integrate

Integrate Aquaculture:
an eco-innovative solution to foster
sustainability in the Atlantic Area

INTERREG Atlantic Area 2014-2020 Project EAPA_232/2016

IMTA : INTEGRATED MULTI-TROPHIC AQUACULTURE

A sustainable solution for Seaweed Aquaculture

Interreg Atlantic Area
European Regional Development Fund

EUROPEAN UNION

www.integrate-imta.eu

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SHEET PACKAGE 1:
Principles of IMTA and seaweeds cultivation

SHEET 1.1 – What is IMTA ?

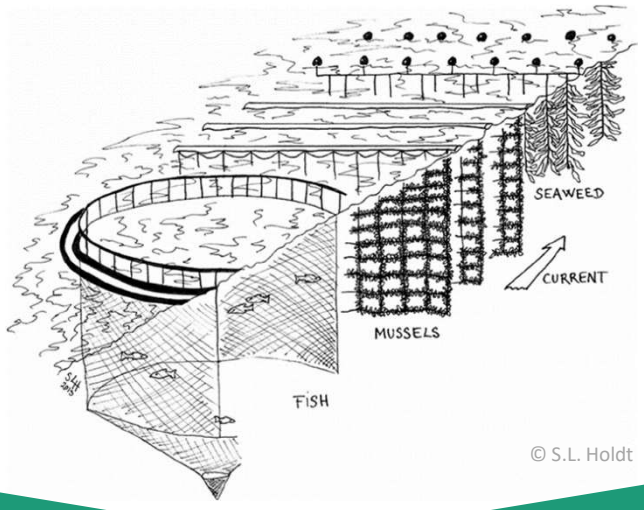
The concept of IMTA and the different systems of interests

SHEET 1.2 – Seaweed Aquaculture

The different groups of seaweeds, their role in the marine ecosystem, the cultivation of seaweeds

SHEET 1.3 – Why use seaweeds in IMTA ?

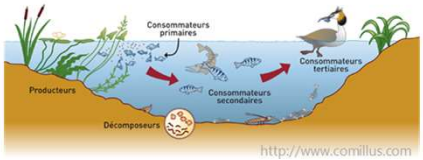
The different roles for seaweeds in an IMTA system



SHEET 1.1:
WHAT IS IMTA ?

To integrate

Place something in a set so that it is in harmony with the other elements.



Multi-Trophic

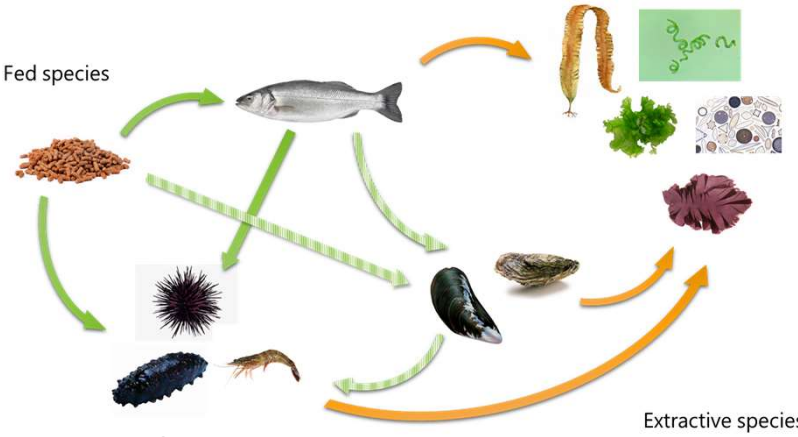
Several feeding strategies/behaviours

- Herbivorous
- Carnivorous
- Detritivorous
- Filtering

Aquaculture

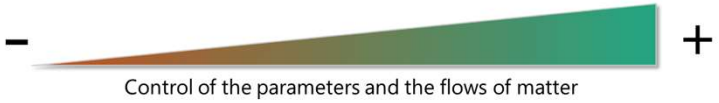
Production of aquatic organisms

IMTA = Imitation of the natural ecosystem



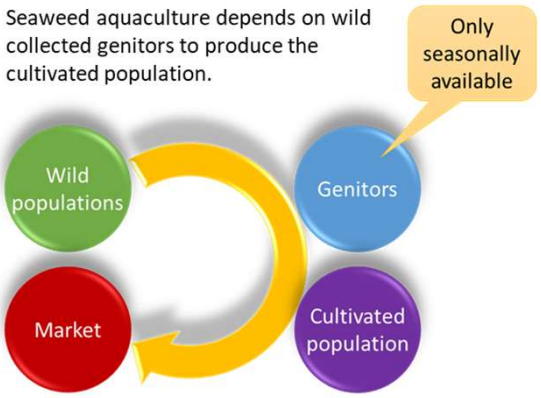
From: www.dfo-mpo.gc.ca

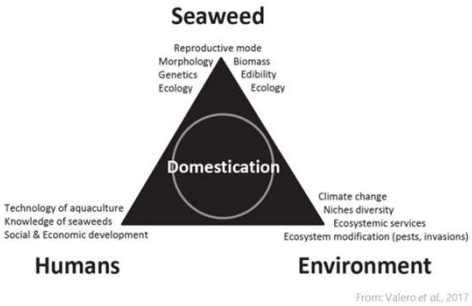
Different ways to develop IMTA systems



SHEET 1.2:
SEAWEED AQUACULTURE

Seaweed aquaculture depends on wild collected genitors to produce the cultivated population.





But seaweed domestication is one complex process which results from the interaction of seaweed, human and environmental factors.

LAND-BASED FARMS

MARSH FARMS

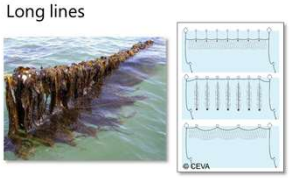
For both Land-based and Marsh systems, seaweeds can be cultivated without artificial substrate (i.e freefloating).

One bubbling system or a paddle wheel ensures the circulation of the seaweeds in the water column.

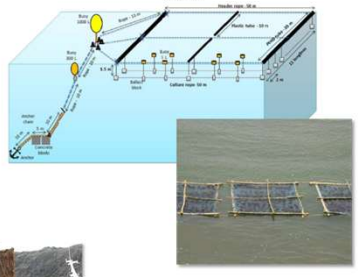
AT-SEA FARMS

Floating structures

Long lines



Rafts

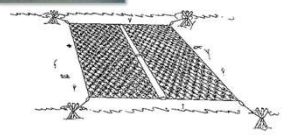


2D textile substrates

Benthic structures

Long lines

Nets



At-sea cultivation of seaweeds necessitates one artificial substrate and so a hatchery phase for the seeding on the structure. This can be done by natural properties of the seaweeds to recruit on the substrate or by-hand attachment.

SHEET 1.3:
WHY USE SEAWEEDS IN IMTA?

Seaweeds as a filter

Seaweeds are at the end of the process

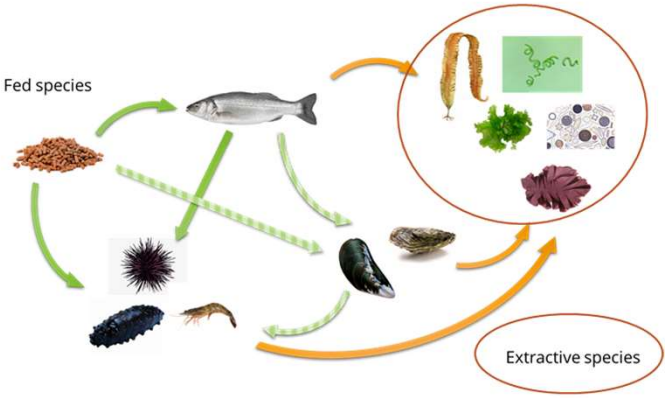
Seaweeds will consume mineral dissolved nutrients

Clean the water from animal production

Produce dissolved O2

But: absorb and accumulate the chemical inputs as heavy metals and veterinary treatments (hormones, antibiotics...)

The quality of seaweed could decrease for the concerned market

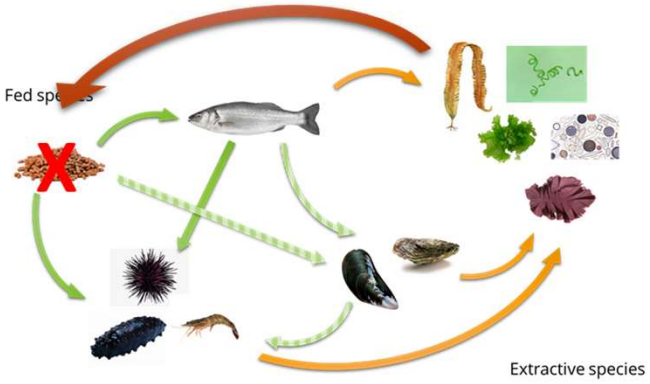


Seaweeds as a feeding source

Seaweeds **are** the fed species

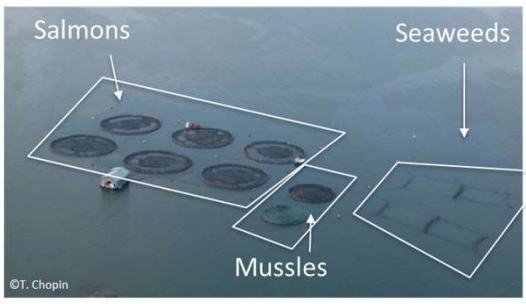
They provide Large organic nutrients

They allow the recycle of the matter



But: absorb and accumulate the chemical intrants as heavy metals and veterinary treatments (hormones, antibiotics...)

The quality of seaweed could decrease for the concerned market



Ex: In Canada, seaweed (*Saccharina latissima*) is downstream from a salmon and mussles production. Here, seaweeds are expected to extract the mineral section of the animals wastes.

Ex: In Malaysia, sea cucumber fed with cultivated seaweed (*Caulerpa racemosa*)

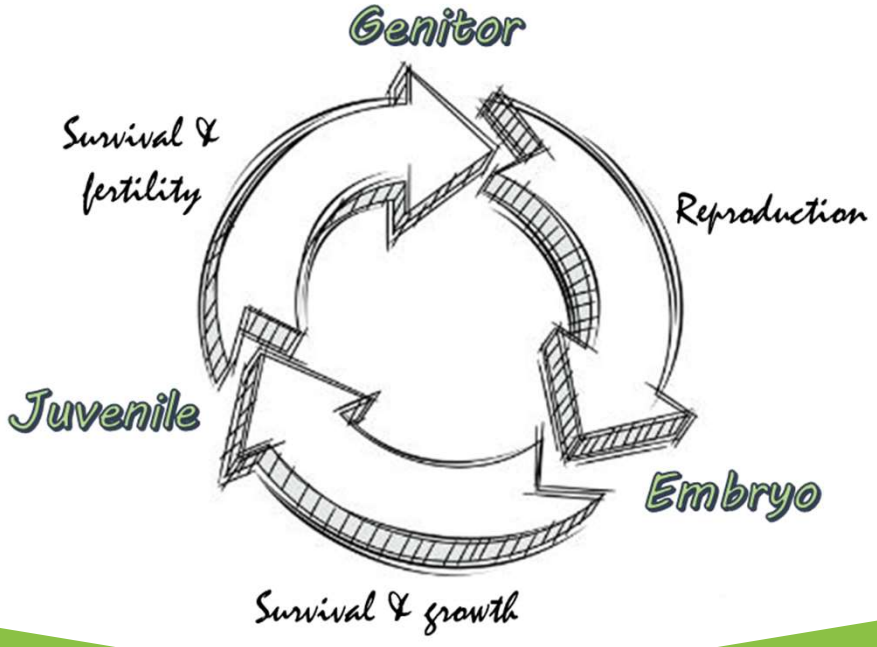
SHEET PACKAGE 2:
Description of the life cycles of the main cultivated seaweed species

SHEET 2.1 – Brown seaweeds life cycle

SHEET 2.2 – Red seaweeds life cycle

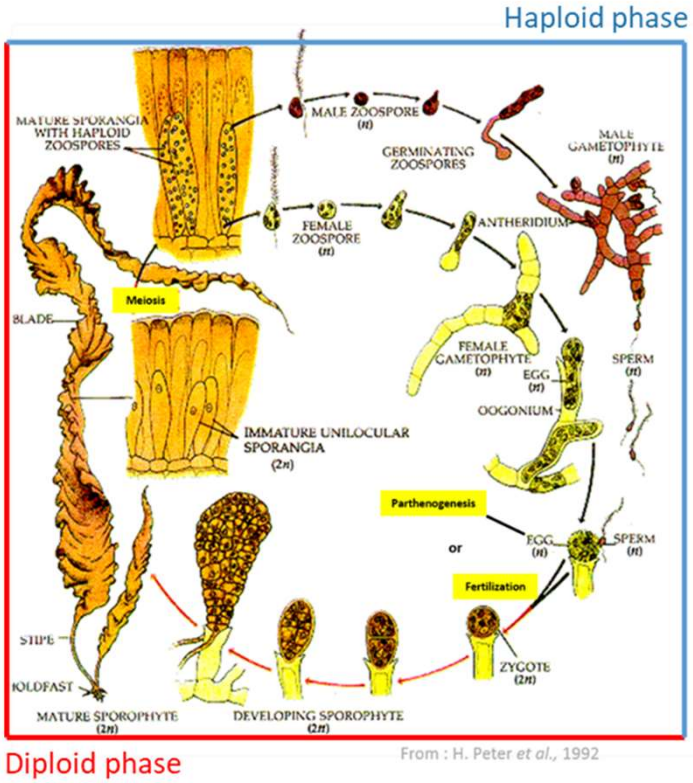
SHEET 2.3 – Green seaweeds life cycle

SHEET 2.4 – Main influencing parameters



SHEET 2.1:
The Brown seaweeds

KELP SPECIES



From : H. Peter *et al.*, 1992

Laminaria sp.

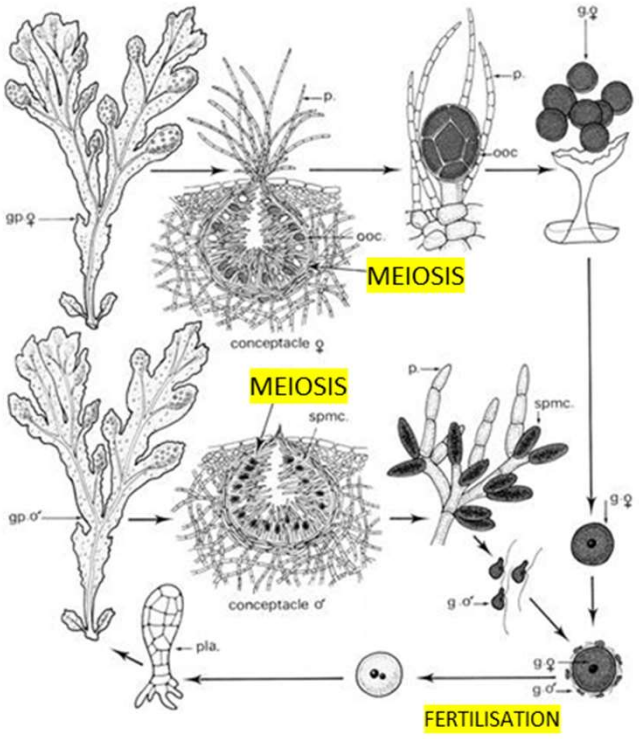
Alaria esculenta

Saccharina latissima

Undaria pinnatifida

N.B: Life cycles can show specificities according to each species.

FUCALES SPECIES



Fucus serratus

Himanthalia elongata

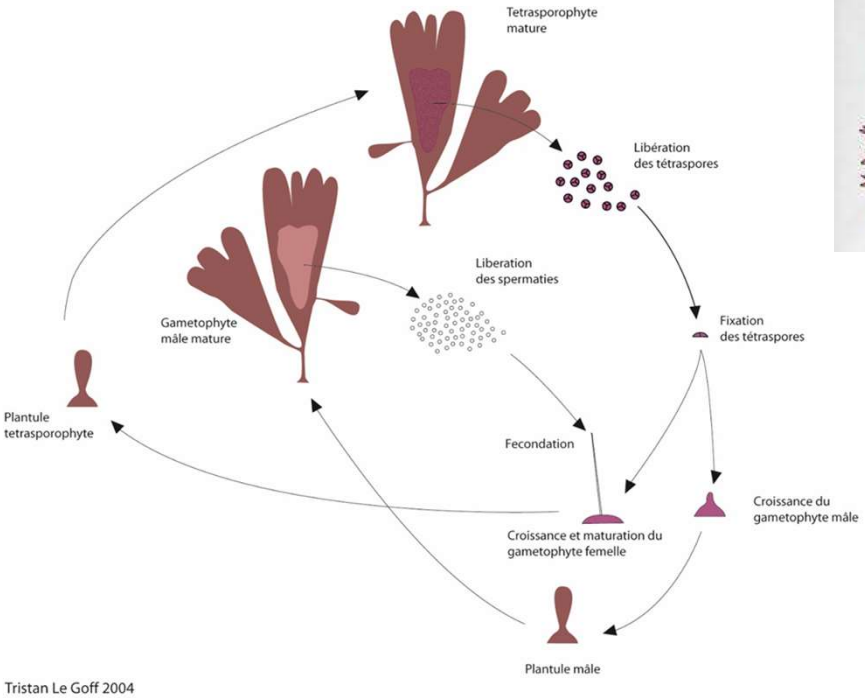
Ascophyllum nodosum

Sargassum muticum

N.B: Life cycles can show specificities according to each species.

SHEET 2.2:
The Red seaweeds

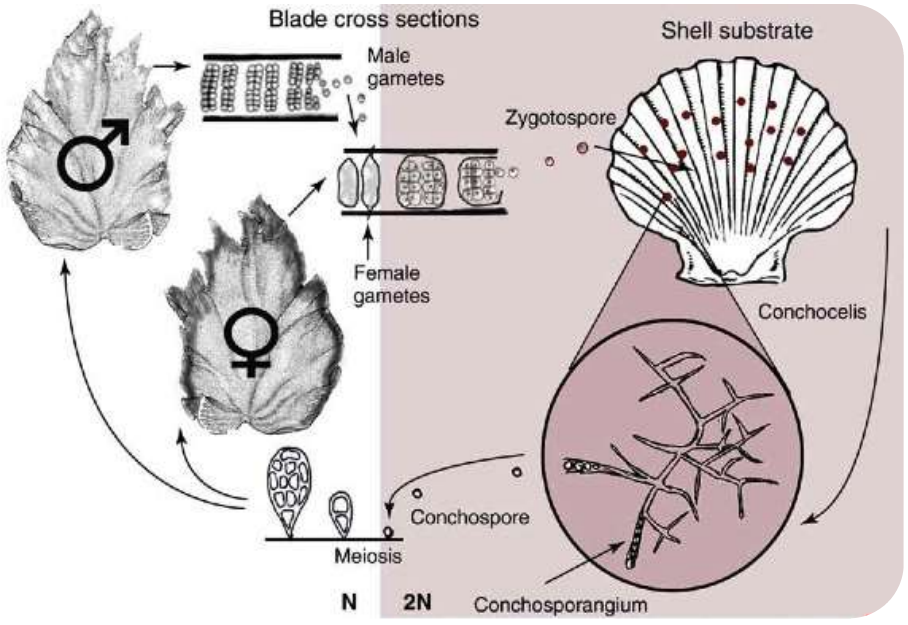
PALMARIALES (DULSE) SPECIES



Palmaria palmata

N.B: Life cycles can show specificities according to each species.

BANGIALES (NORI) SPECIES



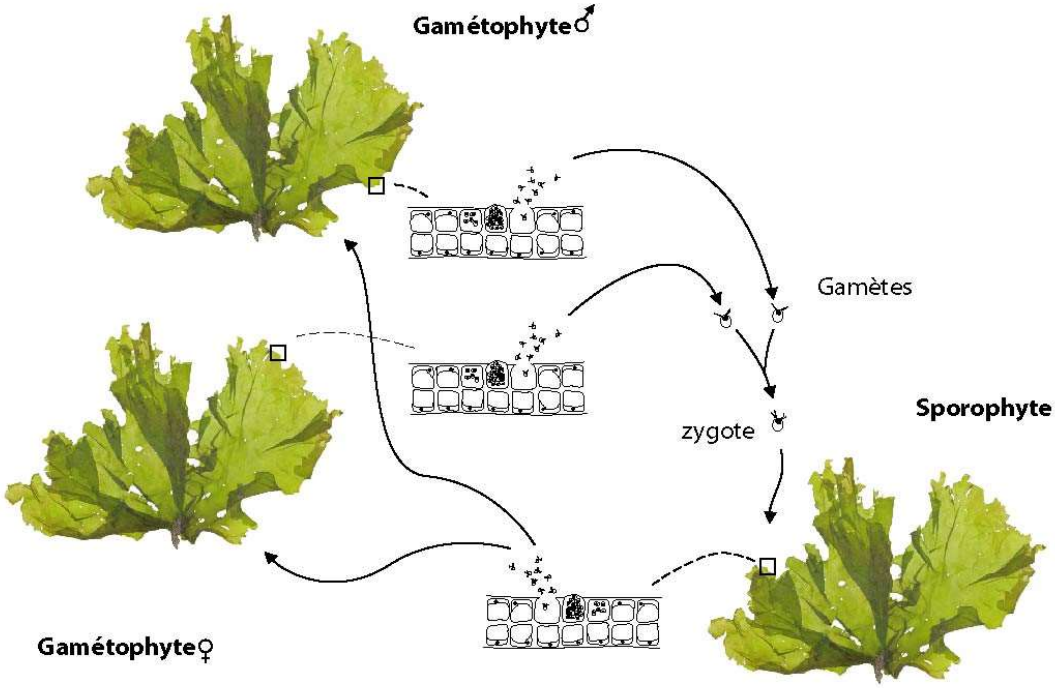
Porphyra sp.
& Pyropia sp.

N.B: Life cycles can show specificities according to each species.

SHEET 2.3:
The Green seaweeds

ULVALES SPECIES

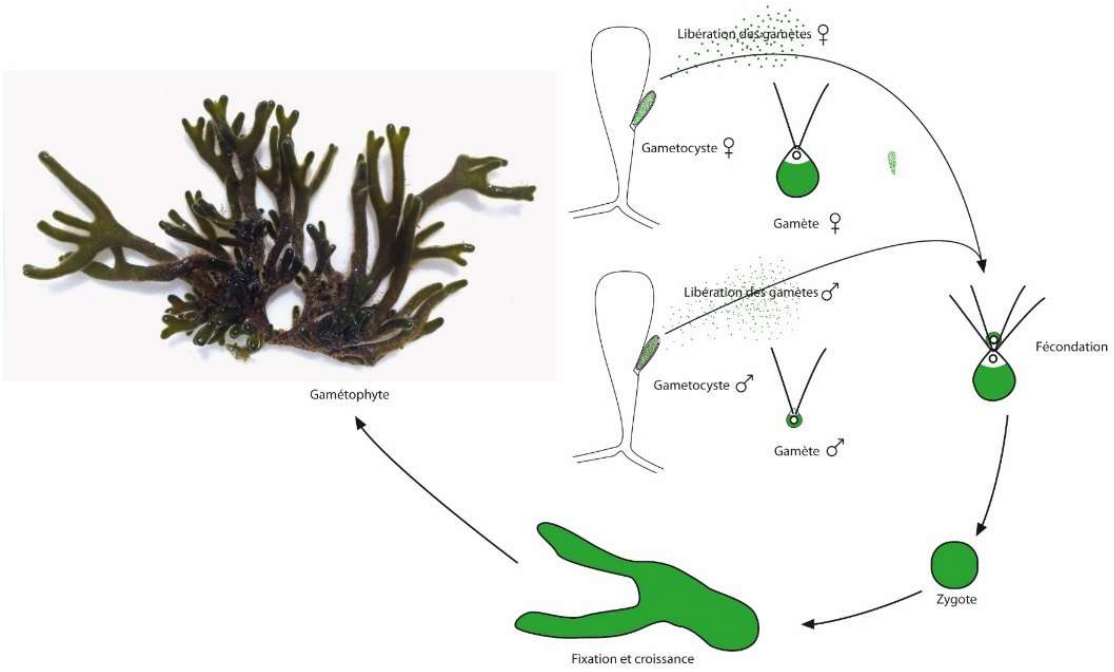
Ex: *Ulva lactuca*



N.B: Life cycles can show specificities according to each species.

BRYOPSIDALES SPECIES

Ex: *Codium tomentosum*



N.B: Life cycles can show specificities according to each species.

SHEET 2.4:
Main influencing parameters

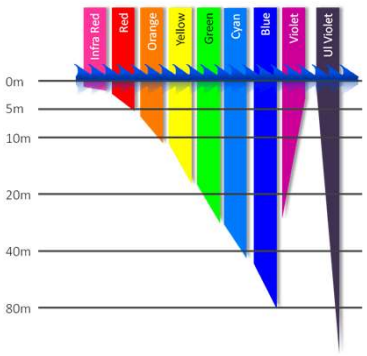
Life cycles are mainly driven by environmental (abiotic)parameters (dealing with seasons)

- Temperature : Growth and reproduction will step in different temperature scales

Annual and season mean temperature
Maximum range (min and max)

- Light

photoperiod (day/night lenght)



- Dessication : for some intertidal species, emersion time induces reproduction

Biotic parameters also contribute (not yet well known):

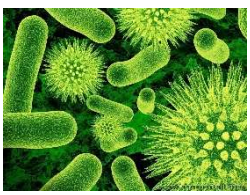
- Chemical communication between individuals

(ex: pheromons for sexual reproduction)

- Interactions with other organisms: positive interactions

(symbiosis, commensalism) or negative interactions

(predators and diseases)



SHEET PACKAGE 3:
The cultivation process

SHEET 3.1 – Vegetative cultivation

How to use fragmentation to produce seaweeds

SHEET 3.2 – Breeding cultivation

How to use sexual reproduction to produce seaweeds

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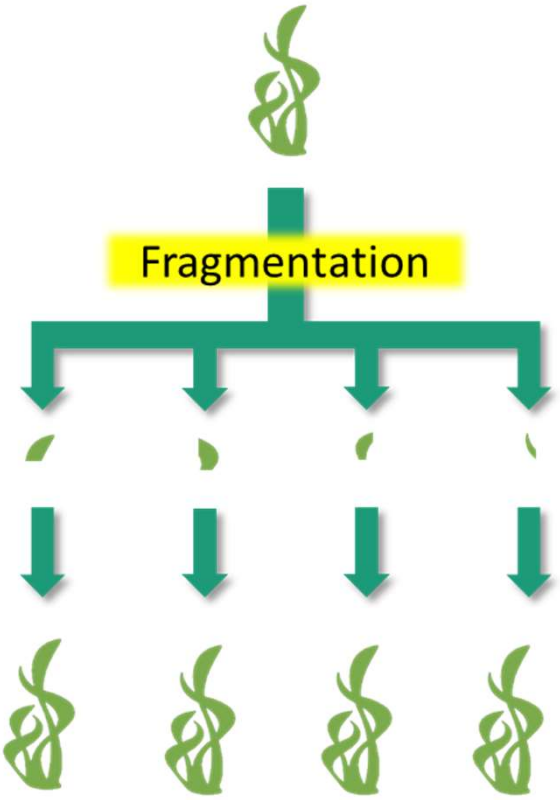
SHEET 3.1:
Vegetative Cultivation

- Can occur by simple fragmentation of the thallus. The fragment then has the ability to regenerate a whole plant.
- Some species cause the fragmentation of their thallus. Fragments then have the ability to attach onto a new medium.
- Other species generate specific organs, propagules, which are released to colonize new environments.



Mainly adapted and used for (non exhaustive list):

Codium sp.

Ulva sp.

Eucheuma sp. & Kappaphycus sp.

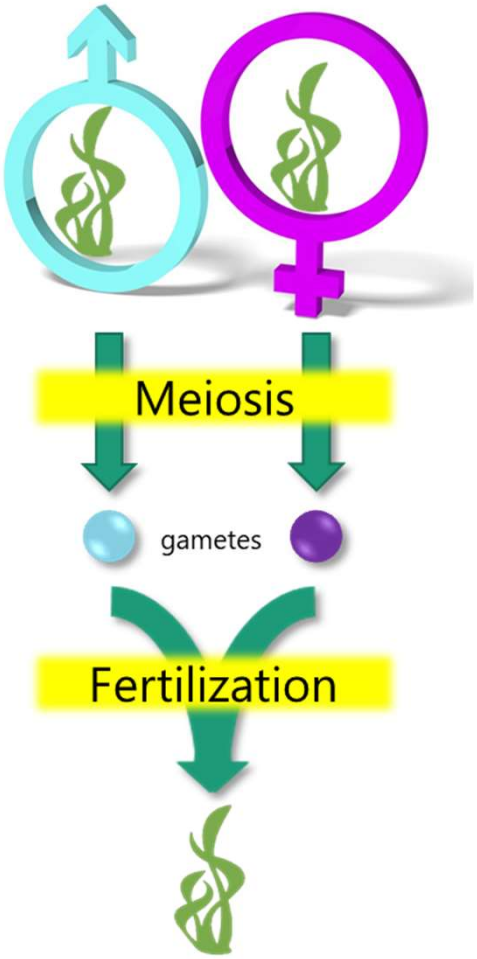
Vegetative cultivation :

- Needs to control the parameters influencing growth.
- Production quality depends on a single genome (eg. clone)
- Allows the cultivation of a single trait of interest

Gracilaria sp.

SHEET 3.2:
Breeding Cultivation

- Sexual reproduction involves a male gametophyte and a female gametophyte that can be morphologically very different.
- Fertilization can be done in the medium after release of the gametes or on the female foot depending on the species.
- The gametes can be mobile and carry one or more flagella.



Mainly adapted and used for (non exhaustive list):

Saccharina latissima

Alaria esculenta

Palmaria palmata

Undaria pinnatifida

Laminaria sp.

Porphyra sp.
& Pyropia sp.

Breeding cultivation :

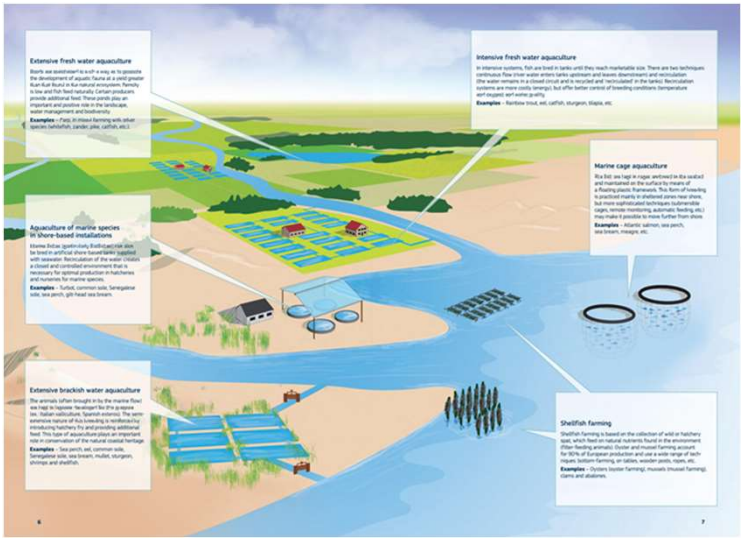
- Needs to control the parameters influencing gametes production, gametes release and fertilization (= fusion between ♂ and ♀ gametes).
- Needs to control the parameters influencing growth
- Needs to have hatchery facilities
- Is more time consuming
- Allows the combination of traits of interests between different strains

SHEET PACKAGE 4:
The seaweed cultivation devices according to the combined organisms in an IMTA system

SHEET 4.1 – Land based systems

SHEET 4.2 – Marsh

SHEET 4.3 – Open sea systems



From : aquacultureworld.wordpress.com

SHEET 4.1:
Land-based systems

From Guttman & Neori (2017)

Tank

Raceway

Level of control:

Cultivation conditions can be well controlled

Interactions/connections between organisms are controlled

Input (nutrient) and outputs (released water) are controlled

Well adapted seaweed species (non exhaustive list):

Porphyra sp.

Ulva sp.

Codium sp.

Chondrus crispus

Gracilaria sp.

Seaweeds can be combined with:

- Fish

- Sea cucumbers

- Shrimps

- Abalones

- Sea urchins

- Worms

SHEET 4.2:
Marsh

Level of control:

Cultivation conditions are not controlled

Interactions/connections between organisms can be partially controlled

Input (nutrient) and outputs (released water) can be controlled

Well adapted seaweed species (non exhaustive list):

Porphyra sp.

Ulva sp.

Codium sp.

Chondrus crispus

Gracilaria sp.

Seaweeds can be combined with:

- Fish

- Shrimps

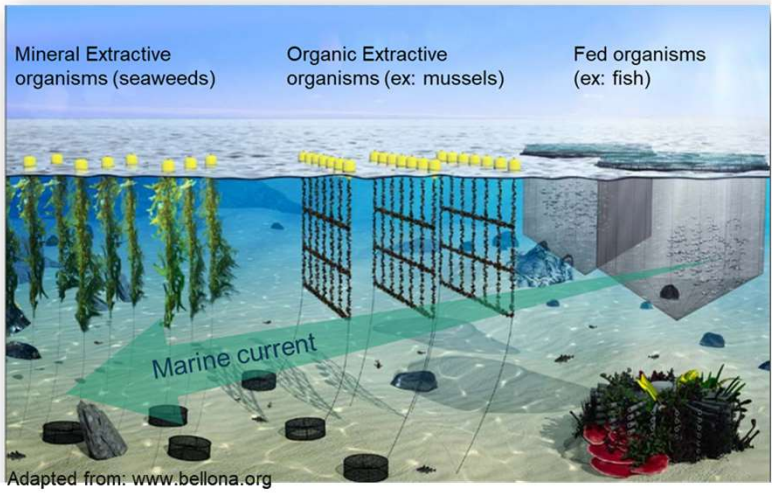
- Sea urchins

- Oysters

- Sea cucumbers

- Worms

SHEET 4.3:
Open-sea systems



Adapted from: www.bellona.org

Level of control:

Cultivation conditions are not controlled

Interactions/connections between organisms are not controlled

Input (nutrient) and outputs (released water) are not controlled

Well adapted seaweed species (non exhaustive list):

Kelp species

Porphyra sp.

Palmaria palmata

Ulva sp.

Gracilaria sp.

Seaweeds can be combined with:

- Fish

- Mussels

- Oysters

- Scallops

- Abalones

- Sea urchins

KEY POINTS

IMTA : A sustainable solution for Seaweed Aquaculture

WHAT TO REMEMBER ?

Chapter 1 – Principles of IMTA and seaweeds cultivation

IMTA is an artificial way to combine ecosystem services.
Land-based systems are easier to manage.
Seaweeds in IMTA can be used as mineral matter extractors and/or as feed for other species

Chapter 2 – Description of the life cycles of the main cultivated seaweed species

Seaweeds are still under domestication process and more knowledge is needed about their life cycles.

Chapter 3 – the cultivation process

Seaweeds can be cultivated from fractioning one single individual or from fertilization of genitors.
Artificial substrates to cultivate seaweed in IMTA systems can be supplied by traditional aquaculture sectors.

Chapter 4 – The seaweed cultivation devices according to the combined organisms in an IMTA system

All the seaweed cultivation techniques can be adapted to other aquaculture sectors.

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to foster sustainability in the Atlantic Area

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