Responsibly farming waters with an ecosystem-based approach and taking advantage of the ecosystem services provided by Integrated Multi-Trophic Aquaculture (IMTA)

T. Chopin and the IMTA team

Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN)
University of New Brunswick
Saint John, N.B., Canada

- Integrated Multi-Trophic Aquaculture
- IMTA
- and

are 12 years old!

26 March 2004 - Hilton Hotel

Saint John, New Brunswick, Canada

Integrated Aquaculture + Multi-Trophic Aquaculture

Thierry Chopin

Jack Taylor

=

Integrated Multi-Trophic Aquaculture (IMTA)

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But the practice is much older…

-2200-2100 BC "You Hou Bin" detailed the integration of fish with aquatic plants and vegetable production in China

What we are developing is IMTA "à la canadienne"…

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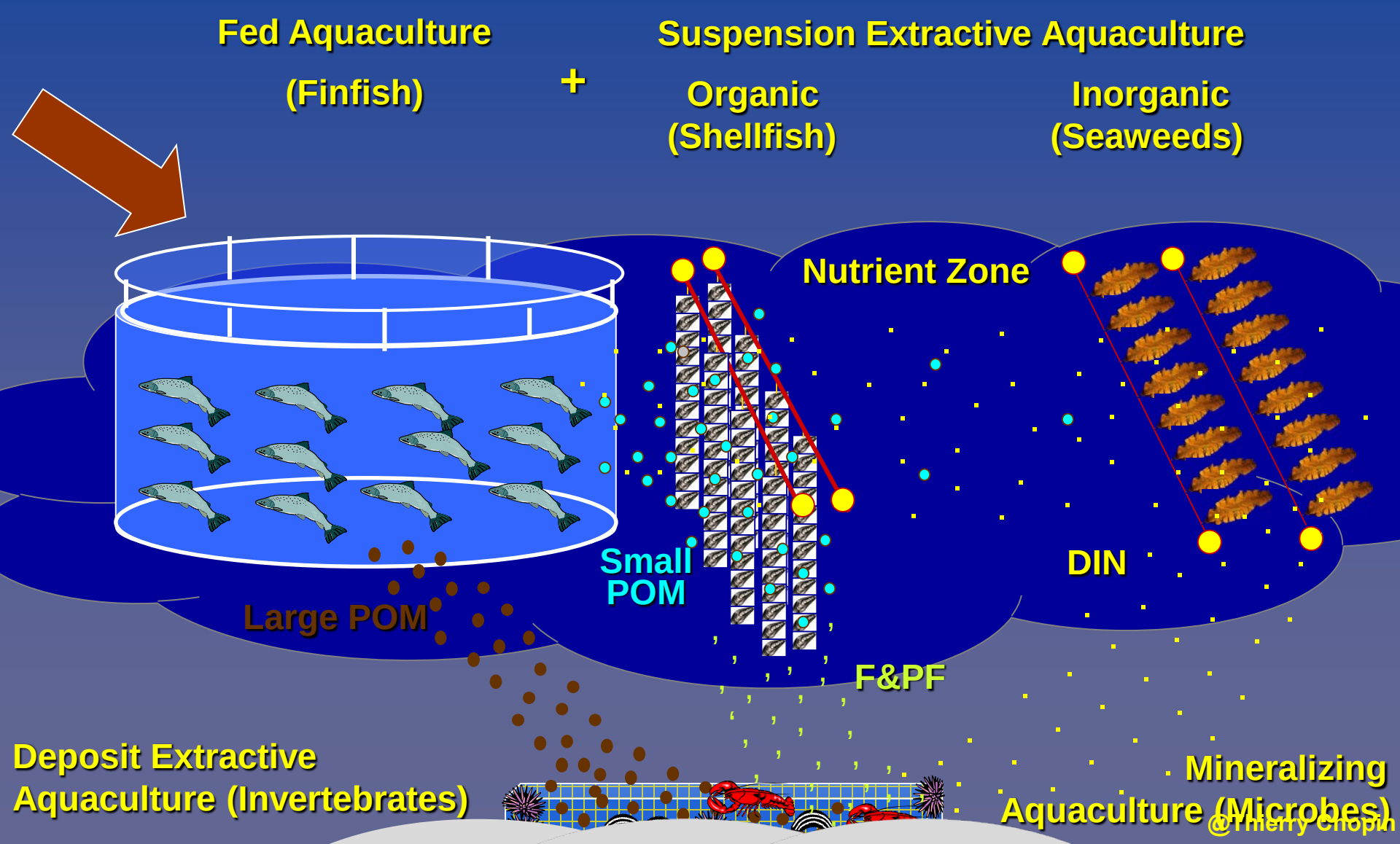
Integrated Multi-Trophic Aquaculture (IMTA)




INTEGRATED MULTI-TROPHIC
AQUACULTURE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The IMTA concept is extremely flexible

- IMTA is the central/overarching theme on which many variations can be developed.

- IMTA can be applied to open-water and land-based systems, marine and freshwater environments, and temperate and tropical climates.

- It is not enough to consider multiple species, they have to be at multiple trophic levels based on their complementary functions in the ecosystem. They should also have an economic value.

- Integration should be understood as cultivation in proximity, not considering absolute distances but connectivity in terms of ecosystemic functionalities, which means that entire bays/coastal areas/regions could be the units of IMTA management.

This is also IMTA…

integrated agriculture aquacultutre (IAA)

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This is also IMTA…

integrated green water aquaculture (IGWA)

integrated biofloc aquaculture (IBFA)

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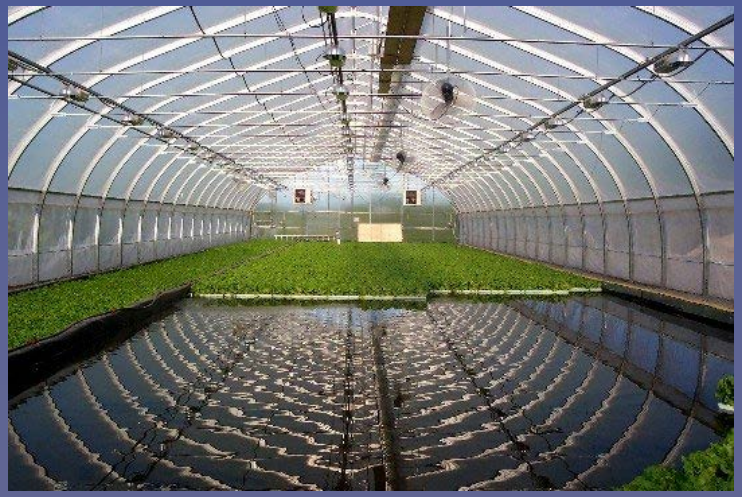
This is also IMTA…

freshwater IMTA (FIMTA) or aquaponics



CIMTAN FIMTA

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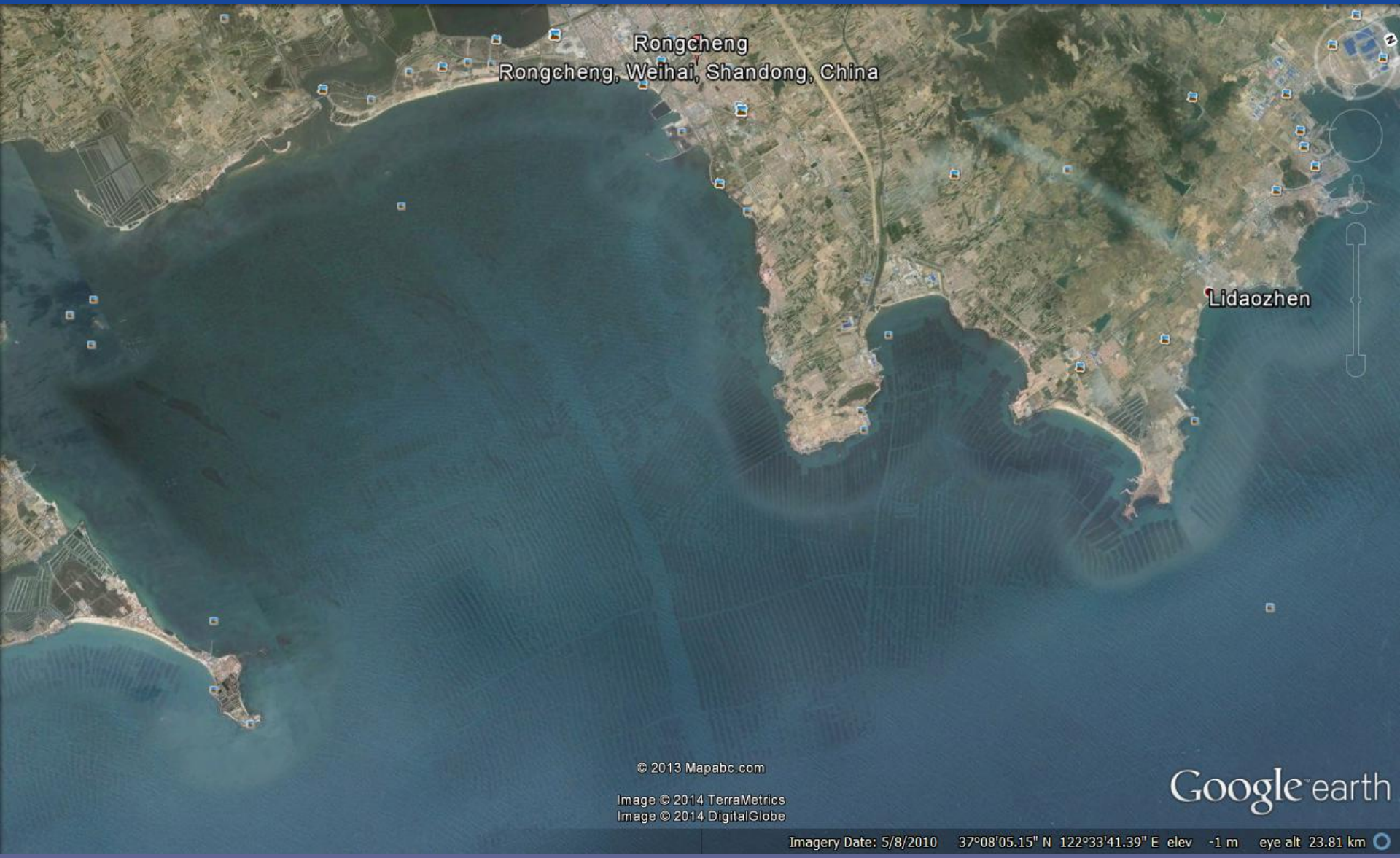
This is also IMTA… Sanggou Bay, China



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This is mostly co-cultivation of seaweeds and invertebrates

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This is also IMTA...

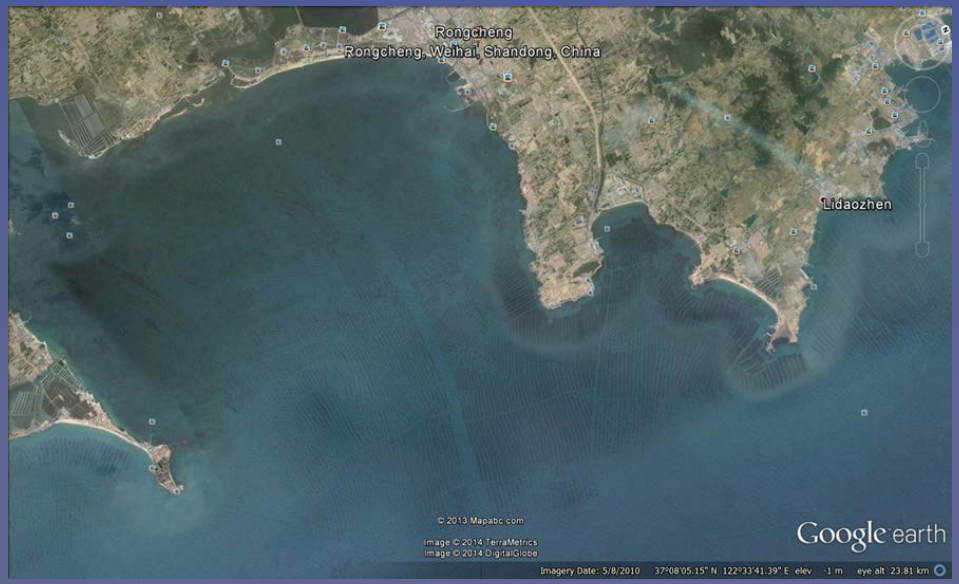
Wando, South Korea

Kelp and abalone co-culture

It is may be adventitious IMTA, but it is IMTA

So, what type of IMTA variations are we talking about?

We have FIS developing IMTA systems in the western world



and SIF larger scale IMTA systems in Asia

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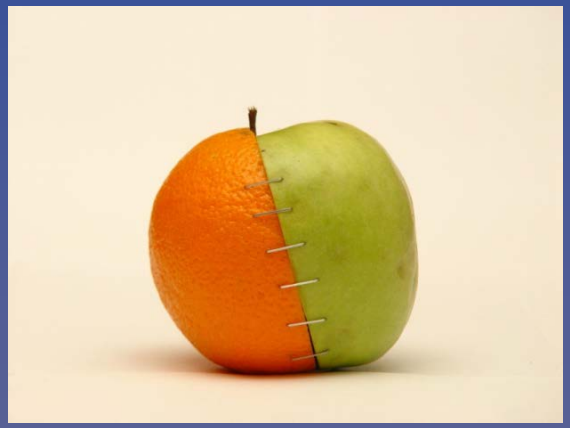
Should they be apples vs oranges?

Or should we work together

towards more



integrative solutions?

There is no ultimate IMTA system to “feed the world”

Different climatic, environmental, biological, physical, chemical, economic, historical, societal, political and governance conditions can lead to different choices in the design of the best suited IMTA systems, but all of them are based on the same principles of the IMTA concept.

IMTA should be developed within the context of an integrated coastal area management (ICAM) strategy.

There is nothing that says that one company should be in charge/producing all the IMTA components. Several companies may have to coordinate their activities within the integrated coastal management area.


s a l m o n
mussels
seaweeds
mussels
seaweeds
mussels

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Fed component of IMTA: salmon

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Inorganic component of IMTA: seaweeds

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Mariculture production

2012: 48.5 million tonnes

	Production (%)					
	1996	2000	2004	2008	2010	2012
Molluscs	48.0	46.2	43.0	42.7	37.2	30.7
Seaweeds	44.0	44.0	45.9	46.2	50.9	49.1
Finfish	7.0	8.7	8.9	8.9	9.1	11.4
Crustaceans	1.0	1.0	1.8	1.8	1.8	8.1
Other aquatic animals	-	0.1	0.4	0.4	1.0	0.7

(FAO 1998, 2002, 2006, 2008, 2011, 2012, 2014)

Now…

How much of this is known in the western world…?

Not much… because 96.3% of seaweed aquaculture is concentrated in 6 Asian countries [China (54.0%), Indonesia (27.4%), The Philippines (7.4%), The Republic of Korea (4.3%), Japan (1.8%) and Malaysia (1.4%)]

Seaweed aquaculture production

- 95.6% of world seaweed supplies
  (seaweeds were the first group of organisms to pass the 50% farmed/wild harvest threshold in 1971)

- production: 23.8 million tonnes (96.3% produced in 6 Asian countries)

- value: US$6.4 billion (99.5% generated in Asia)

- average annual growth rate: 7.7%

- ~ 220 species cultivated

  6 genera provide 98.9% of the production and 98.8% of the value

(FAO 2011, 2012, 2014; Chopin 2012)

Saccharina

Undaria

Porphyra

Gracilaria

Kappaphycus

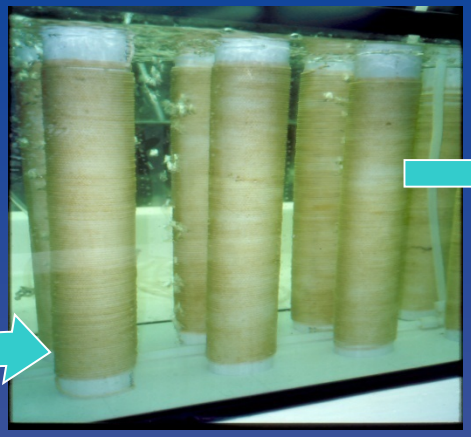
Sargassum

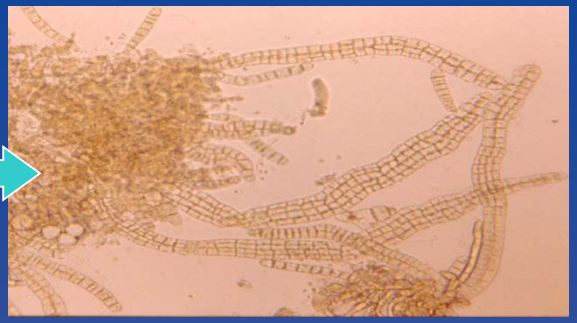
- *Saccharina latissima*
  - previously *Laminaria saccharina*
  - *Saccharina* means sweet
  - similar to other *Saccharina* and *Laminaria* for the Oriental market
  - sold as "*kombu*"

- *Alaria esculenta*
  - *esculenta* means succulent
  - similar to *Undaria* for the Oriental market
  - sold as "*wakame*"

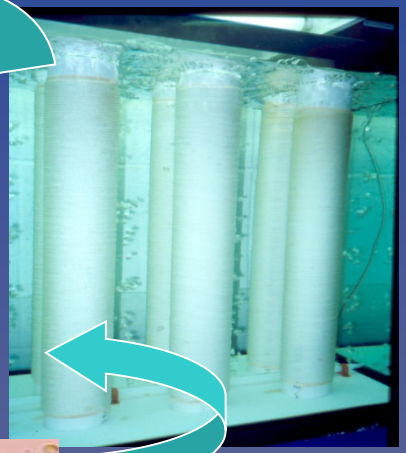
Laboratory Phase

On-site Phase





Harvesting



From R&D to C

Small organic particle component of IMTA: mussels/other shellfish

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Large organic particle component of IMTA: sea urchins, sea cucumbers, sea scallops, sea worms, lobsters

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A major rethinking is needed regarding the functioning of an “aquaculture farm”

It does not work only within the limits of a few buoys on the water, but should be managed using an integrated coastal area management (ICAM) strategy, according to the movement of the different elements considered:

- **large particulate organic nutrients:** management within the site
- **small particulate organic nutrients:** management within the site or around its immediate vicinity
- **dissolved inorganic nutrients:** management at the ICAM scale
- **disease vectors and parasites:** management at the ICAM scale

Different nutrients:

- small particulate organic nutrients
- large particulate organic nutrients
- dissolved inorganic nutrients

>>> different strategies (spatial and temporal)

>>> infrastructures for co-cultivated species of an IMTA system should be placed accordingly

>>> need for regulatory changes instead of regulatory hurdles

>>> need enabling and flexible regulations for the development and implementation of innovative aquaculture practices

There is now a renewed interest in the mariculture of seaweeds for their integrated cultivation, the ecosystem services they provide and novel uses

- Seaweeds are excellent nutrient scrubbers (especially dissolved nitrogen, phosphorus and carbon)

We should take advantage of the benefits of nutrients, which, in moderation (*i.e.* within the assimilative capacity of the ecosystem) are not waste but food

The good nutrient/ the bad nutrient

It's all about recycling!

- It's OK in your hotel room, your office, your garden, your farm on land…

- So, why is it not OK in your farm in the aquatic environment?

We should give a value to recapturing feed and energy, otherwise lost, and their conversion into other commercial crops

To give IMTA its full value, extractive species will have to be valued for not only their biomass and food trading values, but also for the ecosystem services they provide

>>> Introducing the concept of "nutrient trading credits" (NTC), similar to carbon trading credits (CTC)

For example: seaweeds 23.8 million tons US$6.4 billion

Composition	NTC
0.35% N	US$10-30 kg^{-1}
0.04% P	US$4 kg^{-1}
3.00% C	US$30 t^{-1}

>>> Ecosystem services: at least US$892.5 million to US$2.559 billion

***i.e.* as much as 40% of their present commercial value**

There is now a renewed interest in the mariculture of seaweeds for their integrated cultivation, the ecosystem services they provide and novel uses

- Seaweeds are excellent nutrient scrubbers (especially dissolved nitrogen, phosphorus and carbon)

- With IMTA, seaweeds can be cultivated without fertilizers and agrochemicals

- Seaweeds do not need to be irrigated

- Seaweed cultivation does not need more arable soil and land transformation (deforestation)

- Seaweeds can be used for habitat restoration

There is now a renewed interest in the mariculture of seaweeds for their integrated cultivation, the ecosystem services they provide and novel uses

- Seaweeds is the aquaculture component providing O_2, while the other animal and microbial components consume O_2

- Seaweeds sequester carbon dioxide >>> slowing down global warming

- By sequestering carbon dioxide, they also delay ocean acidification

$$CO_2 + H_2O + \underset{\text{carbonate}}{CO_3^{2-}} \rightarrow 2\ \underset{\text{bicarbonate}}{HCO_3^-}$$

There is now a renewed interest in the mariculture of seaweeds for their integrated cultivation, the ecosystem services they provide and novel uses

- The IMTA multi-crop diversification approach (fish, seaweeds and invertebrates) could be an economic risk mitigation and management option to address pending climate change impacts

- Seaweeds can be used for partial fish protein substitution in aquaculture feed

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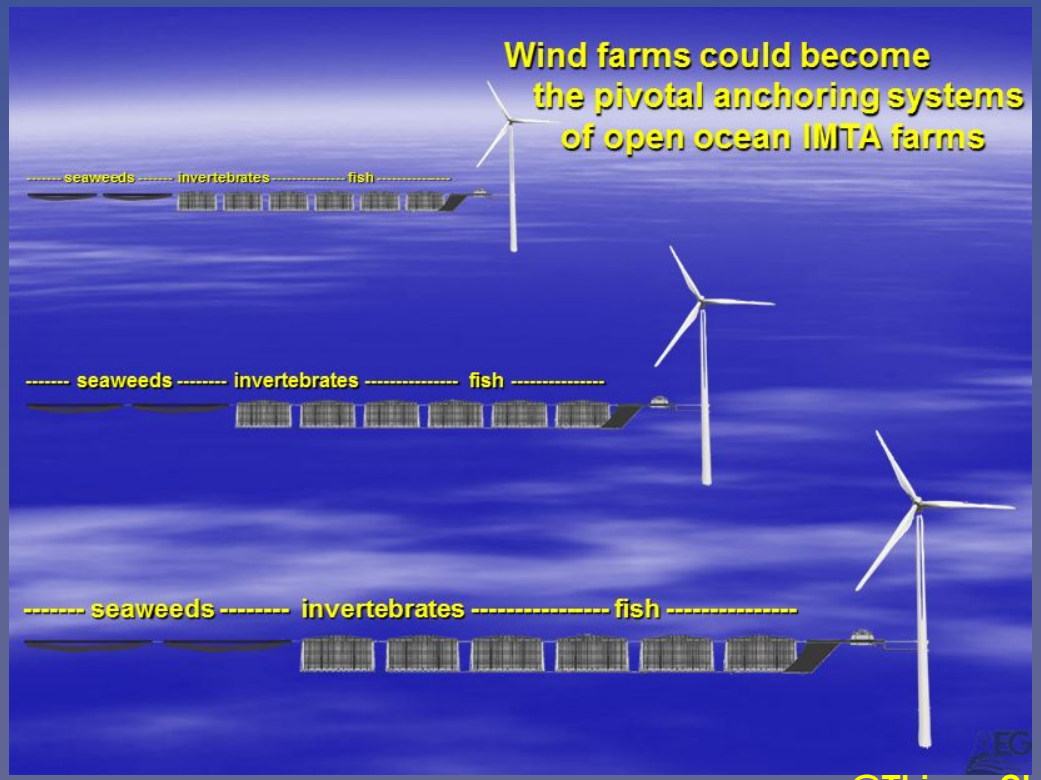
There is now a renewed interest in the mariculture of seaweeds for their integrated cultivation, the ecosystem services they provide and novel uses

- Biochar, methane, bioethanol, biofuels, biodiesels

- Seaweed cultivation in integrated food and renewable energy parks (IFREP) for reduced footprint



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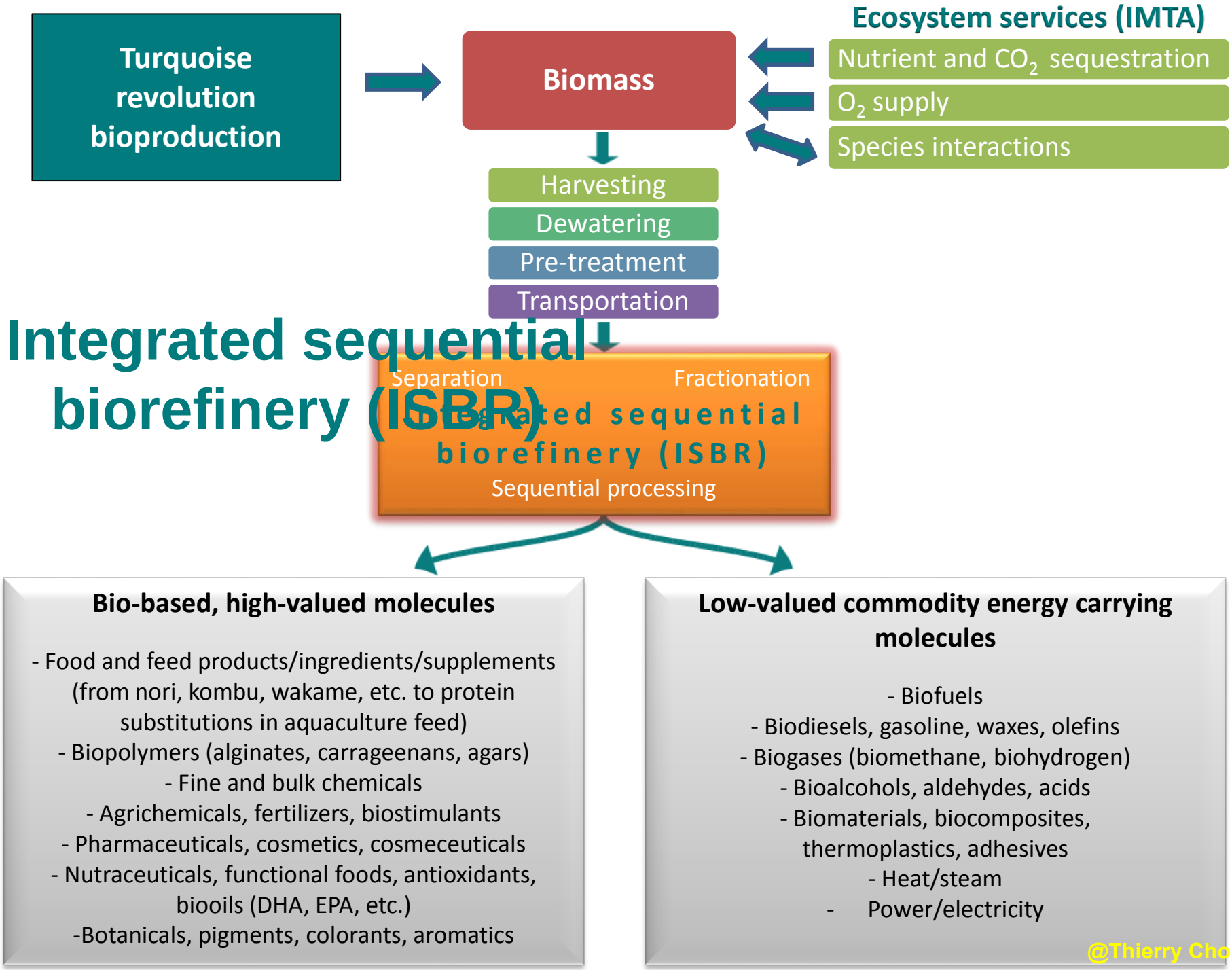
Beyond recapturing biological nutrients, IMTA is also about giving more value to co-products through their valorization and the regenerative diversification of their applications

We will have to change our attitudes and business models to evolve from the linear approach

one species – one process – one product

too often used with fishery and aquaculture products, to move towards the Integrated Sequential Biorefinery (ISBR) approach

one species – several processes – several products


Turquoise revolution bioproduction
Biomass
Ecosystem services (IMTA)
Nutrient and CO_2 sequestration
O_2 supply
Species interactions
Harvesting
Dewatering
Pre-treatment
Transportation
Integrated sequential biorefinery (ISBR)
Separation
Fractionation
Integrated sequential biorefinery (ISBR)
Sequential processing
Bio-based, high-valued molecules
- Food and feed products/ingredients/supplements (from nori, kombu, wakame, etc. to protein substitutions in aquaculture feed)
- Biopolymers (alginates, carrageenans, agars)
- Fine and bulk chemicals
- Agrichemicals, fertilizers, biostimulants
- Pharmaceuticals, cosmetics, cosmeceuticals
- Nutraceuticals, functional foods, antioxidants, biooils (DHA, EPA, etc.)
-Botanicals, pigments, colorants, aromatics
Low-valued commodity energy carrying molecules
- Biofuels
- Biodiesels, gasoline, waxes, olefins
- Biogases (biomethane, biohydrogen)
- Bioalcohols, aldehydes, acids
- Biomaterials, biocomposites, thermoplastics, adhesives
- Heat/steam
- Power/electricity
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ISBR diversification approach for our IMTA products

- Seaweeds for human consumption

- Seaweeds for cosmetics

- Seaweeds for partial fishmeal substitution

- Eco-certified salmon

- Organically-certified IMTA kelps

- Biochar production

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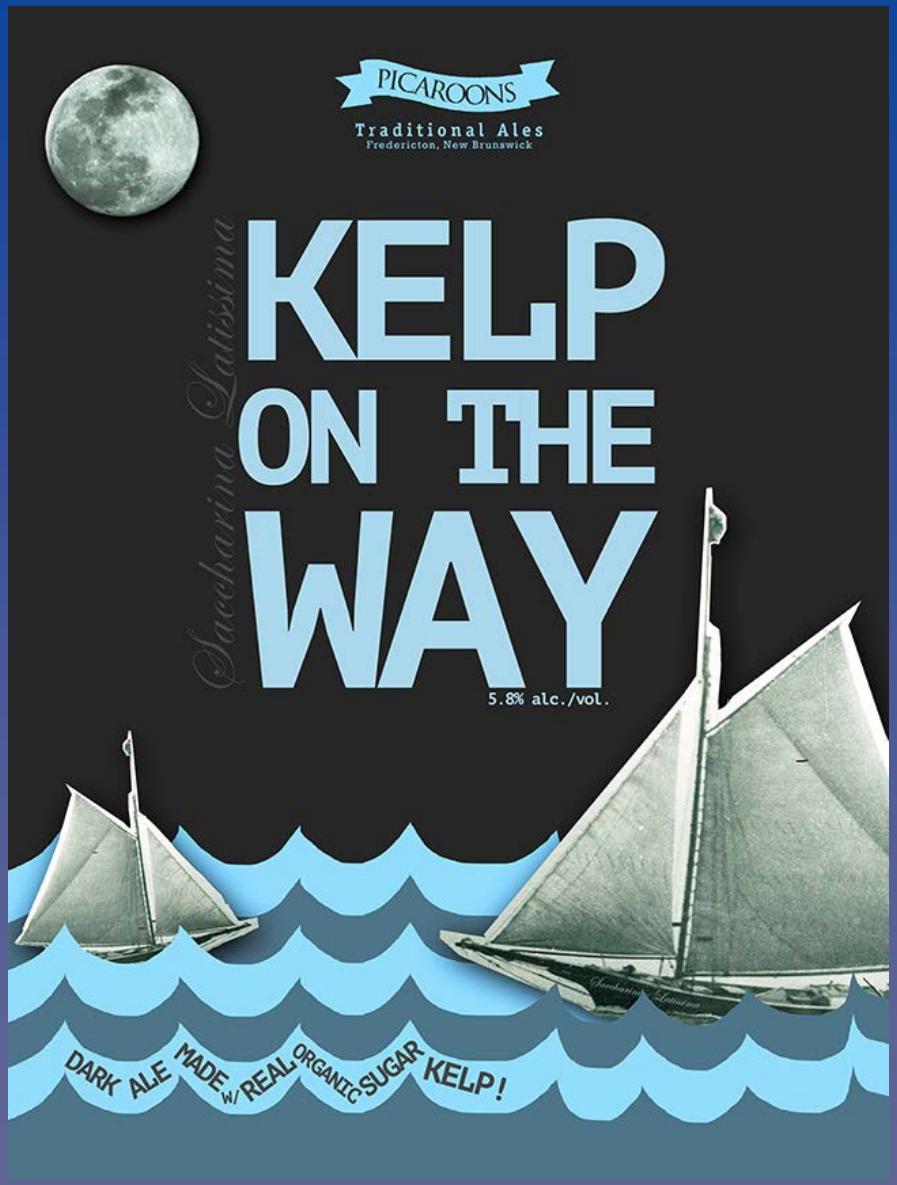

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We need to integrate the economic and societal aspects of IMTA

- Economic benefits derived from the biomitigative effects of IMTA

> Martínez-Espiñeira *et al.* (2015): contingent behaviour method

The aggregate benefit for current salmon consumers in Canada was estimated at about CAN$280 million/year (less restrictive assumptions yielded a figure of about CAN$1.5 billion/year)

> Martínez-Espiñeira *et al.* (2016): contingent valuation method

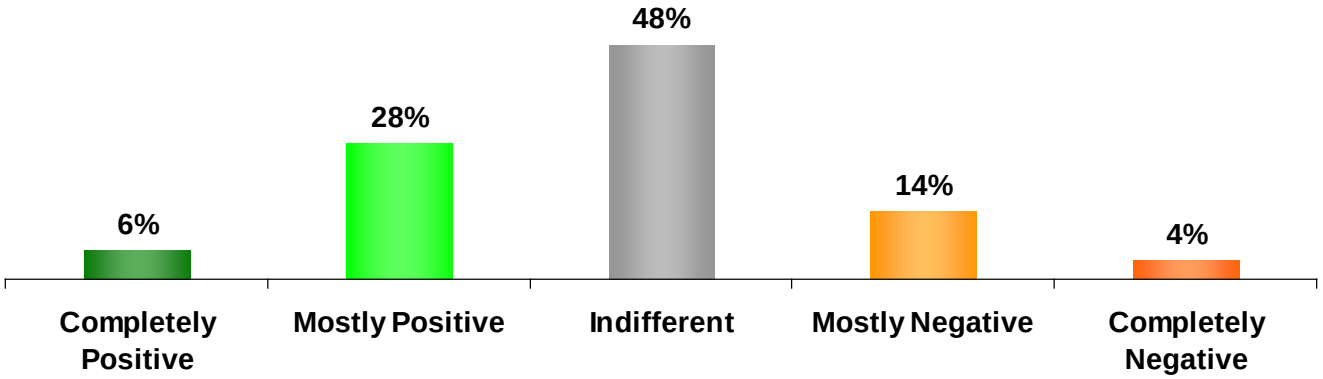
The benefits accruing to households that do not purchase salmon habitually would range between about CAN$43 million/year and CAN$65 million/year

- Intangible societal benefits of IMTA

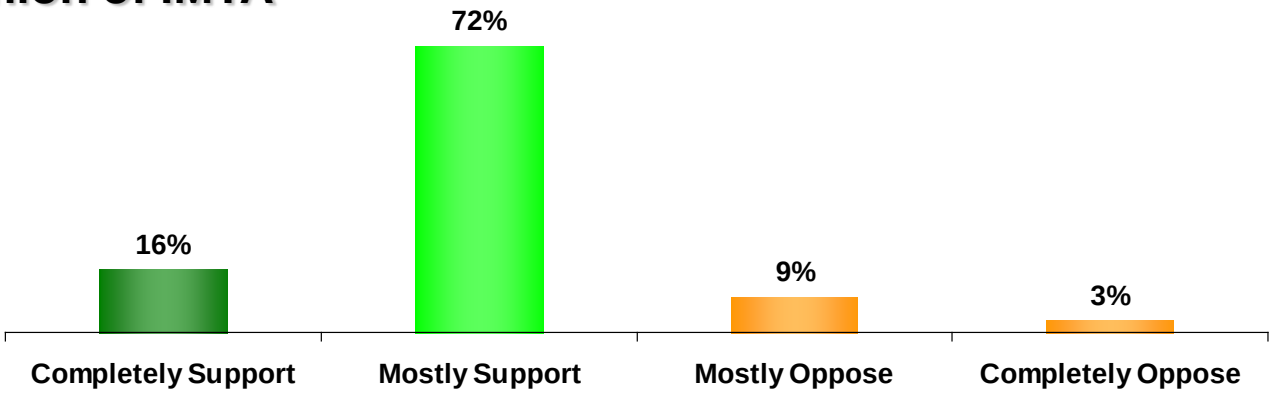
> Gaining consumer trust and societal and political license to operate (increasing aquaculture societal acceptability)

New York consumers are generally indifferent in their opinion of farmed fish and overwhelmingly support an IMTA approach

Current attitude toward farmed fish



Consumer opinion of IMTA



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> Differentiation and eco-certification for premium market prices

Organic

IMTA

kelps

CANADIAN CERTIFIED ORGANIC AQUACULTURE
SEAWEEDS

AQUACULTURE BIOLOGIQUE CERTIFIEE DU CANADA
ALGUES

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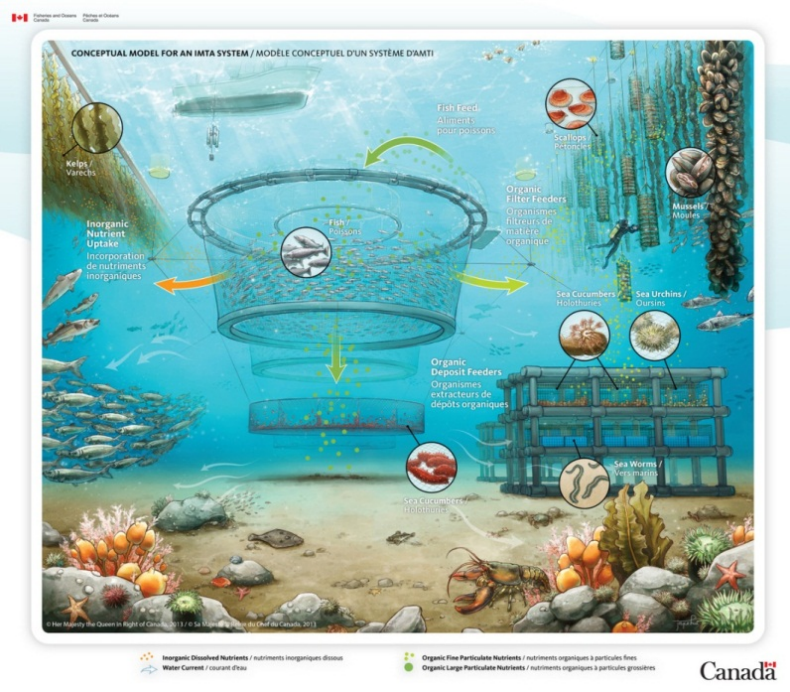
> Interest in IMTA by First Nations

It is time for:

- the Turquoise Revolution (a greener Blue Revolution)



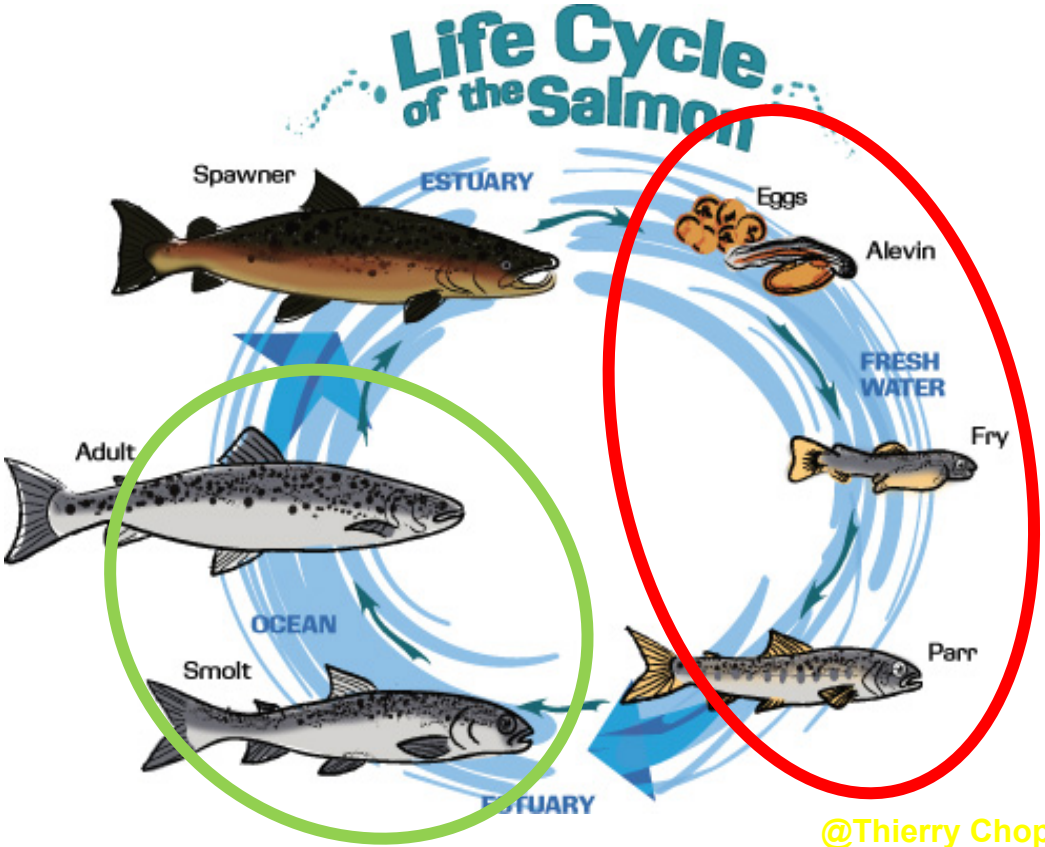
- the application of aquanomic principles in the management of our aquatic fields

- regulatory changes, flexible and enabling the implementation of innovative aquaculture practices

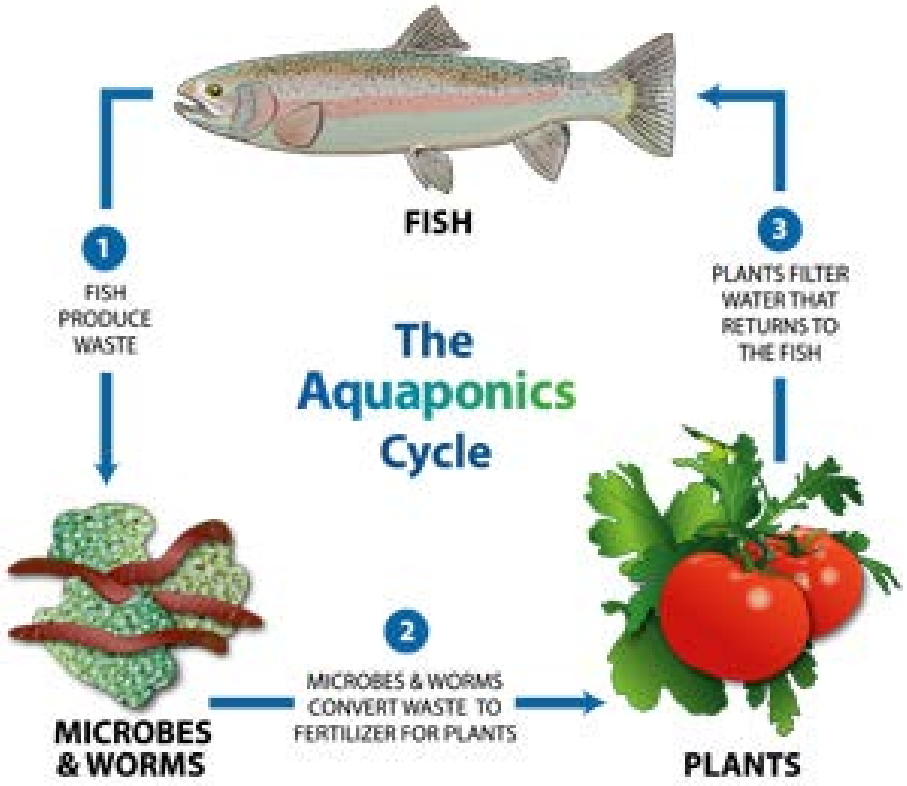
- the proper valuation of the ecosystem services provided by extractive species

- and the implementation of nutrient trading credits used as financial and regulatory incentive tools

- We have been working on developing IMTA for the seawater grow-out phase of Atlantic salmon aquaculture for the last 15 years (MIMTA)
- However, if salmon spend between 1.5 to 2 years in marine pens, it is after they have spent 12 to 18 months in land-based, freshwater hatcheries
- IMTA principles can also be applied to freshwater environments and species (FIMTA)



Freshwater IMTA (FIMTA) or Aquaponics



Benefits:

- Waste/nutrient recycling
- Reducing water usage by reusing it
- Helping farmers to meet water quality guidelines (in particular regarding phosphorus) and prevent eutrophication in the environment
- Product diversification
- Branding: ETPIMTA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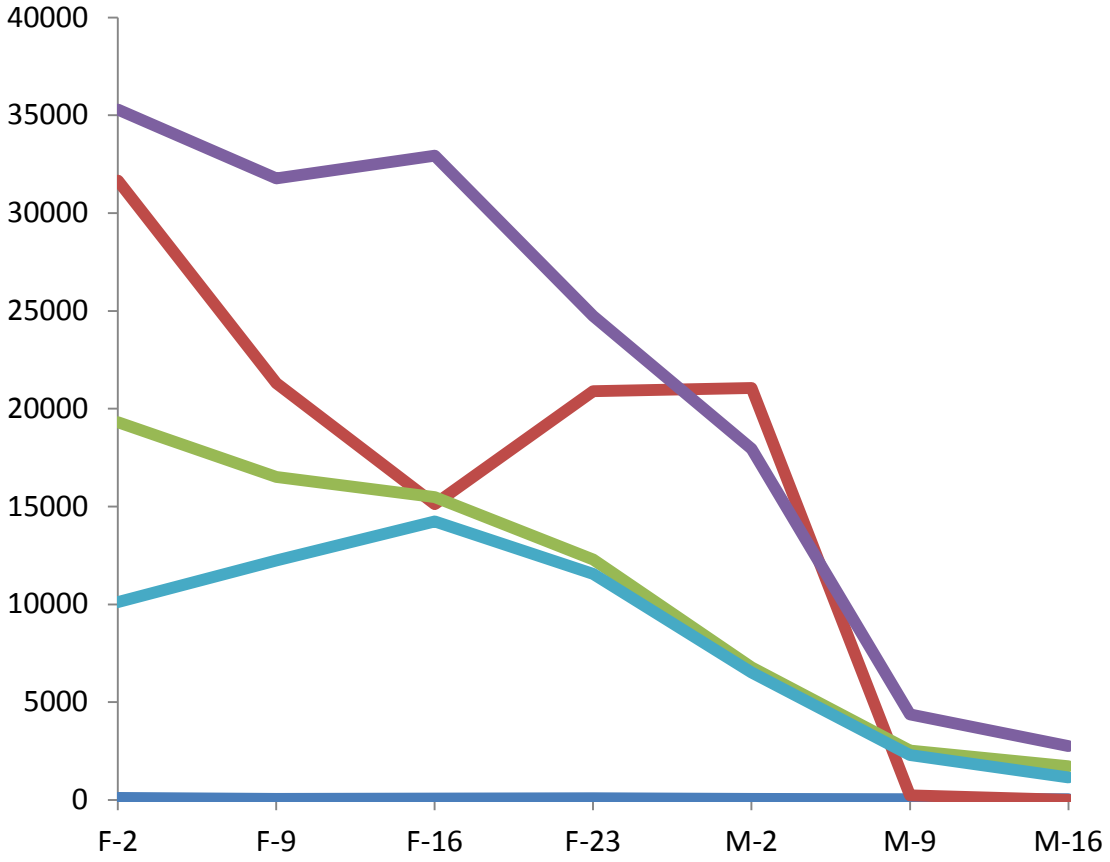
Floating raft trial three



	% change
NH4	61.25
Nitrite	99.97
Nitrate	91.07
TN	92.18
TP	88.65

Change in nutrient content (mg) in three raft tanks and header tank combined over a six week trial



INTEGRATED MULTI-TROPHIC AQUACULTURE

FIMTA + MIMTA = ETPIMTA

(going all the way with IMTA!)



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All that takes time to develop and implement…

Science and society need time to think and evolve…

… IMTA will not happen overnight, especially in the western world

We should realize that we are still in the infancy of western IMTA

Merci et bonne digestion!

www2.unb.ca/chopinlab/

https://www.youtube.com/watch?v=kZup18AZtzk

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