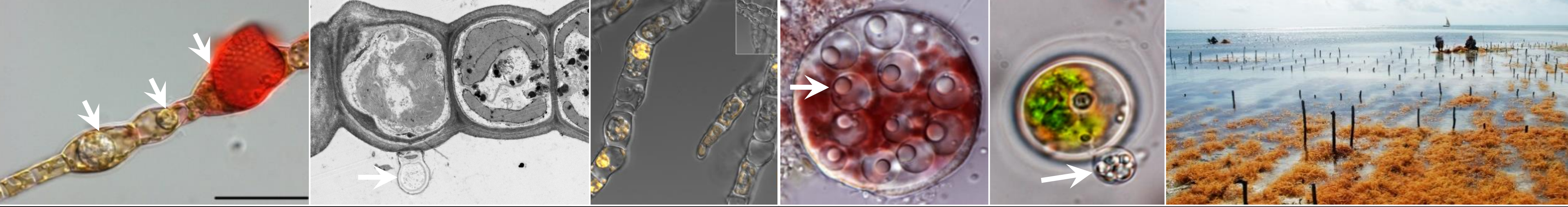

Physiology & ecoanthropology of algae – pathogen interactions

Claire Gachon

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SAMS

UNITED NATIONS UNIVERSITY
UNU-INWEH
Institute for Water, Environment and Health

United Nations University
Institute for Water, Environment and Health (UNU-INWEH) & Scottish Association for Marine Science (SAMS)

POLICYBRIEF

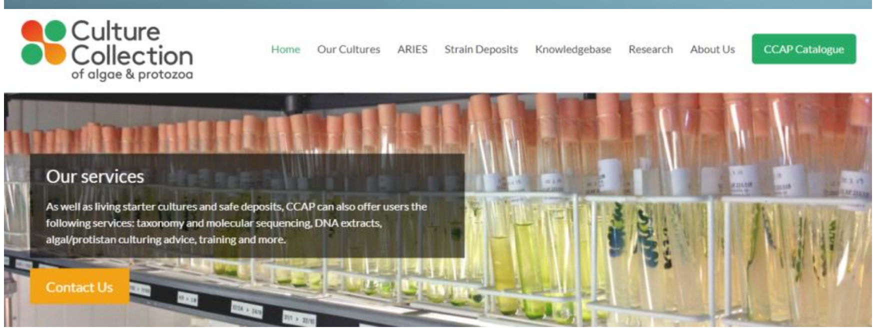
Safeguarding the future of the global seaweed aquaculture industry

Elizabeth J. Cottier-Cook[1], Nidhi Nagabhatla[2], Yacine Badis[1], Marnie L. Campbell[3], Thierry Chopin[4], Weiping Dai[5], Jianguang Fang[6], Peimin He[7], Chad L. Hewitt[3], Gwang Hoon Kim[8], Yuanzi Huo[7], Zengjie Jiang[6], Gert Kema[9], Xinshu Li[10], Feng Liu[11,12], Hongmei Liu[13], Yuanyuan Liu[7], Qinqin Lu[14], Qijun Luo[15], Yuze Mao[6], Flower E. Msuya[16], Céline Rebours[17], Hui Shen[14], Grant D. Stentiford[18], Charles Yarish[19], Hailong Wu[7], Xinming Yang[20], Jihong Zhang[6], Yongdong Zhou[21], Claire M. M. Gachon[1] Corresponding author: ejc@sams.ac.uk

Highlights

1. Global aquaculture production continues to increase, whilst capture fisheries stagnate. Many wild fisheries have been overexploited. Cultivation, if managed sustainably, is a viable alternative.
2. The seaweed industry is undergoing a rapid global expansion and currently accounts for ~49% of the total mariculture production. Unabated exponential growth in the last 50 years has meant that the value of the industry reached US$6.4 billion in 2014, providing jobs, predominantly in developing and emerging economies.
3. There is increasing need to address new challenges imposed by trade and market demand. Case studies clearly show that valuable lessons can be drawn from the major seaweed-producing nations and other aqua- and agriculture sectors.
4. Improving biosecurity, disease prevention and detection measures are critical, together with establishing policies and institutions. This will provide incentives and steer the long-term economic and environmental development of a sustainable seaweed aquaculture industry.
5. This policy brief highlights key issues that need to be addressed to create longterm sustainability of this emerging global industry, as it prepares itself for playing an important role in the 'blue' ocean economy agenda.

Where am I?

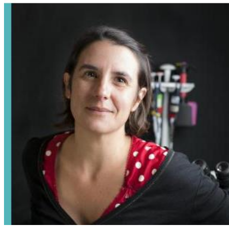


MUSÉUM NAL HIST NATURELLE

ACQUISITION ET ANALYSE
DE DONNÉES
POUR L'HISTOIRE NATURELLE

MENU

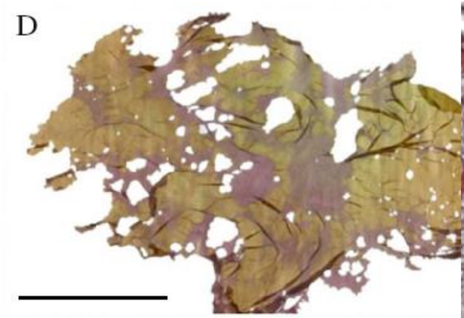
Molécules de Communication et Adaptation des Micro-organismes (MCAM)
UMR 7245

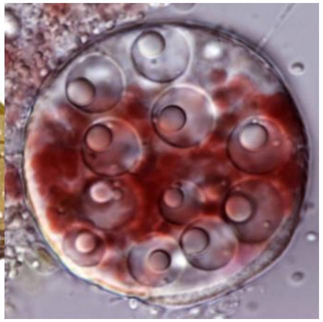


Soizic PRADO

Professeur(e)
Chargé(e) d'enseignement

Outline



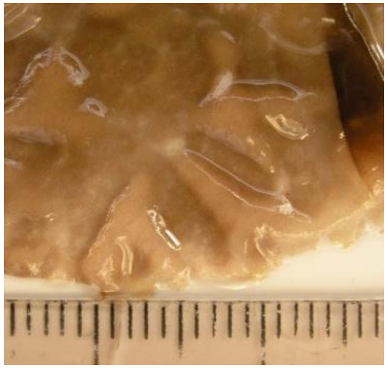


Diseases of cultivated seaweeds: a global barrier to production and to sustainability

From pathogen discovery to a biosecurity framework for seaweed aquaculture

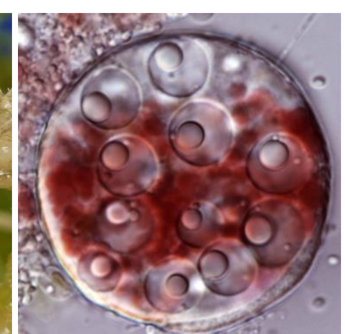
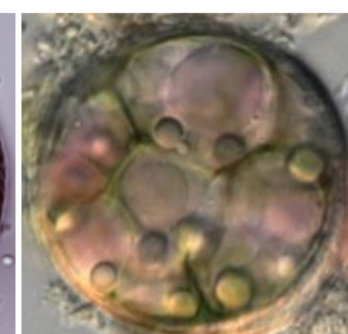
Disease control in seaweed aquaculture

- **Using probiotics: proof of concept**
- **How do seaweed defend themselves against pathogens?**
- **Breeding for disease resistance… Setting the scene**

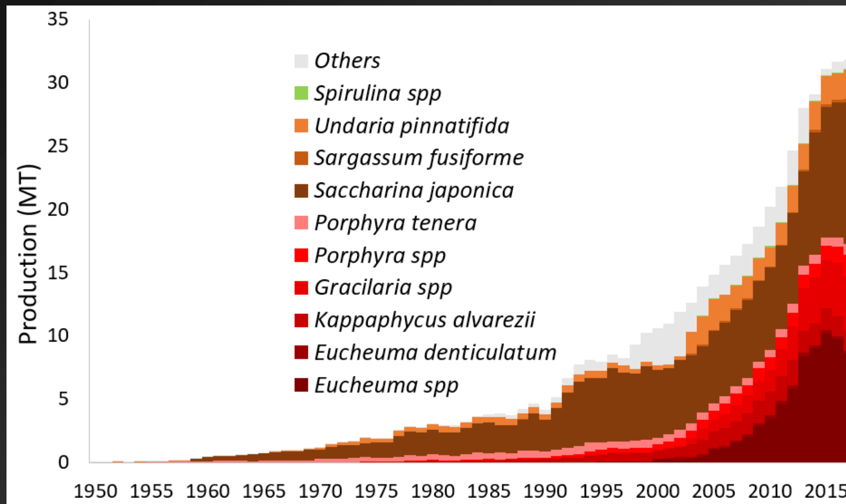


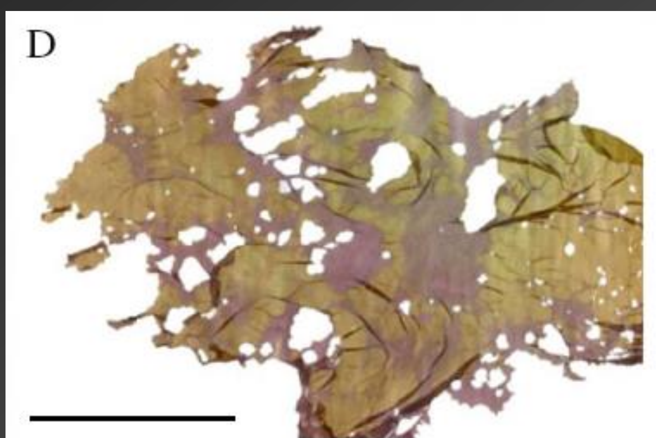
Diseases of cultivated seaweeds: a global barrier to production and sustainability

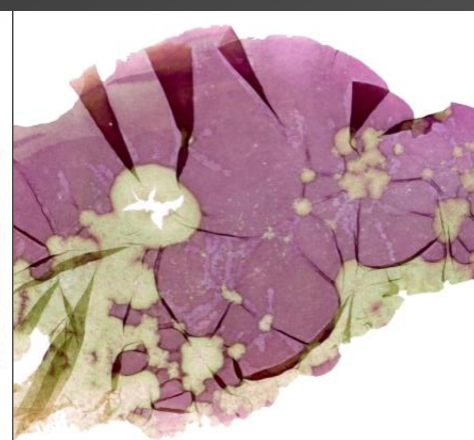


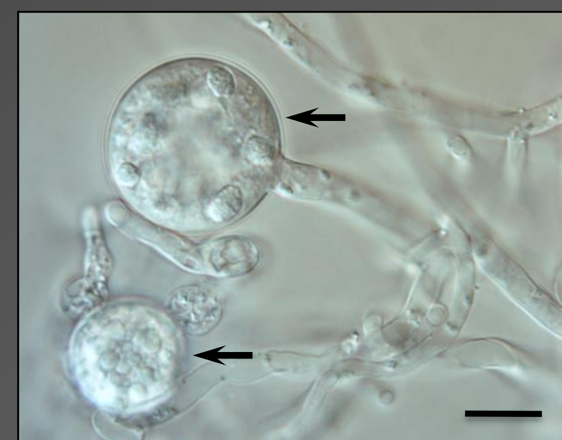



Seaweed cultivation: the true story





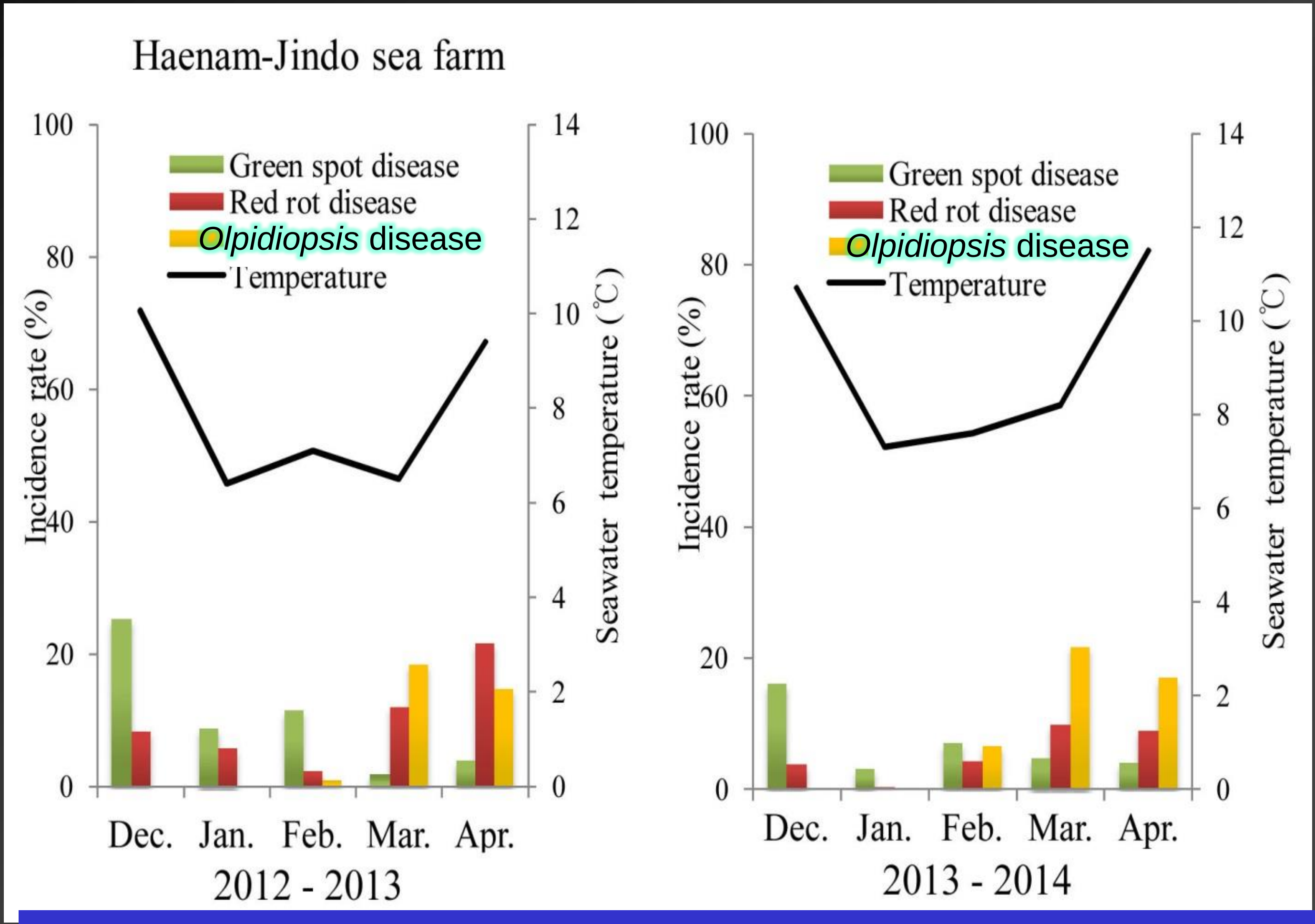


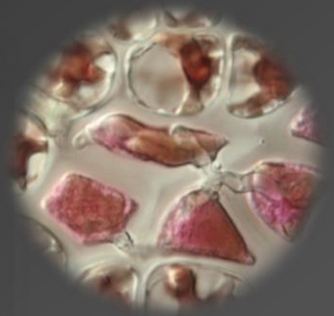


☞ **20-30% of potential production typically lost to diseases (*Olpidiopsis porphyrae*, *Pythium porphyrae*)**

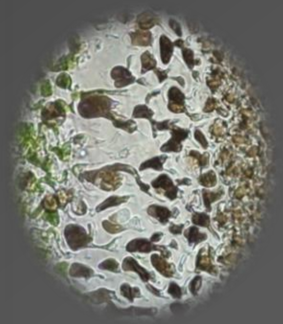
Kim et al. (2014) *Algae*.

Top three most serious diseases of *Pyropia* in Korean farms

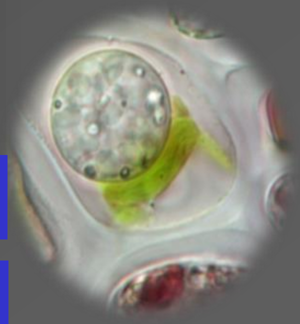




‘Red rot’



Green spot disease



Olpidiopsis disease

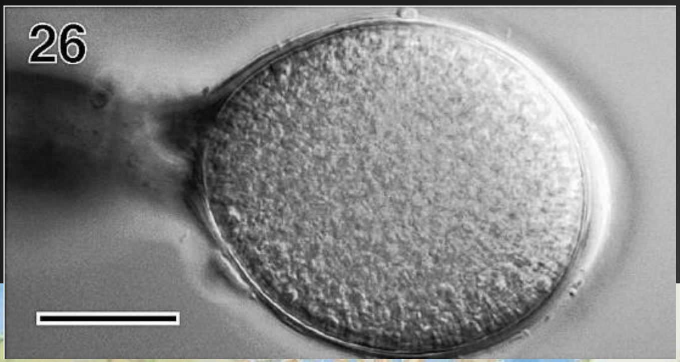
☞ **At any point of time 20% of the crop is infected**

☞ **Diseases are discovered as the industry grows**

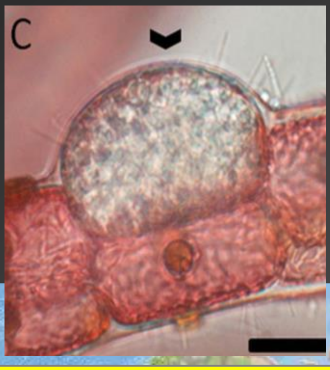
Slide: courtesy GH Kim

Kim et al. ALGAE 2014

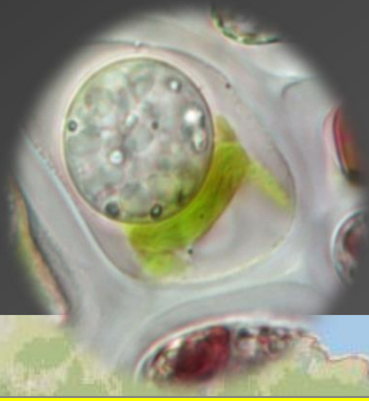
2015: baseline molecular knowledge on *Olpidiopsis* parasites



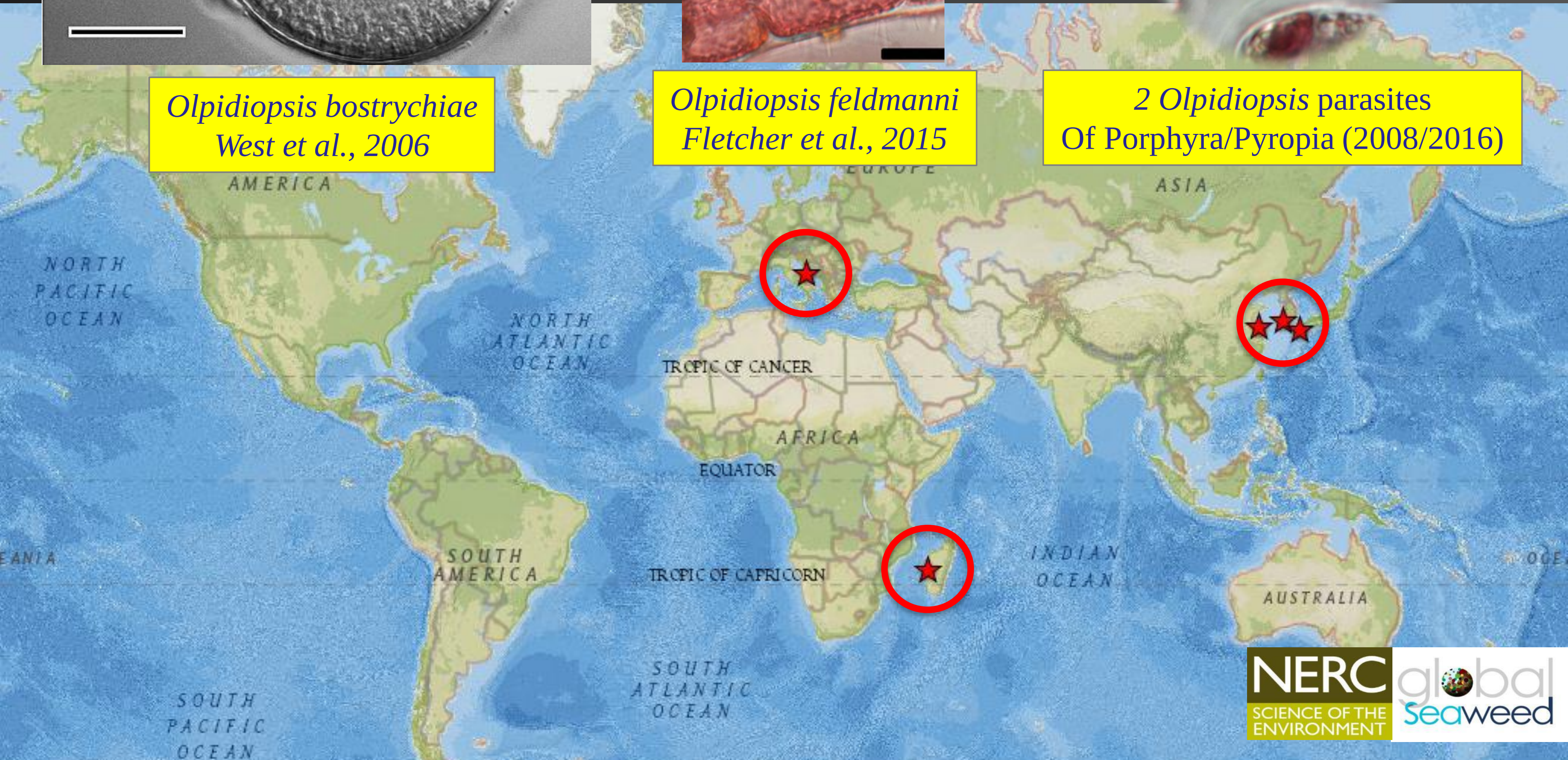
Olpidiopsis bostrychiae
West et al., 2006



Olpidiopsis feldmanni
Fletcher et al., 2015



2 Olpidiopsis parasites
Of Porphyra/Pyropia (2008/2016)

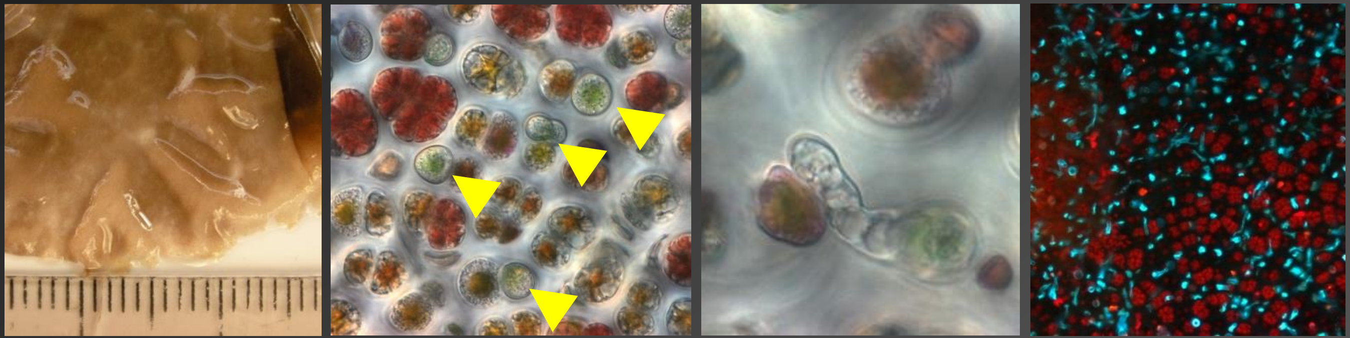


NERC SCIENCE OF THE ENVIRONMENT
global seaweed

Yacine Badis

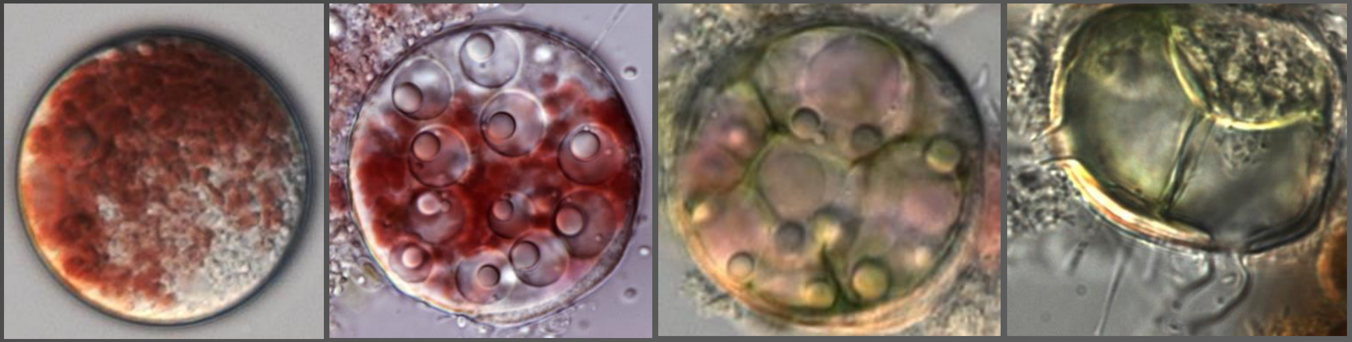
Novel intracellular parasites of red algae

Olpidiopsis muelleri sp. nov infecting blades of *Porphyra* sp.



Olpidiopsis muelleri var. *polysiphoniae* infecting tips of *Polysiphonia* sp.

Olpidiopsis palmariae sp. nov infecting tetraspores of *Palmaria* sp.



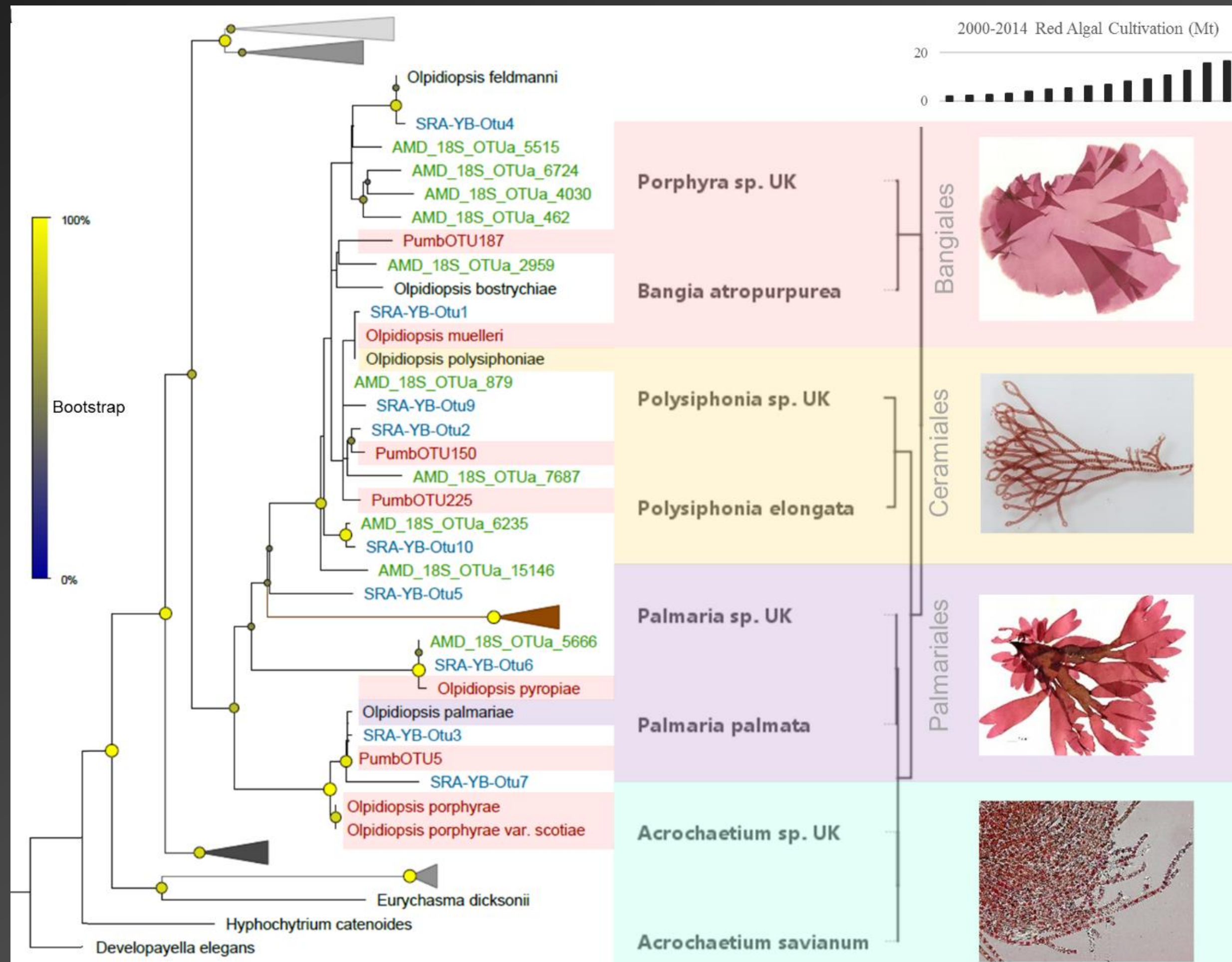
NERC SCIENCE OF THE ENVIRONMENT

global seaweed

Badis et al, J. Appl. Phycol 2018

Yacine Badis

Metabarcoding reveals 20+ novel species of *Olpidiopsis*



☞ **Screen of publicly available marine eDNA data for related pathogen sequences**

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Badis *et al.* 2019, ***Eur. J. Phycol.***

Yacine Badis

A diverse, poorly-known, yet worldwide threat

☞ *Olpidiopsis* is present globally: unknown diversity potentially threatens aquaculture of red seaweeds everywhere

☞ A lot of novel pathogens are being described… Still, there is a need to accelerate discovery of seaweed pathogens worldwide to underpin the growth of the industry

Badis *et al.* 2019, ***Eur. J. Phycol.***

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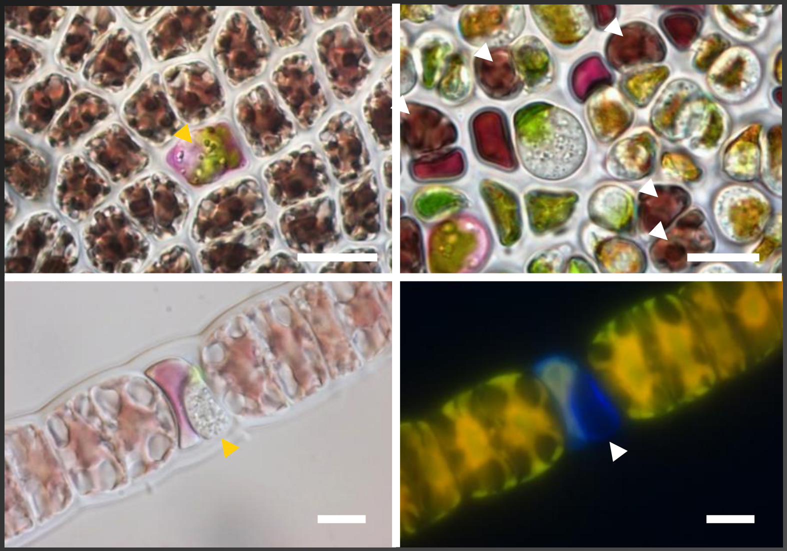
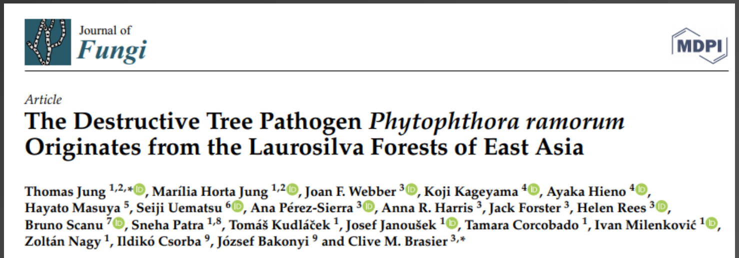
Pathogen movement: an additional threat to crops and the conservation of wild stocks

Yacine Badis

Janina Brakel



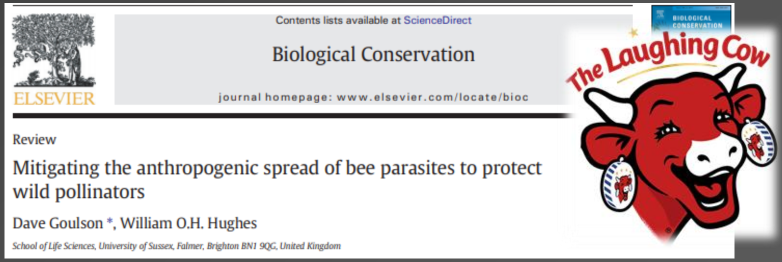


Journal of *Fungi*
MDPI

Article

The Destructive Tree Pathogen *Phytophthora ramorum* Originates from the Laurosilva Forests of East Asia

Thomas Jung [1,2,*], Marília Horta Jung [1,2], Joan F. Webber [3], Koji Kageyama [4], Ayaka Hieno [4], Hayato Masuya [5], Seiji Uematsu [6], Ana Pérez-Sierra [3], Anna R. Harris [3], Jack Forster [3], Helen Rees [3], Bruno Scanu [7], Sneha Patra [1,8], Tomáš Kudláček [1], Josef Janoušek [1], Tamara Corcobado [1], Ivan Milenković [1], Zoltán Nagy [1], Ildikó Csorba [9], József Bakonyi [9] and Clive M. Brasier [3,*]



Contents lists available at ScienceDirect
Biological Conservation
journal homepage: www.elsevier.com/locate/bioc
ELSEVIER

Review

Mitigating the anthropogenic spread of bee parasites to protect wild pollinators

Dave Goulson *, William O.H. Hughes
School of Life Sciences, University of Sussex, Falmer, Brighton BN1 9QG, United Kingdom

- ☞ Non-native *Olpidiopsis* can infect wild and cultivated red algae
- ☞ Mostly no national and definitely no international frameworks pertaining to the movement of seaweed germplasm and pathogens
- ☞ No awareness and no quantificaiton of the risk posed by the potential movement of seaweed pathogens

Badis *et al.* 2019, ***Eur. J. Phycol.***

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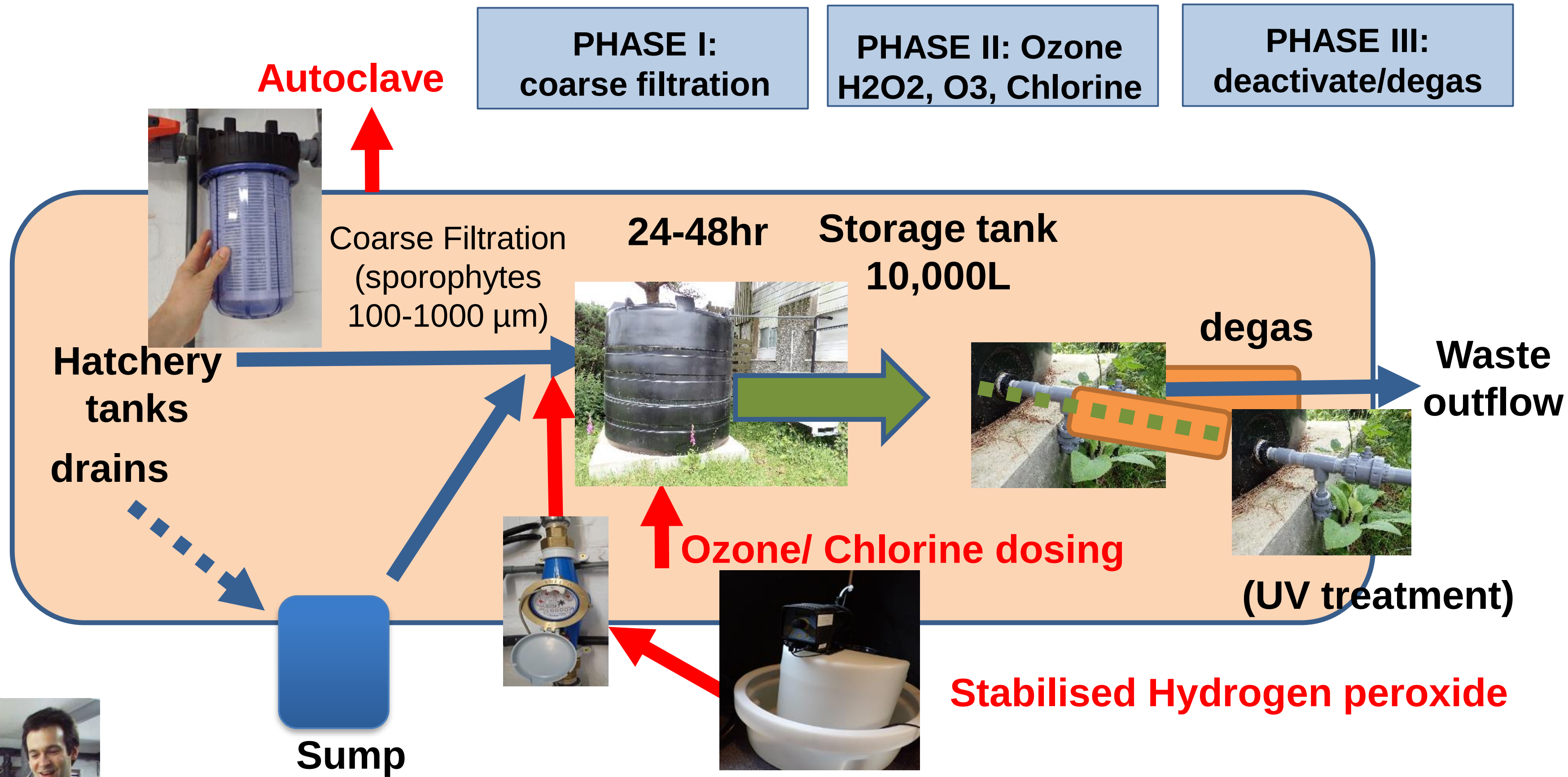
From pathogen discovery to a biosecurity framework for seaweed aquaculture

Better safe than sorry… Let's start with implementing best practice at home

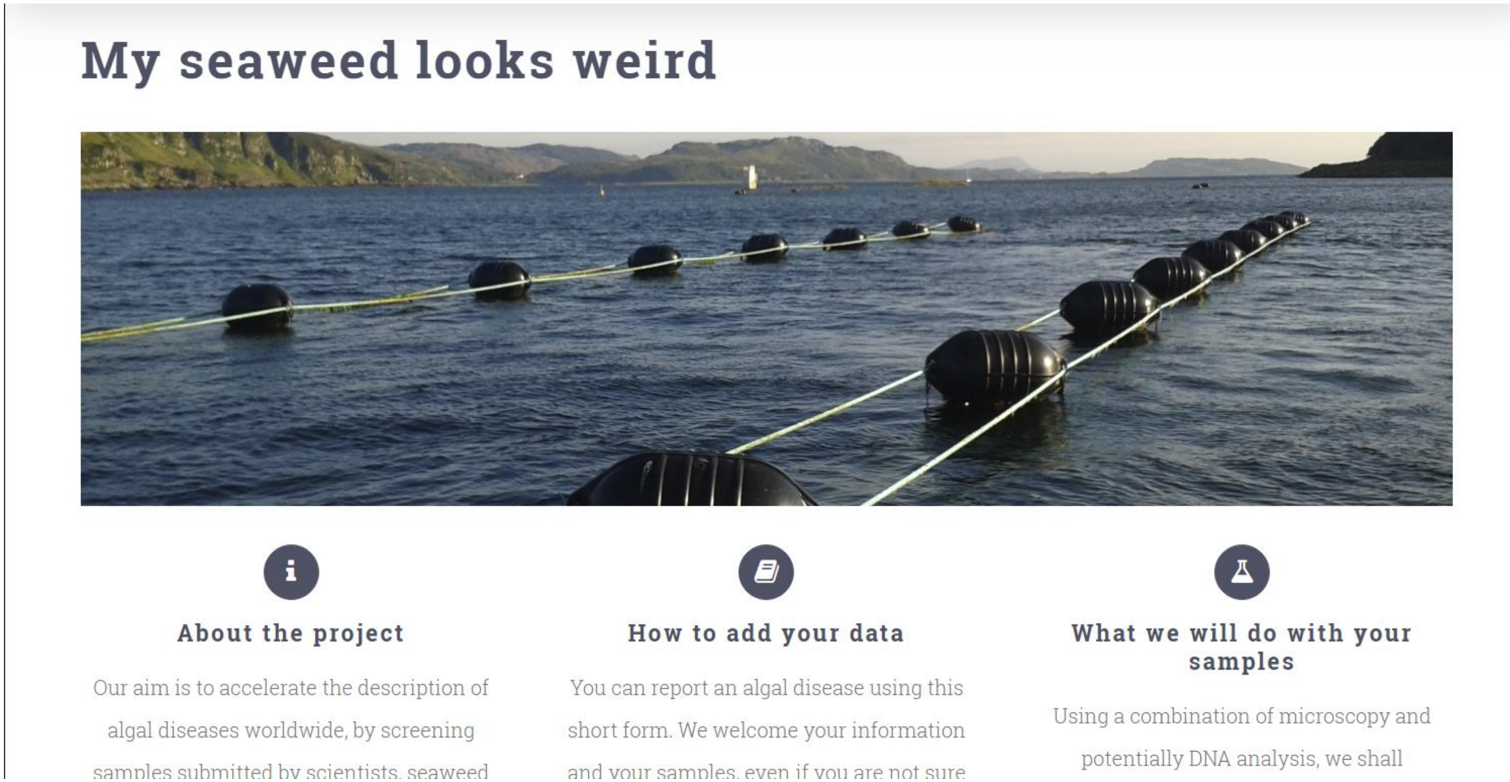
- **Biosecurity upgrade of SAMS hatchery: sterilisation of inflow and outflow**

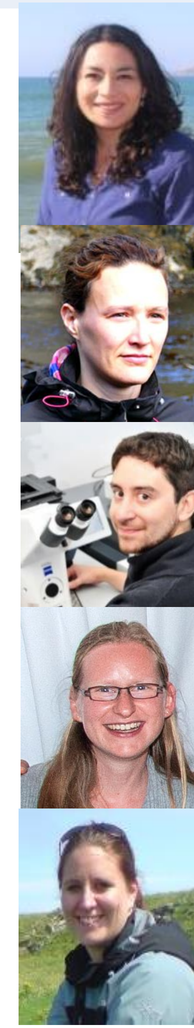


Phil Kerrison

GENIALG SAMS

Accelerating pathogen discovery…
Towards an Open Access Online Atlas of Algal Diseases



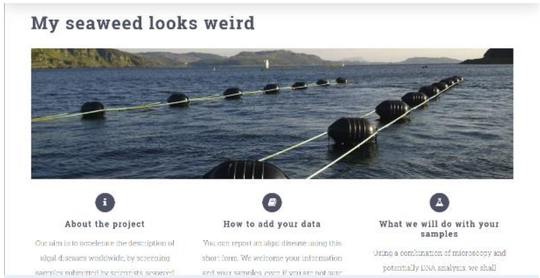


- ➢ Community-based effort to accelerate disease discovery
- ➢ Anyone can contribute a photo or a sample of a diseased alga

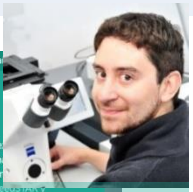
www.globalseaweed.org

Towards an Open Access Online Atlas of Algal Diseases

9 countries, 10+ institutions



Participative portal...



Pedro Murúa

... Now in Spanish & Portuguese

LIMS system

2800+ samples

Paola Arce

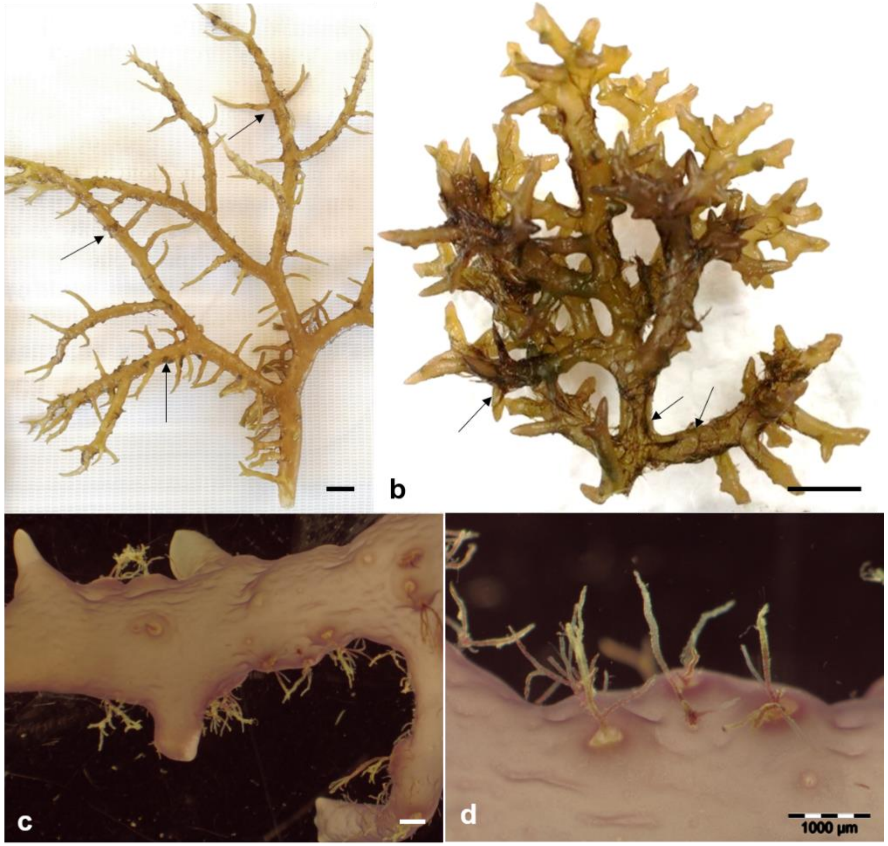
GENIALG

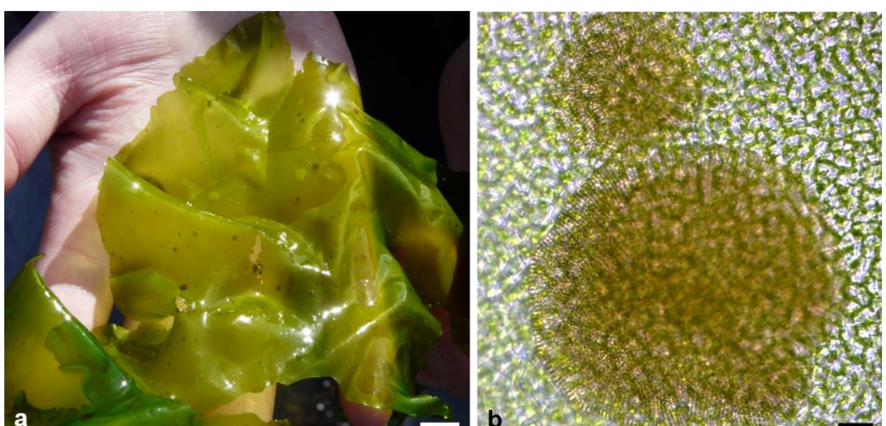
Marie-Mathilde Perrineau

Martina Strittmatter

➢ V1 to be released autumn 2021

Releasing resources on Algal Diseases





Contribution of factsheets for :

Asia Diagnostic Guide to Aquatic Diseases

- A publication by the UN FAO
- Macroscopic and microscopic symptoms, aetiology, management methods…

> **First time that seaweeds are included in a manual on disease diagnostic in aquaculture**

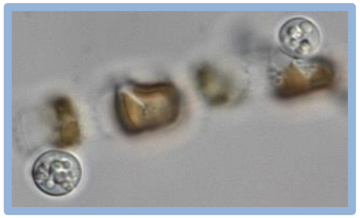
Coordinated by Martina Strittmatter, with multiple inputs by GlobalSeaweed-STAR partners and collaborators

SAMS | NATURAL HISTORY MUSEUM | SEAFDEC | ODI | HEKIMA NI UHURU | UNIVERSITY OF THE PHILIPPINES VISAYAS | UNIVERSITY OF MALAYA | Cefas | UNITED NATIONS UNIVERSITY | UNU-INWEH

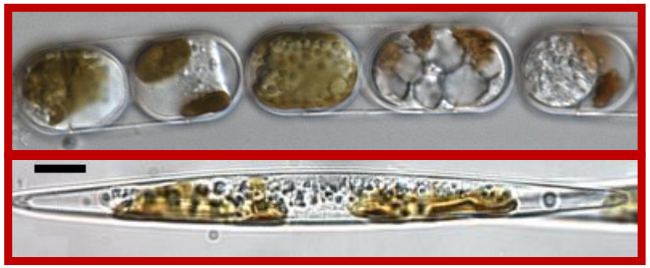
Accelerating pathogen description… Technical advances

Andrea Garvetto

chytrids



oomycetes

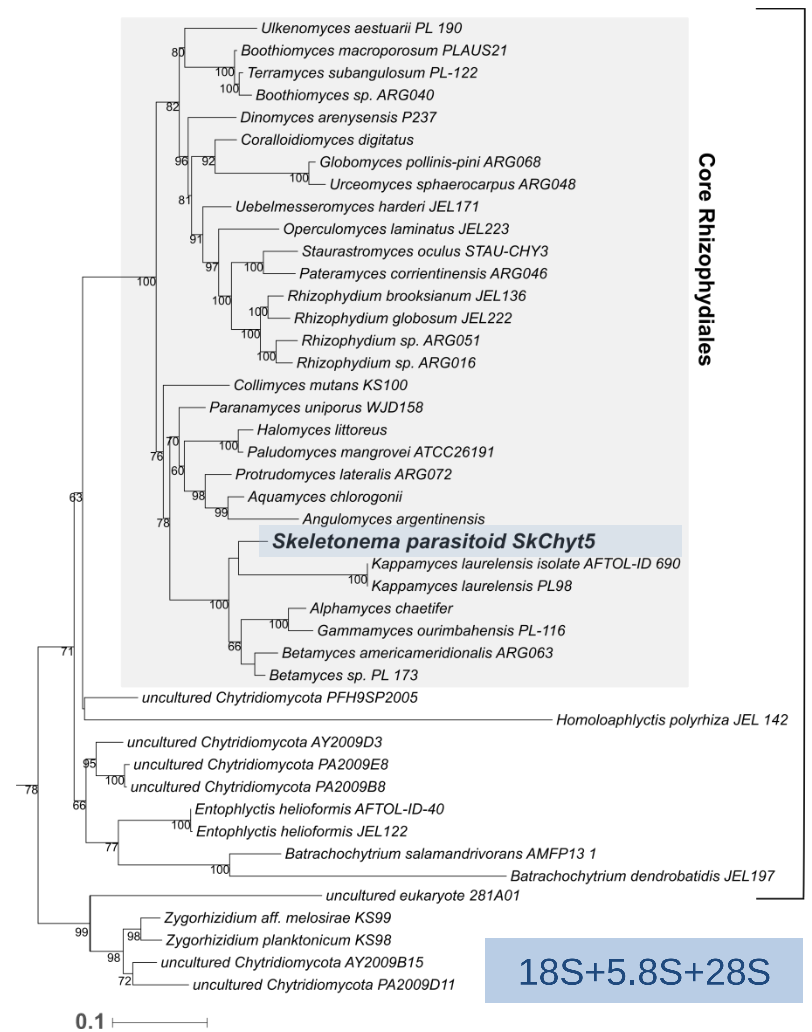


Whole genome amplification

One PCR for QC

Hiseq

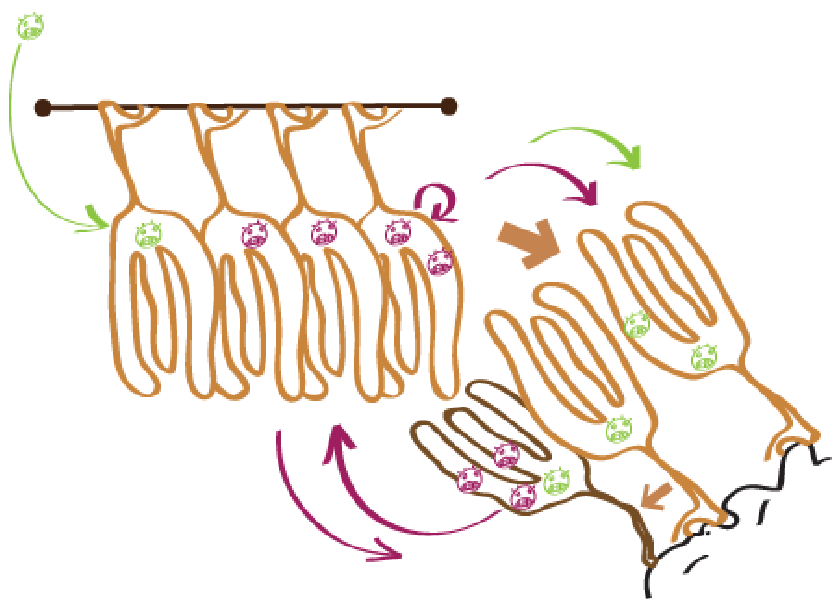
Multigenic phylogeny



Garvetto *et al.*, 2018 Front. Microbiol.; Garvetto *et al.* 2018 Fung. Biol.; Garvetto *et al.* 2019 J.Euk Microbiol.

Diseases as one of several threats to sustainable marine macroalgal aquaculture worldwide…

Liz Cottier-Cook



Loureiro, Gachon & Rebours, ***New Phytol.*** 2015;
Valero et al. ***Persp. Phycol.*** 2017

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POLICYBRIEF

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National and Global biosecurity frameworks for seaweeds, disease management

Liz Cottier-Cook

23RD INTERNATIONAL SEAWEED SYMPOSIUM, JEJU

Check for updates

An analysis of the current status and future of biosecurity frameworks for the Indonesian seaweed industry

Cicilia S. B. Kambey[1,2] · Iona Campbell[3] · Calvyn F. A. Sondak[4] · Adibi R. M. Nor[5] · Phaik E. Lim[1] · Elizabeth J. Cottier-Cook[3]

Check for updates

Biosecurity policy and legislation of the seaweed aquaculture industry in Tanzania

Sadock B. Rusekwa[1] · Iona Campbell[2] · Flower E. Msuya[1] · Amelia S. Buriyo[1] · Elizabeth J. Cottier-Cook[2,3]

Journal of Applied Phycology (2021) 33:997–1010
https://doi.org/10.1007/s10811-020-02352-5

Check for updates

Understanding biosecurity: knowledge, attitudes and practices of seaweed farmers in the Philippines

Jonalyn P. Mateo[1,2,3] · Iona Campbell[4] · Elizabeth J. Cottier-Cook[4,5] · Maria Rovilla J. Luhan[1,3] · Victor Marco Emmanuel N. Ferriols[1] · Anicia Q. Hurtado[1]

23RD INTERNATIONAL SEAWEED SYMPOSIUM, JEJU

Check for updates

Biosecurity policy and legislation for the global seaweed aquaculture industry

Iona Campbell[1] · Cicilia S. B. Kambey[2] · Jonalyn P. Mateo[3] · Sadock B. Rusekwa[4] · Anicia Q. Hurtado[3] · Flower E. Msuya[4] · Grant D. Stentiford[5,6] · Elizabeth J. Cottier-Cook[1]

- Disease monitoring and trials of management methods in seaweed farms
- Risk assessment tool to predict disease outbreaks and help decision on farm management

safe seaweed coalition

UNITED NATIONS UNIVERSITY

United Nations Global Compact

gcrf global seaweed

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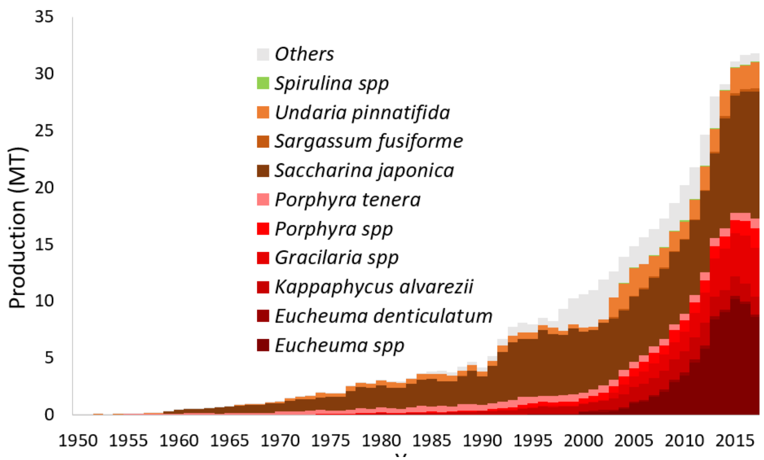
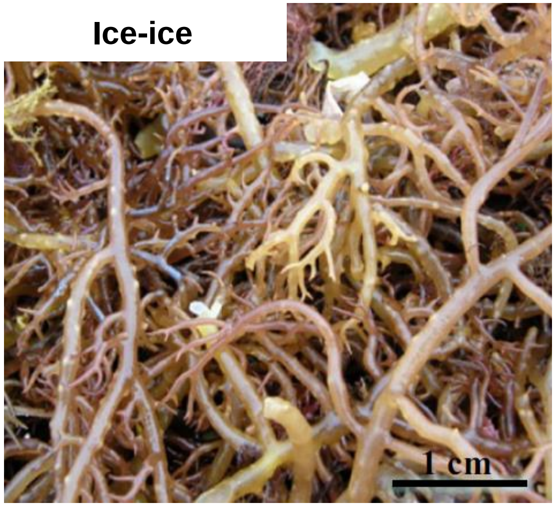
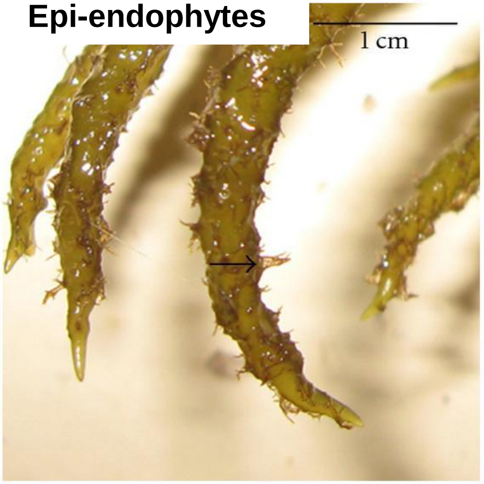
Eucheumoid cultivation: the true story

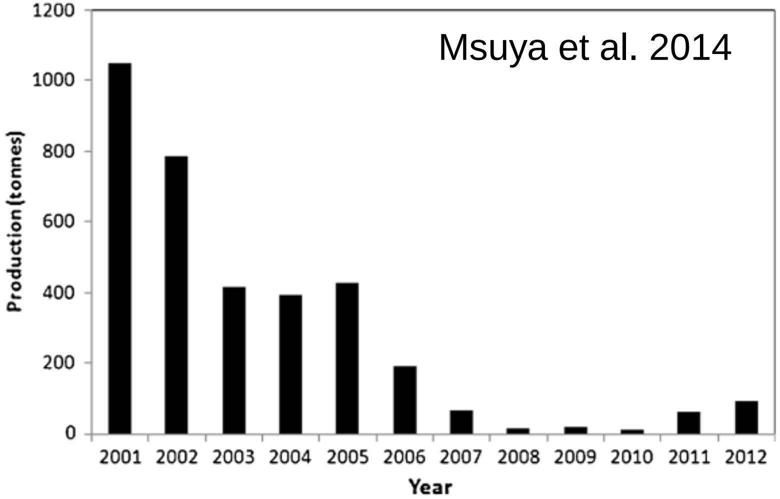


Ice-ice

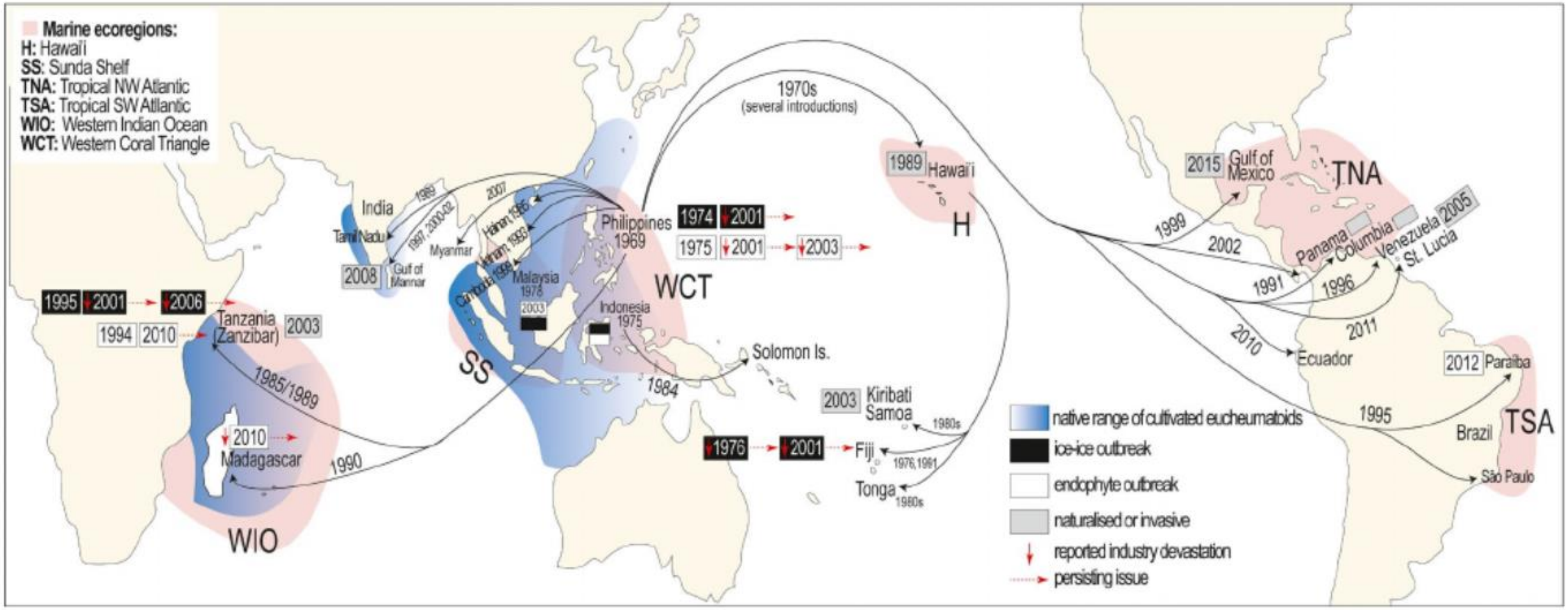


Epi-endophytes





Germplasm movement and diseases in a globalised seaweed industry: *Eucheuma* and *Kappaphycus*



☞ After a grace period, diseases typically worsen due to intensification, sometimes leading to collapse of the local industry.

☞ Worldwide seed movement, yet biosecurity almost inexisting.

☞ Containment options in the marine environment are limited.

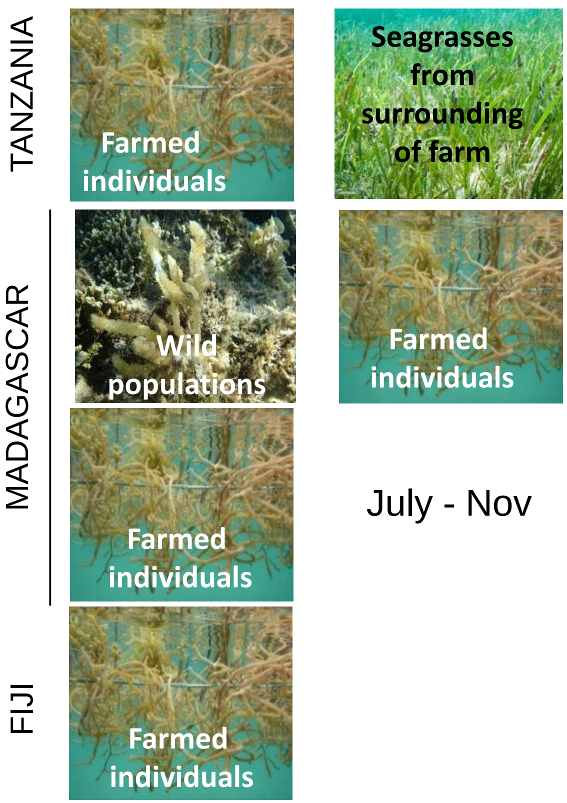
NERC SCIENCE OF THE ENVIRONMENT global seaweed gcrf global seaweed RESEARCH COUNCILS UK

Brakel *et al.*, Plants People Planet 2021.

Epi-endophyte pathogens of *Eucheuma* and *Kappaphycus*

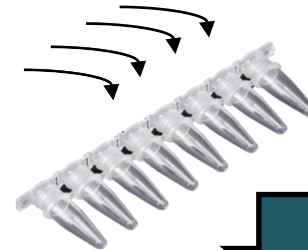
- Which EFA species are key pests in eucheumoid farming? What is the geographic distribution of these species? Are EFA species host specific?
- Can we inform global policy-making and international biosecurity with the outcomes of this work?

Hierarchical sampling design

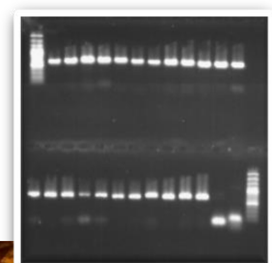


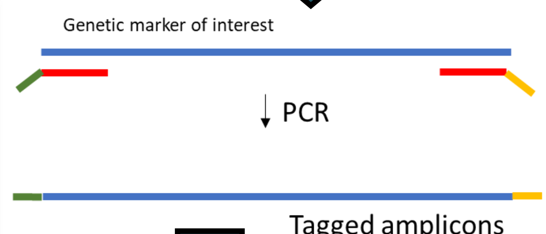
July - Nov

Dissection of individual filaments (~8 / sample) : ~1150 subsamples



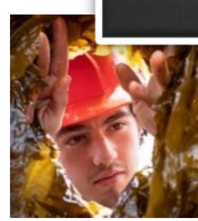
DNA extraction





Highly multiplexed barcoding (also suitable for low-depth metabarcoding)

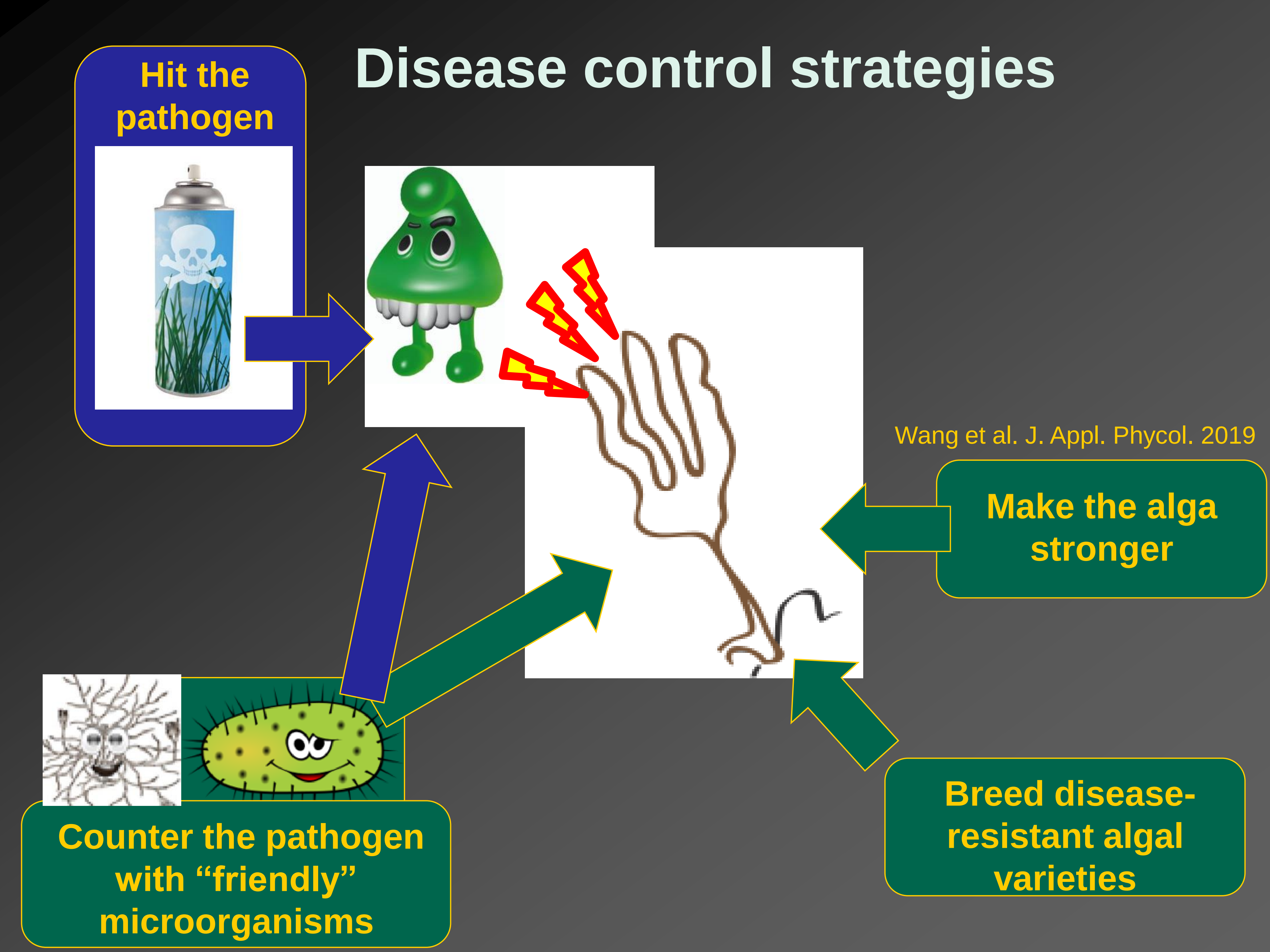
Janina Brakel



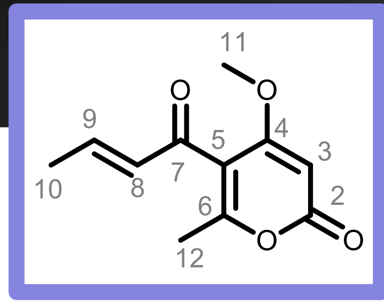
Callum O'Connell

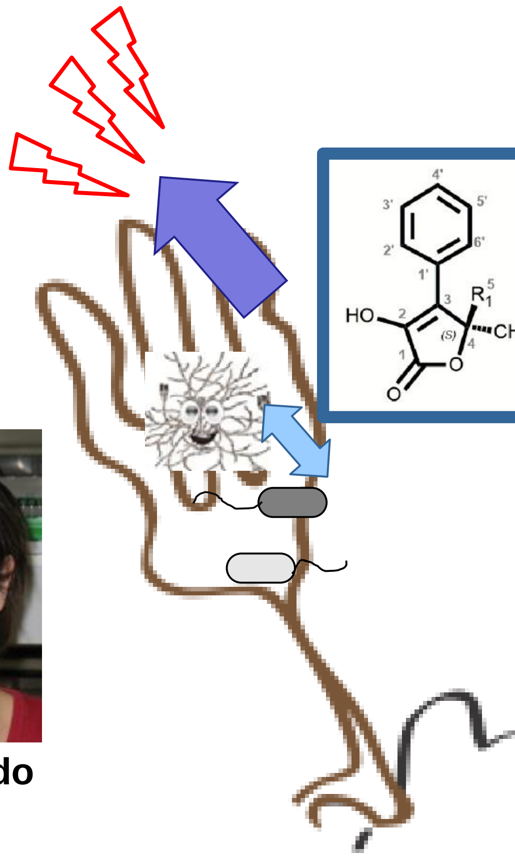
Collaboration with J. Faisan (Philippines), Sze Wan Poong (Malaysia), Juliet Brodie (NHM), Pilar Diaz-Tapia (Spain)

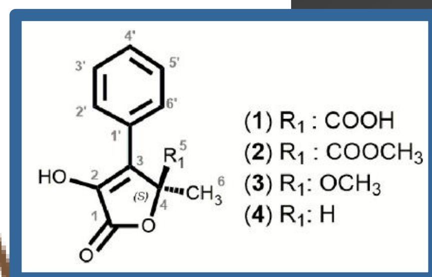
Disease control in seaweed aquaculture


Disease control strategies
Hit the pathogen
Wang et al. J. Appl. Phycol. 2019
Make the alga stronger
Counter the pathogen with “friendly” microorganisms
Breed disease-resistant algal varieties

Engineering marine microbiomes: proof of concept

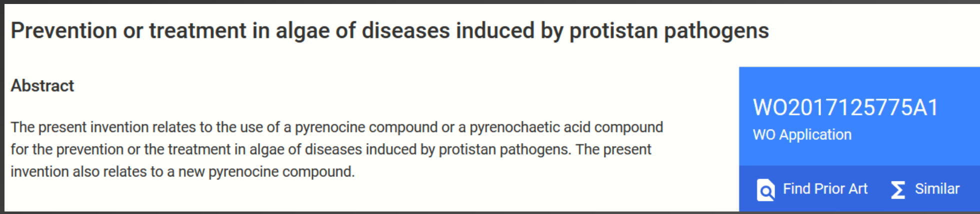






Soizic Prado

☞ Endophytic fungi as sources of anti-prostistan molecules.



☞ Fungal inhibitors of bacterial quorum sensing.

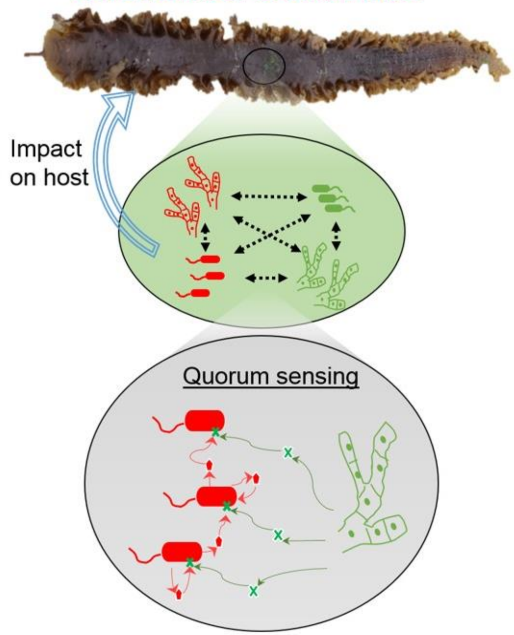
☞ Theoretical possibility to engineer seaweed microbiomes towards crop improvement.

Vallet *et al.*, **Frontiers in Microbiology** 2018
Vallet *et al.*, **Frontiers in Marine Science** 2020

Tourneroche *et al.*, **Frontiers in Marine Science** 2020

Algal microbiota project

MICROBIAL SIGNALING



→ **Chemical communication within the microbiota and impact on algal fitness**

MARINE BIOTECHNOLOGY

❶ Strains taxonomicaly characterized

Collections :
- 200 fungal strains
- 250 bacterial strains

❷ Crude extracts library

→ **New high-value compounds with many applications**

GENOMICS

→ New related gene clusters -Heterologous expression- Transcriptomics
→ Access to higher chemical diversity

SAMS

MUSÉUM NATIONAL D'HISTOIRE NATURELLE

BOREA

KONGJU NATIONAL UNIVERSITY KNU 1948 공주대학교

CNRS UPMC Station Biologique Roscoff

lbbm Laboratoire de biodiversité et biotechnologies microbiennes

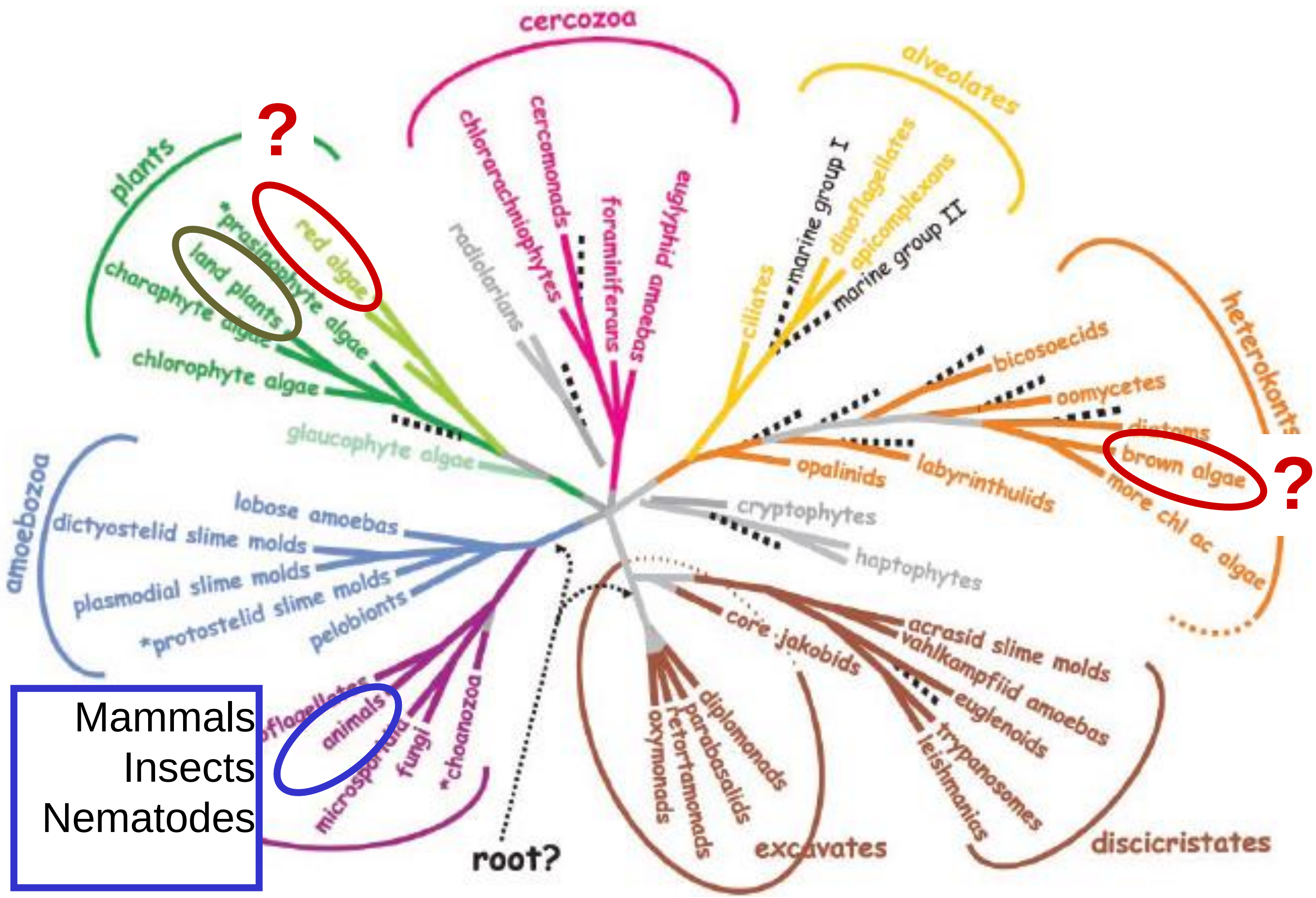
COLLABORATIONS

→ ***Streptomyces*** **genome sequencing (inhibition** ***Botrytis cinerea*****)**

How do seaweeds defend themselves against pathogens?

Innate and acquired resistance of brown algae to infection

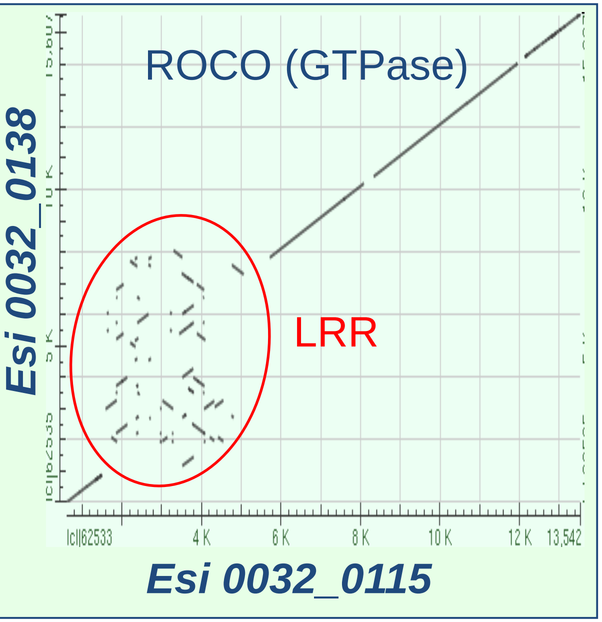
What do we know about macroalgal immune systems?

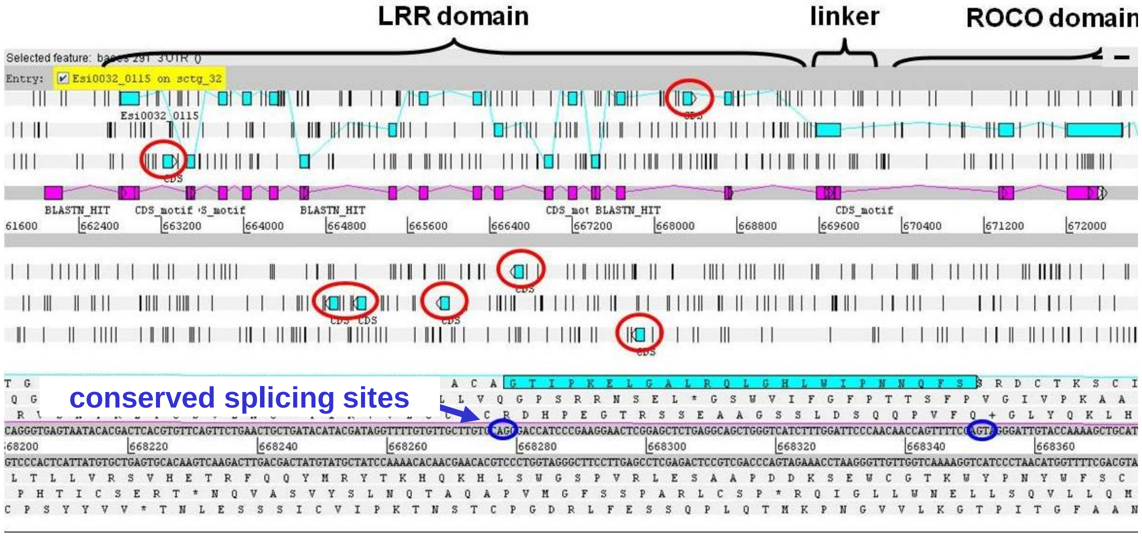


☞ **Can we expect anything similar in brown algae?**

How are pathogens recognised?

We don't know, but have some ideas





☞ Presence in red algal and brown algal genomes of gene families with domains and evolutionary features suggestive of a possible role in pathogen recognition

☞ No clear orthologue of plant disease resistance genes

☞ Probably some original defence mechanisms…

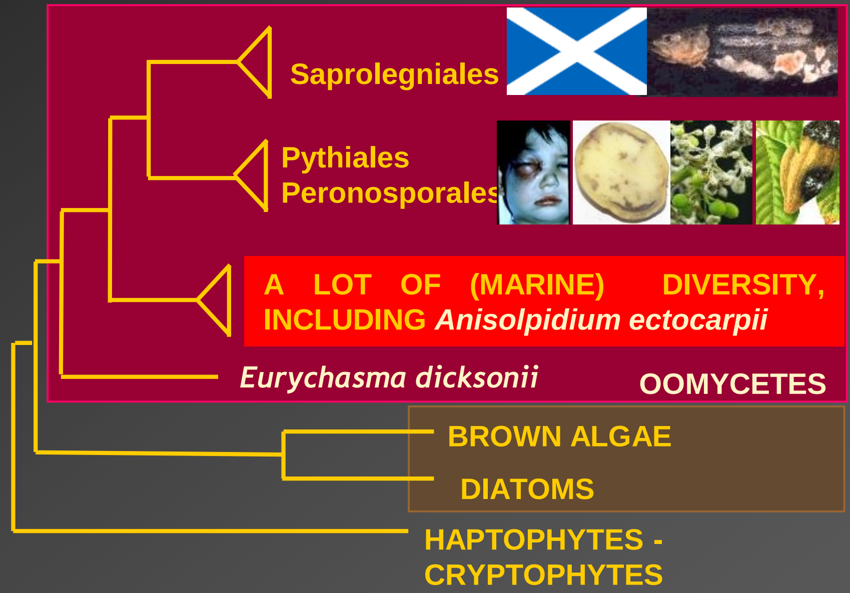
Zambounis et al, Mol. Biol. Evol. 2012; Collen et al. PNAS 2013; Brawley et al. PNAS 2017.

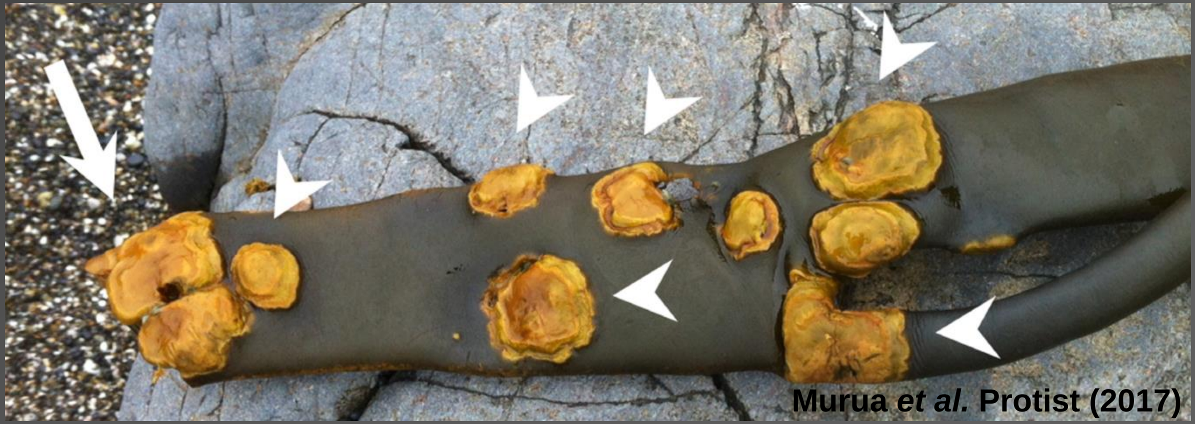
Lab models to investigate the physiology of resistance of brown algae

Anisolpidium ectocarpii
Gachon et al, 2017 Eur. J. Phycol

Eurychasma dicksonii
Sekimoto et al. 2008 Protist

Maullinia ectocarpii
Maier et al. 2000 Protist

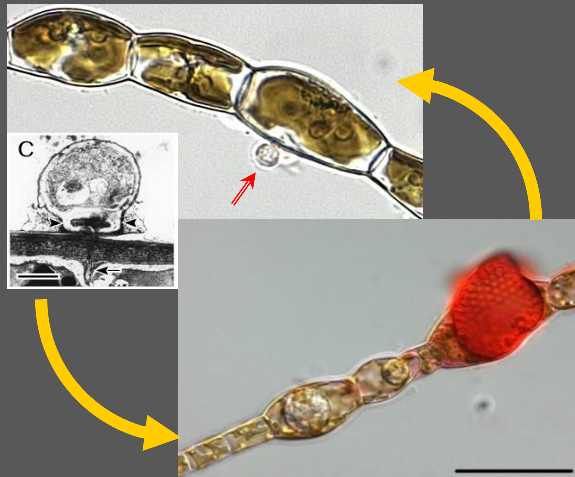




Murua *et al.* Protist (2017)

Differential susceptibility of brown algae to *Eurychasma* infection

Ectocarpus / *Eurychasma* as a lab model



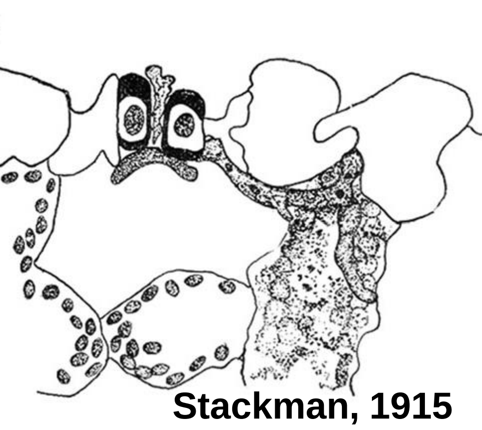
Sekimoto *et al.* Protist (2008)

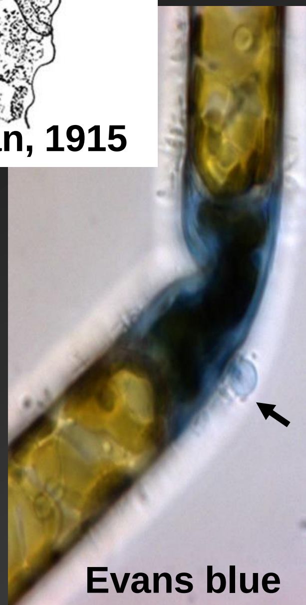
	Ectocarpales						Laminariales	
	Pylaiella littoralis 1330/3	*Ectocarpus* 32m genome strain	*Ecto sp.* 1310/299	*Ectocarpus sp.* 022-10	*Ecto. fasciculatus* 007-04	*Ecto. crouaniorum* 06-29-7	*Laminaria digitata* Ros	*Macrocystis* Mau
***Eury*96**	S	S	S	S	R	S	S	S
***Eury*05**	R	S	S	R	S	R	S	S
***Eury*06**	R	S	S	S	S	S	S	S

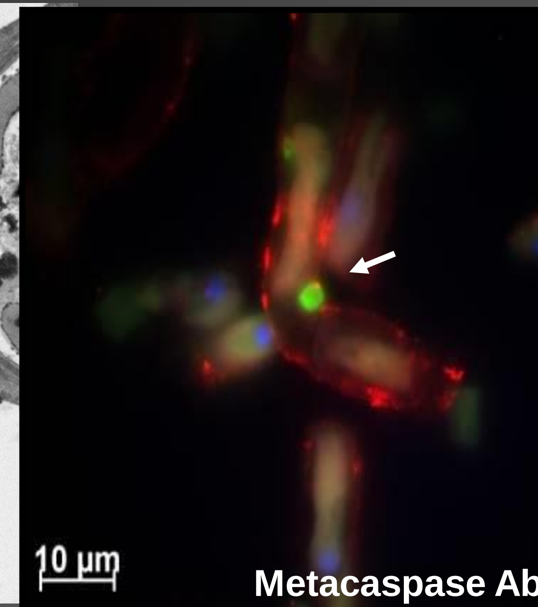
S: susceptibility R: resistance

Gachon *et al.* AEM (2009) 75: 322

Brown algal innate immunity is mediated by a hypersensitive response





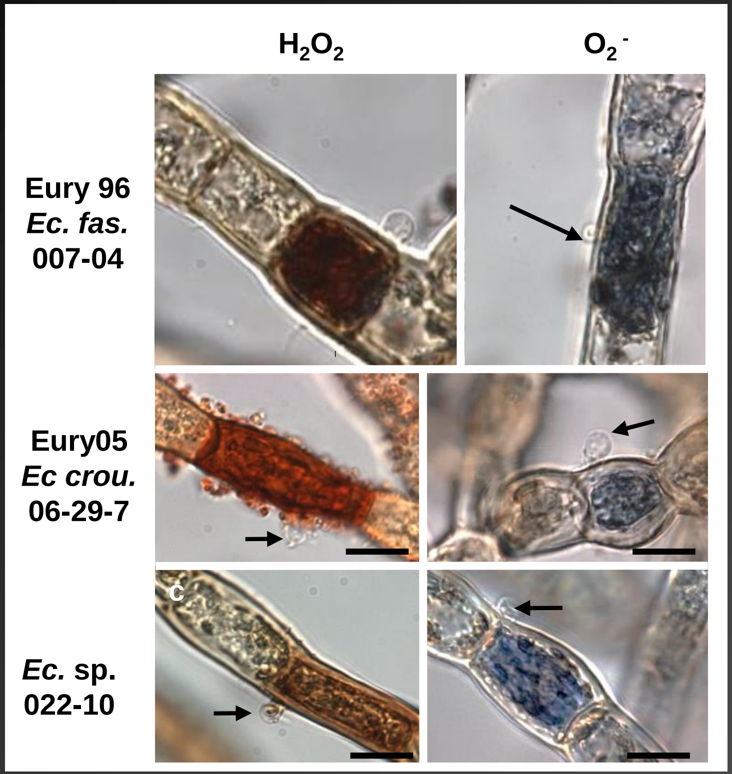


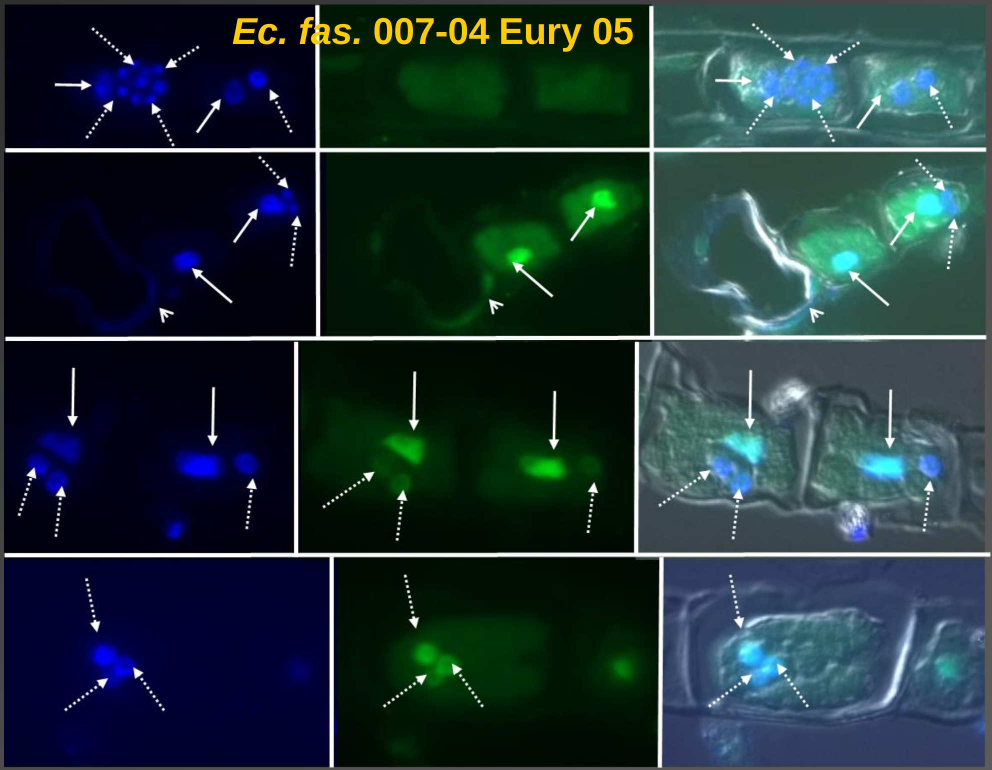
☞ early death of the first infected cell(s), which restricts the pathogen at its point of entry

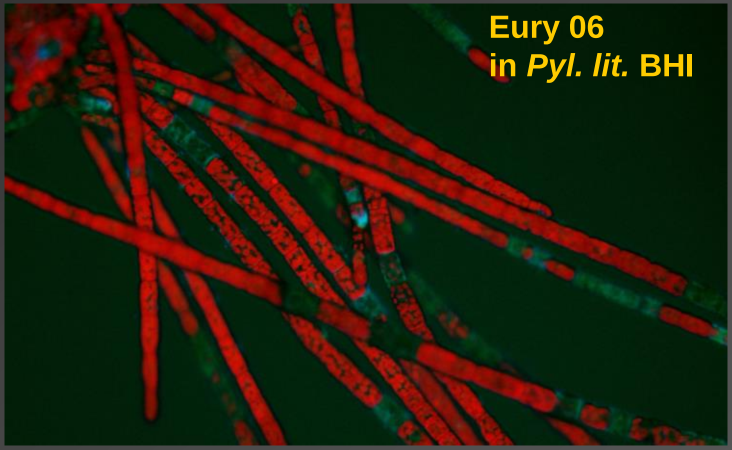
☞ accompanied with expression of programmed cell death markers such as metacaspase

Gachon *et al.* in prep.

Markers of resistance: oxidative stress, secondary metabolism, DNA degardation (TUNEL)





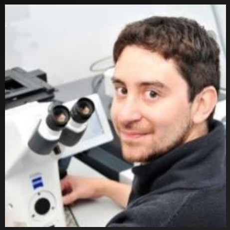


☞ Resistance is a quantitative trait: most "susceptible" strains are in fact partially resistant!

☞ Programmed cell death is conserved across 20+ brown algal sprecies

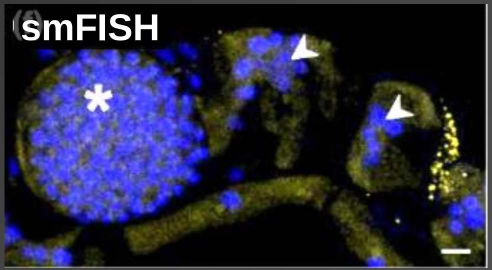
Gachon *et al.* in prep., Murua et *al.*, in prep

The hypersensitive response is conserved across brown algae, but is it conserved with other pathogens?



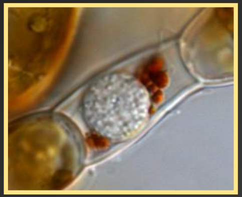
Pedro Murúa

Sigrid Neuhauser, Uni. Innsbruck



Badstöber *et al.* **Sci Rep.** 2020.

Maullinia ectocarpii



Anisolpidium ectocarpii

Eurychasma dicksonii

PATHOGEN

??

Ectocarpus

Kelps

Others

ALGAL HOST

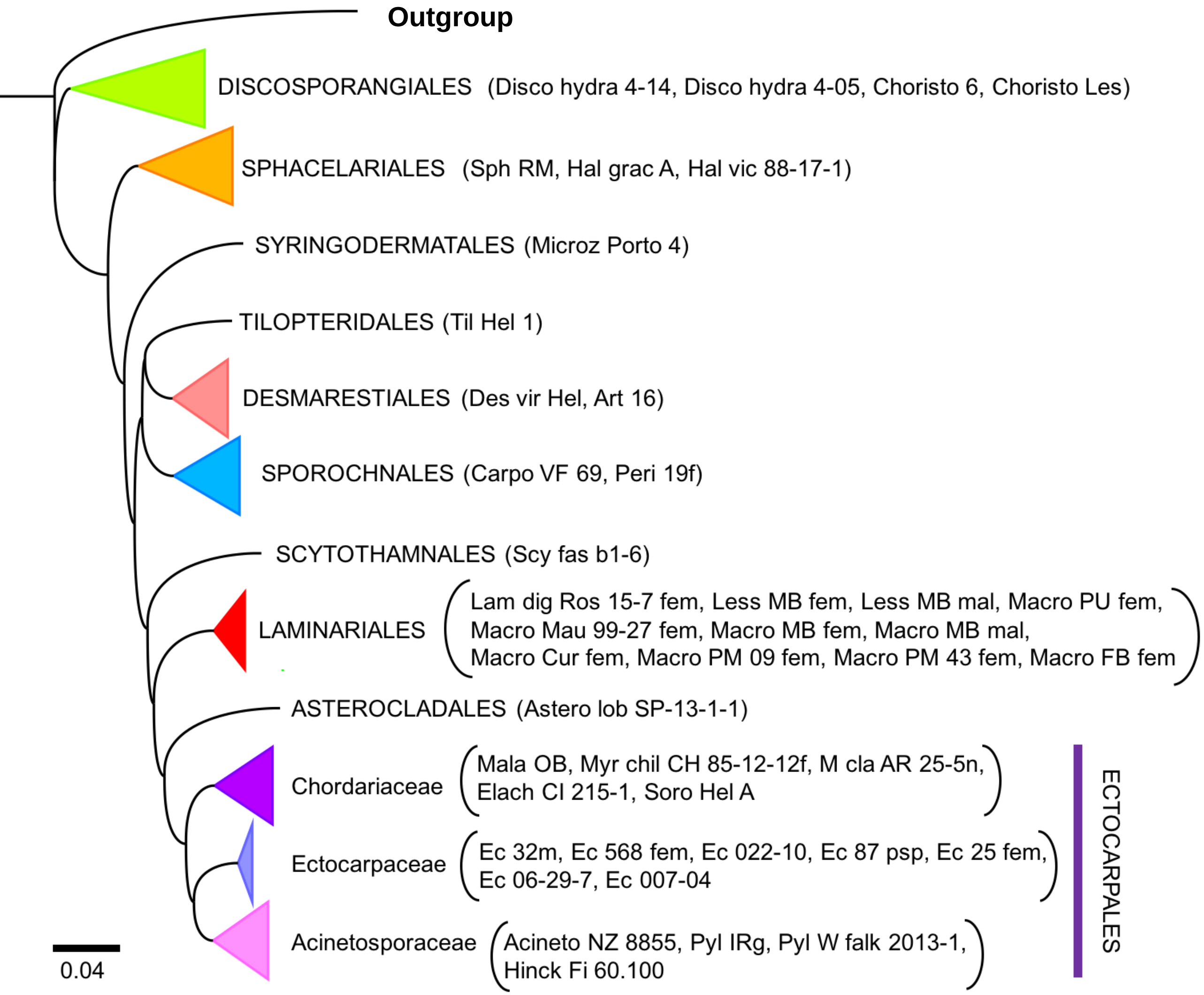
Cell death

- Ox. Stress
- Cell wall
- Metacaspases
- TUNEL

☞ Identification of resistant (or almost resistant) algal strains for both pathogens

Gachon et al, ***Eur. J. Phycol*** 2017.
Murúa et al, **in prep**.

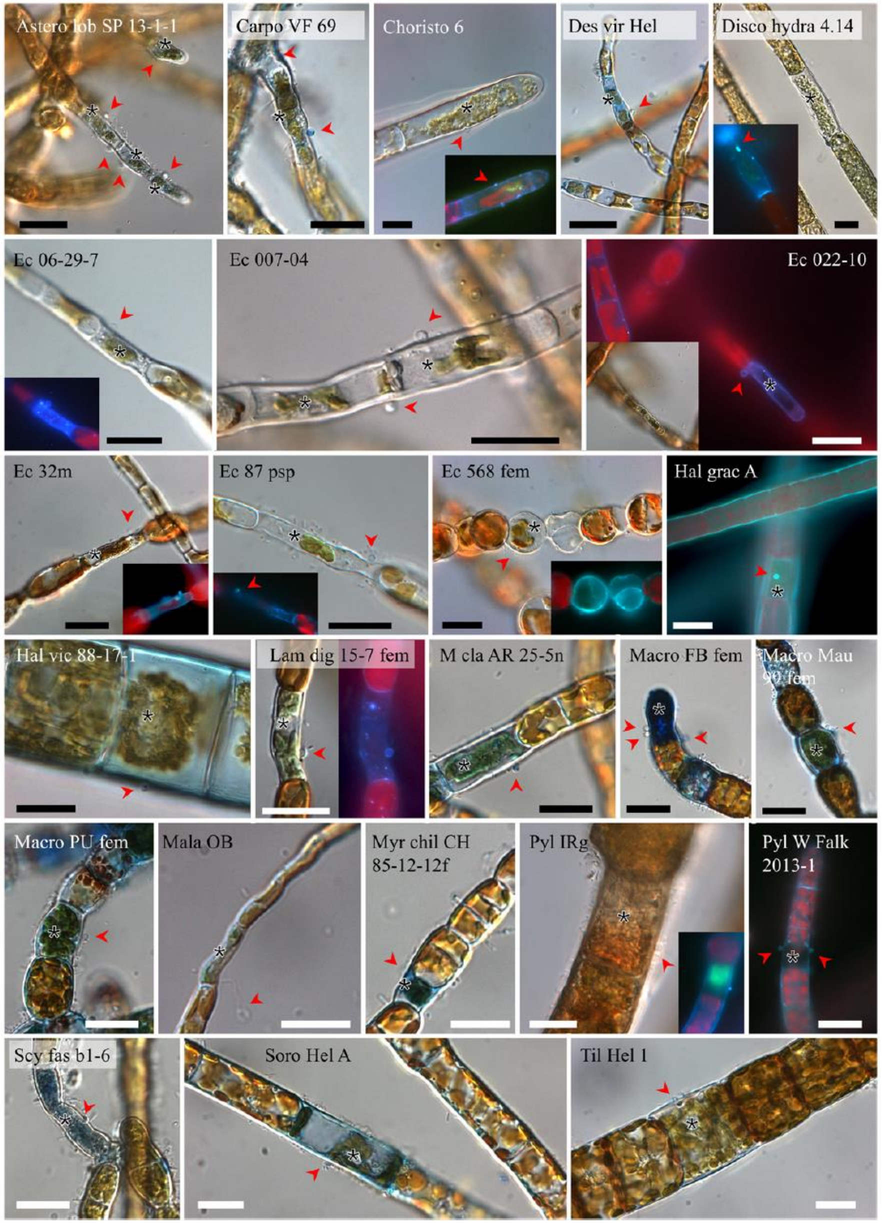
Diversity of algal hosts tested



Species	Strain
Acinetospora crinita	Acineto NZ 8855
Arthrocladia villosa	Art 16
Asterocladon lobatum	Astero lob SP-13-1-1
Botrytella (Sorocarpus) uvaeformis	Soro Hel A
Carpomitra costata	Carpo VF 69
Choristocarpus tenellus	Choristo 6, Choristo Les
Desmarestia viridis	Des vir Hel
Discosporangium mesarthrocarpum	Disco hydra 4-14, Disco hydra 4-05
Ectocarpus crouaniorum	Ec 06-29-7
Ectocarpus fasciculatus	Ec 007-04
Ectocarpus siliculosus	Ec 32m, Ec 87 psp, Ec 25 fem, Ec 568 fem
Ectocarpus sp.	Ec 022-10
Elachista stellaris	Elach Cl 215-1
Halopteris gracilescens	Hal grac A
Halopteris sp.	Hal vic 88-17-1
Hincksia sp.	Hinck FI 60.100
Laminaria digitata	Lam dig Ros 15-7 fem, Lam dig Hel 1003 mal, Lam dig Hel 1004 fem
Lessonia nigrescens	Less MB fem, Less MB mal
Macrocystis pyrifera	Macro Mau 99-27 fem, Macro FB fem, Macro Cur fem, Macro PU fem, Macro PM 09 fem, Macro PM 43 fem, Macro MB mal, Macro MB fem
Microspongium alariae	Mala OB
Microzonia velutina	Microz Porto 4
Myriogloea chilensis	Myr chil CH 85-12-12f
Myriotrichia clavata	M cla AR 25-5n
Perithalia caudata	Peri 19f
Pylaiella littoralis	Pyl Irg, Pyl W falk 2013-1
Scytothamnus fasciculatus	Scy fas b1-6
Sphacelaria sp.	Sph RM
Tilopteris mertensii	Til Hel 1

Murúa et al, **in prep.**

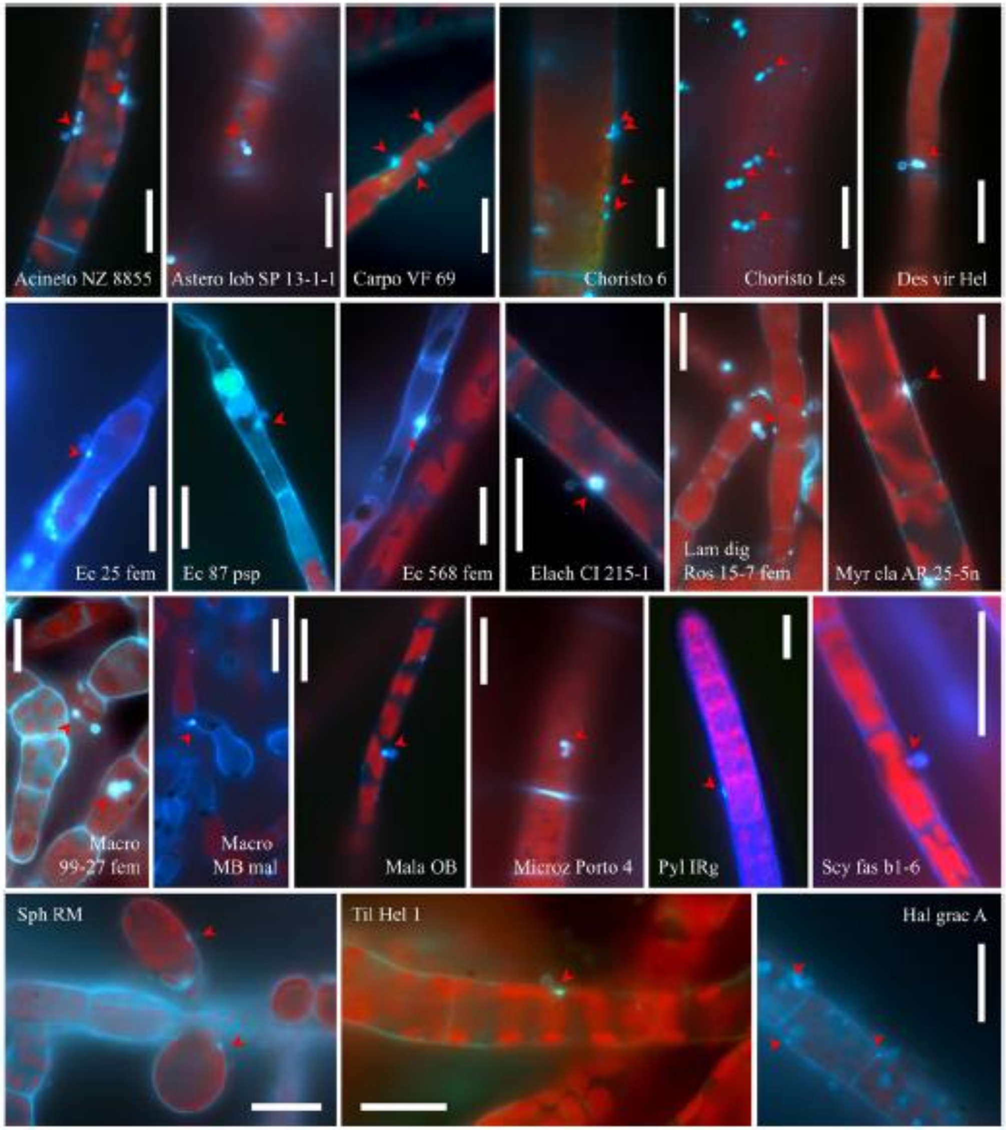
Brown algae use cell death to resist against protistan pathogens other than *Eurychasma*



Cell death

Murúa et al, in prep.

Conservation of cell death cell death marlers against protistan pathogens other than *Eurychasma*

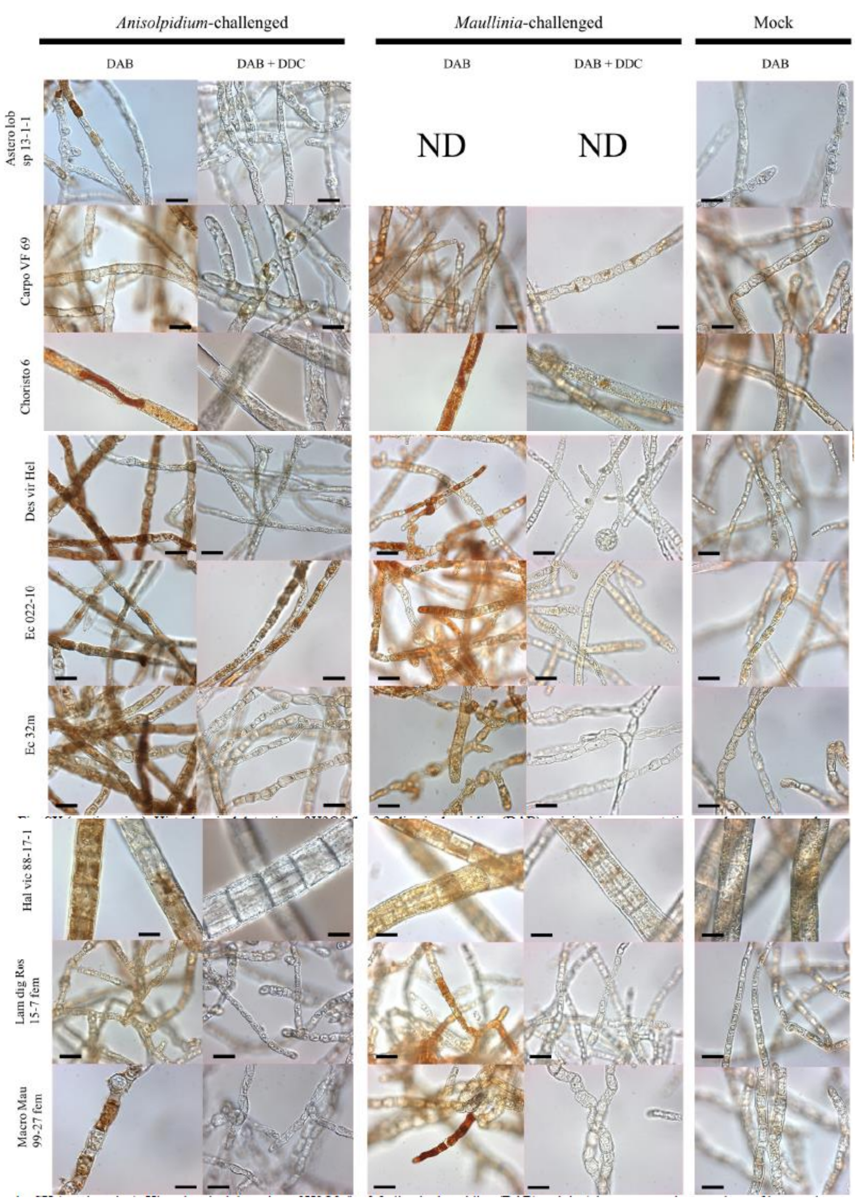


Cell death

Cell wall reinforcements

Murúa et al, in prep.

Conservation of cell death markers against protistan pathogens other than *Eurychasma*



Cell death

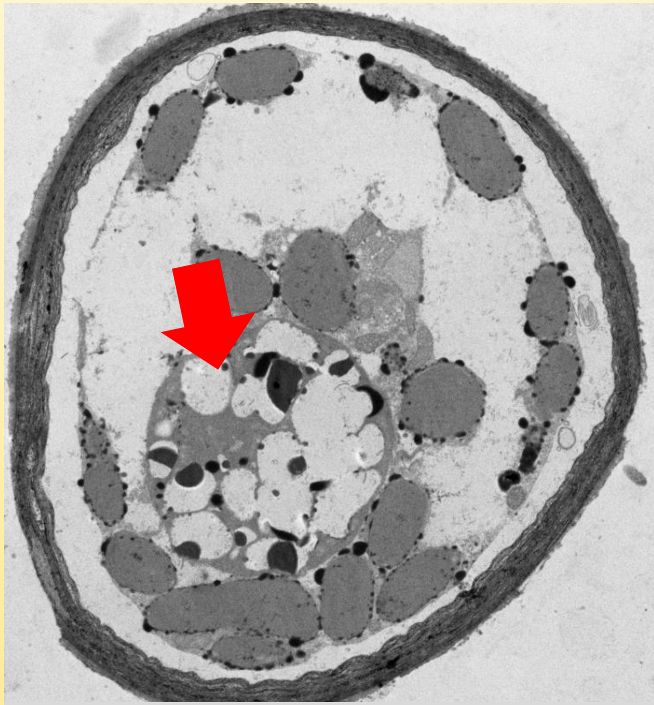
Cell wall reinforcements

Oxidative stress

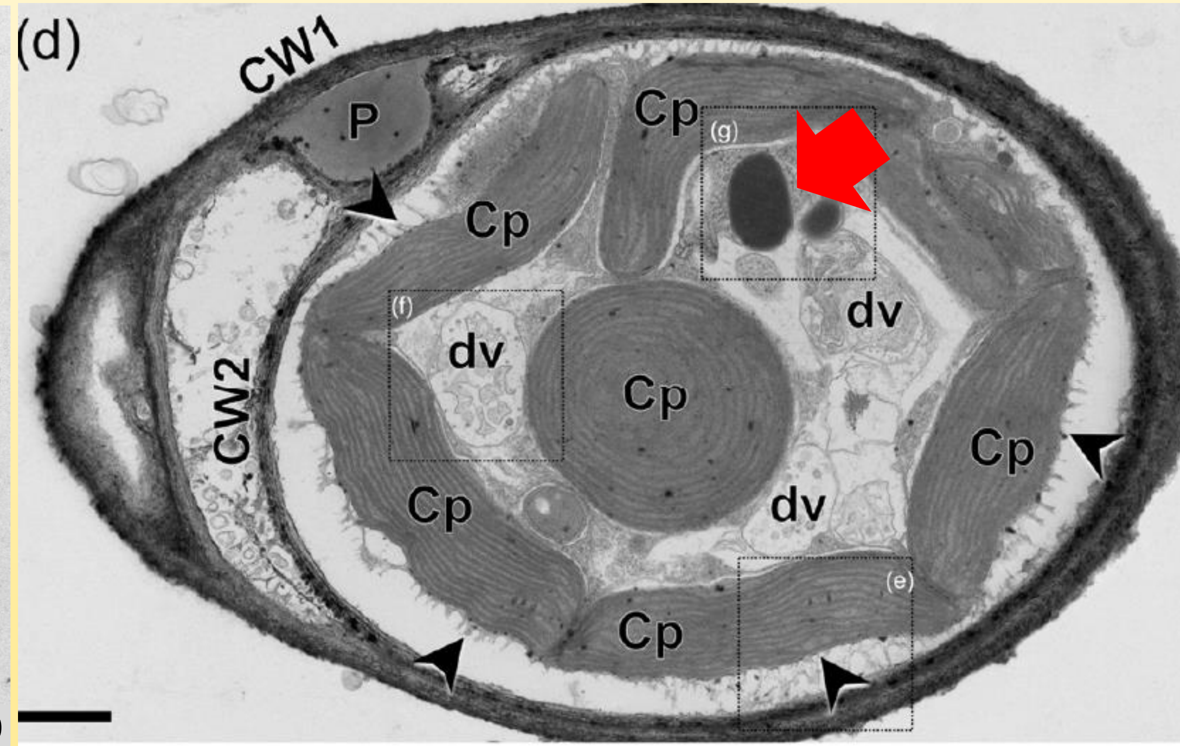
But…

Murúa et al, in prep.

Another type of defence response that allows the infected algal cell to survive ?



Anisol. ec. – Macrocystis pyr. Mau99



?! Disorganised and dying *Anisolpidium* thalli in live algal cells ?!

☞ Inducible autophagic response: the alga digests its own organelles (resource mobilisation) and pathogen thalli (defence)

Murúa *et al.*, New Phytologist 2020

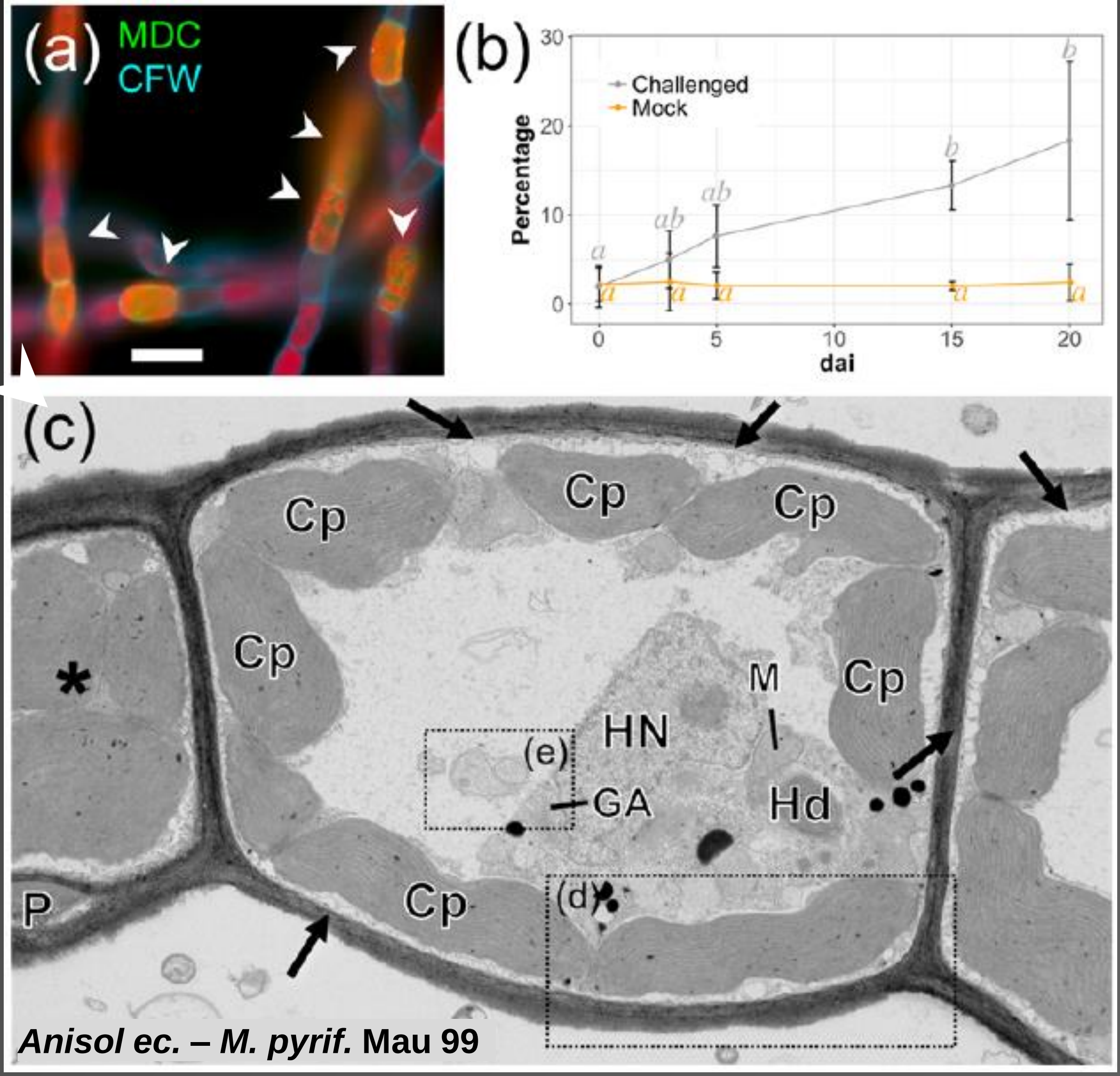
Does this alternative response also occur against *Eurychasma*?

☞ Yes, but very slow induction compared to when *A. ectocarpii* is used

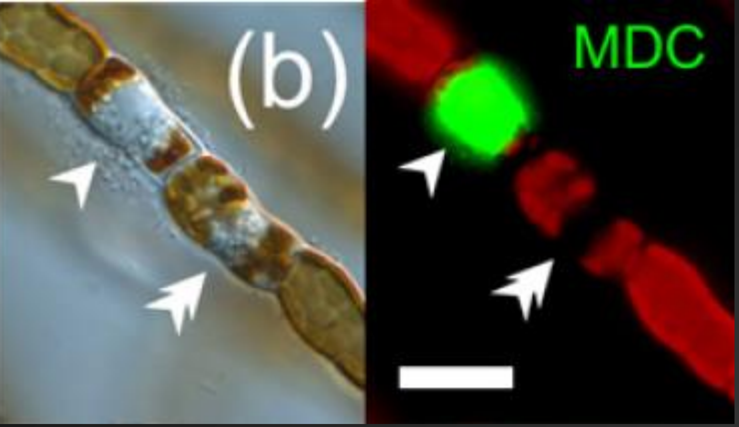
Murúa et al, in prep.

Inducible algal autophagy is a systemic response

- **Uninfected, autophagic, algal cell in a culture infected by *A. ectocarpii***

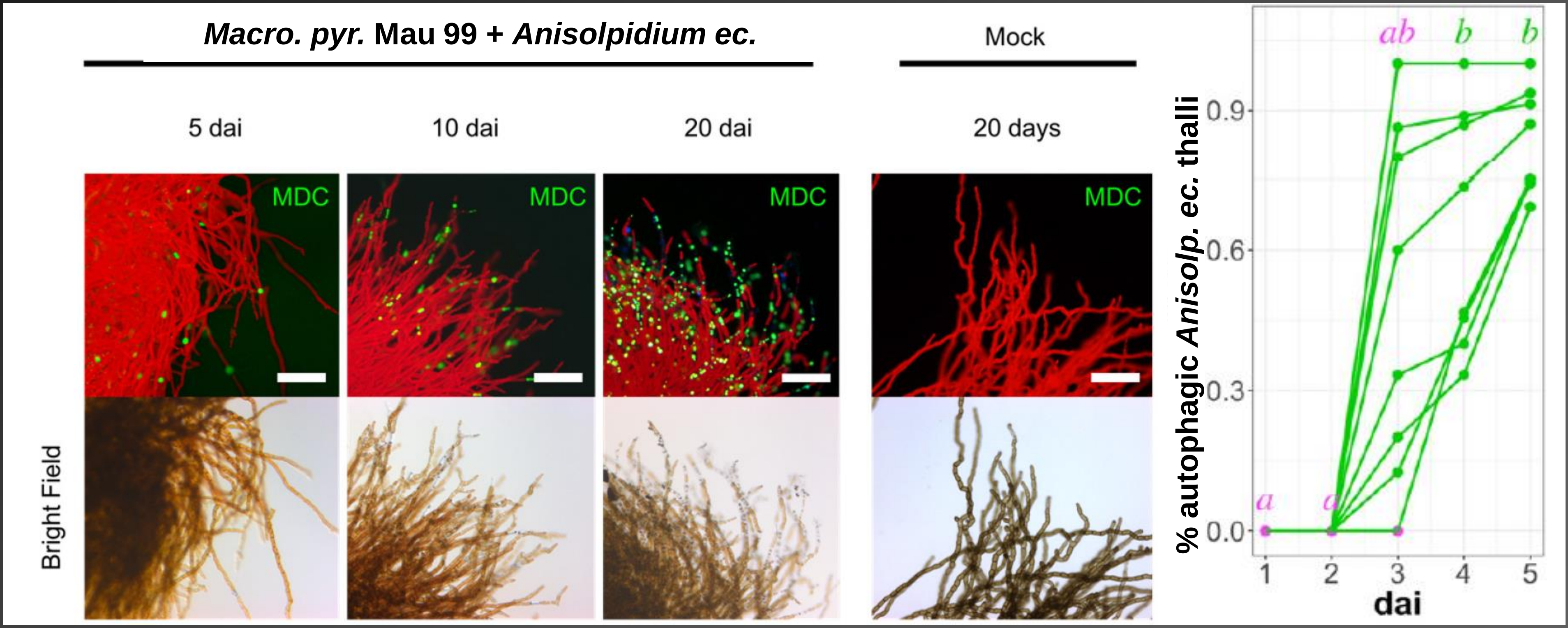


Murúa et *al* ., New Phytol. 2020



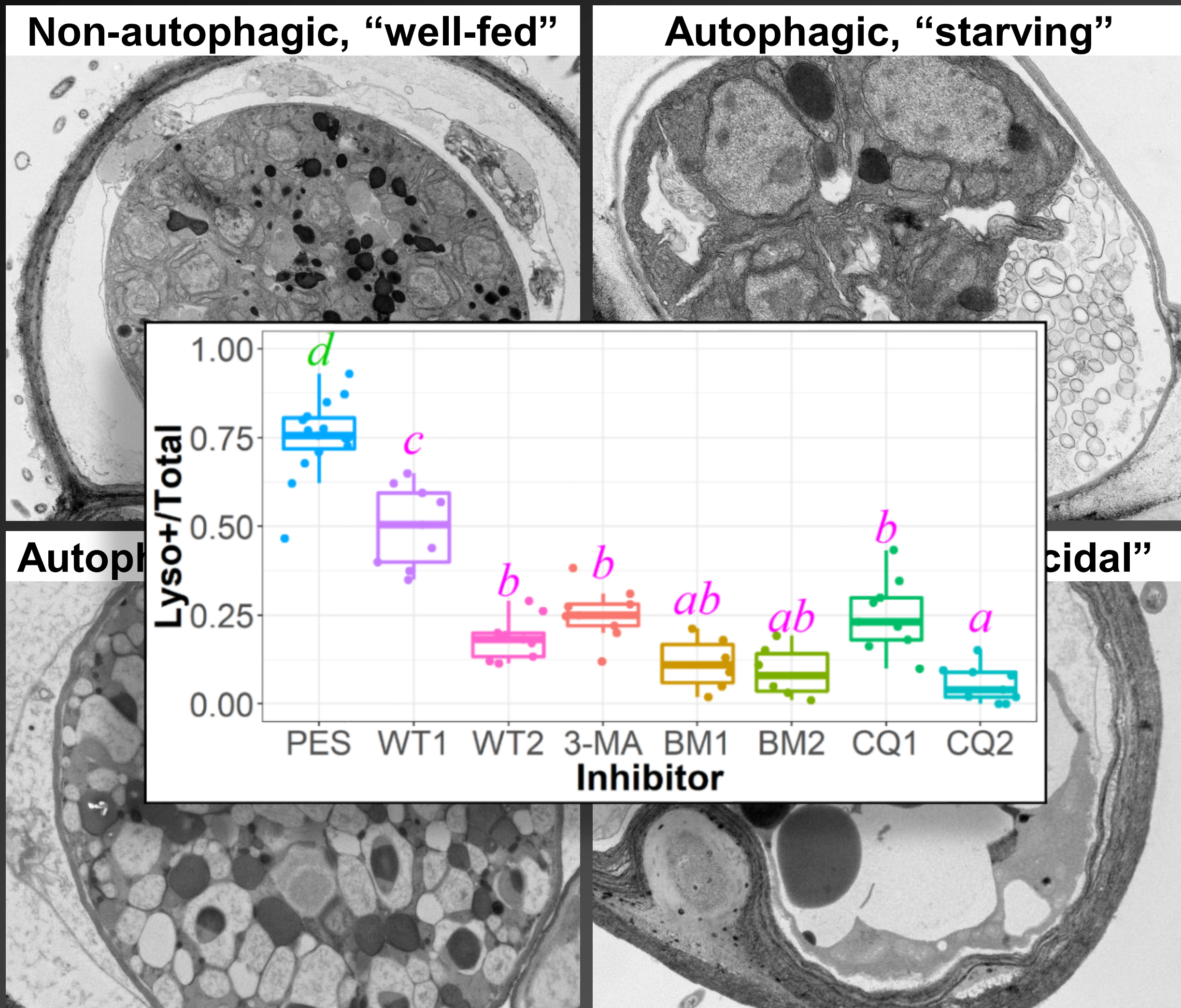
Autophagy is also inducible in the pathogen

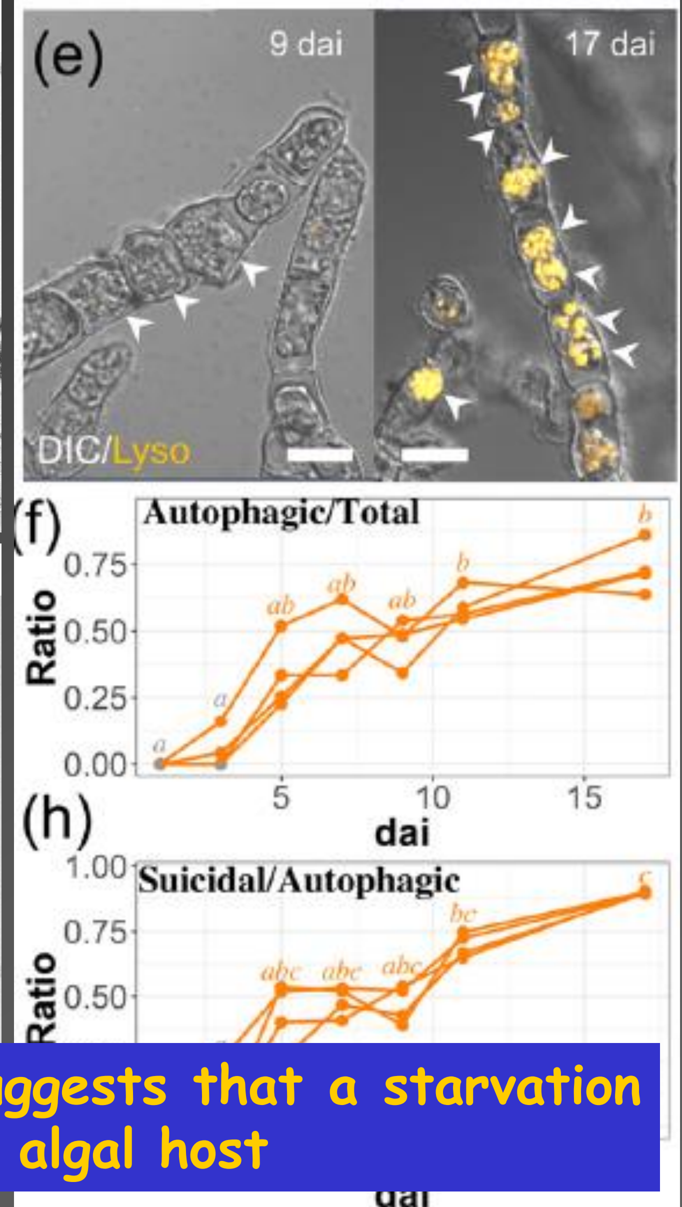
- Autophagic *A. ectocarpii*
- Non-autophagic *A. ectocarpii*



Murúa et *al* ., New Phytol. 2020

Different types of autophagic responses in *A. ectocarpii*

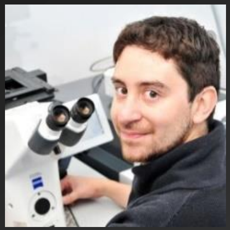




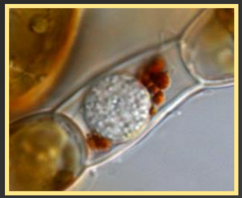
☞ Induction of abortive *Anisolpidium* thalli suggests that a starvation response of the pathogen is subverted by the algal host

Multilayered defence responses of brown algae against intracellular pathogens: a working model





Sigrid Neuhauser, Uni. Innsbruck



Maullinia ectocarpii

Anisolpidium ectocarpii

Eurychasma dicksonii

PATHOGEN

Pathogen autophagy:
- Starvation - zoosporogenesis
- Suicide

TIME

ALGAL HOST

Ectocarpus

Kelps

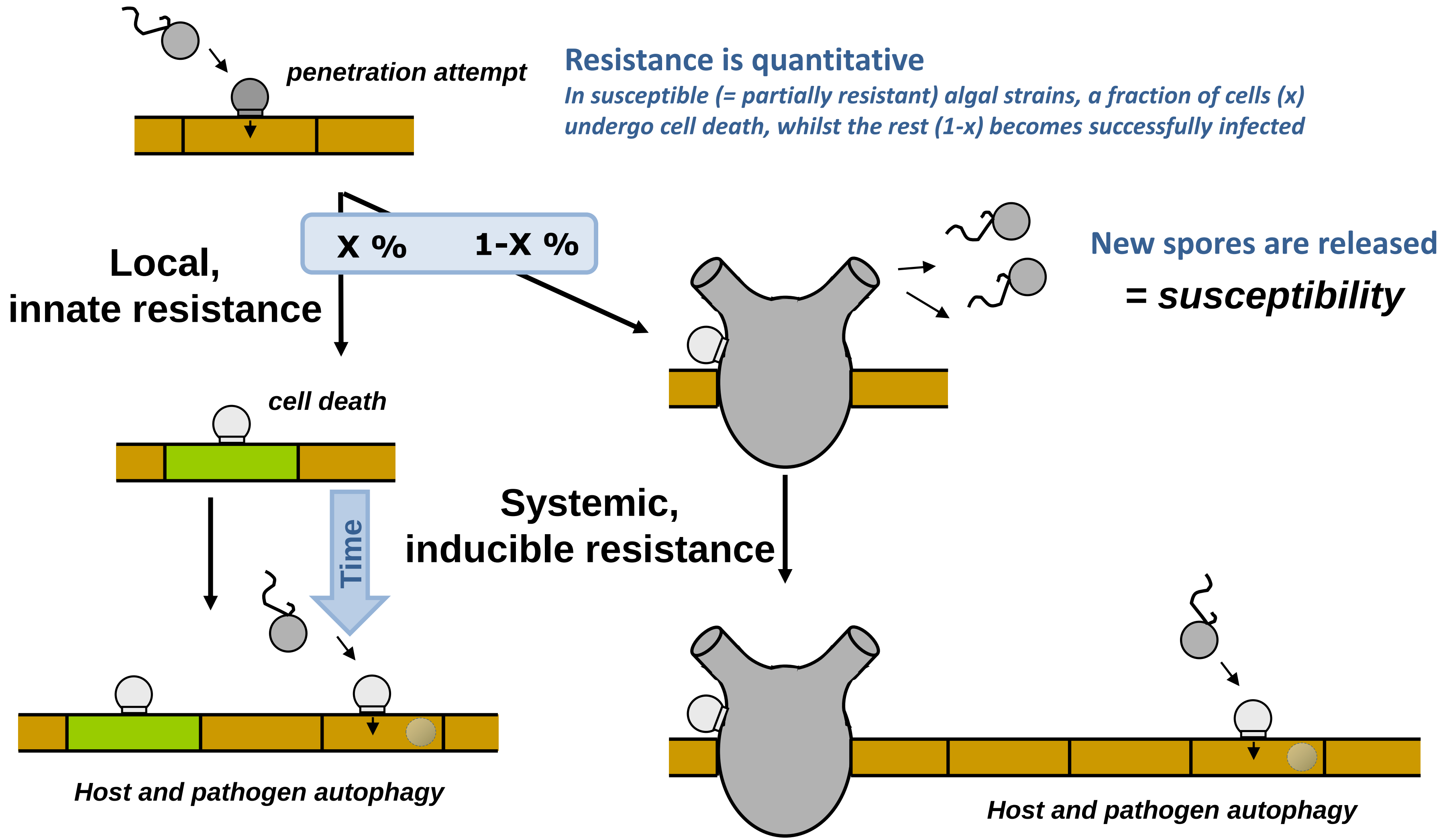
Others

Cell death
- Ox. Stress
- Cell wall
- Metacaspases
- TUNEL

Host autophagy:
- Resource mobilisation
- Cell-cell cooperation
- Pathogen digestion

NERC SCIENCE OF THE ENVIRONMENT · global seaweed · alff · FWF Der Wissenschaftsfonds. · CONICYT COMISIÓN NACIONAL DE INVESTIGACIÓN CIENTÍFICA Y TECNOLÓGICA

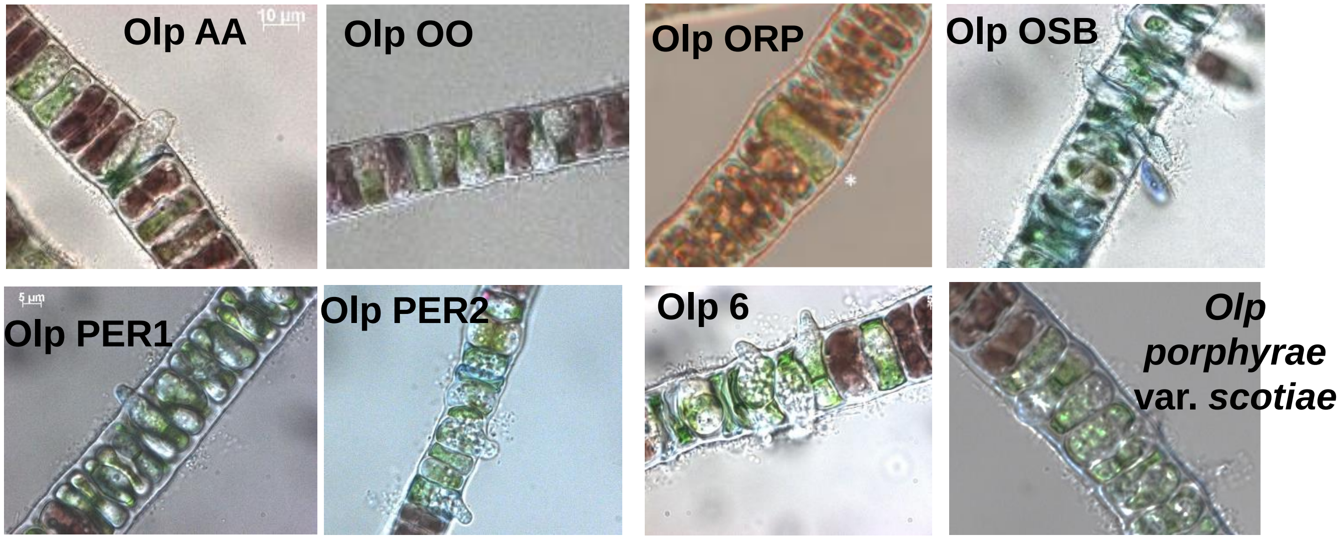
Innate, inducible, local and systemic defences in brown algae: a unified working model



☞ **Conserved across all brown algae, and all pathogens tested**

Gachon *et al.*, in prep.; Murua *et al.*, in prep.

How do red algae defend themselves against pathogens?



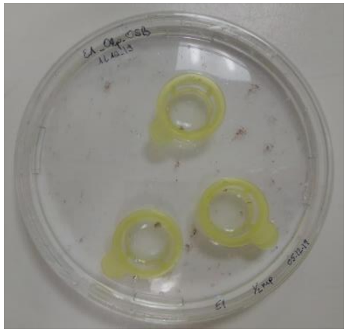

Yacine Badis


Janina Brakel


Martina Strittmatter


Gwang Hoon Kim

☞ Establishment of a collection of *Olpidiopsis* and *Bangia* strains



☞ Development of reproducible inoculation protocols

☞ Single cell whole genome amplification + Hiseq

☞ Transcriptomics *Ongoing…*

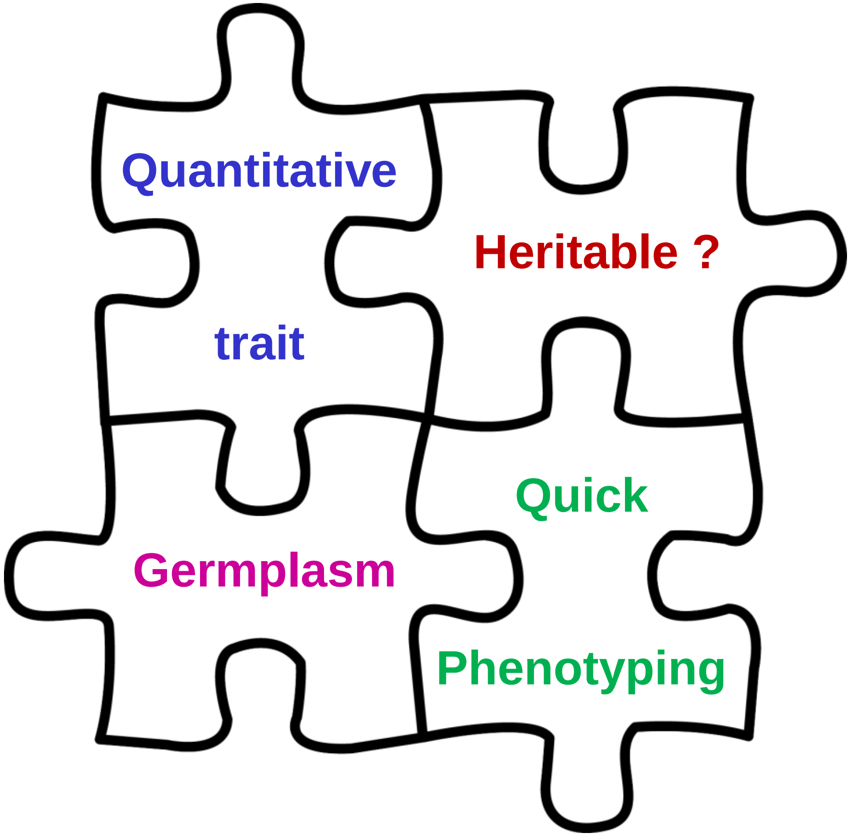

Andrea Garvetto


Sigrid Neuhauser, Uni. Innsbruck

gcrf global Seaweed

RESEARCH COUNCILS UK

Breeding for disease resistance…
Setting the scene



Heritable ?

Heritability of disease resistance in *Ectocarpus*

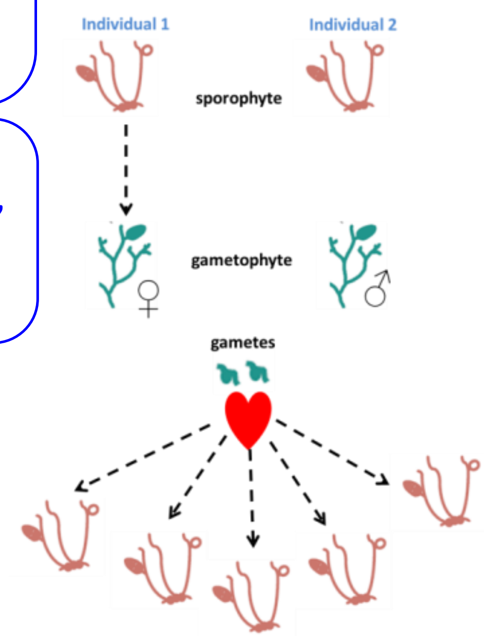
Prerequisite No1: different levels of disease resistance between genotypes, phenotype stable over time

Applied and Environmental Microbiology, Jan. 2009, p. 322–328 Vol. 75, No. 2
0099-2240/09/$08.00+0 doi:10.1128/AEM.01885-08

Detection of Differential Host Susceptibility to the Marine Oomycete Pathogen *Eurychasma dicksonii* by Real-Time PCR: Not All Algae Are Equal▿†

Claire M. M. Gachon,[1]* Martina Strittmatter,[1] Dieter G. Müller,[2] Julia Kleinteich,[2] and Frithjof C. Küpper[1]

Prerequisite No2: resistance to disease is a quantitative, probably heritable phenotype



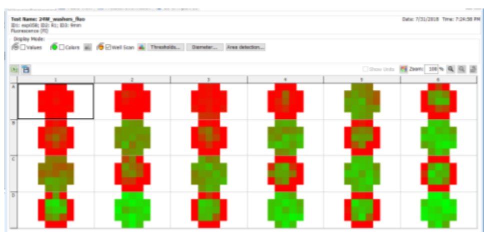
Genomia Fund

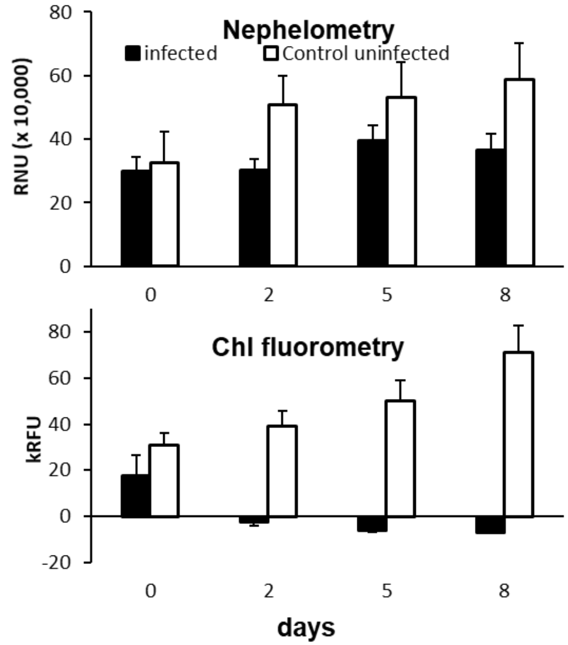
Strittmatter *et al*, in prep.

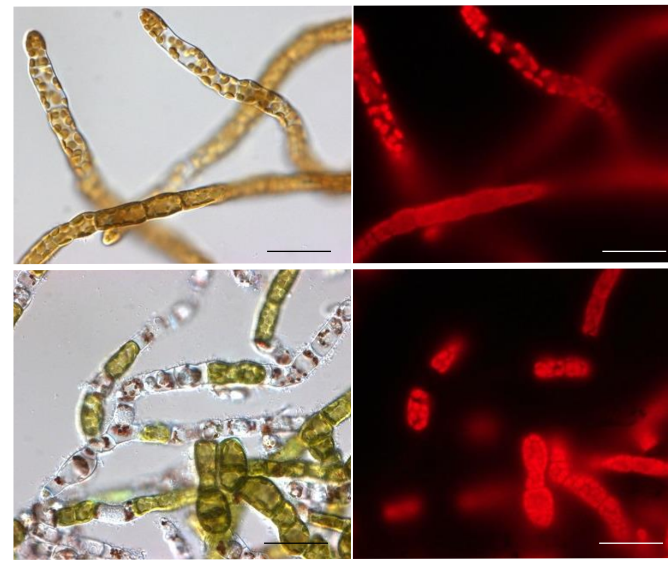
Quantitative, parallelisable, cheap bioassays to measure disease resistance

Quick Phenotyping

Non-invasive, continuous, growth and fertility monitoring with nephelometry

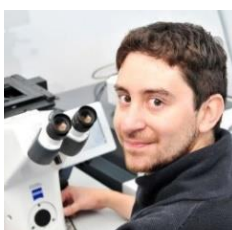






Calmes *et al.*, 2020, **Algal Research**

Benoit Calmes



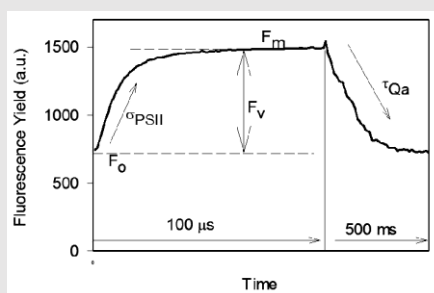
Pedro Murúa

NERC SCIENCE OF THE ENVIRONMENT

global seaweed

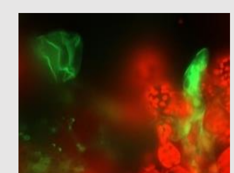
GENIALG

More non-invasive monitoring :
PAM fluorometry

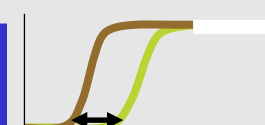


Endpoint measurement

Pathogen /host ratio with WGA-FITC staining



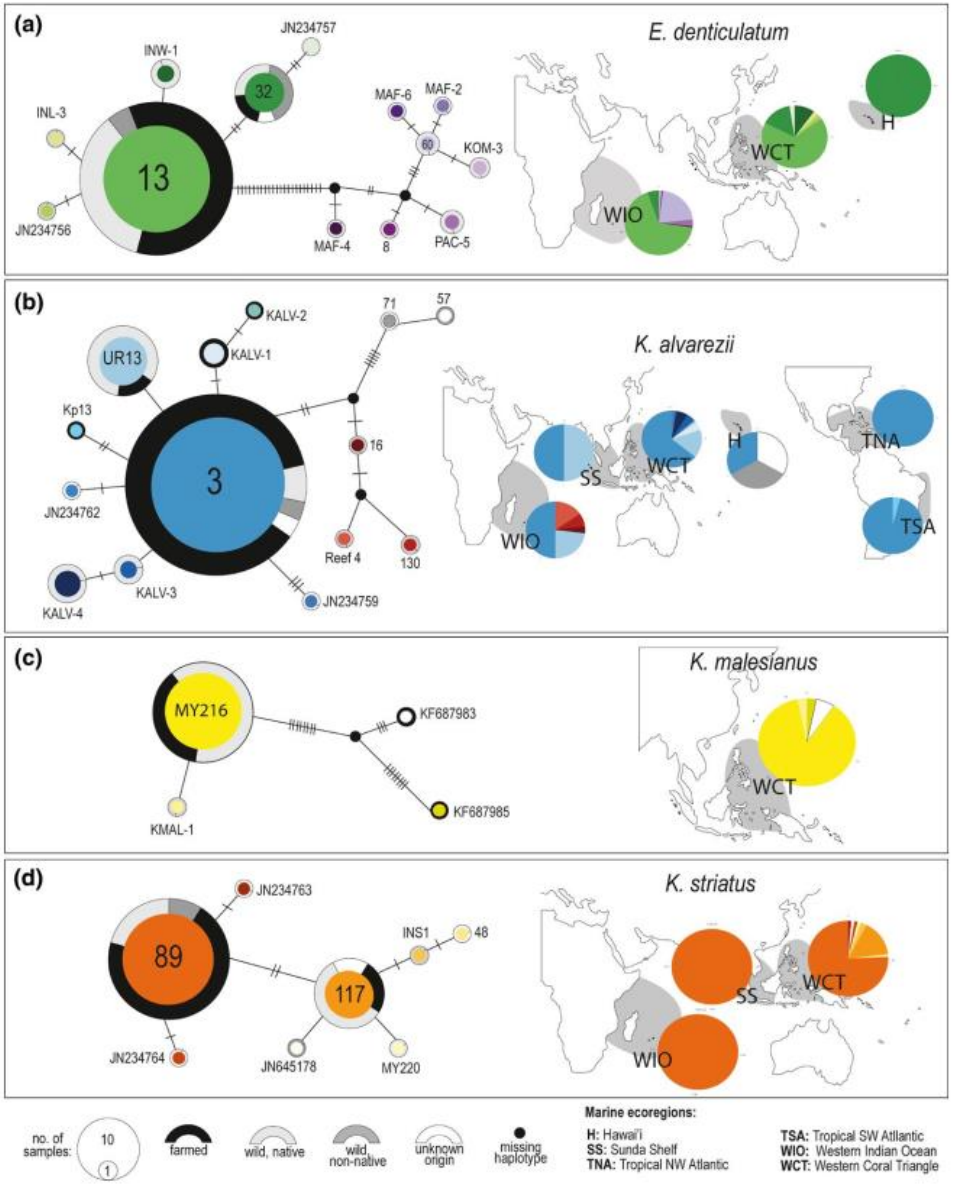
Pathogen/host ratio with qPCR



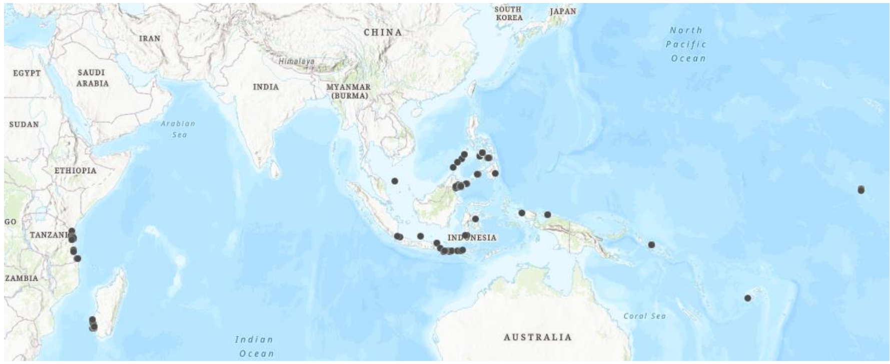
+ lots of cell death and autophagy markers

ΔCt = Ct *Patho* - Ct *Slat*

Exploring and harnessing the global diversity of farmed and wild eucheumatoids



Brakel *et al.*, Plants People Planet 2021.



- Field work in Malaysia, Philippines, Indonesia, Madagascar, Tanzania, Hawai'i, Pacific Islands…
- Search for new markers
- Biobanking in-country.

🡐 Sibonga *et al.*
ISAP conference 2021

Roleda *et al.*, 2021 ***Algae***
Tan *et al.*, in prep.
Brakel *et al.*, in prep.
…

gcrf global seaweed
RESEARCH COUNCILS UK

Exploring and harnessing the European diversity of *Saccharina latissima*: GWAS

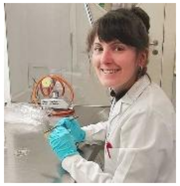
20+ populations in total,
20+ individuals per population
→ Clonal gametophytes isolates
→ Cryopreservation
→ ddRAD-seq genotyping

Callum O'Connell

Cecilia Rad-Menéndez

Marie-Mathilde Perrineau

Martina Strittmatter



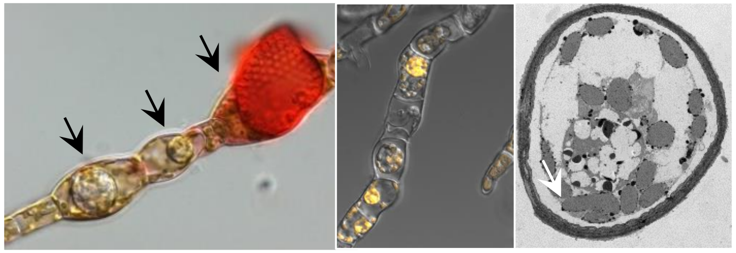
Carla Ruiz-Gonzalez

Culture Collection of algae & protozoa

GENIALG

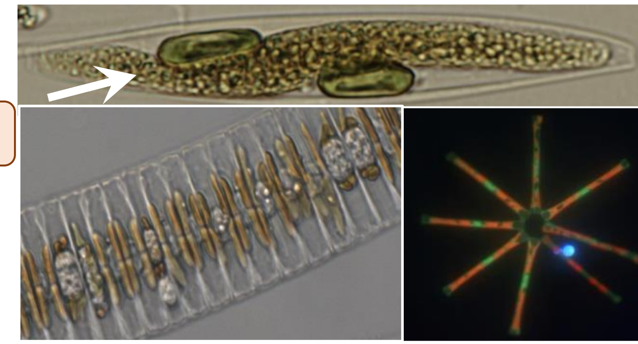
Thank you

Current research (2006-..)



Culture Collection of algae & protozoa

Culture collection



Cell biology

Transcriptomics

Metabolomics

Physiology

Ecology

Taxonomy

GWAS

Genomics

Algal host-pathogen interactions

Metabarcoding

Population genetics

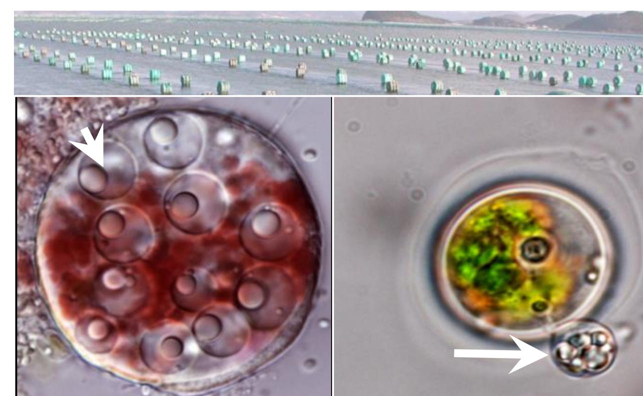
Single-cell -omics

Aquaculture

Biosecurity

Epidemiology

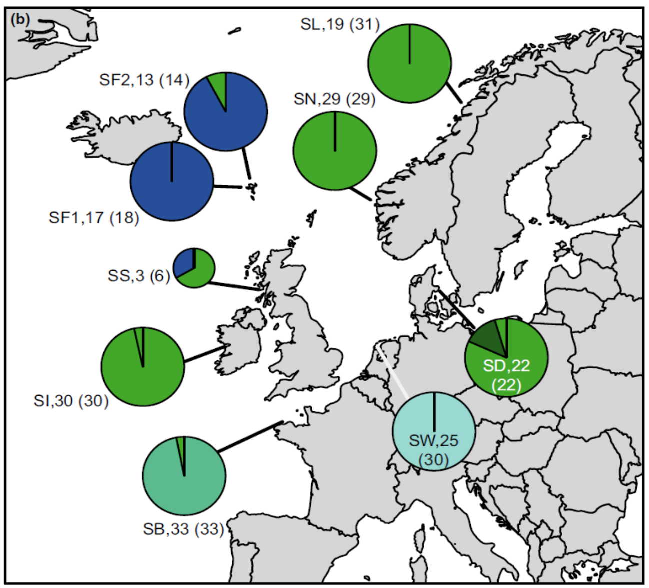
Disease management



GWAS on *Saccharina latissima*

“Biobank as much genetic diversity as possible, to increase chances of gathering best alleles”

Marie-Mathilde Perrineau

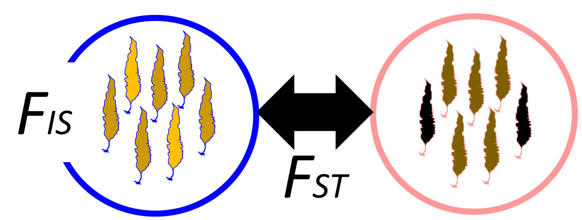


<u>Where to collect?</u>

- **Within-population** genetic diversity is generally low
- Substantial genetic differentiation **across Europe**
- Populations **spatially close are genetically close**

Guzinski et al. 2016, Moller Nielsen et al. 2016, Paulino et al. 2016, Luttikhuizen et al. 2018, Mooney et al. 2018, Neiva et al. 2018

→ Populations geographically distant
→ Focus on hotspot of diversity (IR/UK and PT/SP) and atypical environments.



<u>How many individuals to collect / population?</u>

Kalinowski 2005 shown that “when Fst was greater than 0.05, sampling fewer than 20 individuals (per population) should be sufficient”.

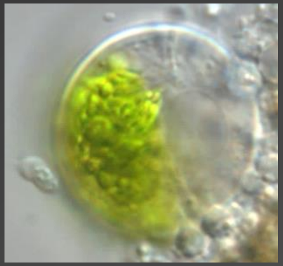
Back to freshwater: can we biocontrol the *Haematococcus* pathogen *Paraphysoderma sedebokerense* with bacteria?

Caroline Kunz

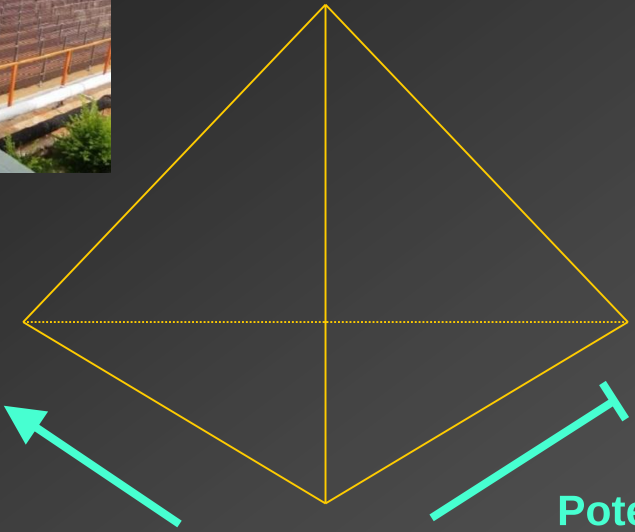
Martina Strittmatter

Claire Mallinger

H. pluvialis



P. sedebokerense



☞ The possibility to axenise both the alga and the pathogen, combined with the availability of a medium-throughput bioassay will be exploited to screen for bacteria able to help control the infection within the bacterial microbiome

Strittmatter et al. J. Appl. Phycol 2015 Allewaert et al. Algal Research 2018