Project information

Keywords
kelp forest, sea urchins, recruitment, crab predation, ecosystem recovery, ecosystem services
Project title
Recovery of coastal kelp ecosystems – driven by climate change or predators?
Year
2017
Project leader
Hartvig Christie
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
Tromsø area (69°85'N, 18°60'E), Vega area (65°78', 11°95'
Participants

Hartvig Christie, NIVA

Project participants: Norwegian Institute for Water Research (NIVA) Eli Rinde, Hege Gundersen, Trine Bekkby, Camilla W. Fagerli, Wenting Chen, Pernilla Carlsson

Akvaplan-niva: Tor Arne Hangstad, Magnus Aune

UiT The Arctic University of Norway: Prof. Torstein Pedersen (just a small contribution)

The project results have benefited a cooperation and comparison with IMR (Hans Kristian Strand and Frithjof Moy) project Fjordkalk in Porsangerfjorden up to 2016. Also participation on the Coralline algae project and the National program for mapping of biodiversity – coast (NIVA) has given input and indirectly support to this project in 2016 and 2017.

Flagship
Fjord and Coast
Funding Source

Fram Centre

Funding from FRAM: 400 000

Other funding:

For 2017 the project has no other direct funding. The 2017 tasks have been fulfilled thanks to a considerable extra effort and equipment from NIVA, and benefitted by cooperation and sharing costs with other NIVA projects in Nordland, Troms and Finnmark: MERCES WP3, MON, ØKOKYST, Nasjonale program for kartlegging av naturtyper.

This project has earlier performed successful field works at recovered kelp beds and compared these kelp beds with adjacent persistent sea urchin barren grounds. Follow up samples in 2016 and 2017 support the results of increasing development of invertebrates and fish in the recovered kelp beds in Nordland and Finnmark. The results show a clear ecosystem change from no visible benthic primary production and dominated by sea urchins and scavengers, flipping to a community function of a more "natural" trophic structure with rich benthic primary production, high density of mesograzers, mesopredators like small fish and crabs, and larger fish (cod). We have in cooperation with environmental economists at NIVA identified ecosystem services gained by the kelp forest recovery:

- Significant increase in benthic primary production
- Increase in biodiversity
- Habitats for juvenile codfish
- Improved nutrient and habitat conditions for commercial fish and crabs
- Bioremediation and storage of CO_2
- Increasing gonad production in remaining sea urchins
- Increased value creation by improving fishery, tourism quality, potentially exploitation of kelp and sea urchins.

The kelp recovery has rather been patchy than a uniform northwards expansion, but has since the 1990ies taken part along a coastline of 660 km. This should imply a very high monetary and non-monetary gain for this coastline.

The 2017 survey and experiment revealed the following pattern of sea urchin recruitment and kelp bed recovery.

Southern Nordland: Low sea urchin recruitment as found earlier, sea urchins are stressed by the increasing temperature and crab predation, kelp recovery on large areas but still considerable bottom areas grazed by remaining old sea urchins. Northern Nordland and Southern Troms: Very high densities of sea urchin recruits/juveniles but many observations of kelp recovery areas. This indicate crab predation of adult sea urchins, but need further testing.

Tromsø area and Vest Finnmark: Very high density of both sea urchin recruits and adult urchins, and no kelp recovery. Cold water and low crab abundance benefit survival of juvenile and adult sea urchins.

East Finnmark: Mainly dominated by sea urchins, but kelp forest recovery observed in Porsanger and Bøkefjord. Here, the red king crab predation affects the sea urchins.

Aquarium experiments revealed that the red king crab is not an efficient predator on juvenile urchins while living cryptic, but rather on the adult open living individuals.

Highlights:

Large areas of the Nordland and southern Troms coast are now covered by productive and diverse kelp forest ecosystems after about 45 years of sea urchin grazing. The gradually reduction of sea urchins in southern Nordland can be linked to a direct effect of climatic change (increasing temperature), but further north to an indirect effect by climatic changes that benefit the crab predator expansion. Crab predation is mainly efficient on the post juvenile stages and kelp recovery occur in spite of high sea urchin recruitment.

The recovered kelp forests support an increasing fauna included fish and crabs, and lead to a number of ecosystem services. The new kelp beds benefit juvenile cod-fish.

For the Management

The large scale shift from underwater desert to rich kelp forests is of great importance for environmental management and value creation. Recovery of kelp forests in patches have now (summer 2017) been observed as far north as to Harstad and have since the 1990ies occurred along 660 km of coastline. These new kelp beds will contribute with many million tons of nutrients (biomass production) to the coastal areas and lead to increased biodiversity at many trophic levels, included fish production. E.g. gill net fishing in the new kelp forests has shown promising results for younger codfish year classes.

Ocean warming is an important driver for the observed changes. Sea temperature seems now to be too high for coastal sea urchin recruitment south of the Arctic Circle. The attached figure on density of juvenile sea urchins illustrate a high recruitment of urchins further north, but in spite of this kelp recovery was found north to the Harstad area. The northwards extension of predators as *Cancer* and *Carcinus* crabs facilitated by increasing temperature

have been related to sea urchin disappearance. Both field observations and aquarium experiments support the hypothesis that crabs do not prey on the small urchins living in cryptic habitats, but are rather efficient predators on adult sea urchins.

The extension of crabs and kelp recovery are expected to gradually expand northwards.

The increasing crab populations is facilitated by low predation, increasing temperature and nutrients from the restored kelp production, and the effects of changes in cod and crab populations and related interactions will be a challenge but also a guideline for future coastal management. Also the role of climate changes, particularly increasing temperature and gradually changes northwards of this system will be a factor for consideration. The finding of kelp forest recovery in southern Troms for the first time indicates a further northwards movement of the sea urchin kelp border.

Published Results/Planned Publications

The data and effort from this Flagship project has to larger or smaller extent contributed to a number of publications and presentations during the last two years:

Norderhaug KM**,** Gundersen H, Hobæk A, Anglès d'Auriac MB, Fagerli CW, Dahl K, Christie H. 2016. Genetic diversity of the NE Atlantic sea urchin *Strongylocentrotus droebachiensis* unveils chaotic genetic patchiness possibly linked to local selective pressure. Mar Biol 163:36-49.

Araujo RM, Assis J, Airoldi L, Barbara I, Bartsch I, Bekkby T, Christie H, et al. (2016). Status, trends and drivers of kelp forests in Europe: an expert assessmen. Biodiversity and Concervation. BIOC-D-15-00974R3

Fagerli CW, Stadniczeñko, SG, Pedersen MF, Christie H, Fredriksen S, Norderhaug KM (2016). Are skeletal ossicles in echinoids unreliable chronometers? Reply to

Russell and Narváez comment on “Population dynamics of Strongylocentrotus droebachiensis in kelp forests and barren grounds in Norway” by Fagerli et al. 2015. (Marine Biology)

Christie H. Norderhaug KM. (2017). Secondary production. In E. Olafsson (Ed) Marine macrophytes as foundation species. CRCPress, Taylor & Francis Group. (pp161-176)

Abdullah MI, Fredriksen S, Christie H. (2017). The impact of the kelp (Laminaria hyperborea) forest on the organic matter content in sediment of the west coastal of Norway. Mar Biol Res, Vol.13(2), p.1-10

Christie H, H Gundersen, E Rinde, KM Norderhaug, C W Fagerli1, T Bekkby, J K Gitmark, T Pedersen. Can multitrophic interactions and climate change regulate large scale kelp - sea urchin distribution? (To be resubmitted after review)

Christie H. Bekkby T. Norderhaug KM. Beyer J, Jørgensen NM. Sea urchin overgrazing make seaweed communities at rocky shores vulnerable for oil spill impacts: Implications for coastal management. (To be resubmitted after review)

Christie H. Fagerli CW. Rinde E. Pedersen T. Recovery of ecosystem structure and function when sea urchin disappear. (Manuscript under preparation)

Two talks at the 11th International Temperate Reef Symposium (ITRS), Pisa, Italy, 2016:

H Christie, E Rinde, C Fagerli, T Pedersen. Restoration of kelp forest ecosystems after 45 years of sea urchin grazing.

Bekkby T, Rinde E, Norderhaug KM, Fagerli CW, Angeltveit G, Gitmark JK, Gundersen H, Tveiten L, Christie H. Interactive dynamics between abiotic factors, sea urchins and kelp forests. Key note presentation.

Christie H 2017. Dette vinner vi når kråkebollene dør. Forskning.no

Christie H. Fagerli CW. 2017. Recovery of coastal kelp ecosystems. Foredrag på årsmøte til Flaggskip Fjord og Kyst.

Christie H m fl. Mekanismer bak skifte fra kråkeboller til tareskog, som igjen fører til mer mat og mangfold langs kysten. Foredrag i Norske Havforskeres Forening, oktober 2017.

Christie H. Om tareskog, kråkeboller, forvaltning og dyrking av tare. NRK radio P2, Ekko, to innslag, 18 og 25 oktober 2017.

Communicated Results

The results concerning large scale sea urchin decrease, crab increase and kelp reforestation have been communicated through media, directly to environmental authorities (mainly Miljødirektoratet), and to commercial kelp and sea urchin harvest industry.

Results have been presented in Forskning.no, NRK2 radio and newspapers (DN), and on talks at national events (Norske Havforskeres Forening and on Flagship workshops).

Two oral presentations from the project have been given at the International Temperate Reef Symposium in Italy in 2016, and two on EMBS, Germany 2015.

Results have been directly communicated to the SINTEF seaweed production NRC project MACROSEA under the Havbruk2 program, the NIVA project KELPRO in Havbruk2, to Seaweed Energy Solutions and other commercial seaweed actors, and to the sea urchin company KASTON.

The results have been supporting national reports on environmental and ecosystem services in northern Norway.

Interdisciplinary Cooperation

The project application includes cooperation between marine biologists and environmental economists. The social sciences and environmental economists have been working with data from this project in 2016 and 2017 and identified win-win situations and a number of ecosystem services by kelp forest recovery so far. This will be further developed in close cooperation in new projects and proposals and will strengthen the communication of the value of kelp forest recovery as well as increasing value of remaining sea urchins and the increasing crab populations. The same core persons are involved in our project and the sea urchin project in MIKON Flagship and data from these projects develop mutually.

This inter-disciplinary cooperation has led to strengthening of the communication between biologists and social sciences and lead to more cooperation of other applications and projects. The Flagship results has been an important contribution to the initiative of the interdisciplinary BLUE FOREST Network between NIVA, IMR and Grid Arendal, the interdisciplinary cooperation in the EU project MERCES on habitat restoration, and to an Ocean Acidification project to AMAP.

The cooperation between both benthic ecologists, social science and mathematicians in NIVA, fishery scientists at NOFIMA, and both social scientists and fishery biologists at UiT has been successful through the above mentioned activities.

Budget in accordance to results

The Fram Centre funding has been the only direct funding of the activity in 2016 and 2017. The project has in earlier years benefited from activities funded by KLD and NRC for completing the activities. Field activities over larger areas including diving and fishing are connected with high expenses. The activity plan has been somewhat reduced due to the limited funding, but travel cost cooperation with the Corraline algae project, Fjordkalk (IMR in Porsanger), and National program for mapping of biodiversity – coast (Finnmark), MON (miljøovervåking i Nordland) and ØKOKYST have been to great support for å fulfilling of a successful sampling strategy. The funding from the FRAM Centre to the Ecourchin project in MIKON has boosted the work with the social science part of the project.

The funding from the FRAM Flagship has been of great value for keeping up a continuation of the studies crucial for the understanding of the ongoing changes from sea urchins to kelp. It is important to take the opportunity of this large scale event to explore the processes of changes in climate and predation behind the regime shift. As the scientist experienced in this field of sea urchin and kelp problems are at the end of their careers, this project has been important to introduce and transfer relevant competence to younger scientists in the field. The ongoing flips from sea urchins to kelp forests are of such a considerable scale of space, time, and

economy that it is important to keep up the knowledge and the research activities. Further, the funding of this project has been of importance for initiating new projects and proposals in collaboration of coastal ecology and social science.

Could results from the project be subject for any commercial utilization

Yes

If Yes

Recovery of millions of tons of kelp may be a future resource directly and may contribute to increased production of commercial resources as fish and crabs. This will also benefit tourism. The bullet points in section 5. show ecosystem services and possible value creation.

A combination of increasing temperature and nutrients (kelp production) will benefit northwards increase in edible crab (*Cancer pagurus*) and also other resources as scallops. Catch statistics support this gradual northward exploitation.

The kelp trawling industry has taken advantage of our results and has now permission from fishery authorities to increase their harvest activity further north. The increasing interest in cultivation and exploitation of other seaweed species has resulted in extensive contact with the kelp farming and seaweed industry. Our results showing more persistent and healthy sugar kelp beds in North Norway than further south have increased interest in commercial activities of kelp farming in the north.

The remaining sea urchins, which still cover large coastal areas, have a growing interest, and our results can be utilized directly and for a future planning of sustainable harvest. The industrial company KASTON has been interested in our data on the remaining resources and the findings of increased roe quality (increased gonad index) close to the recovered kelps. Sea urchin harvest may contribute to further kelp recovery, a problem we cheer with the Ecourchin project in MIKON. This topic has also resulted in closer cooperation with NOFIMA.

Conclusions

This project has given documentation on further large scale management and utilization perspectives of coastal resources belonging to four trophic levels that interact, however the strength of the interactions are more vague further up trophic levels. In a future management of this system, e.g. dealing with conflicts between exploitation and conservation, or enhancement of ecosystem flip to kelps, there is a need for more quantitative knowledge about the interactions, phase shifts and resilience within the two states of the system.

The ocean warming gives perspectives of further kelp recovery and migration of species northwards, with the interest of follow up observations of future development. Of particular interest is how the Cancer and Carcinus crabs will extend further north and affect coastal communities, and likewise if new areas in the Finnmark fjords show increasing kelp recovery due to king crab predation on urchins.

Further, the results on kelp forest ecosystem recovery have documented interesting data on invertebrate and fish distribution, and a follow up of the ecosystem is of importance to study the development towards a mature kelp forest ecosystem. We have also started to provide these data for ecosystem services analyses, which is a future activity of interest.

The project has taken advantage of remote video that when it comes to semi quantitative sampling has been a more efficient tool/method than diving.