Food and Biofuels from Microalgae Cultures: Opportunities and Challenges

which the ocean drives forces globally, while the debate has directed unprecedented public attention to the ocean at the same time that the vaunted North Atlantic cod collapsed, then failed to recover as expected. Some experts propose that the influence of human activities is significant enough to constitute a new geological period, the Anthropocene. Suddenly, the ocean has come into focus not only among natural scientists discovering ocean acidification and trophic cascades, but also among archaeologists studying early human evolution and migration and historians newly conscious that the ocean environment and human activities connected to it demand and deserve historical scrutiny. As our terrestrial bias slips aside, we find ourselves glimpsing the long and inextricable relationship between people and oceans, extending to evolutionary time but tightening with industrialization. Articulating this third discovery of the sea reveals a role for the humanities, and particularly for the history of science, in comprehending how knowledge about the nature enabled its use, and indeed its misuse, on a planet where the oceans are central rather than peripheral. *

The global ocean carbon sink: Recent trends and variability

PLENARY 3: THE OCEAN AND CLIMATE
Nicolas Gruber, ETH Zürich, Schweiz
FEBRUARY 17
13:30–14:30

Since the onset of the industrial revolution in the late 18th century, the ocean has taken up about 30% of the total anthropogenic emissions of CO2, thereby constituting the most important sink for this CO2. While the annual rate of uptake has increased considerably over this period, largely in response to the increase in atmospheric CO2, there is considerable concern that this sink might saturate or even reverse in response to future climate change. Here, I present and discuss the most recent estimates of the oceanic sink strength for atmospheric CO2 and how this sink might have changed and varied in the recent decades. These estimates are based on two very complimentary sets of observations, i.e. (i) surface ocean observations of the partial pressure of CO2, from which monthly resolved global air-sea CO2 fluxes can be estimated for the period from 1980 onward, and (ii) ocean interior observations of dissolved inorganic carbon and ancillary properties, from which the accumulation of anthropogenic CO2 between the 1990s and the mid-2000s can be derived. The ocean interior results suggest a global increase in the anthropogenic CO2 inventory of about 25 Pg C between 1994 and 2006, while the cumulative air-sea CO2 flux over this period amounts to about 19 Pg C. Assuming a cumulative outgassing flux of ~5 Pg of "natural" carbon stemming from the carbon input by rivers, the global ocean interior and surface perspective are consistent with each other, suggesting a mean oceanic uptake flux of about 2.0 Pg C yr-1 over this period. This flux is at the lower end of most other estimates (e.g., atmospheric data and ocean inversions). If correct, the ocean sink would have been smaller than expected from the increase in atmospheric CO2. The surface ocean observations suggest that most of this lower than expected uptake stems from the Southern Ocean, whose sink strength was particularly weak in the 1990s. However, over the last decade, the Southern Ocean sink strength appears to have increased substantially, causing the global ocean uptake to increase commensurably. These substantial decadal variations and trends in the ocean carbon sink suggest that the sink strength could be more susceptible to the impact of future climate change than currently suggested by Earth System Models. *

Shipping regulation, trade realities and social license: the promise (or not) of short sea shipping

PLENARY 4: SHIPPING
Mary Brooks, Rowe School of Business, Dalhousie University, Nova Scotia, Canada
FEBRUARY 18
8:30–9:30

Governments seeking to induce the growth and development of short sea shipping often pass market access regulations, either unilaterally or multilaterally, to create a broader market for short sea shipping or provide subsidies to operators to help them grow the market. As is often the case in business decisions, whether or not the private sector invests in the service by either buying it or selling it is more complex than just a case of "incentivize it and we will come." The presentation will build on a career of research on the topic in North and South America, Europe, Australia and New Zealand. It will examine three perspectives on the development of short sea shipping and the regulatory environment that supports it: (1) what governments seek and how they propose to implement, (2) what traders and ship operators require to commit and what completely deters their interest, and finally (3) what role is played by citizens and taxpayers. Each interest group can encourage short sea shipping or prevent its development. Taking such a holistic approach allows the audience to contemplate the promise and the reality of short sea shipping, and its probability of being more than just a niche transportation service. *

Food and Biofuels from Microalgae Cultures: Opportunities and Challenges

PLENARY 5: BLUE BIOTECHNOLOGY
Mario R. Tredici, Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente - Università degli Studi di Firenze, Italia
FEBRUARY 18
13:30–14:30

Microalgae present several advantages over plants as source of biofuels and food. They can be cultivated on arid lands unsuitable for agriculture using saline or brackish waters, do not require pesticides, have less dependency on seasonal variations, can accumulate high amounts of protein, oil or sugars, and synthesize at the same time valuable molecules such as vitamins, pigments and polyunsaturated fatty acids. These benefits have drawn significant interest in algae as source of biofuels and food in recent years.

Undoubtedly, microalgae as biofuel source have a huge potential, but it is also clear that many companies, particularly in the US, did a too early start based on the false assumption that algae can provide even 100 times as much biomass per hectare than traditional crops. In reality, productivity of algae cultures is not much higher than that of C4 crops, and their industrial exploitation is limited by several barriers, among which sustainable cultivation of selected strains at hundreds of hectares scale and the negative energy balance of the process are the major ones. In conclusion the potential is huge, but at present microalgae biomass is too expensive to compete with traditional food sources (crops) and fossil fuels.

Despite that large-scale commercial production of microalgae is mostly carried out in open ponds, most of the start-ups in the algae biofuel sector focus on photobioreactors (PBR) that

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provide a more controllable environment and limit the risk of contamination. Unfortunately, these advantages rarely compensate for the higher cost of PBR, although new low-cost designs are emerging, such as the Green Wall Panel (GWP), developed at the University of Florence and commercialized by Fotosintetica & Microbiologica S.r.l., Italy.

To reach a positive EROI the energy inputs for algae cultivation must be drastically reduced. However, some inputs, like that for mixing, are difficult to decrease without negatively impacting on the performances of the culture. For this reason a new stand-alone GWP has been designed that uses part (about 15%) of the impinging photons for photovoltaic (PV) generation of electric energy, thus covering all the operational energy needs of the cultivation (including harvesting). Experiments carried out in Florence have shown that, up to 20% of the impinging photons can be diverted from photosynthesis to photovoltaic generation of electric energy without impairing culture productivity. ⋆

REFERENCES

Tredici M. R. (2010) – Photobiology of microalgae mass cultures: understanding the tools for the next green revolution. Biofuels 1(1): 143–162,

Ocean ecosystem evolution in the face of global change

EVOLUTION IN THE SEA — FEBRUARY 17

Thorsten B. H. Reusch, GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany — 15:00–15:40

The organisms and species of the future ocean may not be the same as those we investigate today. More than 150 yrs after the publication of Darwin's theory of natural selection, the idea of adaptive evolutionary changes in response to climate change is slowly gaining momentum in the marine world. This talk views the major anthropogenic perturbations in the oceans, such as de-oxygenation, warming, fisheries and ocean acidification, as selection factors that elicit genetic changes at the population level if genetic variation is present. I summarize current approaches to study evolution in 'real time'. There are now several empirical examples that adaptive evolution may at least partly compensate the adverse effects of global change on populations and species we increasingly observe today. Some organismal groups such as marine microbes and phytoplankton may be particularly prone to rapid adaptive change, while others such as long-lived fish may not be able to evolve fast enough. Important knowledge gaps are conflicts between selection regimes, changes in interactions between species that are modulated by evolution, and the genetic/genomic basis to evolutionary change, which can now be addressed thanks to the revolution in '-omic' technologies. ⋆

Exploring microevolution and pelagic dispersal ecology using a common diatom

EVOLUTION IN THE SEA — FEBRUARY 17

Anna Godhe, University of Gothenburg, Department of Biological and Environmental Sciences, Sweden — 15:40–16:20

Marine planktonic diatoms are through their photosynthesis responsible for 20% of the global oxygen production, and constitute a high-quality base for the marine food chain world wide in coastal waters. Phytoplankton, including diatoms, are considered to have a ubiquitous

dispersal potential, as a consequence of their small size and immense population sizes. Our studies, using a common diatom species *Skeletonema marinoi*, have in contrast showed that phytoplankton populations are highly structured. Priority effects and local adaptation are prospective mechanisms for the strong genetic differentiation in absence of apparent physical dispersal barriers. Additionally, local populations anchor in their native area through a rich propagul bank of resting stages in the sediment. Resting stages of *S. marinoi* are viable in anoxic sediment for more than 100 years and we have found that a single population monopolize a local site for more than a century. From isotope dated sediment we germinate populations from the past and compare their respective genomes and phenotypes with the present populations. This promising system is currently used to evaluate evolvability of the genome over 100 years, which in this organism represent 40 000 generations. It also allows the study of genetic and phenotypic adaptation as a consequence of anthropogenic driven marine eutrophication. ⋆

Genomics in the sea: adaptation and speciation in marine snails Littorina

EVOLUTION IN THE SEA — FEBRUARY 17

Marina Panova, Biological and Environmental Sciences, Gothenburg University, Tjärnö, Sweden, The Linnaeus Centre for Marine Evolutionary Biology — 16:20–17:00

For a century genetic research has been limited to a handful of model species, none of which was marine. However, during the past few years new sequencing techniques gave us tools to study genetics of the evolution of the amazing biodiversity in the sea.

The focus of my research is on the rocky snails *Littorina*, especially on *Littorina saxatilis*. Over its North Atlantic range this species demonstrates extreme morphological variation (it has been described under 30 different species names) and wide spectrum of environmental adaptations. One of the most pronounced is adaptations to crab predation and wave exposure, that evolved independently in three geographic regions: the coast of Britain, the Galician coast of Spain and the Swedish west coast. For decades these locally adapted and morphologically distinct populations (called "ecotypes") attracted the attention of evolutionary biologists; now we can start search for genes behind this variation.

In my talk I will present our recent advances on understanding the genetic changes underlying the adaptations in *Littorina* using various molecular tools: characterization of variation and expression of single genes; analysis of expression of thousands of genes with micro-arrays, whole genome scan for variations by RNA-seq and RAD genotyping techniques and, finally, the *Littorina de-novo* genome sequencing project.

I will finish with few words about challenges to study "genomics in the sea": the complexity of genomes of many marine species (not least the molluscs), still low number of sequenced genomes as compared to the vast biodiversity in the sea and novel genes that are likely harboured by marine genomes. ⋆

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17 FEBRUARY

9:00	**INTRODUCTION**, STAFFAN NORMARK, PERMANENT SECRETARY, THE ROYAL SWEDISH ACADEMY OF SCIENCES
9:10	**WELCOME**, KARIN MARKIDES, VICE CHANCELLOR, CHALMERS UNIVERSITY OF TECHNOLOGY
9:20	**WELCOME**, PAM FREDMAN, VICE CHANCELLOR, UNIVERSITY OF GOTHENBURG
9:30–10:30	PLENARY 1: **LOSS AND GAIN OF SOCIO-ECONOMIC VALUES OF ECOSYSTEM** CHAIR: KERSTIN JOHANNESSON, UNIVERSITY OF GOTHENBURG *Ecosystem tipping points and the death spiral of coral reefs: chemical ecology as drug discovery at the ecosystem scale* Mark Hay, Georgia Institute of Technology
10:30–11:00	REFRESHMENT BREAK
11:00–12:00	PLENARY 2: **HISTORY OF MAN AND THE SEA** CHAIR: THOMAS STERNER, UNIVERSITY OF GOTHENBURG *Third Discovery of the Sea?* Helen Rozwadowski, University of Connecticut
12:15–13:15	LUNCH BREAK (LUNCH CAN BE PURCHASED AT THE CONFERENCE CENTRE)
13:30–14:30	PLENARY 3: **THE OCEAN AND CLIMATE** CHAIR: LEIF G. ANDERSON, UNIVERSITY OF GOTHENBURG *The global ocean carbon sink: Recent trends and variability* Nicolas Gruber, ETH Zürich
14:30–15:00	REFRESHMENT BREAK

	EVOLUTION IN THE SEA CHAIR: CARL ANDRÉ, UNIVERSITY OF GOTHENBURG	**LIVING BY THE SEA** CHAIR: LENA MOSSBERG, UNIVERSITY OF GOTHENBURG
15:00–15:40	*Ocean ecosystem evolution in the face of global change* Torsten B.H. Reusch, Geomar	*Quantifying and Valuing Ecosystem Services for Coastal Management* Edward B. Barbier, University of Wyoming
15:40–16:20	*Exploring microevolution and pelagic dispersal ecology using a common diatom* Anna Godhe, University of Gothenburg	*Prospect for successful management of marine resources* Sverker C. Jagers, University of Gothenburg
16:20–17:00	*Genomics in the sea: adaptation and speciation in marine snails Littorina* Marina Panova, University of Gothenburg	*re-calibrating Coastal Governance: Challenges and Opportunities* Dianne Dredge, Aalborg University

18 FEBRUARY

8:30–9:30	PLENARY 4: **SHIPPING** CHAIR: JOHAN WOXENIUS, UNIVERSITY OF GOTHENBURG *Shipping regulation, trade realities and social license: the promise (or not) of short sea shipping* Mary Brooks, Dalhousie University
9:30–10:00	REFRESHMENT BREAK

	THE SEA AS A RESOURCE FOR HUMANS CHAIR: EVA ALBERS, CHALMERS	**THE BALTIC SEA SYSTEM** CHAIR GÖRAN BJÖRCK, UNIVERSITY OF GOTHENBURG
10:00–10:40	*Eating fish for two* Sean Strain, University of Ulster	*Understanding Hypoxia in the Baltic Sea* Caroline P. Slomp, Utrecht University
10:40–11:20	*Biorefinery of microlgae* René Wijffels, Wageningen University	*The ecology of the 'coastal filter' in the Baltic Sea: structure, function, and ecosystem adaptation under environmental stress* Erik Bonsdorff, Åbo Akademi University
11:20–12:00	*Chemical signaling in marine ecosystems: From microscopic algae to food webs to drug discovery* Julia Kubanek, Georgia Institute of Technology	*Baltic Sea physical oceanography supports interests of society* Jüri Elken, Tallinn University of Technology
12:15–13:15	LUNCH BREAK (LUNCH CAN BE PURCHASED AT THE CONFERENCE CENTRE)	
13:30–14:30	PLENARY 5: **BLUE BIOTECHNOLOGY** CHAIR ANNE-MARIE HERMANSSON, CHALMERS *Food and Biofuels from Microalgae Cultures: Opportunities and Challenges* Mario R. Tredici, University of Florence	
14:30–15:00	REFRESHMENT BREAK	

	FISHERIES CHAIR: FRIEDERIKE ZIEGLER, THE SWEDISH INSTITUTE FOR FOOD AND BIOTECHNOLOGY (SIK)	**OCEAN ACIDIFICATION** CHAIR: DAVID TURNER, UNIVERSITY OF GOTHENBURG
15:00–15:40	*Population Dynamics, Species Resilience, and Adaptation to Environmental Change: The Importance of Spatial Scale* Jeff Hutchings, Dalhousie University	*Ocean Acidification: A Global Problem with Local Impacts* Richard A. Feely, NOAA, Pacific Marine Environmental Laboratory
15:40–16:20	*Effects of nutrient pollution and overfishing on the coastal ecosystem of western Sweden* Per Moksnes, University of Gothenburg	*Responding to Ocean Acidification in the United States* Libby Jewett, NOAA, Office of Oceanic and Atmospheric Research
16:20–17:00	*Population divergence in marine fishes; genomic signatures with implications for conservation and management* Jakob Hemmer Hansen, Technical University of Denmark	*Get ready for ocean acidification* Sam Dupont, University of Gothenburg