IMTA, a circulatory approach to aquaculture

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BioRural, Aquatic Systems, online, 28 November 2023

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Problem definition

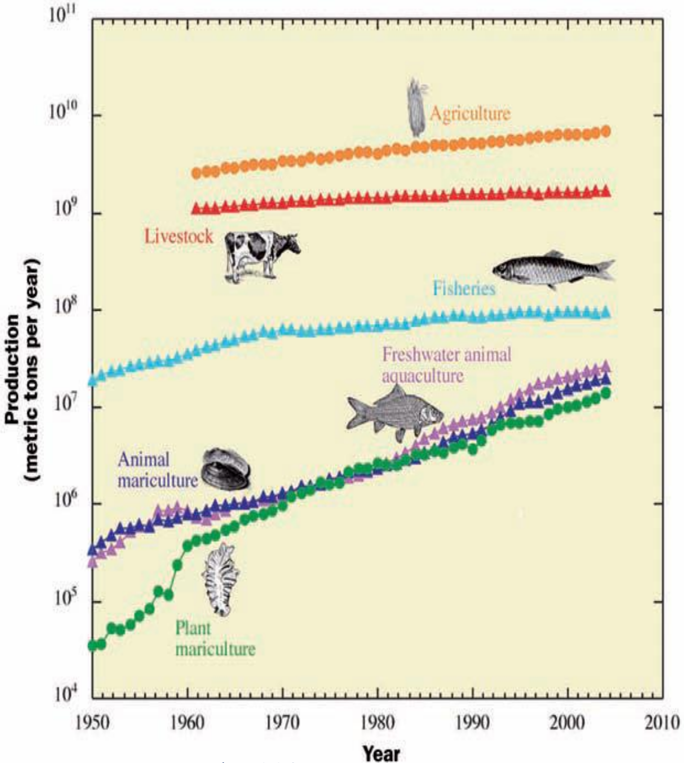
Increase in world population: 9 billion people by 2050 (UN)

Challenge: provide protein (food) for this population in a world that is already facing resource limitations (water, space, fertilizer, etc.) under pressure of climate change

Unlikely that agriculture can meet the demand

Global fisheries landings have fallen drastically since the mid-1980s, mainly due to overexploitation of fish stocks

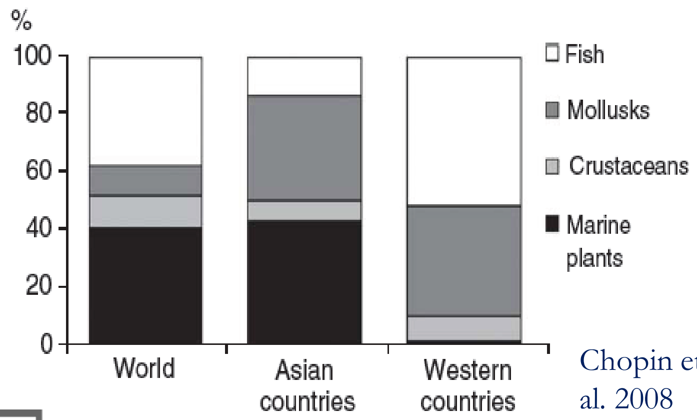
World is looking towards aquaculture (in particular marine aquaculture) as potential solution: **blue revolution**



Duarte et al. 2009

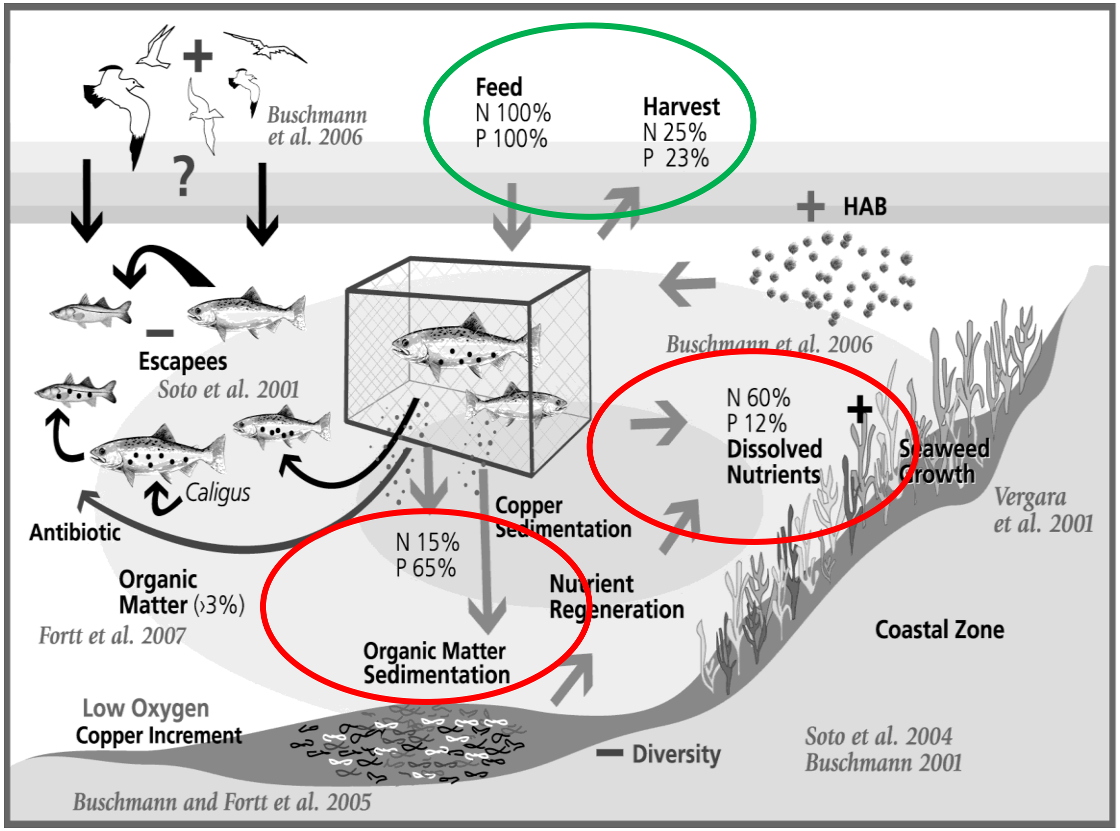
Problem definition

Large contrast agriculture and (western) aquaculture: aquaculture largely consists of carnivorous finfish aquaculture (salmon, sea bream, sea bass, etc.)



Chopin et al. 2008

Consequences for nutrient dynamics:



Buschmann et al. 2008

Only 25 % of the nitrogen added as feed is converted into product, the rest stays in the medium, provoking eutrophication, micro- and macroalgae blooms, etc.

Challenge

Circular approach required that decreases dependence on natural resources (fishmeal and fish oil) and reduces losses of energy and matter to the environment (closing of cycles), thereby also potentially improving economic benefits:

Integrated Multitrophic Aquaculture (IMTA)

- Enhanced production of aquatic organisms (with or without terrestrial organisms) of two or more functional groups, that are trophically connected by demonstrated nutrient flows and whose biomass is fully or partially removed by harvesting to facilitate ecological balance (Dunbar et al. 2020).
- IMTA is a form of aqua farming that utilizes the ecosystem services provided by organisms of low trophic levels (e.g. shellfish and seaweed) raised in appropriate ratio to mitigate the effects of organisms of high trophic levels (e.g. fish) (White 2007, Troell et al., 2003).

Definition is the means and not an end

Basis for implementation of IMTA in policies aimed to improve its commercial uptake

Possibilities for industry-driven eco-certification

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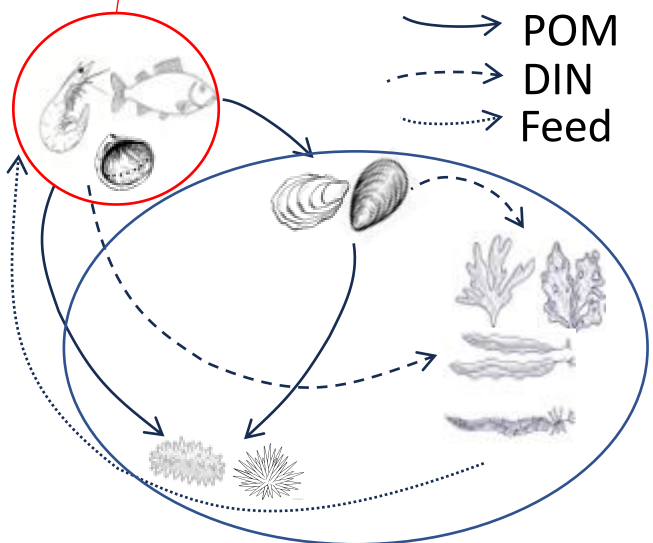
IMTA scheme

IMTA is a system that utilizes the waste from one species as nutrients for another to maximise the use of resources within the system

IMTA promotes environmental sustainability and economic viability

Fed species



Extractive species

Different species from various trophic levels are integrated in the system to balance it

IMTA can be applied in different environments and production units

Term IMTA is from 2004, however practice has a history of > 2,000 years

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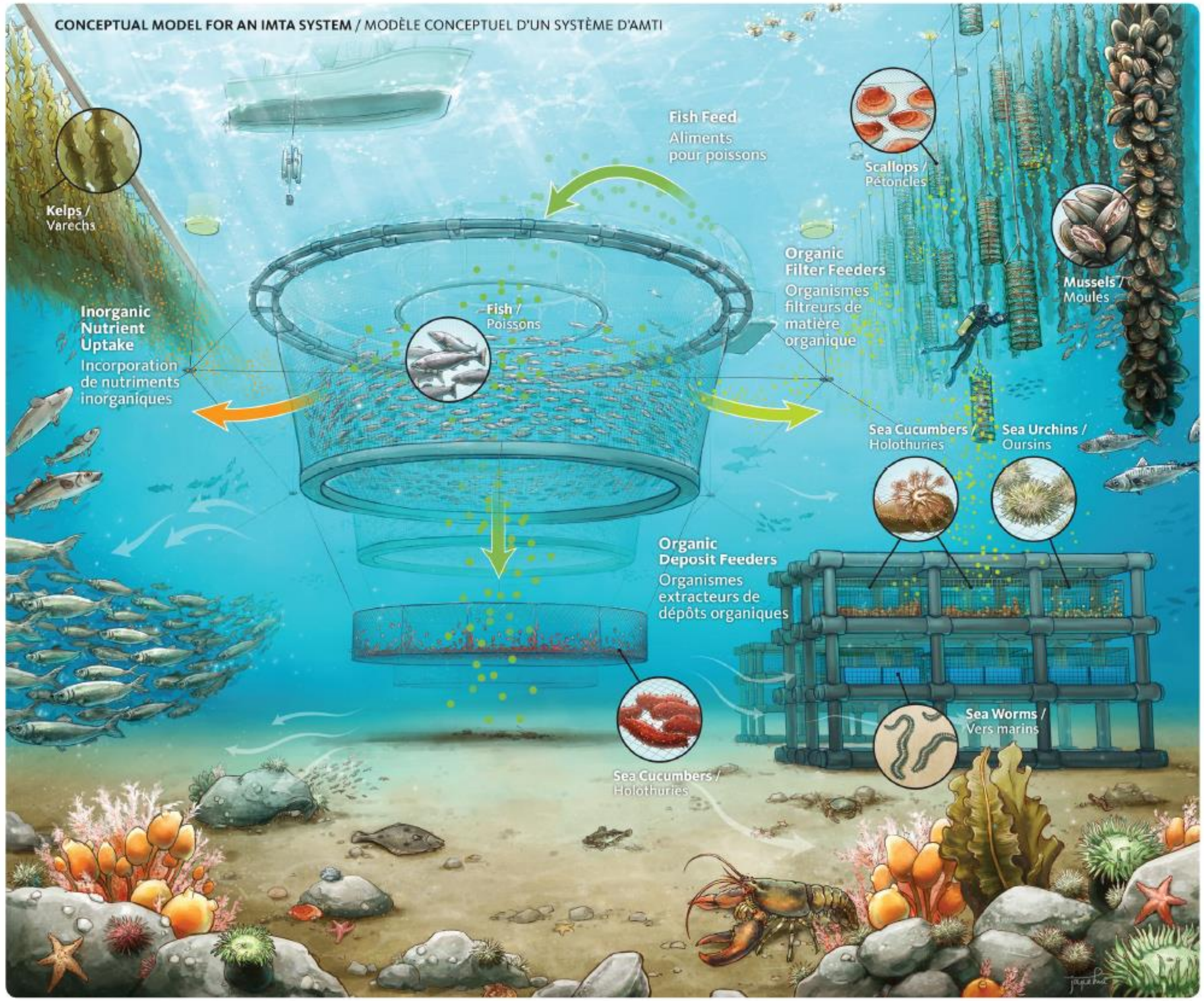
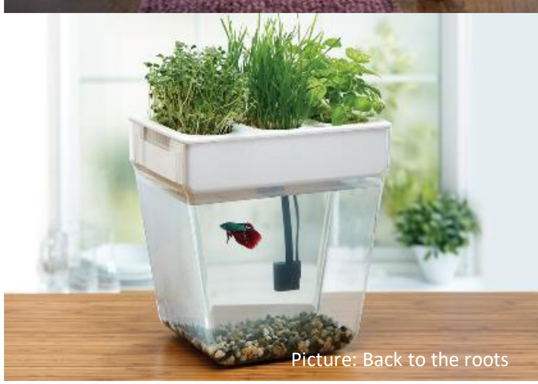
IMTA species systems and designs



Inorganic Dissolved Nutrients / nutriments inorganiques dissous
Water Current / courant d'eau
Organic Fine Particulate Nutrients / nutriments organiques à particules fines
Organic Large Particulate Nutrients / nutriments organiques à particules grossières

IMTA species systems and designs



Picture: Back to the roots

Buck et al. 2018

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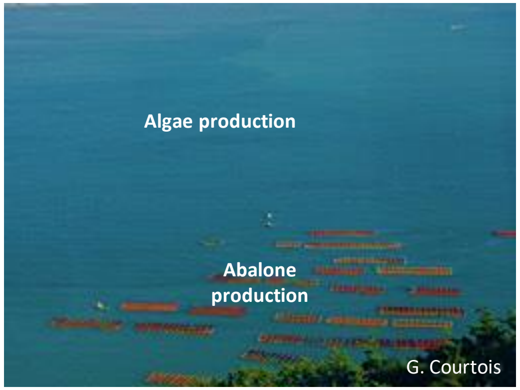
IMTA species systems and designs

Land based IMTA of low trophic species

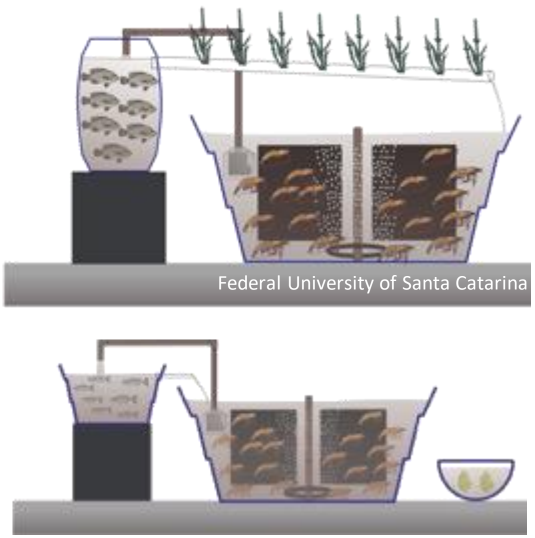
Land based IMTA of low trophic species



Sea Based IMTA of low trophic species

Applicability at different scales

IMTA species systems and designs



Biofloc IMTA Shrimp, tilapia,

Salicornia, shrimp, mullet seaweed

Higher yields and N&P retention,
increased seaweed nutritional quality

Aquaponics

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IMTA species systems and designs

Photo: Viking Aquaculture (https://www.vikingaquaculture.co.za/)

Ulva in combination with abalone

- Biofiltration
- Yield seeweeds reused as Feed ingredient

Bottlenecks

Problems with commercial uptake of IMTA-approach. Companies often specialist in one crop, but lack knowledge in others. **VERTICAL INTEGRATION** of enterprises is key here, IMTA is not necessarily limited to one company only.

Can also be applied to spatial planning of aquaculture activities, important is the balance of all activities with respect to use and recycling of nutrients.

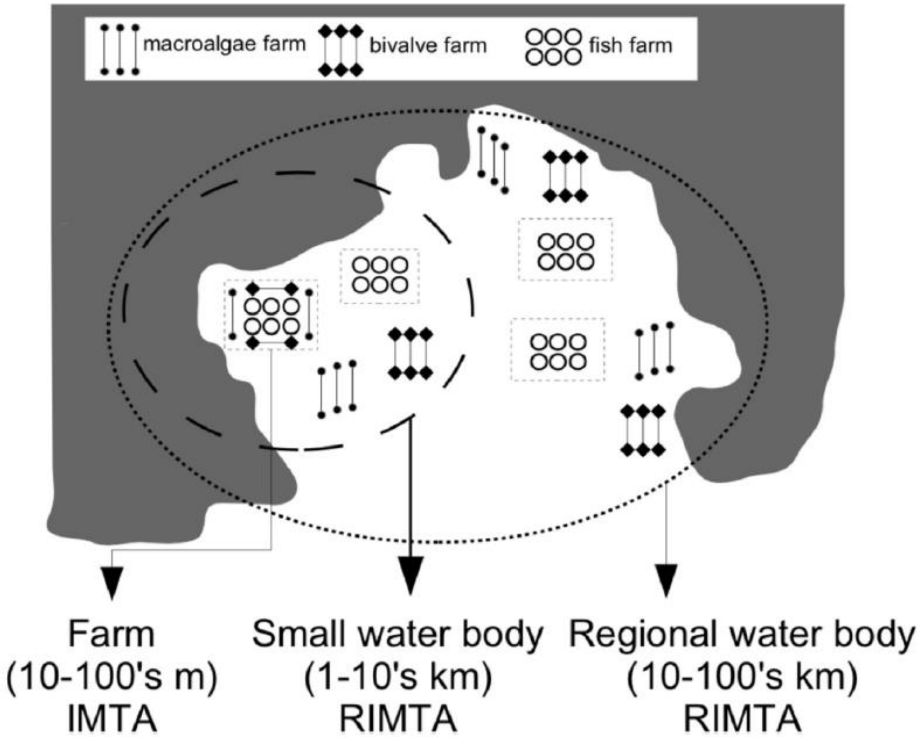

Fig. 2. Spatial scales of integrated multitrophic aquaculture (IMTA) and regional integrated multitrophic aquaculture (RIMTA).

Sanz-Lazaro & Sánchez-Jerez (2020) J Environ Manage 271

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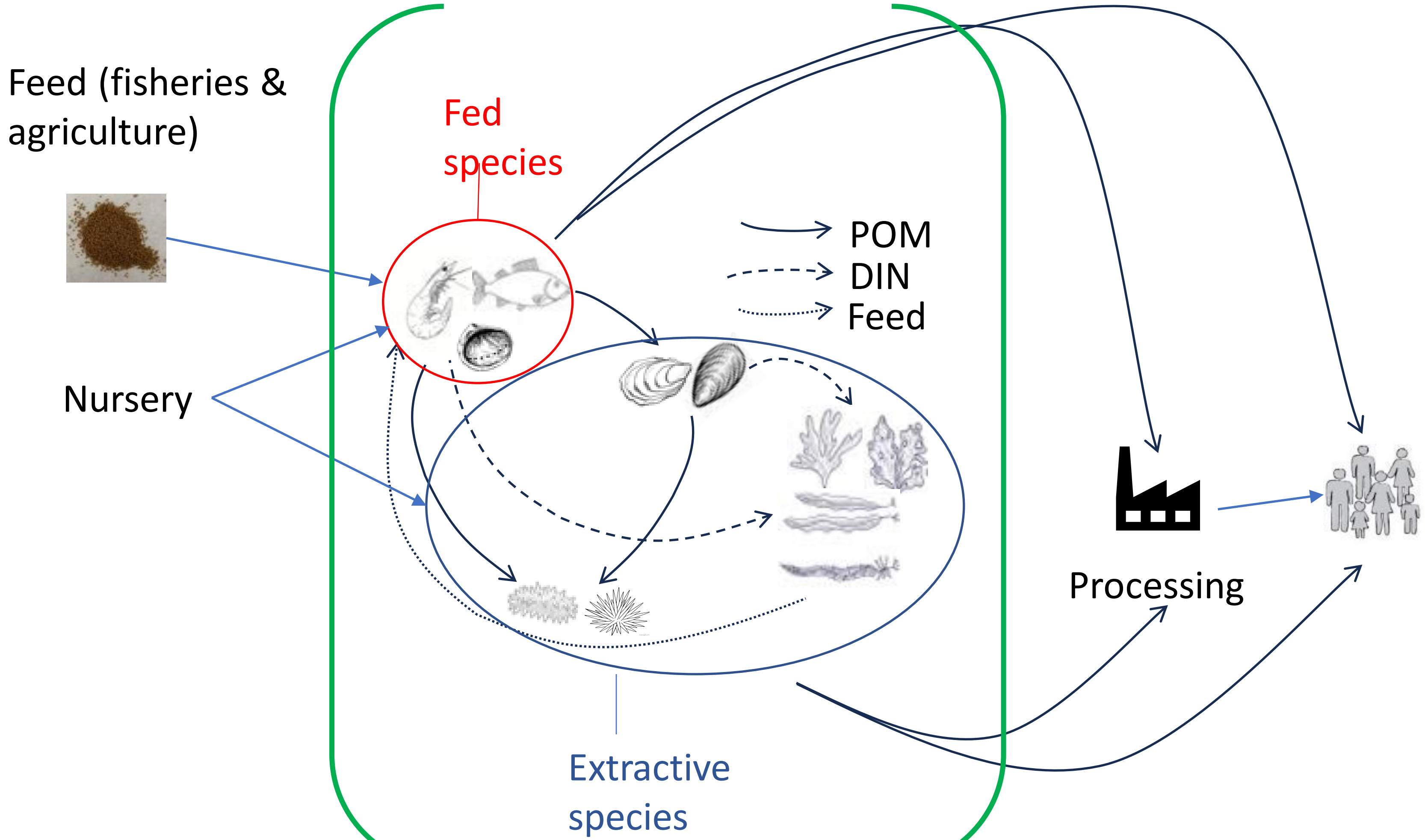
Application of circularity to IMTA systems, generally more limited to circularity (RECYCLING) of nutrients during production part



Tools for determining the degree of circularity

- Nutrient (C, N and P) fluxes and mass balances
- Fatty acid and stable isotope tracing
- (LCA)

MODELLING

Simplest mass balance model (static)

Input

Data: total amount provided cultivation period, nutrient composition

Crops

Data: total starting biomass, total harvested biomass, initial and final nutrient compositon of each crop

Simplest mass balance model

$$\% \, CIRC = \frac{\left(\sum MASS_{final} \times \%N, C, P_{final} - \sum MASS_{initial} \times \%N, C, P_{initial}\right)}{\sum_{t=0}^{t} FEED \times \%N, P, C_{FEED}} \times 100\%$$

Advantages:

Little data required

Fast, easy & cheap

Disadvantages:

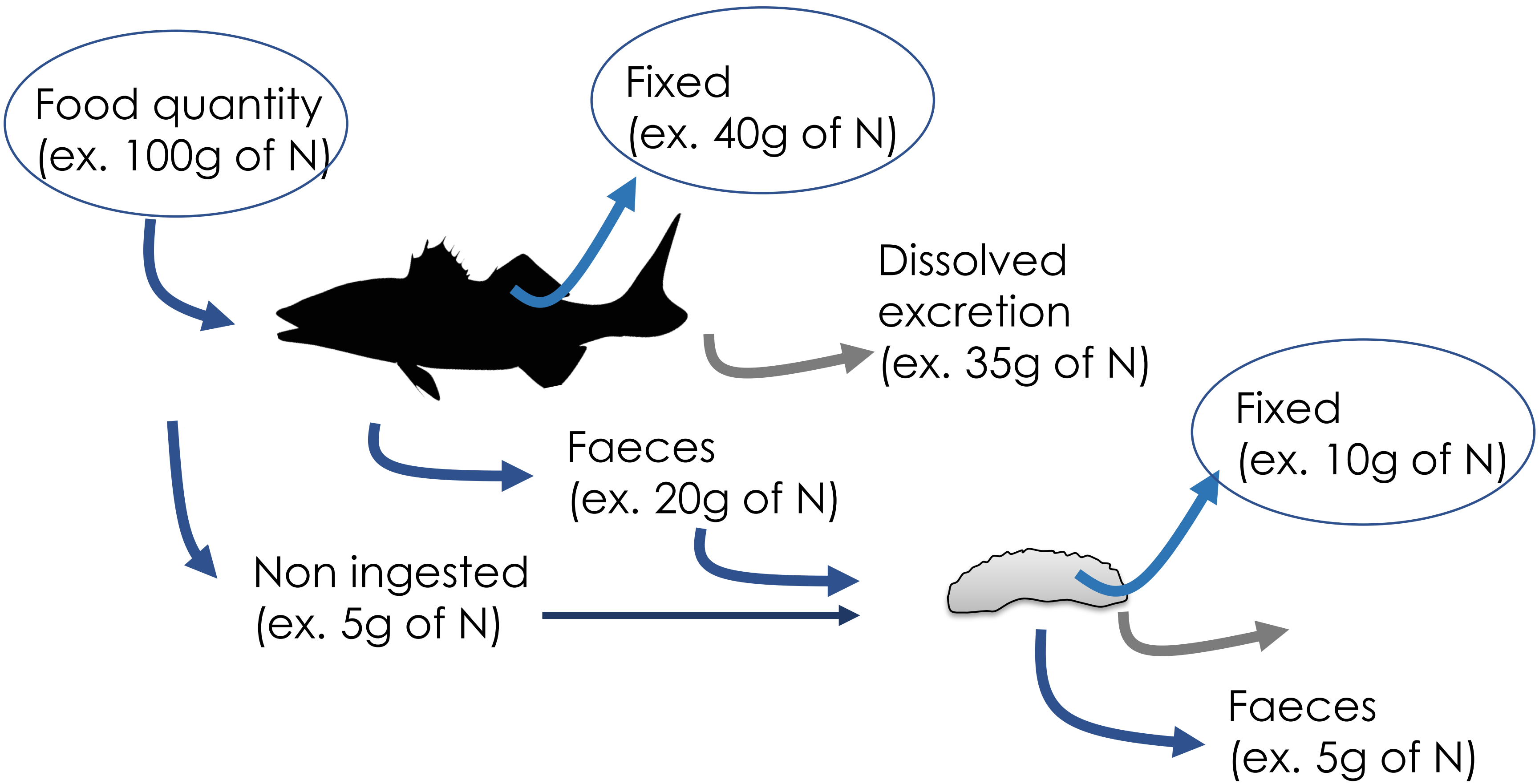
No process information

Does not account for other in- and outputs (e.g. dissolved nutrients)

Does not account for (intermediate) losses

Largest deviation expected in open water systems

More advanced flux models



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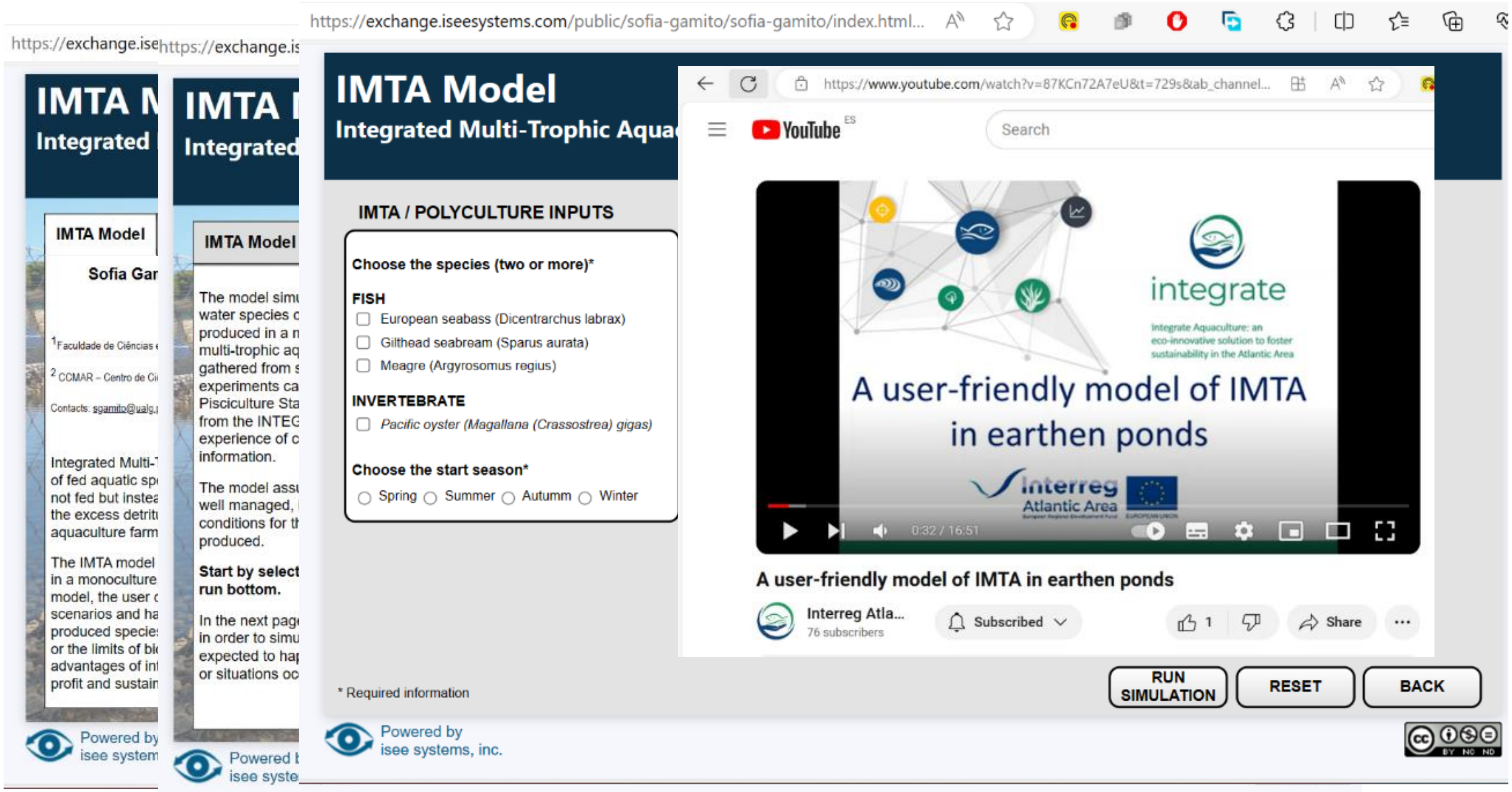
More advanced flux models

Many models already available in the literature and some online

University of the Algarve developed a user-friendly model of IMTA in earthen ponds within the Integrate project:



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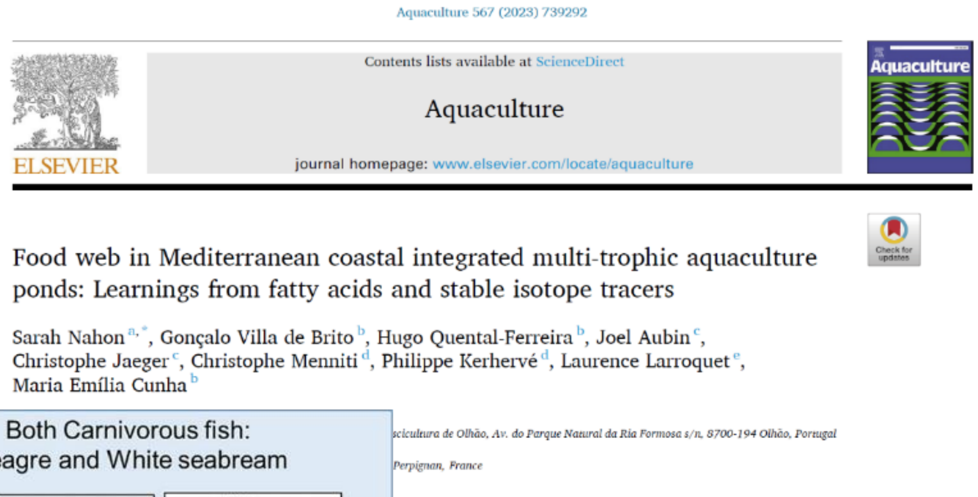
Fatty acid and stable isotope tracing

Combined routine measurements with the **SIA technique** and **FA analysis** can elucidate these trophic relationships and quantify nutrient sinks and sources for each trophic component.


Aquaculture 567 (2023) 739292

Contents lists available at ScienceDirect

Aquaculture

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Food web in Mediterranean coastal integrated multi-trophic aquaculture ponds: Learnings from fatty acids and stable isotope tracers

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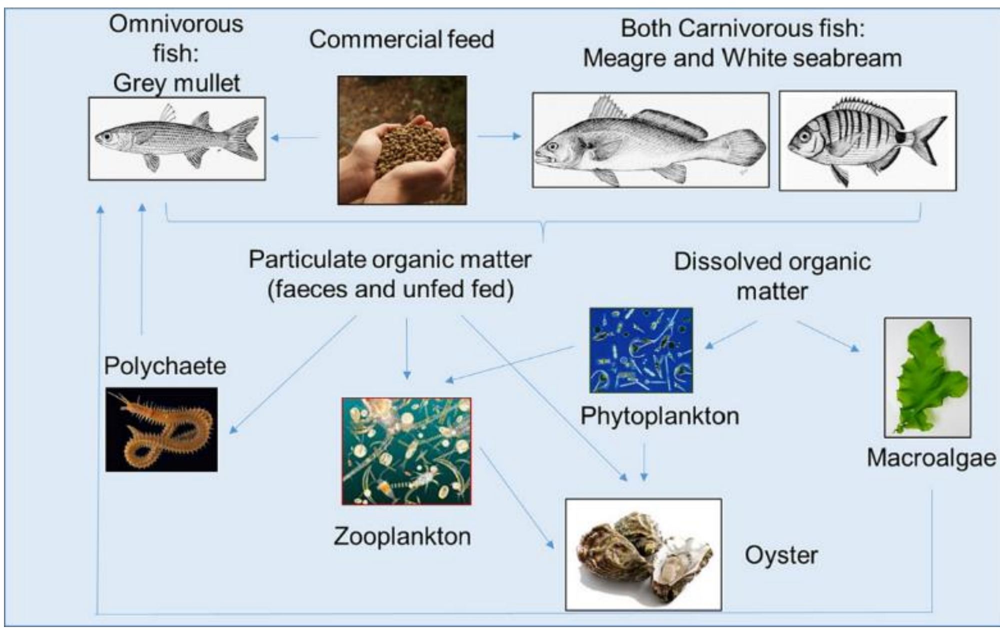

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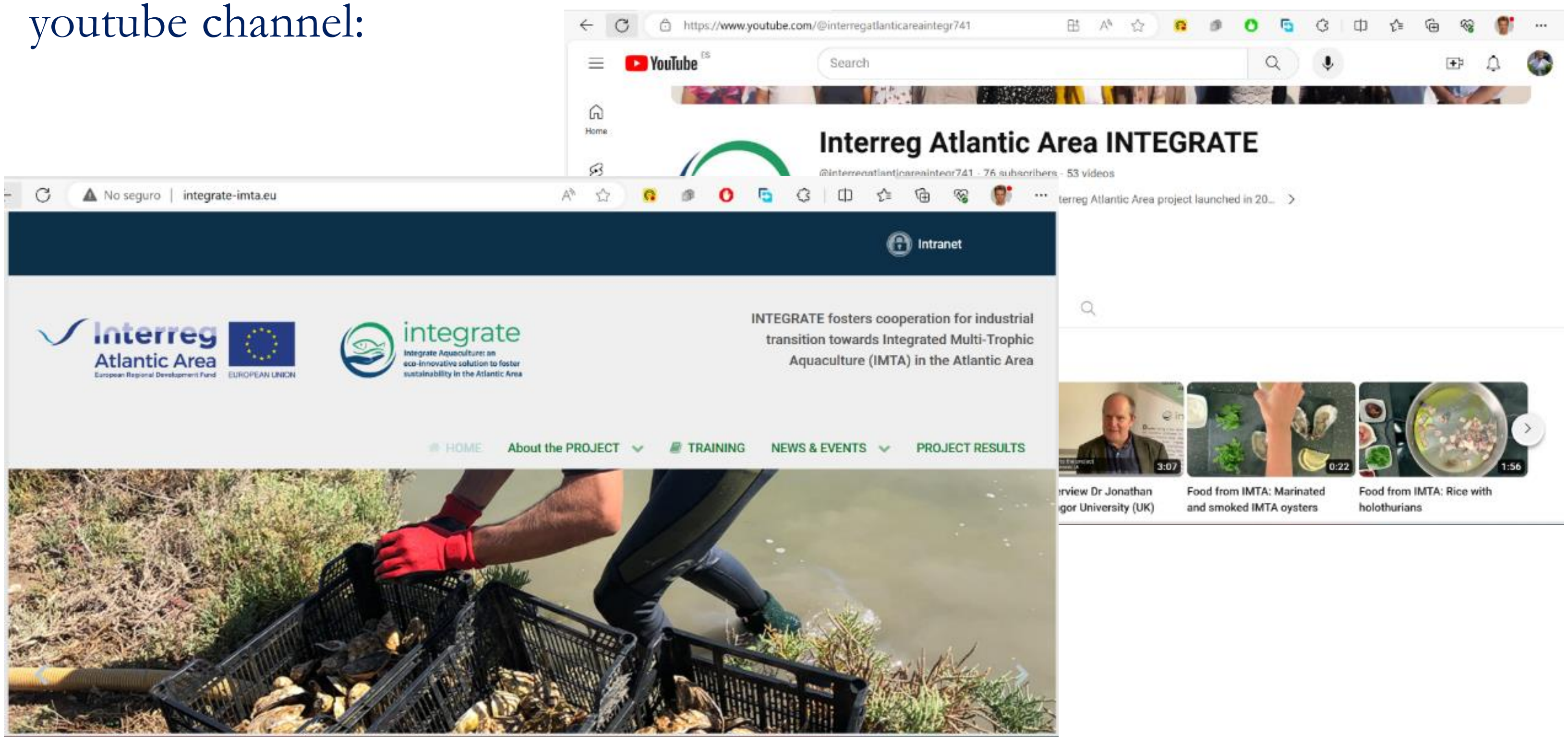
More information soon on…

Integrate project is finishing online course (11 modules, 20 – 40 mins. per module). Will be made available (end of this month) on Integrate website and youtube channel:



Many thanks to module presenters for the material used in this presentation:

Sofia Gamito & Emilia Cunha (Univ. Algarve), Bastien Sadoul (Inst. Agro), Nathalie Fenner (Bangor Univ.), Gercende Courtois (Univ. Las Palmas), Lais Sperenza (GreenCoLab) & María Galindo (CTAQUA)

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THANK YOU FOR YOUR ATTENTION

FUNDACIÓN CENTRO TECNOLÓGICO DE ACUICULTURA DE ANDALUCÍA

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