# Carbon pathways for Nordic kelp forests

## *Status of knowledge for Nordic carbon cycling in blue forests*

### *16-17 November at Miljødirektoratet, Helsfyr, Oslo*

*Kasper Hancke, Hege Gundersen,* Karen Filbee-Dexter, Eli Rinde, Eva Ramirez-Llodra, Trond Kristiansen, *Helene Frigstad, Guri Sogn Andersen,* Trine Bekkby *(NIVA), Jon Albretsen, Kjell Magnus Norderhaug (IMR),* Morten Foldager Pedersen (Roskilde Univ.), Thomas Wernberg (Univ. Western Australia)



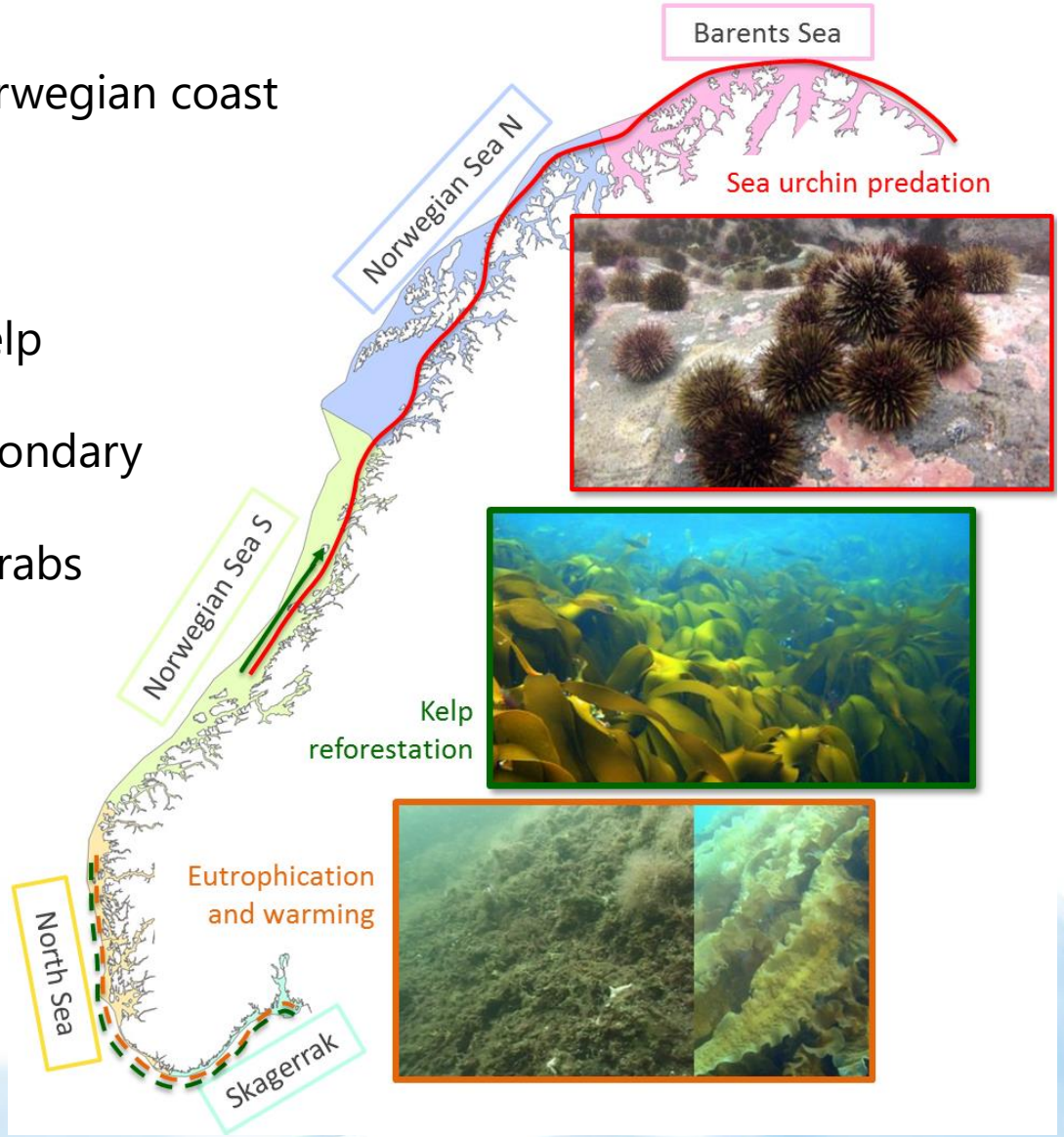
Photos: NIVA (J Gitmark, K Hancke)

# The ecological relevance of kelp forest ecosystems

~9000 km$^2$ of kelp forest on Norwegian coast
~40 mill. ton of kelp carbon

Kelp forest ensure

- Coastal primary production (kelp biomass)
- Increasing biodiversity and secondary production
- Increase harvestable fish and crabs

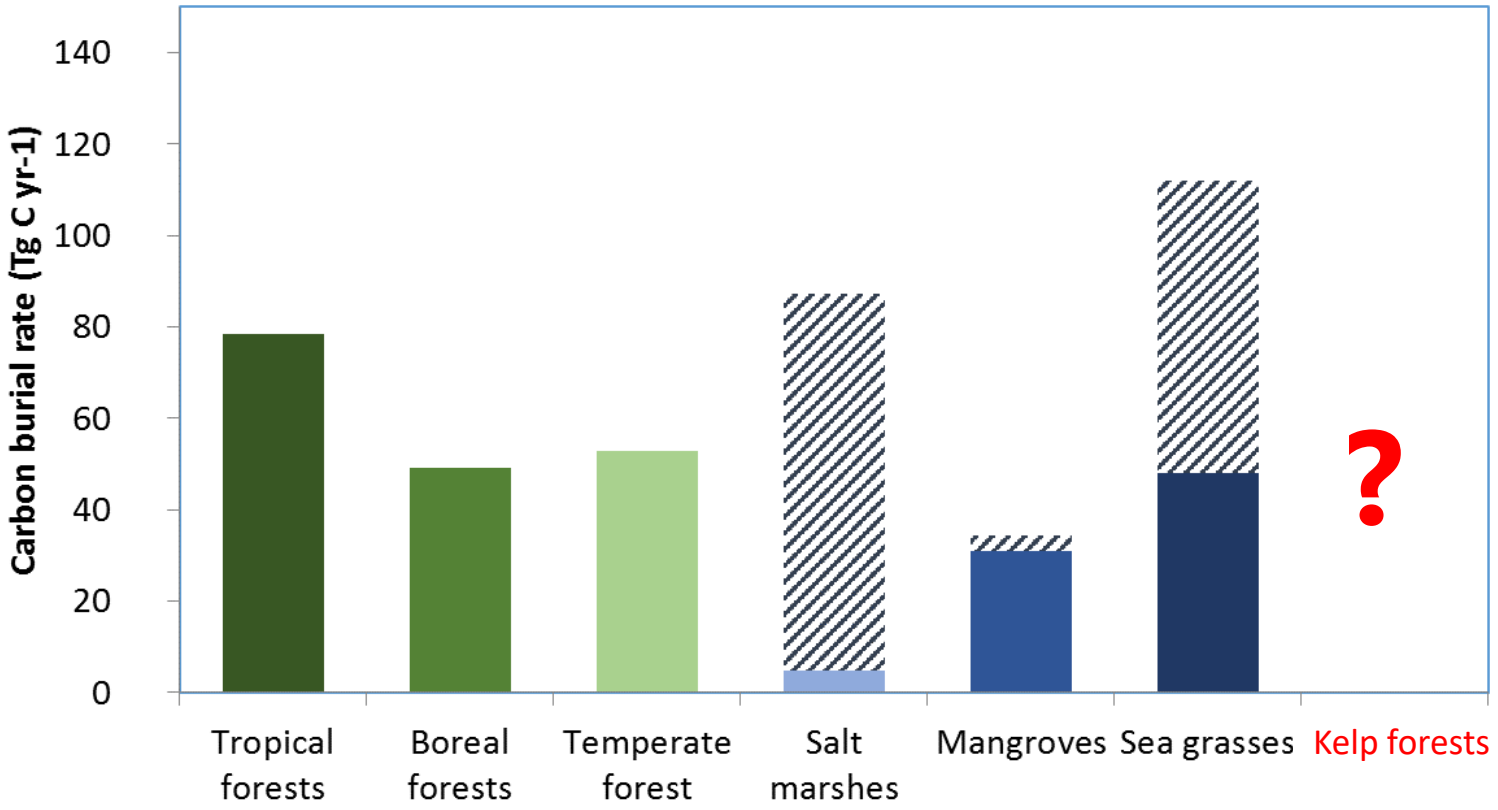

Gundersen et al 2010, Christie et al 2009, subm.


Blue carbon sinks are built by plants and trees (otherwise known as angiosperms such as mangroves, salt-marsh plants and seagrasses) but the coastal ocean also contains vast areas covered by algal beds. Most macroalgal beds (including kelp forests) do not bury carbon, as they grow on rocky substrates where burial is impossible.

Modified after Nellemann m.fl. 2009

# Marine *versus* terrestrial carbon storage

Globally, the marine carbon sequestration is on the same scale as the terrestrial sequestration

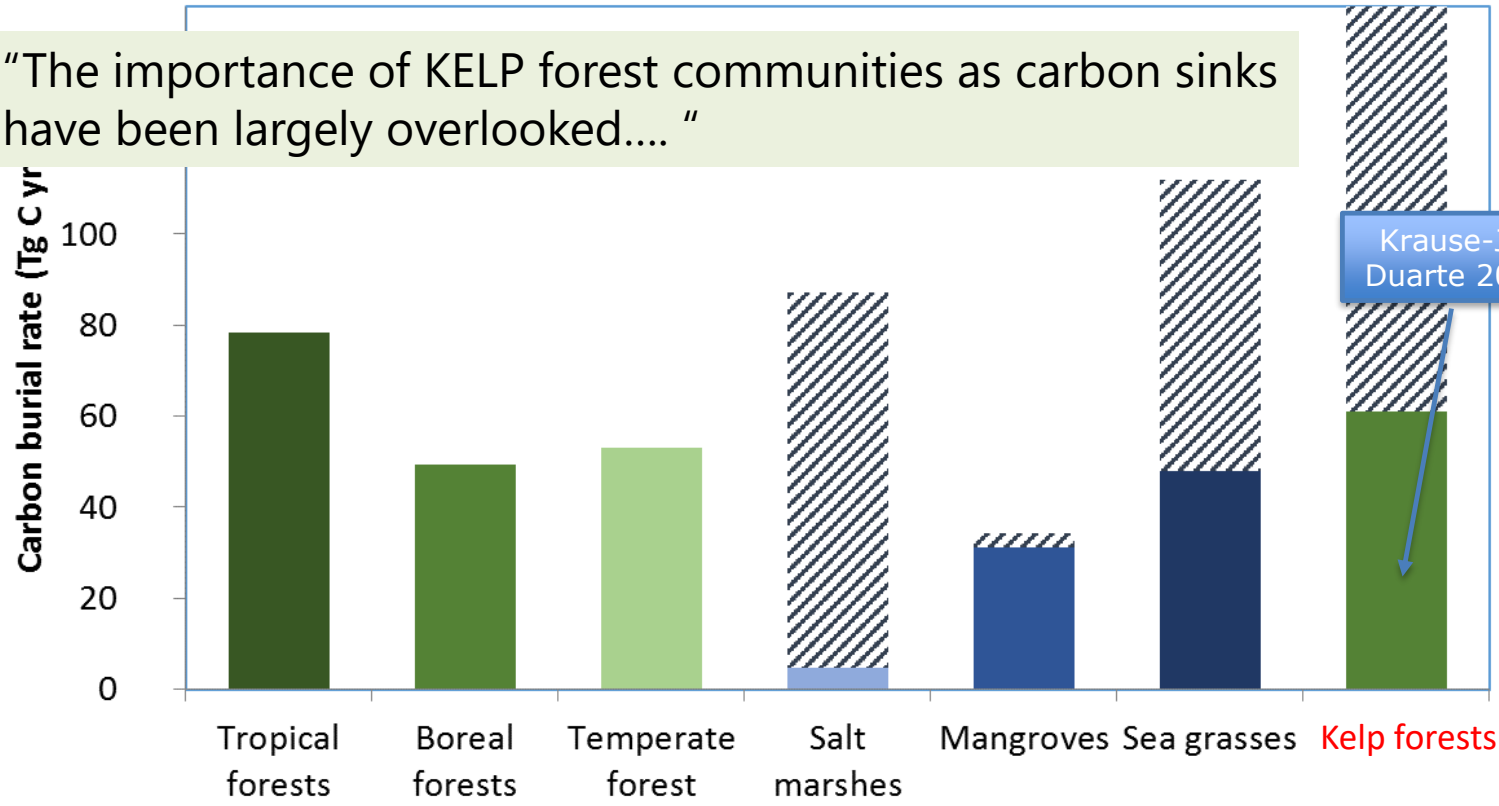



Data from McLeod m.fl. 2011

# Marine *versus* terrestrial carbon storage

Putting marine kelp forests on the global carbon map!

"The importance of KELP forest communities as carbon sinks have been largely overlooked…. "




Data from McLeod m.fl. 2011 and Krause-Jensen and Duarte 2016

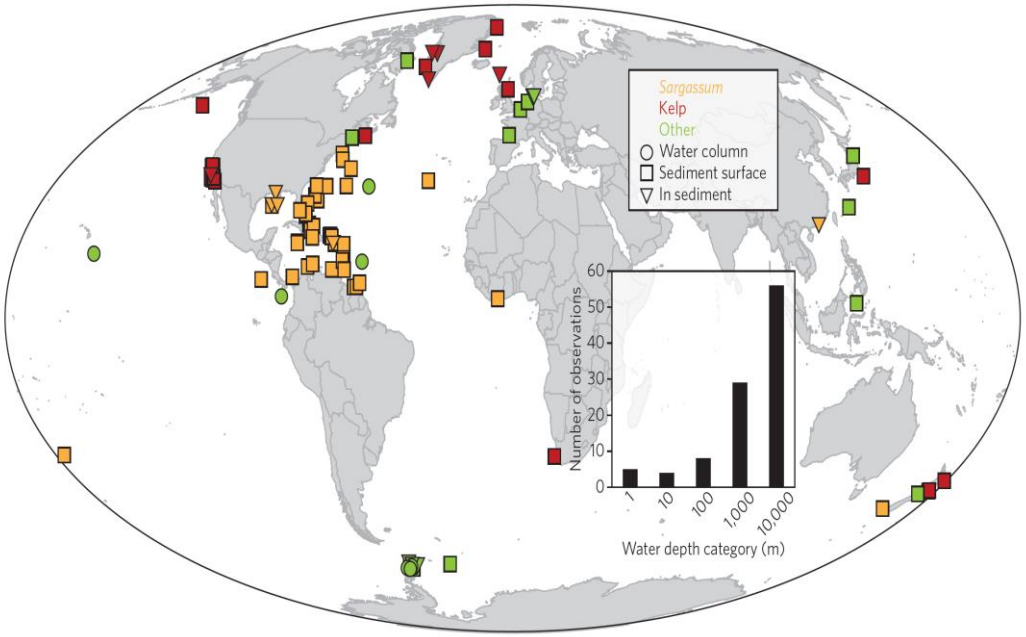
nature geoscience

PROGRESS ARTICLE

PUBLISHED ONLINE: 12 SEPTEMBER 2016 | DOI: 10.1038/NGEO2790

# Substantial role of macroalgae in marine carbon sequestration

Dorte Krause-Jensen[1,2]* and Carlos M. Duarte[3]



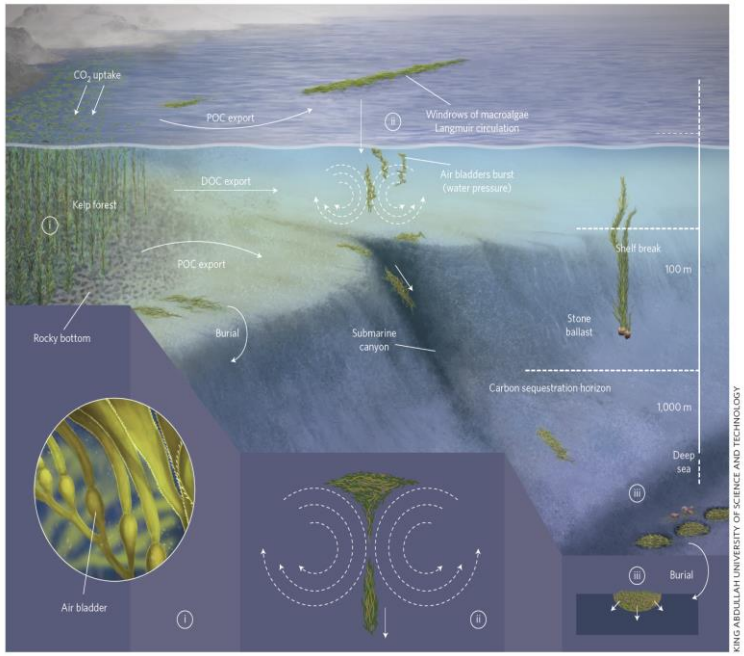
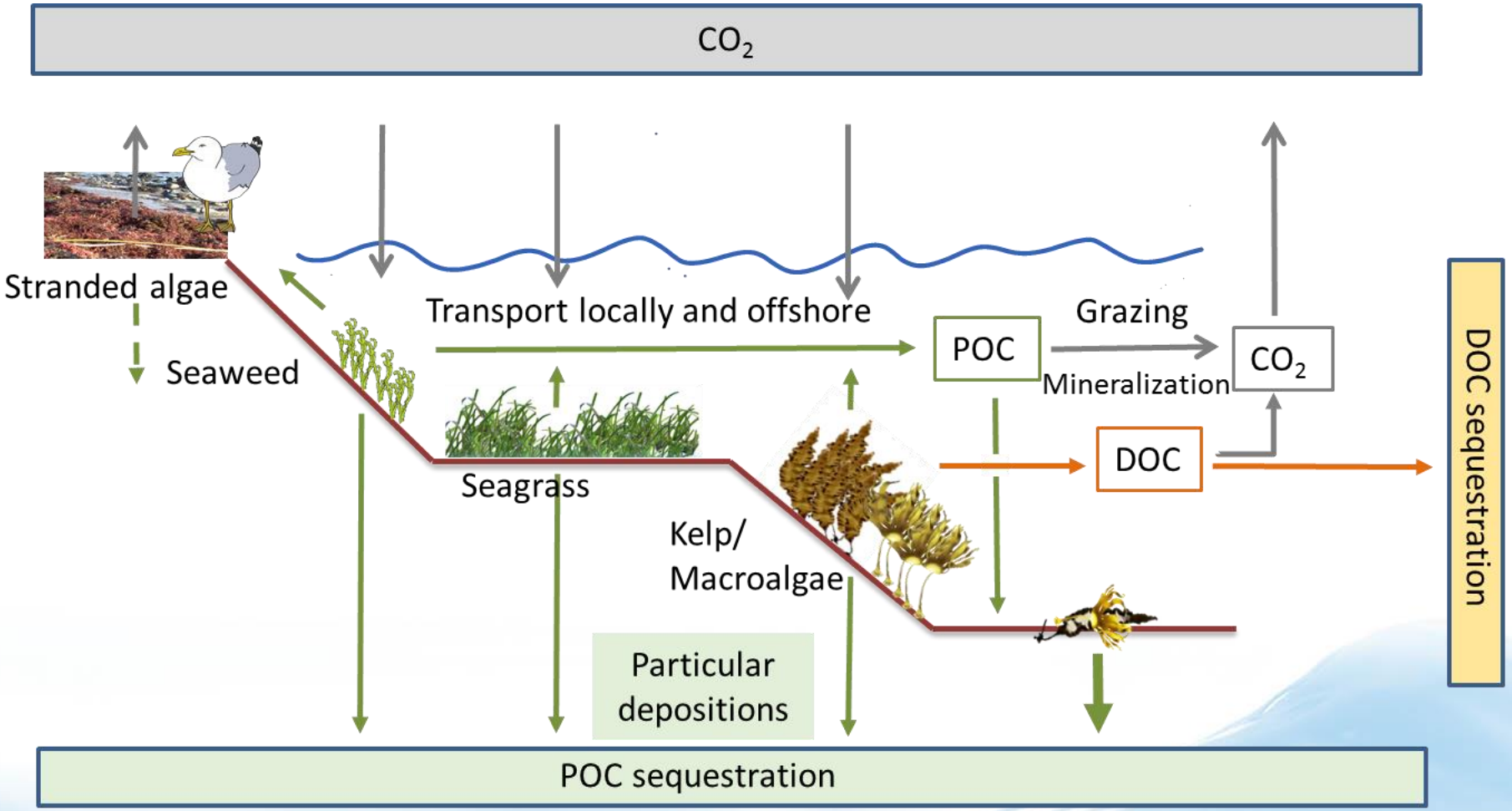




**Figure 1 | Map of the locations where macroalgal carbon storage has been reported.** The types of macroalgae are indicated for observations

# So here we are!

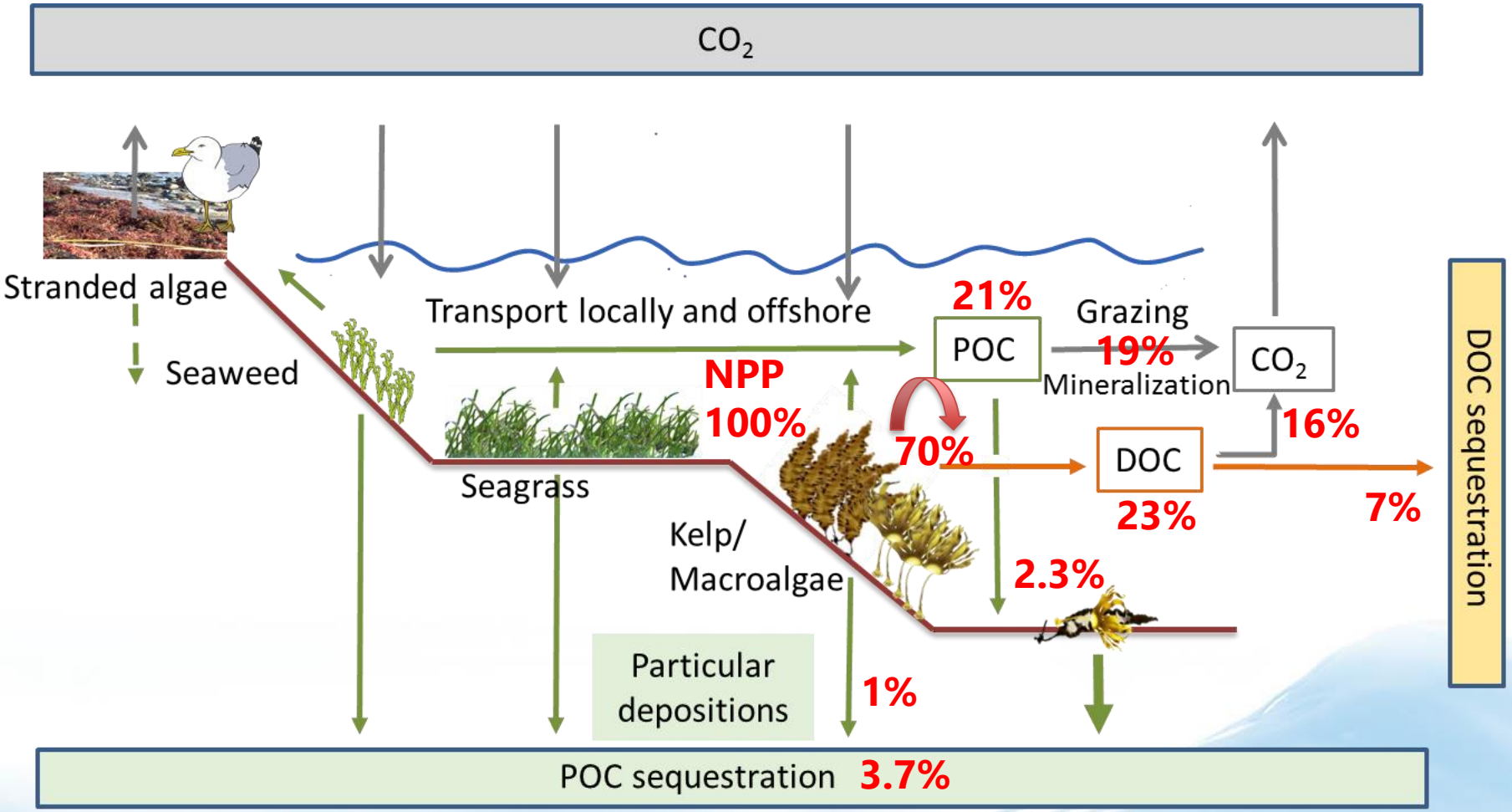
## The major Blue Forest Carbon pathways of Nordic waters




Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# Does the global budget apply to the Nordic?

% according to Krause-Jensen & Duarte 2016



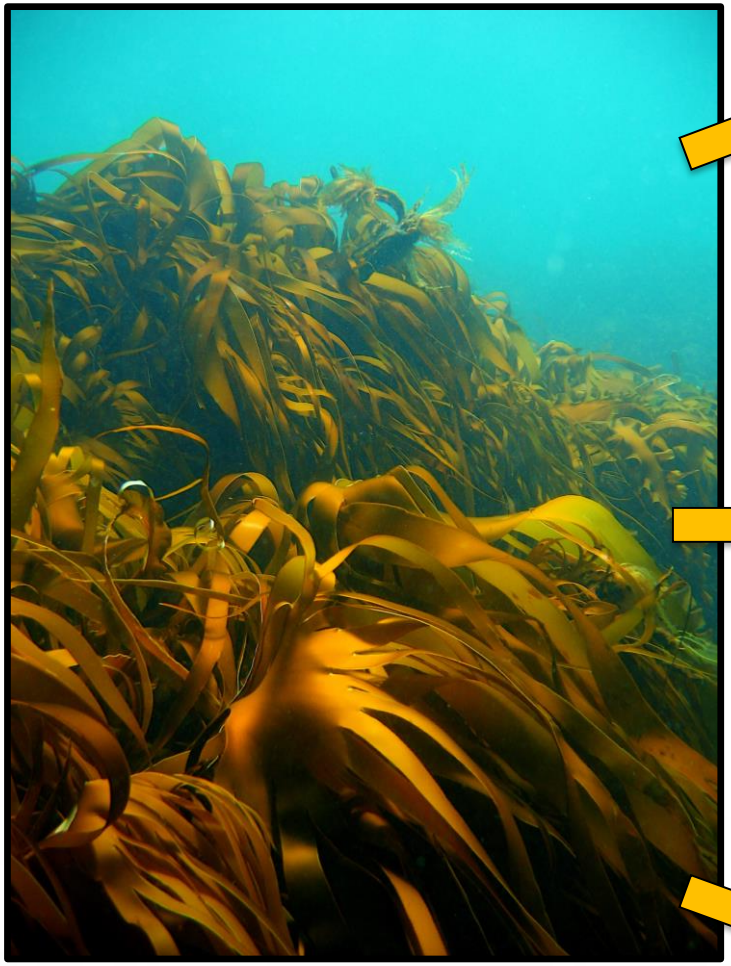

**Total C sequestration 11%**

Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

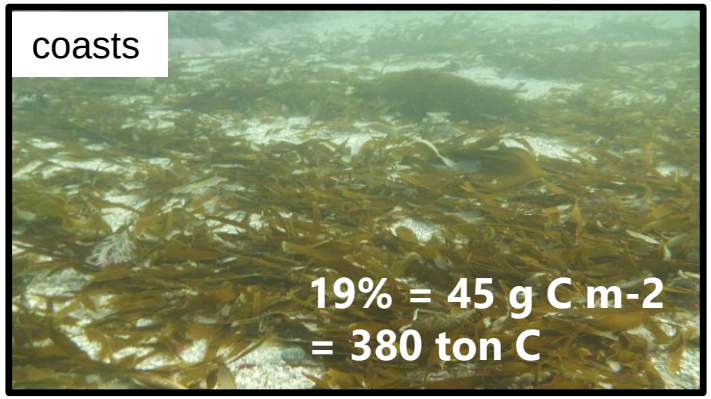
# The carbon budget

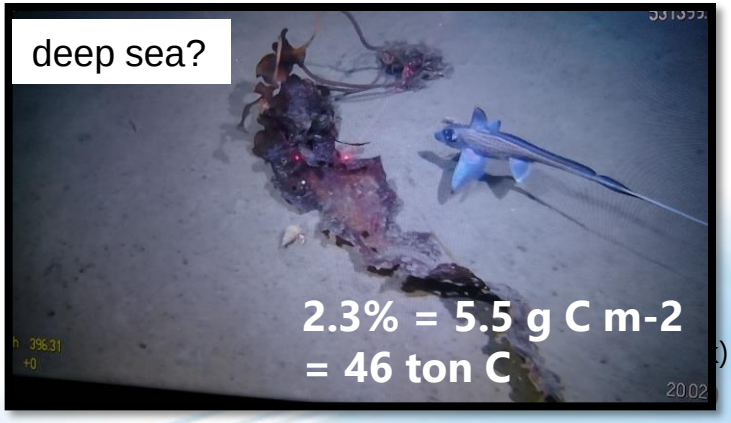
Production: 100 – 500 g C $m^{-2}$

(Krumhansl & Scheibling 2011, and others )



Photographs: K. Filbee-Dexter and T Bakken

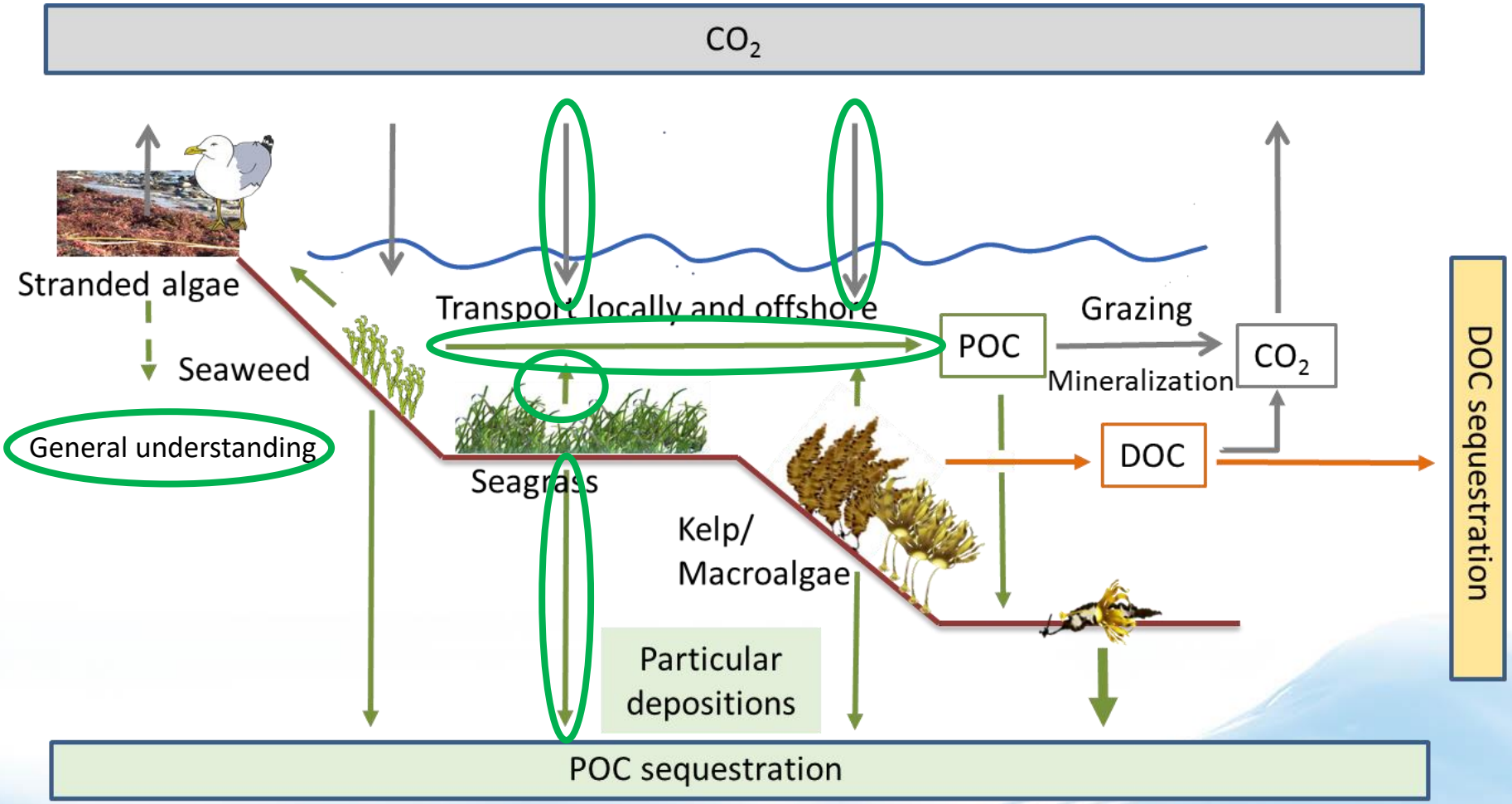




Numbers refer to C export per year to Norwegian waters, assuming 8000km2 of kelp forest (calculations according to Krause-Jensen & Duarte 2016, global assessment budget).

# Here was we do have a good grip on…

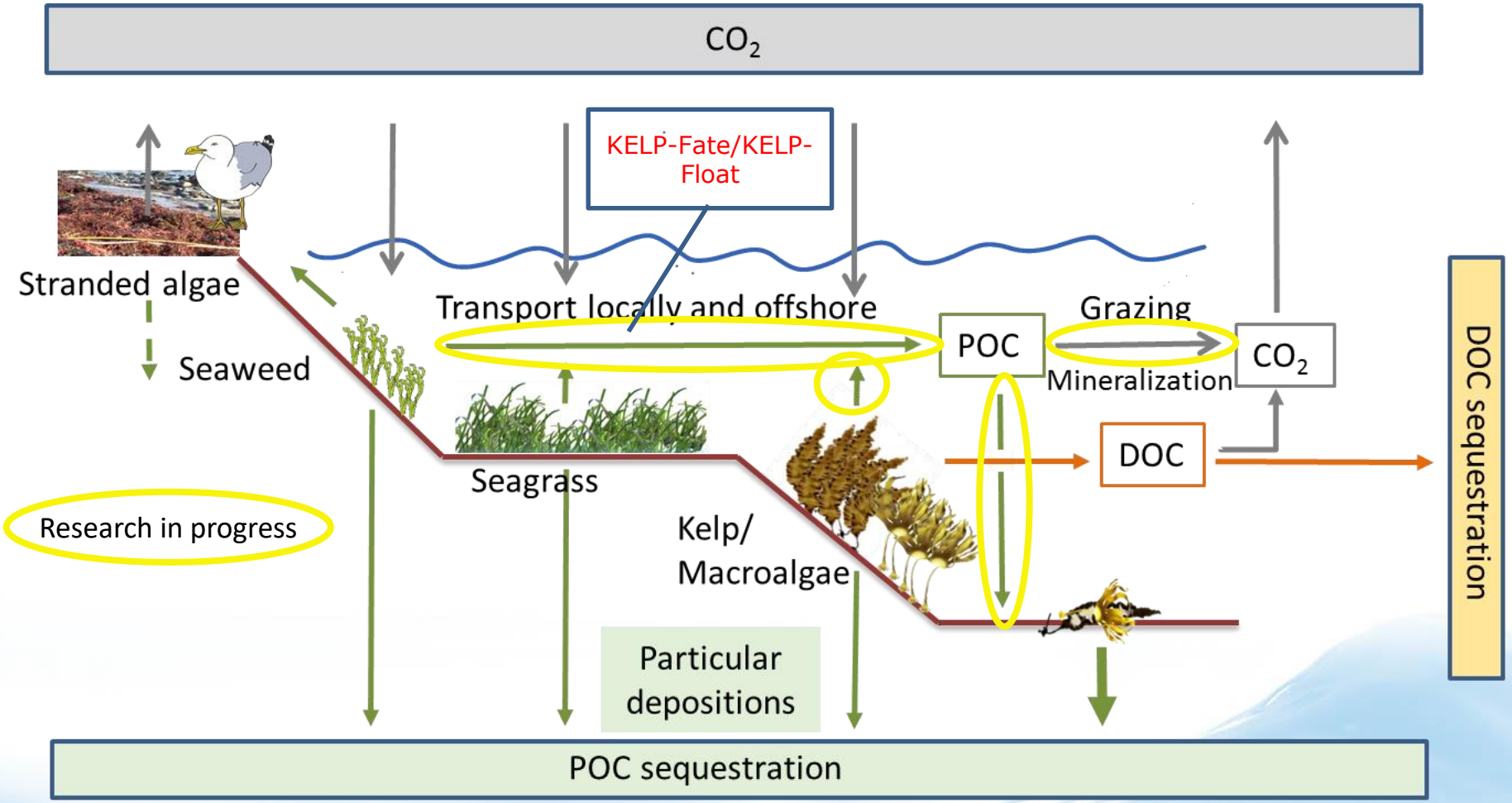
## The major Blue Forest Carbon pathways of Nordic waters




Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# Research in progress….

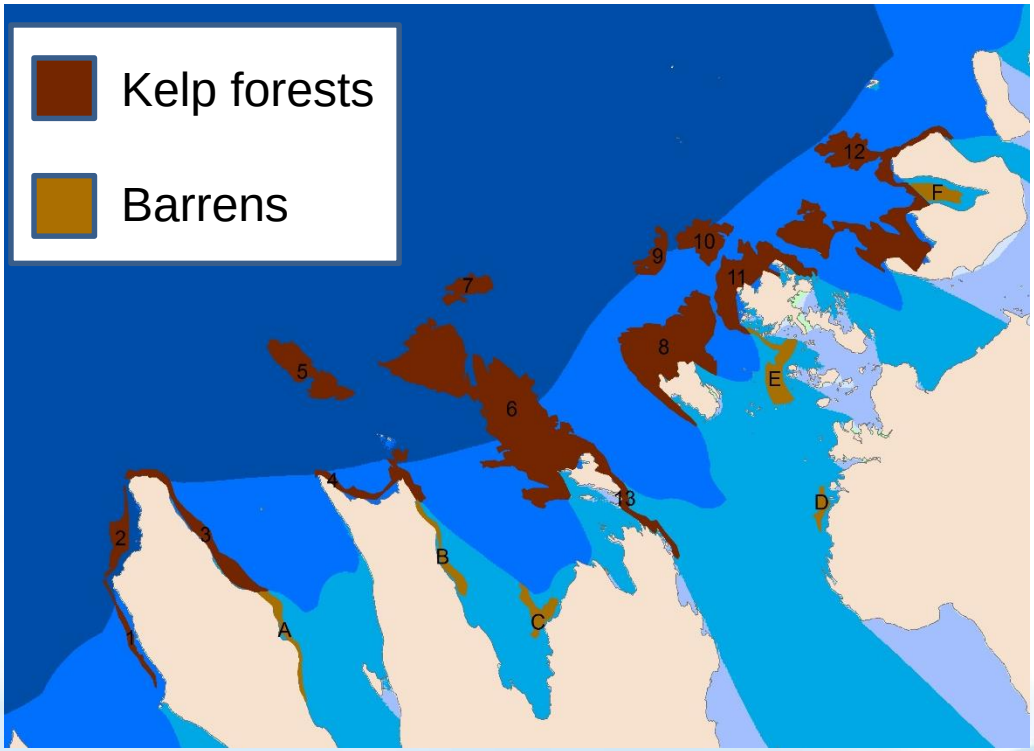
## The major Blue Forest Carbon pathways of Nordic waters

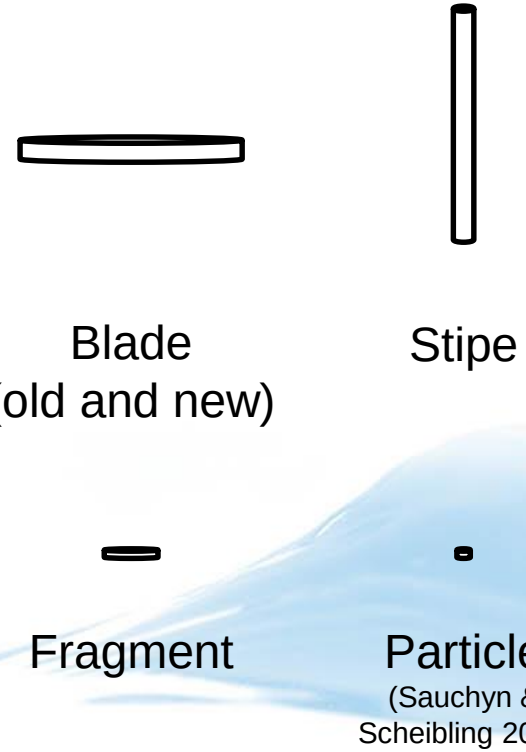



Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# KELP-Fate & KELP-Float
# Modelling the transport of drift kelp under changing ocean conditions

- **Approch**: Simulate dispersal and transport of released kelp particles (stipes, blades and blade fragments) by using a high resolution (160 m) 3D hydrodynamic model and a particle transportation model.

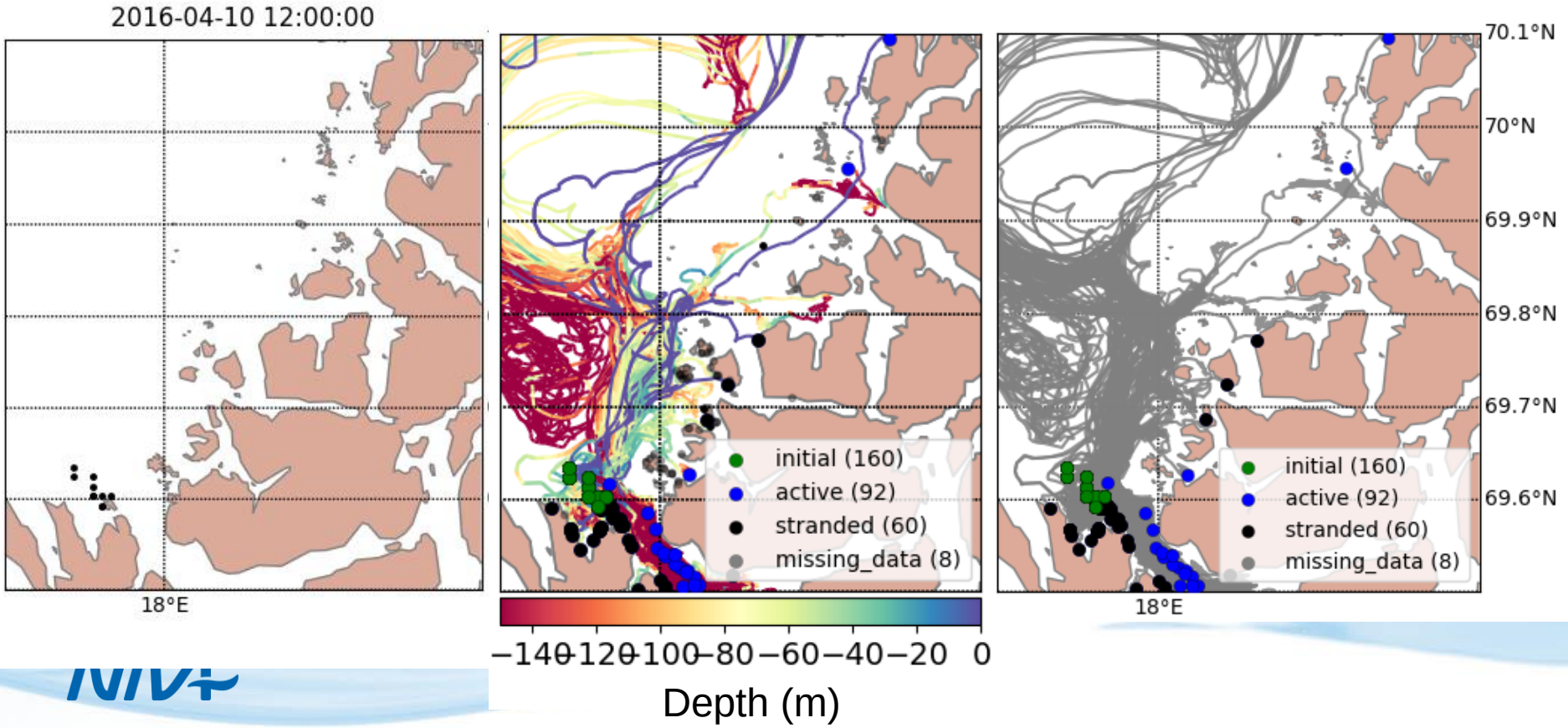


# KELP-Fate & KELP-Float
# Modelling the transport of drift kelp under changing ocean conditions

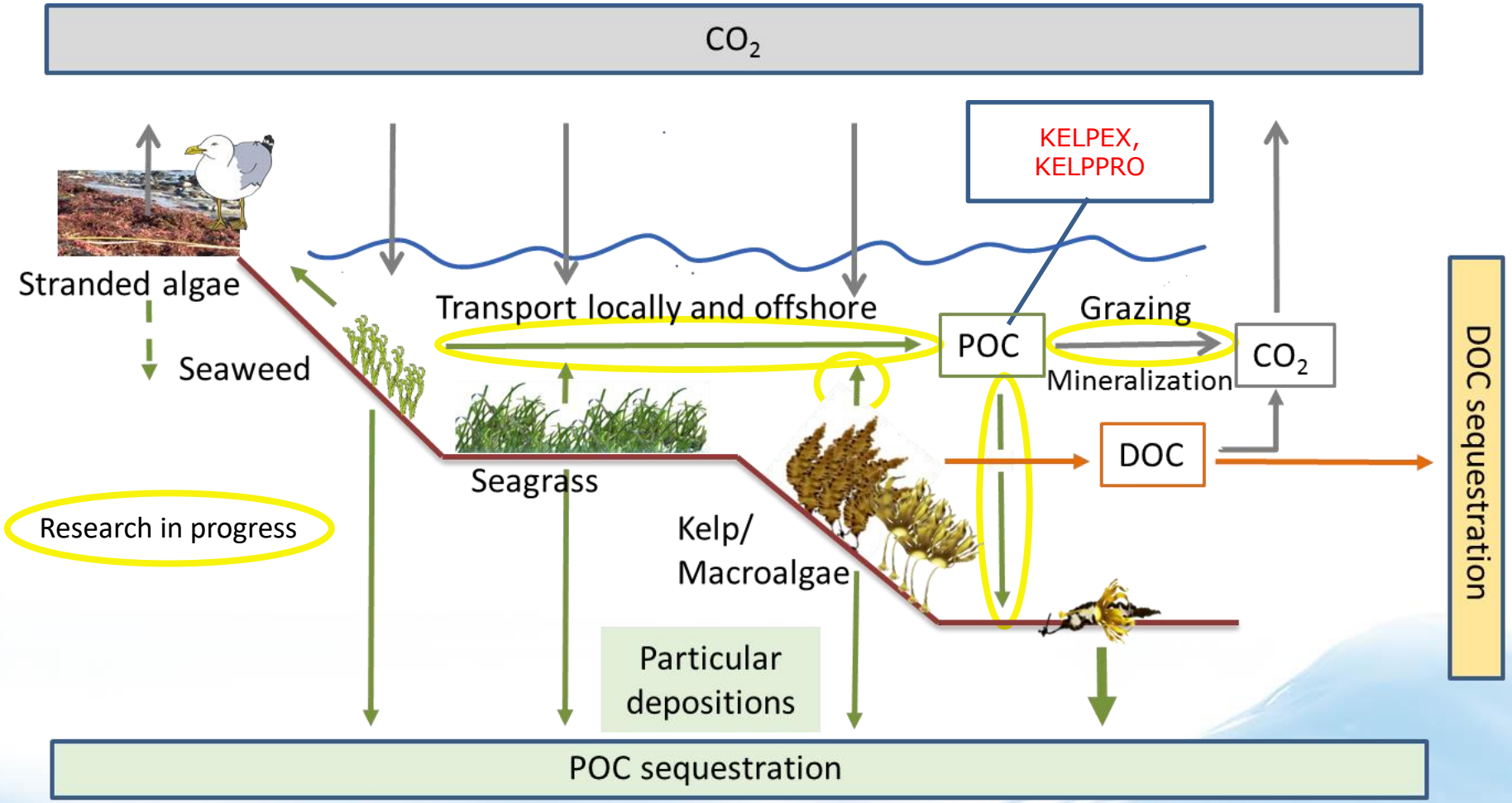
**Main questions (shortened):**

1. How will seasonal production impact the export?
2. How will fragmentation alter drift export?
4. How will regime shift alter drift export?



# Research in progress….

## The major Blue Forest Carbon pathways of Nordic waters

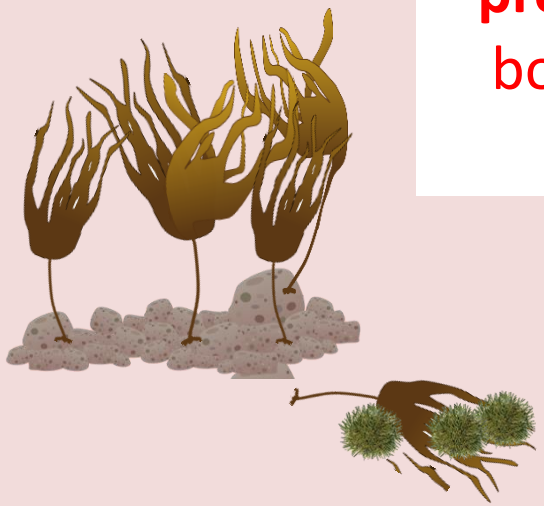



Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# KELPEX: Project structure and aims

**WP1**

**AIM**: Quantify kelp **production** and **export…** to both **shallow** and **deep**, in arctic Norway.



**Pelagic**

**WP2**

**Beaches**

**WP3**

**Deep sea**

**Produced in kelp forest**

**Exported from kelp forest**

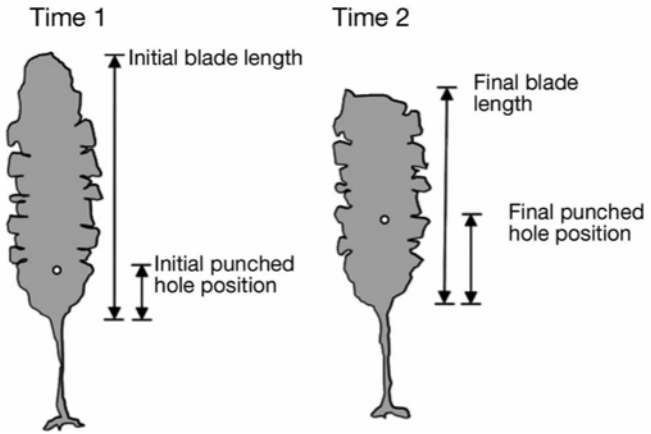
**Community uptake**

Data by **KELP-EX** (NFR-2016-2018) by Thomas Wernberg, Morten Foldager Pedersen, Kjell Magnus Norderhaug, Eva Ramirez-Llodra, Karen Filbee-Dexter

# WP1: Production, export and turn-over of kelp detritus

## Task 1.1: Quantifying the detritus budget - methods

- Repeated quantification of density, morphology, kelp biomass & production.
- Growth & erosion measured using the hole punch method.

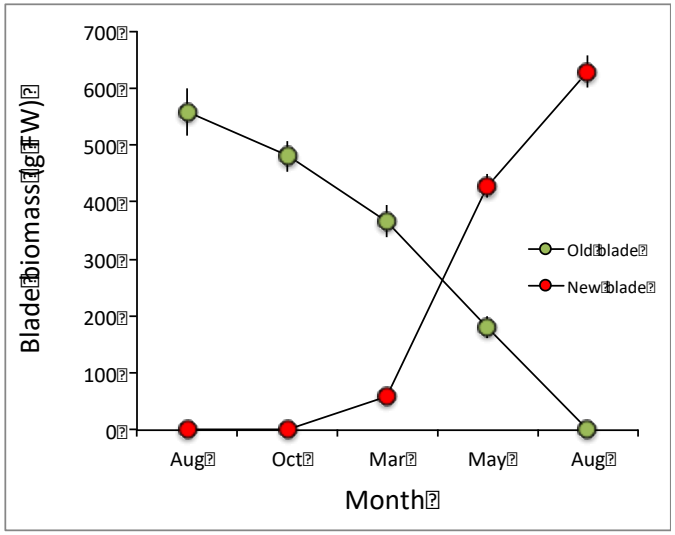


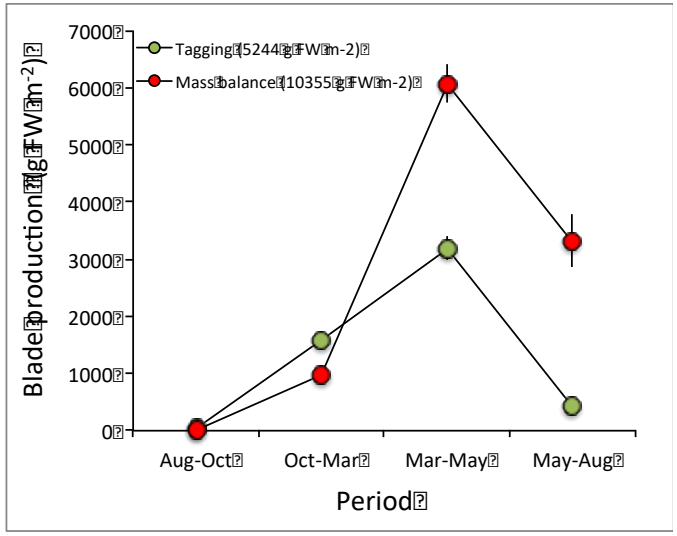

- Detritus formation based on:
  - blade erosion (hole punch method),
  - loss of entire blades in winter,
  - loss of whole individuals (loss of tagged plants).

Data by **KELP-EX** (NFR-2016-2018) by Thomas Wernberg, Morten Foldager Pedersen, Kjell Magnus Norderhaug, Eva Ramirez-Llodra, Karen Filbee-Dexter

# WP1: Production, export and turn-over of kelp detritus

## Task 1.1: Kelp growth & productivity:




*Seasonal changes in individual blade biomass and blade production $m^{-2}$.*

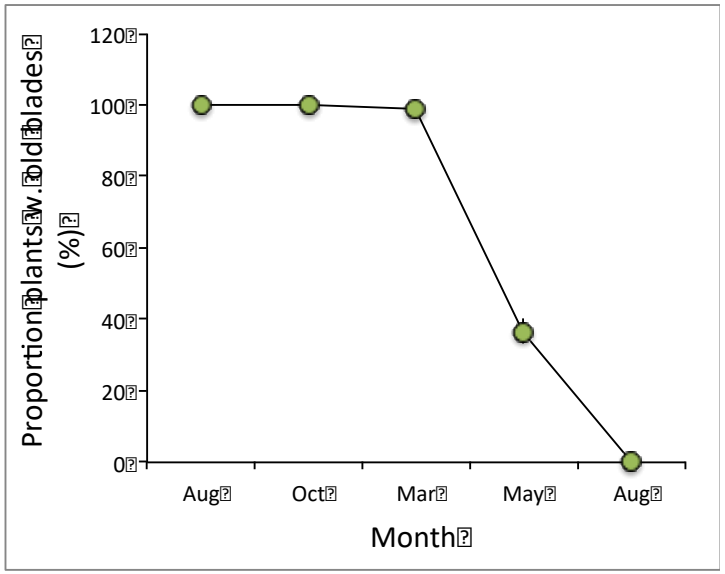
- Individual blade biomass increases rapidly in winter/spring and decreases through autumn/winter.
- Annual kelp production reaches 5 - 10 kg FW $m^{-2}$ depending on method (tagging seems to under-estimated true growth by ca. 50%).

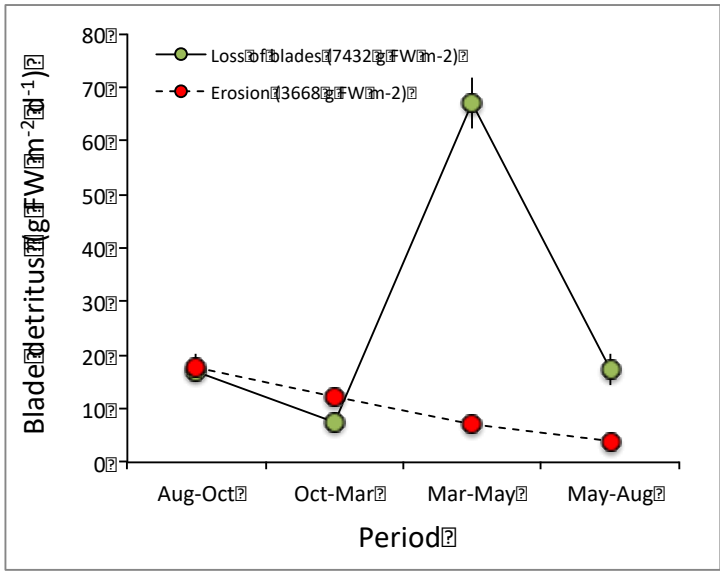
NIVA

Data by **KELP-EX** (NFR-2016-2018) by Thomas Wernberg, Morten Foldager Pedersen, Kjell Magnus Norderhaug, Eva Ramirez-Llodra, Karen Filbee-Dexter

# WP1: Production, export and turn-over of kelp detritus

## Task 1.1: Loss of kelp material - detritus formation:




*Proportion of plants carrying an old blade and detritus 'production' due to loss of whole blades and through erosion.*

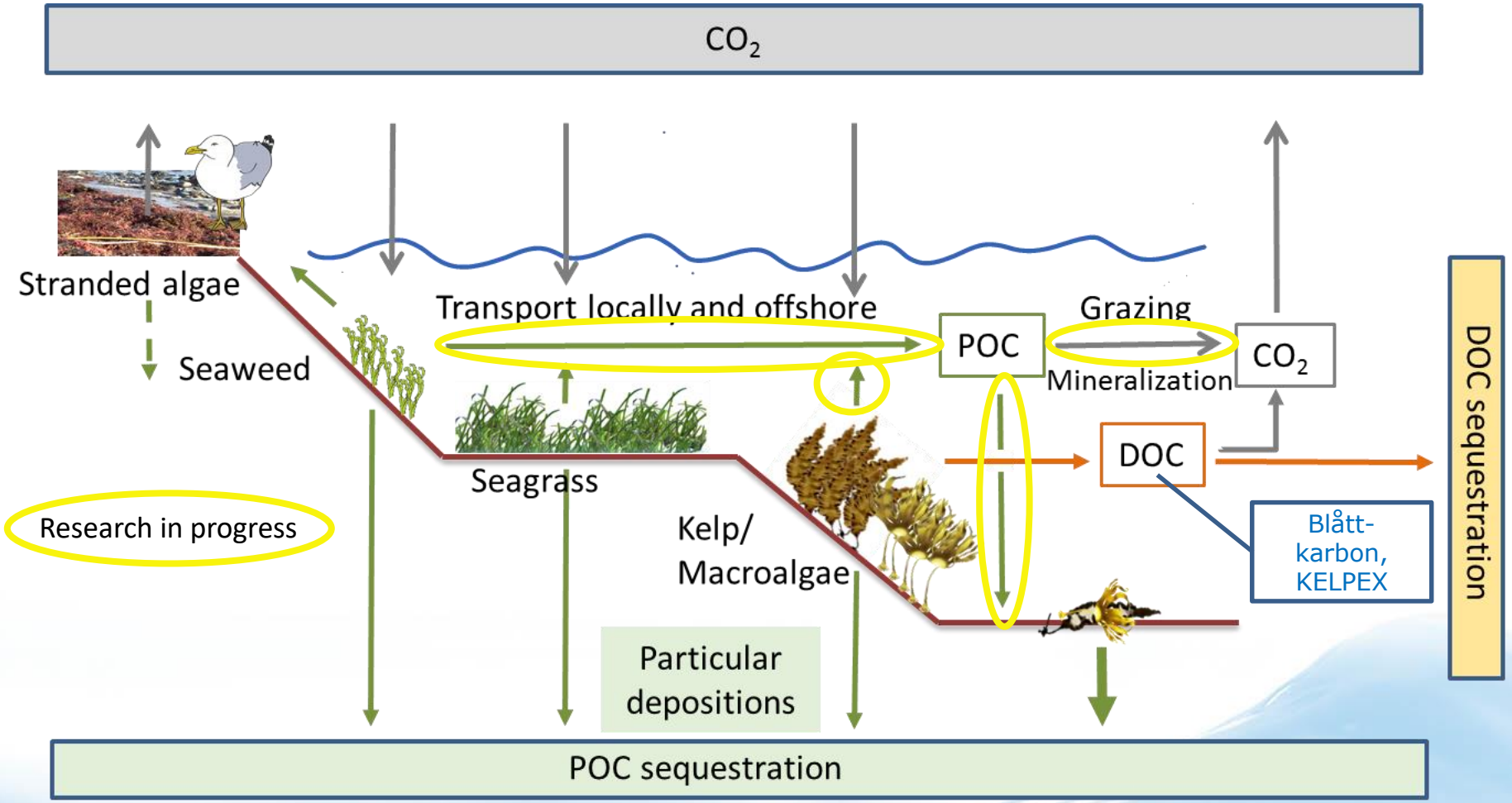
- Old blades are mainly lost between March and May-June – the annual loss of whole blades (old, new and attached to lost plants) = 7.4 kg FW $m^{-2}$.
- Loss through distal blade erosion occurs at low rate over the year – the annual loss through erosion = 3.7 kg FW $m^{-2}$.

NIVA

Data by **KELP-EX** (NFR-2016-2018) by Thomas Wernberg, Morten Foldager Pedersen, Kjell Magnus Norderhaug, Eva Ramirez-Llodra, Karen Filbee-Dexter

# So here we are!

## The major Blue Forest Carbon pathways of Nordic waters

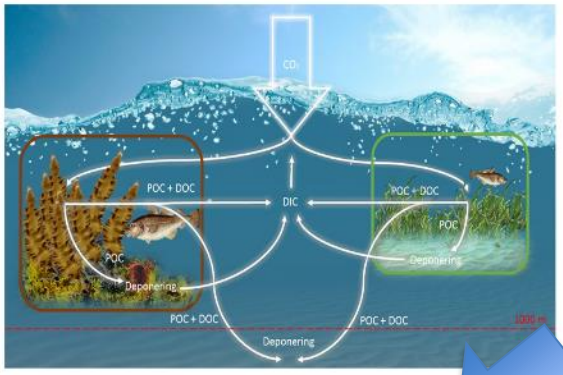



Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# WP2 - Fieldwork – kelp carbon export and sequestration

## 2.3 Production of Dissolved Organic Matter (DOC) in kelp forests

**Work in progress….. (samples in the lab from fieldwork Aug 2017)**




LIMNOLOGY and OCEANOGRAPHY — ASLO

Patterns and controls of reef-scale production of dissolved organic carbon by giant kelp *Macrocystis pyrifera* — 2015

Daniel C. Reed,[1*] Craig A. Carlson,[1,2] Elisa R. Halewood,[1] J. Clinton Nelson,[1] Shannon L. Harrer,[1] Andrew Rassweiler,[1] Robert J. Miller[1]

[1]Marine Science Institute, University of California, Santa Barbara, California
[2]Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, California

Estuarine, Coastal and Shelf Science

Volume 129, 1 September 2013, Pages 77-85

ELSEVIER

The contribution of macroalgae to the coastal dissolved organic matter pool — 2013

Shigeki Wada *, Takeo Hama

Show more

https://doi.org/10.1016/j.ecss.2013.06.007

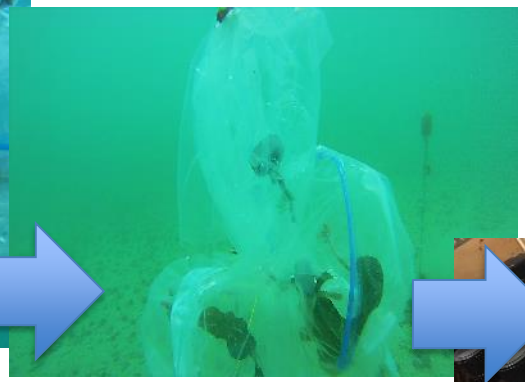
Get rights and content

Production, respiration and exudation of dissolved organic matter by the kelp *Laminaria hyperborea* along the west coast of Norway — 2004

Mohammed I. Abdullah* and Stein Fredriksen

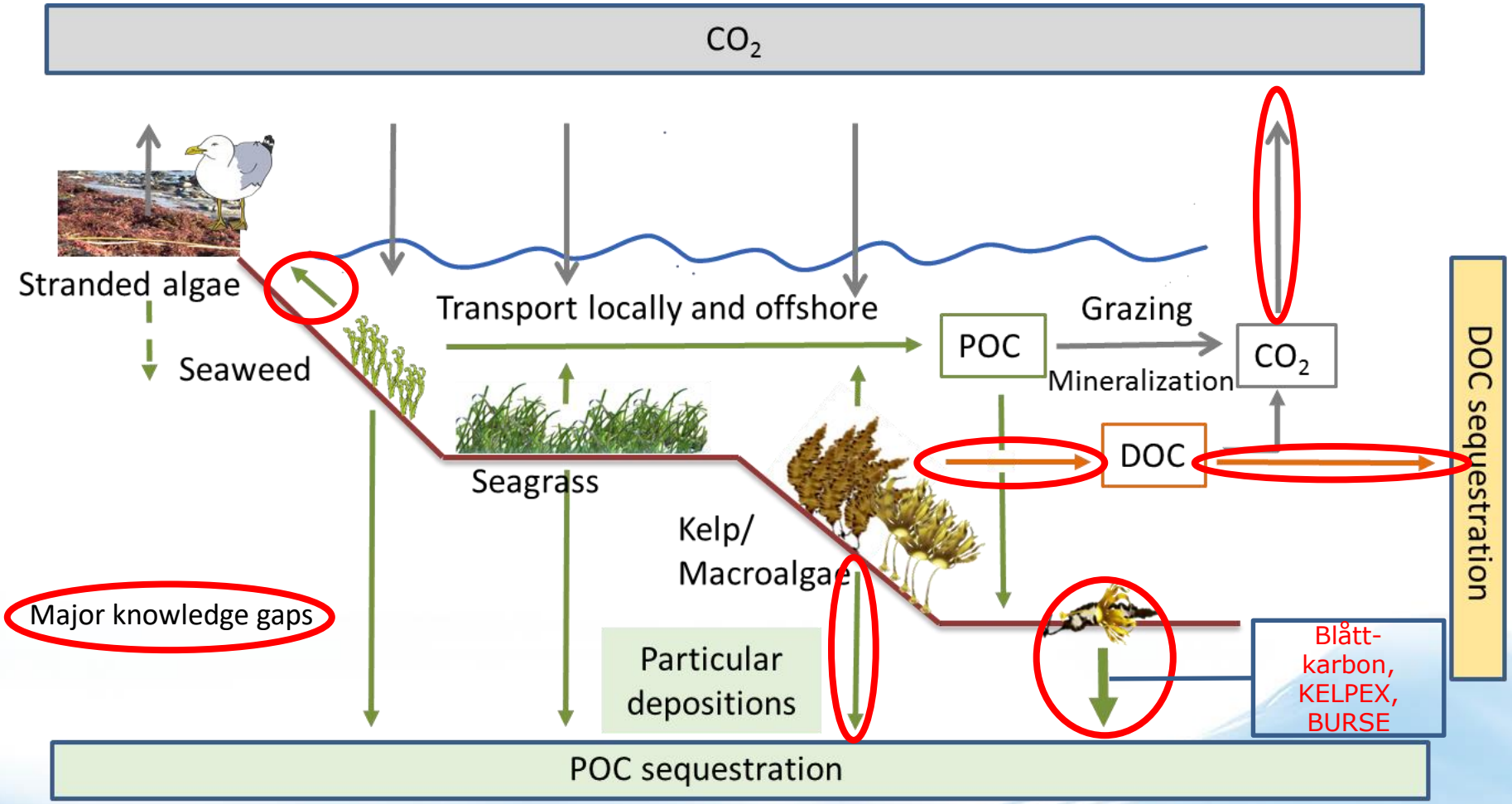
University of Oslo, Department of Biology, PO Box 1066 Blindern, 0316 Oslo, Norway

*Corresponding author, e-mail: abdullah@bio.uio.no



# Major knowledge gaps..!

## The major Blue Forest Carbon pathways of Nordic waters




Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# **KELP-EX** WP3: EFFECTS OF DRIFT ON DEEP SEA COMMUNITIES

**Kelp collections from trawl**
**4 kg inner fjord**
**~0 kg $m^{-2}$ offshore**

**Particles of kelp from box cores:**
**22 g $m^{-2}$ inner fjord**
**16 g $m^{-2}$ offshore**

Data by **KELP-EX** (NFR-2016-2018) by Thomas Wernberg, Morten Foldager Pedersen, Kjell Magnus Norderhaug, Eva Ramirez-Llodra, Karen Filbee-Dexter

# WP2 - Fieldwork – kelp carbon export and sequestration

## 2.2 Degradation rates and long-term storage of kelp organic matter in sediments

- **Fieldwork** in the Trondheimsfjord region, **sediment cores** will be collected to track kelp organic matter and its degradation

- Possible trace methods include:
- Isotope analysis (C, N)
- Corotenoids
- eDNA
- Lipid analysis
- Aging using Pb210

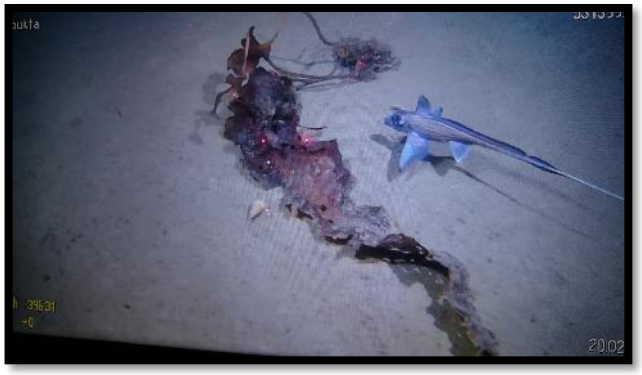
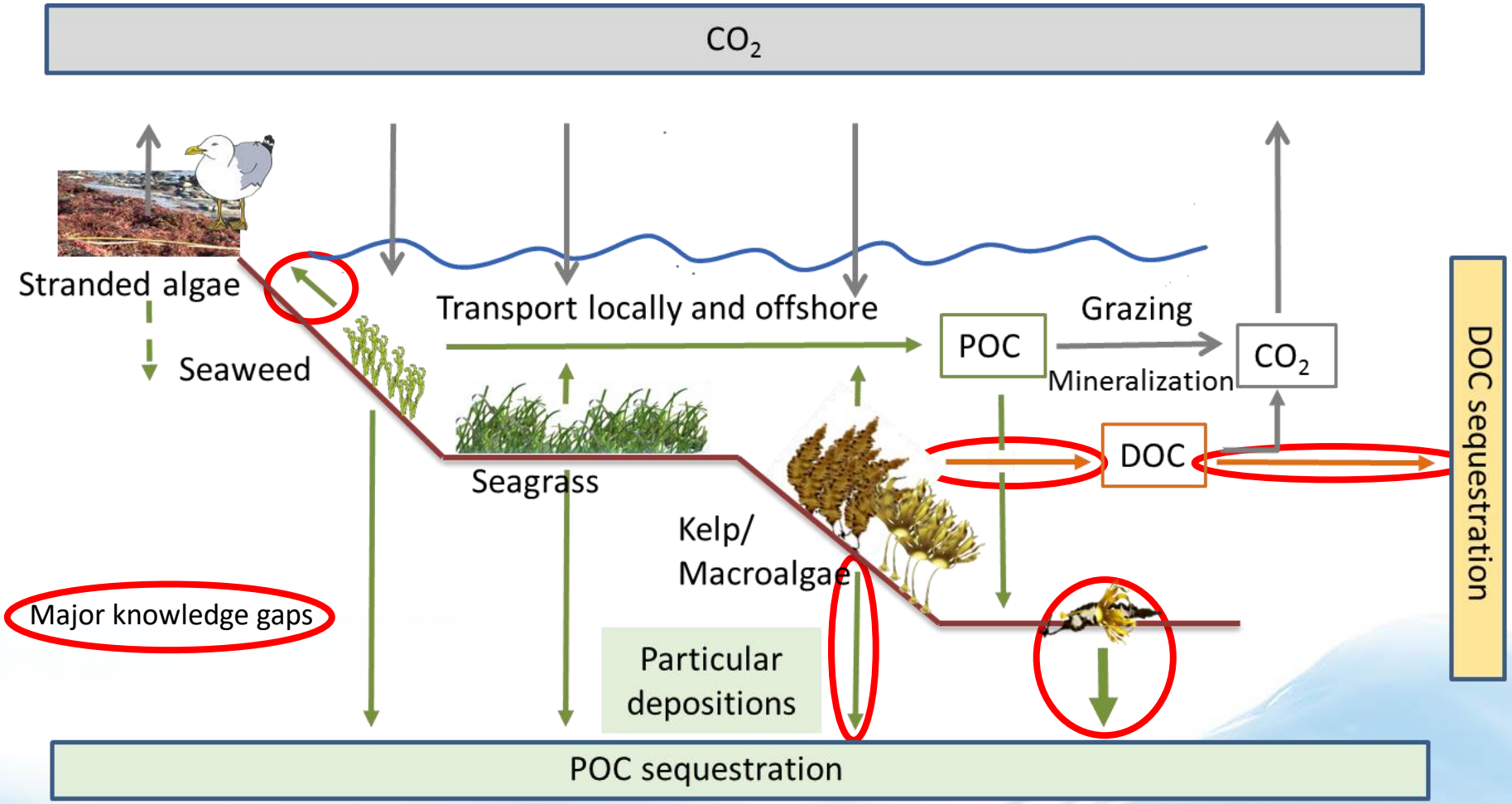


photo by T Bakken

**Figur 2.** Kjerneprøvetaker og sedimentkjerne (Foto: NIVA)

# Major knowledge gaps.. Summering up.

## The major Blue Forest Carbon pathways of Nordic waters




Figurer by K Hancke, H Gundersen, GS Andersen un. publ.

# Any questions or comments?

## Thanks to all the contributing authors and related on-going research projects:

*Hege Gundersen,* Karen Filbee-Dexter, Eli Rinde, Eva Ramirez-Llodra, Trond Kristiansen, *Helene Frigstad, Guri Sogn Andersen,* Trine Bekkby *(NIVA), Jon Albretsen, Kjell Magnus Norderhaug (IMR),* Morten Foldager Pedersen (Roskilde Univ.), Thomas Wernberg (Univ. Western Australia).

*KELP-EX (NIVA)*
*KELP-Fate (NIVA)*
*KELP-Float (NBFN)*
*KELP-PRO (NIVA)*
*BURSE (NBFN)*
*SEAME (NBFN)*

*Looking forward to further collaborations with:*
*Dorte Krause-Jensen (Aarhus Universitet), Christoffer Boström (Åbo Akademi University), and Susanne Baden (Göteborg Universitet), and others….*