Project information

Keywords

Regime shifts Arctic benthos Macroalgae Ice cover

Project title

Climate-driven regime shifts in arctic rocky-bottom communities: Causation and implications for ecosystem functioning

Year

2016-2018

Project leader

Raul Primicerio

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

78 °N, 10 °E, 80 °N, 20 °E

Participants

UiT, The Arctic University of Norway – Raul Primicerio (PL), Bodil Bluhm, Susanne Kortsch, Kim Scherrer, Jørgen Berge, Bjørn Gulliksen

AkvaplanNIVA – Frank Beuchel

UNIS – Øystein Varpe

Flagship

Fjord and Coast

Funding Source

Fram centre

Summary of Results

Climate driven change in water temperature and sea-ice coverage have been suggested as triggers of observed ecological regime shifts in arctic ecosystems. To investigate the causes of documented regime shifts in rocky-bottom benthic communities, and their implications for ecosystem functioning, we: i. parametrized and analyzed a mechanistic model of algae competition, with parameter values influenced by light and temperature, to explain macroalgae takeover; ii. extended and analysed long-term series data of two benthic communities from Svalbard fjords; iii. evaluated the implications of the observed regime shifts for ecosystem functioning.

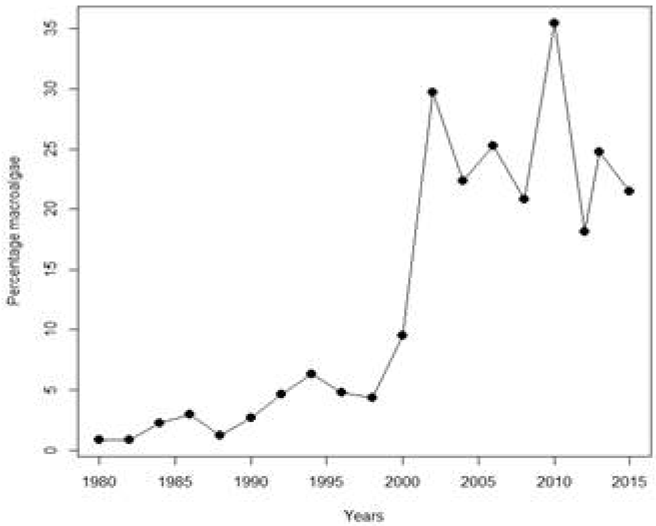

Figure 1. Time series of macroalgae cover in Smeerenburgfjord. The sudden increase after year 2000 coincides with a regime shift in the benthic community.

We used a competition model to investigate the dynamics of interacting calcareous algae and macroalgae. The

areal expansion of each species depends on the growth rates, death rates and competitive abilities of the

interacting species. By assessing how the equilibrium states were affected by the light and temperature effects

on model parameters, we evaluated the importance of light and temperature for algae dominance.

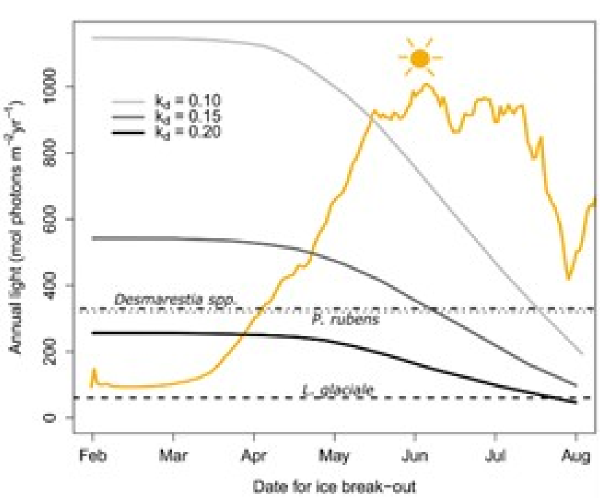

Figure 2. Modelled annual light budget (ALB) at 15 m depth as a function of the date for ice break-out in Svalbard. The minimum annual light requirements (mALB) for each algal species are marked with dashed lines. The turbidity of the water, represented by the light attenuation coefficient (k_d=0.10, 0.15, 0.20), has a large impact on annual light. Yellow line represents mean daily irradiance in Kongsfjord.

Our modelling study suggests that, in the Arctic, increasing underwater light triggers climate-driven benthic regime shifts that involve macroalgae. Warmer seawater temperature only plays a secondary role. Yet, both temperature and competitive abilities can influence the dominance patterns among the macroalgae.

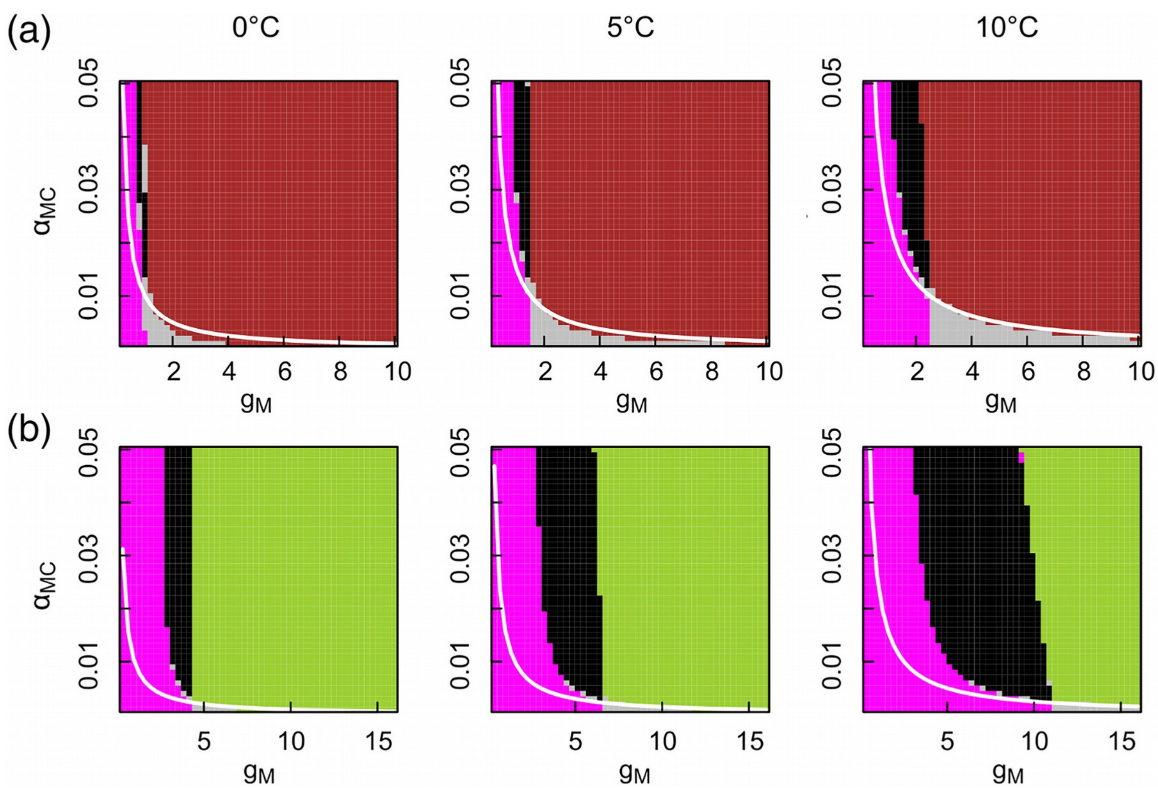

Figure 3. Model outcomes at 0 C, 5 C, and 10 C, for the interaction between calcareous algae and (a) *P. rubens*, and (b) *Desmerestia* spp. The pink area represents a region of competitive exclusion of macroalgae. The brown and green areas represents competitive exclusion of calcareous algae. The grey area is a region of stable coexistence and the black area shows start-dependent exclusion. White lines represent the (g*k) values at which the respective overgrowth rates are equal. Below this line calcareous algae are superior overgrowers, above the line macroalgae are the better

overgrowers.

The observed light-driven expansion of macroalgae at the expense of calcareous algae and sessile benthic invertebrates has implications for the functioning of polar benthic communities. Suggested implications include alterations in regional biodiversity, increased carbon sequestration, and a new three-dimensional habitat, facilitating and promoting biodiversity and community complexity via ecosystem engineering.

An analysis of the structural change in invertebrate communities associated with the macroalgae takeover supports the notion that macroalgae are foundation species in these ecosystems, their pivotal role being mediated by both ecological interactions and ecosystem engineering. A functional traits analysis further indicates that the observed structural change, which is partly triggered by the climate driven macroalgae takeover, results in an alteration of functional characterization and an increased functional diversity of the benthic communities. The latter results imply that both ecosystem functioning and vulnerability (adaptability) are being affected by the documented climate driven regime shifts.

Master and PhD-students involved in the project

Master student Amalia Keck

PhD student Kim Scherrer

Postdoc Susanne Kortsch

For the Management

Our findings suggest that macroalgae takeover in Arctic benthic communities is driven by climate warming, and that it triggers rapid and extensive changes in the associated invertebrate communities with substantial implications for ecosystem functioning and vulnerability to environmental perturbation. Such findings have relevance for the management and conservation of Arctic coastal waters, in a period of quick transition to macroalgae dominated communities due to a rapid warming of the Arctic.

Published Results/Planned Publications

Kim Scherrer, Susanne Kortsch, Øystein Varpe, Gesa Weyhenmeyer, Bjørn Gulliksen, Raul Primicerio. 2018. Mechanistic model identifies increasing light availability due to sea ice reductions as cause for increasing macroalgae cover in the Arctic. *Limnology & Oceanography* https://doi.org/10.1002/lno.11043

Susanne Kortsch, Raul Primicerio, Frank Beuchel, Bodil Bluhm, Jørgen Berge, Bjørn Gulliksen. Structural and functional change in arctic benthic communities following climate driven regime shifts. *Ecology* In prep

Amalia Keck, Susanne Kortsch, Raul Primicerio, Frank Beuchel, Jørgen Berge, Bjørn Gulliksen, Bodil Bluhm. Resilience and adaptability of Arctic rocky bottom communities. *Marine Ecology Progress Series* In prep

Communicated Results

Bodil Bluhm (2016) Climate driven regime shifts in Arctic benthos. Circumpolar Biodiversity Monitoring Program (CAFF , Arctic Council)

Kim Scherrer (2016) Modelling climate driven macroalgae takeover in the Arctic. Oral presentation, UiT AKVASEM seminar, Tromsø

Raul Primicerio (2016) Climate-driven regime shifts in arctic rocky bottom communities. Causation and implications for ecosystem functioning. Oral presentation, Fjord and Coast flagship meeting, Sommerøy

Raul Primicerio et al. (2016) Climate-driven regime shifts in arctic rocky bottom communities. Causation and implications for ecosystem functioning. Poster, Fram dagen, Tromsø

Kim Scherrer et al. (2017) Modelling climate driven macroalgae takeover in the Arctic. Oral presentation, *Arctic Frontiers* conference, Tromsø

Susanne Kortsch et al. (2017) Climate driven regime shifts in Arctic benthic communities. Oral presentation, *ESSAS* conference, Tromsø

Amalia Keck (2018) Master thesis presentation. Course 'Life history adaptations to seasonality'. UNIS, Svalbard

Amalia Keck (2018) Master thesis defense. UiT, Tromsø

Raul Primicerio (2018) Benthos and Arctic marine ecosystems management. Oral presentation, Fjord and Coast flagship meeting, Fram Centre, Tromsø

Interdisciplinary Cooperation

The project developed a process based modelling approach linking physical (underwater light) and biological phenomena that was instrumental to address climate change related triggers of regime shifts in benthos.

Budget in accordance to results

Funding from Fram was essential to cover the model analyses by Kim Scherrer, including her travel costs and the production of the manuscript (Scherrer et al.), and the functional analysis of the extended time series by postdoc Susanne Kortsch. It also played an important role in promoting activities, communication and scientific exchange among participants from the different institutions involved in the project that ensured rapid and substantial progress.

Could results from the project be subject for any commercial utilization

No

Conclusions

The modelling results have stressed the importance of underwater light for the dominance of macroalgae in Artcic sea bottom communities. Underwater light in the Arctic is a function of sea ice cover and turbidity, and both are affected by climate warming. Future applications of our model will help predict the depth distribution of macroalgae and their dominance under specific combinations of ice cover and turbidity. In addition to our mathematical model of algae competition, we have developed qualitative models addressing the impact of macroalgae takeover on benthic invertebrates, and quantitative tools to assess ecosystem functioning relying on functional traits and food web topology data.