Project information

Keywords
kelp forest, sea urchin, recruitment, predation, ecosystem recovery, ecosystem services
Project title
Recovery of coastal kelp ecosystems – driven by climate change or predators?
Year
2016
Project leader
Hartvig Christie, NIVA
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
Meløyvær 69,03282705 16,92737399, Kvalsund 69,84957755 18,94879868, Porsanger 70,40521408 25,33974496
Participants

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

UiT The Arctic University of Norway: Prof. Torstein Pedersen

The project results have benefited a cooperation and comparison with IMR (Hans Kristian Strand and Frithjof Moy) project Fjordkalk in Porsangerfjorden. 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.

The project includes a follow up of the Research Council project RESTORE and thereby a continuation of cooperation with Professor Bob Steneck, University of Maine, USA, he is also a part of the Coralline project.

Flagship
Fjord and Coast
Funding Source

Funding source: Fram Centre

For 2015 the project has no other direct funding, but a considerable extra effort from NIVA and UiT researchers, and benefitted by cooperation with other projects in Nordland (NIVA) and Porsanger (IMR).

The funding and research activity was for complementary field work to that of 2014, and of analyzing and reporting. The project also included an environmental socioeconomic task, but this task of evaluation of ecosystem services became limited due to reduction of funding.

Summary of Results

This project has for 2014 and 2015 performed a successful field work at the recovered kelp forest at Vega and compared the kelp beds with persistent sea urchin barren ground at both Vega and Senja. The last data from this activity has been analyzed in 2016 and show an increasing development of invertebrates and fish in the recovered kelp beds that are supported by similar results from Porsanger. 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). Of particular interest is the importance of the kelp beds for abundance of juvenile cod and saithe. The recovered kelps at Vega were found to house a rich fauna of invertebrates, but species richness and abundance had not so far reached that of kelp forests further south. We have identified ecosystem services gained by the kelp forest recovery:

- Significant increase in benthic primary production and nutrition
- 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.

An estimate based on spatial modelling of potential kelp forests within Vega community comes up with a gain of almost 2 million tons of annual kelp production when all kep beds have recovered. This should imply a very high monetary and non-monetary gain for this community, and similarly for other coastal communities if kelp beds recover.

The 2016 survey 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 most areas but still bottom areas grazed by remaining sea urchins.

Southern Troms: Very high densities of sea urchin recruits as also found two years earlier, but this year first observation of kelp recovery areas. The hypothesis is *Cancer* crab predation of adult sea urchins, but need further testing.

Vest Finnmark (Hammerfest area): Very high density of sea urchin recruits and no kelp recovery. Hypothesis is that the cold sea water benefits sea urchin recruitment and minor or no crab abundance benefit suevival of juvenile and adult sea urchins.

Porsanger: In spite of low and favorable temperatures for sea urchins we found low densities of sea urchin recruits and increasing kelp forest recovery. The present hypothesis is that the red king crab predation affects both juvenile and adult sea urchins.

These findings indicate that the kelp recovery are gradually moving northwards, and also to some extent increase in the Porsanger fjord, however the hypothesizes mentioned must be further tested.

Highlights:

Large areas of the Nordland 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 Nordland can be linked to a direct effect of climatic change (increasing temperature) and indirectly by climatic changes that benefit the predator *Cancer* crab north going distribution. Sea urchin mortality and kelp recovery have during 2016 spead to southern parts of Troms

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

Master and PhD-students involved in the project

No students involved in 2016.

However, the participation of young scientists will have an educational perspective by transfer long time knowledge and experience in the topic from the experienced to younger scientists within the team, particularly to ensure persisting competence in the field of sea urchin and kelp science in Norway.

For the Management

The large scale shift from underwater desert to rich kelp forests is of great importance for environmental management and value creation. The new kelp forests 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. This year guill net fishing in the new kelp forests at Vega has shown promising results for younger cod year classes.

The increasing crab populations is facilitated by low predation, increasing temperature and nutrients from the restored kelp, and the effects of changes in cod and crab populations and related interactions will be a challenge 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.

Increase of resources will benefit tourism and tourist fishing industry.

The increasing interest for kelp and seaweeds as a valuable resource has already taken advantage of our observations, and our results will be important for a management regime for harvest or cultivation of these resources. Harvest of *Laminaria hyperborea* has already moved northwards, the sugar kelp industry is following the north moving trend, and the sea urchin industry is interested in the remaining resources and our findings of increased roe quality (increased gonad index) close to the recovered kelps.

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 years:

Fagerli CW. Norderhaug KM. Christie H. (2013). Can lack of sea urchin settlement explain kelp forest recovery in overgrazed areas in Norway? Mar Ecol Prog Ser 488: 119-132.

Fagerli CW, Norderhaug KM, Christie H, Pedersen MF, Fredriksen S. (2014). Predators of the destructive sea urchin grazer (Strongylocentrotus droebachiensis) on the Norwegian coast. Mar Ecol Prog Ser. Doi:10.3354/meps10701

Rinde E. H Christie; C W Fagerli; T Bekkby; H Gundersen; K M Norderhaug; D Ø Hjermann. (2014). The influence of physical factors on kelp and sea urchin distribution in previously and still grazed areas in the NE Atlantic. PLOS ONE 9:1-15.

Anglès d'Auriac M B, A Hobæk, H Christie, H Gundersen, C W Fagerli, J Haugstetter, K M Norderhaug.2015. New microsatellite loci for the green sea urchin *Strongylocentrotus droebachiensis* using universal M13 labelled markers. BMC Research News. In press.

Fagerli CW, Stadniczeñko SG, Pedersen MF, Christie H, Norderhaug KM.2015. Population dynamics of Strongylocentrotus droebachiensisin kelp forest and overgrazed areas in Norway. Marine Biology 162: 1215-1226

Ling SD, Scheibling RE, Johnson CR, Rassweiler A, Shears N, Connell SD, Salomon A, **Norderhaug KM**, Perez-Matus A, Hernandez JC, Clemente S, Blamey L, Hereu B, Ballesteros E, Sala E, Garrabou J, Cebrian E, Zabala M, Fujita D. (2015) Global regime shift dynamics of catastrophic sea urchin overgrazing. Philosophical Transactions B. 370. DOI: 10.1098/rstb.2013.0269 (Our Norwegian data represented here by Norderhaug)

Bennett S, T Wernberg, T de Bettignies, G A Kendrick, R Anderson, J Bolton, K Rodgers, N Shears, J-C Leclerc, L Lévêque, D Davoult, H Christie. 2015. Positive interactions and environmental stress gradients in subtidal marine communities. Ecology Letters. doi: 10.1111/ele.12446

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, in press)

Christie H. Norderhaug KM. (2016). Secondary production. In E. Olafsson (Ed) Marine macrophytes as foundation species. CRCPress, Taylor & Francis Group. (pp161-176)

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? (Resubmitted after review)

Christie H. Gundersen H. 2014. From sea urchin deserts to rich kelp forests.

Crabs and climate as drivers in ecosystem shifts in southern Nordland and eastern Finnmark. Fram Forum, 4p.

Christie, H. 2014. Tareskog og kråkeboller ved Vega gjennom 50 år. Innspill til Vega Verdensarv hefte. 4p.

Christie, H. Tareskog og kråkeboller ved Vega gjennom 50 år. Poster til Vega dagan, 2014

Christie, H. 2014. Tareskogdød og gjenvekst i verdensarven. Foredrag på Vega dagan.

Fagerli CW, Christie H. 2014. Krabber bidrar til gjenvekst av tareskog. Forskning.no. (red. HB Borgchgrevink)

Christie H. 2014. From sea urchin deserts to rich kelp forests. Fram shorts. http://www.framshorts.com/video/from-sea-urchin-deserts-to-rich-kelp-forests/

In prep: Climate change and Fishing Transforms the North Atlantic Coastal Ecosystem. NIVA group in cooperation with Prof. Bob Steneck, Maine, USA.

Two abstacts/presentations on the International Temperate Reef Symposium (ITRS) in Perth, Austalia, januay 2014. Rinde: The influence of physical factors on kelp and sea urchin distribution in previously and still grazed areas in the NE Atlantic. Christie: Multitrophic interactions and climate change regulate large scale kelp - sea urchin distribution.

Christie, H. Storskala skiftninger I tare-kråkebolle balansen. Endringer i klima og predasjon gir spennende økologiske og forvaltningsmessige perspektiver. Foredrag, Norske Havforskeres Forening, Årsmøte 2014.

Christie H m fl. 2015. Sukkertare i nord: En glemt naturtype og ressurs på frammarsj etter 45 års fravær. Foredrag Norske Havforskeres Forening, Årsmøte 2015.

Christie H. 2015. Forskjeller i fisk og invertebrater mellom ny tareskog og kråkebolle dominert bunn: Hva skjer med kyst økosystemer når kråkeboller går tilbake og tareskog vokser fram. Foredrag Forskermøte FRAM Flaggskip fjord og kyst.

Christie H. 2015. Climate and crab predation cause large scale changes in the kelp forest – sea urchin system. Foredrag FRAM Science Days.

Hartvig Christie, NIVA, Kjell Magnus Norderhaug, NIVA, Stein Fredriksen, University of Oslo, Patrik Kraufvelin, Aabo Akademi University. 2015. How can kelp and seagrass beds persist being both food and habitat? Foredrag og abstract EMBS 50.

Norderhaug KM, Fagerli CW, Andersen G, Christie H, Moy F, Gundersen H, Bekkby T, Rinde E, Fredriksen S, Pedersen MF, K Dahl. 2015. Regime shifts in Norwegian kelp forests. Foredrag og abstract EMBS 50. This talk was also given at the HAVKYST closing conference in April 2015.

Kelp sea urchin ecology and social sciences presented on Forskningstorget 2015 in Oslo. H Christie and W Chen, NIVA

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. 2016. Interactive dynamics between abiotic factors, sea urchins and kelp forests. Key note presentation.

Communicated Results

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

Results have been presented in TV and newspaper, and on talks and posters at national events (Norske Havforskeres Forening 2014 and 2015 and on Flagship workshops 2014 and 2015). The project results have been presented at the FRAM center presentations to the environmental authorities in Oslo and Trondheim in 2015.

Two oral presentations from the project have been given at the International Temperate Reef Symposium in Italy in 2016.
Results have been communicated to scientists, management, public and seaweed and sea urchin commercial actors.
See the list of publications and presentations above.

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Two oral presentations from the project have been given at the International Temperate Reef Symposium in Australia in January 2014, two in the same symposium in Italy in 2016, and two on EMBS, Germany 2015.

See the list of publications and presentations above.

Results have been directly communicated to the SINTEF seaweed production NRC project MACROSEA and particularly the Aquaplan-niva participation, to Seaweed Energy Solutions, and to the sea urchin company KASTON.

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 identified a number of ecosystem services so far. This will be further developed in close cooperation and will strengthen the communication of the value of kelp forest recovery as well as increasing value of remaining sea urchins. The same core persons are involved in our project and the Ecourchin project in MIKON Flagship and data from these projects deveop 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 cooperation between benthic ecologists in NIVA and fishery biologists at UiT has been successful.

Budget in accordance to results

The Fram Centre funding has been the only direct funding of the activity in 2016. The project has in earlier years benefited from activities funded by DN and NRC for completing the large field 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 cooperation with the Corraline project in Troms, Fjordkalk in Porsanger and National program for mapping of biodiversity – coast (Hammerfest area) 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 of the ongoing changes from sea urchins to kelp. It is important to use the opportunity of this large scale event to explore the processes of climate and predation behind the regime shift. As scientist experienced in the field of sea urchin and kelp problems are at the end of their careers, this project has contributed to build up relevant competence among younger scientists in the field as well as increasing the understanding of interdisiplinary cooperation. The 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 activity. Further, the funding of this project has been of importance for initiating new projects and proposals in both 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 and scallop resources.

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 for cultivation and exploitation of other kelp species, particularly sugar kelp, has resulted in extensive contact with the seaweed industry. Our results showing more persistent and fresh sugar kelp beds North Norway than further south have increased interest for commercial activities 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. We have established contact with the industrial company KASTON.

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, 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. Particularly if kelp reforestation (and the edible crab) extend further north than Lofoten and southern Troms, and if other areas in the Finnmark fjords show increasing kelp recovery due to king crab predation on urchins.

The results from 2014 and 2015 have focused on the development of kelp forest ecosystem recovery and have documented interesting data on invertebrate and fish distribution within the new kelps as well as on the barren grounds. We have also started to provide these data for ecosystem services analyses, which is a future activity of interest.

Our recent data give perspectives for going further into the role of recruitment of sea urchins for determination of a gradually kelp recovery northwards, but also for explaining the patchiness of kelp recovery within persisting barren ground areas.

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.