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Koninklijk Nederlands Instituut voor Onderzoek der Zee (NIOZ)  
Royal Netherlands Institute for Sea Research

## Introducing NIOZ & MARINE PLANT BIOMASS for food or energy?

Prof. Dr Klaas Timmermans, NIOZ / U. Utrecht & U. Groningen



Het NIOZ is een instituut van de Nederlandse Organisatie voor Wetenschappelijk Onderzoek





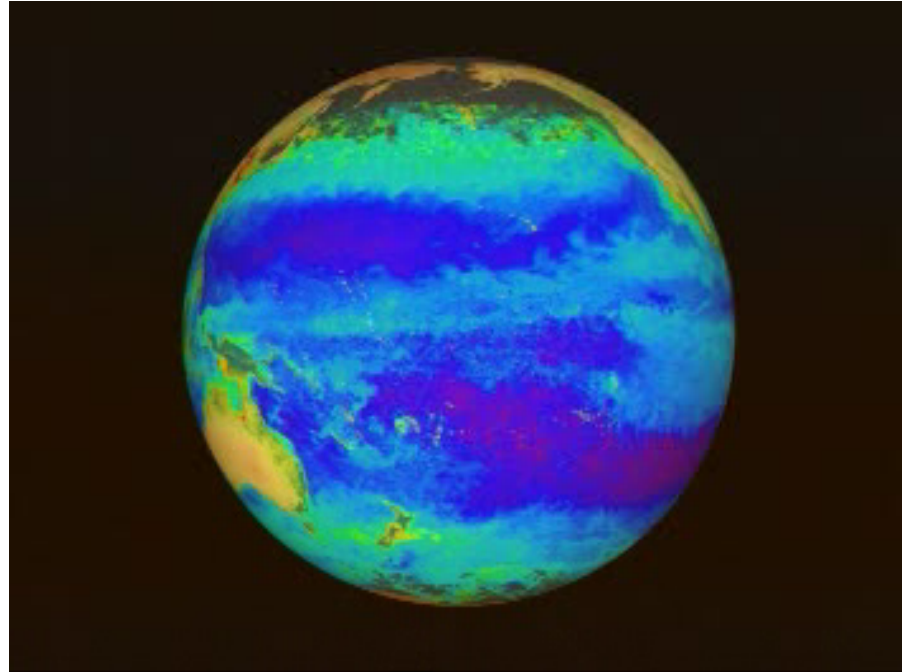
# Sea Research

## Some facts:

- 71% of our planet's surface consists of oceans & seas

Oceans and coastal seas are of great importance for:

- Climate
- Transport/shipping
- **Energy**: oil, gas, wind- & tidal-energy
- Recreation
- **Food supply**



## MARINE ECOSYSTEM SERVICES

- 60% of the world's population lives and works in coastal areas





# Royal NIOZ: Netherlands Institute for Sea Research

## MISSION:



1. Perform and communicate fundamental and frontier applied marine scientific research for better understanding of coastal seas and oceans for a sustainable future.
2. Manage and support national infrastructure and facilities for marine research of The Netherlands.
3. Support research and education of marine research in NL and abroad.





# Brief overview of NIOZ history

## Zoölogical Station - NDV



## 't Horntje – Texel (NIOZ-TX)



## Den Helder – Zoölogical Station



## Yerseke – Zeeland (NIOZ-YE)







# Our fleet

"Pelagia"



"Navicula"



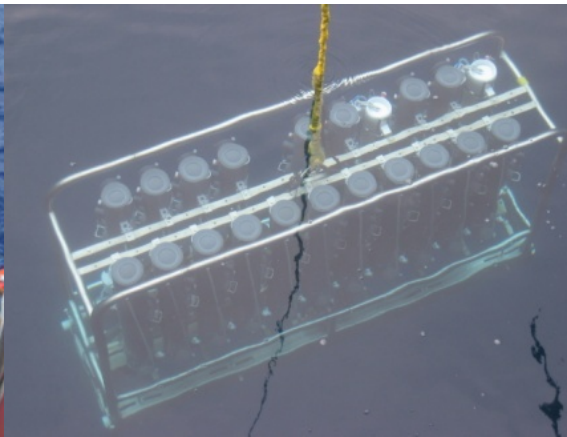
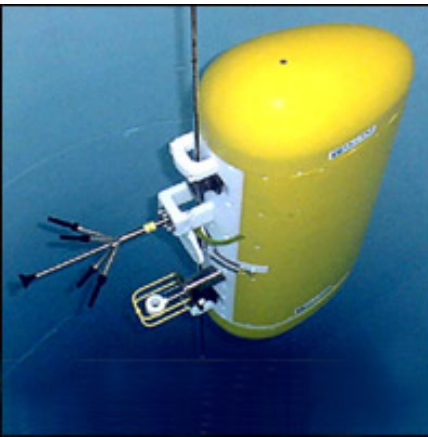
"Stern"





# Our main products

- Scientific projects, resulting in scientific publications in international, peer-reviewed journals. In 2015: 270 peer-reviewed publications
- PhD theses (9 in 2015)
- Master and PhD-courses
- Design, manufacturing, maintenance and operation of research equipment for Dutch scientists







# NIOZ is dedicated to fundamental marine research

For example:

Research on sustainable high-quality products from  
marine origin for a bio-based economy:  
efficient production & use of **marine plant biomass**  
for **food/feed** and **energy**

**IS THERE A ROLE FOR SEAWEEDS ?**



**But first.....**

## **The role of SEAWEEEDS in a BIO-BASED ECONOMY**

**Seaweeds, seaweed biomass ?????**

**Primitive plants, multicellular, living in the sea**

**Capable of photosynthesis.... (photo-autotrophes)**

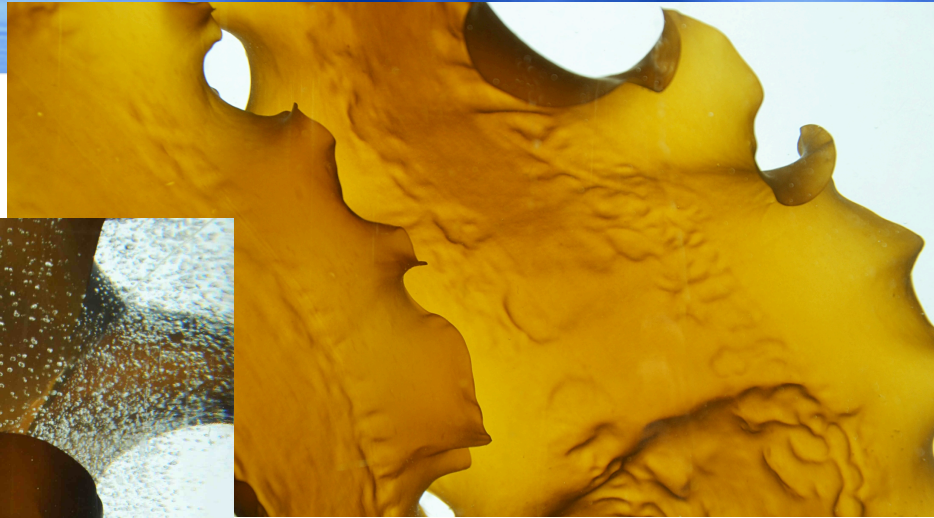


**Plant material, basis for all life**

**70% of the earth is sea, enormous potential for new source of biomass production for food and energy !**



# Brown, red en green seaweeds



*Saccharina latissima* (suikerwier)



*Laminaria digitata* (vingerwier)



*Ulva lactuca* (zeesla)



*Palmaria palmata*

## Micro-algae cultures



Why seaweeds and not micro-algae (their microscopic relatives) ??

Seaweeds attach themselves to e.g. ropes,  
allowing cultivation at sea







And further.....

## The role of SEaweeds in a **BIO-BASED ECONOMY**

Bio-based economy versus fossil-fuel-based economy  
Anything new ?? **NO !!**

Where do fossil fuels come from ?

Remainders of plants !!! (took some million years....)

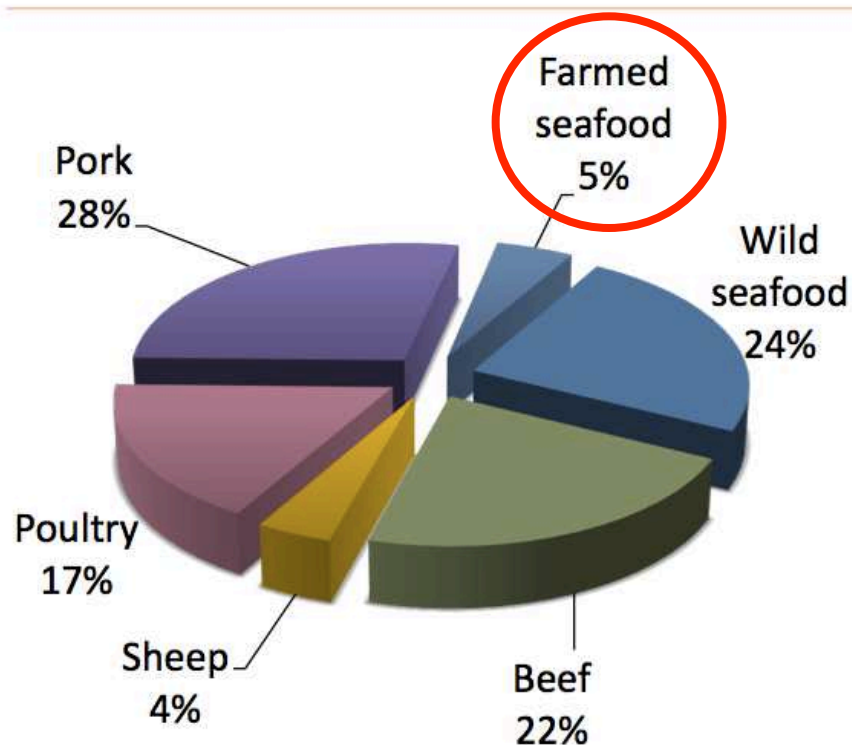
The challenge: grow plant material today and  
use it for **food and energy** tomorrow !  
(.....just a matter of time....)



# Aquaculture is fastest growing farming sector

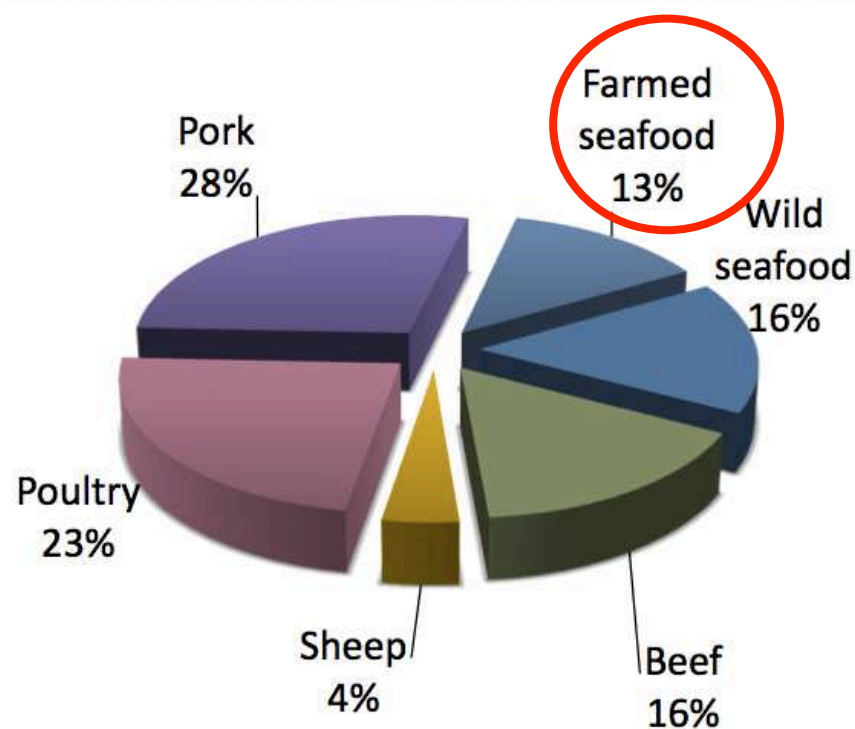
**obviously there is a role for seaweeds!**

**1990**



**250 Mt**

**2006**

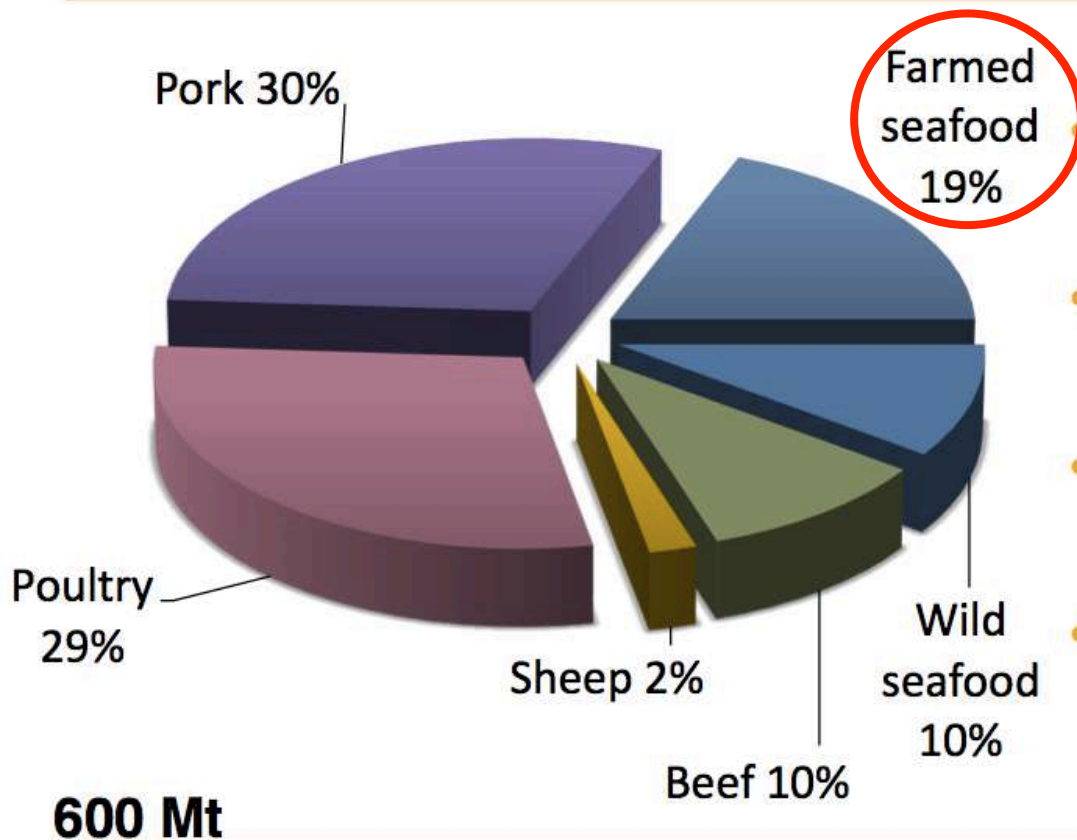


**360 Mt**

Global meat and seafood production (Fishstat & FAOstat)



# How much farmed seafood in 2050 ?



Assumes no growth in wild caught seafood

- Assumes similar relative seafood demand (29%)
- Assumes meat and seafood demand of 600 Mt
- Farmed seafood is roughly double 2006 production.



# Let's be careful !

## **Aquaculture (and expected increases) can have effects on:**

- land conversion and degradation
- benthic & pelagic organism, as well as on water quality
- disease and parasite transfer
- use of antibiotics and other chemicals
- depletion of wild populations
- escapes, and interbreeding with local populations
- social conflicts and labor issues
- ....



# The seaweed hype...

26 Oktober 2015

RTL-Z:

**21:30: Van Liempt Live - Vergeet windmolens, allemaal aan de zeewier-energie**

26 oktober 2015 18:47



Nieuws

Cultuur & Leven

de Volkskrant

Economie



Moderne, experimentele zeewierteelt op speciale matten. © Judith Baas

## 'Zeewier is energiebron van de toekomst'

Opbrengst kan die van windmolens overtreffen

Met de productie van zeewier op de Noordzee kan over tien tot twintig jaar evenveel duurzame energie worden geproduceerd als met windmolens in 2020. Dat zeggen onderzoekers van het Energieonderzoek Centrum Nederland over het Europese zeewierproject At Sea.





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# The SEAWEED challenge:

## **Seaweed biomass offers great possibilities:**

- \* Growth on saltwater (no freshwater)
- \* No claims on agricultural land
- \* Combination with other offshore activities (windmills)
- \* Uptake of nutrients (less eutrophication) and CO<sub>2</sub>
- Essential components made (proteins, carbohydrates, lipids)

## **Contribution from marine sciences:**

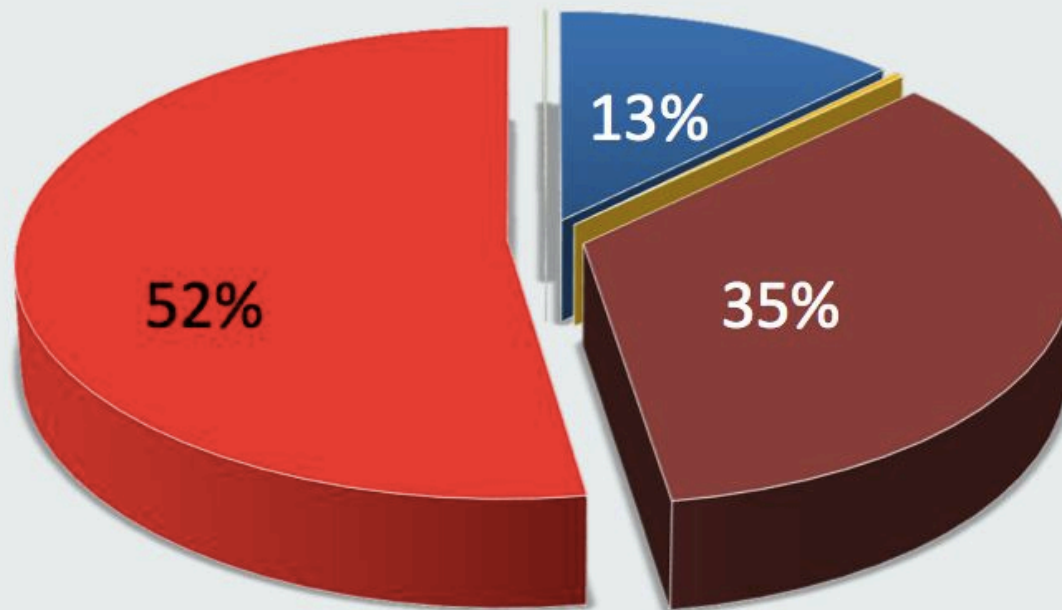
**Physiology:** production & loss of seaweed biomass in relation to environment

**Genetics:** selection of most productive strains, prevention of interbreeding with local populations

**Ecology:** effects on biodiversity, nursery & shelter: balancing between preservation of natural seaweed ecosystems and unlocking potential of seaweed cultivation

# Marine “plant” biomass

**24,9 MT fresh seaweed**



■ Aquatic plants

■ microalgae

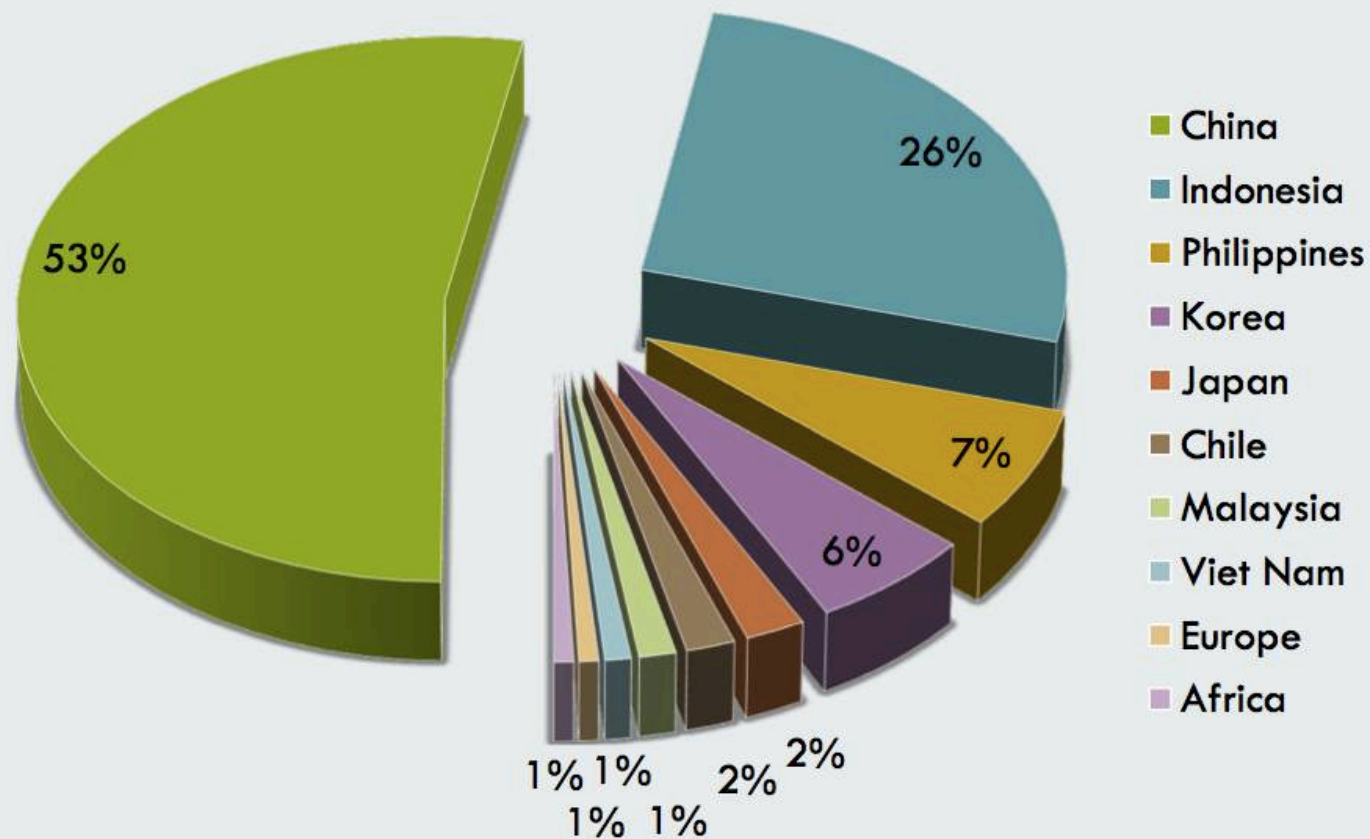
■ Brown seaweed

■ Red Seaweed

■ Green Seaweed



## □ Seaweed producers





For **seaweed cultivation** we are in Europe still mainly in the Stone-age: "**hunting and collecting**".

**Urgent need for seaweeds research and practical applications !**



*in Europe 95% of seaweed production is collected in the field, 5% from aquaculture*



# Seaweeds & their products in our daily life, possibly for transition to bio-based economy ?

- Sushi
- CARBOHYDRATES / POLYSACCHARIDES
  - Cell walls: alginates
  - Storage products (Laminarin, Ulvan)
    - Gelforming substances (agar)
- PROTEINS (e.g. replacing soy)
- Fibers







# NIOZ SeaweedCentre



Close cooperation with SME Hortimare: *"propagating seaweeds for a sustainable future"*



## **Zooming in on some research questions for seaweeds:**

- **Can seaweeds be grown at sea (e.g. in the dynamic North Sea, what is the best time for that, can we expect ecological consequences, can we model seaweed growth)?**
- What do we do with the seaweed biomass produced ? Use it as “whole” plant, is biorefinery necessary, can we “steer” on concentration of specific compounds ?



# Establishing sustainable seaweed cultivation in the North Sea:

- Traffic
- Fisheries
- Mining / Wind Energy
- Tourism



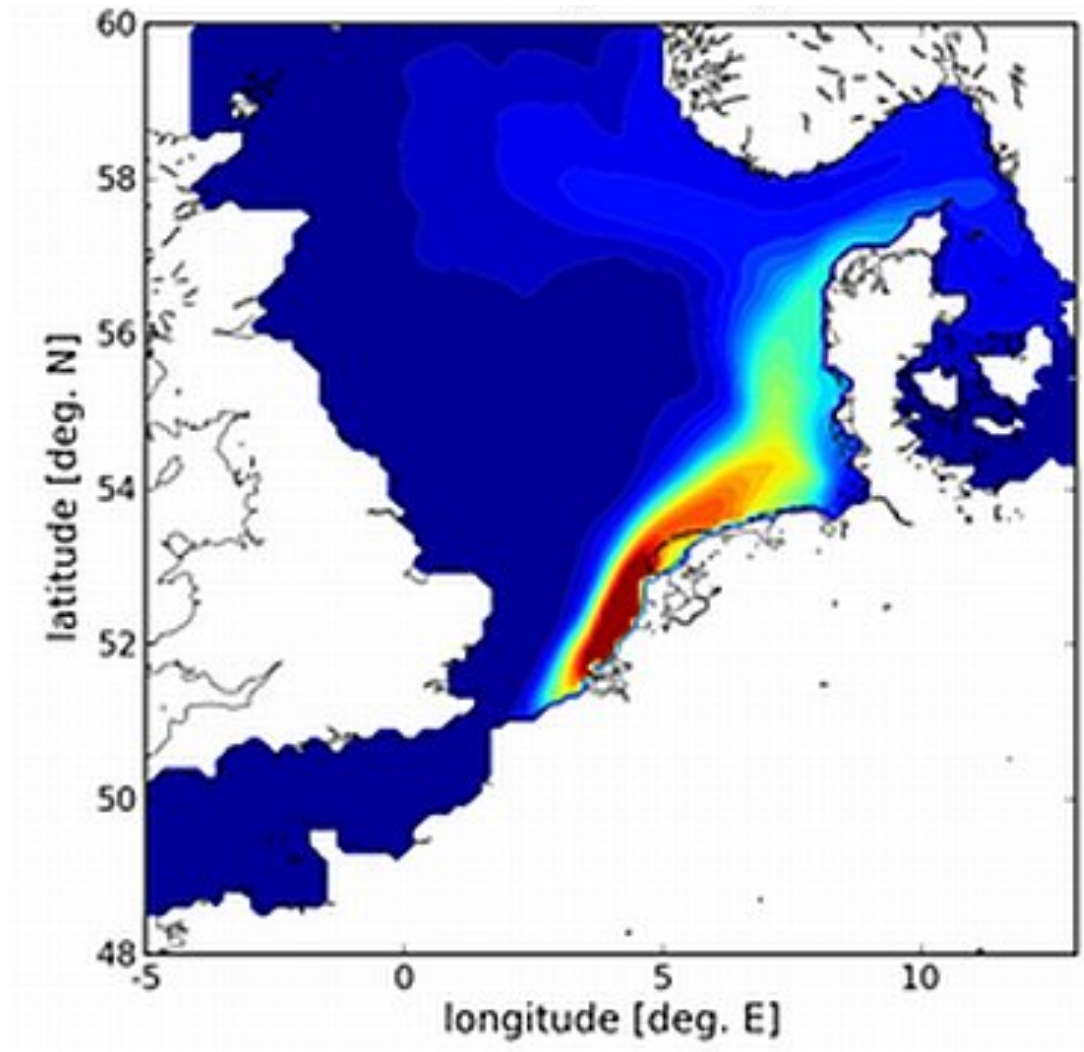
**“interesting” environment**



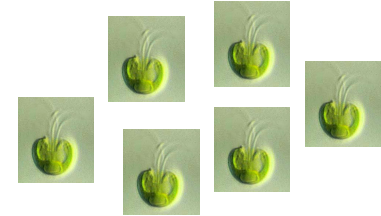
# Plenty nutrients in the North Sea

Shown: nitrate concentrations,

**red** is high, **blue** is low concentration



# Physiology seaweeds vs micro-algae

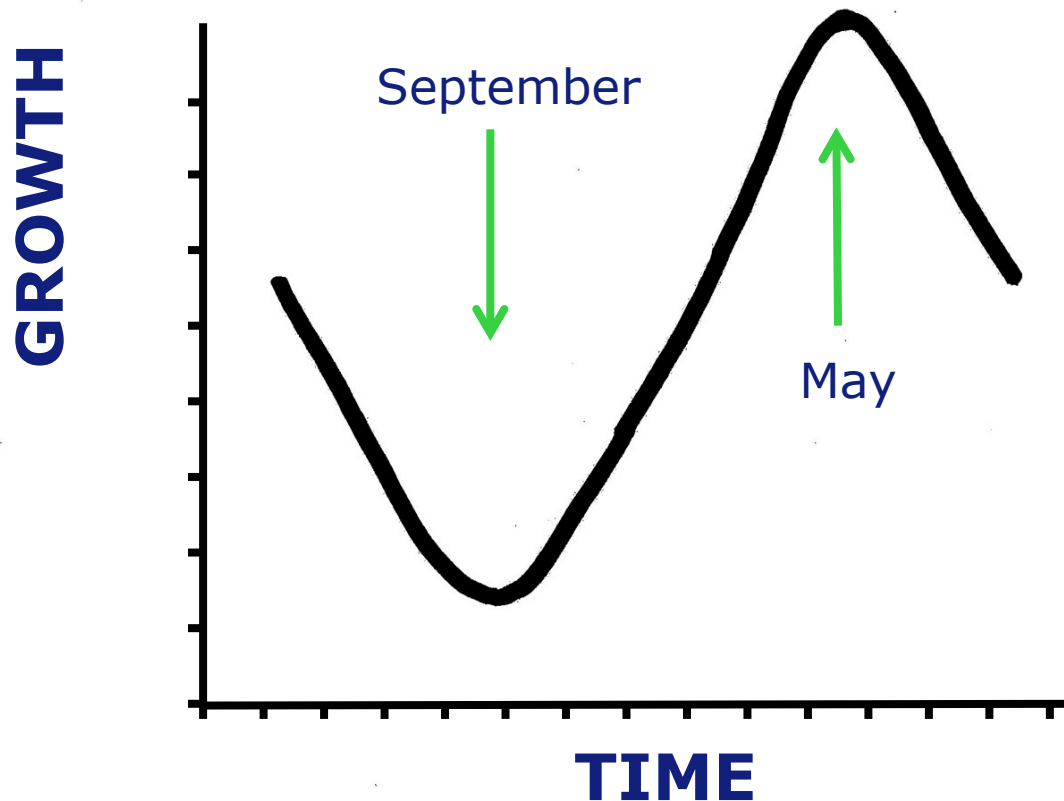


- Surface to volume much better for micro-algae. Nutrients taken up faster.
- Growth rates of micro-algae higher.

**Under many circumstances the micro-algae will win!**

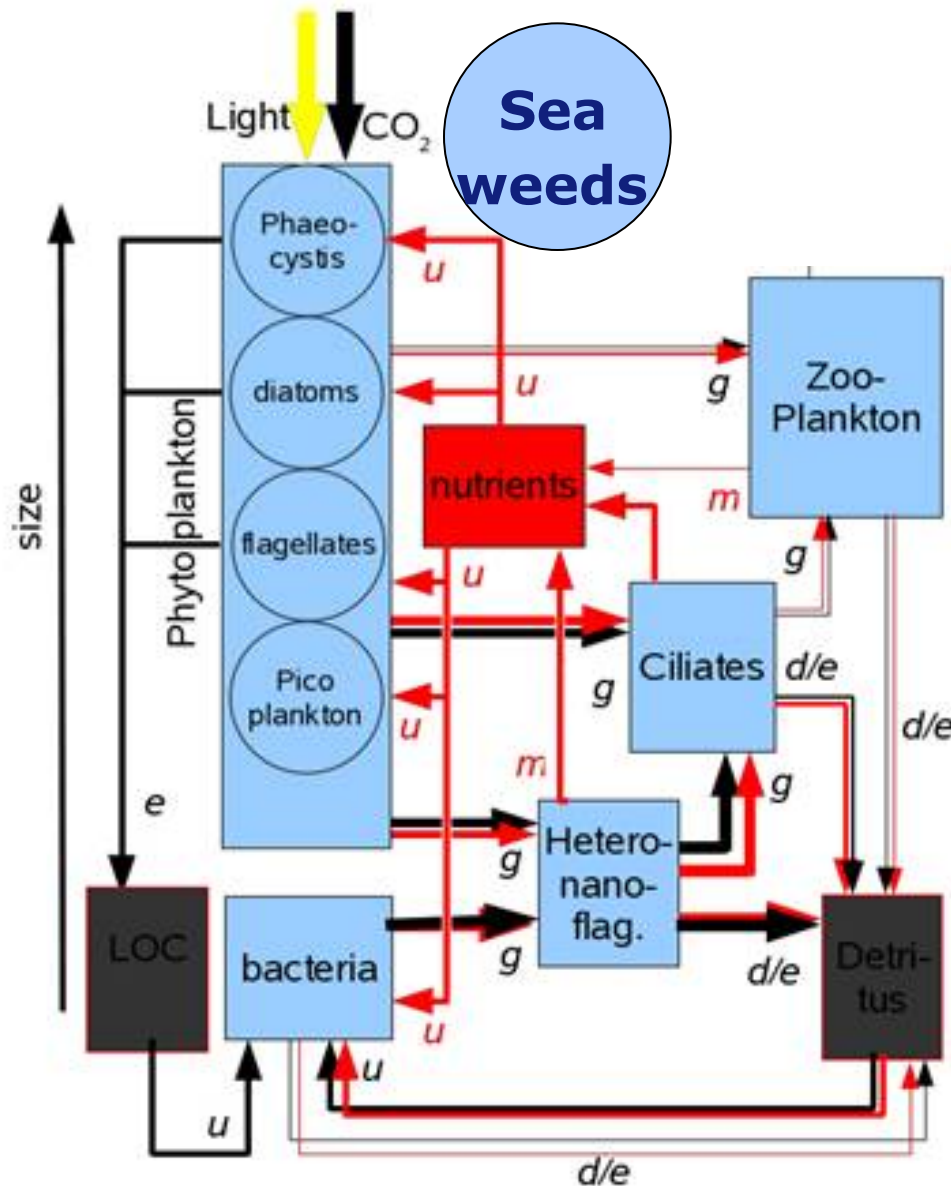
# MODELLING SEAWEED GROWTH

Seaweeds grow well in winter





# SUSTAINABLE SEAWEED PRODUCTION?



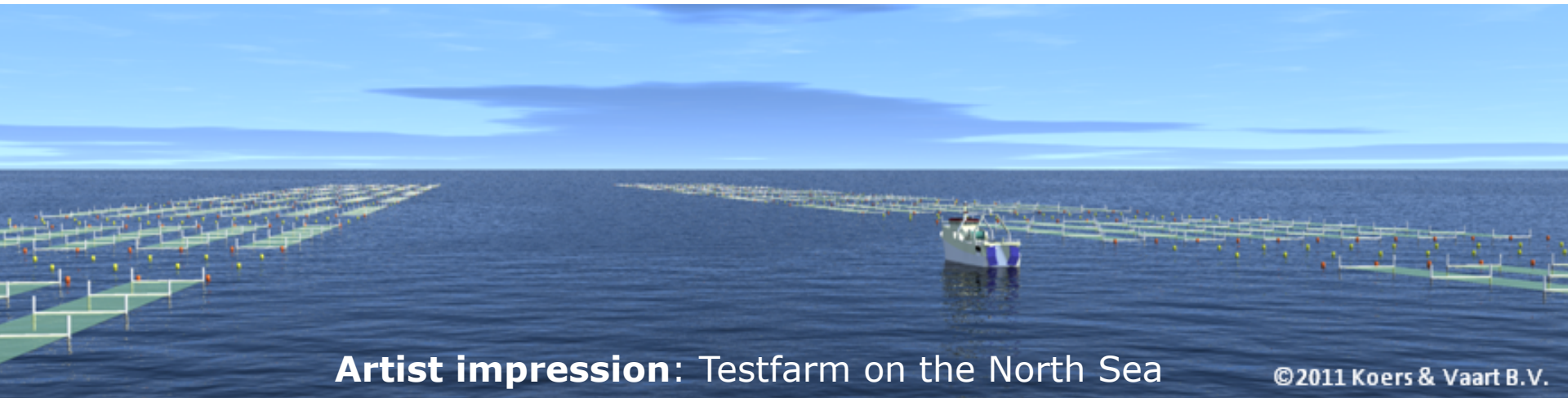
Combine nutrients,  
physiology  
seasonal growth in  
**ERSEM model**

Now with seaweeds!



# SEAWEEDS in ERSEM

Competition for nutrients?



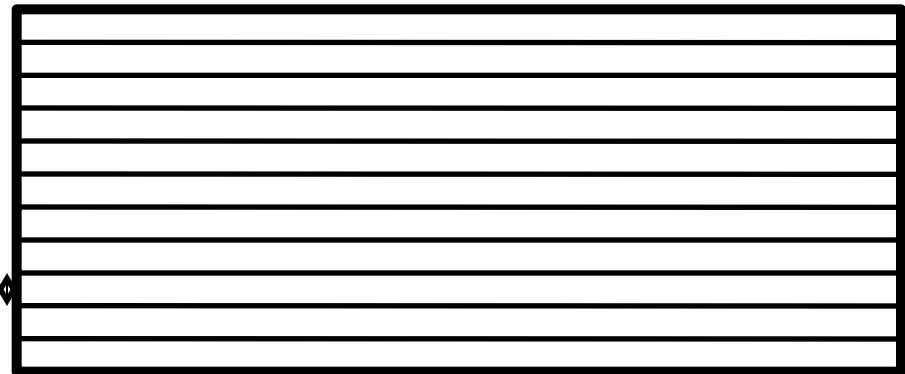
**Artist impression:** Testfarm on the North Sea

© 2011 Koers & Vaart B.V.



10 m

1 m

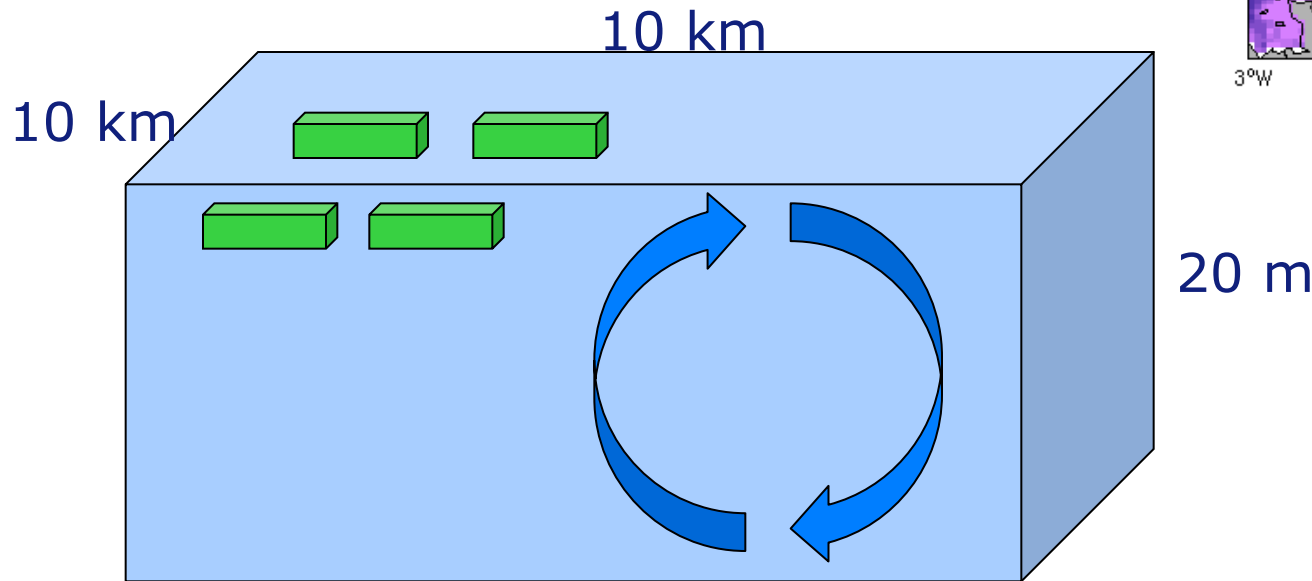


120 m

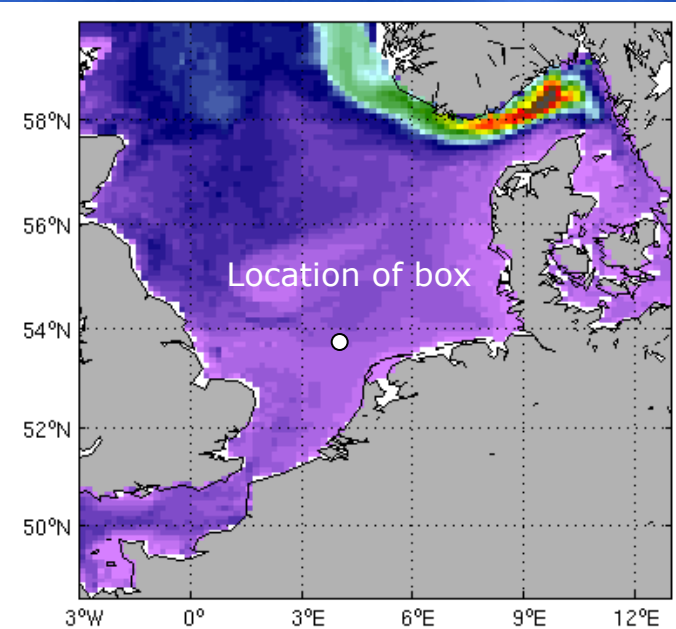


## SEAWEEDS vs MICRO-ALGAE

Seaweed attached to 4 floaters at  
3 m depth, micro-algae mixed in  
the watercolumn

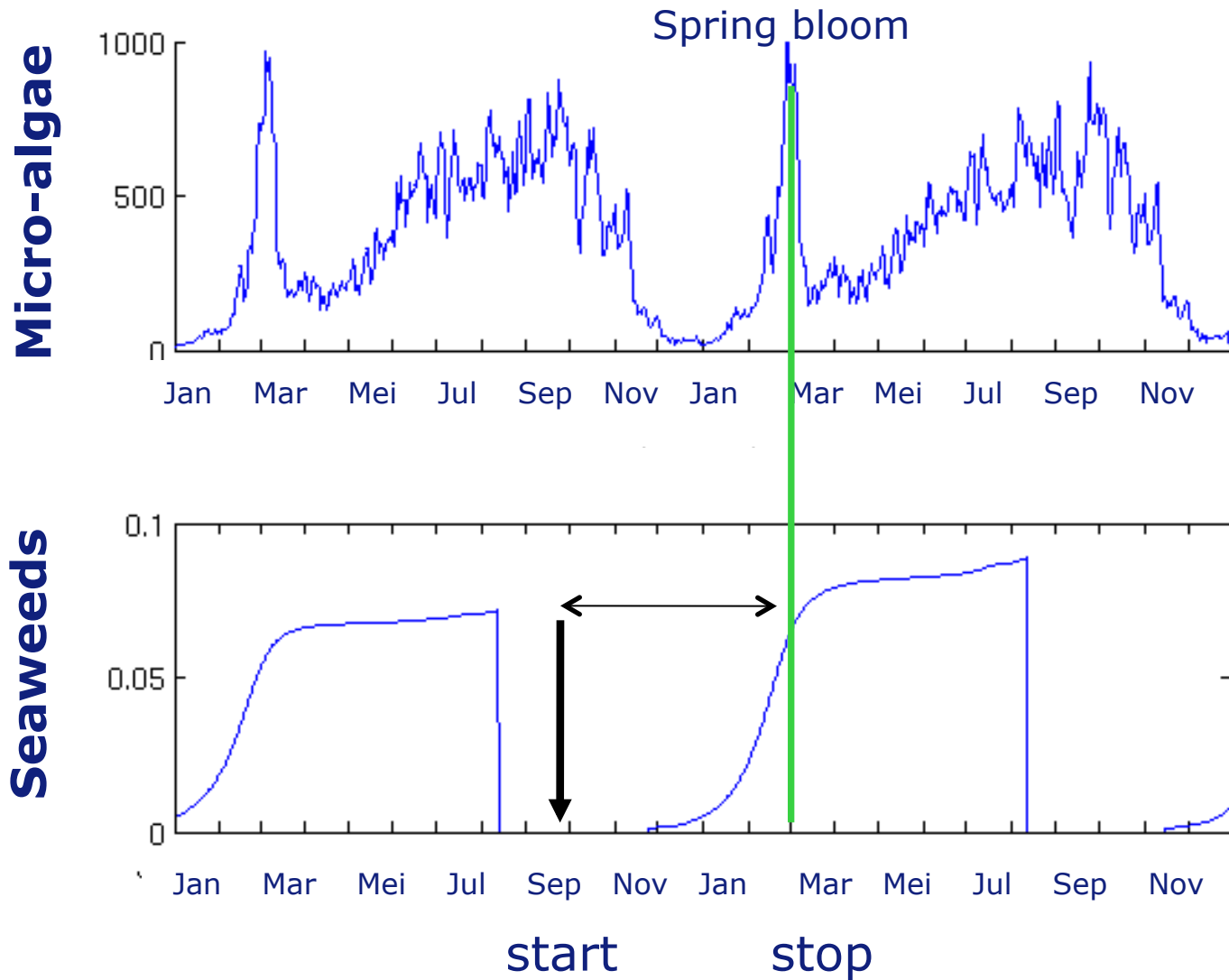


closed box without in- or outflow  
of nutrients





# MODEL RESULTS





# Some observations for seaweed production:

**Seaweed cultivation in the North Sea appears possible during winter months.** Unfortunately, this is also the storm season.

**Nutrient supply (N & P) in the North Sea is enough to sustain seaweed production.** There is a trend of decreasing nutrient loads. The coastal zone may become P-limited. Nutrient fluxes from the sediment may become more important, but are poorly quantified. So, exact location of seaweed cultivation matters.

**Model calculations show that in extreme conditions (200 or more floating bodies in 10 x 10 km box) net micro-algal production can decrease significantly, with possible consequences for higher trophic levels.**

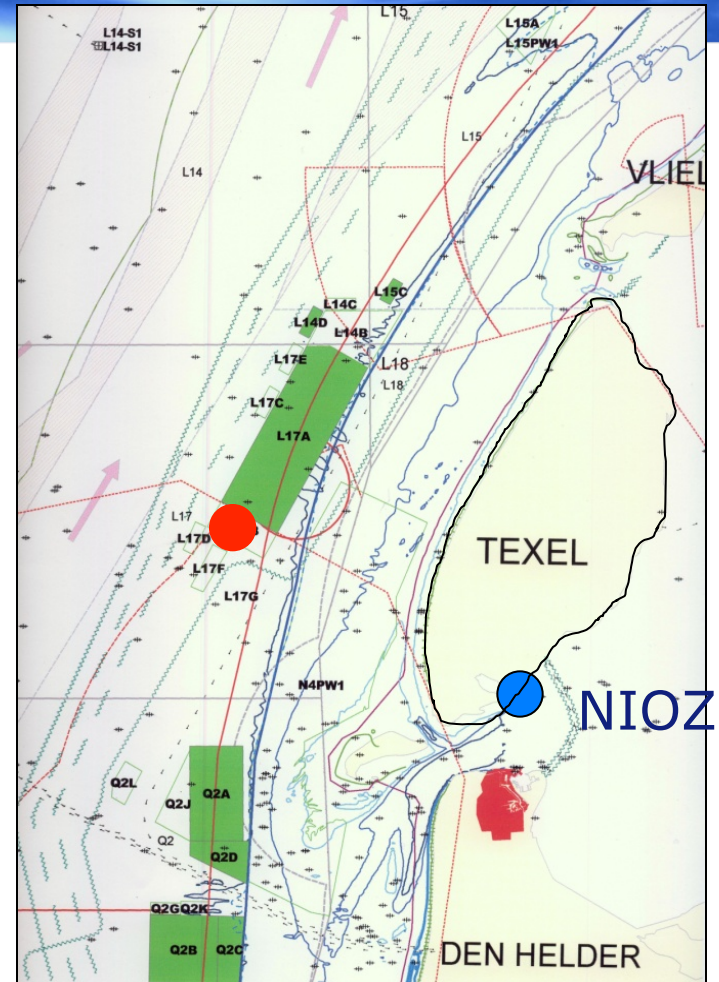


# Establishment of North Sea seaweed farm

Test farm – 1km<sup>2</sup>, near-shore  
20 m depth line

**Rijkswaterstaat** (executive body  
of the Dutch Ministry of Infra-  
structure and the Environment)  
**supports** and **enables** (e.g. Green  
Deal).

NIOZ is an independent supervisor.





# First results (2015!): **16 kg wet weight**



"kilo-proef", Stichting Noordzeeboerderij, April 2015

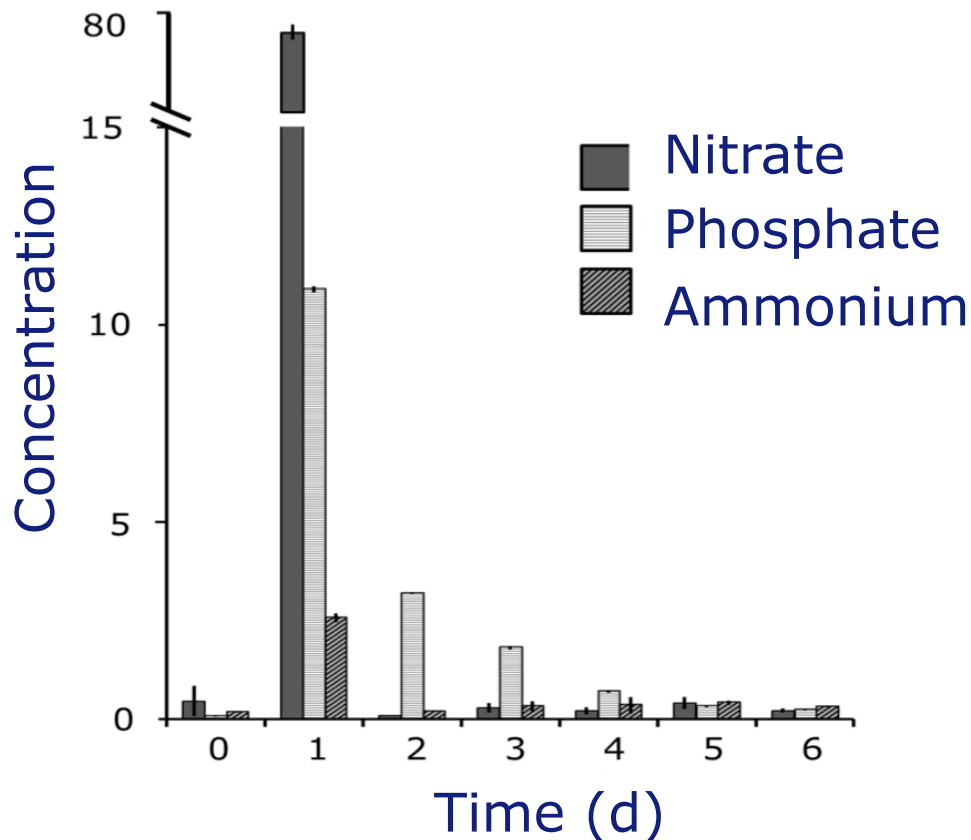


## **Zooming in on some research questions for seaweeds:**

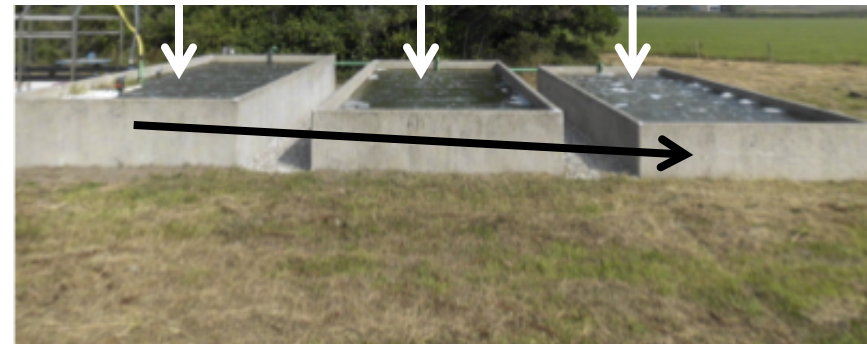
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Use it as “whole” plant, is biorefinery necessary, can we “steer” on concentration of specific compounds ?**

# SEAWEED BIOFILTER

Sea lettuce takes up nutrients,  
forms biomass used as fertilizer



Tank 1    Tank 2    Tank 3







Sea lettuce as **fertilizer** for  
salt tolerant potatoes







# Biorefinery: ZeeViVo project 2015-2019

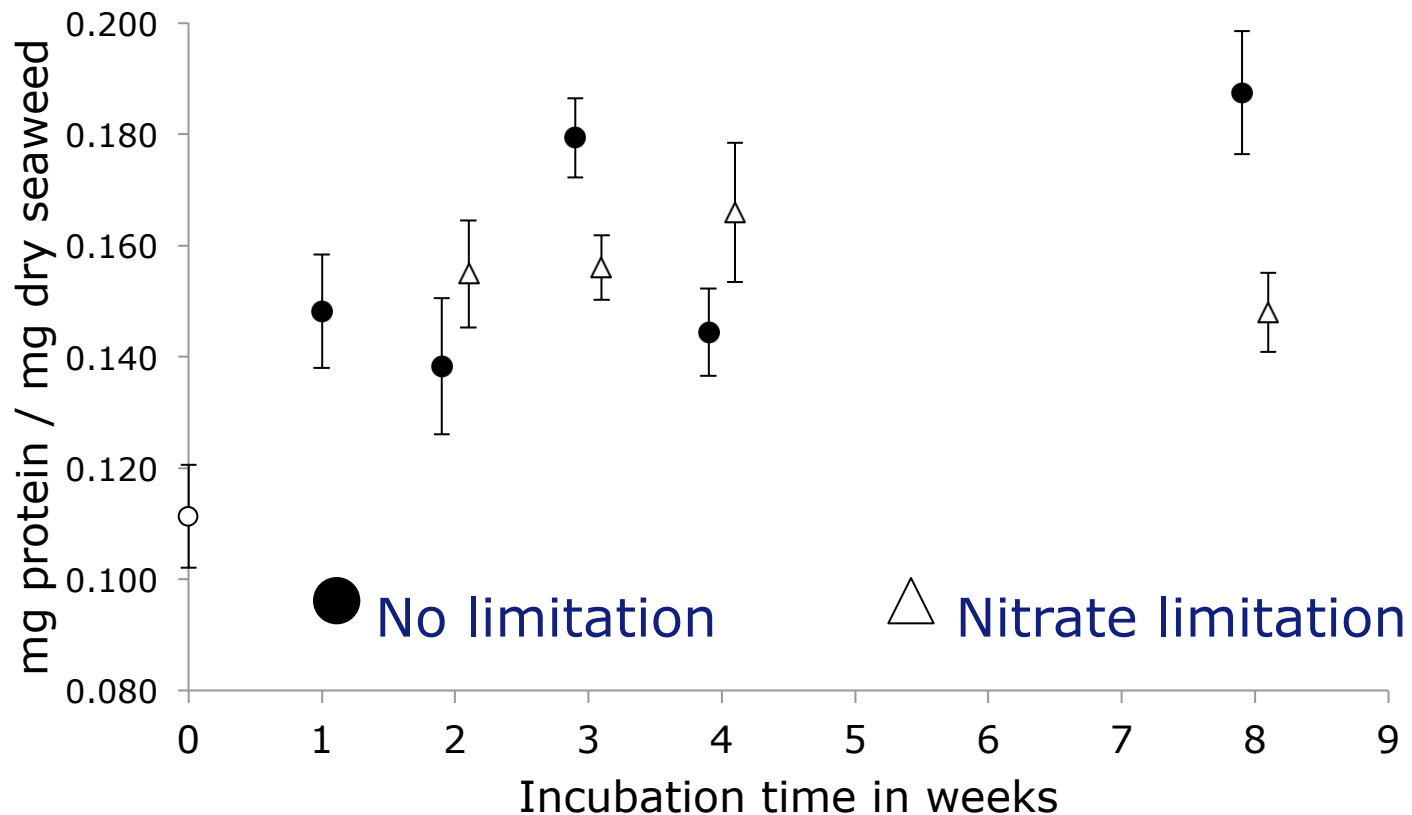
BIOREFINERY: extraction of useful/valuable products from (in this case) seaweeds. For example, proteins, carbohydrates, etc. Seaweeds contain some 20% (DW) marine proteins, that can be used for **FISH FEED** (production sustainable fish – no soy or fish meal needed). Can also be for human food, but needs certification.



# Manipulating protein concentrations in brown seaweeds.

## Effects of external N and P availability on internal concentration of proteins/carbohydrates ?

*S. latissima*, proteins, average  $\pm$  SD (n=5)







# Plenty of opportunities for use of biomass:

As “whole” biomass; green fertilizer, but also for humans (sushi).

Biorefinery: proteins and carbohydrates can be separated and harvested.

Manipulation of protein/carbohydrate concentrations appears possible e.g., nutrient limitation, light conditions.

Possibilities of selecting most productive strains (genetics).

**Let's get addicted to seaweeds:**

**going “the marine green way” !**



## SUMMARY/CONCLUSIONS

Saltwater is not so much a threat, but a challenge for future plant biomass production.

**Do not expect miracles, but it looks good !**

**Scientific challenge:** fundamental knowledge on production and loss of “plant” biomass, role of seaweeds (and micro-algae) in marine ecosystems.

**Practical challenge:** is it possible to make use of the “plants” from the sea in a sustainable way, for the production of food, feed and energy of the future ?



**THANK YOU !**



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