Department of Agriculture, Food and Environment & Department of Veterinary Sciences
University of Pisa

Webinar

The SIMTAP project for sustainable aquaponics

19th March, 2021 (MS TEAMS platform)

02.30 – 03.00 PM: ***Welcome and agenda***

- Marcello Mele, Chairman of the Department of Agriculture, Food and Environment
- Alberto Pardossi, SIMPTAP Coordinator
- Marco Gilmozzi (President of OP Acquacoltura Orbetello)

03.00 – 05.00 PM: ***Conceptual schemes of SIMTAP prototypes and first results in France, Italy and Turkey***

- Joël Aubin (INRAE, Rennes, France)
- Carlo Bibbiani (University of Pisa, Pisa, Italy)
- Mehmet Ali Kocer (Mediterranean Fisheries Research Production and Training Institute, Antalya, Turkey)
- Daniele Torreggiani (University of Bologna, Bologna, IT

05.00 – 05.15 PM: ***Break***

05.15 – 05.35 PM: ***General approach and methodology for the assessment of SIMTAP sustainability***

- Joël Aubin (INRAE, Rennes, France)
- Jacopo Bacenetti (University of Milano, Milano, Italy)

05.35 – 06.15 PM: ***General discussion and conclusions***.

REGISTRATION: the participation in this webinar is free. Participants are pleased to fill out the registration form by **March 14th, 2021**; the registration will be on first come-first serve basis due to the participant limit on MS Teams. The URL link to the webinar will be sent by email to the registered participants.

INFO*:* www.simtap.eu; Prof. Alberto Pardossi, alberto.pardossi@unipi.it.

Videorecording on YouTube

University of Bologna | University of Milano | Korolev GmbH | INRA UMR SAS Sol Agro et hydrosystème Spatialisation | Lycée de la Mer et du Littoral | Ministry for the Environment, Sustainable Development & Climate Change | Mediterranean Fisheries Research Production and Training Institute | University of Pisa

Department of Agriculture, Food and Environment & Department of Veterinary Sciences
University of Pisa

“Self-sufficient Integrated Multi-Trophic AquaPonic systems for improving food production sustainability and brackish water use and recycling – SIMTAP

Carlo Bibbiani, Baldassare Fronte, Lorenzo Rossi, Chingoileima Maibam, Adriana Ciurli, Martina Puccinelli, Chiara Sangiacomo, Giulia Carmassi, Rita Maggini, Riccardo Pulizzi & Alberto Pardossi

European Commission

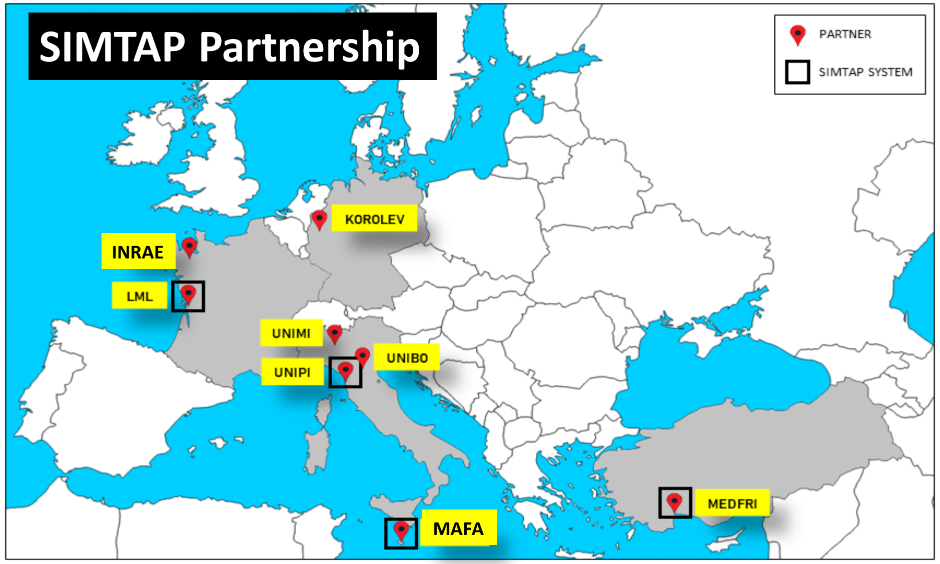
The PRIMA programme is supported under Horizon 2020, the European Union’s Framework Programme for Research and Innovation

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

The partnership

- **UNIPI**: University of Pisa (ITALY); PI/TL Proff. Alberto Pardossi and Carlo Bibbiani.
- **UNIBO**: University of Bologna (ITALY), TL Prof. Daniele Torreggiani.
- UNIMI: Università di Milano (ITALY); team leader Dott. Jacopo Bacenetti.
- **INRAE**: INRAE-Agrocampus, SAS Sol Agro et hydrosystème Spatialisation, Rennes (FRANCE), TL leader Dott. Joel Aubin.
- **LML**: Lycée de la Mer et du Littoral, Bourcefranc le Chapus (FRANCE), TL Dott. Vincent Gayet.
- **MEDFRI**: Mediterranean Fisheries Research Production and Training Institute, Antalya (TURKEY), TL Dott. Mehmet Ali Turan Koçer.
- **MAFA**: Ministry for Agriculture, Fisheries and Animal Rights, Agriculture Directorate Marsa (MALTA), TL Marcelle Agius)
- **KOROLEV**: Korolev GmbH, Bonn (GERMANY), TL Dott. Rainer Linke)

www.simtap.eu

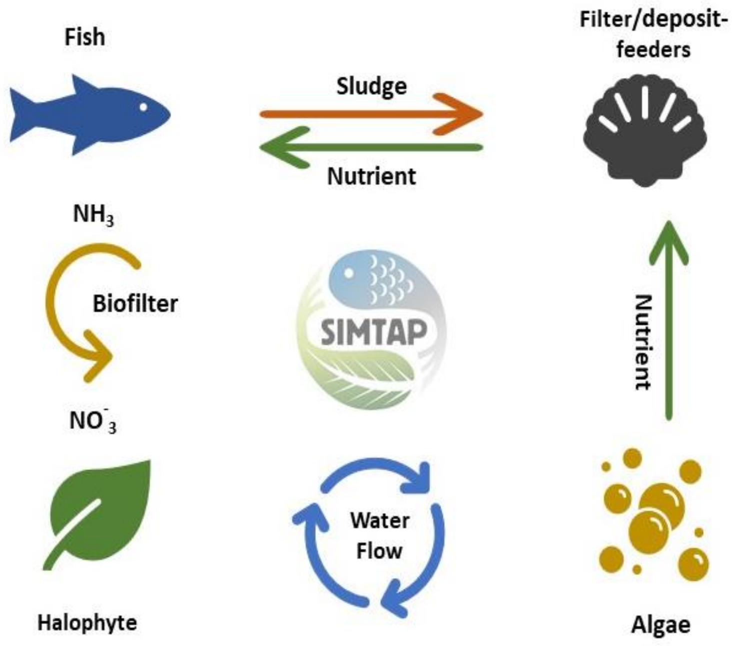


The conceptual framework of SIMTAP (1)

Integrated Multitrophic Aquaculture (IMTA) is one of the most promising pathways in the evolution of sustainable aquaculture systems.

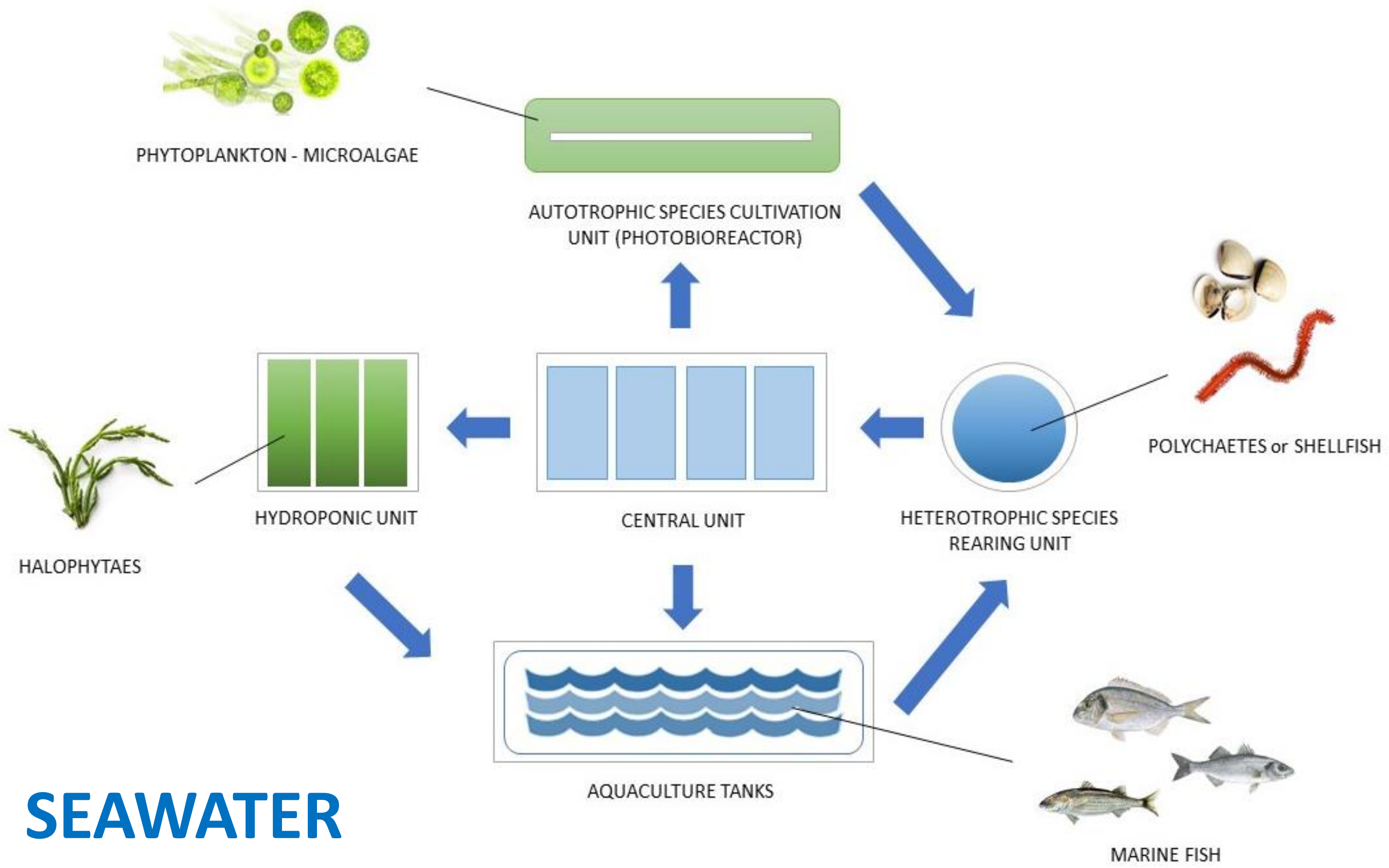
Inorganic and organic wastes coming from fed aquaculture species (e.g. finfish) are respectively assimilated by:

- autotrophic species (e.g. phytoplankton, micro/macroalgae and plants) and
- heterotrophic species (i.e. oysters, mussels, crustacean, echinoderms and polychaetes) that are co-cultured with the aquaculture species.



The **SIMTAP** project was born from this concept!

The conceptual framework of SIMTAP (2)



A simplified layout of a SIMTAP system with polychaetes and/or shellfish unit as deposit/filter feeders.

The goals of the SIMTAP project are:

- reducing faeces/solid substrates from fish farms discharged into the environment;
- assessing to what extent an integrated production of micro/macro algae and deposit/filter feedes can replace the feed production;
- using water runoff from greenhouse crops as a viable source of water and nutrients (N, P) for algae growth.

The conceptual framework of SIMTAP (3)

Project aims

- Evaluating performance of four SIMTAP systems/prototypes installed in France,Italy, Turkey and Malta:
    - food production
    - use of energy
    - use of water
    - other resources.

- Life Cycle Cost (LCC) studies will be specifically linked to the technical proposal for achieving reasonable prized solutions for low-medium technological level countries.

- Life Cycle Assessment (LCA)
- Emergy assessment
- Economic assessment

THANK YOU VERY MUCH FOR YOU ATTENTION

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The SIMTAP project for sustainable aquaponics
March 19th 2021

SIMTAP

Conceptual schemes of SIMTAP prototypes and first results

in France

Joël Aubin, Vincent Gayet, Christophe Jaeger,

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Rationale of the protoype

Despite the increasing demand in seafood, several factors impair the development of aquaculture in Mediterranean countries.

The global changes :

- Climate change, with increasing frequency of warm periods
- Prices volatility of seafood and inputs (aquafeed)
- Availability of resources in competition with human or livestock

The environmental impacts

- Emissions of polutants in surrounding aquatic ecosystems
- Settlement on sensitive areas : coastal areas having specific biodiversity
- Use of fragile resources such as fishmeal and fishoil
- Contribution to climate change

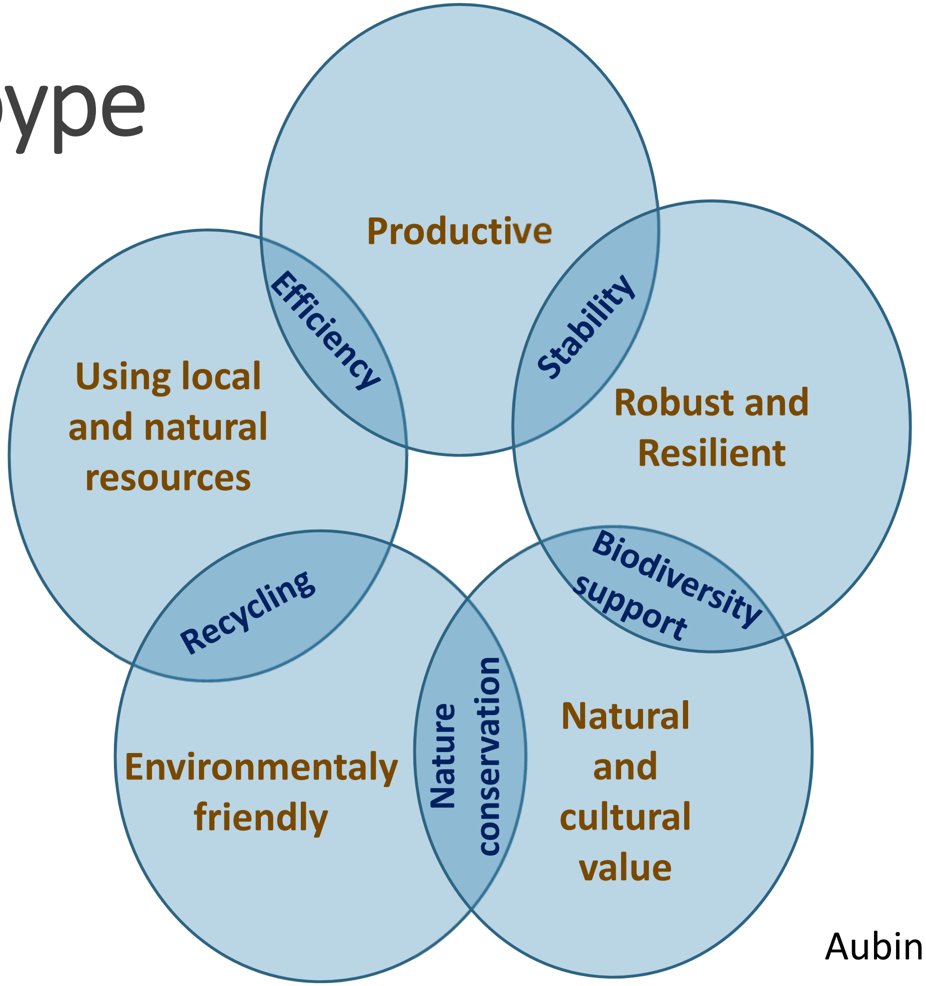
The perception by consumers and citizens

- Another kind of intensive livestock
- Comparison with fisheries considered as « natural sources »
- competition for access to coastal areas, especially with tourism

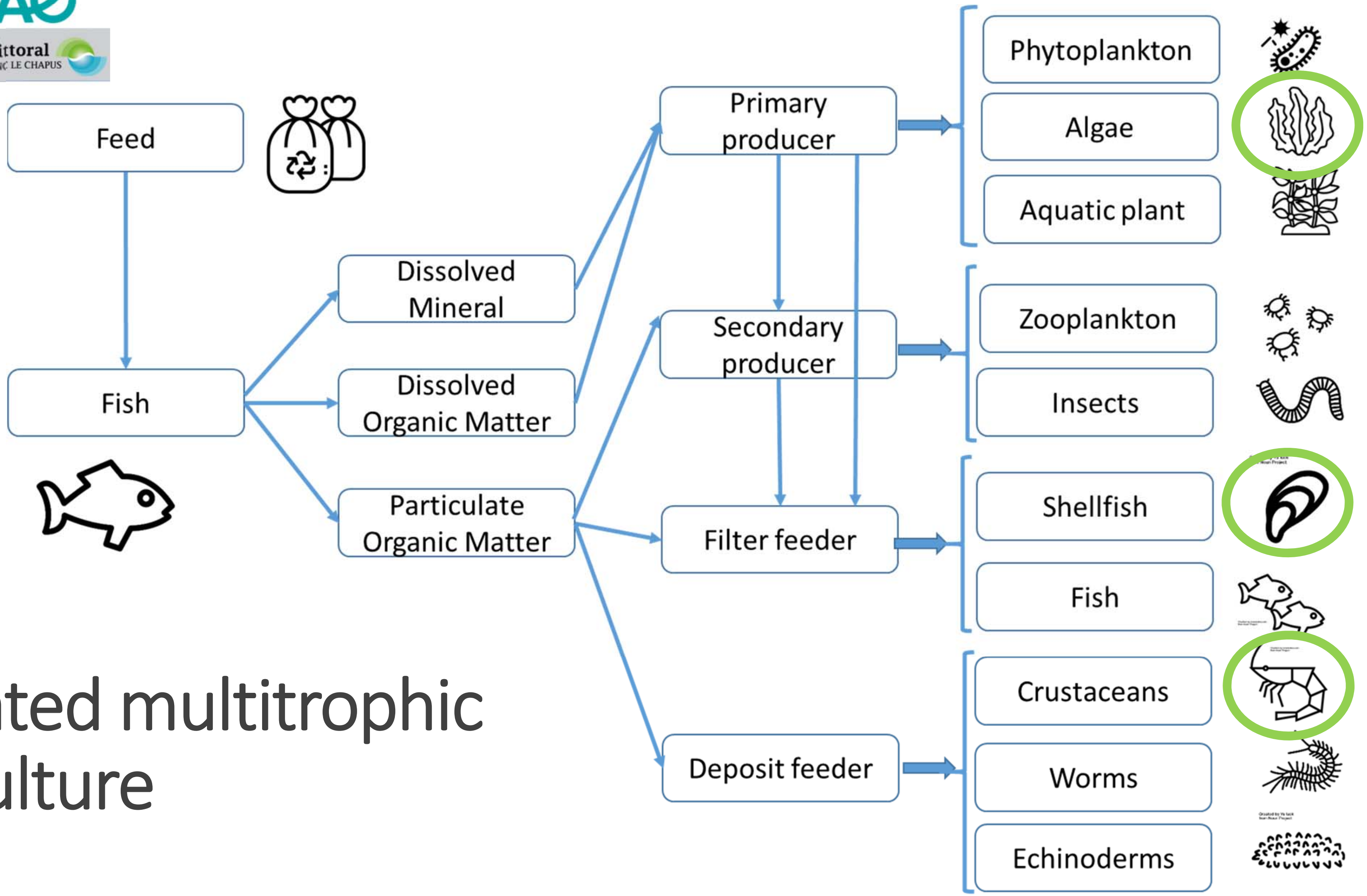
Rationale of the protoype

Principles to drive the development of agroecological pond systems

Specific Integrated Multi Trophic Aquaculture system



Aubin et al. 2017



IMTA
integrated multitrophic aquaculture

Rationale of the protoype

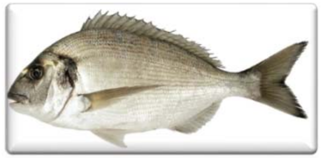
- **Productive :** producing species at good yield and having economic sense : oyster, clam, prawn, seabream, Ulva

- **Robust and Resilient :** producing several species to balance market variations, using robust species adapted to fluctuating environment

- **Natural and cultural value :** Using species having cultural and gastronomic value, reared in traditional oyster pond

- **Environmentaly friendly:** recycling the nutrient, closing the water loop and using low level of energy

- **Using local and natural resources :** using low level of feed, with no fishmeal and fishoil, with no imported ingredients, and complemented with local discarded mussels.



Saprus aurata

Crassostrea gigas

Ruditapes philippinarum

Marsupenaeus japonicus

Ulva lactuca

Partnership

INRAE-UMR SAS

National reasearch institute for agriculture, environment and food.

Research Unit specialist in environmental assessment and design of agri and aqua –culture systems

- Joël Aubin
- Aurélie Wilfart
- Christophe Jaeger
- Nouraya Akkal-Corfini
- Marc Roucaute
- Samuel Le Féon
- Théo Dubois

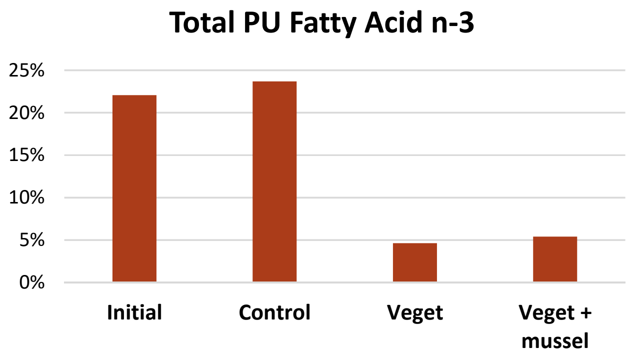
Lycée de la Mer et du Littoral

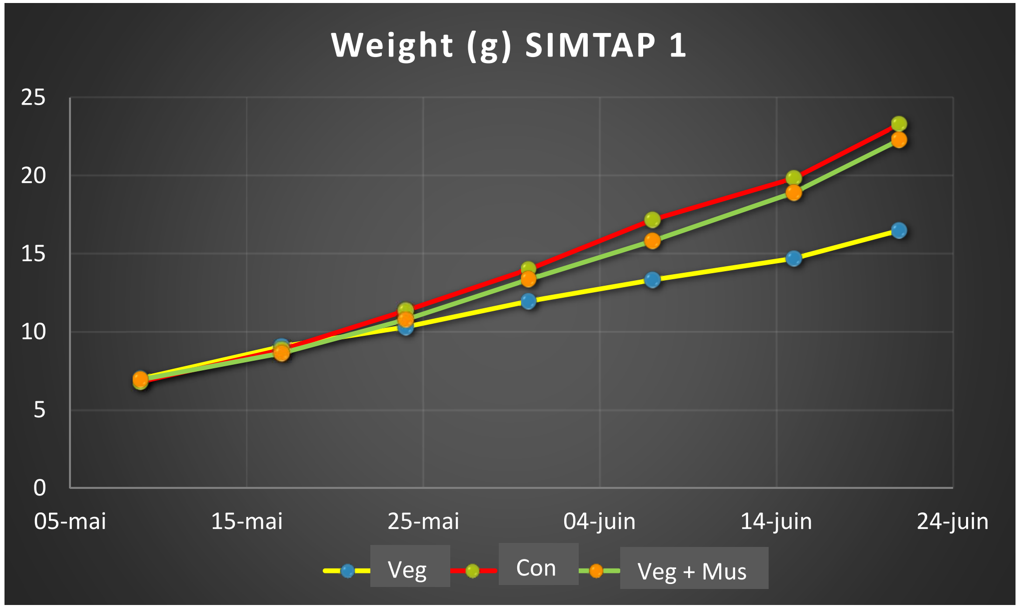
- General and technological (aquaculture) school up to BAC+2
- Professional licence with La Rochelle University
- Oyster educational farm
- Educational aquaculture facilities

- Vincent Gayet
- Thomas Jamet
- Marie Durollet
- And the students…

Question: is it possible to feed seabream without fishmeal and fish oil using mussel complementation?

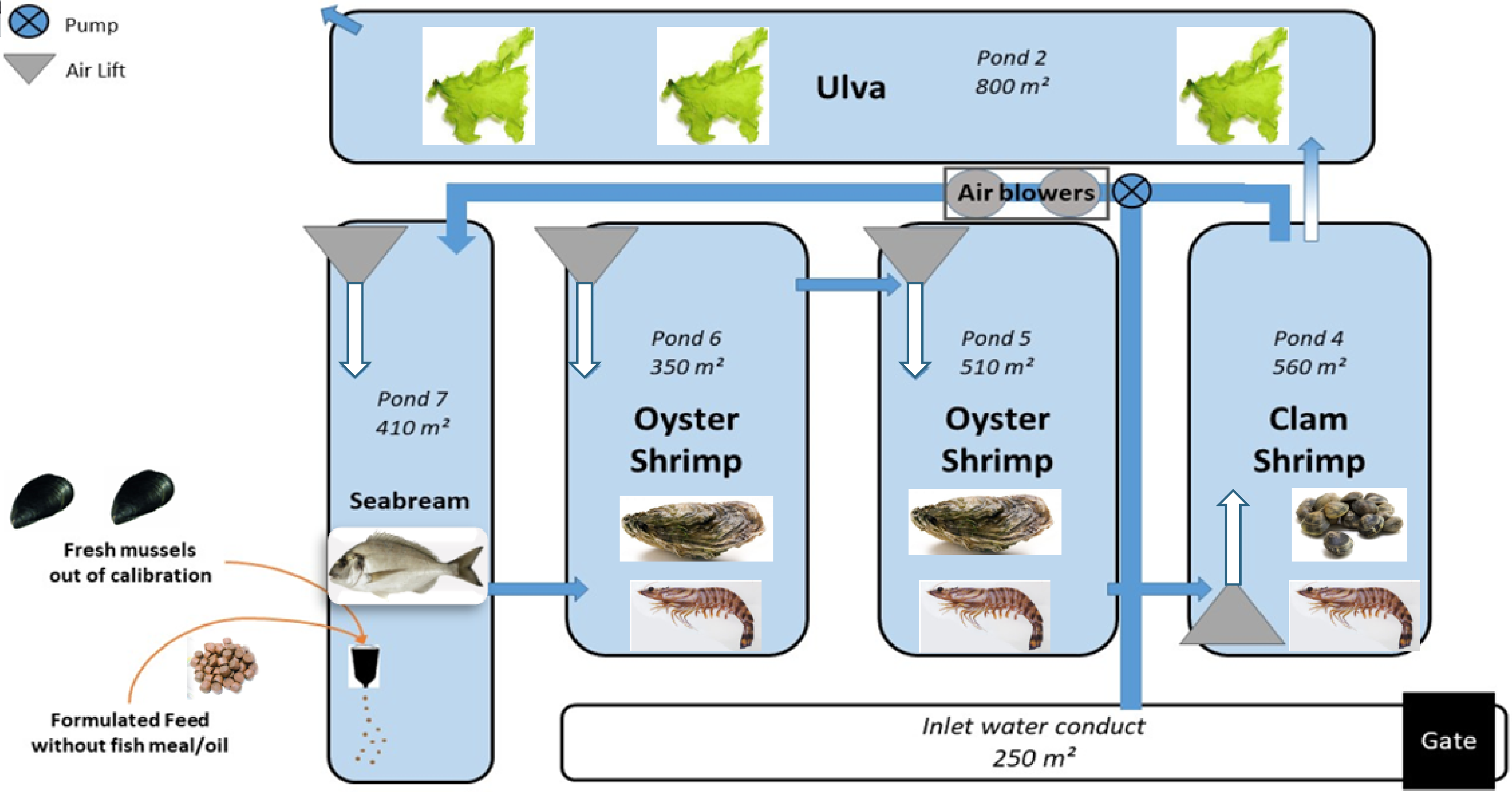
Seabreams of 6.9g
3 groups fed with:
- Commercial feed (53% prot, 17% lipid), 6 days/week B2
- Plant based feed (53% prot, 17% lipid), 6 days/week B1
- Vegetable feed, 5 days/week + mussel (iso energetic to feed), 1 day/week B3



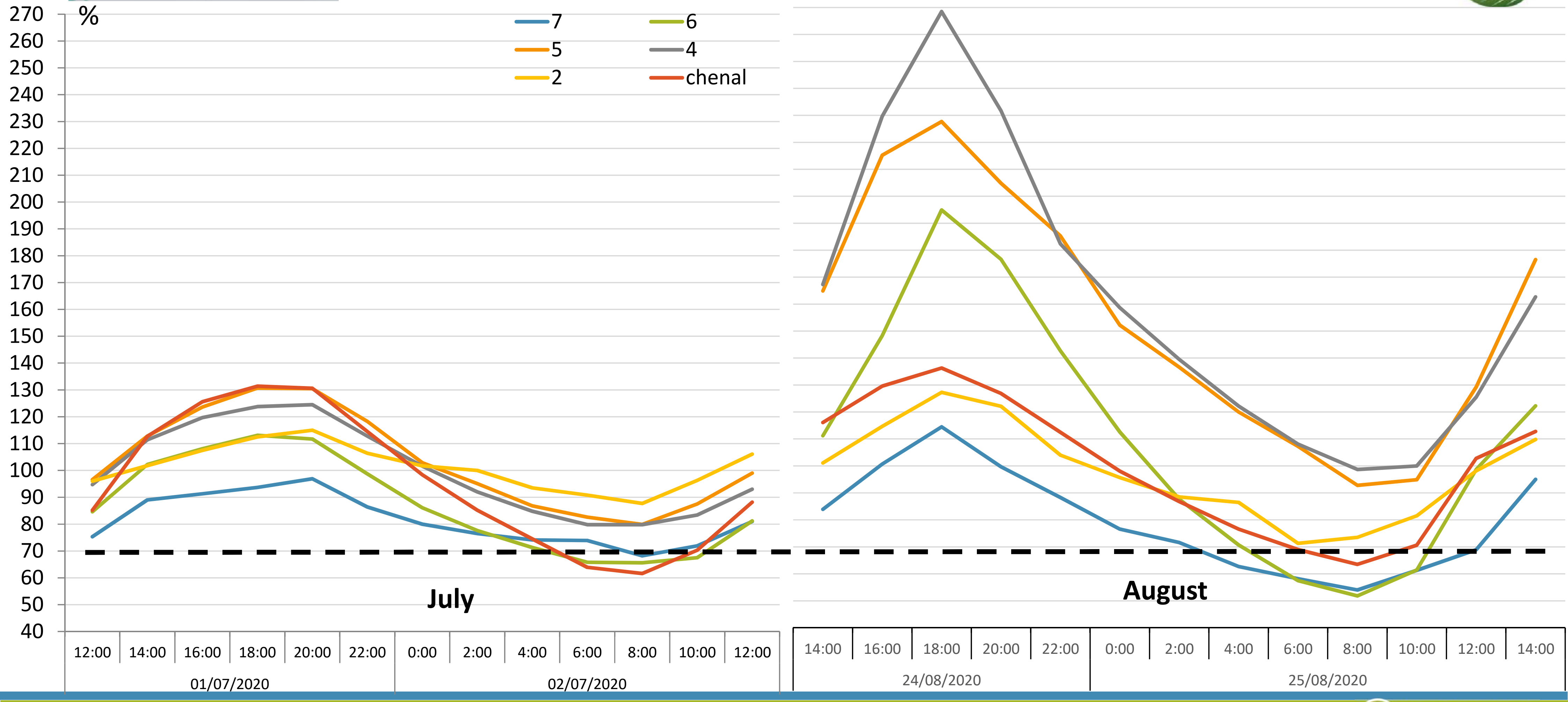


Conclusions:
- Identical growth between Commercial and Veg + Mussel Feeds
- Decrease lack of EPA and DHA in Veg Seabreams
- Slight increase of EPA and DHA using mussel complement

Experimental design

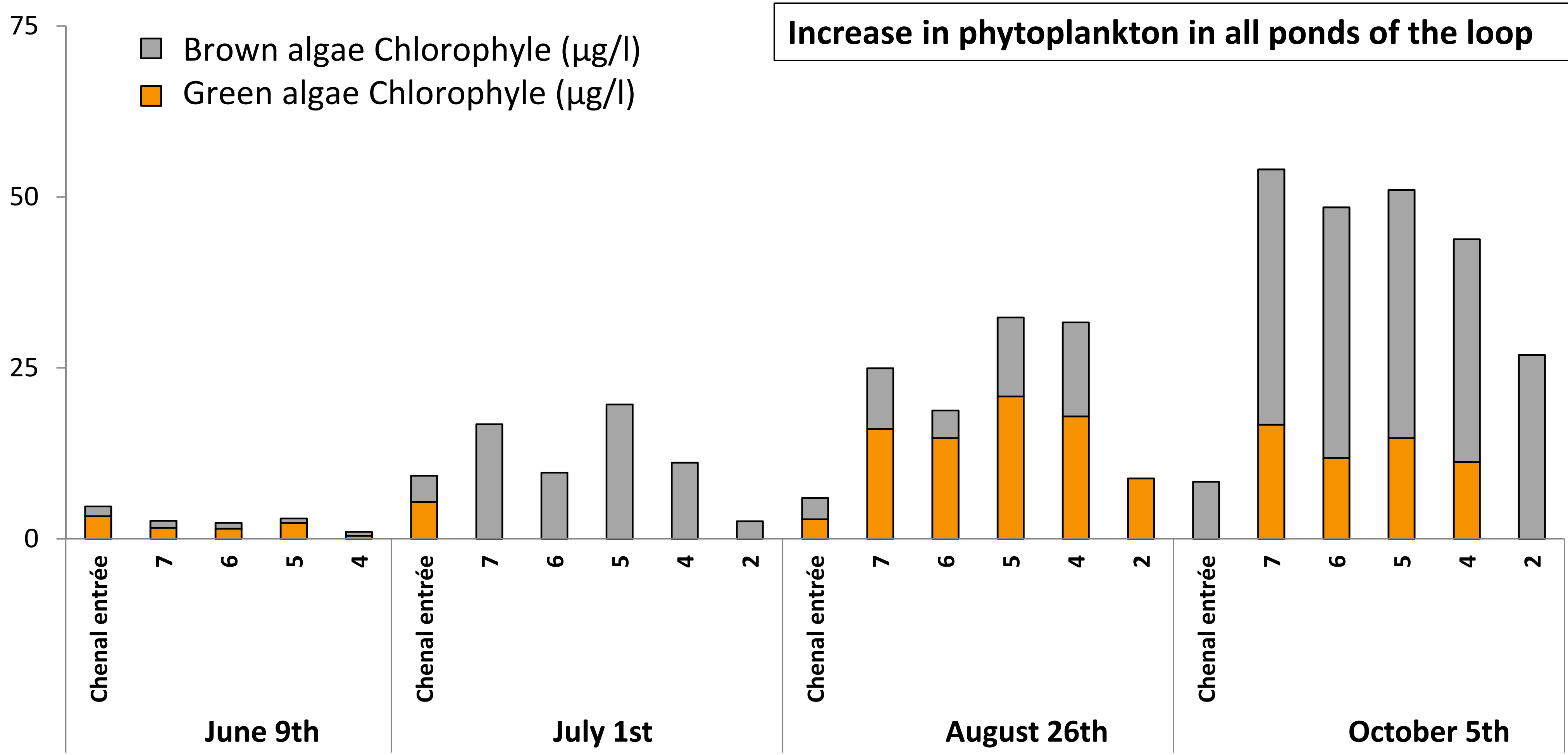


Oxygene saturation 24H Cycle

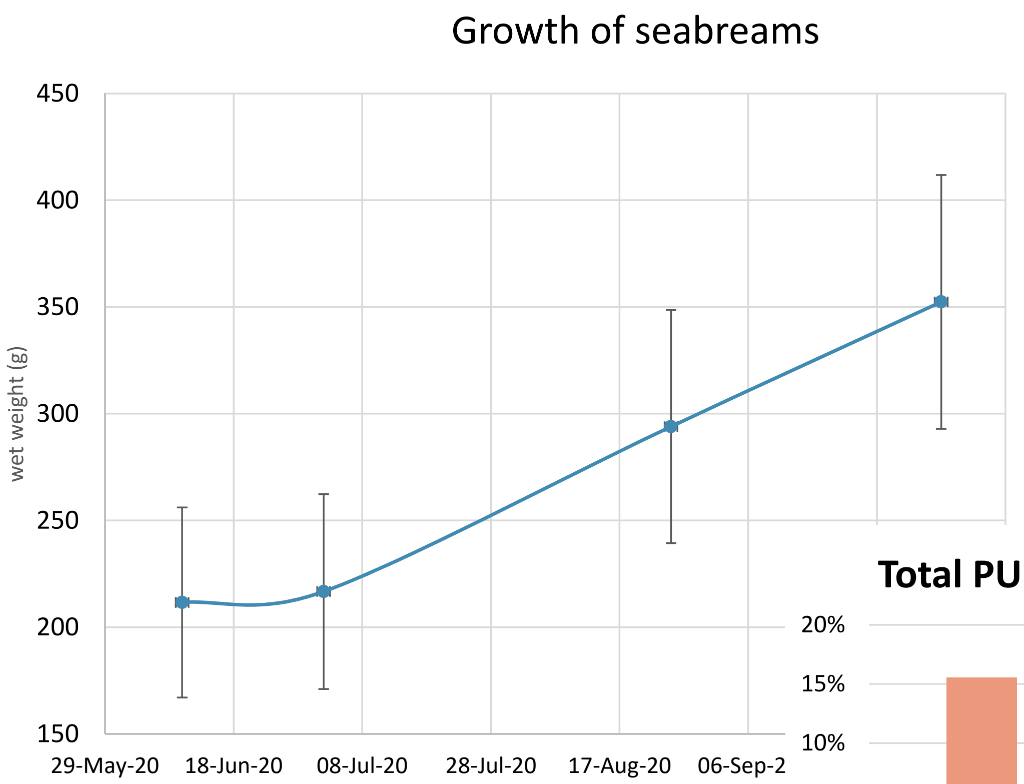


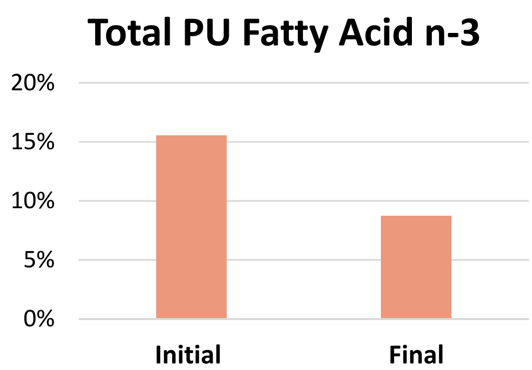
Phytoplankton

Increase in phytoplankton in all ponds of the loop



Gilthead seabream





- **Good growth except during the first month due to the adaptation of fish**
- **FCR : 1.9 (in eq. form. feed)**
- **Survival rate : 90%**
- **Decrease in PUFA**

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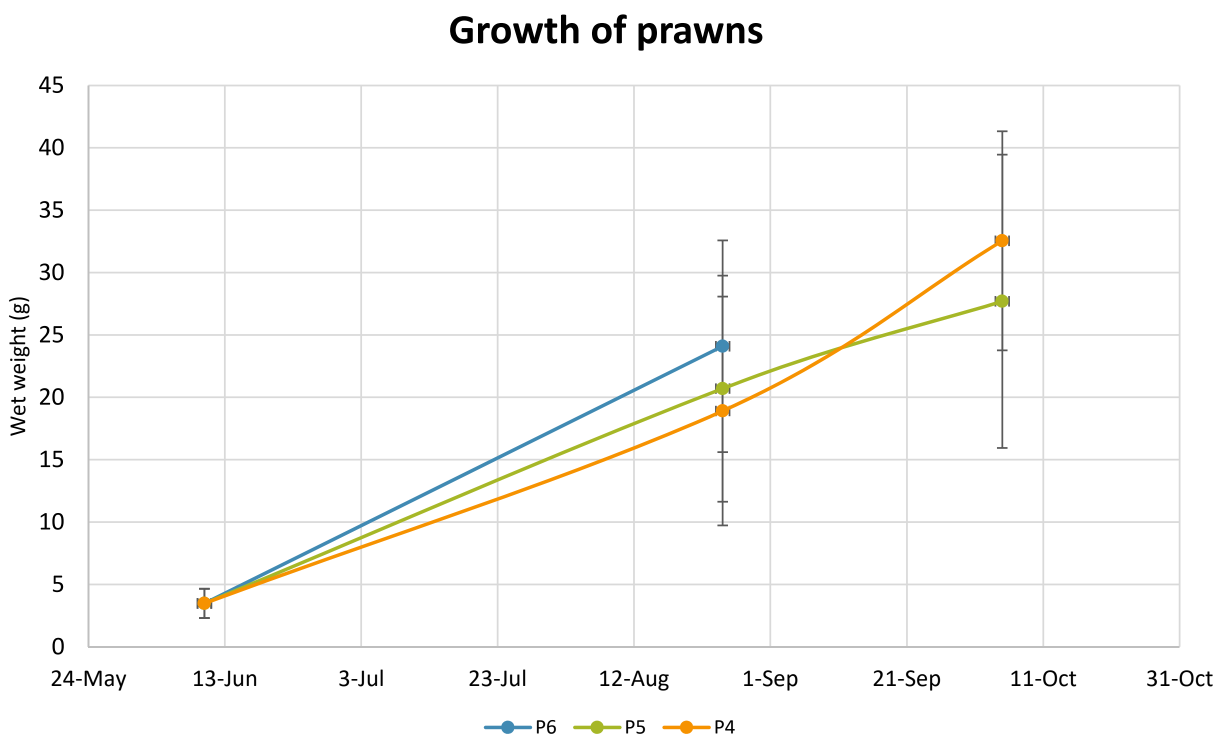
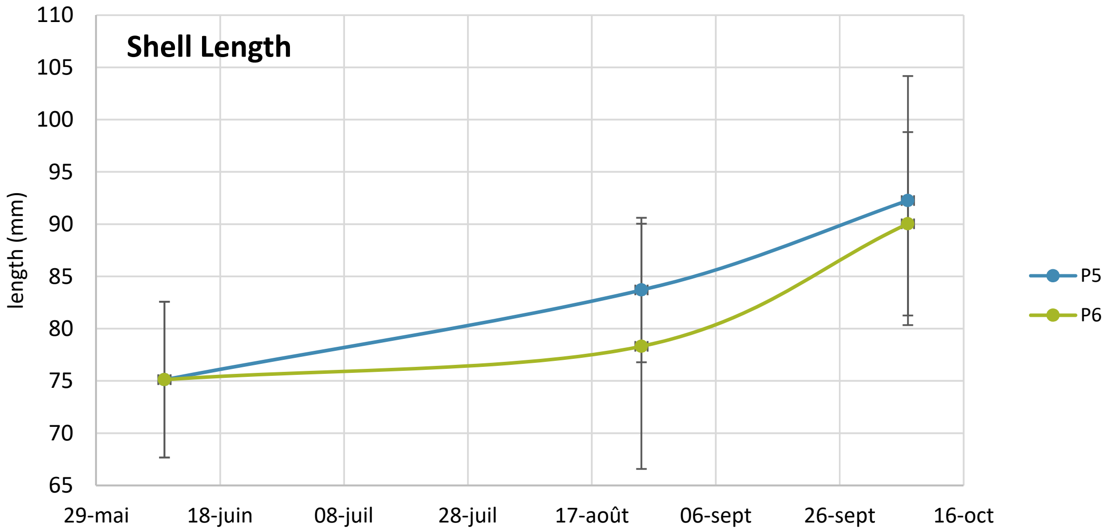
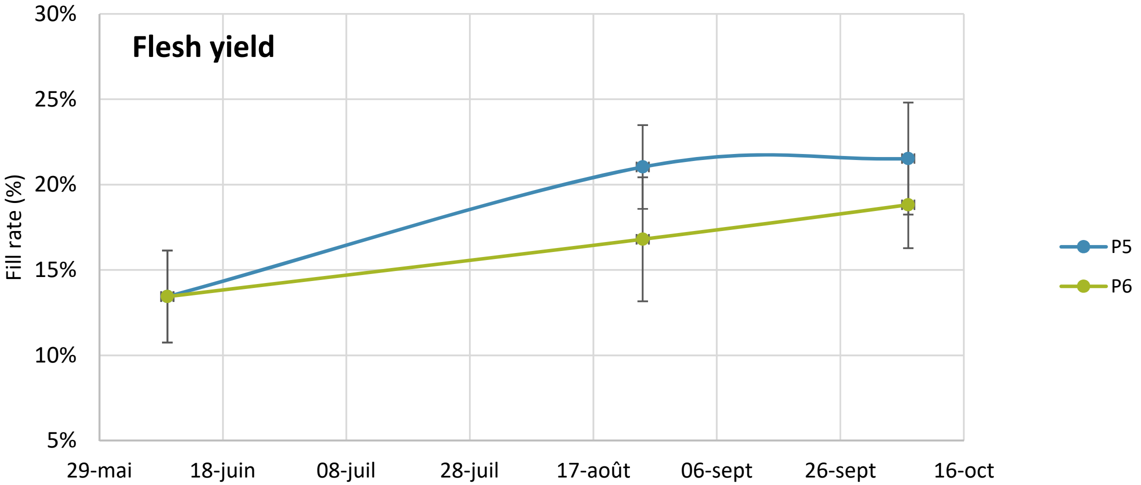
Prawn



- **Mean weight increased 9-fold**
- **High variability due to sexual dimorphism**
- **All prawns from the pond 6 died, just a few days before harvesting.**
- **survival rate : 38% pond 5, 58% pond 4**

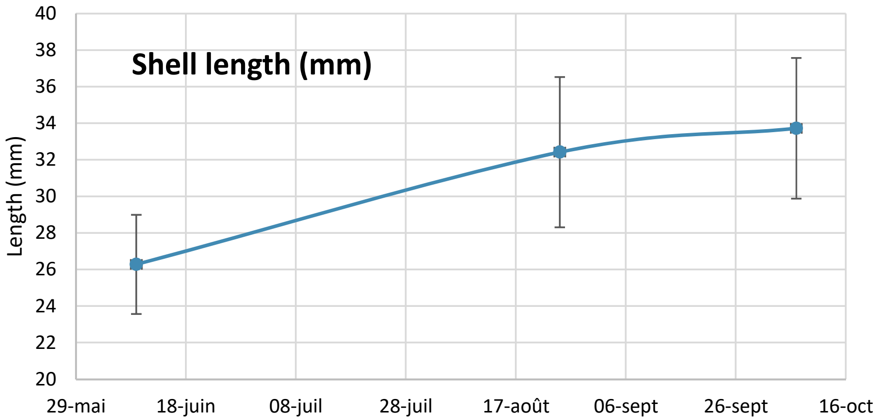
Oyster

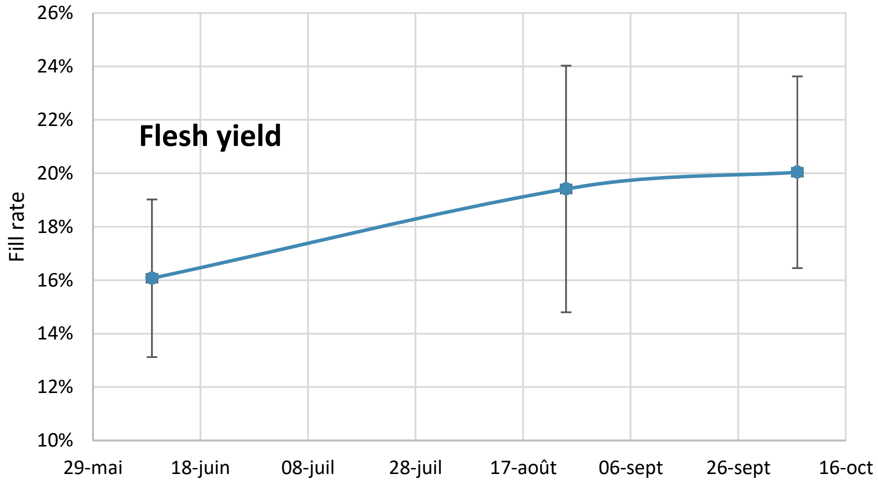




- **Good growth**
- **Survival rate estimated at around 90%**
- **Fill rate over the quality standard (12%-15%)**

Clam



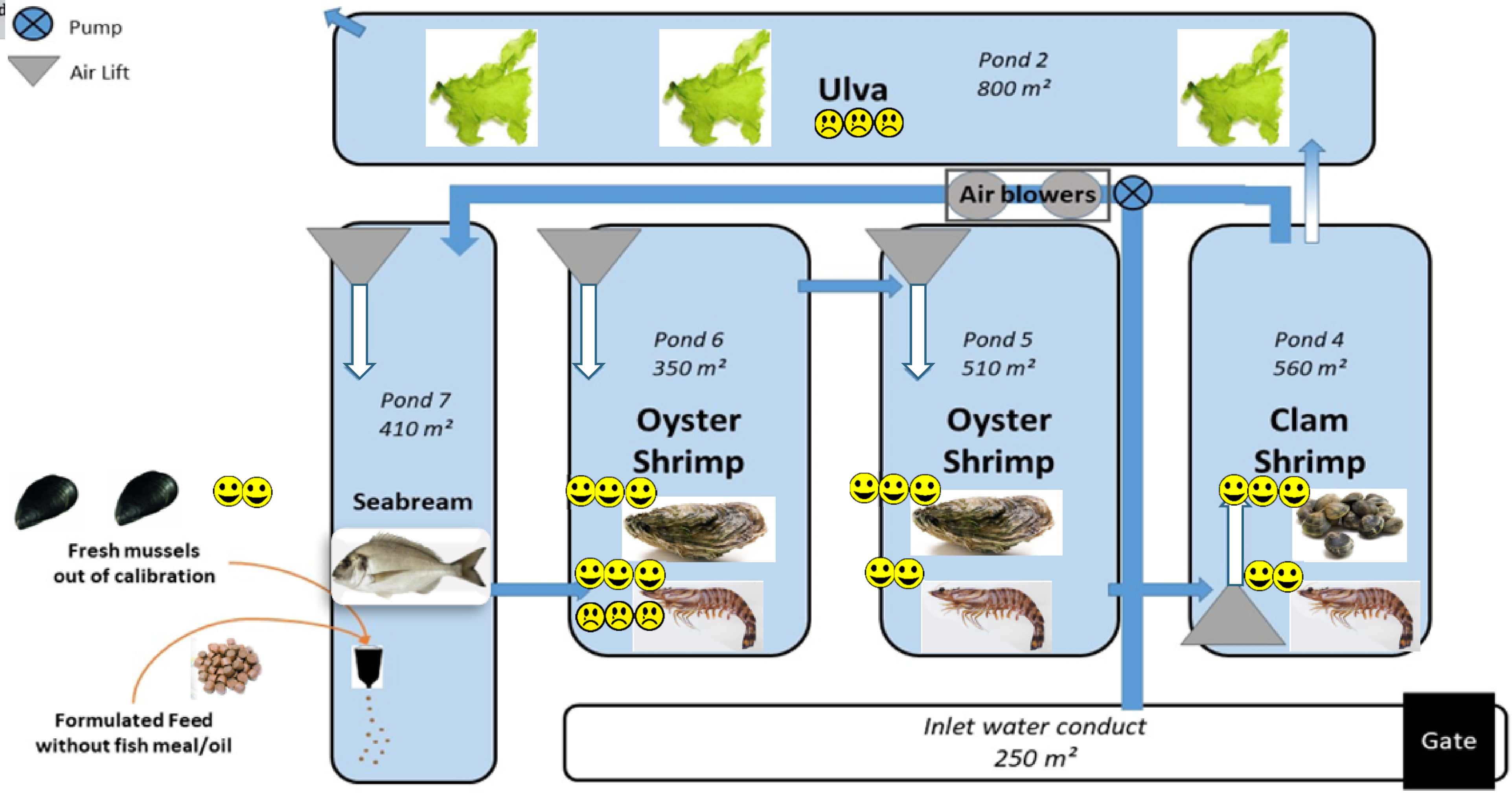


- **Mean fill rate 20% at harvest (*vs* 16% at stocking)**
- **Survival rate estimated around 70%**

Ulva

No production of Ulva due to lack of water movement
To be tested anew with a change in the water loop.

To sum up



Pump
Air Lift
Ulva
Pond 2
800 m²
Air blowers
Pond 7
410 m²
Seabream
Pond 6
350 m²
Oyster
Shrimp
Pond 5
510 m²
Oyster
Shrimp
Pond 4
560 m²
Clam
Shrimp
Fresh mussels
out of calibration
Formulated Feed
without fish meal/oil
Inlet water conduct
250 m²
Gate

Conclusions

- **Productive :** yes! The best for oysters, and good for clams and shrimp. Reconception needed for algae production

- **Robust and Resilient :** yes for oysters. To be consolidated for fish and shrimp

- **Natural and cultural value :** biodiversity diagnostic in progress

- **Environmentaly friendly:** no emission of waste water (except at draining), low level of nutrient emitted in water

- **Using local and natural resources :** good performance of seabreams with vegetable+mussel feed

Perspectives

- Try again : new run of the system in 2021 to confirm the results with
  - Probes for close monitoring of water quality
  - Revision of air adduction
  - Addition of mullets to the seabreams?
  - Better management of Ulva production
  - Mixing oysters and clams in ponds (better use of plankton?)
- Modelling of the production system: growth and fate of nutrient
- Dissemination to local producers, students, scientists…

Thank you very much for your attention

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Webinar

The SIMTAP project for sustainable aquaponics

Carlo Bibbiani, Alberto Pardossi, Baldassare Fronte, Lorenzo Rossi, Chingoileima Maibam, Adriana Ciurli, Martina Puccinelli, Rita Maggini, Giulia Carmassi, Riccardo Pulizzi, Luca Incrocci

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SIMTAP at UNIPI

ENVIRONMENTAL CONDITIONS

The SIMTAP system at UNIPI was designed according to climatic conditions expected inside a greenhouse. Due to the experimental purpose of the system, a heat pump was installed to cope with high temperature related risks.

SIMPLIFIED SOLUTIONS

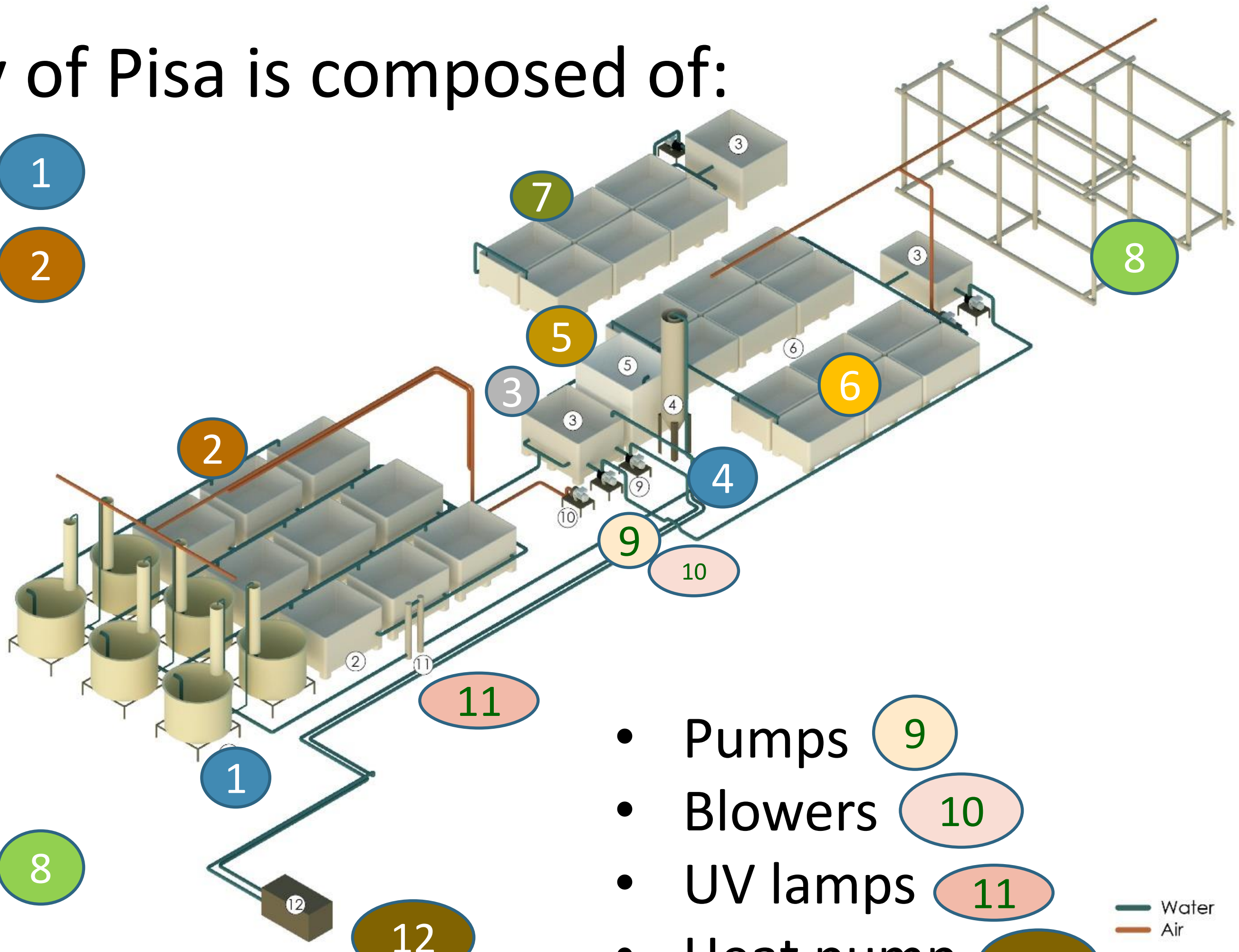
During the design of the system some issues were addressed:

1) substitution of the drum filter with the concept of ‘large surface particulate removal settler’, provided the deposit/filter feeder organism (DFFO) presence, such as polychaetes and mussels.
2) substitution of the skimmer provided the filter feeder organism presence

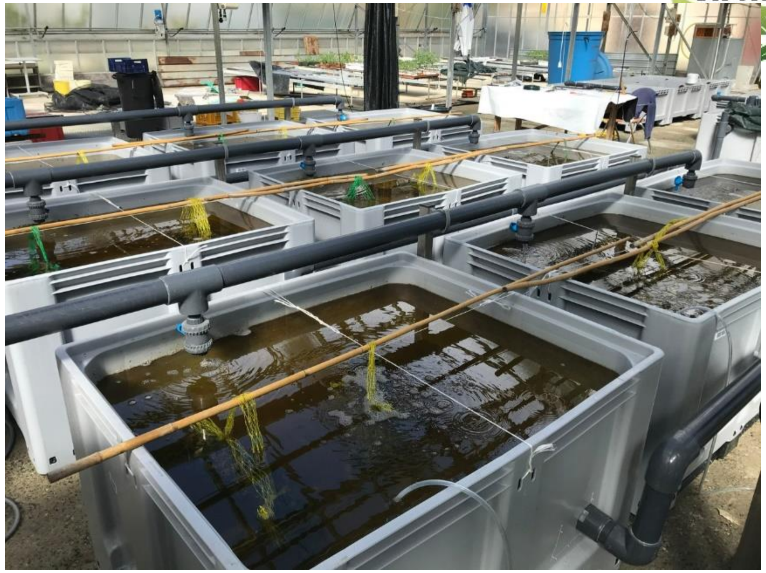
SIMTAP at UNIPI

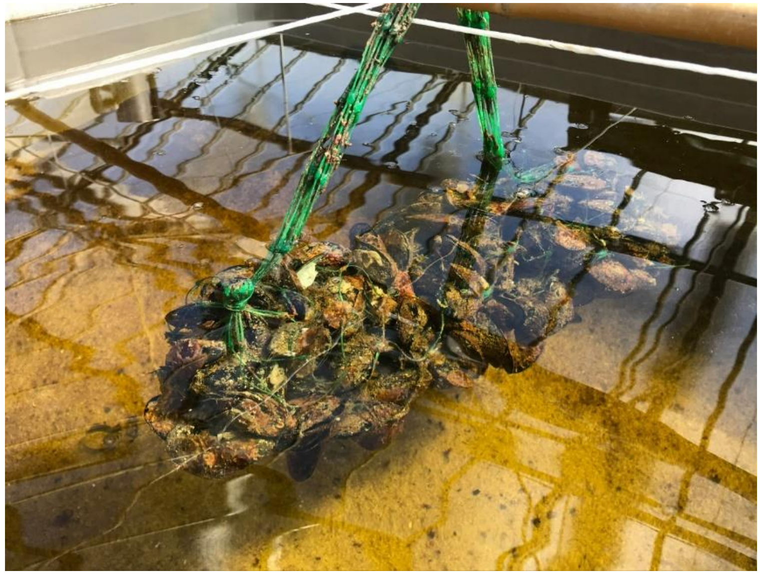
The SIMTAP System at the University of Pisa is composed of:

- Fish culture unit (6 tanks of 0,6 m^3 each) 1
- DFFO unit (9 tanks of 1 m^2 each) 2
- Water sump and skimmer 3 4
- Biofilter unit (1 tank of 1.0 m^3) 5
- Halo/Glyco-phytes+ Macroalgae unit (12 tanks of 1 m^2 each) 6
- Side hydroponic for run-off (from other greenhouse crops) 7
- Microalgae unit (8+8 bags of 100 L each) 8



- Pumps 9
- Blowers 10
- UV lamps 11
- Heat pump 12





SIMTAP at UNIPI

Main water flow design parameters:

FISH TANKS (Sea bream)

Maximum fish density of 10 kg/m^3

Tank surface	0.9	m^2
Water exchange rate (WER)	1.5 (150%)	N° Tank-volume/h
Hydraulic loading rate (HLR)	15.2	$L/m^2/min$
Detention time (HRT)	39.5	min

Before the water runs back to the fish tanks accumulated gases that must be removed by aeration of the water (stripping).


The trickling system provided by pipes full of bioballs.

Water is led to the top of the filter over a distribution plate with holes, flushed down through the plastic media to maximize turbulence and contact, the so-called stripping process.

Polychaetes unit

Polychaete and mussel/oyster tanks

Tank surface	1.0	m^2
Water exchange rate (WER)	0. (90%)	N° Tank-volume/h
Hydraulic loading rate (HLR)	9.2	L/m^2/min
Detention time (HRT)	64.8	min

The water flows downwards, so the sedimentation of fecal matter and debris is easied.
Maximum filter organism density of 10 kg/m^3 (Total live weight with shell).
Maximum density of polychaetes 1900 ind/ m^2.

SIMTAP at UNIPI

BIOFILTER

the Biofilter (MBBR) was packed with

- 0.5 m^3 Bioball® media to obtain a:
- total surface area of 300 m^2.
- The target ammonia removal rate by nitrifying bacteria = 0.2 g /d/m^2
- Total Ammonia processable per day = 60 g

A commercial mixture of selected bacterial cultures
(Bacterya, Équo S.r.l., Prato, Italy) was also inoculated into MBBR.

This parameters led to a
fish total biomass around **30 kg (5 kg per tank)**.

SIMTAP at UNIPI

Hydroponics and Macro-algae

From the MBBR system, water is divided through four floating raft hydroponic plant beds operated in parallel.

One of them is dedicated to Macro-algae, such as:

- *Ulva rigida*
- *Chaetomorpha linum*

The other three, are dedicated to crop species:

- *Salicornia europaea* (obligate halophyte)
- *Beta vulgaris* subsp. *maritima* (facultative halophyte)
- *Beta vulgaris* var. *cycla* (salt-tolerant glycophyte)

SIMTAP at UNIPI

Monitoring devices

To maintain optimal water parameters, salinity, pH , levels of dissolved oxygen, total ammonia nitrogen (TAN), nitrite, nitrate, and temperature must be monitored.

Some of them are continuously monitored (EC, T, pH, DO)

The control system, a Programmable Logic Controller (PLC) is capable of:

1) switching on/off all the pumps and blowers under a set of rules related to the measured parameter values;
2) sending out alarms to the system personnel to cope with power crush or low oxygen level;
3) sending out all the measured data of sensors and actuators, setting the frequency. In fact, the PLC is connected to the web via a router with a SIM smart card.

SIMTAP at UNIPI

Emergency generator

To minimize the risk associated with the grid black-out and the consequent low level of oxygen, an electric generator has been connected to the system by an automatic transfer switch.

Within seconds, the generator system begins supplying electricity to the critical emergency circuits.

Report on research work at UNIPI

Plant unit

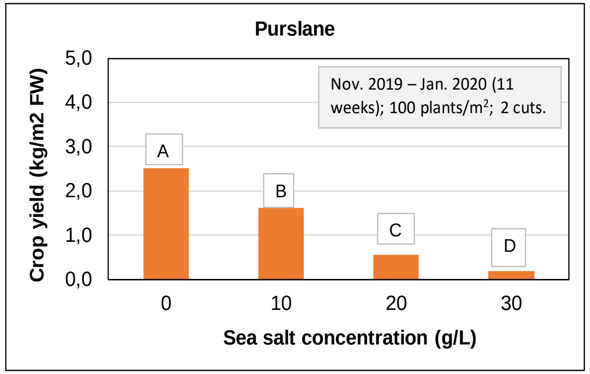
Experiments on halophytes and salt-tolerant glycophytes

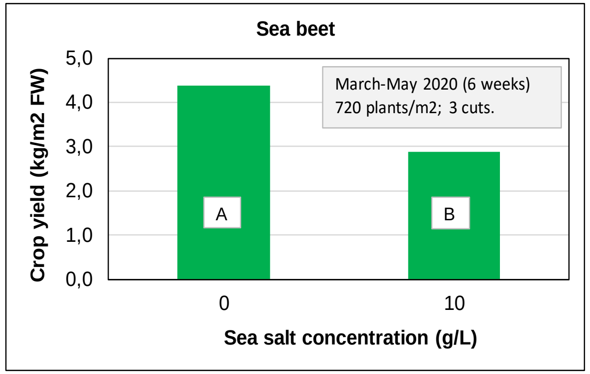
Goal: to assess the growth response and nitrogen uptake of halophytes and salt-tolerant glycophytes to sub-optimal nutritional conditions in seawater aquaponics.

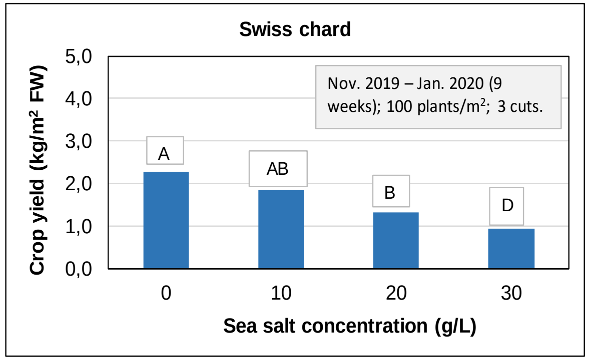
Species:

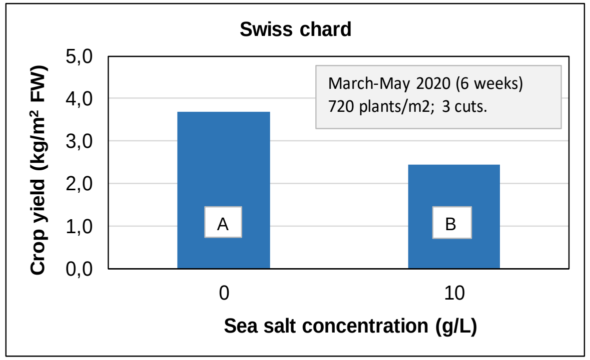
- *Portulaca oleracea* L. (purslane), facultative halophyte
- *Beta vulgaris* var. *cicla* (Swiss chard), salt-tolerant glycophyte
- *Beta vulgaris* subsp. *maritima* (sea beet), facultative halophyte
- *Salicornia europaea* L. (glasswort), obligate halophyte

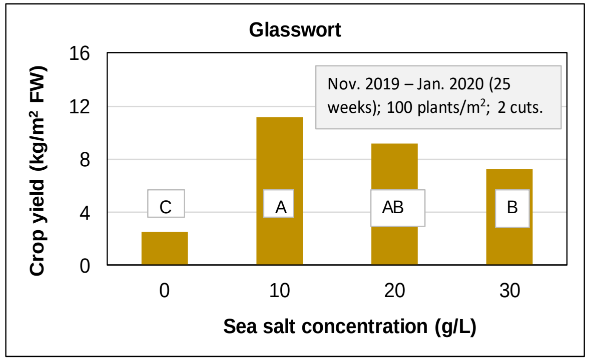
Plant unit

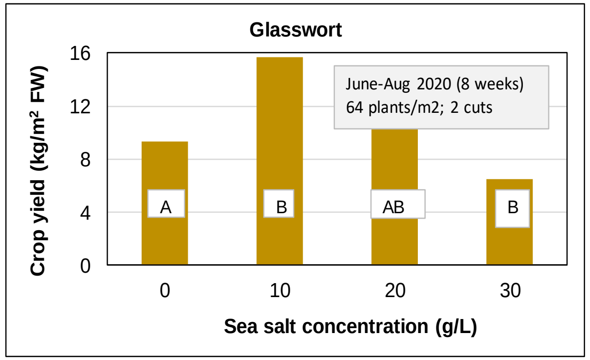










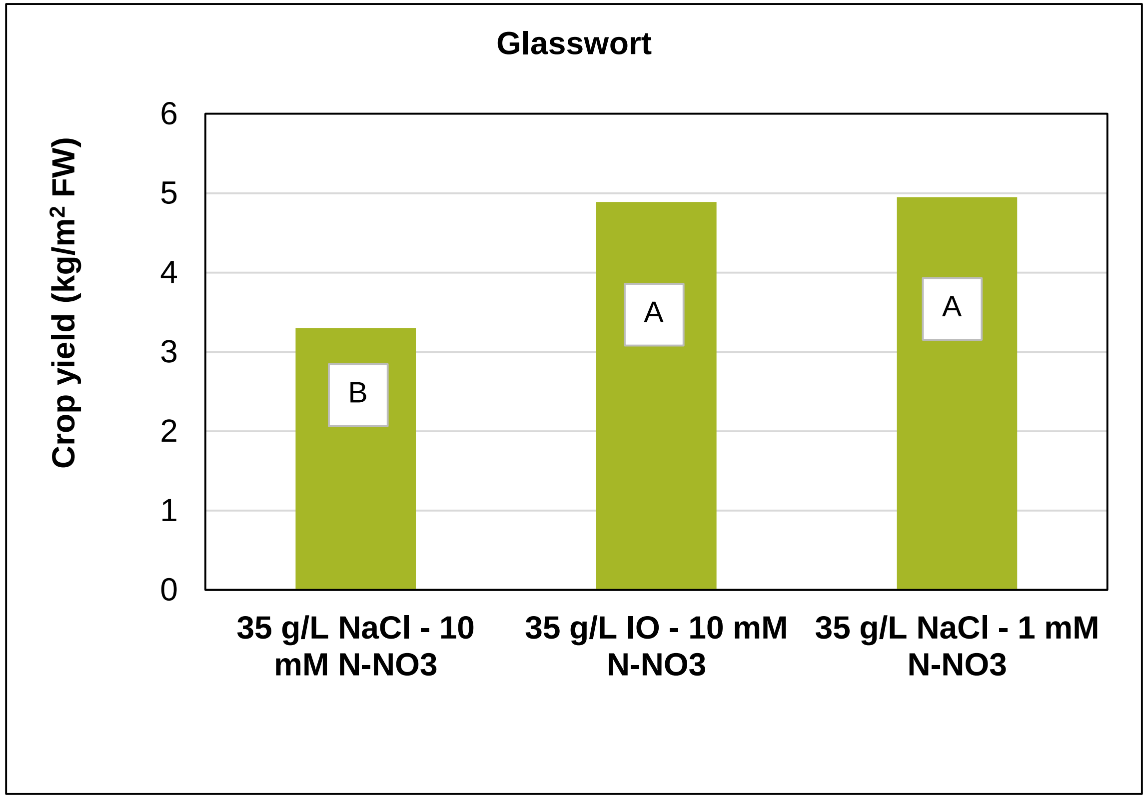


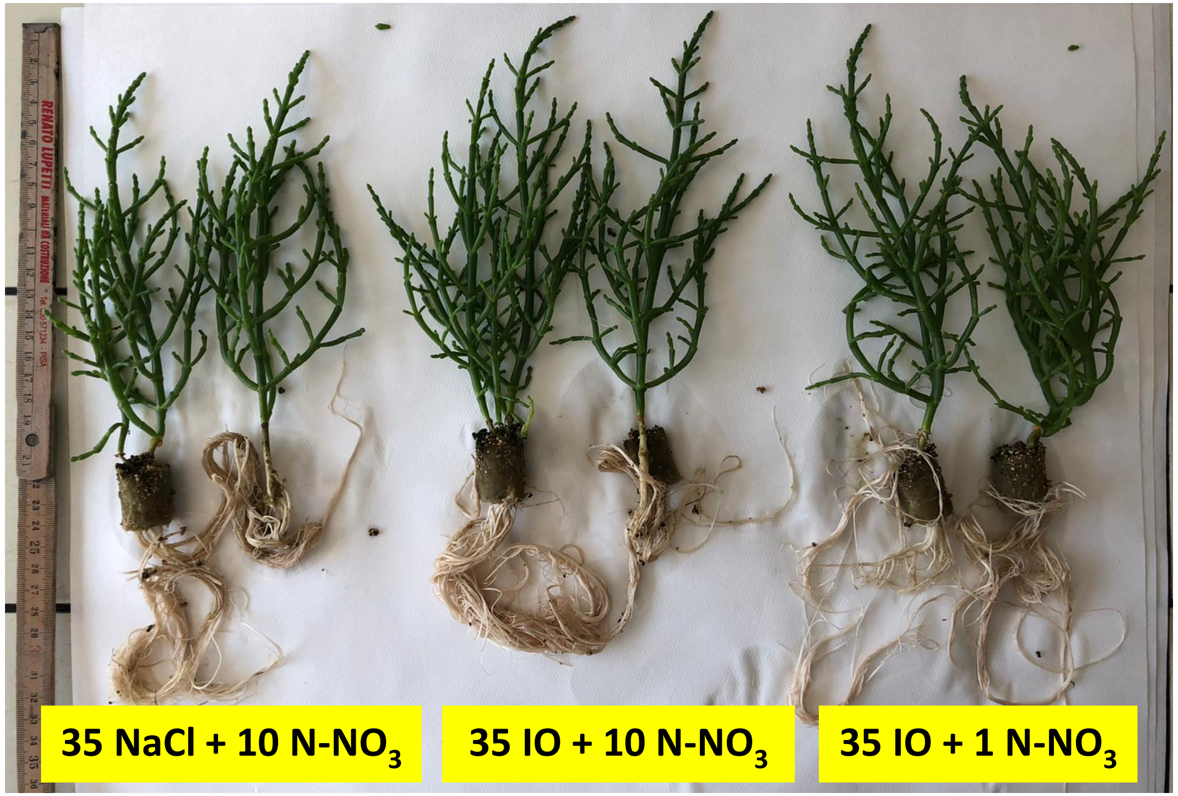
Salicornia europaea (glasswort)

IO-0 IO-10 IO-20 IO-30

Crop yield (fresh leaves or shoots) in four plant species grown in closed-loop hydroponic system under greenhouse with different concentration of synthetic sea salt Instant Ocean™ in the nutrient solution. Some information on the experiments is reported inside each graph. Mean values (n=3) keyed by the same letter are not significantly different according to Tukey test ($p<0.05$).

Plant unit





Crop yield (fresh Shoots) of *Salicornia europaea* (glasswort) grown in stagnant nutrient solution with different concentration of NaCl or synthetic sea salt Instant Ocean™ and N-NO_3 level in the nutrient solution. Mean values (n=3) keyed by the same letter are not significantly different according to Tukey test ($p<0.05$).

Plant unit

[IO] o [NaCl] (g/L)	[N-NO3] (mM)	Growing period (days)	Yield (kg/m²)	Dry shoot biomass (kg/m²)	N content (% DW)	Total N uptake (g/m²)	Mean daily N uptake (g/m².day)
Portulaca oleracea							
0	10	77	2.50	0.094	4.0	3.76	0.05
10	10		1.65	0.073	4.1	2.99	0.04
20	10		0.54	0.029	3.9	1.13	0.01
30	10		0.18	0.011	3.8	0.42	0.01
Beta vulgaris var. *cicla*							
0	10	63	2.27	0.18	4.3	7.74	0.12
10	10		1.85	0.14	4.2	5.88	0.09
20	10		1.33	0.13	3.9	5.07	0.08
30	10		0.95	0.07	4.0	2.80	0.04

[IO] o [NaCl] (g/L)	[N-NO3] (mM)	Growing period (days)	Yield (kg/m²)	Dry shoot biomass (kg/m²)	N content (% DW)	Total N uptake (g/m²)	Mean daily N uptake (g/m².day)
Salicornia europaea							
0	10	175	2.54	0.25	3.4	8.50	0.05
10	10		11.15	0.96	3.9	37.44	0.21
20	10		9.15	0.76	3.8	28.88	0.17
30	10		7.23	0.67	3.7	24.79	0.14
Salicornia europaea							
35 (NaCl)	10	56	3.30	0.31	3.44	10.66	0.19
35	10		4.89	0.42	3.95	16.59	0.22
35	1		4.95	0.42	3.58	15.03	0.20

Crop yield (fresh leaves or shoots), dry shoot biomass, and total and mean daily uptake of nitrogen in four plant species grown in closed-loop hydroponic system under greenhouse with different concentration of synthetic sea salt Instant Ocean™ (IO) or NaCl in the nutrient solution. Some information on the experiments is reported inside each graph. Mean values (n=3) keyed by the same letter are not significantly different according to Tukey test ($p<0.05$).

Plant unit

Conclusions:

- **Crop density:** 100 plants per m^2.
- **Salt adaption of seedlings:** progressive salinization of the nutrient solution.
- **Best crop species:** *Beta vulgaris var. cicla* in autumn-winter and *Salicornia europaea* in spring-summer.
- **N uptake (phytodepuration capacity):** < 1 g/m^2 per day (<1 mg/L*day, for the SIMTAP in Pisa)

Aquaculture unit

Fish farming

- **Gilthead Sea Bream** (*Sparus aurata*) juveniles were stocked at 5-g (mean weight) into the 6 fish rearing tanks

Exp. 1: Mussels feed replacement

Aim: Effects of artificial feed **(F)** replacement with fresh-chopped mussels* **(M)**

Experimental design

- 6 different diets (F%/M%): 100/0, 80/20, 60/40, 40/60, 20/80, 0/100
- 6 weeks trial (three-fold BW increase from 5 to 15 g)

Parameters

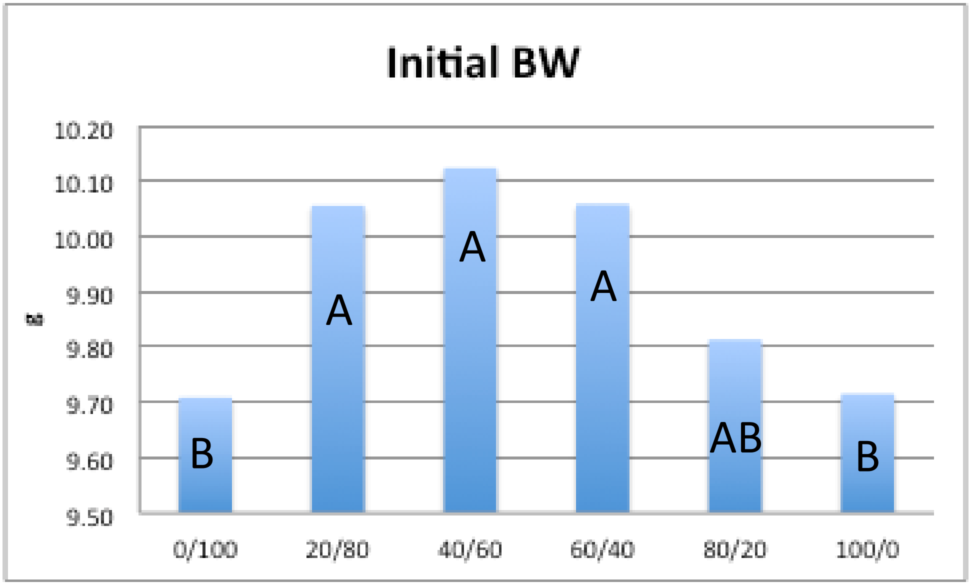
- Feed conversion rate - FCR,
- Daily growth rate - DGR, Specific growth rate – SGR

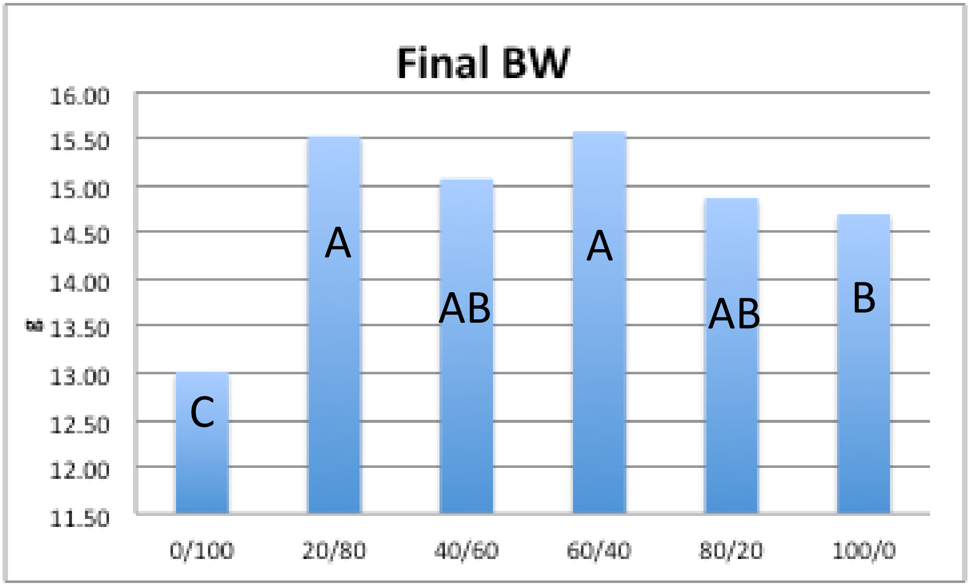
*Frozen mussels (Chilean mussel, *Mytilus chilensis*) are kindly provided by ARBI® Blue Resolution Association.

Aquaculture unit

Exp. 1: Mussels feed replacement preliminary results

Groups are shown according to the Feed/Mussels diet ratio. Final BW were co-variated for initial BW (P<0.05)



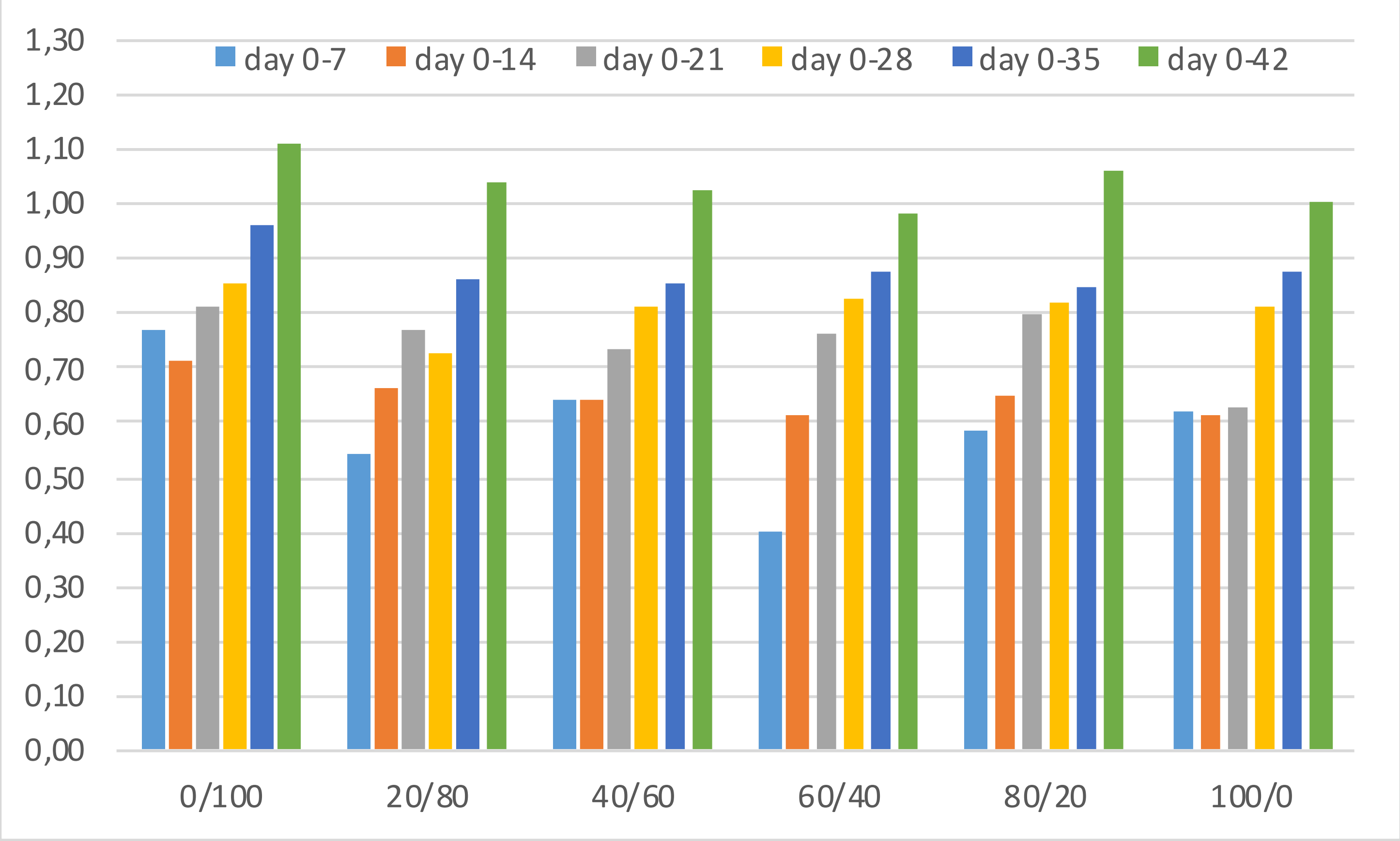


Aquaculture unit

Exp. 1: Mussels feed replacement preliminary results

Groups are shown according to the Feed/Mussels diet ratio

- FCR ranged between 0.4 and 1.1
- No significant (P>0.05) differences were observed between groups
- The lowest cumulative FCR was observed for group fed 60% Feed and 40% Mussels, the highest for that fed mussels only (0/100)



Aquaculture unit

Exp. 1: Mussels feed replacement

- Mixed diets positively influenced fish growth performances
- Slight growth reduction (-11%) when artificial feed was totally replaced by mussels

Exp. 2: Feed replacement with a mussel & clam mixture (50%/50%; trial ongoing)

Aim: Effects of artificial feed **(F)** replacement with fresh-chopped mussels & clams **(M)**

Experimental design

- 2 different diets (F%/M%): 100/0, 0/100 (3 replicates)
- 6 weeks trial (three-fold BW increase from 5 to 15 g)
- Diets will be weekly adjusted on total biomass and fish fed 3% of their BW

Parameters

- FCR, DGR, SGR, VSI (Viscerosomatic index) and HIS (hepatosomatic index).

*Frozen mussels (Chilean mussel, *Mytilus chilensis*) and clams are kindly provided by ARBI®

Polychaetes unit

Polychaetes laboratory

- A small-scale experimental facility for filter-detritivores feeder was built between January and March 2020.
- This system allows to test different treatments (up to 6 with 3 replicates each) contemporaneously,
- It has been used for breeding and feeding experiment in polychaetes.

Polychaetes unit

Experiment on worm breeding

Goals:

To determine:

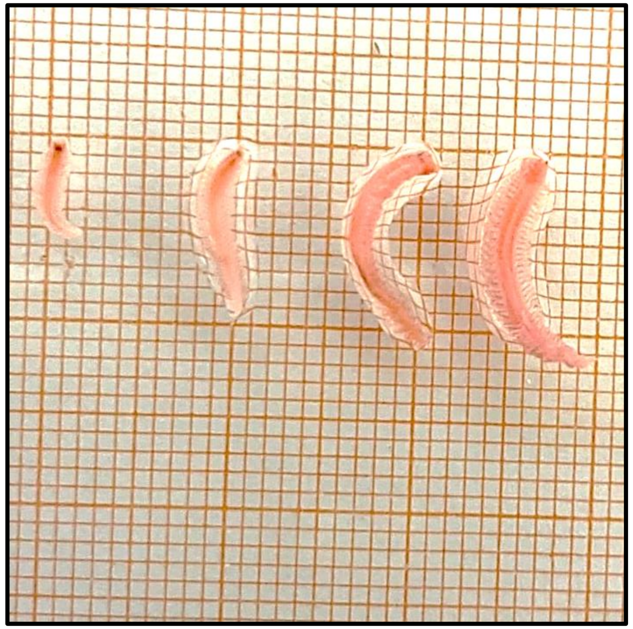
i) if spawning can be induced to polychaetes outside of their breeding season, under laboratory conditions,

ii) if lunar cycle effectively induce synchronous spawning;

iii) the right time to sample larvae from the sand

Hediste diversicolor

Polychaetes unit



Larvae with different sizes
From left:
L1<5mm;
L2:5-10mm;
L3>10mm

Treatment	Treatment length (days)	Thermal shock	Moon-light	L1 (%)	L2 (%)	L3 (%)	Unspawned worms
Control	42	No	No	17^{b}	44^{ab}	39	16^{a}
T1	42	Yes	Yes	**81**^{a}	19^{a}	0	1^{b}
T2	56	Yes	Yes	10^{b}	**75**^{b}	15	2^{b}

Larval size (L1: < 5 mm; L2: 5-10 mm; L3: >10 mm) and unspawned adults of *H. diversicolor* harvested at different time-period after thermal shock treatment. Mean values of three replicates. Different superscripts from a to b within columns indicate significant difference ($p<0.05$) according to Tukey test

Polychaetes unit

Experiment on how lunar cycle affects synchronus spawning of *Hediste diversicolor*

In conclusion, the lunar cycle did play an important role in synchronizing the spawning in H. diversicolor in agreement with the findings of Bartels-Hardege and Zeeck (1990).

H. diversicolor can be induced to spawn under laboratory conditions with **blue light** to mimic lunar cycle and with **cold shock** to generate synchronous spawning in well-fed worms.

Polychaetes unit

Experiment on worm feeding

Goals:

To determine:

i) growth performances and survival of *H. diversicolor* reared on a diet of microalgae and mussels;

ii) the nutritional composition of the worms fed different diets

Experimental design

Feed type	Microalgae: Mussel	Treatment code
100% microalgae	1:0	$T1_{100\%}$
75% microalgae + 25% mussel	3:1	$T2_{75\%}$
50% microalgae + 50% mussel	1:1	$T3_{50\%}$
25% microalgae + 75% mussel	1:3	$T4_{25\%}$
100% mussel	0:1	$T5_{M100\%}$

Polychaetes unit

Treatments (microalgae:mussel)	SGR (% d^{-1})	Final Biomass (g)	Survival (%)
T1 (100:0)	0.68 ± 0.16^{b}	0.73 ± 0.06^{c}	66.6 ± 1^{b}
T2 (75:25)	3.63 ± 0.55^{a}	**7.66 ± 0.76^{ab}**	93.3 ± 1^{a}
T3 (50:50)	4.30 ± 0.65^{a}	**8.32 ± 1.34^{a}**	91.1 ± 1.5^{a}
T4 (25:75)	1.07 ± 1.1^{b}	1.48 ± 0.58^{bc}	73.3 ± 1^{ab}
T5 (0:100)	3.20 ± 0.88^{a}	6.04 ± 0.84^{abc}	80.0 ± 1^{ab}

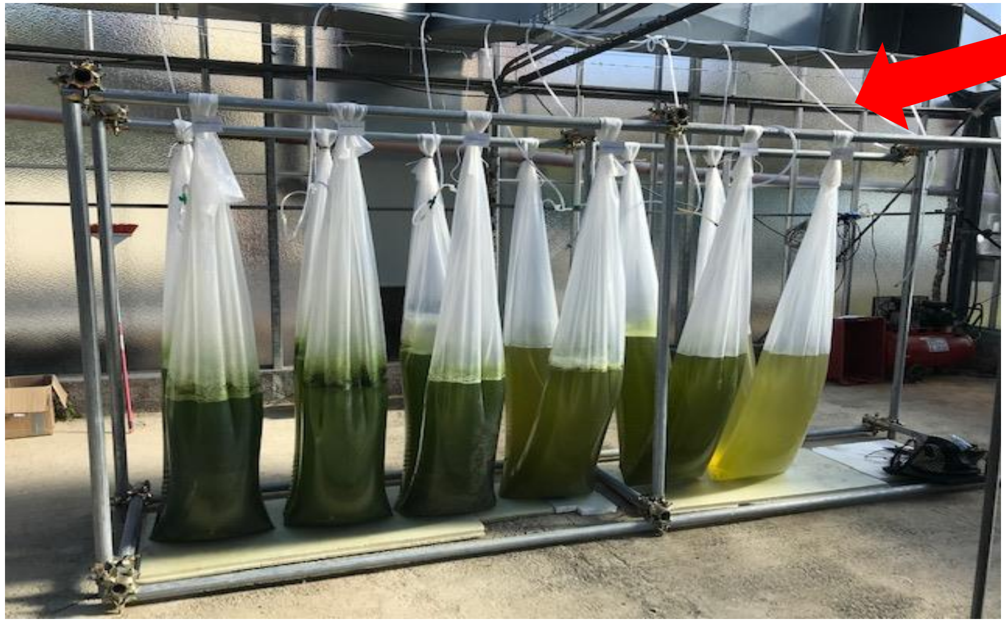
Growth performance and survival percent of Hediste diversicolor fed with different diets based on microalgae and mussel for 5 weeks. (mean ± SD, n=3 replicates). Different superscripts (a-c) within columns indicate significant difference according to Tukey test

Algae unit

Bag photobioreactors in greenhouse

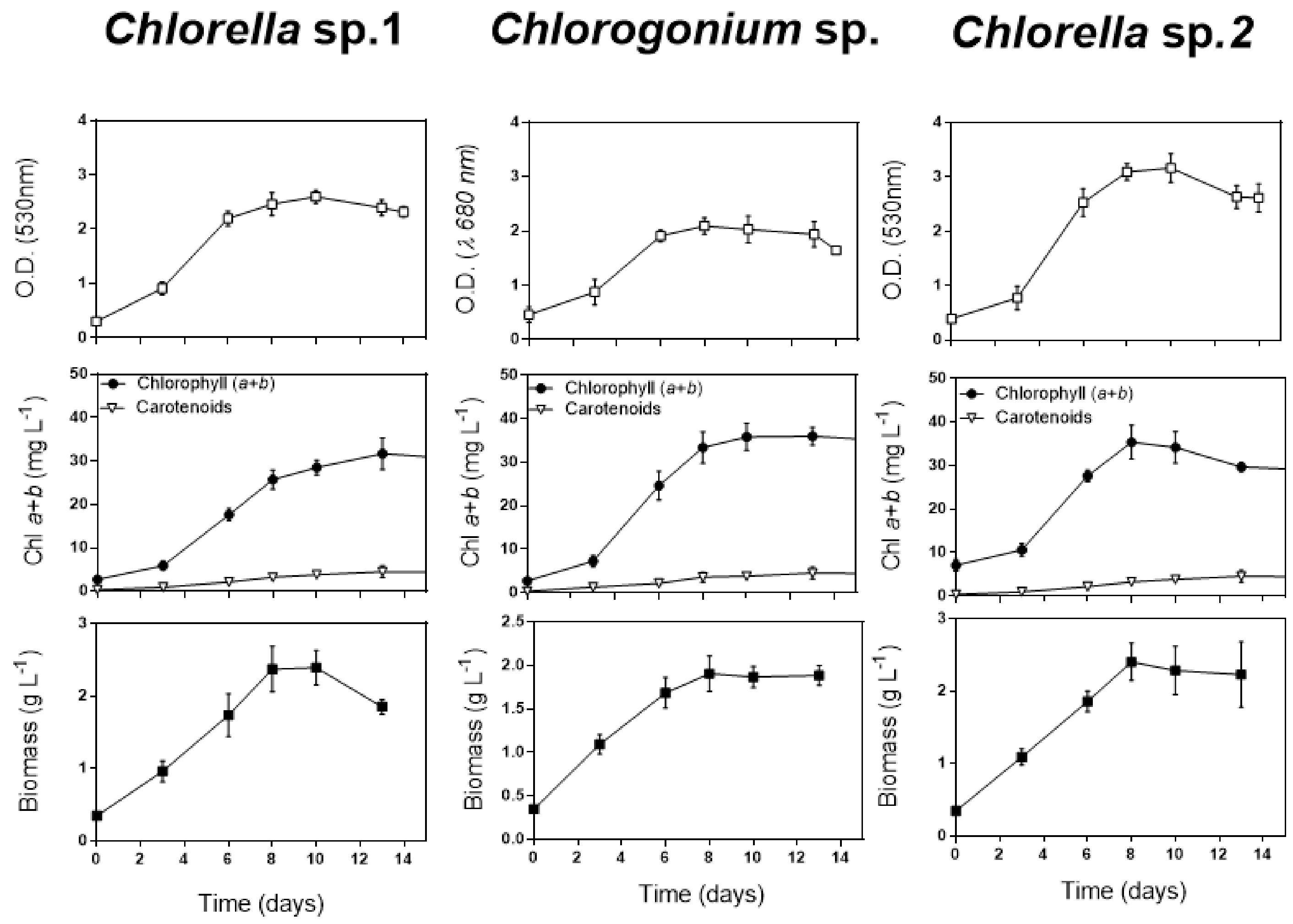
A sterile pre-culture of each species was carried out in the laboratory.

An aliquot (3%) of sterile pre-culture with $OD_{580} \geq 2.0$ and chl concentration of 30 mg/L was poured to 100-L bag photobioreactors.



Freshwater algae

- *Chlorella* sp. 1
- *Chlorogonium* sp
- *Chlorella* sp. 2



Trend of optical density (OD at 530 nm) and the content of chlorophylls and dry biomass in laboratory cultures of three freshwater algae strains conducted for 13 days in sterile conditions and controlled temperature and light conditions. Mean values of three replicates (± se)

Growth parameters of fresh water microalgae in bag photobioreactor

The experiment in photobioreactors was conducted in the period **September-December 2020**

The growth of the **Chlorella (ChL_1 strain)** was reduced in the photobioreactors

The dry biomass content of the culture medium averaged

0.17 ± 0.13 g/L in greenhouse photobioreactors

3.05 ± 0.01 g/L in the laboratory.

In contrast, no significant differences were found between the two types of cultures in terms of N and C content, which averaged 9.4 and 49.3%, respectively.

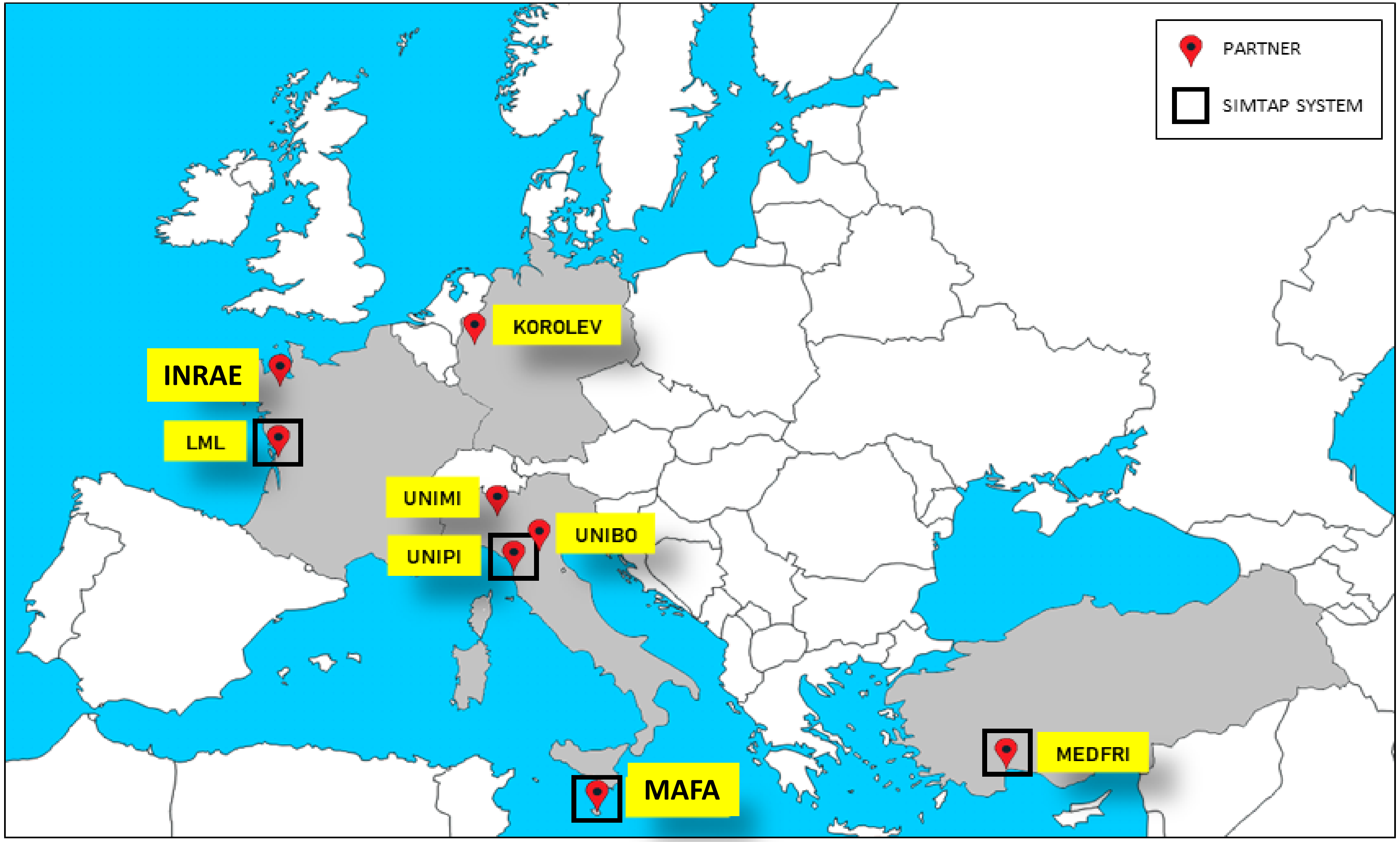
Department of Agriculture, Food and Environment & Department of Veterinary Sciences
University of Pisa
Webinar

THANK YOU VERY MUCH FOR YOU ATTENTION

Carlo Bibbiani, Alberto Pardossi, Baldassare Fronte, Lorenzo Rossi, Chingoileima Maibam, Adriana Ciurli, Martina Puccinelli, Rita Maggini, Giulia Carmassi, Riccardo Pulizzi, Luca Incrocci

The PRIMA programme is supported under Horizon 2020, the European Union's Framework Programme for Research and Innovation

SIMTAP Project



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The Partnership for Research and Innovation in the Mediterranean Area will devise new R&I approaches to improve water availability and sustainable agriculture production in a region heavily distressed by climate change, urbanisation and population growth

Webinar
The SIMTAP project for sustainable aquaponics
19 March 2021

SIMTAP PROTOTYPE IN TURKEY (Main activities and the first results)

Mehmet Ali T. Koçer*, Hüseyin Sevgili, Serkan Erkan, Murat Yeşiltaş, İsa Aydın, Adem Kurtoğlu, Özgür Aktaş, Durali Eraslan, Aytürk İslam, Mahir Kanyılmaz

Mediterranean Fisheries Research Production & Training Institute
Antalya/Turkey

The PRIMA programme is supported under Horizon 2020, the European Union's Framework Programme for Research and Innovation

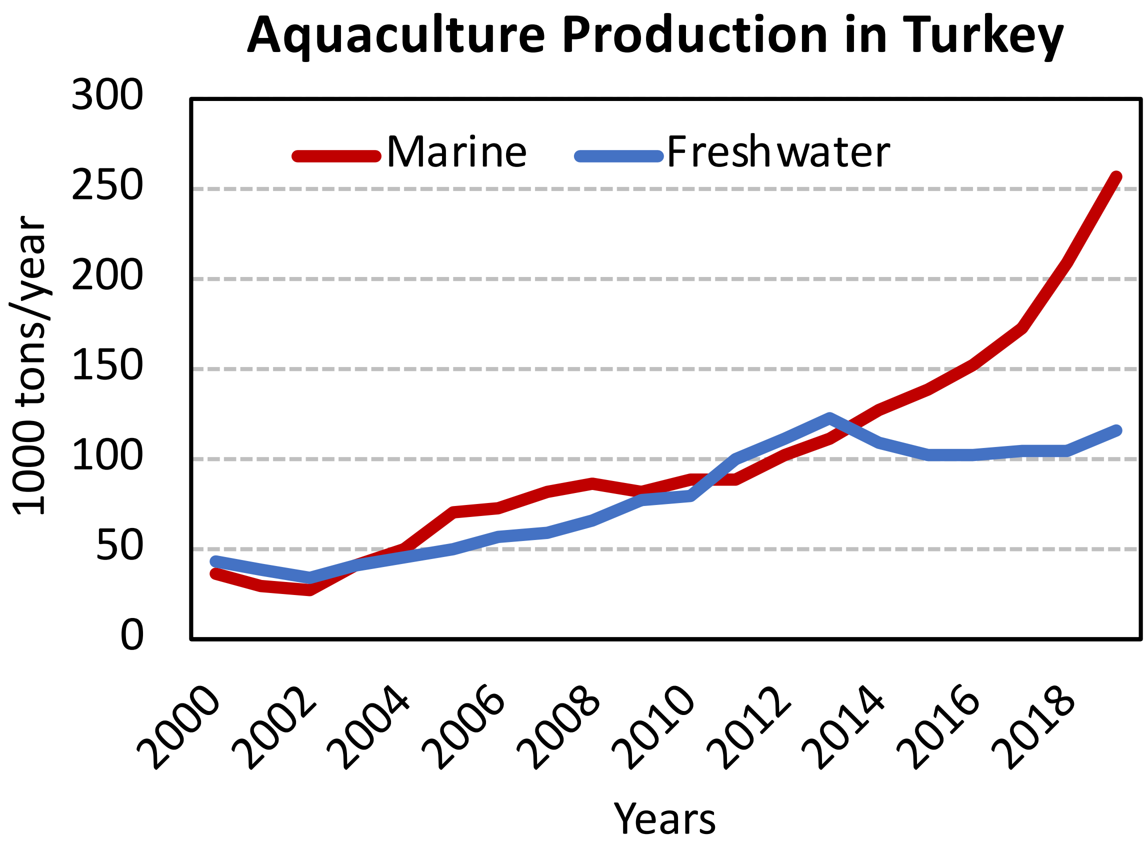
European Commission

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Content

- ✓ Description of marine aquaculture in Turkey
- ✓ SIMTAP concept in Turkey
- ✓ Description of SIMTAP prototype
- ✓ Studies completed in the prototype
- ✓ Next studies

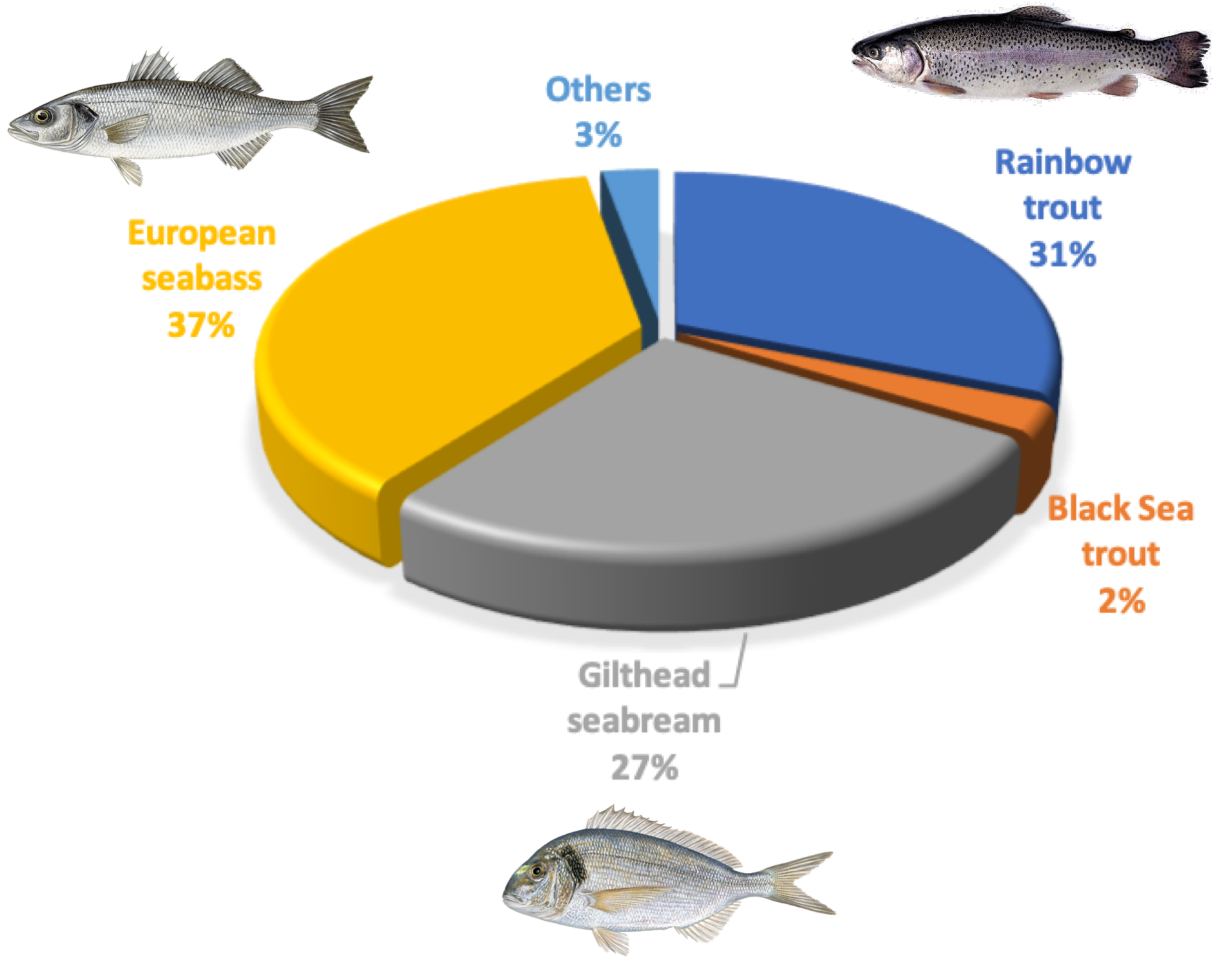
A short introduction



- ✓ Total aquaculture production reached 373.000 tons in 2019
- ✓ Marine aquaculture showed a high growth trend during last 5 years

Source: Turkish Statistical Institute, 2020

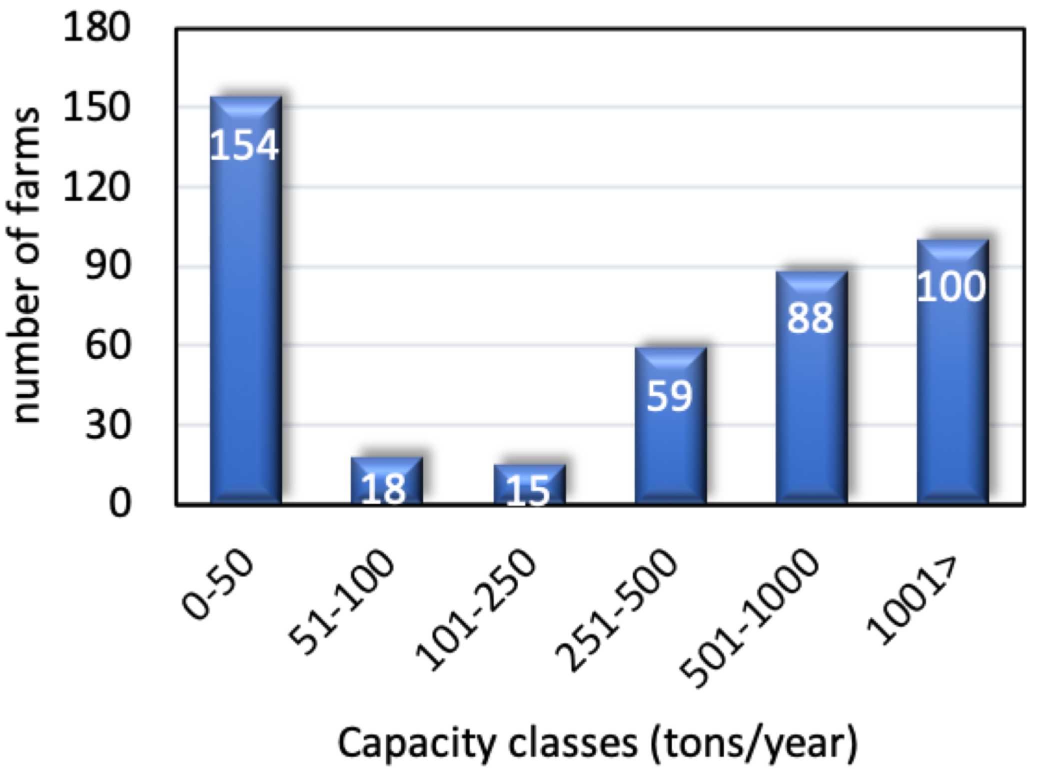
A short introduction



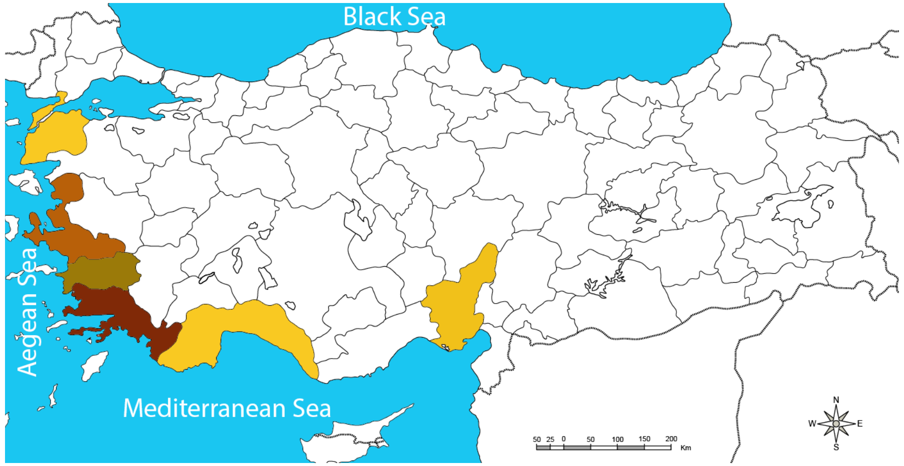
- ✓ Marine aquaculture supplied about 2/3 of total production in 2019

Source: Turkish Statistical Institute, 2020

A short introduction



- ✓ There are a total of 434 marine farms
- ✓ The majority are offshore cages



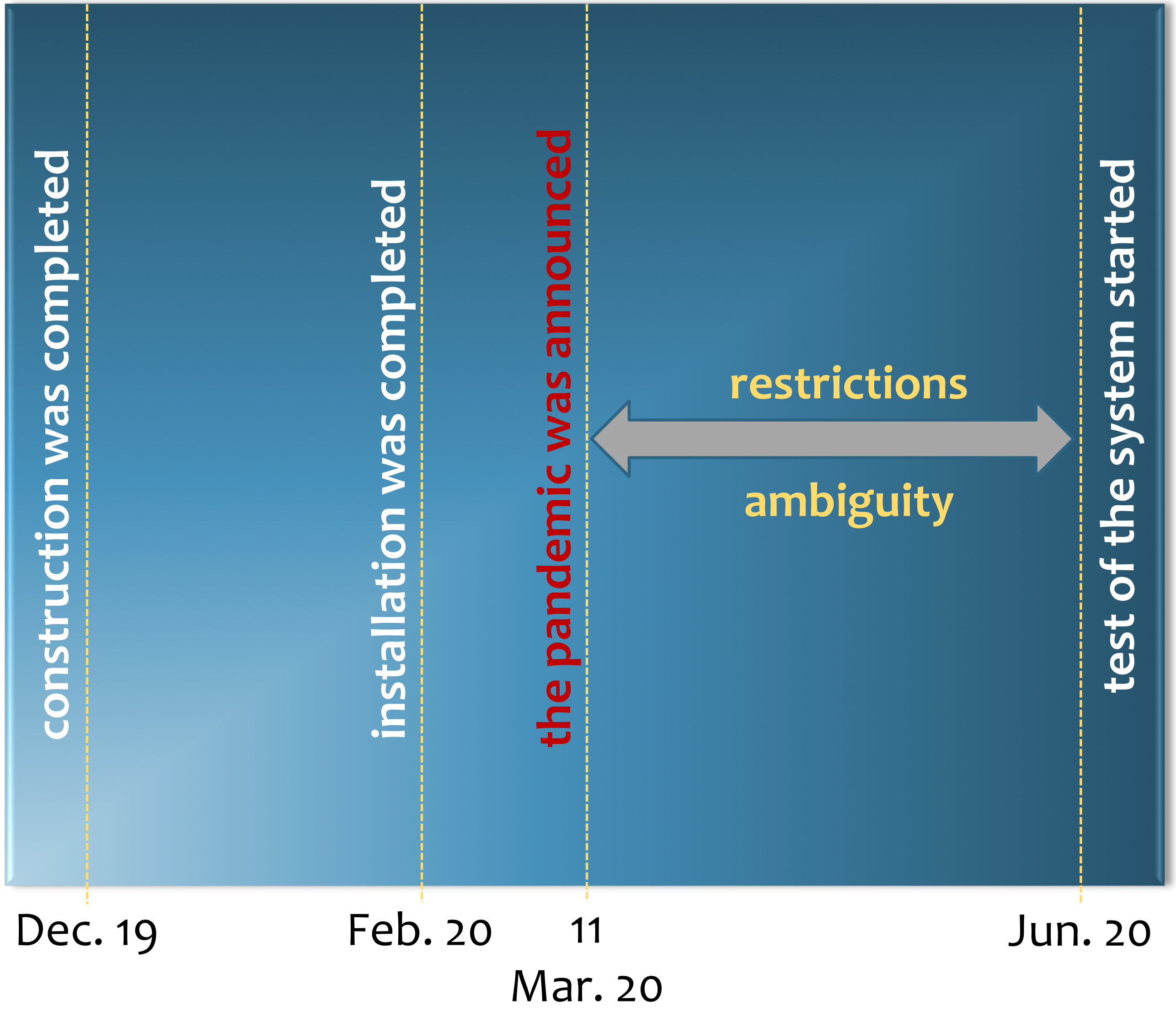
- ✓ There are also 27 marine finfish hatcheries

Source: DG Fisheries And Aquaculture, 2020; 2021

The SIMTAP concept

- ✓ The sustainability of marine finfish hatcheries was major source of inspiration for the SIMTAP concept in Turkey
- ✓ The SIMTAP concept mainly aimed
  - ➢ to test a cost-effective integrated RAS for an indoor SIMTAP prototype under extreme environmental conditions of the Mediterranean
    - high indoor air temperatures (≈ 40 °C during summer)
    - high water temperatures (≥ 30 °C during summer)
    - high salinities (≥ 40 ppt during summer)
  - ➢ to test a SIMTAP prototype for marine hatcheries and a possibility of utilization for growth period of European seabass and gilthead seabream

Description of the SIMTAP prototype - Timeline



The conditions of pandemic prevailed during the spring months resulted in miss of:

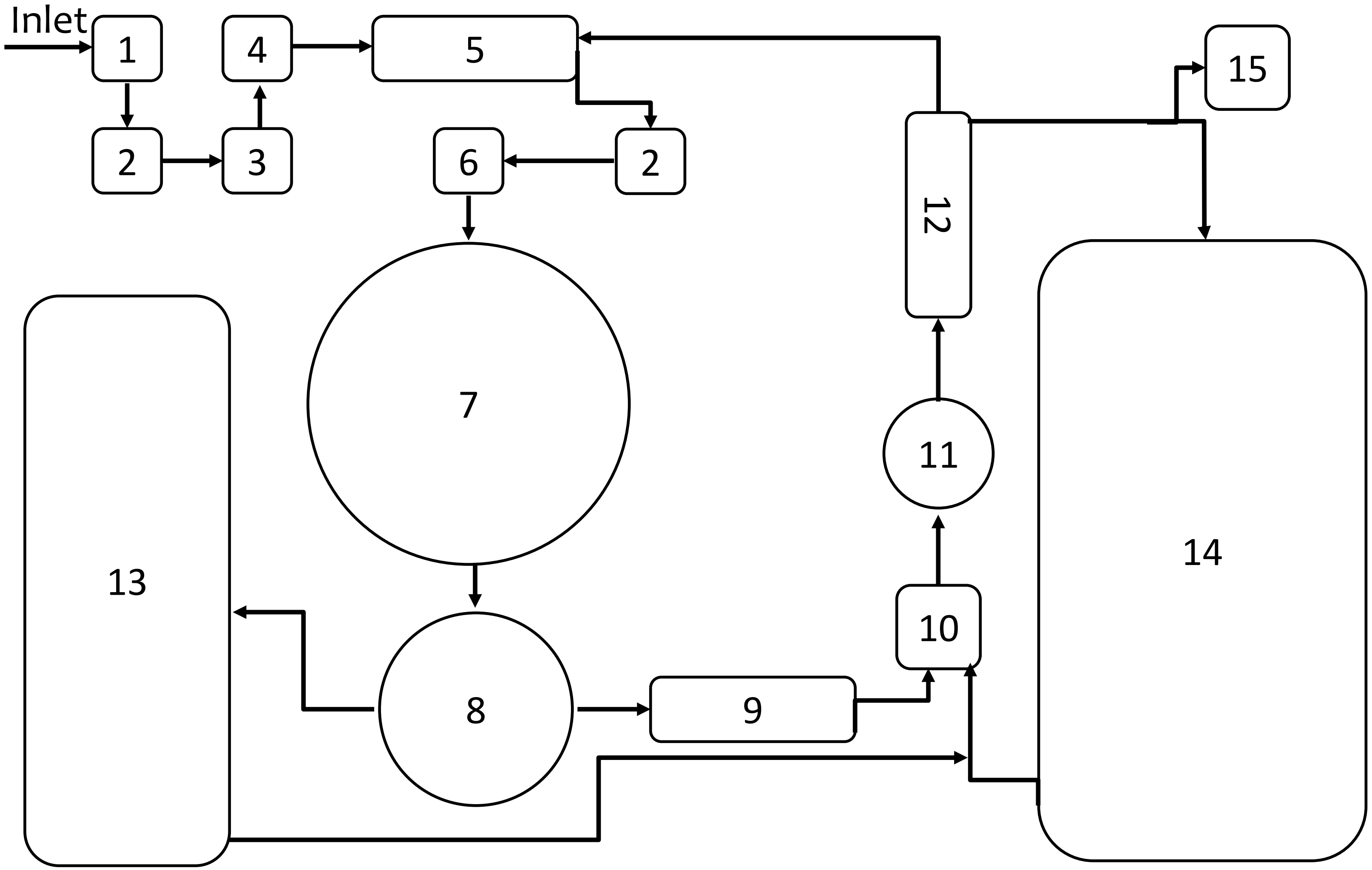
- ✓ early fingerling period for the selected fish species (1 g)
- ✓ seedling period of *Salicornia europea*
- ✓ breeding period of polychaete worms

Description of the SIMTAP prototype

System was mainly composed of

- Fish culture unit (4 tanks of 5 m³ each)
- Polychaete unit (90 tanks of 0.1 m² each)
- Hydroponic unit (18 tanks of 3 m² each)
- Microalgae unit (12 bags of 50 L each)
- Water recycling, particle removal and disinfection/sterilisation equipment

Description of the SIMTAP prototype



1. Particle filter
2. UV disinfection
3. Ozonation
4. Reservoir tank
5. Sump pump
6. Degassing column
7. Fish rearing tanks
8. Radial flow settler
9. Settling tank
10. Reservoir tanks
11. Protein skimmer
12. Moving bed bioreactor
13. Polychaete culture tanks
14. Hydroponic tanks
15. Microalgae culture unit

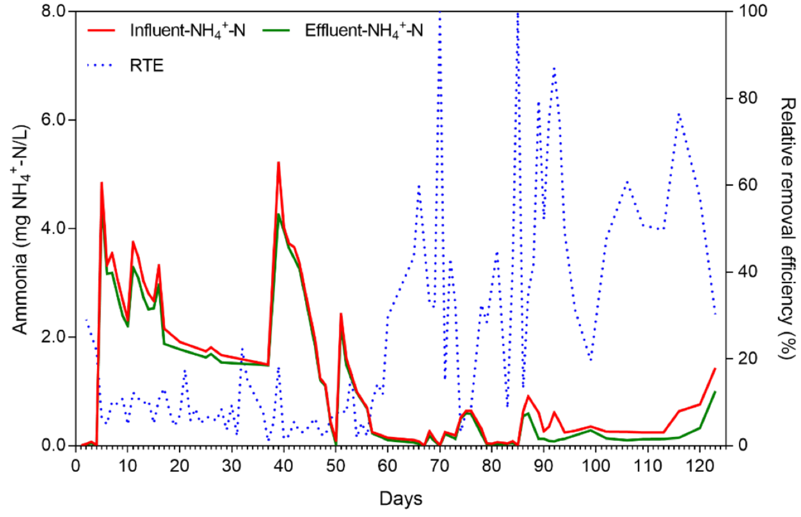
Description of the SIMTAP prototype

- ✓ The fish culture unit was successfully integrated with recirculation equipment and a rearing period was completed
- ✓ Polychaete unit was fed by flushing of the bottom of radial flow settlers
- ✓ The hydroponic unit was fed by biofilter outflow with a hydraulic residence time of two hours
- ✓ Microalgae culture unit was intermittently fed by the backwash of protein skimmer through the aerobic digestion and disinfection

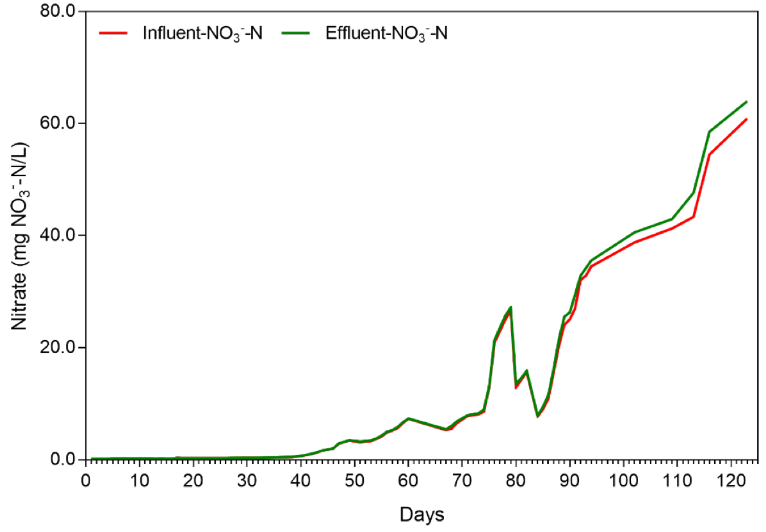
Studies completed - SIMTAP system starting & biofilter conditioning

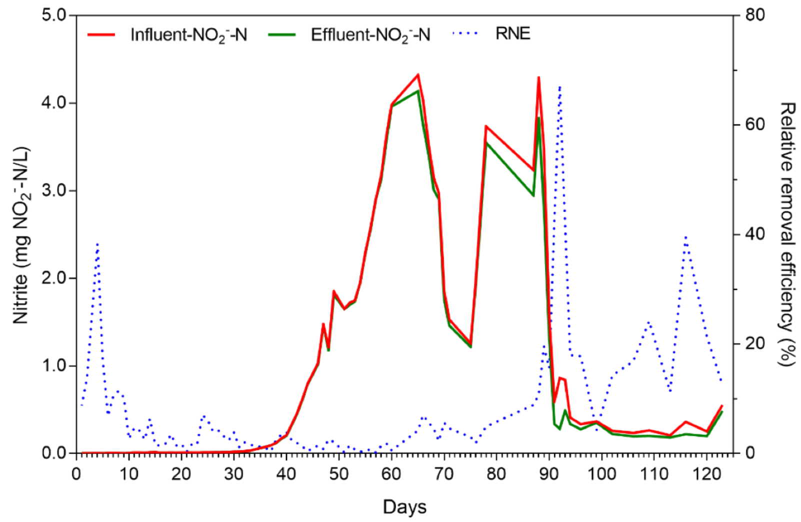
- ✓ Tests of SIMTAP prototype started up on 1 June 2020
- ✓ The concentration of ammonia nitrogen was increased to 5 mg N/L
- ✓ A commercial mixture of bacterial cultures was inoculated into MBBR on 5th day
- ✓ Ammonium chloride supplementations were repeated on 38th, 51st, 68th, and 71st days
- ✓ European seabass (14.6±0.2 g) and gilthead seabream (20.5±0.1 g) were stocked at a density of 7.1 kg/m^3 and 9.5 kg/m^3 respectively on the 79th day
- ✓ MBBR were monitored daily/every other day for a total of 123 days

Studies completed - SIMTAP system starting & biofilter conditioning



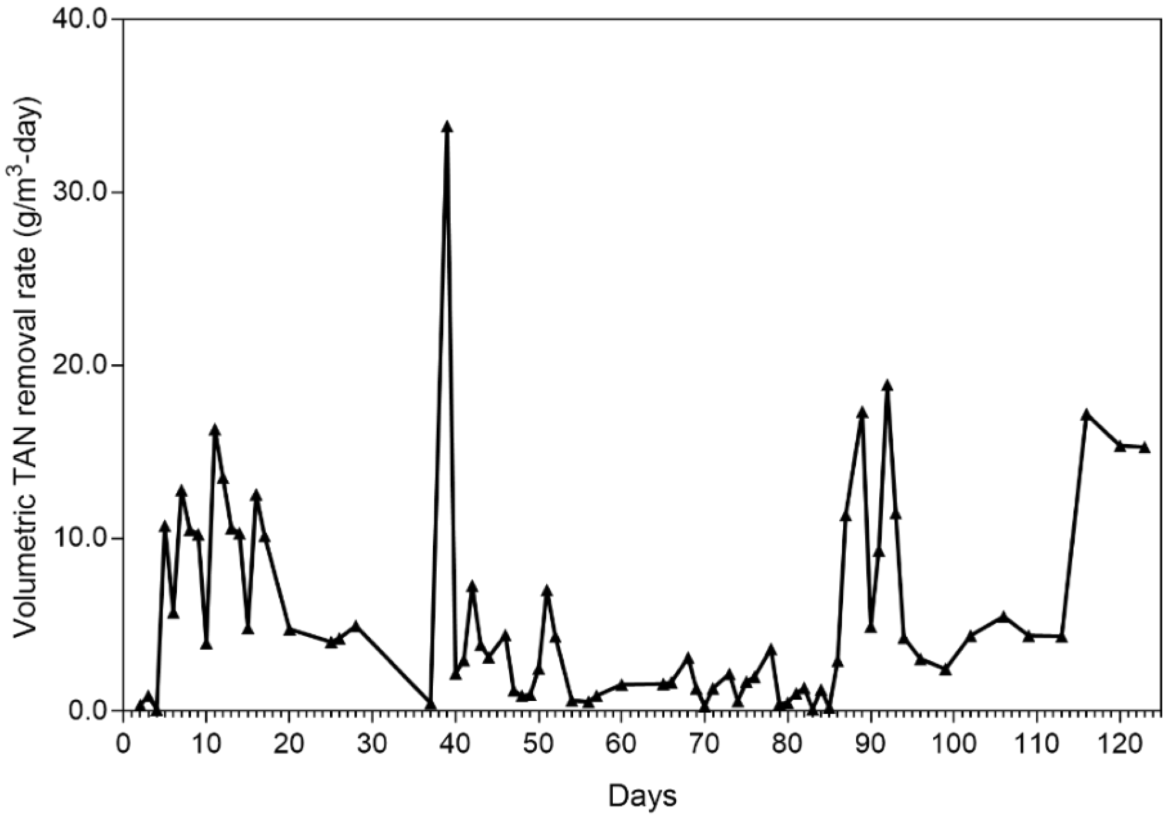
- ✓ A sharp decrease in ammonia and a sharp increase in removal efficiency (RTE) were observed on 40th day





- ✓ A sharp increase in nitrite on 40th day and a sharp decrease in removal efficiency (RNE) on 90th were observed

Studies completed - SIMTAP system starting & biofilter conditioning

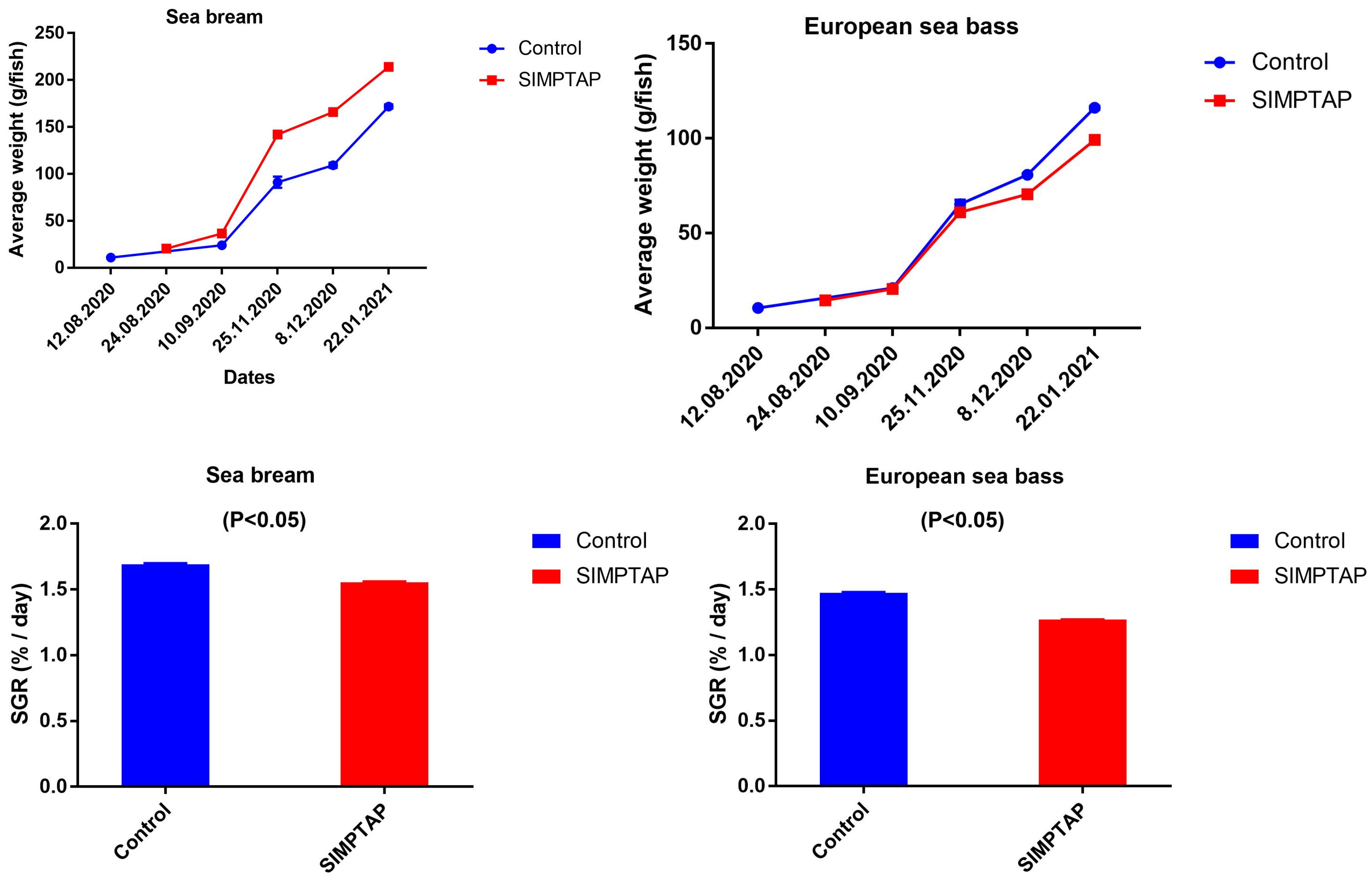


✓ The complete acclimatization of nitrifying bacteria nearly took three months in the SIMTAP prototype

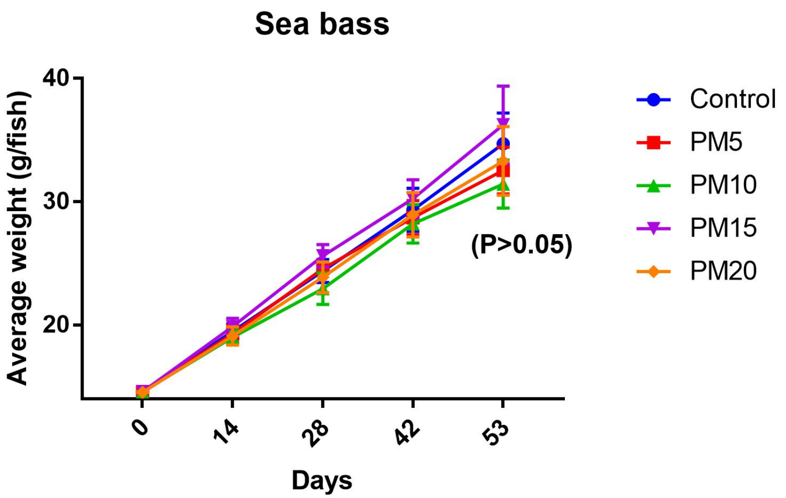
Studies completed - Fish growth performances in SIMTAP prototype

- ✓ By using the same fish tanks and stocking density, a flow-through system was used as a control
- ✓ European seabass (14.6±0.2 g) and gilthead seabream (20.5±0.1 g) were stocked at a density of 7.1 kg/m^3 and 9.5 kg/m^3 respectively
- ✓ Fish were fed at predetermined levels based on the total biomass in each tank twice a day
- ✓ The growth period was carried out for more than 5 months

Studies completed - Fish growth performances in SIMTAP prototype

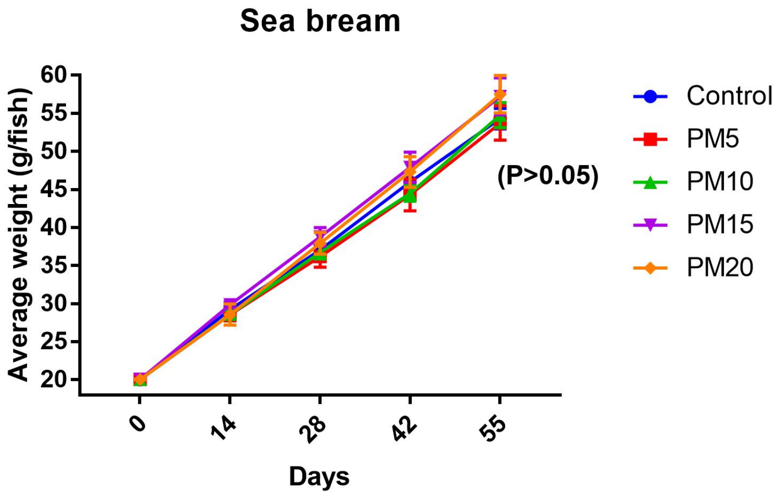


- ✓ Proximate composition
- ✓ Fatty acid profile
- ✓ Amino acid profile



A total of 30 experimental tanks (0.5 m^3; 15 for European sea bass and 15 for Gilthead Sea Bream) was prepared

Initial weights of European sea bass and Gilthead Sea Bream were 14.56±0,01 g and 20.03±0,02 g



5 levels of inclusion of polychaete meal in place of fish meal (0%, 5%, 10%, 15% and 20%)

The study was conducted about 8 weeks

No significant difference between the treatments for growth

Next studies

- ✓ Germination, seedling and growth of *Salicornia europea* in the SIMTAP prototype
- ✓ Polychaete stocking and growth
- ✓ Microalgae growth in batch, semi-continious and continious cultures and their integration to SIMTAP system
- ✓ Adaptation period prior to cage transfer will be carried out in European sea bass and gildhead sea bream

Thank you very much for your attention

The SIMTAP project for sustainable aquaponics
March 19th 2021

General approach and methodology for the assessment of SIMTAP sustainability

Joël Aubin, Jacopo Bacenetti, Samuel Le Féon, Théo Dubois, Nouraya Akkal-Corfini, Christophe Jaeger, Aurélie Wilfart, Michele Costantini, Giuseppe Coppola and all partners of SIMTAP project

The PRIMA programme is supported under Horizon 2020, the European Union's Framework Programme for Research and Innovation

Sustainable development

"**Sustainable development** is **development** that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Our Common Future; Brundtland Report 1987).

Questions :

- How to guide aquaculture systems towards sustainability?

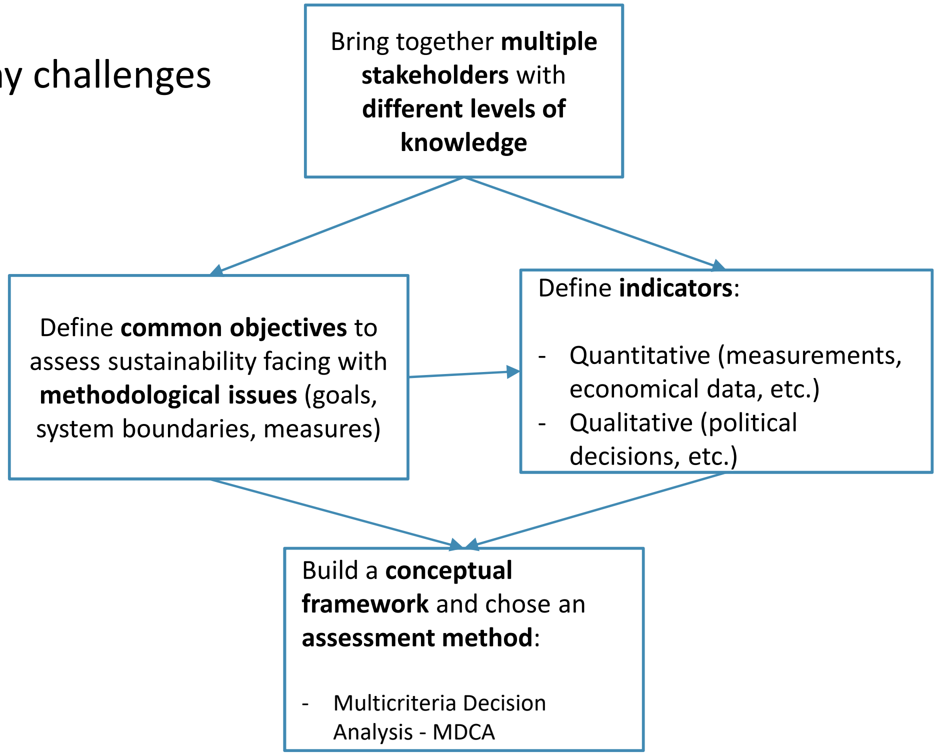
A proposal :

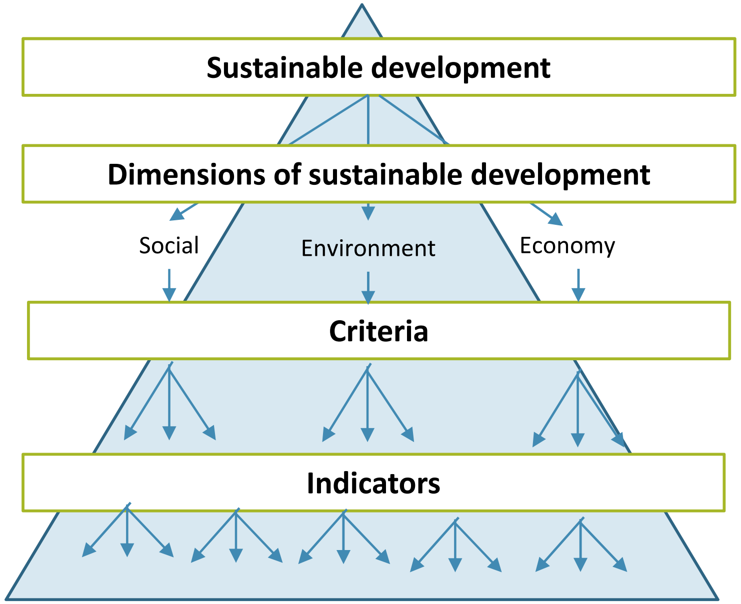
- Conducting a sustainability assessment to guide improvements

Sustainable Development Goals of United Nations

Conducting a sustainability assessment

Many challenges





Conceptual framework for sustainability assessment

MultiCriteria Decision Analysis

- Aims to take account of multiple criteria in helping individuals or groups to explore decisions that matter (Belton et al., 2002)

- Helps integrating objective measurement with value judgement, using quantitative or qualitative indicators, and makes explicit and manages subjectivity through the organized intervention of concerned people

- Aims to face problems of aggregation and weighting in the organization of indicators and criteria

- Different methods exist: weighted sums, Outranking methods, Multi-attribute utility theory…

We chose DEXI method

DEXi method

DEX for **D**ecision **Ex**pert

Conception in 1979 and used in various areas

(economy, finance, agriculture, tourism, …)

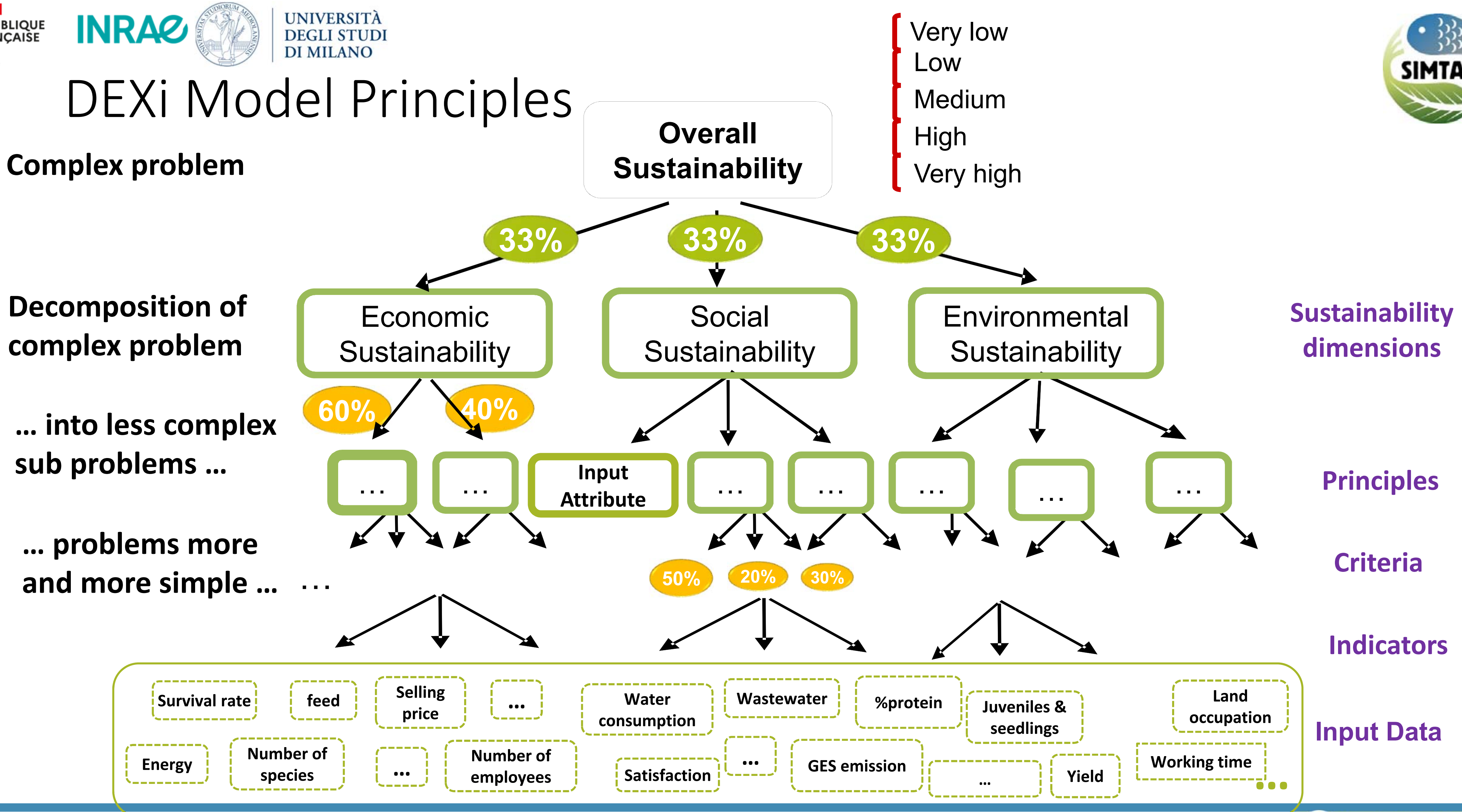
DEXi method is a **multi-criteria** decision modelling and support.

DEXi has three key chararcteristics:

- **Hierarchical**
- **Qualitative**
- **Rule-based**

It is supported by an open access software

DEXi Model Principles



DEXi Model Principles

Input data :

- derived from (i) contextual, technical-economic-social data
- estimated by calculations/model/experimental results (LCA, Emergy Accounting, LCC, SLCA)

Input data are scored on a **qualitative scale** using threshold values

- Qualitative scores (e.g. high, medium, low)
- Classes (e.g. treatment numbers 15<20<25<35)

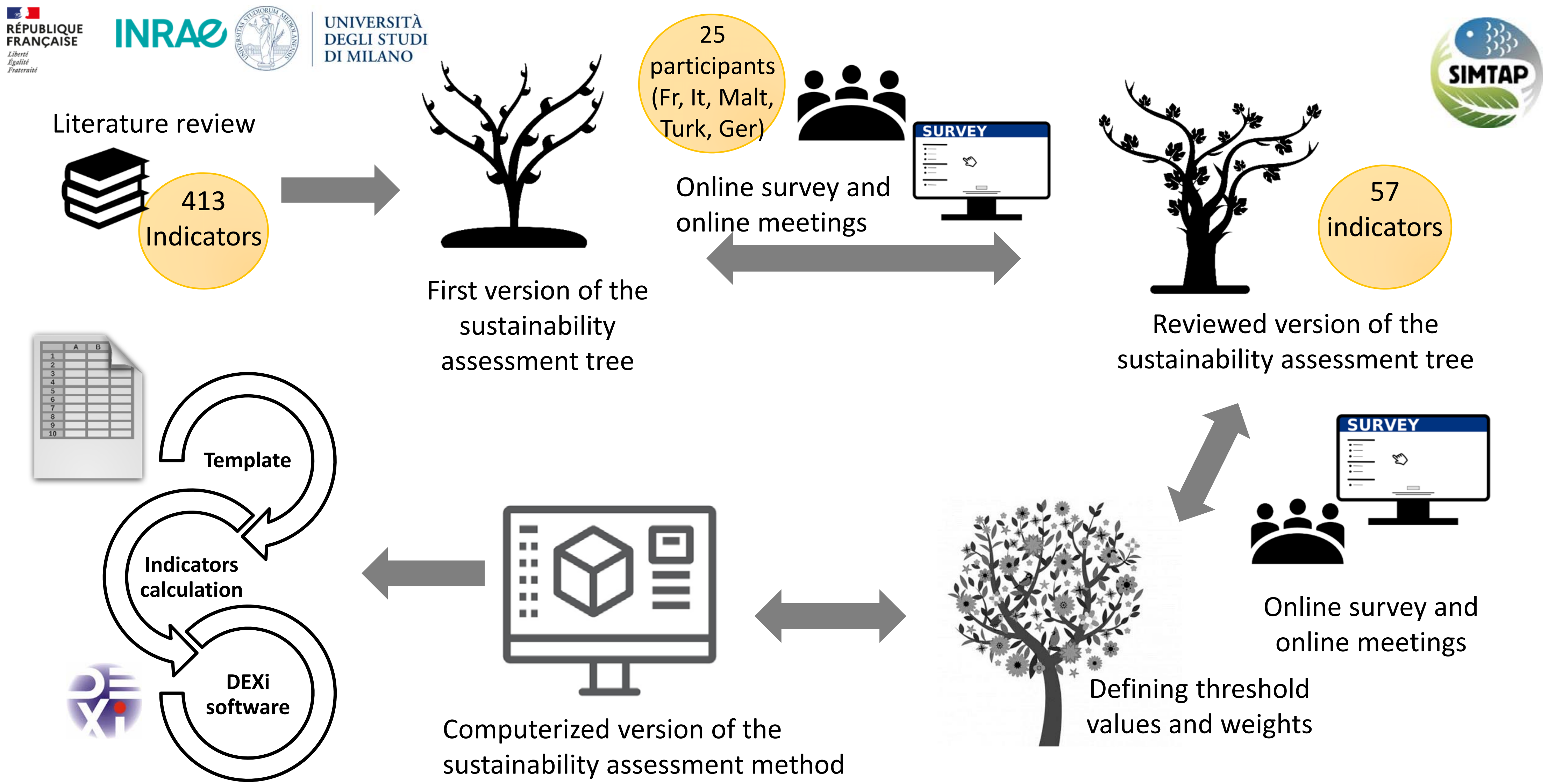
Aggregated through

utility functions (if…. ; then… qualitative rules) which determine the importance of each basic attribute on the upper one.

Utility functions based on decision rules)

If If and if then

Economic Sustainability 33%	Social Sustainability 33%	Environmental Sustainability 33%	Overall Sustainability
Very low	*Very low*	*Very low*	Very low
Low	*Medium*	*Very low*	Low
Medium	*Very high*	*Low*	Medium
Medium	*High*	*Very high*	High
Very high	*High*	*Very high*	Very high


Literature review
413 Indicators
First version of the sustainability assessment tree
25 participants (Fr, It, Malt, Turk, Ger)
SURVEY
Online survey and online meetings
57 indicators
Reviewed version of the sustainability assessment tree
SURVEY
Online survey and online meetings
Defining threshold values and weights
Computerized version of the sustainability assessment method
Template
Indicators calculation
DEXi software

Different methods to provide indicators

- Technical data (materials, energy consumptions, etc.)
- Input-output data (feed, biomass produced, etc.)
- Environmental data (direct emissions, etc.)

→ **LCA + Emergy** →

Global Warming Potential
Eutrophication
…
Emergy Yield Ratio
…

- Social data (number of employees, salaries, etc.)

→ **SLCA** →

Gender Equality
Full-time Employment
…

- Technical data (materials, energy consumptions, etc.)
- Input-output data (feed, biomass produced, etc.)
- Economic data (incomes, costs)

→ **LCC** →

Gross Value Added
Net Present Value
…

- Technical data (materials, energy consumptions, etc.)
- Input-output data (feed, biomass produced, etc.)
- Economic data (incomes, costs)

→ **Other indicators** →

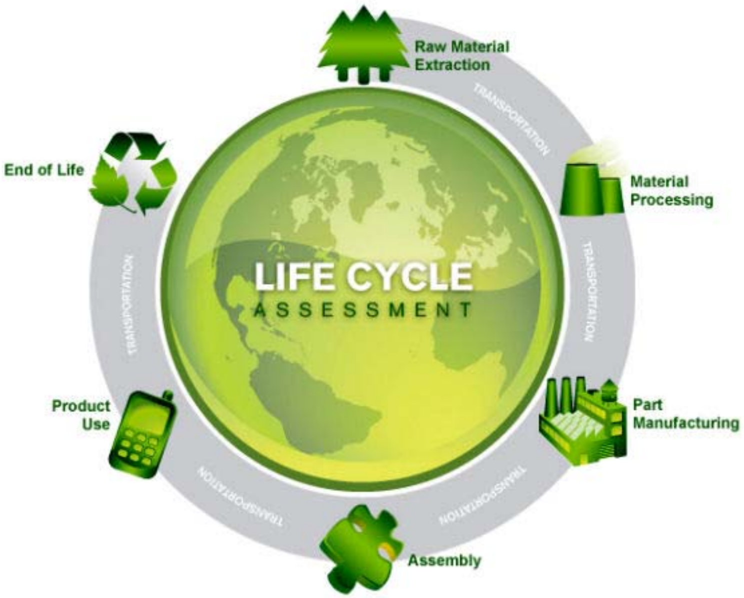
Fish in Fish Out ratio
…

→ DEXi →

Environmental indicators
Economic indicators
Social indicators

Overall Sustainability

LCA



The **life cycle** of a product corresponds to its journey "from cradle to grave", i.e. from the acquisition of raw materials, to its production, its use and its end of life (disposal, recycling).

LCA is a method for quantitatively assessing the environmental impacts of a system that includes all activities related to a product or service from the extraction of raw materials to the disposal and treatment of waste (ISO 14040, 14044).

- Impacts are expressed using a **functional unit** (FU): per kg of product, ha, km travelled...
- LCA considers the resources used and the pollutants emitted.
- LCA produces indicators of environmental sustainability

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SIMTAP

LCA

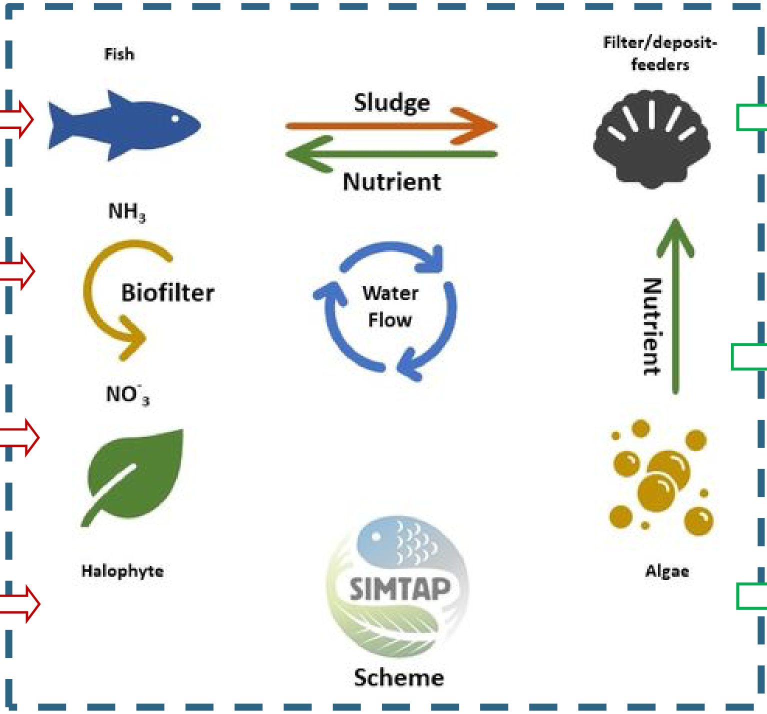
→ Collection of **inventory data** for the studied systems and life cycle **impact assessment**

→ Potential environmental impact evaluated for the provided function (1 kg of fish, 1 kg of vegetables)

cradle-to-gate approach

Inputs

- Raw materials (feeds, chemicals...)
- Juveniles and seedlings
- Energy
- Water



Outputs

- Products & co-products
- Emissions to the environment
- Waste & wastewater

Life Cycle Impact Characterization

Impact categories

- Water demand m^3
- Net primary production use kg C eq
- Global warming potential kg CO_2 eq
- Acidification potential kg SO_2 eq
- Eutrophication potential kg PO_4^{3-} eq
- Global land competition m^2
- Cumulative energy demand GJ

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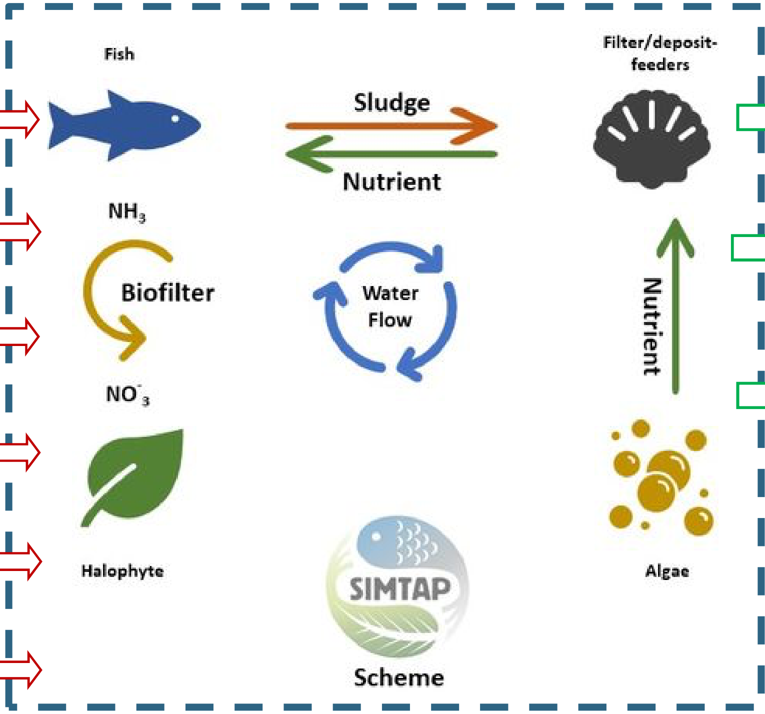
SIMTAP

LCC

- → Collection of **inventory data** for the studied systems
- → Economic performance (Net present value, pay-back time, gross value) evaluated for the whole plant/system

Cost item

- Raw materials (feeds, energy, etc.)
- Juveniles and seedlings
- Subsidy
- Waste & wastewater management cost
- Infrastructures (buildings, devices)
- Maintenance costs



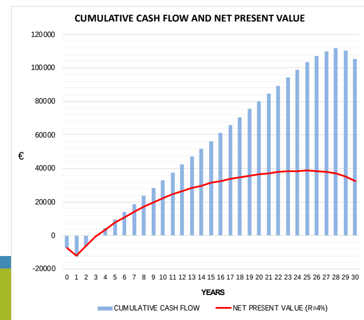
Outputs

- Products & co-products
- Emissions to the environment
- Waste & wastewater

Life Cycle Cost

Economic performance

- Net present value
- Pay-back time
- Internal rate of return
- Gross added value



S-LCA

- → Collection of **inventory data** for the different affected stakeholders
- → Choice of sub-indicators
- → Collection of indicators data and definition of scoring principle

SIMTAP System (gate-to-gate approach)

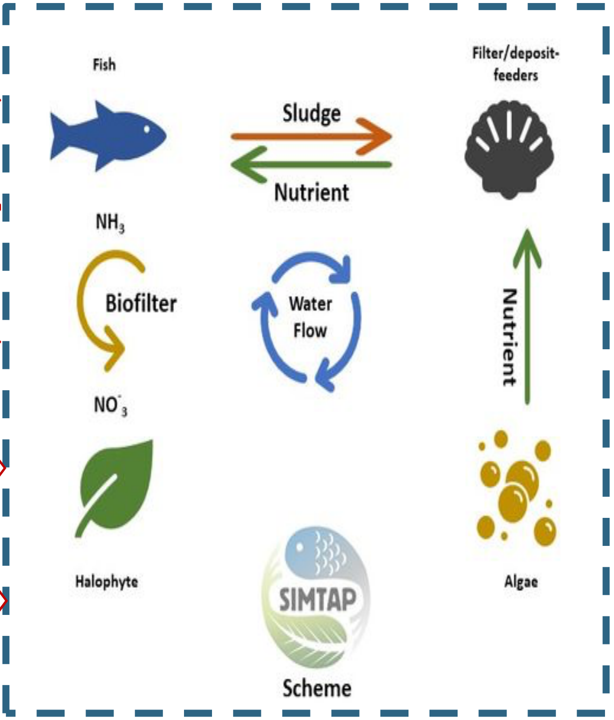
Working time

Salary

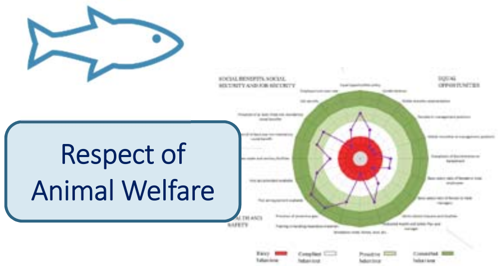
Survival rate

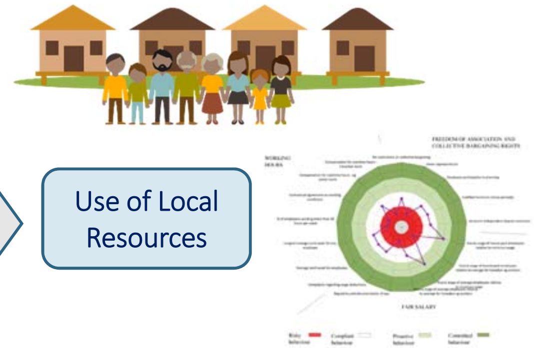
Fish stocking density

Biosecurity practices



Sub-indicators	Scoring principle	Social Impact categories
Fish Physical Damages: (# Number of fish with skin or fin damages or deformities / # Fish Sampled)*100	High: More than 20% Medium: Between 4% and 20 % Low: Less than 4%	Respect of Animal Welfare
Feedstuff locally Produced: (Quantity of feedstuff not imported/ Total quantity of feed stuff used)*100	High: More than 60% Medium: Between 40 and 60% Low: Less than 40%	Use of Local Resources



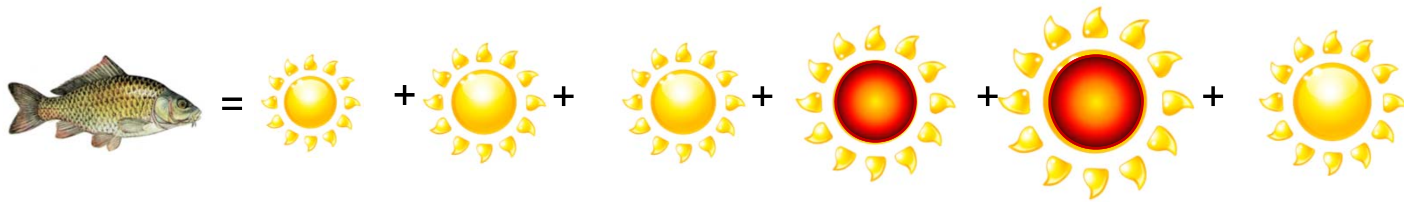


Emergy

Energy: The ability to cause work (i.e. potential-available energy/exergy)

There are many “forms” of energy to produce something…

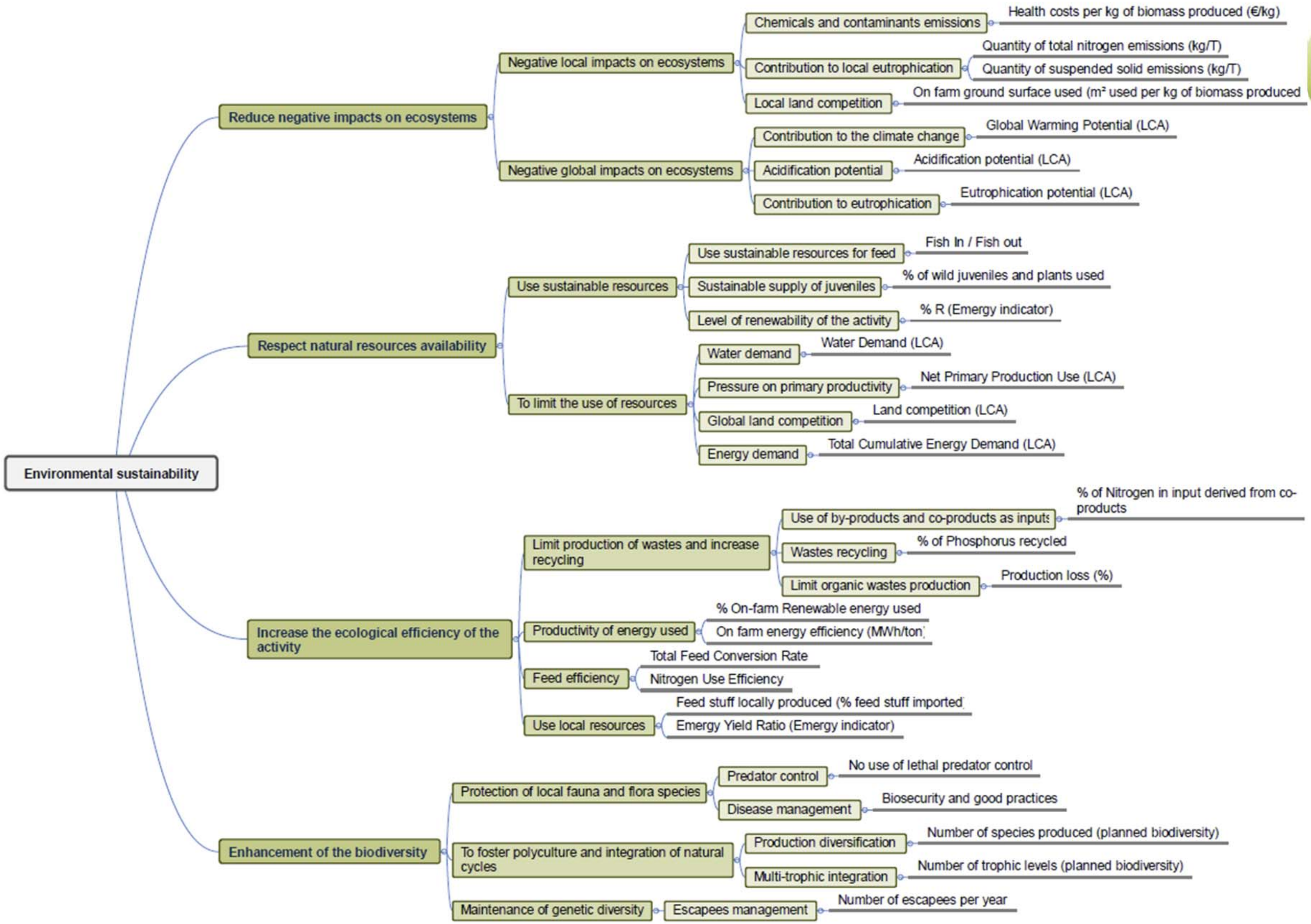
EMERGY: **The energy required directly and indirectly to make something**
Expressed in energy of the same FORM … solar energy ;



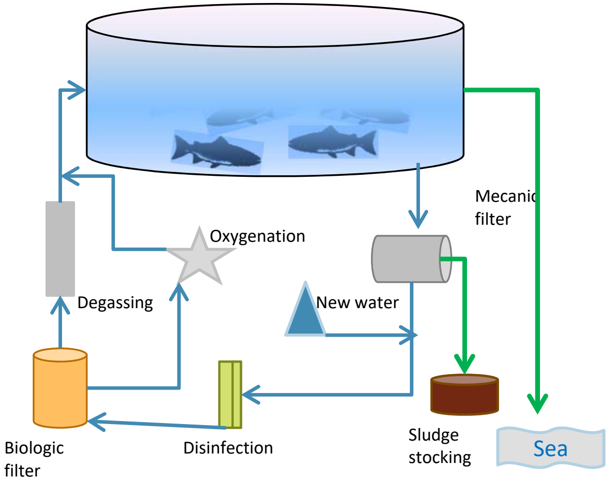
Wilfart et al, 2012

Unit = Solar Emergy joules = sej

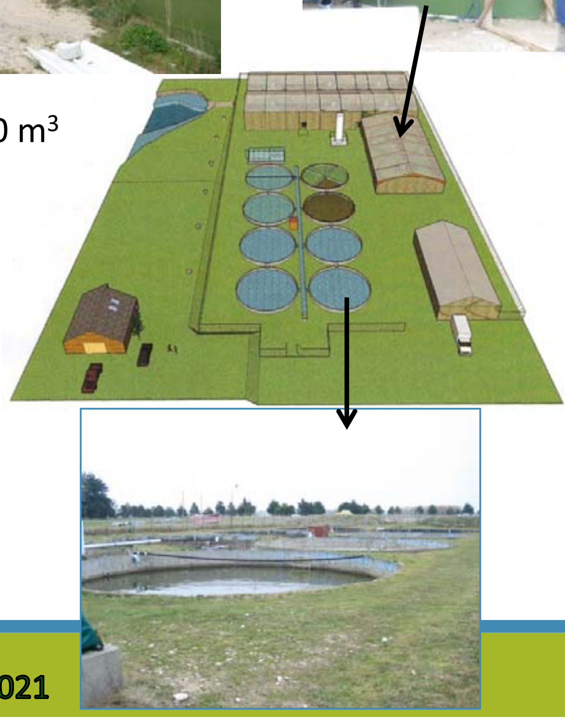
Exemple: Branches for environmental sustainability assessment



Example: Application on a salmon RAS scenario



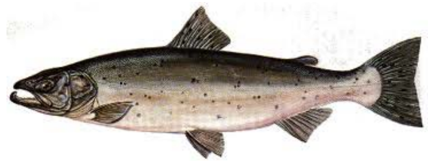
1 tank: 1400 m^3



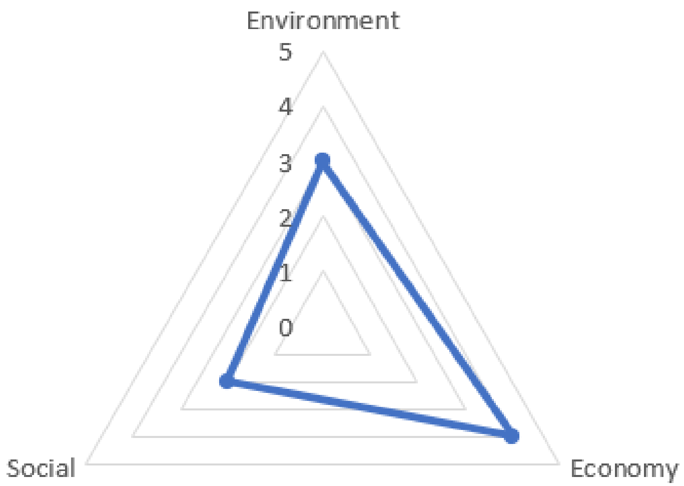
Production

- 50 T. yr^{-1}, density =120 kg m^{-3} ,
- 20 m^3/h water renewal, 250 kg feed/day, 2500 m^3/h air
- 0.8 kg O_2 per kg feed.

Wilfart et al, 2013



Sustainability diagnostic



Overall sustainability representation	Sustainability branch	Score	Sub-branches	Score
	Environment	Medium	Reduce negative impacts on ecosystems	High
			Respect natural resources availability	Medium
			Increase the ecological efficiency of the activity	Medium
			Enhancement of the biodiversity	Medium
	Economy	High	Production efficiency	Medium
			Viability	High
	Social	Low	Relationship with other actors	Very low
			Employment and working conditions	Medium
			Meeting social expectations	Medium
			Contribution to local development	Very low

Perspectives

- Application and adaptation to the different SIMTAP case studies
- Application to reference aquaculture systems in the different countries of SIMTAP project
  - ⇒ Overall analysis of sustainable hot spots in aquaculture systems
  - ⇒ Improvement of the DEXi model
- General discussion on the crossing of different approaches : DEXi, LCA, LCC, SLCA, Emergy
- Make available the tools for other users and projects

Thank you very much for your attention