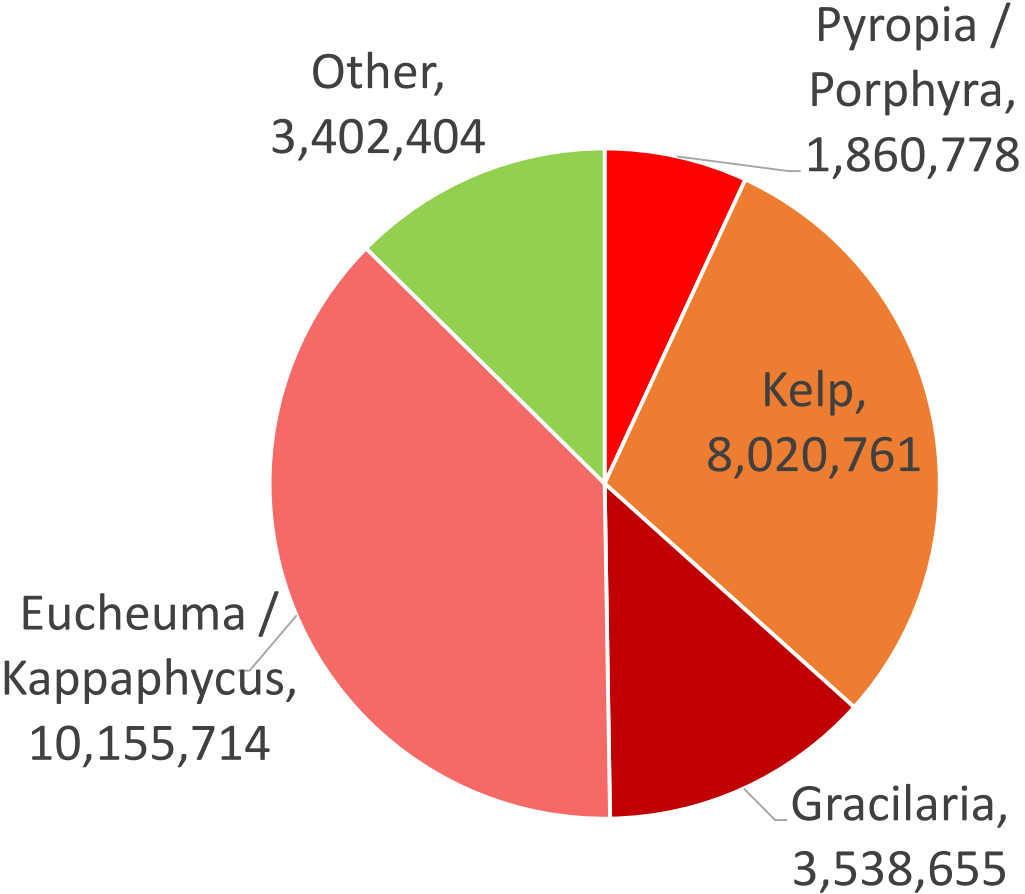
**Jang K. Kim^{1,2}, Miseon Park³, Youngdae Kim³, Byunghwa Min³, Eun
Kyoung Hwang³, Il Ki Hwang³, Eun-Jeong Park³, Hyun il Yoo³, Taejun
Han¹, Chang-Hoon Kim⁴ and Charles Yarish²**

¹Incheon National University, Korea; ²University of Connecticut, USA

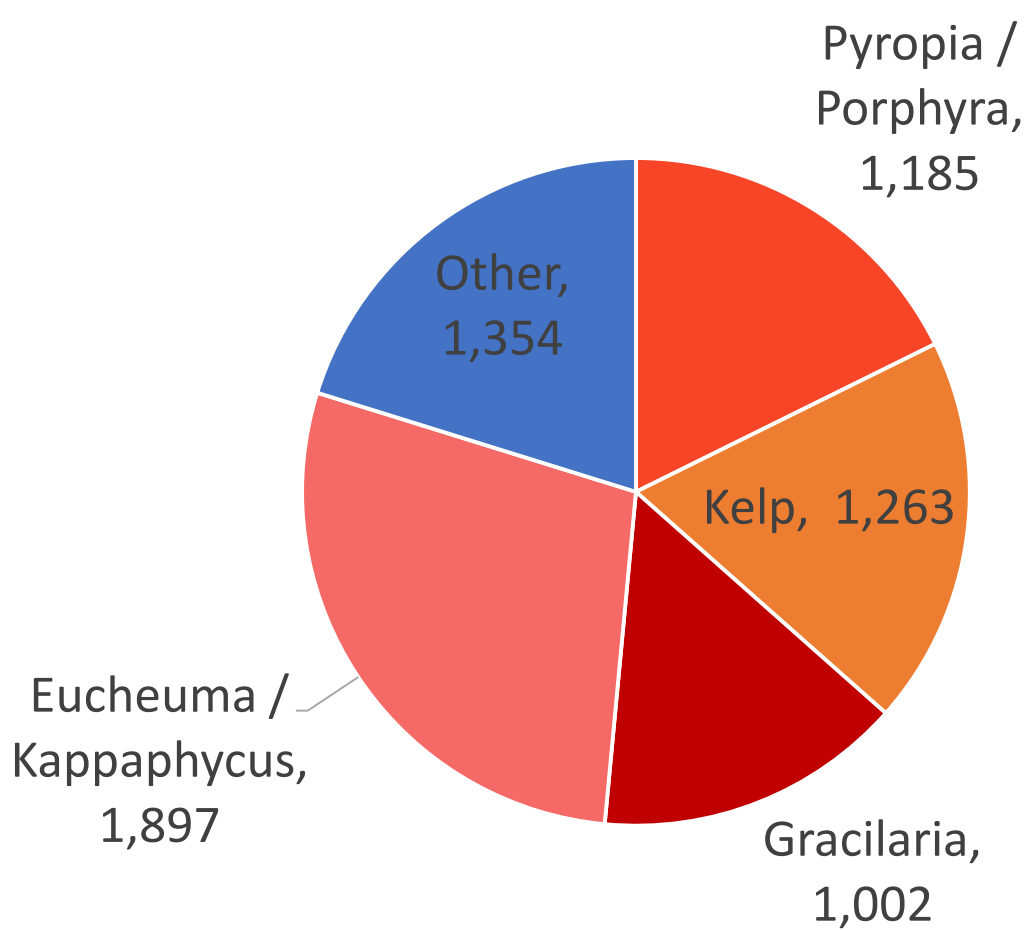
³National Institute of Fisheries Science, Korea; ⁴Pukyong National University

(Photo: NASA)

Global Seaweed Production (MT) by Species (2013)

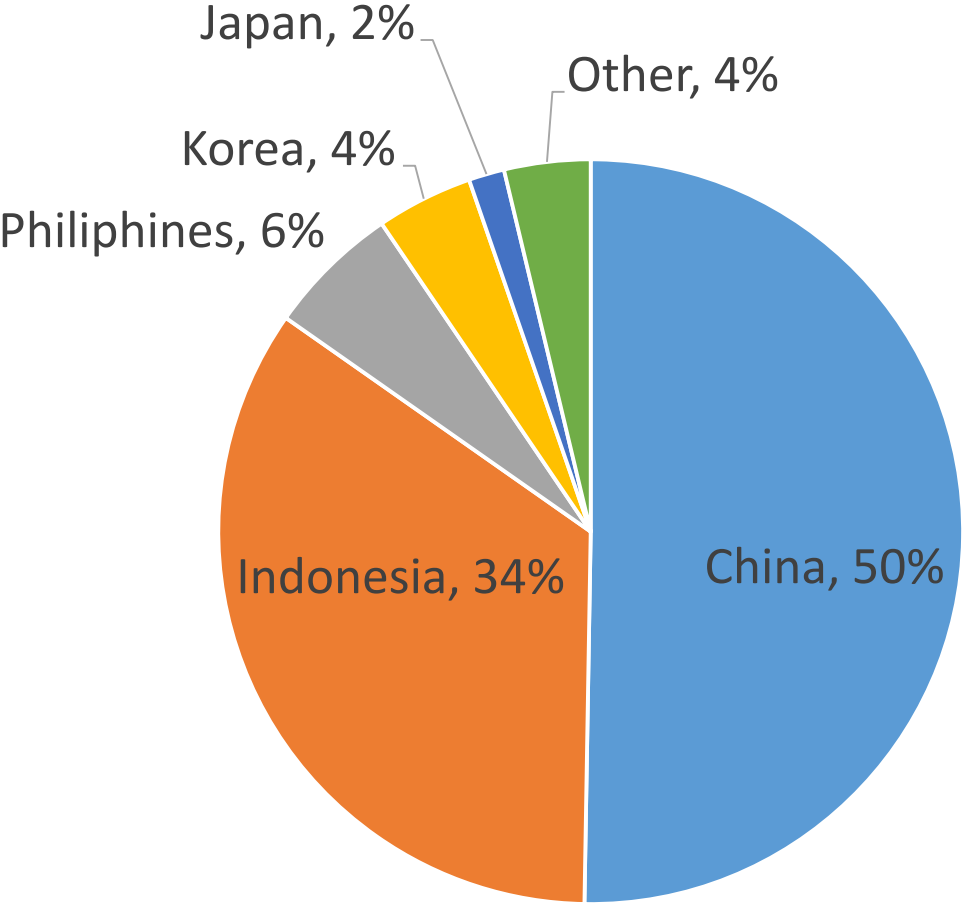


Economic Value (million dollar) by Species (2013)

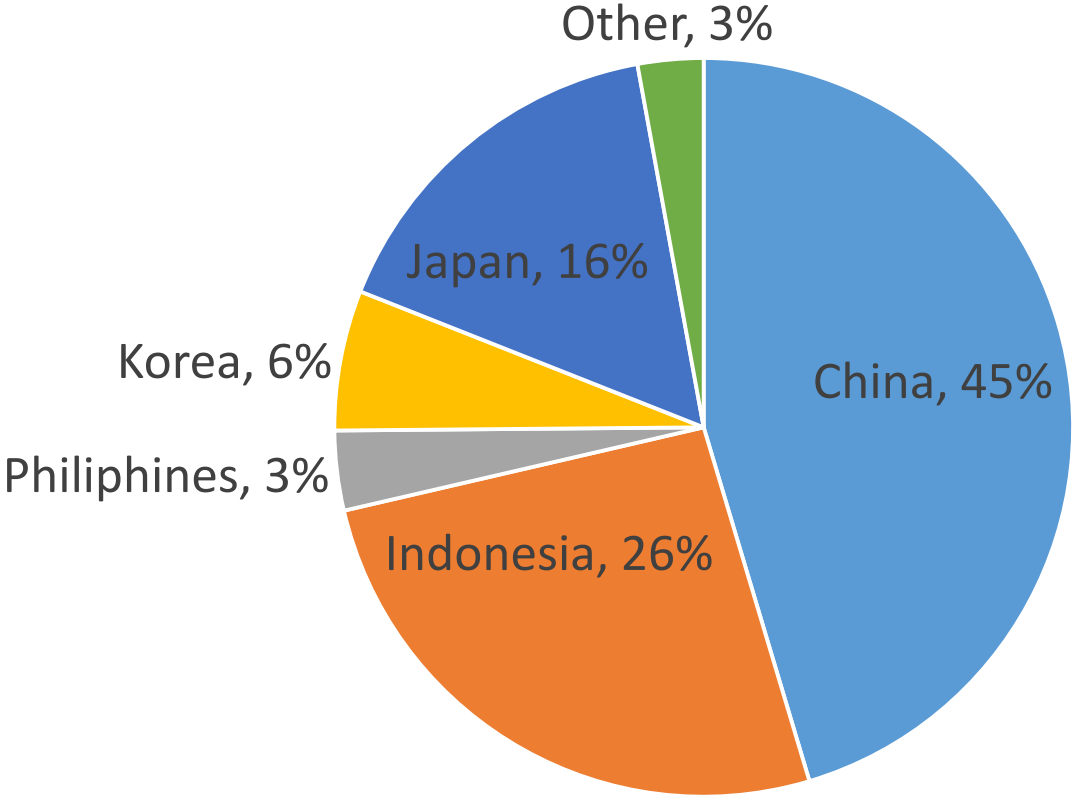


(FAO 2016)

Global Seaweed Production (MT) by Country (2013)



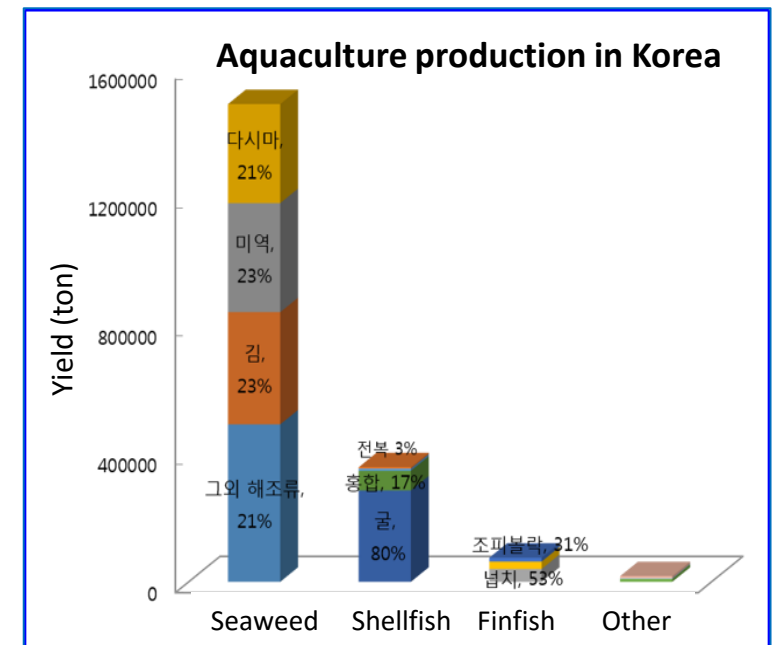
Economic Value (\$) by Country (2013)



(FAO 2016)

Seaweed Aquaculture in Korea

- Seaweed species reported in Korea: 753 (98 green, 166 brown, and 489 red) (Lee & Kang, 2002)
- The 4th country with the most seaweed production (FAO 2016)
- Exported >\$340 million (34,470 MT) in 2014 (105% increase in comparison to 2010)
- >70% of total aquaculture production in Korea



Seaweed Aquaculture in Korea

	Production (MT)	Economic value (\$)
<i>Pyropia / Porphyra</i> (Gim)	419,024	269,447,654
<i>Saccharina / Laminaria</i>	372,311	67,515,494
<i>Undaria</i>	283,714	58,614,306
Other	30,449	26,177,014
Total	1,105,498	421,754,469

(Ministry of Oceans and Fisheries, 2015)

Seaweed Aquaculture in Korea (*Pyropia*/*Porphyra*, Gim)



(Photo: NFRDI Seaweed Research Center)

Kelp species in Korea



Saccharina japonica



Kjellmaniella crassifolia



Costaria costata



Agarum cribrosum



Undaria pinnatifida



Ecklonia cava



Ecklonia kurome

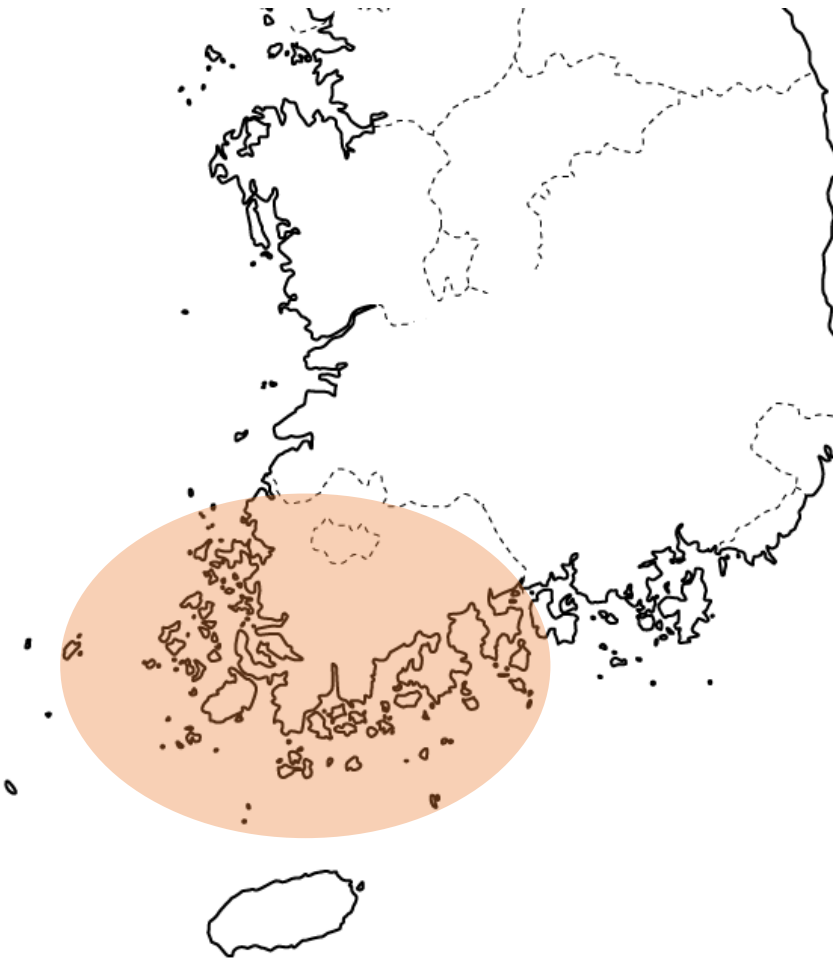


Ecklonia stolonifera

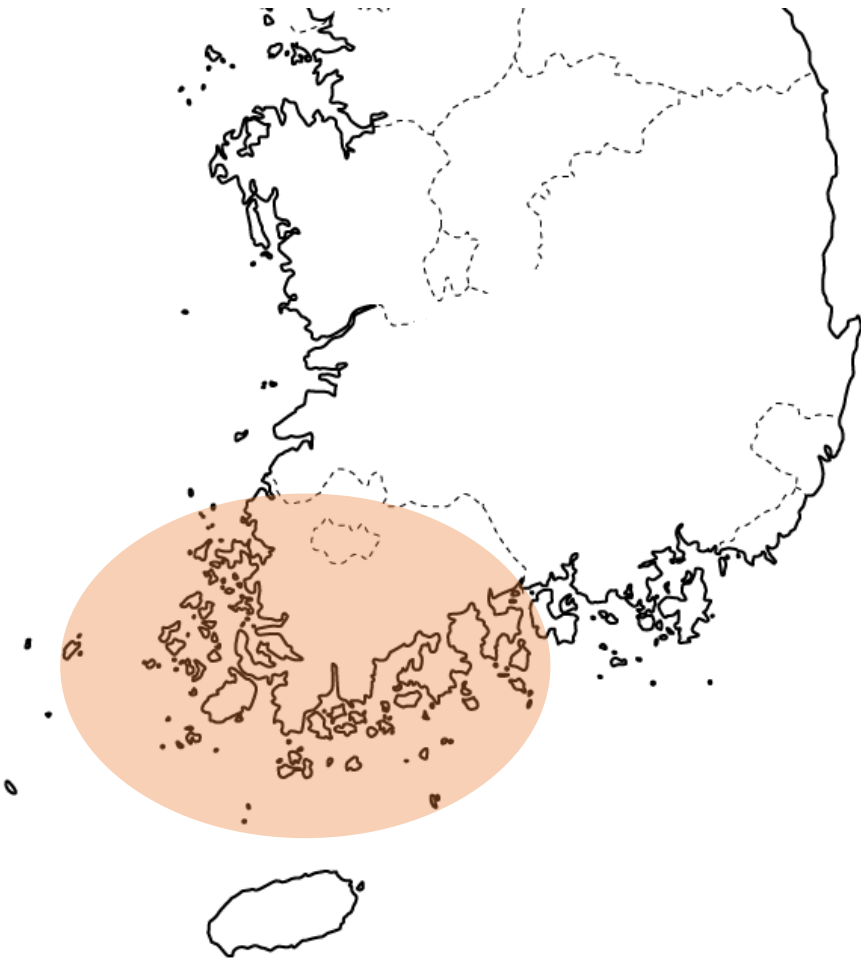


Eisenia bicyclis

Kelp aquaculture in Korea (*Undaria pinnatifida*)



Kelp aquaculture in Korea (*Saccharina japonica*)



Yield: 24 – 45 kg m⁻¹

Selective Breeding

- Desirable strain development
- Fast growth
- Preferable morphology and flavor
- Disease and temperature tolerant strains



Selective Breeding

Pyropia / Porphyra

- ▶ 1950s: Strain/species selections
- ▶ 1962: *Pyropia tenera*
- ▶ 1967: *Pyropia yezoensis*
- ▶ 1980s ~ 1990s: intra-species selective breeding, color mutants
- ▶ 1990s: Inter-species selective breeding, protoplast fusion



Undaria



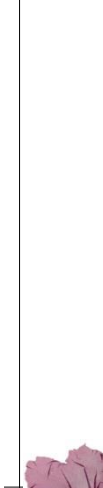
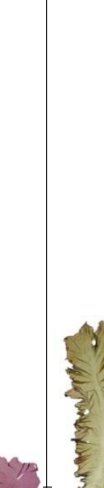
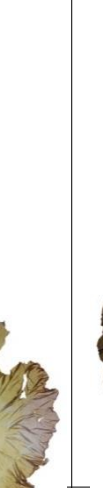









- ▶ 1970s: Strain selections (fast growth, large blade)
- ▶ Male and female gametophyte clone cultures 📌 selective breeding

Saccharina / Laminaria

- ▶ 1960s: Strain selections
- ▶ 1970s - : Gametophyte clone cultures
 - Intra-species selective breeding, X-ray treatment
 - Radiation treatment 📌 mutant

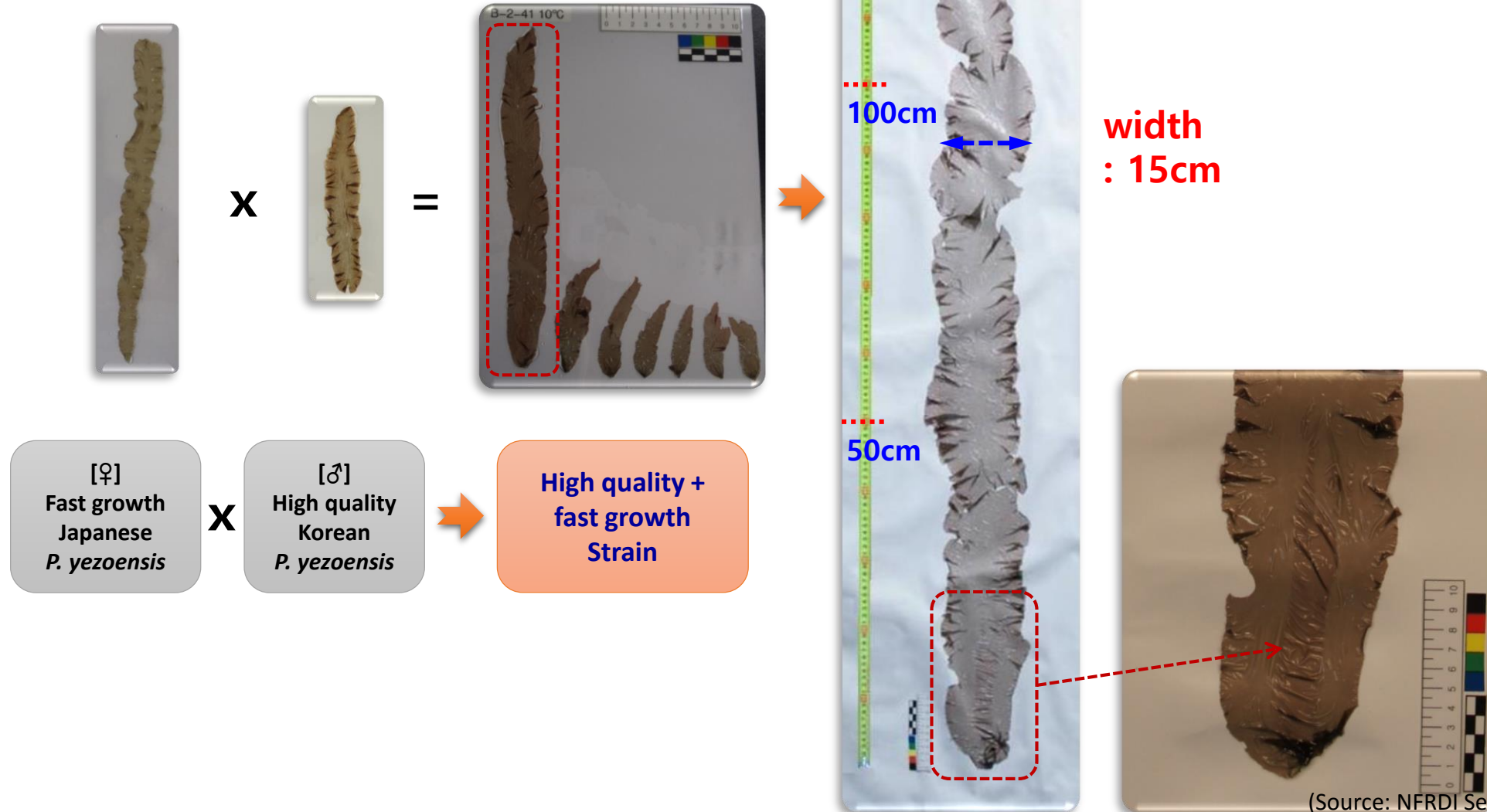


Pyropia / Porphyra Strains

	New strain selection (pure line)							Hybridization	Mutation Breeding					
Species	<i>Pyropia tenera</i>			<i>Pyropia yezoensis</i>										
품종명	수과원 101호	수과원 102호	수과원 103호	수과원 104호	수과원 105호	수과원 106호	수과원 107호 (잇바디)	전수 1호	속성장 교잡체	속성장 방사무늬김	속성장 방사무늬김	고온내성 방사무늬김		
Morph														
Character	Mutant (narrow)	Mutant (green)	Mutant (red)	Fast growth (60.5cm, 36cm)	Fast growth (63.3cm, 17cm)	Fast growth	Fast growth	Anti-oxidant	Fast growth (124cm, 15cm)	Fast growth (mutant) (185cm, 9.5cm)	Fast growth (mutant) (181cm, 7.8cm)	(high temp. mutant) (48cm, 6.2cm)		
	2012	2012	2012	2013	2014	2015	2015	2015	-	2016	2016	2016		

Hybridization

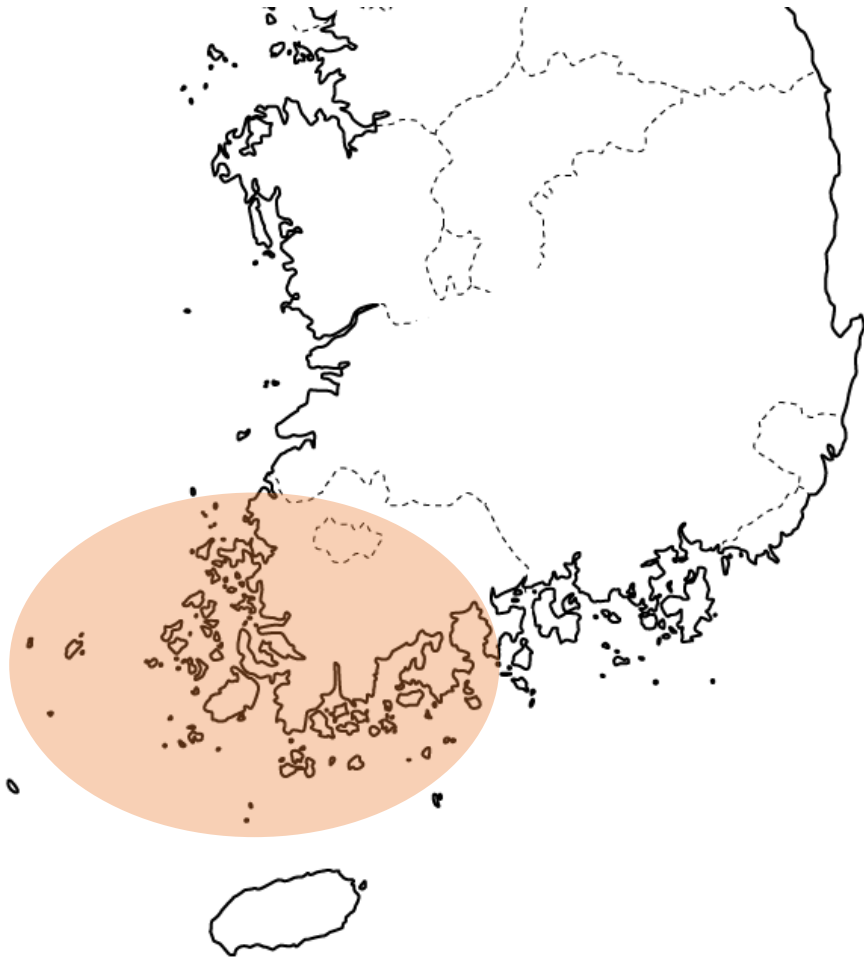
Fast growth – high quality *P. yezoensis* strain



Selective Breeding (*Undaria pinnatifida*)



Selective Breeding (*Saccharina japonica*)



(Photo: NFRDI Seaweed Research Center)

Selective Breeding (Kelp)

- 98% of the kelp culture overlaps the abalone culture
- Abalone feed

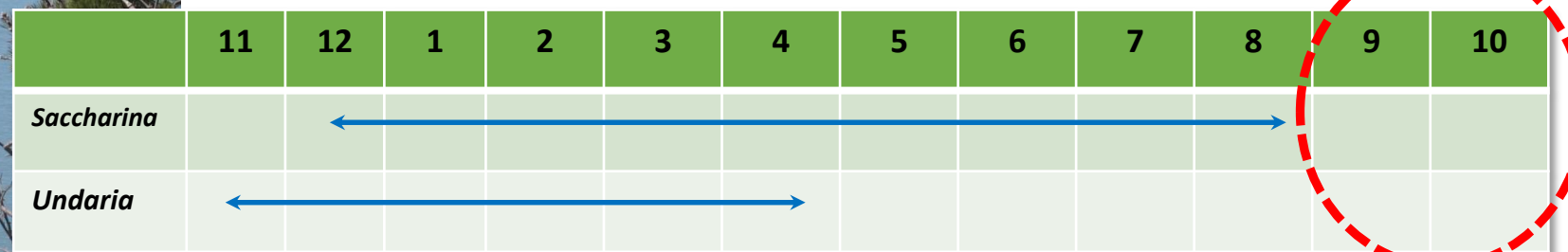


Selective Breeding (Kelp)



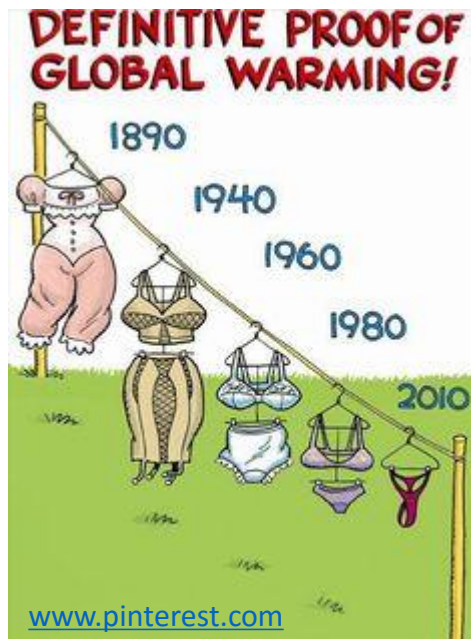
- 98% of the kelp culture overlaps the abalone culture
- Abalone feed
- Sept an Oct: NO seaweed to feed abalones
→ requires extended kelp growing season

Kelp and Undaria harvest for Abalone feed



Global climate change

- Water temperature \uparrow \rightarrow damage to kelp \rightarrow yield \downarrow
- Water temperature \uparrow \rightarrow shorter growing season \rightarrow yield \downarrow



#NoSnow: Brace yourselves for an unusually warm Christmas

Hopes of a white festive period were dashed by an unusually warm weather, with many countries expecting record temperatures. Social media users react, partly by trying to raise awareness to the perils of global warming.



Source: Dan Wasserman, Tribune Media Services, Inc.

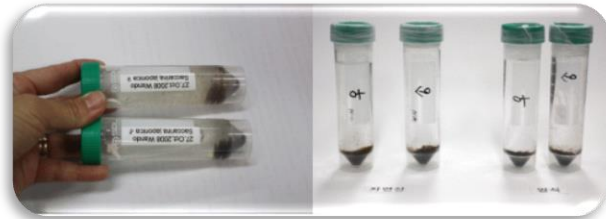
Development of temperature tolerant strains (Kelp)



<Long term>

High temperature tolerant strain development

- ❑ During the early growing season, high temperature (22°C) is critical → decrease



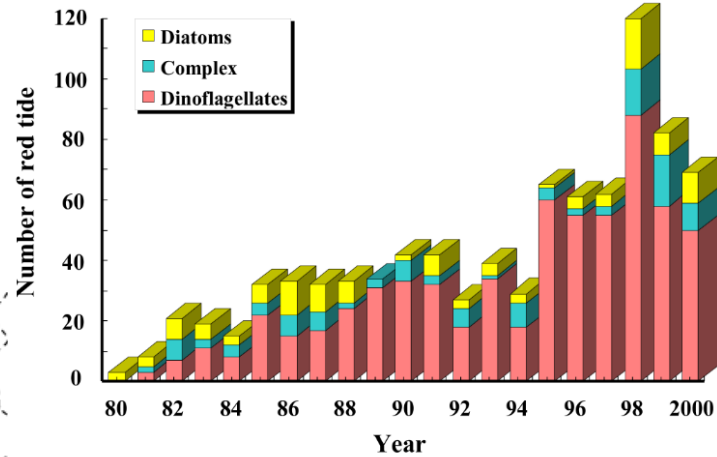
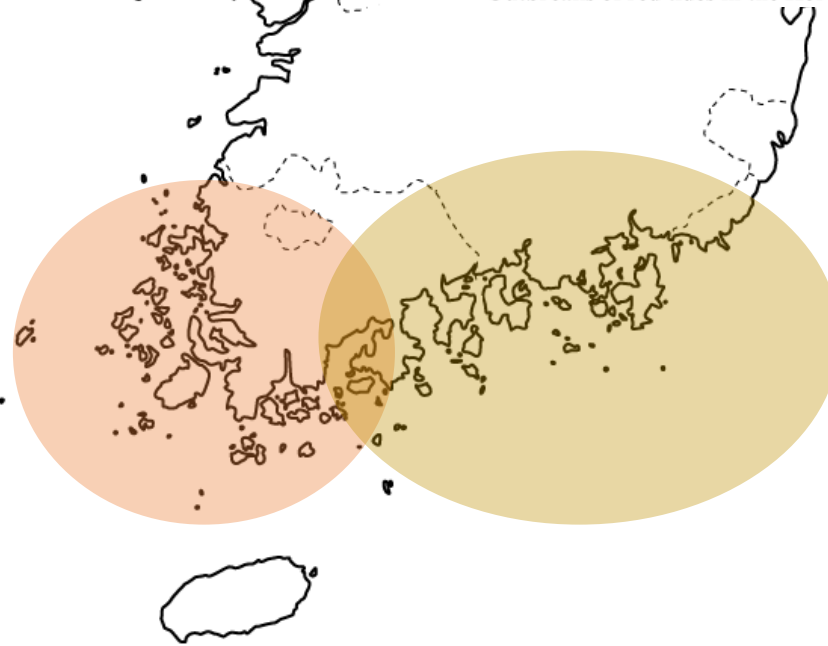
<Short term>

Extend growing season

- ❑ Late outplanting → late harvest, providing kelp for abalone feed in Sept and Oct.

Seaweed aquaculture

- Nutrient limitation
- Chlorosis
- Low production



Outbreaks of red tides in the Korea coastal waters since 1980



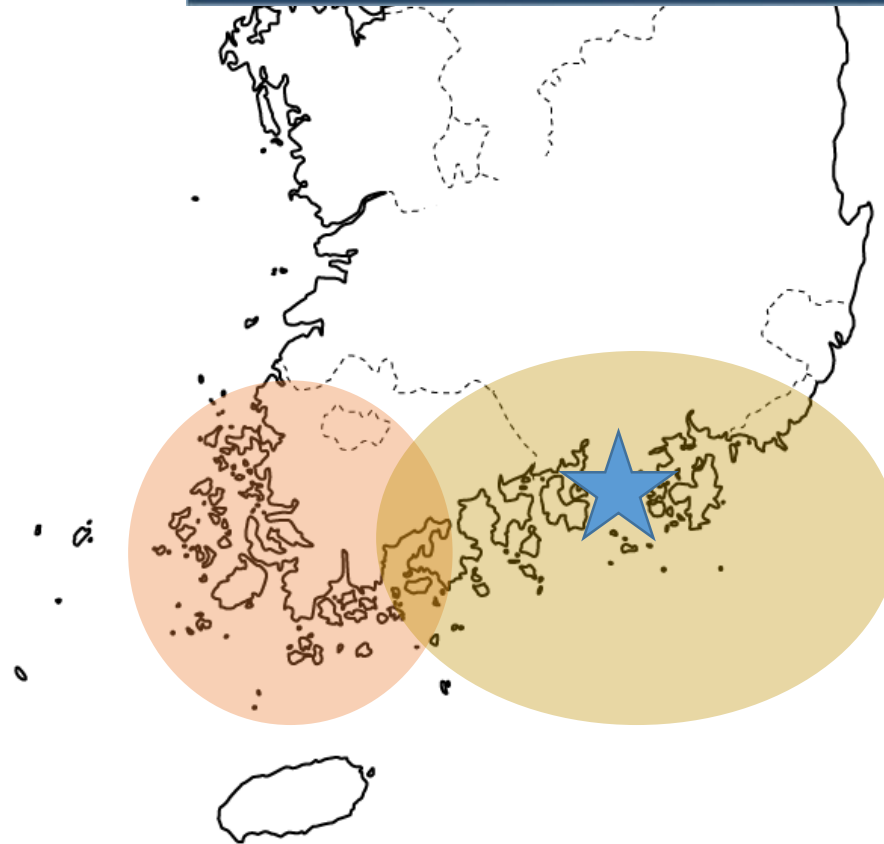
Fin- and shell-fish aquaculture

- Eutrophication
- HABs
- Shellfish contaminated by PSP producing *Alexandrium* spp.
- Fish kills

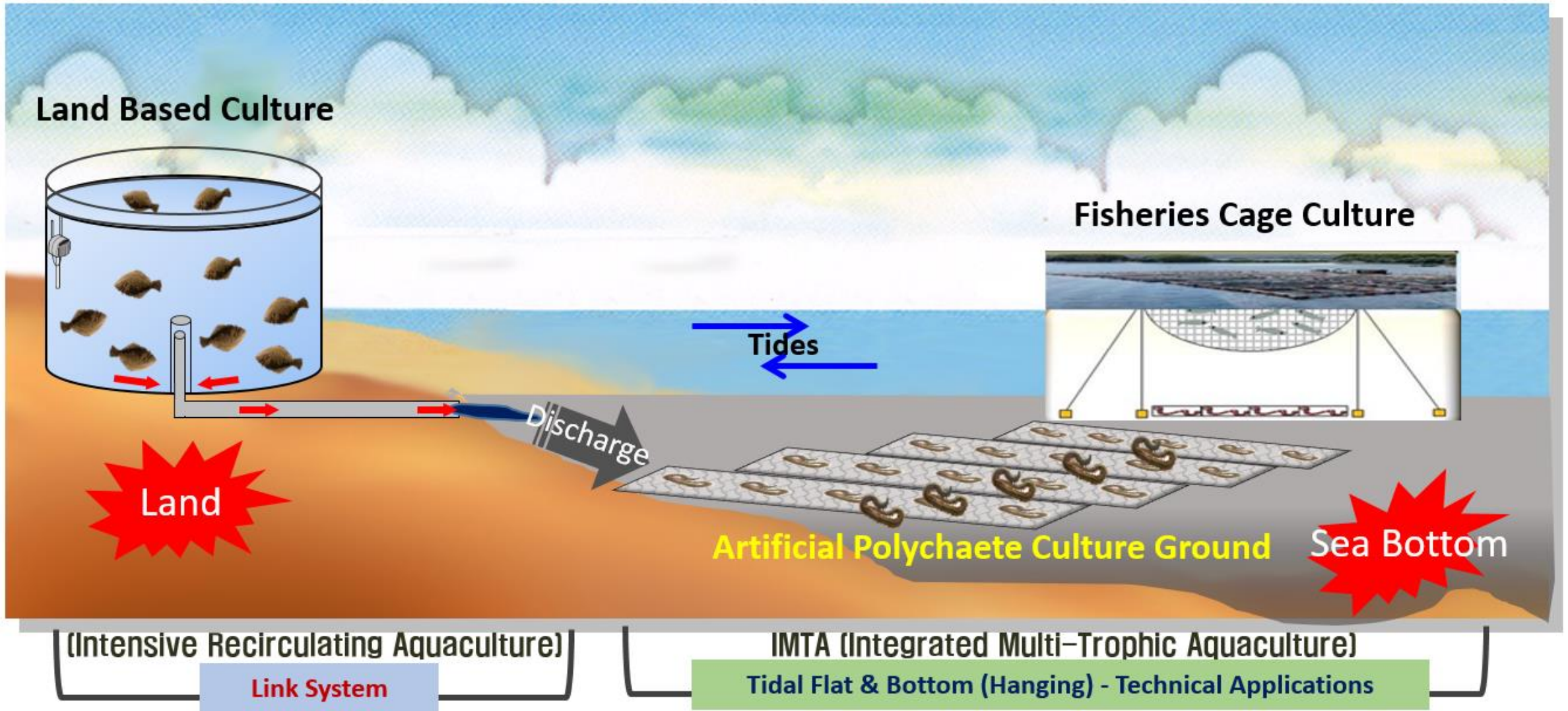
Open water Integrated Multi-trophic Aquaculture (IMTA)



Open water Integrated Multi-trophic Aquaculture (IMTA)



Integrated Link System in Coastal Areas

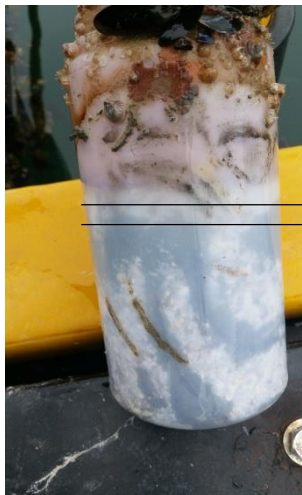


With rock worms



1.5 mos

0.5cm

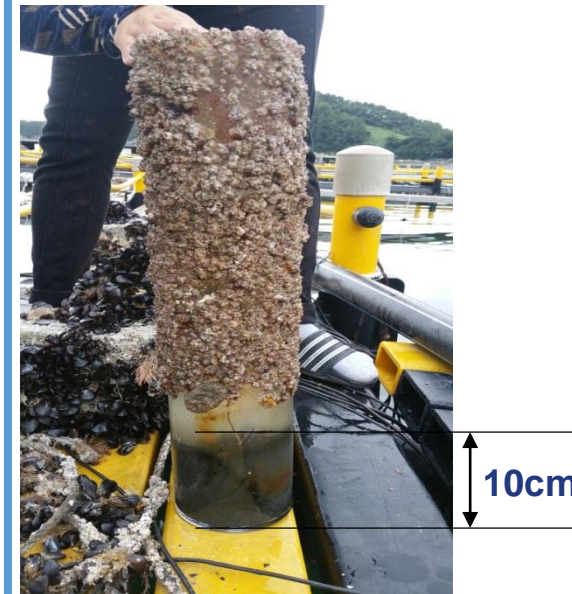


3.0 mos

1.5cm



Without rock worms



10cm

Smart Aquaculture

Smart – Intelligent, ICT

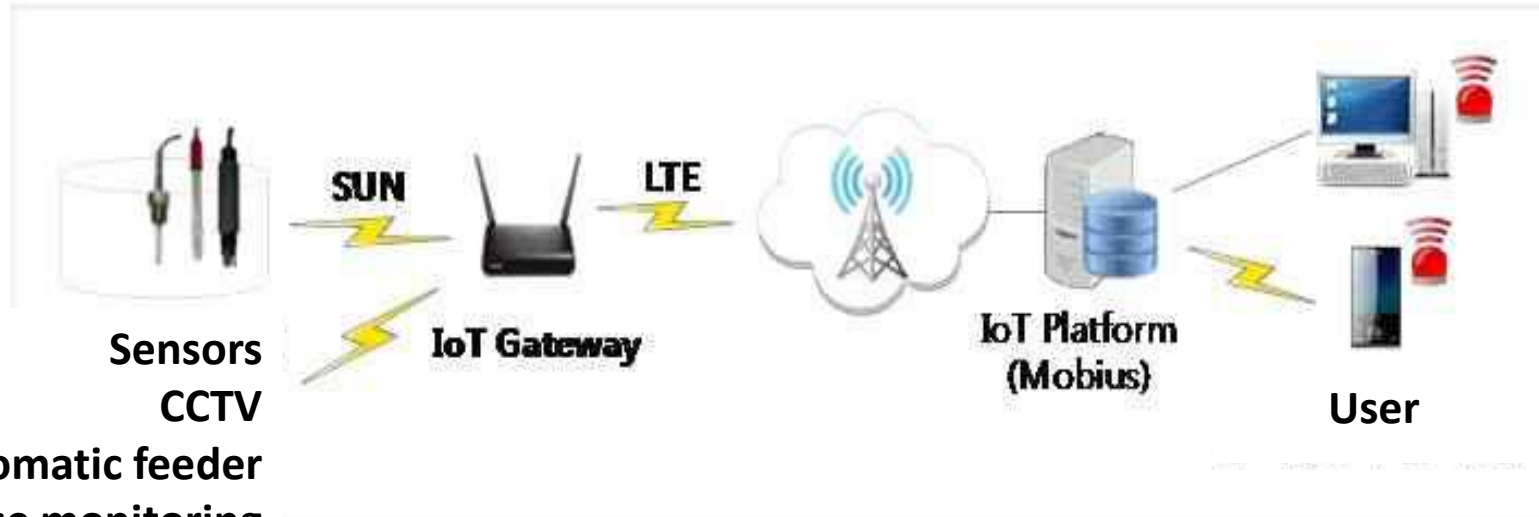


5200A Multiparameter;
DO, pH, Cond, Salinity,
pH, ORP with 4 ea 10
amp relays

Aquaculture Management



Sensors
CCTV
Automatic feeder
Disease monitoring
...



Acknowledgements

- Advanced Research Projects Agency - Energy (ARPA-E), US Dept. of Energy
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- Incheon National University
- University of Connecticut

