trans algae

Seaweed 101

EUROPEAN UNION Interreg Botnia-Atlantica European Regional Development Fund

Kempestiftelserna Arctic Seaweed

Österbottens förbund Pohjanmaan liitto

Nordland FYLKESKOMMUNE

bodø KOMMUNE

Landstinget Västernorrland

Länsstyrelsen Västerbotten

THOSE CURIOUS AND DELICIOUS Seaweeds

A FASCINATING VOYAGE FROM BIOLOGY TO GASTRONOMY

José Lucas Pérez Lloréns
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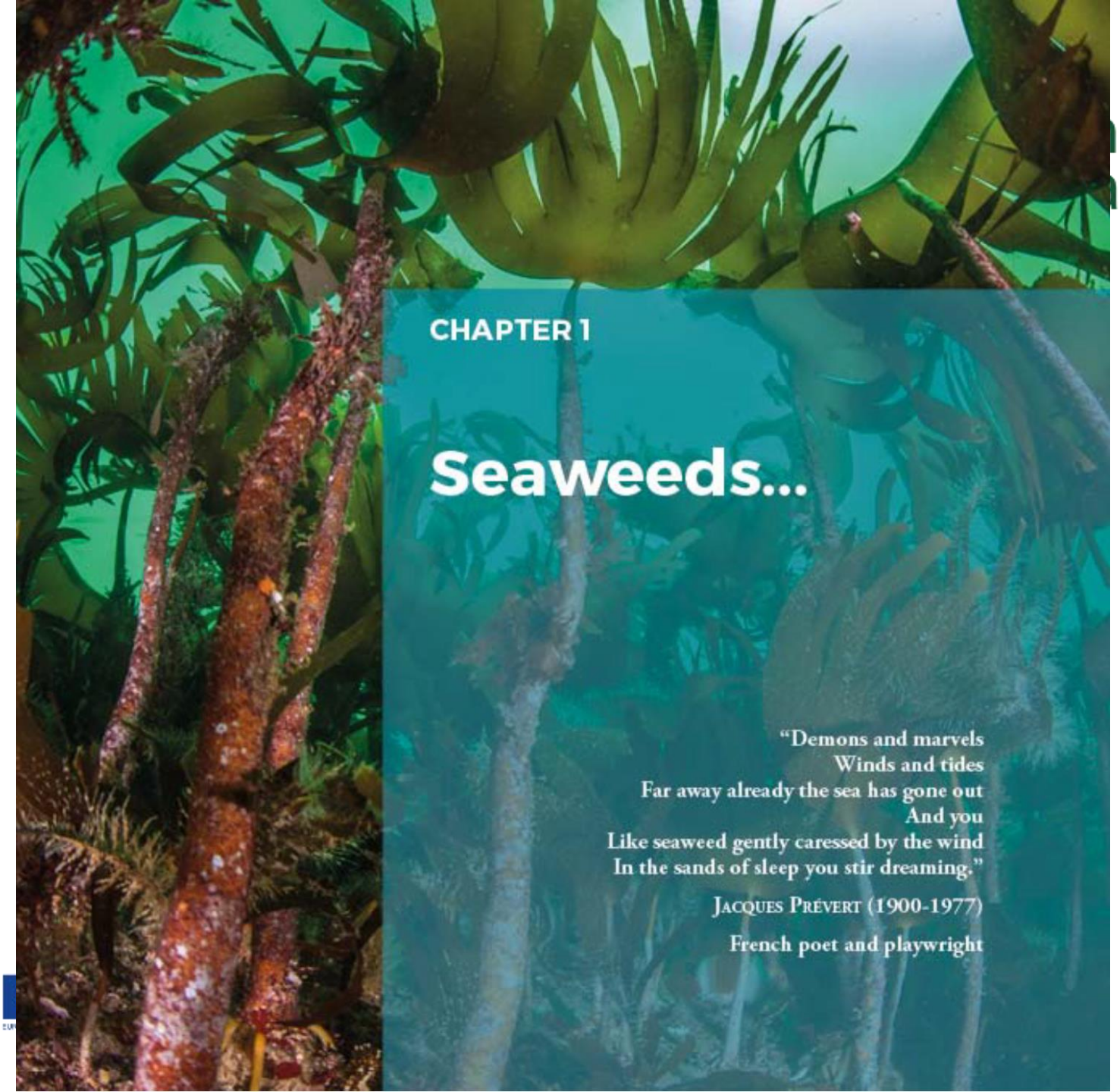
Juan José Vergara Oñate
Fernando G. Brun Murillo
Ángel León

With the collaboration of some of the best-known and avante garde chefs in Spain

Editorial UCA



CHAPTER 1

Seaweeds...

"Demons and marvels
Winds and tides
Far away already the sea has gone out
And you
Like seaweed gently caressed by the wind
In the sands of sleep you stir dreaming."

JACQUES PRÉVERT (1900-1977)

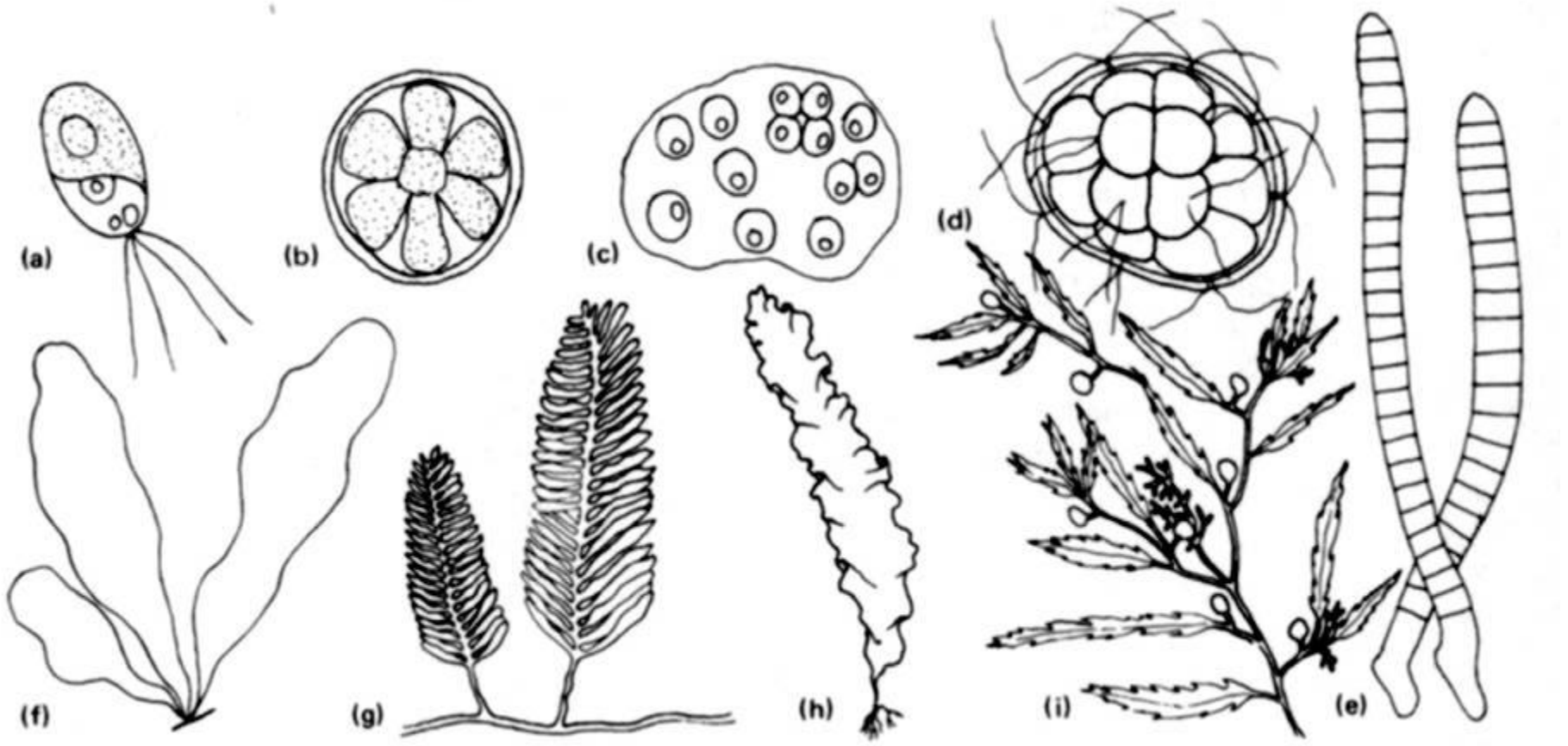
French poet and playwright

What are seaweeds?

What are seaweeds?

- Seaweeds are algae

Algae: From single cell to highly differentiated thallus



What are seaweeds?

- Seaweeds are algae
- Kingdom Plantae & Chromista
- Simple to highly differentiated morphology
  - No roots: holdfast to attach to the rock*

* With few exception

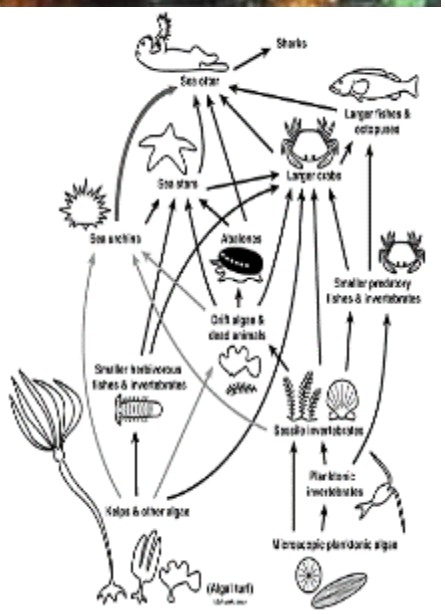
Macroalgae: Taxonomic Classification

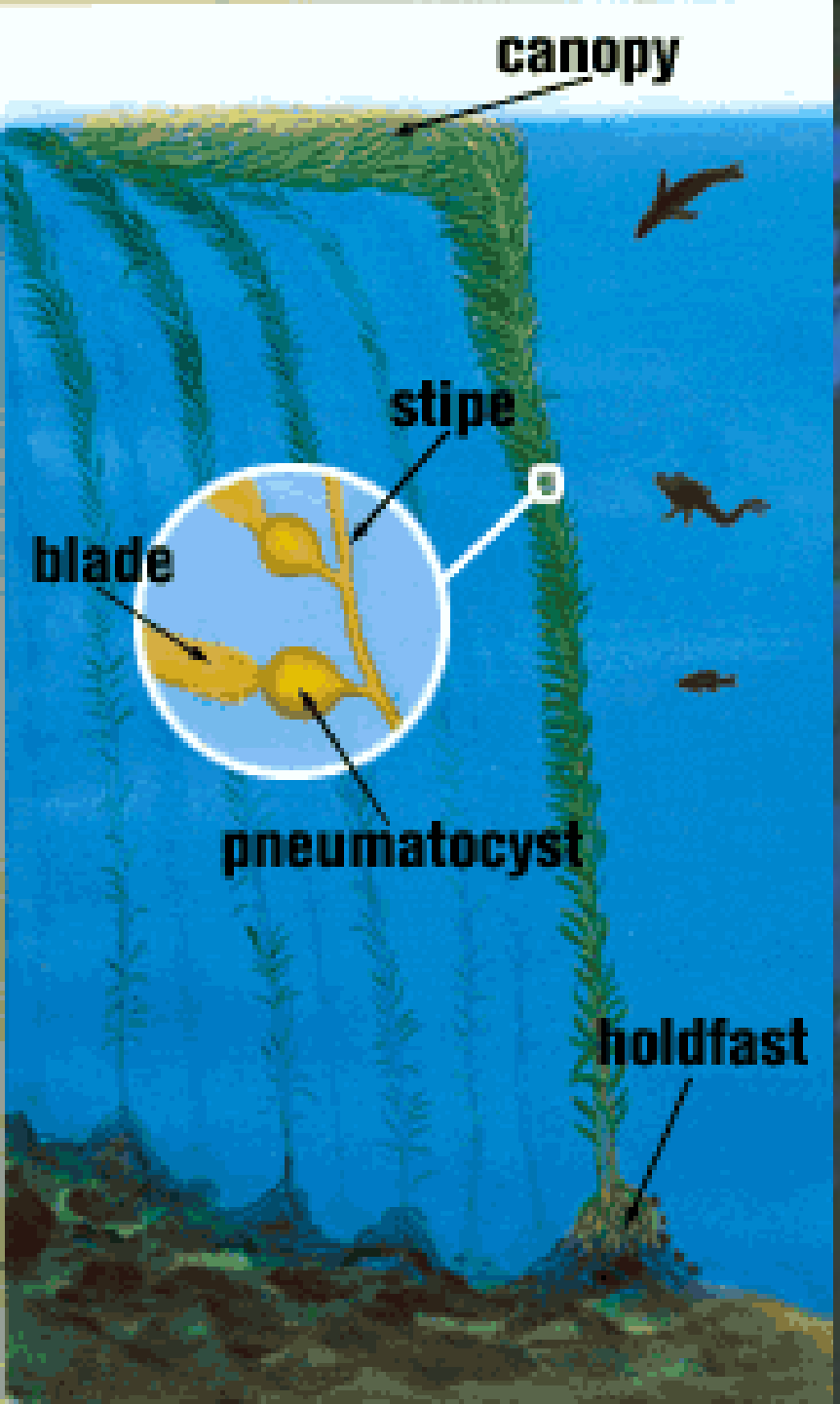
Kingdom	Plantae	Chromista	Plantae
Phylum	Chlorophyta	Ochrophyta	Rhodophyta
		Bacillariophyceae (Diatoms)	
	Chl a, b	Chl a, c_1, c_2 Fucoxanthin	Chl a, d Phycobilins

What are seaweeds?

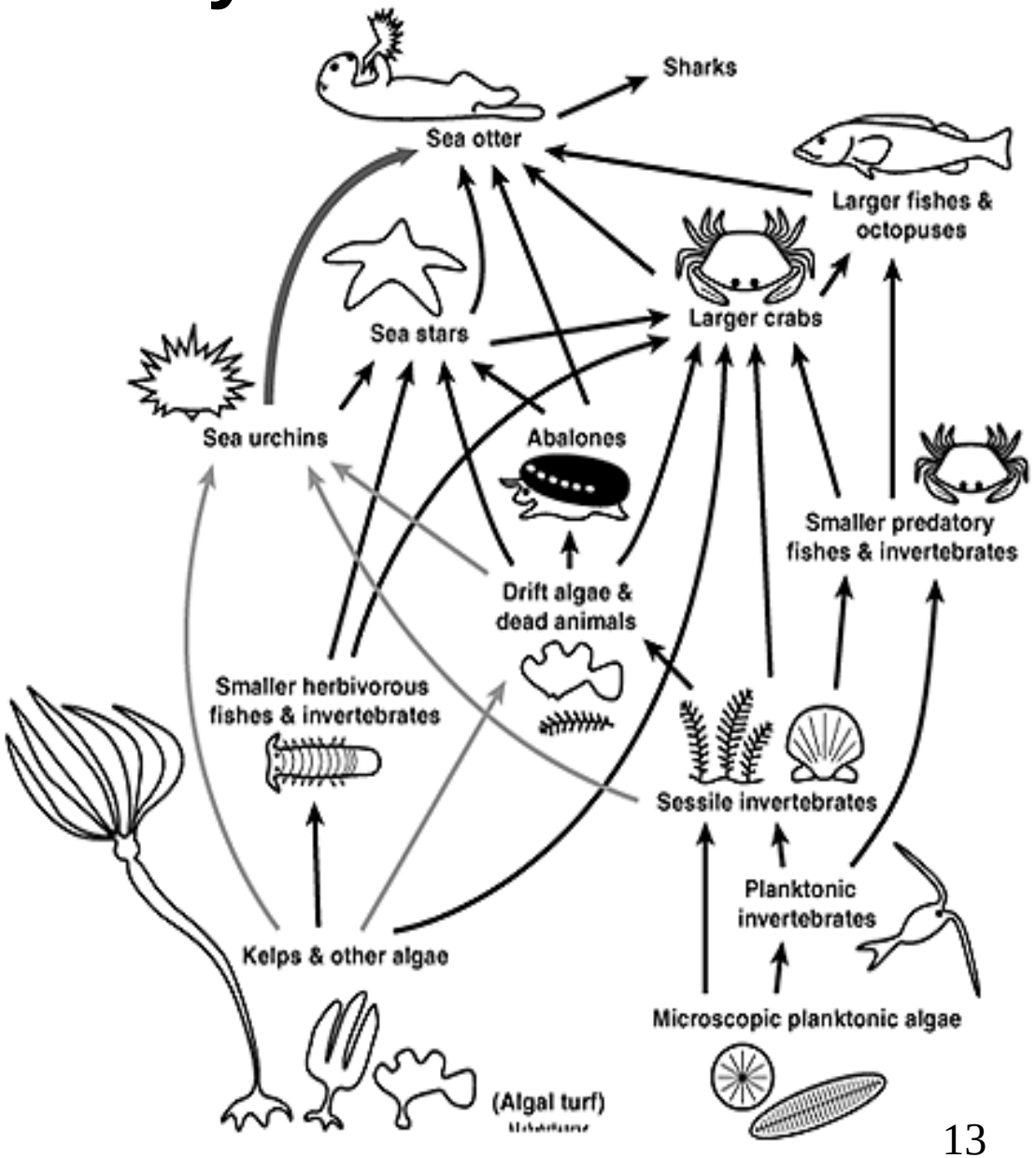
- Seaweeds are algae
- Kingdom Plantae & Chromista
- Simple to highly differentiated morphology
  - No roots: holdfast to attach to the rock*
  - No seeds: spores
  - Most have a flagella on some part of their life cycle

Structural and functional role of (canopy-forming) seaweeds: 3D-structure, habitat, nursery ground, and food source



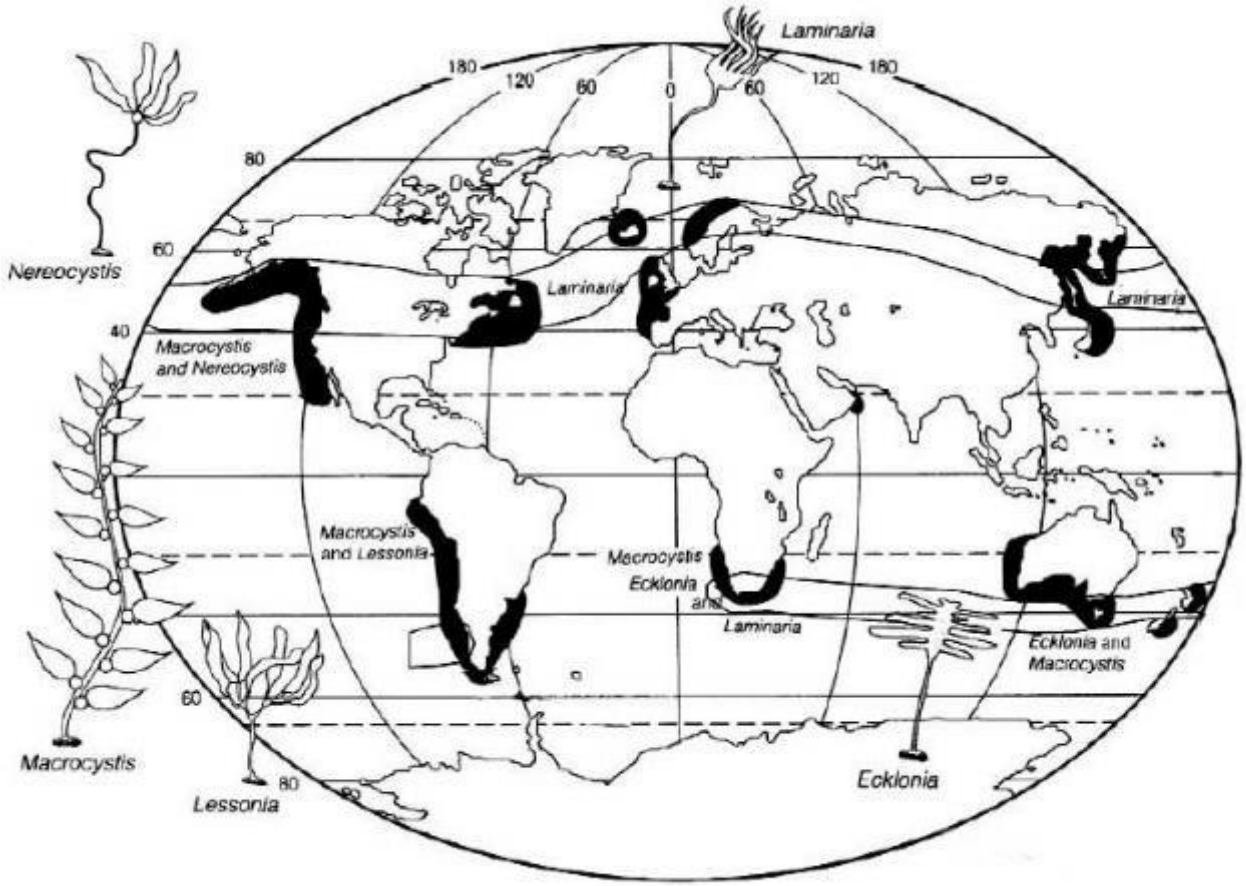

canopy
stipe
blade
pneumatocyst
holdfast

Coastal ecosystem food web



Global distribution pattern

Figure 1 Kelp forest distributions of the world and their dominant genera (from Raffaelli & Hawkins 1996).



Order: Laminariales

CHAPTER 2

Do people eat seaweeds?: Past, present and future

"Man, who has been humorously defined as a cooker of animals, not content with the bounty of fish bestowed upon him by the Ocean, converts many of its vegetable products into items for his diet."

ROBERT KAYE GREVILLE (1794-1866)

British botanist

Icelandic literatures:Seaweed use

Oldest documentation of seaweed for human consumption in the Western World

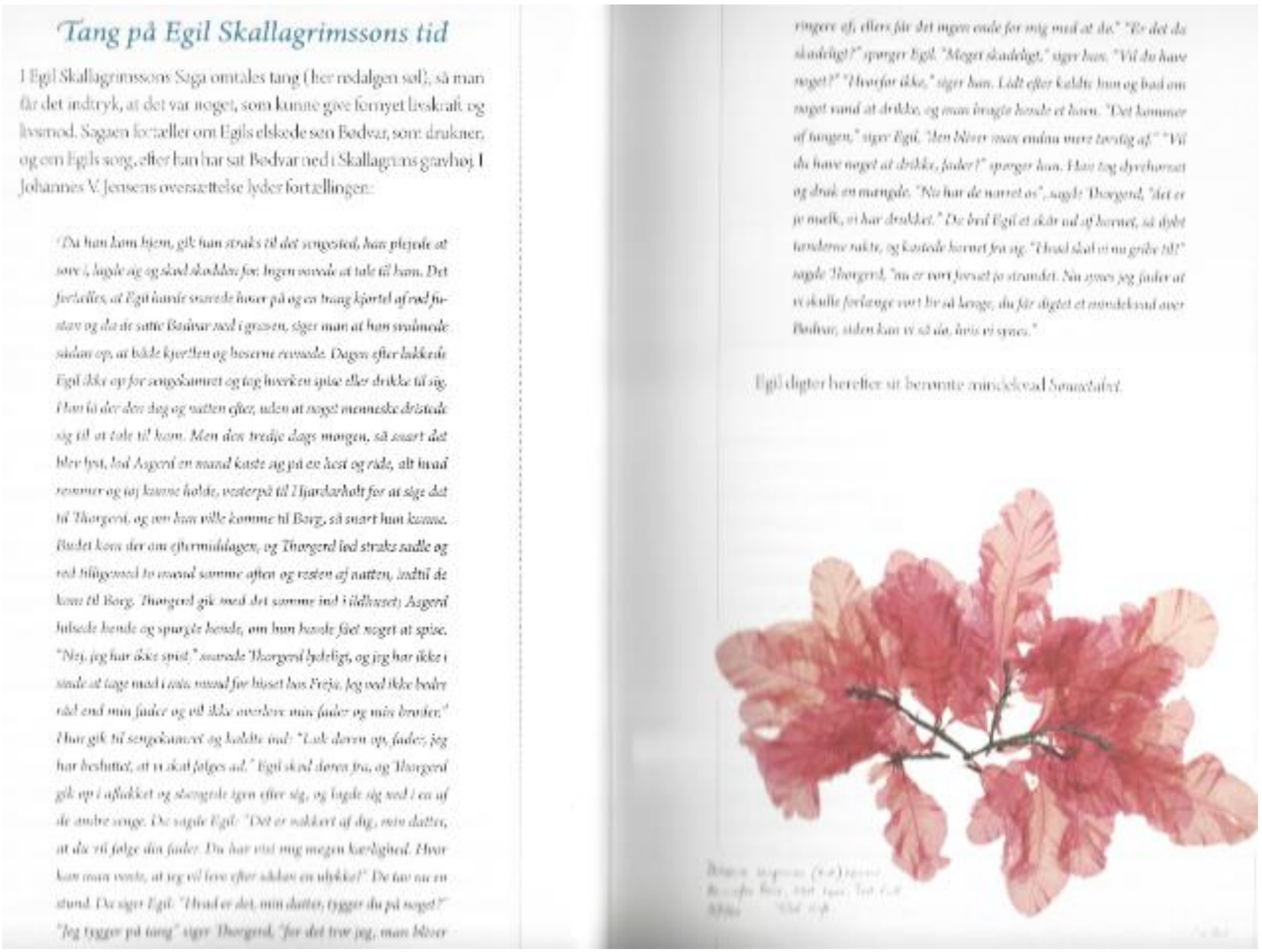
- *Palmaria palmata "sol"* - known to be edible since at least the year 961.

-The oldest law book "Gragas":

- First half of the 12th century: right to collect *sol* and the right to eat *sol* when on another man's land which means that *sol* was also eaten fresh.
- The right to collect *sol* was considered a great concession and license were issued to many churches all around Iceland.

- 1118 to end of 19th century: Collection and trading of *sol*- transported over long distances and sold in exchange for wool, meat, etc., to the inland farmers. Thus *sol* apparently was eaten by both poor and rich.

Icelandic literatures:Seaweed use



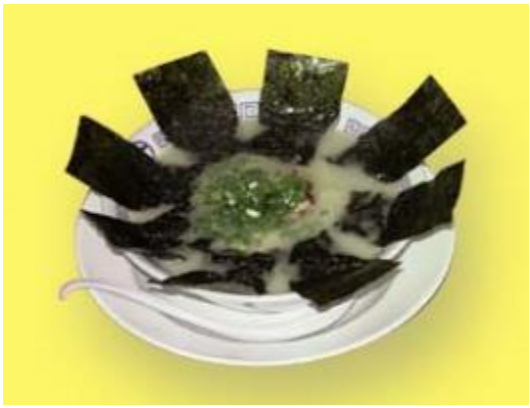
Tang på Egil Skallagrimssons tid

I Egil Skallagrimssons Saga omtales tang (her rødalgen søl), så man får det indtryk, at det var noget, som kunne give fornyet livskraft og livsmod. Sagaen fortæller om Egils elskede søn Bødvar, som drukner, og om Egils sorg, efter han har sat Bødvar ned i Skallagrims gravhøj. I Johannes V. Jensens oversættelse lyder fortællingen:

"Da han kom hjem, gik han straks til det sengested, han plejede at sove i, lagde sig og skød skodden for. Ingen vovede at tale til ham. Det fortælles, at Egil havde snævre hoser på og en trang kjortel af rød fustan og da de satte Bødvar ned i graven, siger man at han svulmede sådan op, at både kjortlen og hoserne revnede. Dagen efter lukkede Egil ikke op for sengekamret og tog hverken spise eller drikke til sig. Han lå der den dag og natten efter, uden at noget menneske dristede sig til at tale til ham. Men den tredje dags morgen, så snart det blev lyst, lod Asgerd en mand kaste sig på en hest og ride, alt hvad remmer og tøj kunne holde, vesterpå til Hjardarholt for at sige det til Thorgerd, og om hun ville komme til Borg, så snart hun kunne. Budet kom der om eftermiddagen, og Thorgerd lod straks sadle og red tilligemed to mand samme aften og resten af natten, indtil de kom til Borg. Thorgerd gik med det samme ind i ildhuset; Asgerd hilsede hende og spurgte hende, om hun havde fået noget at spise. "Nej, jeg har ikke spist," svarede Thorgerd lydeligt, og jeg har ikke i sinde at tage mad i min mund før huset hos Freja. Jeg ved ikke bedre råd end min fader og vil ikke overleve min fader og min broder." Hun gik til sengekamret og kaldte ind: "Luk døren op, fader, jeg har besluttet, at vi skal følges ad." Egil skød døren fra, og Thorgerd gik op i aflukket og stængede igen efter sig, og lagde sig ned i en af de andre senge. Da sagde Egil: "Det er smukt af dig, min datter, at du vil følge din fader. Du har vist mig megen kærlighed. Hvor kan man vente, at jeg vil leve efter sådan en ulykke?" De tav nu en stund. Da siger Egil: "Hvad er det, min datter, tygger du på noget?" "Jeg tygger på tang" siger Thorgerd, "for det tror jeg, man bliver ringere af, ellers får det ingen ende for mig med at dø." "Er det da skadeligt?" spørger Egil. "Meget skadeligt," siger hun. "Vil du have noget?" "Hvorfor ikke," siger han. Lidt efter kaldte hun og bad om noget vand at drikke, og man bragte hende et horn. "Det kommer af tangen," siger Egil, "den bliver man endnu mere tørstig af." "Vil du have noget at drikke, fader?" spørger hun. Han tog dyrehornet og drak en mængde. "Nu har de narret os", sagde Thorgerd, "det er jo mælk, vi har drukket." Da bed Egil et skår ud af hornet, så dybt tænderne nåede, og kastede hornet fra sig. "Hvad skal vi nu gribe til?" sagde Thorgerd, "nu er vort forsæt jo strandet. Nu synes jeg fader at vi skulle forlænge vort liv så længe, du får digtet et mindekvad over Bødvar, siden kan vi så dø, hvis vi synes."

Egil digter herefter sit berømte mindekvad *Sønnetabet*.

Present:



CHAPTER 3

Well, I've never eaten seaweeds... Are you sure?

"Since the discovery of agar-agar (gelatinous seaweed), [at El Bulli] we can work with materials either cold or hot, just as with a fine and smooth paste of cement, mud or clay, or a malleable material, like in sculpture."

José Luís Subíes

Have you eaten seaweed today?

Interreg
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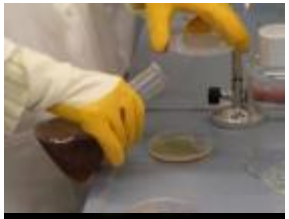
Have you used seaweed today?

Macroalgal natural products


Brown algae: Alginate


Red algae: Carageenan


Red algae: Agar



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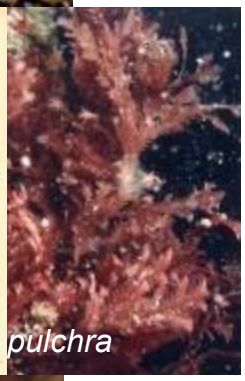
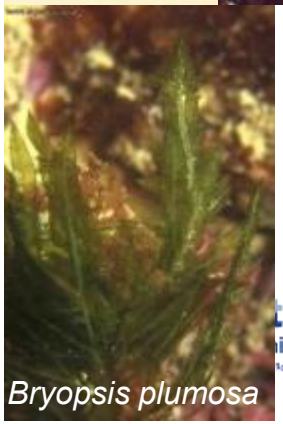
Pharmacological importance of seaweed secondary metabolites


Durvillaea antartica


Nothogenia fastigiata


Delisea pulchra




Bryopsis plumosa

Substance	Biological activity
Sulphated polysaccharides	Antiviral substances
Halogenated furanones	Antifouling compound
Kahalalide F	Possible treatment of cancer

Kahalalide F, a new marine-derived compound, induces oncosis in human prostate and breast cancer cells

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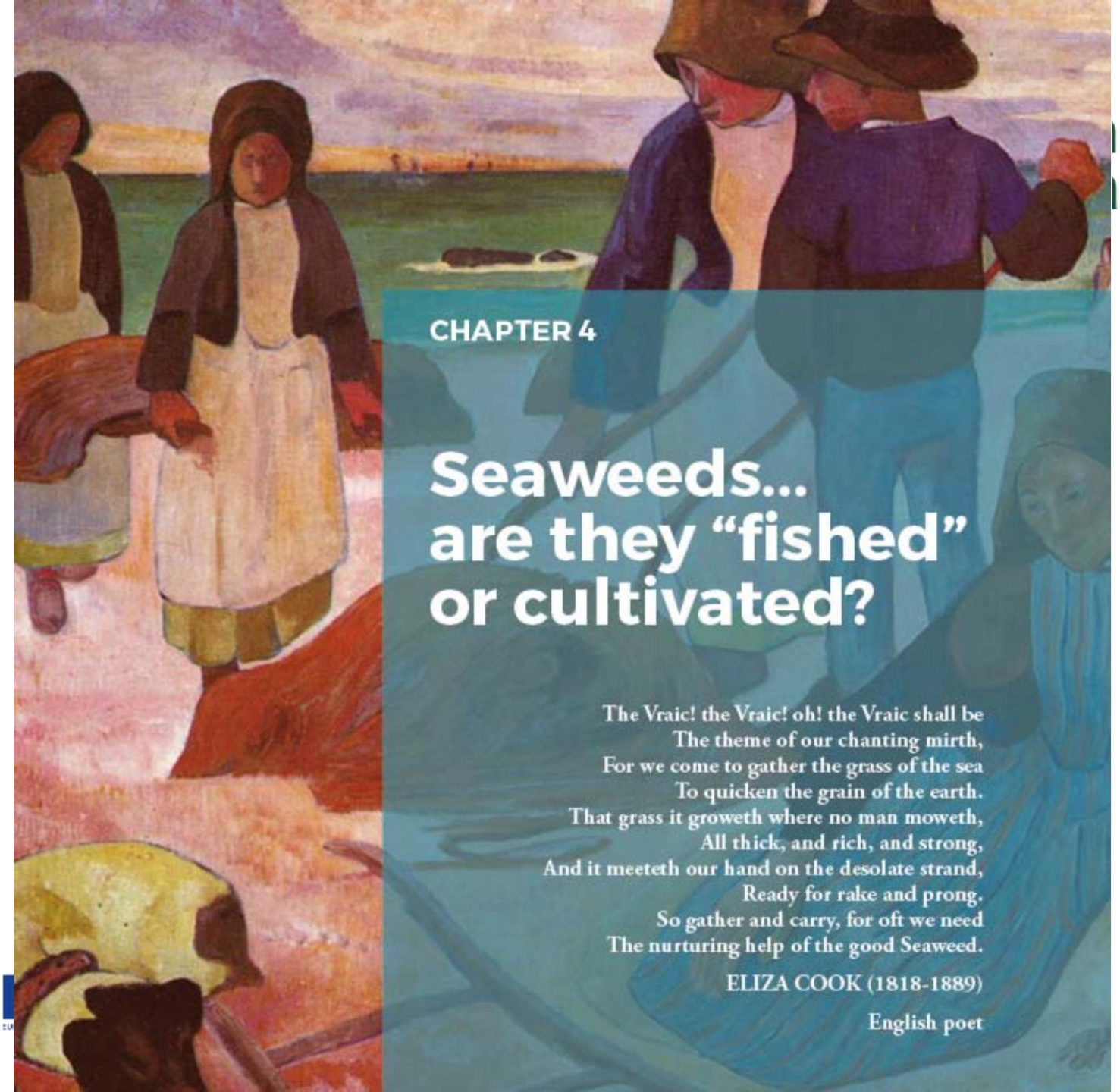
Abstract

Kahalalide F (KF) is a novel antitumor drug of marine origin under clinical investigation. KF showed a potent cytotoxic activity against a panel of human prostate and breast cancer cell lines, with IC_{50} ranging from 0.07 μM (PC3) to 0.28 μM (DU145, LNCaP, SKBR-3, BT474, MCF7). Importantly, nontumor human cells (MCF10A, HUVEC, that KF induces cell death via oncosis preferentially in tumor cells. (Mol Cancer Ther. 2003;2:863–872)

Introduction

Kahalalide F (KF) ($C_{75}H_{124}N_{14}O_{16}$, M_r = 1476; Fig. 1A) is one of the families of natural depsipeptides isolated from the Hawaiian herbivorous marine mollusk *Elysia rufescens* (1, 2). Like other kahalalides, it is probably a secondary metabolite synthesized by the mollusk from peptides produced by a diet of the green algae *Bryopsis pennata*. KF has potent cytotoxic activity *in vitro* against cell lines from solid tumors including prostate, breast and colon carcinomas, neuroblastoma, chondrosarcoma, and osteosarcoma (3–6). In animal models *in vivo*, KF has also shown activity against human prostate cancer xenografts (4). Cytotoxicity against human tumor specimens has been seen with breast, colon, non-small cell lung, and ovarian



CHAPTER 4

Seaweeds... are they "fished" or cultivated?

The Vraic! the Vraic! oh! the Vraic shall be
The theme of our chanting mirth,
For we come to gather the grass of the sea
To quicken the grain of the earth.
That grass it groweth where no man moweth,
All thick, and rich, and strong,
And it meeteth our hand on the desolate strand,
Ready for rake and prong.
So gather and carry, for oft we need
The nurturing help of the good Seaweed.

ELIZA COOK (1818-1889)

English poet

Beach safaris

Strandsafari

Høsting av tang og spiselige vekster

Beach safaris

Kelp-Harvester ca. 1920

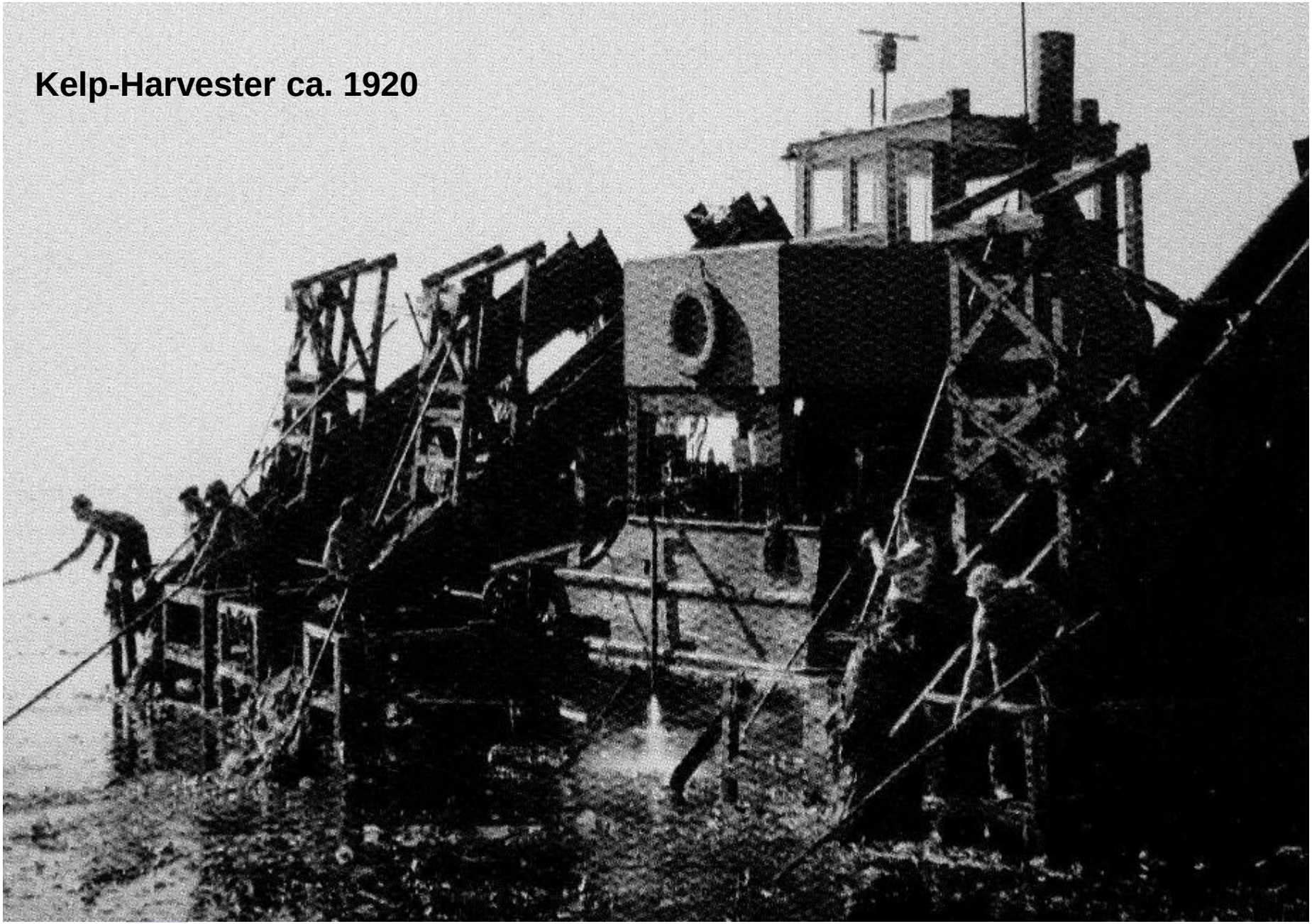


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Fig. 2. Preparation of *Laminaria* harvest from a ring-system after growth in the sea near Helgoland (Germany; North Sea). The ring was lifted from the water by a land-based crane (from Buck & Buchholz, 2004 with kind permission of Springer Science and Business Media; original figure in colour).

Porphyra farm

CHAPTER 5

What are the benefits of consuming seaweeds?

"Seaweeds are like Cinderella. They are looked on as the lowest of the low. But it's got the same nutrients, vitamins and minerals as land crops. And they're more easily absorbed. It's only now that more knowledge is coming from the Far East that people are starting to give different seaweeds a try."

GUS HEATH

Founder of the Dolphin Sea Vegetable Co.

Research Article

Received: 26 September 2017 Revised: 21 November 2017 Accepted article published: 28 November 2017 Published online in Wiley Online Library: 18 January 2018

(wileyonlinelibrary.com) DOI 10.1002/jsfa.8798

Chemical characterization of 21 species of marine macroalgae common in Norwegian waters: benefits of and limitations to their potential use in food and feed

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Table 2. Fatty acid composition (mg g^{-1} algal DW) of 21 macroalgal species

Species	14:0	16:0	18:0	Sum SFAs	16:1*n*-7	18:1*n*-9	18:1*n*-7	Sum MUFAs	16:3*n*-3	18:2*n*-6 (LA)	18:3*n*-3 (ALA)	20:4*n*-6	20:5*n*-3 (EPA)	Sum PUFAs	Sum *n*-3	Sum *n*-6	*n*-6/*n*-3
Red algae																	
C. crispus	0.01	0.04	0.01	0.04	0.01	0.02	0.01	0.02	0.3	<LOQ	<LOQ	0.01	0.01	0.03	0.01	0.01	0.9
F. lumbricalis	0.06	0.65	0.02	0.74	0.14	0.25	0.02	0.41	<LOQ	0.02	0.01	0.36	0.92	1.34	0.92	0.40	2.3
M. stellatus	0.08	0.62	0.03	0.75	0.08	0.42	0.05	0.58	0.01	0.04	0.03	0.72	0.57	1.45	0.63	0.80	0.8
P. palmata	0.23	0.74	0.03	1.04	0.03	0.16	0.08	0.32	0.02	0.14	0.20	0.13	1.50	2.31	2.00	0.31	6.4
P. dioica	0.06	2.03	0.11	2.31	0.11	0.28	0.16	0.74	<LOQ	0.23	0.10	1.06	2.79	4.76	3.11	1.64	1.9
P. purpurea	0.02	0.47	0.02	0.51	0.02	0.08	0.08	0.32	<LOQ	0.06	0.01	0.13	0.86	1.17	0.88	0.28	3.1
P. umbilicalis	0.06	0.39	0.03	0.50	0.06	0.11	0.05	0.27	0.2	0.06	0.08	0.13	0.70	1.25	0.96	0.27	3.5
Green algae																	
C. rupestris	0.41	1.12	0.04	1.66	0.98	0.28	0.20	1.50	0.01	1.12	0.11	0.16	0.32	2.33	0.80	1.34	0.6
U. intestinalis	0.03	0.86	0.02	0.95	0.05	0.03	0.46	0.56	0.18	0.29	0.97	0.02	0.05	2.17	1.80	0.36	4.9
U. lactuca	0.03	1.05	0.04	1.19	0.03	0.10	0.43	0.58	0.13	0.27	0.78	0.08	0.10	2.13	1.68	0.43	3.9
Brown algae																	
A. esculenta	0.28	0.98	0.08	1.43	0.13	0.99	0.03	1.15	<LOQ	0.38	0.25	0.74	0.48	2.31	1.09	1.21	0.9
A. nodosum	1.83	2.05	0.12	4.16	0.29	8.62	0.04	9.22	<LOQ	1.78	0.49	2.50	1.09	7.23	2.08	5.12	0.4
C. flagelliformis	1.58	2.88	0.77	5.59	0.04	3.54	<LOQ	3.58	<LOQ	2.86	0.99	1.23	1.76	8.75	4.34	4.41	1.0
F. serratus	2.65	3.23	0.14	6.23	0.30	10.31	0.03	10.9	<LOQ	2.52	0.71	2.52	0.95	7.67	1.99	5.63	0.4
F. spiralis	4.65	3.63	0.33	9.05	0.46	19.69	0.04	20.9	<LOQ	4.28	1.45	3.91	1.57	13.5	3.89	9.57	0.4
F. vesiculosus	2.82	2.40	0.14	5.60	0.24	8.09	0.02	8.61	<LOQ	2.83	1.09	3.02	1.30	9.81	3.07	6.71	0.5
H. siliquosa	0.39	1.24	0.07	1.88	0.05	1.12	0.01	1.21	<LOQ	0.38	0.45	1.10	0.42	2.96	1.37	1.57	0.9
H. elongata	0.26	1.17	0.03	1.57	0.10	0.62	0.01	0.76	<LOQ	0.44	0.43	0.91	0.46	2.58	1.14	1.43	0.8
L. digitata	0.29	1.09	0.05	1.56	0.13	1.23	0.01	1.41	<LOQ	0.56	0.42	0.59	0.82	3.10	1.89	1.21	1.6
P. canaliculata	2.50	2.70	0.76	6.51	0.45	17.37	0.04	18.2	<LOQ	4.99	1.51	6.32	2.06	18.8	4.57	14.1	0.3
S. latissima	0.45	0.67	0.04	1.23	0.13	0.48	0.01	0.64	<LOQ	0.33	0.24	0.48	0.39	2.03	1.15	0.88	1.3

Data represent mean values of two analytical measurements conducted on pooled algal material of several individuals per species. SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; LA, linoleic acid; ALA, α-linolenic acid; EPA, eicosapentaenoic acid; PUFAs, polyunsaturated fatty acids; LOQ, limit of quantification (0.1 area %).

Table 3. Macro- and micromineral concentrations (g kg^{-1} algal DW for Ca, Mg, P, K and Na; mg kg^{-1} algal DW for Cu, Fe, I, Mn, Se and Zn) of 21 macroalgal species

Species	Ca	Mg	P	K	Na	Cu	Fe	I	Mn	Se	Zn
Red algae											
C. crispus	13	9	2.4	30	18	7.6	330	200	22	0.14	55
F. lumbricalis	3.7	8.9	1.2	42	10	6.2	130	84	7.5	0.1	23
M. stellatus	6.7	7.9	1.4	20	27	3.7	200	340	7.1	0.1	72
P. palmata	2.5	1.2	2.1	28	3.2	4.1	73	220	4.1	0.1	42
P. dioica	19	3.8	3.3	26	4	10	570	84	25	0.29	24
P. purpurea	5.4	17	3.3	31	100	8.0	89	22	6.7	0.05	29
P. umbilicalis	7	3.8	2.5	17	4.4	8.8	160	110	21	0.17	67
Green algae											
C. rupestris	8.6	4.0	1.6	21	1.8	7.0	930	480	56	0.68	13
U. intestinalis	29	11	1.7	12	8.5	5.7	5800	130	180	0.76	21
U. lactuca	16	27	2.2	28	7.0	7.1	1800	43	26	0.14	19
Brown algae											
A. esculenta	22	7.9	3.7	54	16	2.0	72	380	3.7	0.18	55
A. nodosum	17	8.6	0.83	17	33	3.6	100	670	13	0.06	84
C. flagelliformis	16	8.2	2.3	34	21	1.0	63	1100	140	0.12	43
F. serratus	16	7.4	0.76	30	32	2.1	240	440	69	0.09	37
F. spiralis	17	8.2	1.1	28	27	2.5	120	150	33	0.09	42
F. vesiculosus	30	6.7	1.0	25	18	3.7	290	260	37	0.08	28
H. siliquosa	16	6.2	1.1	36	13	0.77	16	710	2.7	0.03	16
H. elongata	18	9.4	1.5	47	39	1.1	20	59	6.1	0.05	23
L. digitata	15	6.3	1.6	31	27	1.3	150	10000	3.1	0.07	81
P. canaliculata	14	7.9	0.70	17	23	3.9	300	200	8.0	0.05	28
S. latissima	17	7.7	2.5	100	24	1.2	160	4600	5.7	0.06	25

Data represent mean values of two analytical measurements conducted on pooled algal material of several individuals per species. Ca, calcium; Mg, magnesium; P, phosphorus; K, potassium; Na, sodium; Cu, copper; Fe, iron; I, iodine; Mn, manganese; Se, selenium; Zn, zinc.

Contents lists available at ScienceDirect

Food Chemistry

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Southern Australian seaweeds: A promising resource for omega-3 fatty acids

Matthias Schmid[a,*], Lesleigh G.K. Kraft[a,b], Luna M. van der Loos[a,c], Gerald T. Kraft[d,1], Patti Virtue[a,e], Peter D. Nichols[a,e], Catriona L. Hurd[a]

Table 1

Total fatty acid (TFA) concentrations (as % dry weight) in Chlorophyta and Phaeophyceae species. Fatty acid composition (expressed as % of TFA) of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids and ratio of n-6/n-3 PUFA. Sum of EPA (20:5n-3) and DHA (22:6n-3) expressed as mg/10 g of DW. ALA (18:3n-3) expressed as mg/10 g of DW. All values are given as mean ± standard deviation.

Chlorophyta								
Order								
Family	*Species*	TFA	SFA	MUFA	PUFA	n-6/n-3	EPA + DHAmg/10 g DW	ALA mg/10 g DW
Bryopsidales								
Caulerpaceae	*Caulerpa geminata*	1.5 ± 0.3	29.9 ± 0.5	13.9 ± 1.0	55.8 ± 0.7	0.9 ± 0.1	8.1 ± 0.9	5.5 ± 1.6
	Caulerpa longifolia	3.9 ± 0.1	24.7 ± 0.3	13.4 ± 0.3	61.3 ± 0.1	0.6 ± 0.1	29.8 ± 2.7	48.1 ± 3.9
	Caulerpa scalpelliformis	2.7 ± 0.2	32.9 ± 0.3	17.6 ± 0.1	48.9 ± 0.3	0.3 ± 0.0	23.1 ± 1.8	39.7 ± 4.2
	Caulerpa simpliciuscula	1.8 ± 0.1	26.8 ± 1.2	15.0 ± 0.7	57.6 ± 1.4	0.4 ± 0.0	12.9 ± 0.4	33.1 ± 2.2
	Caulerpa trifaria	3.0 ± 0.6	25.7 ± 0.4	21.9 ± 0.5	51.5 ± 0.8	1.7 ± 0.0	5.1 ± 0.1	1.6 ± 0.3
Codiaceae	*Codium fragile*	2.2 ± 0.1	32.7 ± 0.9	12.6 ± 0.2	54.4 ± 1.1	0.3 ± 0.0	6.3 ± 0.1	46.6 ± 2.8
Cladophorales								
Cladophoraceae	*Chaetomorpha coliformis*	0.7 ± 0.1	29.1 ± 1.3	19.9 ± 0.3	50.2 ± 1.5	2.0 ± 0.1	3.0 ± 0.5	0.4 ± 0.0
	Cladophora sp.	1.7 ± 0.2	31.2 ± 1.8	28.0 ± 0.8	40.0 ± 1.4	0.6 ± 0.0	8.0 ± 1.8	15.6 ± 1.1
Ulvales								
Ulvaceae	*Ulva australis*	1.7 ± 0.2	28.8 ± 0.6	22.1 ± 1.8	48.9 ± 1.4	0.4 ± 0.0	1.6 ± 0.3	25.1 ± 3.8
	Ulva compressa	0.5 ± 0.2	38.4 ± 5.6	20.1 ± 1.1	40.8 ± 6.3	0.3 ± 0.0	1.5 ± 0.4	5.6 ± 2.1
	Ulva stenophylloides	1.9 ± 0.4	29.7 ± 1.0	18.0 ± 0.1	52.0 ± 0.9	0.2 ± 0.0	1.9 ± 0.1	34.2 ± 8.1
Phaeophyceae								
Dictyotales								
Dictyotaceae	*Dictyopteris muelleri*	4.8 ± 0.4	39.3 ± 1.5	25.4 ± 0.6	34.8 ± 1.5	1.3 ± 0.2	18.8 ± 3.5	18.6 ± 2.7
	Zonaria turneriana	1.6 ± 0.1	29.1 ± 1.7	19.5 ± 0.3	51.0 ± 1.8	0.8 ± 0.1	23.1 ± 3.2	3.3 ± 0.3
Ectocarpales								
Scytosiphonaceae	*Scytosiphon lomentaria*	1.9 ± 0.1	29.8 ± 2.3	21.6 ± 1.7	48.1 ± 4.1	0.5 ± 0.1	30.3 ± 5.0	10.6 ± 1.7
Fucales								
Hormosiraceae	*Hormosira banksii*	1.0 ± 0.1	31.3 ± 0.9	21.1 ± 1.4	47.4 ± 0.7	1.0 ± 0.2	9.2 ± 1.2	8.9 ± 3.0
Sargassaceae	*Carpoglossum confluens*	0.6 ± 0.0	35.7 ± 1.1	24.3 ± 0.7	39.7 ± 1.8	2.4 ± 0.6	1.1 ± 0.4	3.0 ± 0.7
	Caulocystis cephalornithos	1.6 ± 0.2	25.4 ± 0.7	19.6 ± 0.4	54.0 ± 0.4	0.7 ± 0.0	5.5 ± 1.6	13.5 ± 2.4
	Cystophora torulosa	0.8 ± 0.1	30.2 ± 0.7	17.8 ± 0.6	51.6 ± 1.2	1.4 ± 0.2	3.6 ± 0.6	5.8 ± 0.8
	Cystophora sp.	1.0 ± 0.0	33.8 ± 0.5	20.4 ± 1.2	45.6 ± 1.1	1.2 ± 0.2	8.7 ± 1.2	5.6 ± 0.5
	Phyllotricha verruculosa	1.7 ± 0.2	30.7 ± 1.9	21.8 ± 1.4	47.1 ± 3.0	0.9 ± 0.3	14.7 ± 3.0	16.1 ± 5.6
	Sargassum fallax	2.0 ± 0.1	30.5 ± 0.2	19.8 ± 0.6	49.3 ± 0.9	1.3 ± 0.1	13.3 ± 1.2	14.2 ± 1.9
Xiphophoraceae	*Xiphophora gladiata*	0.8 ± 0.1	26.1 ± 0.5	20.1 ± 0.6	53.3 ± 1.1	2.4 ± 0.5	5.0 ± 0.8	4.3 ± 1.1
Laminariales								
Alariaceae	*Undaria pinnatifida*	1.9 ± 0.3	26.1 ± 3.3	13.0 ± 0.8	60.3 ± 4.2	0.7 ± 0.1	18.0 ± 3.0	14.7 ± 4.7
Laminariaceae	*Macrocystis pyrifera*	1.0 ± 0.1	33.2 ± 2.2	20.7 ± 0.4	45.5 ± 2.1	0.9 ± 0.0	6.4 ± 0.6	5.9 ± 0.8
Lessoniaceae	*Ecklonia radiata*	1.2 ± 0.2	25.0 ± 1.9	22.3 ± 2.1	52.3 ± 4.0	1.1 ± 0.2	6.8 ± 1.5	7.9 ± 1.4
	Lessonia corrugata	1.6 ± 0.2	32.8 ± 5.2	24.2 ± 2.4	42.6 ± 6.9	2.3 ± 0.7	5.3 ± 1.3	5.5 ± 2.5
Sphacelariales								
Cladostephaceae	*Cladostephus spongiosum*	1.4 ± 0.2	26.4 ± 1.6	18.1 ± 1.2	55.3 ± 2.7	1.0 ± 0.1	12.0 ± 0.9	12.2 ± 0.5
Sporochnales								
Sporochnaceae	*Bellotia eriophorum*	7.8 ± 0.8	54.4 ± 2.7	16.1 ± 0.7	28.4 ± 1.0	19.9 ± 6.8	2.8 ± 0.2	3.7 ± 2.0

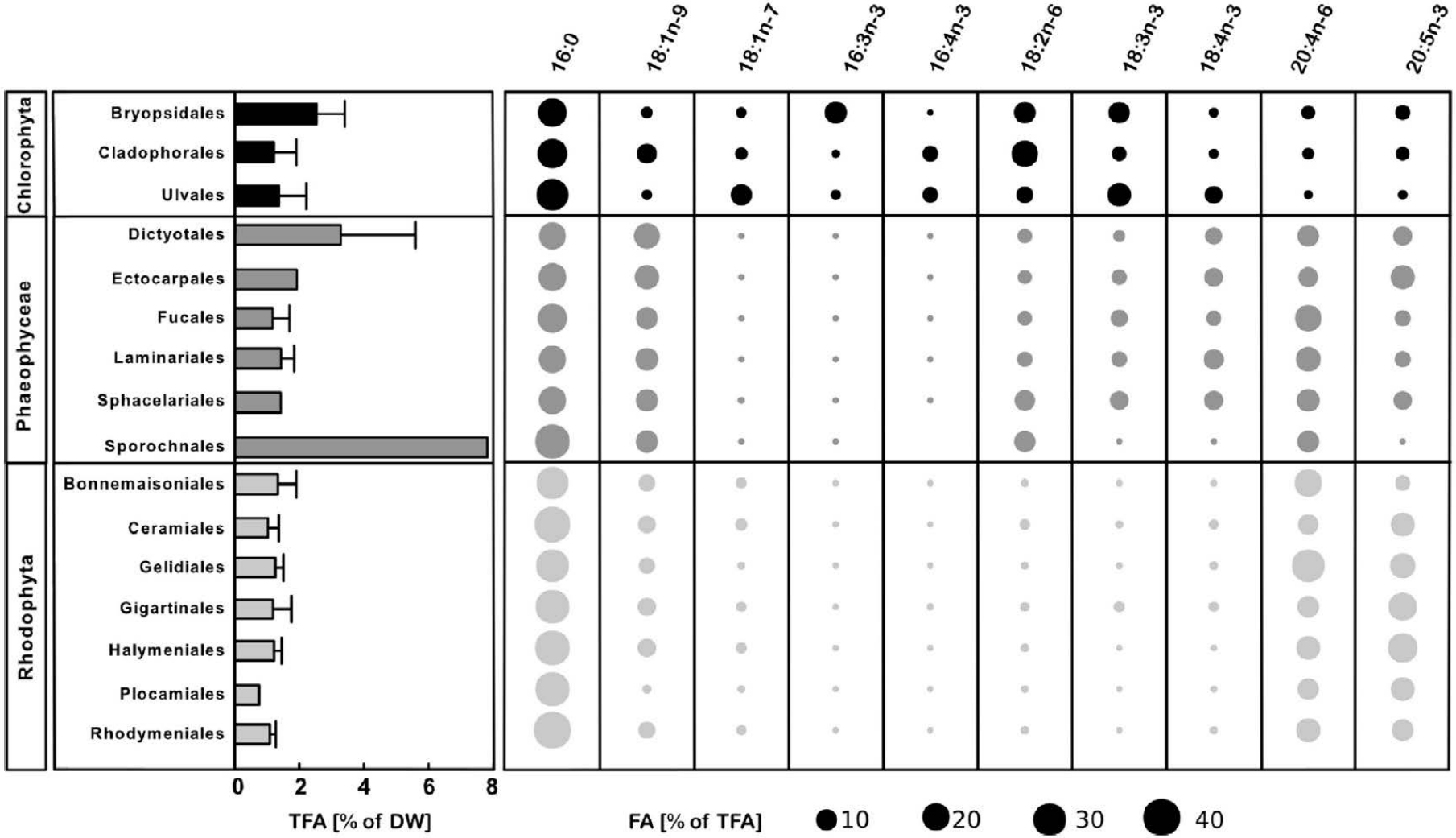

Fig. 1. Total fatty acid (TFA) content (expressed as % of dry weight (DW)) of all investigated macroalgae orders of Chlorophyta, Phaeophyceae and Rhodophyta. Distribution and proportion of most common and main discriminating fatty acids [% of TFA] of all orders of Chlorophyta, Phaeophyceae and Rhodophyta are displayed as a balloon graph. Fatty acid [FA] data are displayed as % of DW.

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GLOBAL CHANGE BIOLOGY
BIOENERGY

GCB Bioenergy (2012) **4**, 919–930, doi: 10.1111/j.1757-1707.2012.01175.x

Total lipid and fatty acid composition of seaweeds for the selection of species for oil-based biofuel and bioproducts

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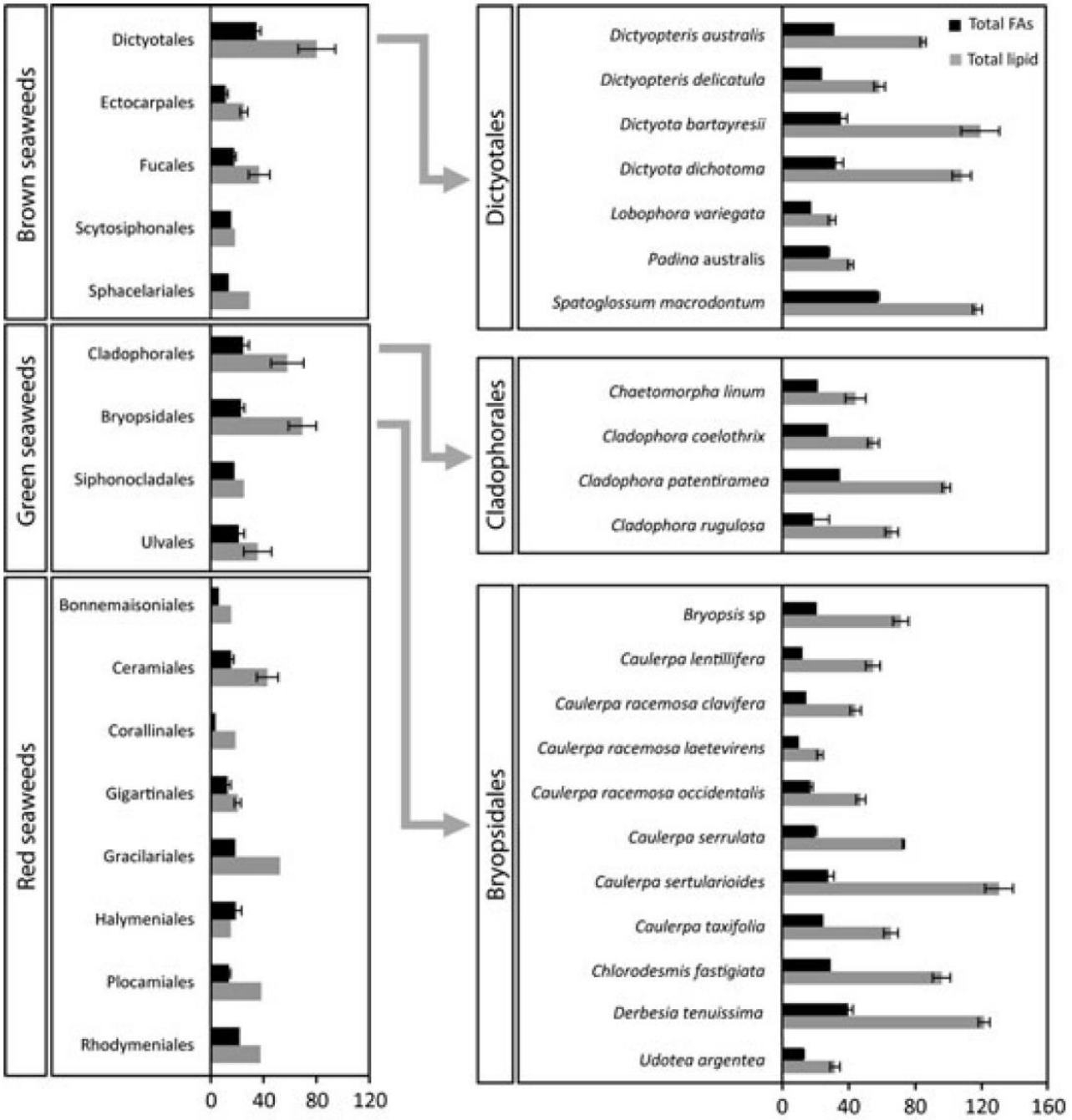
School of Marine & Tropical Biology, James Cook University, Townsville, QLD, 4811, Australia


Brown seaweeds
Dictyotales
Ectocarpales
Fucales
Scytosiphonales
Sphacelariales
Green seaweeds
Cladophorales
Bryopsidales
Siphonocladales
Ulvales
Red seaweeds
Bonnemaisoniales
Ceramiales
Corallinales
Gigartinales
Gracilariales
Halymeniales
Plocamiales
Rhodymeniales
0 40 80 120
Dictyotales
Dictyopteris australis
Dictyopteris delicatula
Dictyota bartayresii
Dictyota dichotoma
Lobophora variegata
Padina australis
Spatoglossum macrodontum
Total FAs
Total lipid
Cladophorales
Chaetomorpha linum
Cladophora coelothrix
Cladophora patentiramea
Cladophora rugulosa
Bryopsidales
Bryopsis sp
Caulerpa lentillifera
Caulerpa racemosa clavifera
Caulerpa racemosa laetevirens
Caulerpa racemosa occidentalis
Caulerpa serrulata
Caulerpa sertularioides
Caulerpa taxifolia
Chlorodesmis fastigiata
Derbesia tenuissima
Udotea argentea
0 40 80 120 160
Mean fatty acid and total lipid content (mg g⁻¹ dw ± SE)

CHAPTER 6

From sea to shop

"If you like fish or shellfish, you will like seaweeds. People who say they do not like them usually say so because they have eaten seaweeds on their own or in disproportionate amounts in a dish. For a good tasting experience, it is crucial to understand that seaweeds are a complement, an accompaniment, never the main ingredient."

Clemente Fernández
Algamar

trans algae

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trans algae

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CHAPTER 7

Which species of seaweeds are consumed in Spain?

"We use them not only for eating but also to give the dish taste: oysters with seaweed, *txangu-rro* with seaweed, sole with seaweed, monkfish with seaweed... We obtain most of the seaweed we use from Galicia, Spain's sea garden *par excellence*."

JUAN MARI ARZAK

Three Michelin star chef


© ROLEDA, M.Y.


©ROLEDA MY

CHAPTER 8

Enjoying a fine dish (...with seaweeds), a question of good sense(s)

"I am not just somebody passionate about the sea. I am obsessed, but as we consume more and more fish and shellfish we are exhausting the resources. In the future, if we want to enjoy the flavour of the sea, we shall have to make use of seaweeds."

ÁNGEL LEÓN

The Chef of the Sea

Pickle preparation

Ascophyllum nodosum receptacles

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Pickle preparation

Pickle preparation

Appetizer

Salad preparation

Pelvetia canaliculata

trans algae

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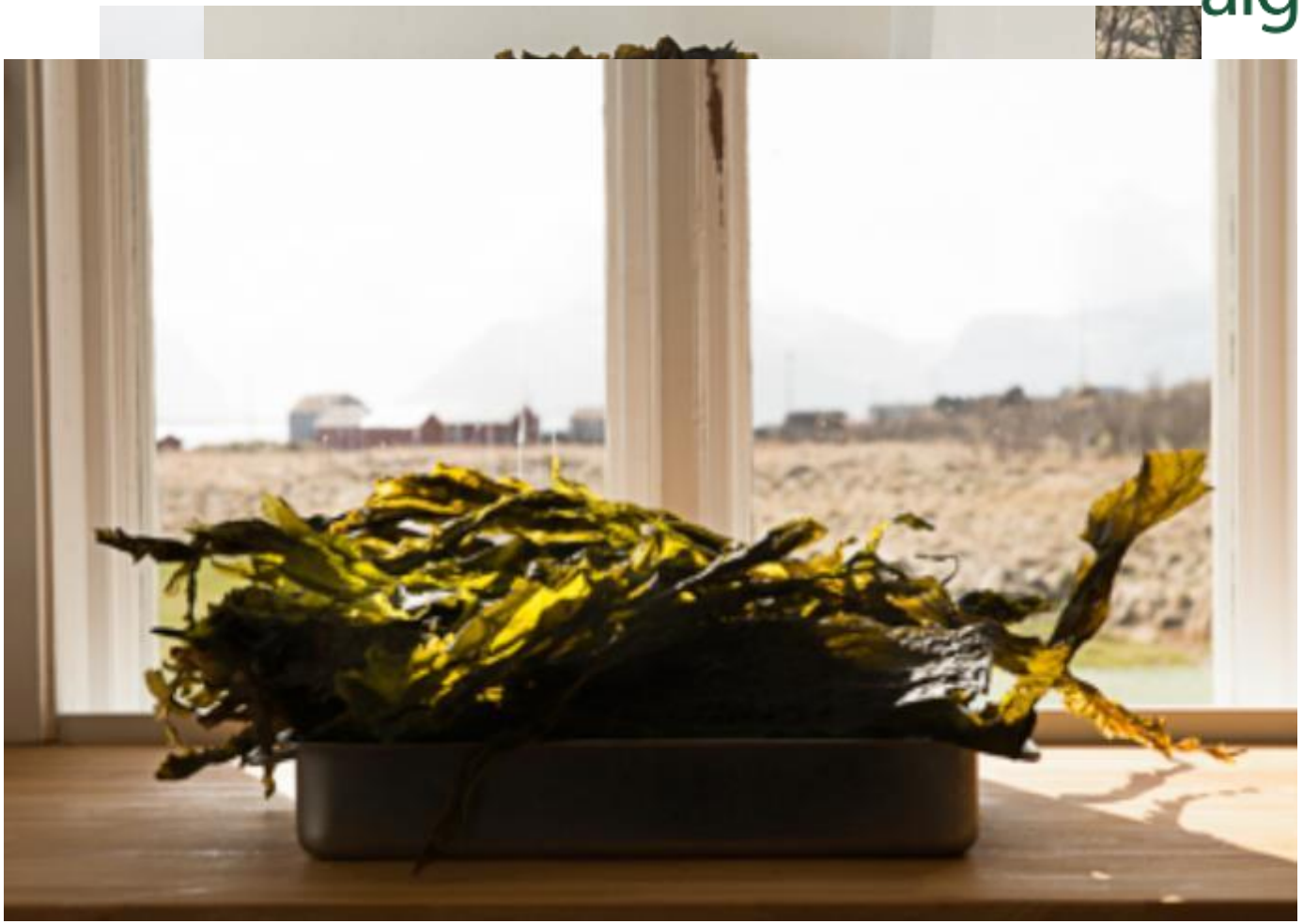
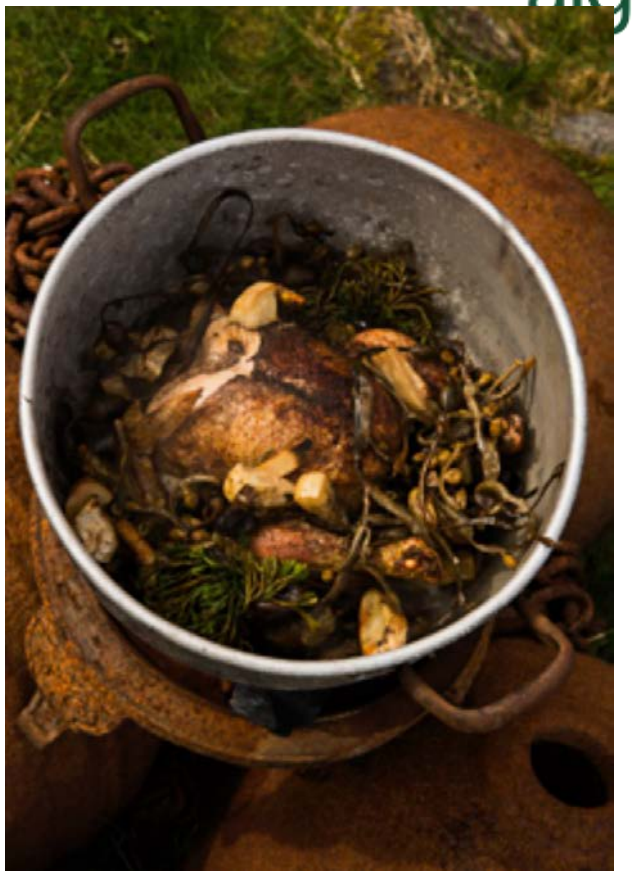
Drying *Saccharina*



Bread with *Saccharina*

Grilling with seaweed

Grilling with seaweed



Dessert preparation

Mastocarpus stellatus

CHAPTER 9

Seaweeds in *haute cuisine: Bon appétit!*

"With its complexity in flavour and texture, seaweed is the culinary trend taking diners' palates to another dimension."

RICHARD CORNISH

A renowned food critic

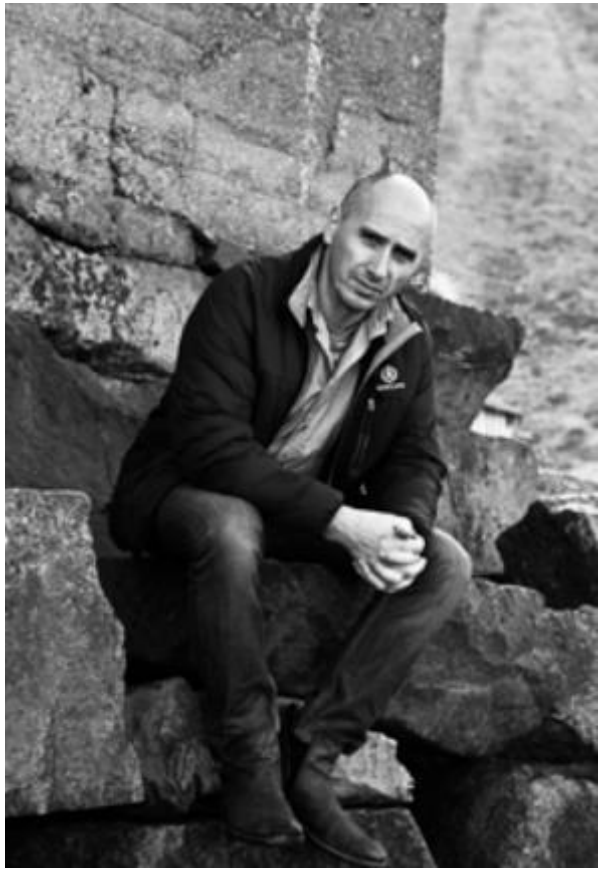
The Chef

Siv Hilde Lillehaug, Lofotmat Henningsvær, Lofoten, Norway

The Chef

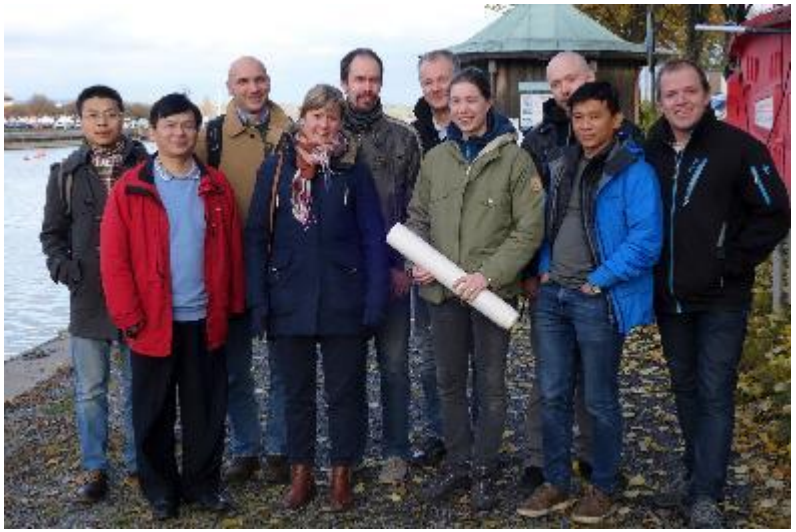
Thorir Bergsson, Bergsson Mathús,
Reykjavik, Iceland

The Chef



Leif Sørensen, Tórshaven, Faroe Islands

www.biofuelregion.se/transalgae



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Arctic Seaweed
Kempestiftelserna
Österbottens förbund
Pohjanmaan liitto
Nordland
FYLKESKOMMUNE
bodø
KOMMUNE
Landstinget Västernorrland
Länsstyrelsen
Västernorrland

Project leaders & Partners

Project leader

Swedish University of Agricultural Sciences (SLU)
Department of Wildlife, Fish and Environmental Studies

Partners

BioFuel Region AB

Nattviken Invest - Hugo Wikström

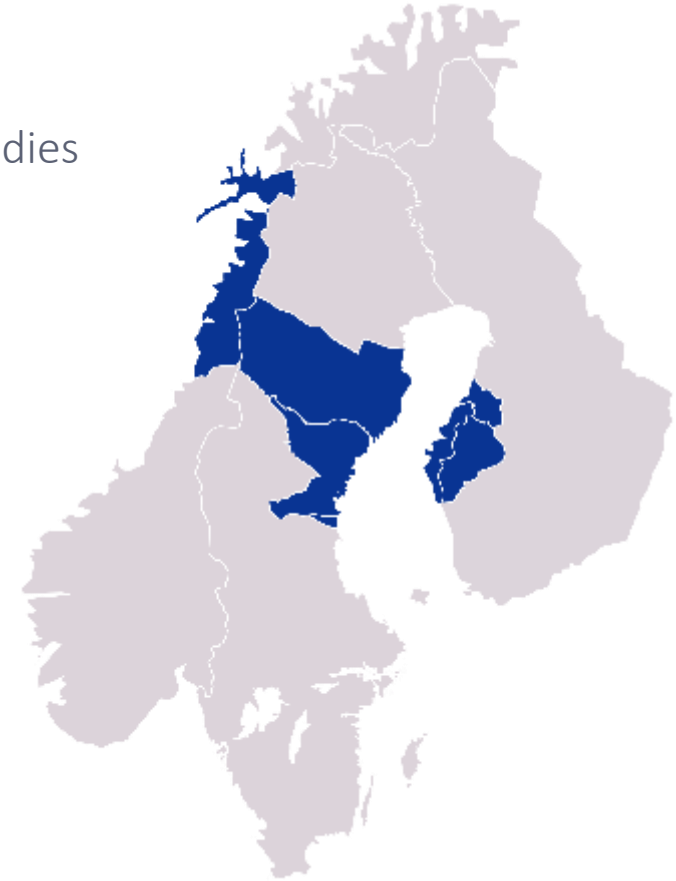
NIBIO Bodö

Mid Sweden University

Novia – University of Applied Science, Vaasa
University of Vaasa

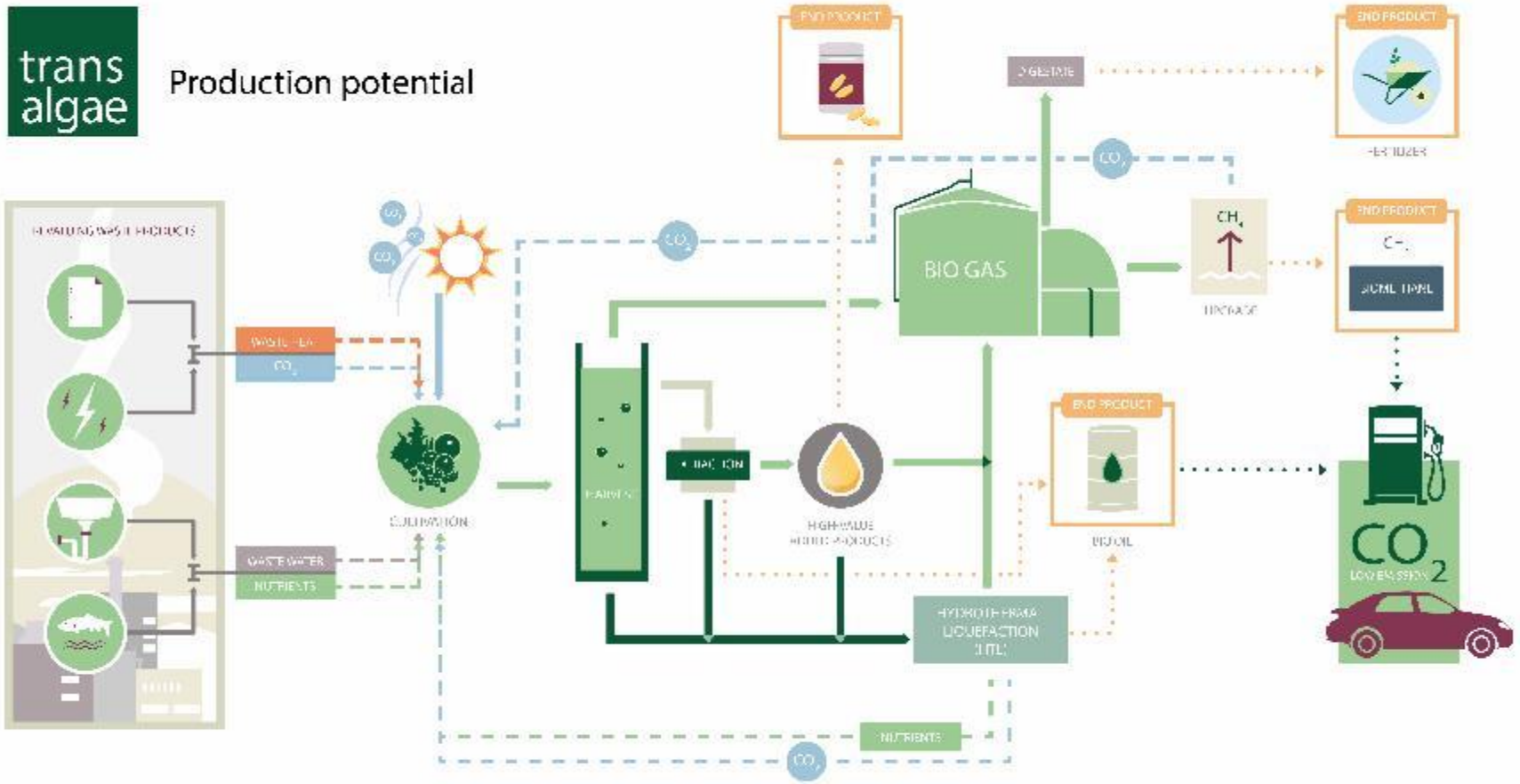
Financiers

Botnia-Atlantica, Länsstyrelserna i Västerbotten och Västernorrland, Österbottens förbund, Kempestiftelserna, Arctic Seaweed, partners



trans algae

Production potential



PROJECT COURSE

EVALUATION OF WASTE PRODUCTS | CULTIVATION | HARVEST | TRANSFORMATION | SYSTEM ANALYSIS

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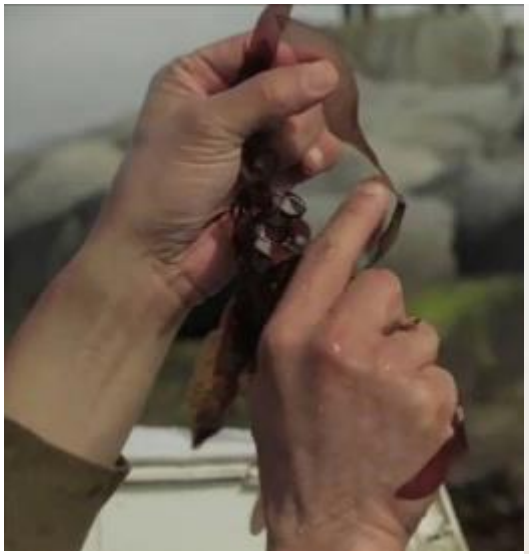
Palmaria palmata




UNITED
STATES
Gulf Stream
NORTH ATLANTIC
OCEAN
Bermuda
Sargasso Sea
Miami
Key
West
TROPIC OF CANCER
CUBA
Caribbean Sea