Integrating Red Macroalgae into Land-based Marine Finfish Aquaculture

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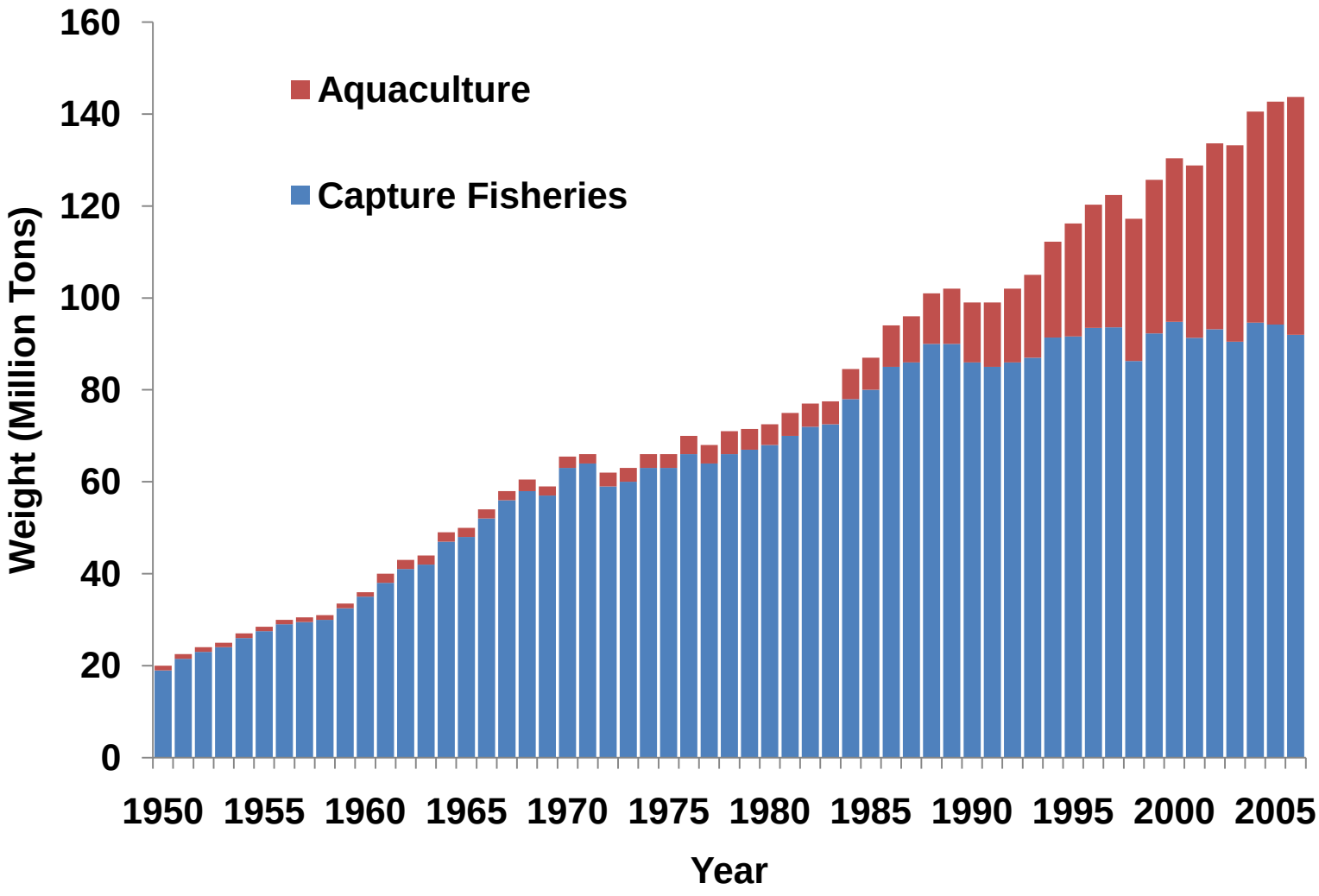
World Capture Fisheries and Aquaculture Production



Source: FAO, The State of World Fisheries and Aquaculture 2008

Finfish Aquaculture Waste Production

- Solid wastes
  - Uneaten Food
  - Feces
- Dissolved Metabolic Wastes
  - CO_2
  - NH_4
  - PO_4

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  - 20-50% of feed N
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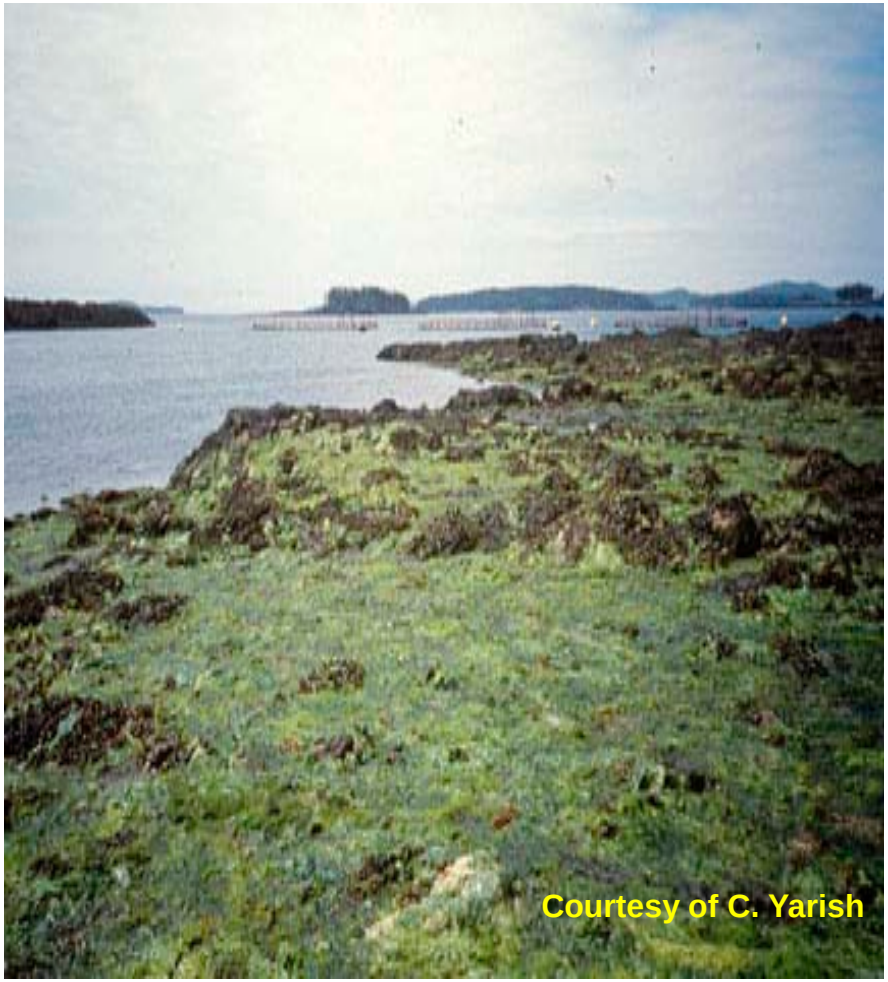

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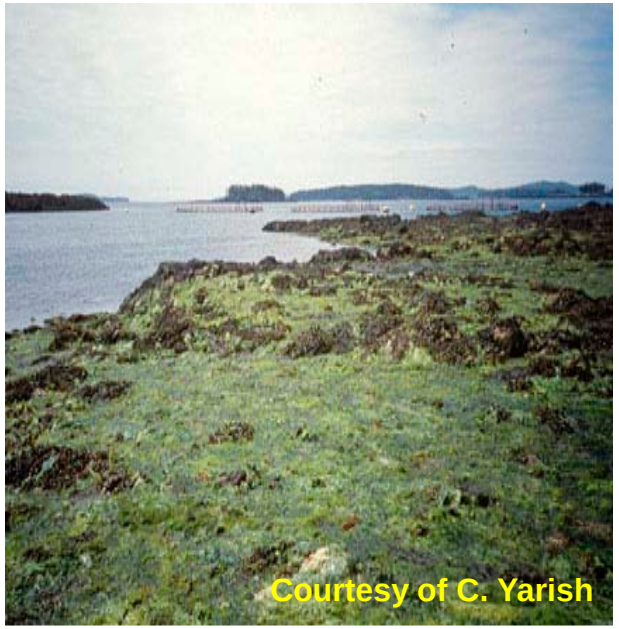

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Economic Loss:

- **Nutrient loss**
- **Cost of effluent treatment**

Integrated Multi-trophic Aquaculture (IMTA)

- Seaweeds grown downstream from finfish
- Ecological and economic incentives
  - Convert N and P in the animal effluent into a valuable product
  - Reduce the risk of eutrophication problems in the local waters
  - Reduce the carbon dioxide levels in the rearing water

Integrated Multi-Trophic Aquaculture (IMTA)

- Israel: Sea bream + *Ulva*; abalone + fish + *Ulva*
- Canada: salmon + *Laminaria* + mussel
- Chile: seaweed biofilters - *Gracilaria* +turbot; *Macrocystis* + *Gracilaria* + salmon + mussels
- China: Shrimp + crab + seaweeds; mussel + scallop + *Laminaria*; fish + *Gracilaria* + abalone ; fish + *Kappaphycus* + pearl oysters
- France: sewage treatment system-*Ulva*
- Hawaii (USA): shrimp + *Gracilaria*
- Japan: shrimp + *Ulva*
- Maine (USA): salmon + *Porphyra*
- Norway: salmon + mussel + *Laminaria*
- Philippine (with Norway): sea urchin/sea cucumber + *Kappaphycus*/*Gracilaria*
- Portugal: seaweed biofilter – *Asparagopsis* + seabream
- South Africa: finfish aquaculture effluent + *Gracilaria* + abalone
- Southeast Asia: shrimp + seaweeds (primarily *Gracilaria*)
- Australia: shrimp + oyster + *Gracilaria*

N removal efficiency

Culture facility	Species	N removal	References
Tank	salmon/*Gracilaria*	70-95% (NH_4^+)	Buschmann et al., 1994
Tank	salmon/*Gracilaria*	Up to 90% (NH_4^+)	Buschmann et al., 1996
Tank	salmon/*Laminaria*	45% (NH_4^+)	Subandar et al., 1993
Tank	seabeam/algae	30-90% (DIN)	Pagand et al., 2000
Tank	seabeam/*Ulva*	19-97% (DIN)	Jimenez del Rio et al., 1996
Tank	seabeam/*Ulva*	85% (NH_4^+)	Vandermeulen & Gordin, 1990
Tank	seabeam/*Ulva*	39-96% (NH_4^+)	Neori et al., 1991
Tank	seabeam/*Ulva*	34-49% (DIN)	Neori et al., 1996
Tank	seabeam/*Ulva*	34-49% (DIN)	Krom et al., 1995
Tank	fish/*Gracilaria;Ulva*	32-100% (NH_4^+)	Harlin et al., 1978
Tank	abalone/*Gracilaria;Ulva*	3-88% (DIN)	Neori et al., 1998
Tank	tapes/*Hypnea*	70% (NH_4^+)	Langton et al., 1977
Pond/Tank	seabeam/oyseter/clams/*Ulva*	90% (NH_4^+)	Shpigel et al., 1993
Tank	fish, oyster, sea urchins /*Gracilaria*	100% (NH_4^+)	Chow et al., 2001
Tank	abalone/*Ulva;Gracilaria*	70-100% (NH_4^+)	Neori et al., 2000
Lab	Shrimp/oyster/*Gracilaria;*	2-76% (NH_4^+)	Jones et al., 2001

*Open-water system is NOT included

Integrated Halibut/Red Seaweeds Recirculating Aquaculture System

Food

New Water

N P O_2

N P CO_2

Waste water

Solid waste

What is the good seaweed species to integrate into an animal aquaculture operation?

- Rapid growth
- High accumulation of N and P in tissue (ecological value)
- Potential economic value
- Local species

Chondrus crispus & Palmaria palmata

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Why

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- High accumulation of N and P in tissue (ecological value)

√ • Potential economic value
  - Edible seaweeds,
  - High carrageenan content (>70% DW *Chondrus*; Chopin 1999)
  - High protein (~ 41% DW) and carbs (~ 74% DW) (Martinez and Rico, 2002)

√ • Local species

Why

Chondrus crispus & Palmaria palmata?

- Rapid growth

√
- High accumulation of N and P in tissue (ecological value)
  - *Chondrus*: 6.5% N DW, 0.45% P DW (Chopin et al 1995, 1999)
  - *Palmaria*: 4.5% N DW, 0.65% P DW (Martinez and Rico, 2002)

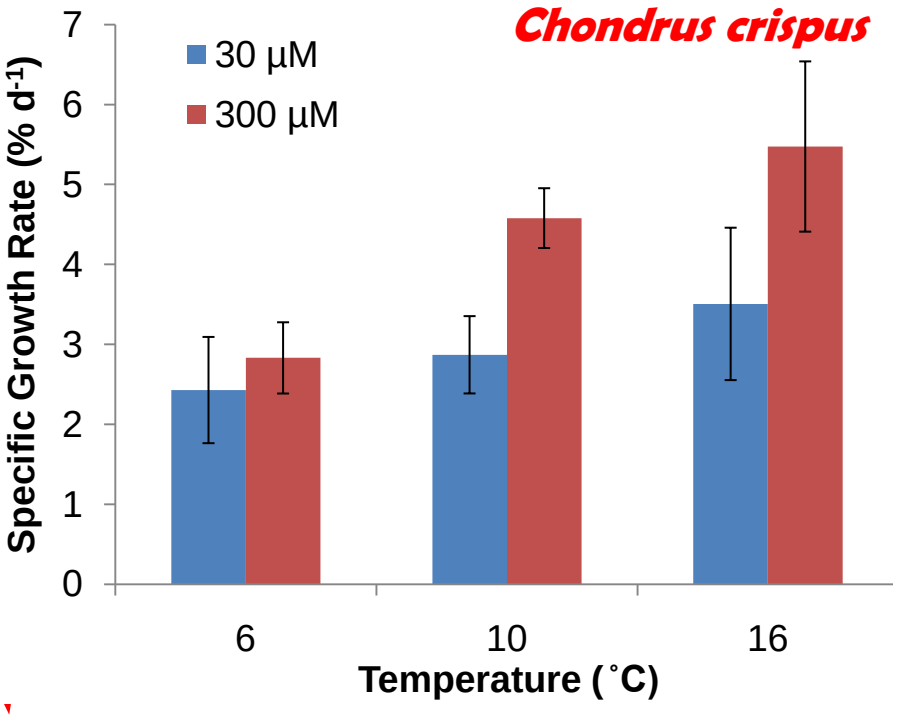
√
- Potential economic value

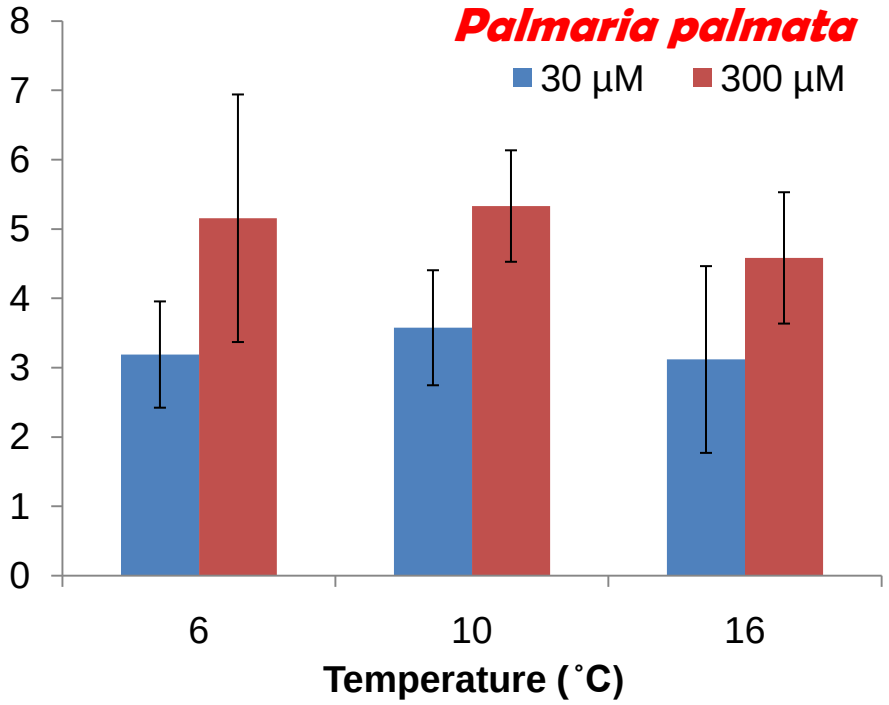
√
- Local species

Why

Chondrus crispus & Palmaria palmata?

- √ Rapid growth





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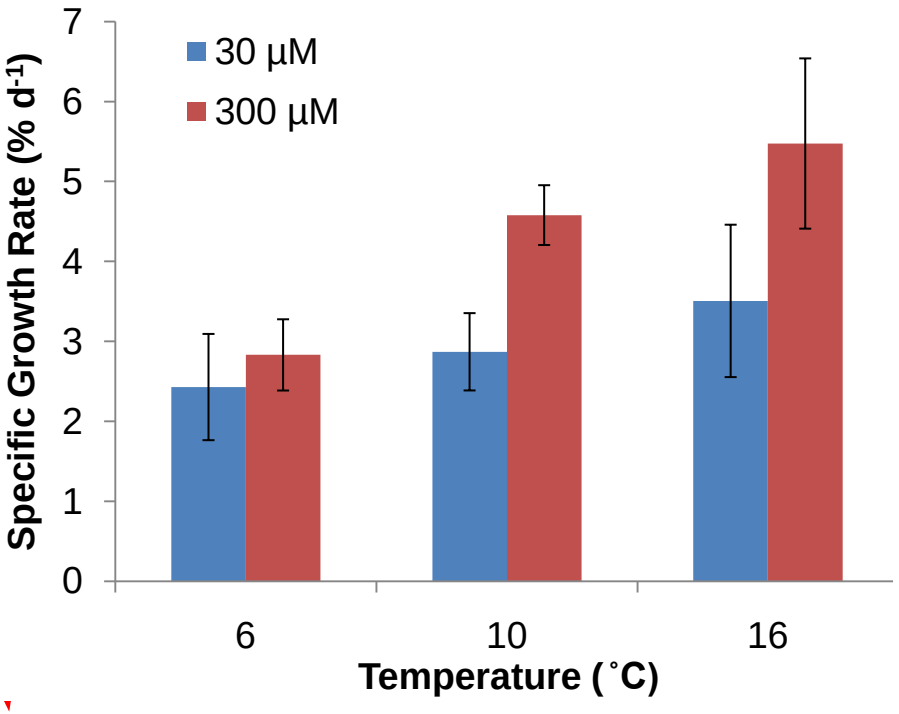
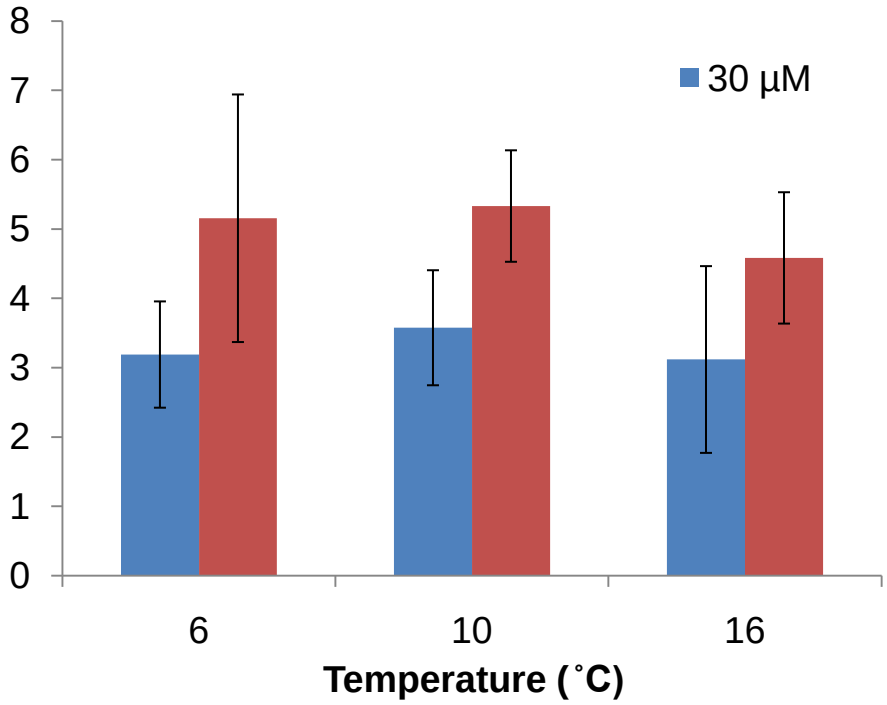


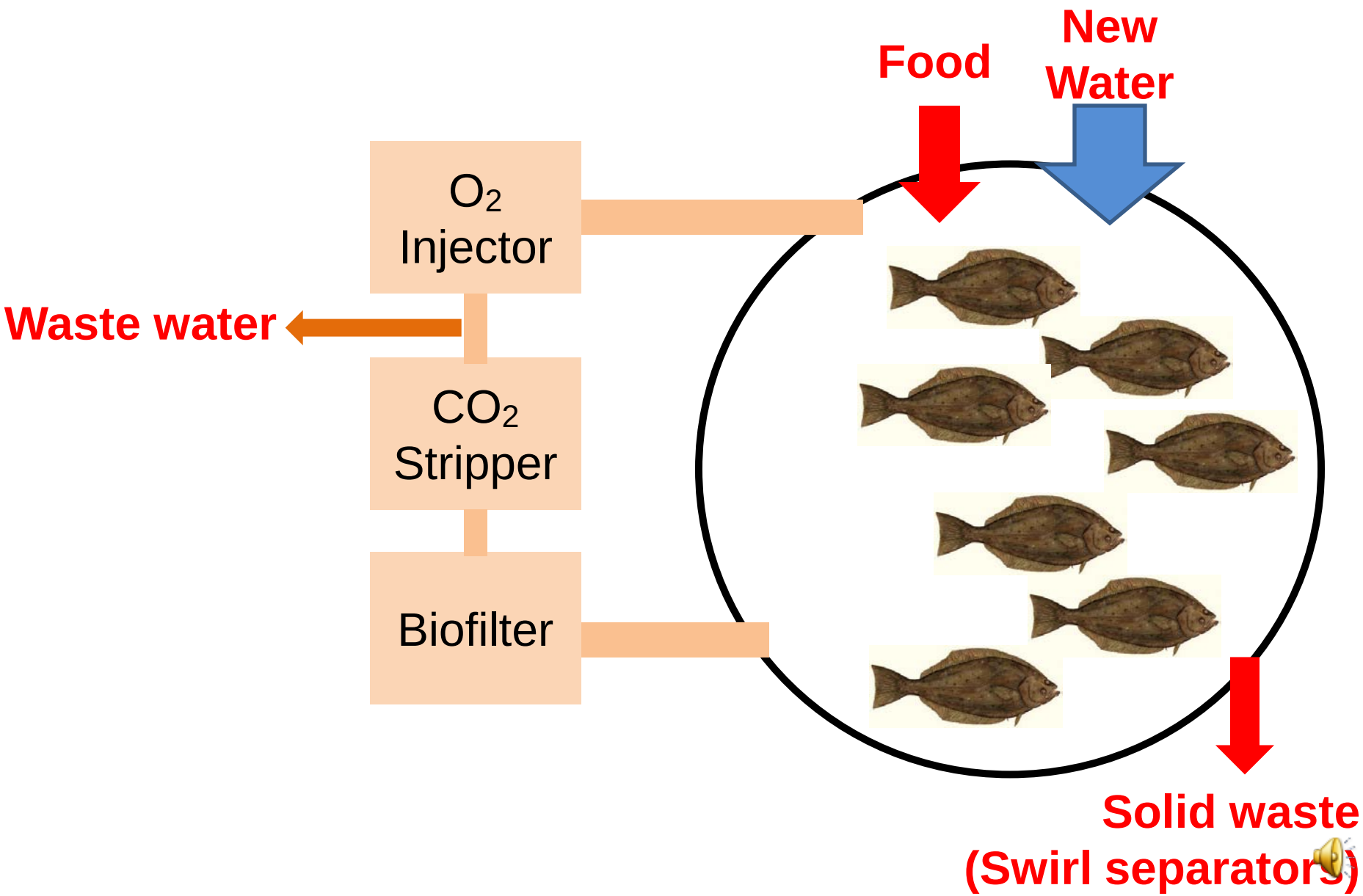


Why

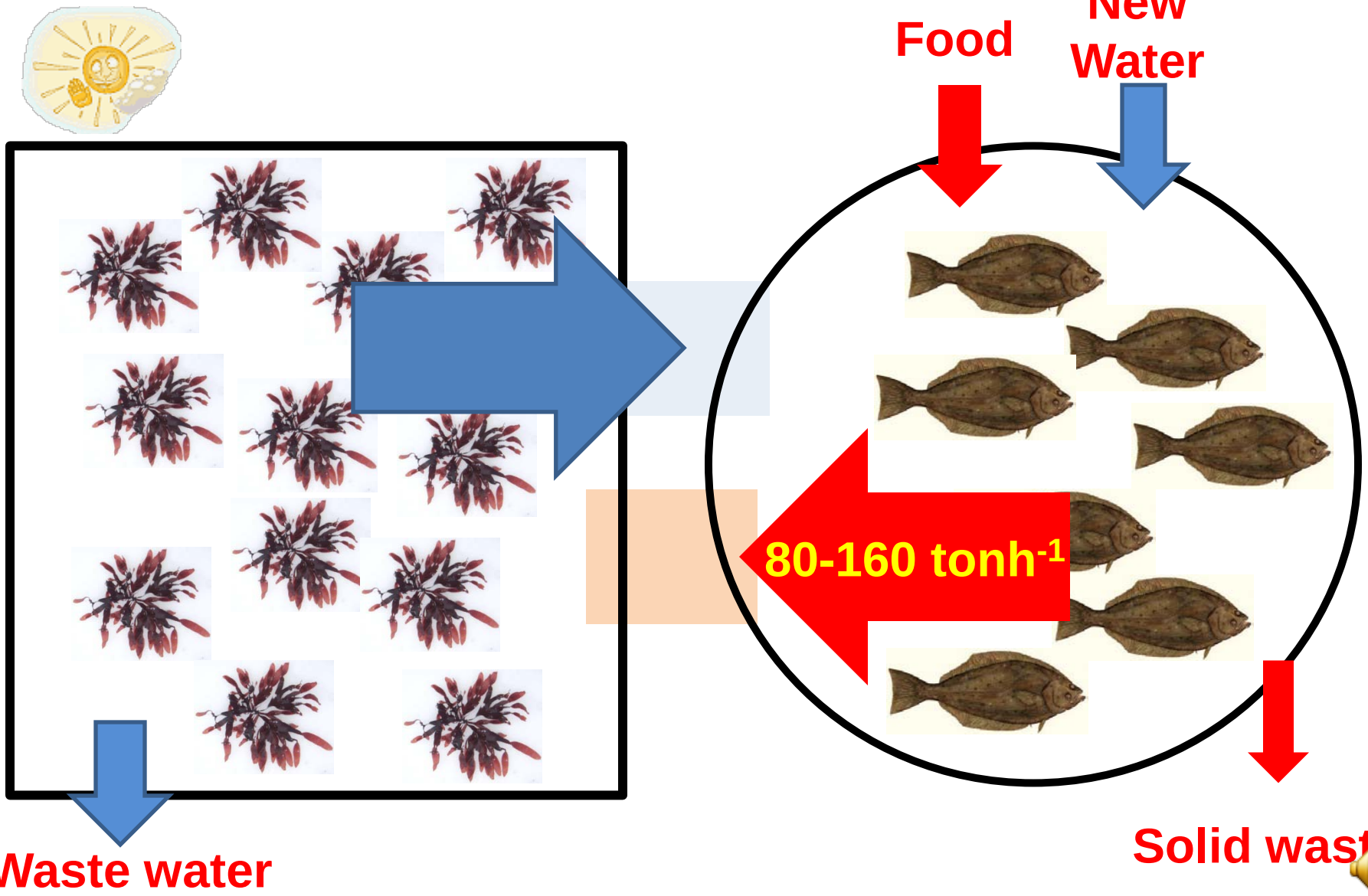
Chondrus crispus & Palmaria palmata?

- Rapid growth
- High accumulation of N and P in tissue (ecological value)
- Potential economic value
- Local species
- Grow well at temperature range of 6 – 16 ºC

Halibut Aquaculture System at Scotian Halibut Ltd.



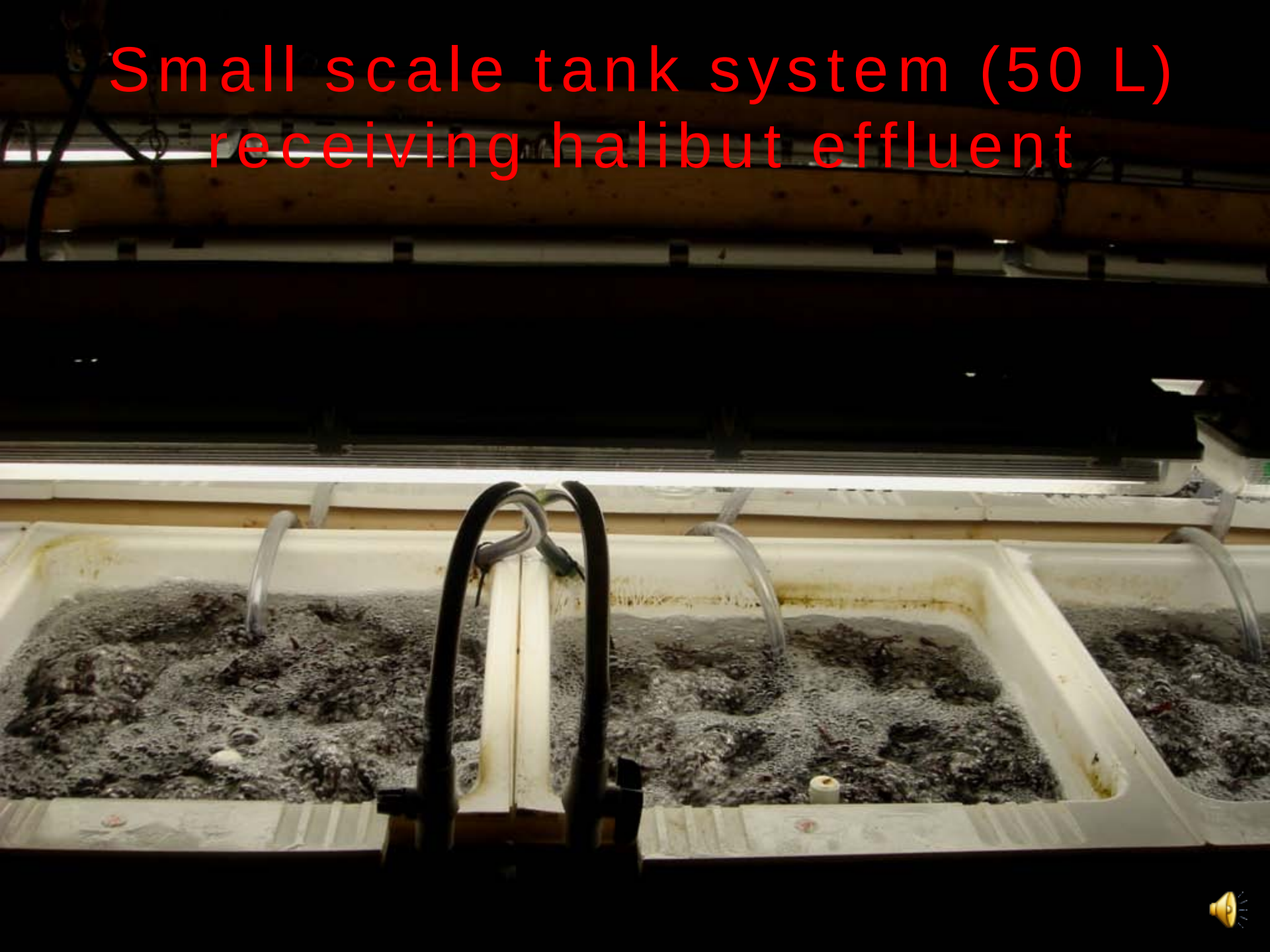
Integrated Halibut/Red Seaweeds Recirculating Aquaculture System



Objective

To determine optimal stocking density of seaweed at fast turnover rate to maximize nutrient removal and productivity

Small scale tank system (50 L) receiving halibut effluent



Materials and Methods

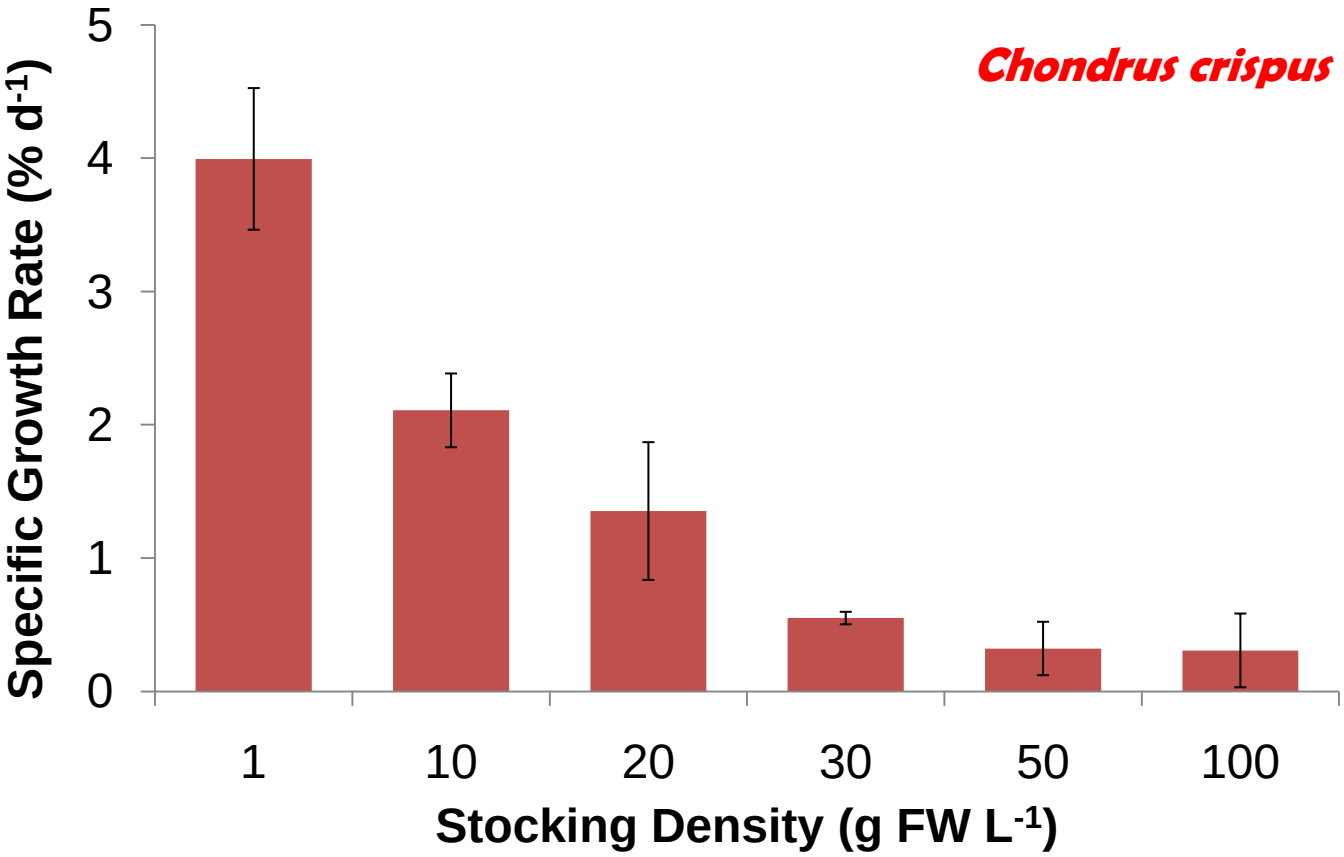
- Species: *Chondrus crispus*
- Light intensity: 140 ± 10 µmol $m^{-2}s^{-1}$
- Photoperiod: 16:8 L:D
- Temperature: 6 2˚C
- Stocking density: 1, 10, 20, 30, 50 and 100 g L^{-1}
- Water source: Halibut effluent
- Turn over rate: 0.5 h
- Water sampling: Inlet and Outlet

  8:00 - Before feeding

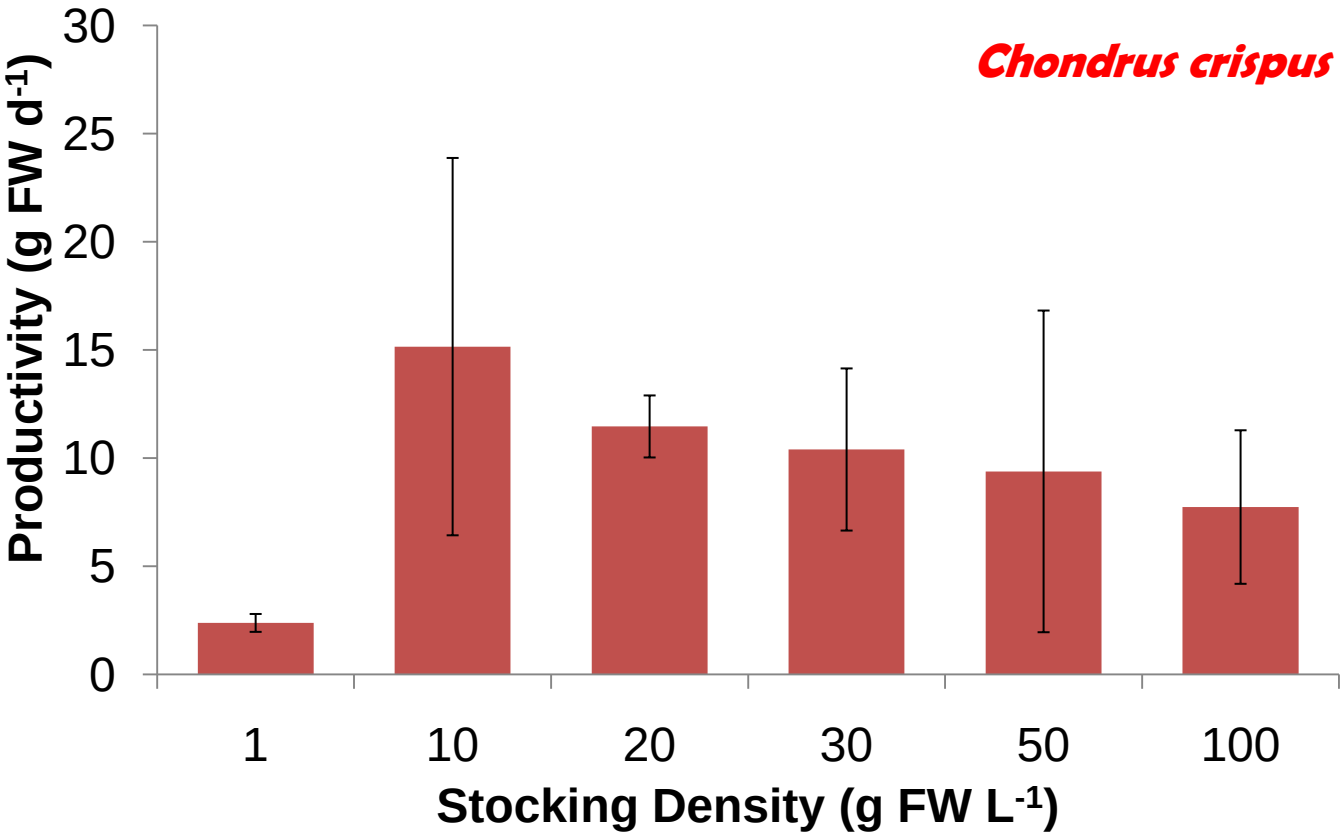
  14:00 – 3 h after morning feeding

  19:00- 3 h after afternoon feeding

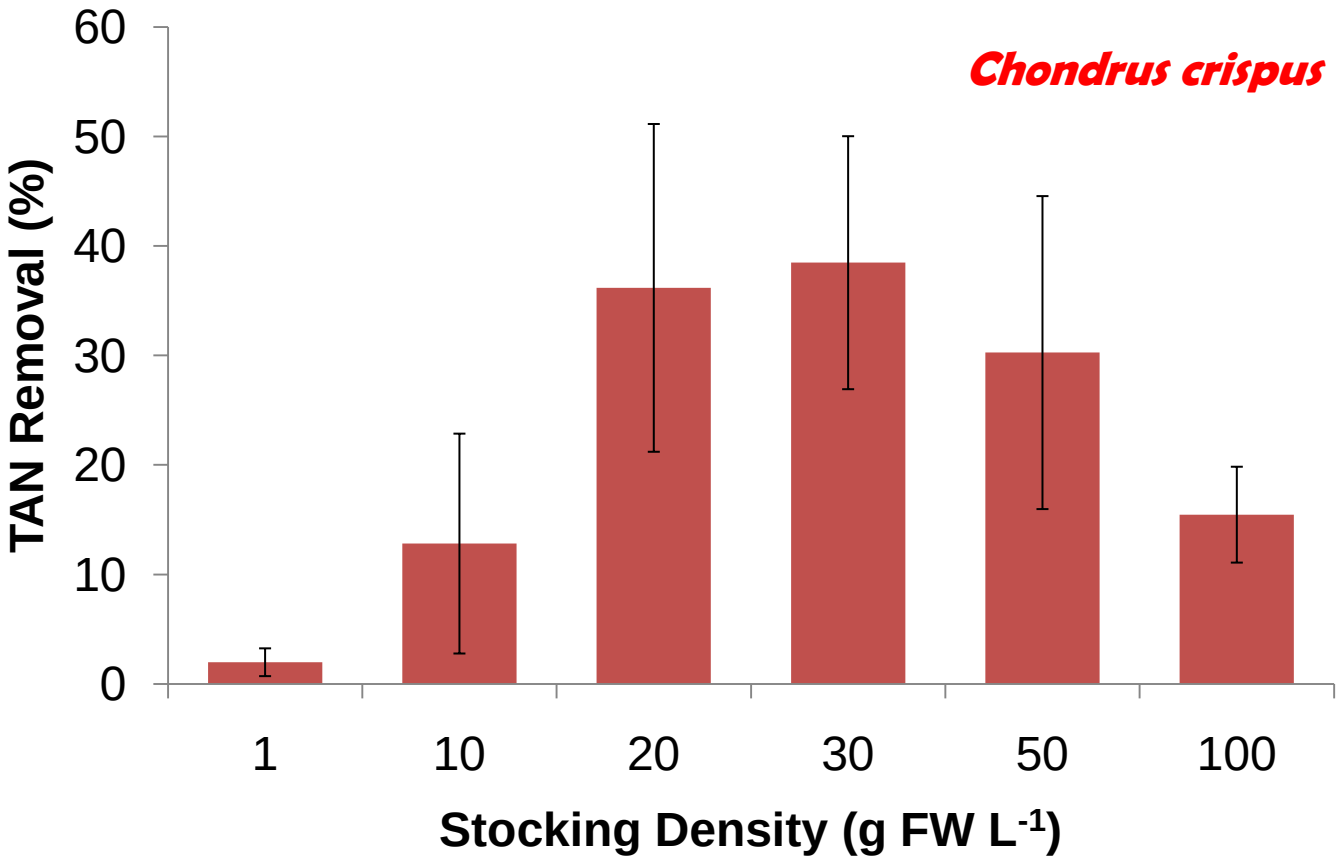
Growth Rate


Chondrus crispus
Specific Growth Rate (% d-1)
0
1
2
3
4
5
1
10
20
30
50
100
Stocking Density (g FW L-1)

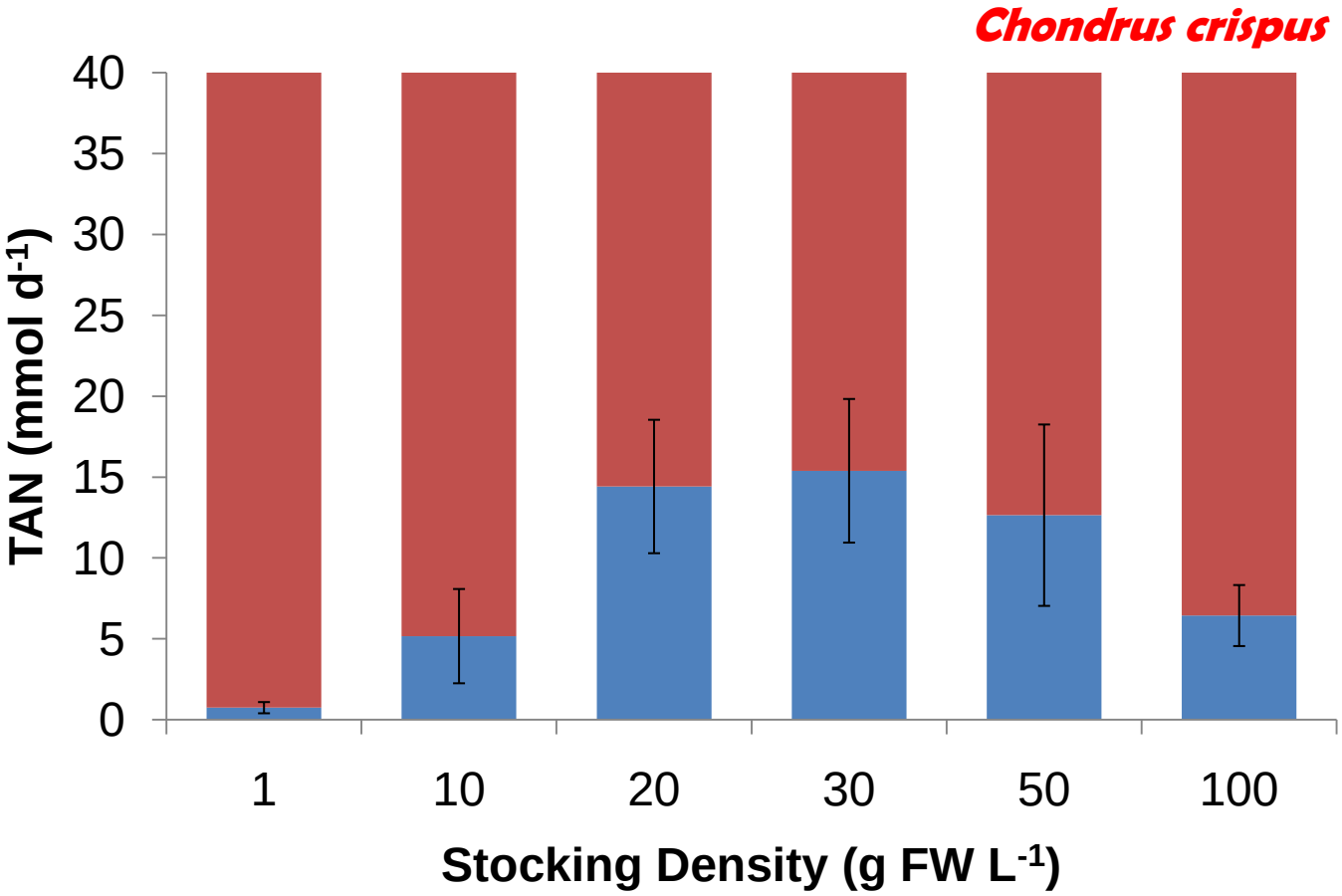
Productivity



% TAN Removal


Chondrus crispus
TAN Removal (%)
60
50
40
30
20
10
0
1
10
20
30
50
100
Stocking Density (g FW L-1)

TAN Removal


Chondrus crispus
40
35
30
25
20
15
10
5
0
TAN (mmol d-1)
1
10
20
30
50
100
Stocking Density (g FW L-1)

What biomass of Chondrus is needed to remove 40% of TAN from the Halibut effluent

Food

New Water

700-1400 kg

6-8 tons of halibut

34-64 mol d^{-1}

Waste water

Solid waste

Conclusions

- *Chondrus* has the highest growth rate at low stocking density, 1 g L^{-1} and decreased as the density increased
- TAN removal: highest at 20-30g L^{-1} stocking density at 6 2 ˚C
- 34-64 mol $d^{-1}$of ammonia nitrogen is released from the fish culture system with 6-8 tons of halibut during winter
- 700-1300 kg of *Chondrus* may be required to remove 40 % of TAN during winter

Future Research

- Stocking density experiments at 10 and 15 ˚C
- Stocking density experiments with *Palmaria palmata*
- High stocking density 20-30 g L^{-1} and

  Higher light intensity (> 150 $\mu molm^{-2}s^{-1}$)
- Large sump experiments

  - Monitor water quality: N, P and CO_2 removal

  - Determine the quality of seaweed products grown in fish effluent (e.g. proteins, carbohydrates, lipids, etc.) for human consumption, fertilizer, fish meal, etc.

Acknowledgements

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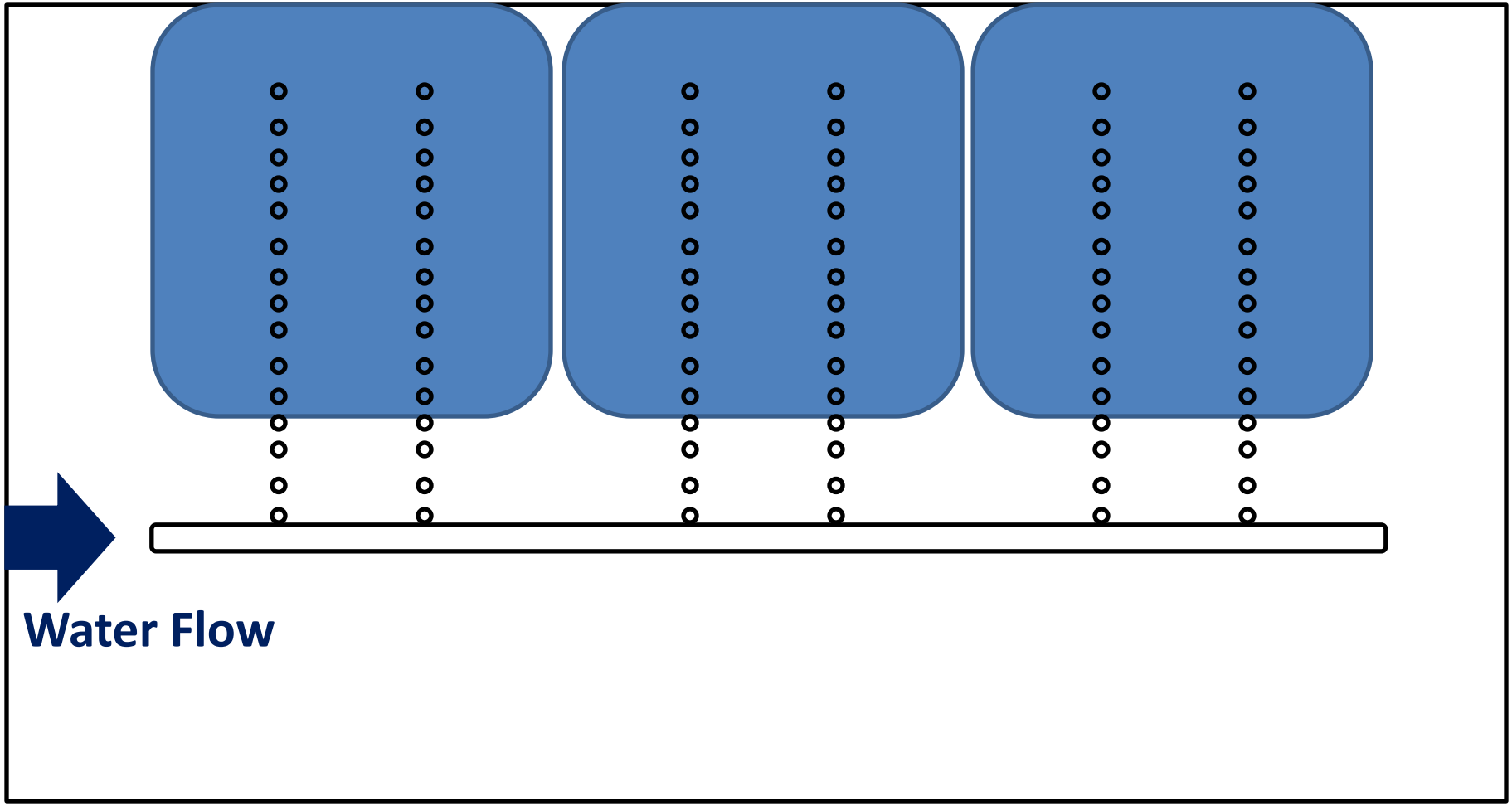
- NSAC: Paul MacIsaac, Kyle MacRae
- Scotian Halibut Ltd.: Philip Nickerson, Graham Dixon, Dr. Harry Murray, Carmen Nickerson, Joe Mersereau, Eric Cameron, Tera Brommit

Chondrus crispus

Palmaria palmata


Water Flow