information

Project title

Sea urchin harvest: ecosystem recovery, integrated management of social-ecological system, ecosystem service and sustainability (ECOURCHIN)

Year

2017

Project leader

Wenting Chen and Hartvig Christie (NIVA)

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

65°70′N to 70°70′N along the Norwegian Coast

Participants

Norwegian Institute for Water Research (NIVA): Wenting Chen, Hartvig Christie, Hege Gundersen, Eli Rinde, Trine Bekkeby, Karen Filbee-Dexter, Camilla With Fagerli

The Arctic University of Norway (UiT): Claire Armstrong, Godwin K. Vondolia

NOFIMA: Philip James

University of California Berkeley: Peter Berck

Associated partner from Industry who newly joined in May this year: KASTON International: Brain Takeda

Flagship

MIKON

Funding Source

MIKON Flagship from the Fram Centre

No other funding source

Summary of Results

Extensive work has been carried out in each WP in 2017 based on the work done in 2016 and in 2015 where we projected future kelp recovery area by using rule based GIS model along the coast for all Norwegian communes, qualitatively studied environmental impacts of urchin harvesting and the relevant ecosystem services, reviewed the field work on urchin kelp population dynamics and developed basis for urchin harvest bioeconomic model and bioeconomic model for kelp forest contribution to coastal cod production.

-WP1: Where to harvest?

We constructed both basedline spatial distribution of kelp along the three northern counties in Norway, i.e. Nordland, Troms and Finnmark. A GIS programming tool is used to cover a gradient of different depths in addition to (and disentangled from) distances to kelp forest, which enables us to compile all the relevant dataset. The GIS programming makes use of information on relevant existing mapping layers including geophysical modelling data of depth, wave- and current exposure, sea bed terrain.

In the first round we mapped the existing area with kelp forest (Laminaria hyperborea) which is now located in coastal areas with relatively high wave exposure. This is due to green sea urchins (Strongylocentrotus droebachiensis) are susceptible to strong waves so that they are not able to grow in the area with high wave exposure.

In the second round, we predict the areas where both Laminaria Hyperborea and Saccharina Latissma will be recovered. As scuba divers will not go deeper than 20m for urchin harvesting and dredging is commonly used for example in Iceland for urchin harvesting at a depth more than 20m. We thus look at two scenarios of harvesting technics, the scuba diving and the dredging. The baseline distribution of urchin population is also mapped according to the two different harvest techniques.

The basedline distribution for sea urchins and kelp forest (both Laminaria Hyperborea and Saccharina Latissma) are mapped at community level. All the 83 communities in the three northern counties are covered. We do not present the maps for all the 83 community here due to the size of the map.

Figure 1 shows an example from Skrova. The dark blue area shows the existing Laminaria Hyperborea. The light blue area indicates the future area with the recovered Laminaria Hyperborea after the removal or harvesting of the small sea urchins. The red area indicates the future area with the recovered Saccharina Latissma after the urchin removal. The light yellow area marks the region with the depth between 0-20 m. This is the area that divers could reach by using scuba diving technique when harvesting sea urchins. The deeper yellow marks the area with depth between 20 m and 30 m where dredging technique can be used for urchin harvesting.

-WP2: Impact of harvest on ecosystem and how to harvest?

Impact of harvest on ecosystem

Several potential impacts were identified in 2015, i.e. food production service (cod and other commercial fishery), cultural regulation service (diving, recreational fishery), and carbon regulation service (carbon storage in the kelp biomass), other services like wave damping, water cleaning.

In 2015 we do find that urchin density, size, and roe quality vary with distance to kelp. The green sea urchin aggregate, and the largest individuals (test diameter about 50-60 mm) can aggregate in densities between 50 and 100 per m2 close to kelp vegetation. Data from Vega show that sea urchins grow faster and develop larger gonads close to kelp. Resent unpublished results from Porsanger (Finnmark) revealed 5 times higher gonad weight close to kelp than far from kelp vegetation. Gonad index vary with season, but in autumn, sea urchins close to kelp vegetation may reach size and gonad index ready for marked quality.

In 2016 and 2017, we further deepened the knowledge on the potential impacts by analyizing the data collected via “Sea urchin-kelp” project in Flagship “Fjord and coast” in 2017. We find out the increase in development of invertebrates and fish in the recovered kelp beds. In kelp recovery area, we found the ecosystem services have the following characteristics.

-Significant increase in biodiversity

- Habitats for juvenile codfish and potentially increase in coastal cod fish stock.
- Improved nutrient and habitat conditions for commercial fish and crabs
- CO_2 storage

-Increase in gonad production in the remaining sea urchins.

The 2017 survey and experiment revealed the following pattern of sea urchin recruitment and kelp bed recovery. 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 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. (In collaboration with the project “Recovery of coastal kelp ecosystems – driven by climate change or predators?”)

How to harvest

We developed a bioeconomic model to quantify how much economic value of urchin harvesting will be over the years under the harvesting scenario "repeated harvest of sea urchins on barren grounds”. It is a social planner model for harvesting urchins on the barrens.. As no cost data on urchin farming and harvesting available this year, we only calculated the gross revenue of the urchin harvesting when harvest is done from barrens. Our result shows that the maximum sustainable yields could be up to 0.81 mill tonne per year if we do not consider harvesting capacity constraints. With the current harvesting capacity constraints, the maximum harvesting is estimated to be 0.5 mill tonne per year. If we assume the wet raw urchins are sold at a fixed market price at 48 NOK/kg before farming, the gross annual revenue without considering harvesting costs will be 39000 million NOK per year.

In 2016, we deepened our analysis by looking at the second harvesting scenario "Harvesting the big sea urchins along the recovered kelp forest". We first looked at different techniques of harvesting. And then the data on cost of harvesting are collected. Secondly, a bioeconomic model for "harvesting along the recovered kelp forest" is constructed and programed. In the model we assume the kelp forest is already recovered and we develop optimal harvesting strategy between the two.

In 2017, we improved the model and updated simulation. We found the total benefits from harvesting depending on which market the urchin business is targeted. Norwegian market will provide higher price but with smaller market size. And EU market has lower price but larger market size.

-WP3: Impact on communities and ecosystem services
In 2015 we qualitatively identified the potential ecosystem services that may be benefited from urchin harvesting industry, e.g. carbon regulation services, food production services and cultural services (tourism). In 2016 we quantified two of the services that is carbon regulation services and the coastal cod fishery from kelp forest recovery.

Carbon regulation services
Kelp forest is playing an important role in binds CO2 in the ocean For the current estimation, we only look at the potential recovery of Saccharina Latissma. A hotspot for kelp recovery is identified in Northern Norway between 65 N and 70 N. The storage of carbon in the kelp biomass could be amount to 4 Million ton. When translated into social cost of carbon, with the US estimation the total social benefits of carbon stored in the recovered Saccharina Latissma will be amount to 1000 Million NOK if 5% social discount rate is used.

Coastal cod fishery from kelp forest recovery
The ecosystem-based fisheries management proposes a broader scope for fisheries management in order to address the effects of fishing on the marine ecosystems including diversity for sustainable management of

fisheries (Pope and Syme, 2006). In addition, the ecosystem-based management requires policies to take explicit account of the interconnectedness within systems with recognition of the importance of interactions between target and non-target species (McLeod et al., 20015). This part of the project presents another variant of bioeconomic model of habitat-fisheries interactions for kelp forest and the coastal cod fisheries in Norway. Specifically, the bioeconomic model considers the case in which kelp forest serves a habitat for coastal cod but at the same time, standing kelp forests provide other supporting ecosystem services such as carbon storage.

In 2017 , we further developed the model and carried out the simulation. We found kelp forest is very important for recovery of coastal cod fishery.

Valuation of cultural and supporting services

In 2017, we carried out a nationwide survey to evaluate the cultural and supporting services of the potentially recovery kelp forest in the northern of Norway. The results will show how much willingness to pay for the two ecosystem services from general public.

Reference:

Kahui, V., C. W. Armstrong and G. K. Vondolia, 2016. Bioeconomic analysis of habitat-fishery connections: fishing on cold water coral reefs. Land Economics 92 (2): 328 – 343

McLeod, K. L., J. Lubchenco, S. R. Palumbi, et al., 2005. Scientific Consensus Statement on Marine Ecosystem-Based Management. http://www.compassonline.org/sites/all/files/document_files/EBM_Consensus_Statement_v12.pdf

Pope, J. G. and D. Syme, 2006. An Ecosystem Based Approach to the Common Fisheries Policy: Defining the Goals. Petersborough, UK: JNCC.

Figure 1: Baseline kelp recovery and urchin distribution along the recovered kelp belt.

Figure 4: The Uni from Norwegian Sea Urchins ready for the Japanese market

For the Management

Sea urchin harvesting industry is still at the cradle stage in Norway. While in the past two years, urchin harvesting has caught more and more attention in the research world (e.g. EU project: ResUrch and the Northern Peripheries and Arctic pre-project (Sea urchin fishing in the European Northern Periphery Area). Long coast line with abundant sea urchin population in the North and the high demand in the international market provide a unique potential for Norway to develop large scale urchin harvesting. The increasing sea urchin demand and the shortage of sea urchins supply in the world market provide Norway with a unique opportunity to develop a profitable sea urchin harvesting industry. Initiations on urchin industries from Norwegian local private companies such as Kaston International has spread to different parts of the world in 2016. And our concept on sustainable urchin harvesting from barrens has been presented to international stakeholders on China Sea Food Expo in 2017. Developing sea urchin industry in Northern Norway will not only affect local economy and ecosystem services, but also have effects on marine ecosystem and habitats in the northern coastal region and support blue growth. The effects of kelp recovery such as carbon storage could contribute to the both Norwegian national GHG emission reduction but also the new goal of COP21 Paris meeting. Tourism and tourist fishing industry could be another important benefit for local community. The project establishes a knowledge base for estimating the effects of a potential sea urchin harvesting industry on ecosystem and habitat recovery and the effects on ecosystem services and economy in the local communities, and to develop an integrated management strategy for social-ecological system and sustainable industry development. The project is the first comprehensive study on ecological and economical sustainable industry development of sea urchin harvesting with consideration on how urchin harvesting will affect kelp-urchin dynamics and marine ecosystems as well as its impact on ecosystem services and economy in the Northern Norway. The knowledge is highly demanded by both local fishery management, national and international environmental NGOs as well as the publics.

Published Results/Planned Publications

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

Christie H and Chen, W. 2016. Grønn vekst langs kysten . DN debat http://www.dn.no/meninger/debatt/2016/08/08/2121/Milj/grnn-vekst-langs-kysten

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

Christie H, H Gundersen, E Rinde, KM Norderhaug, C W Fagerli, T Bekkby, J K Gitmark, T Petersen. Can multitrophic interactions and climate change regulate large scale kelp-sea urchin distribution. (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)

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, Hartvig NIVA, KJell Magnus Norderhaug, NIVA, Stein Fredriksen, University of Oslo, Pathrik Kraufvelin, Aabo Akademi University. 2015.

How can kelp and seagrass beds persist being both food and habitat? Foredrag og abstract EMBs50

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

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

Chen W., Berck P. , Norling M. D., Christie, H., Gundersen, H., James, P., Armstrong C, Vondolia C. Sea urchin harvesting in Norway: a sustainable social-ecological system, work in progress

James P. and W. Chen 2017. Norwegian Sea urchin stakeholder workshop- Nofima/NIVA report.

James, Phil. 2016. Commercial scale sea urchin roe enhancement in Norway, NOFIMA report.

Vondolia C., Chen W, Armstrong C, Norling, M. D., Fishery and kelp habitat recovery, an example from Northern of Norway, work in progress.

Communicated Results

Communication in 2017

- A joint stakeholder group meeting was hold together with EU URCHIN project (NOFIMA) on 3 October 2017.

The workshop was titled 'Possibilities and pitfalls in the development of a sea urchin industry in Norway'. The aim was to determine 'why Norway does not have an established sea urchin fishery and what are the effects of the potential industry on ecosystem services and socio-ecological system including the economic and associated kelp ecosystem restoration benefits of establishing such a fishery'. The workshop brought together different stakeholder groups who are interested in developing a sea urchin industry, ecosystem restoration and ecosystem services from kelp recovery in Norway. The workshop theme is directly linked to blue growth and sustainable marine resource management in Norway. Attendees at the meeting included SME's, representatives of large business, Research Institutes, Higher Education Institutes, Government regulatory bodies and funding bodies. Project results are presented at the meeting and stakeholders feedbacks were collected.

- Results are presented at the MIKON annual workshop in Tromsø in November 2017.

- Results have been presented to the general public via Forskning.no, NRK2 radio, Framsenter website, and newspapers (DN and Fiskeribladet).

- Project results were presented to both national and international academics at EU «Ocean Governance for Sustainability» conference in March 2017 and Økonomårsmøte in January 2017

- In collaberation with a company from industry, the Urchinnomics, the project concepts were presented via video on China Seafood Expo 2017 in November where the concept on harvesting urchins in barrens and help kelp recover was promoted to both Chinese and international consumers and industrial partners.

Communication in 2016

A **pre-kick-off meeting** with all the partners was held on 2-3 May 2015 in Oslo: NIVA, NOFIMA, UC Berkeley, UiT (via skype) and KASTON joined the meeting. Each participants presented their plan for their responsible working packages. Interaction and how to collaborate between WPs were discussed. An improved bioeconomic model for urchin harvesting were made for WP2

There were numerous small meetings within each working packages among all the partners during the year.

Another **end of project meeting** in 2017 was in planning with collaberating potential with EU Northern periphery project URCHIN led by NOFIMA.

Dissemination 1: One popular article on “Grønn vekst langs kysten” on DN and Aftenposten.

Dissemination 2: NIVA, NOFIMA collaborated with KASTON International, an industry partner who interested in urchin harvest and aquaculture, on 24 October, met one of the biggest Canadian aquaculture and sea food research institute on further promoting the ECOURCHIN idea to Canada.

Dissemination 3: NIVA on 26 October presented ECOURCHIN project to the Chinese Ambassador in Norway during their visit to NIVA Oslo.

Dissemination 4: Part of the results this year will be presented at Fram Science Day on 10 November 2016.

Dissemination 5: ECOURCHIN project idea was conveyed also on the Norwegian -South Africa week in October 2016 in Cape Town.

Communication in 2015

A **pre-kick-off meeting** between NIVA and NOFIMA on 12 March 2015: discuss the synergy between ECOURCHIN and URCHIN (EU Northern Periphery and Arctic Program). Data and results sharing among the two projects were agreed upon.

Kick-off meeting on 4 May 2015: The kick-off meeting was hold via skype due to the limited funding this year. NOFIMA, UiT and NIVA discussed the plan for the project this year and each institute. Action plan was made during the meeting. UC Berkeley was in a roll of consultancy this year due to the budget limit.

Discussion on economic modelling was done via two meetings on 20 May and 11 June in Tromsø between NIVA and UiT.

Dissemination 1: ECOUCHIN project idea is promoted among Norwegian and international urchin harvesters from Finland, Scotland and Canada during the NOFIMA URCHIN (EU) prject kick-off meeting on 19 May in Tromsø Local industry on urchin industry.

Dissemination 2: NIVA is collaborating with Kaston International, an industry partner who interested in urchin harvest and aquaculture to further promoting the idea to e.g. USA, Hellas, Japan and Netherland.

Dissemination 3: ECOURCHIN project was NIVA flagship project on Oslo Forskningstoget on 18-19 Setember. The idea of "sustainable harvesting/eating sea urchins and saving the kelp forest" were presented to the general public particularly school children.

Dissemination 4: Part of the results will be presented at Fram Science Day in November 2015.

Dissemination 5: An article on Aftenposten of the project is under preparation, a NIVA report and a manuscript.

Dissemination 6: A seminar had be hold in Tromsø in November 2015 where results and project idea has been presented within the project group.

Interdisciplinary Cooperation

ECOURCHIN is a project cross several disciplines. The research team has expertise on benthic ecologists, social science and mathematicians in NIVA, fishery scientists at NOFIMA, and both social scientists and fishery biologists at UiT. We included industrial partners as our associated partner to provide more information and needs from urchin industry. The project results further strengthen the interdisciplinary network BLUE FOREST between NIVA, IMR and Grid Arenda. the interdisciplinary cooperation in the EU project MERCES on habitat restoration, and to an Ocean Acidification project to AMAP.

We identified win-win situations and a number of ecosystem services by kelp forest recovery in collaboration with "Recovery of coastal kelp ecosystems" project from Fjord and coastal ecosystems Flagship from which the biological data were collected. The collaboration will be further developed in close cooperation in new projects and proposals.

Budget in accordance to results

Funding from MIKON is the only direct funding for the project and has been essential to perform the studies planned in the project. There is no other funding sources.

The funding from the FRAM center "Fjord and coast" flagship to project "Recovery of coastal kelp ecosystems -driven by climate change or predators?" has provided newest sampling data for urchin density and urchin-kelp dynamics.

The funding from MIKON will provide vital source for successful knowledge development of the upcoming urchin industry in Norway and for sustainable development of the industry together with the ecosystem benefits gained from kelp forest recovery in the long run.

The funding from the FRAM Flagship has been of great value crucial for the understanding of the potentials of urchin harvesting and kelp recovery in the North. The project helped to identify also the new research problem such as complex predation relations behind the regime shift and integrated harvesting of various species related to urchin and kelp forest. 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.

Could results from the project be subject for any commercial utilization

Yes

If Yes

Both the sea urchins and the ecosystem services derived from recovered kelp beds (e.g. fishery, tourism, kelp harvesting) have the commercial values. Local private fishery industry such as Kaston International and C-flows will benefit directly from our results on where and how much to fish the sea urchins so as to develop a profit and sustainable urchin harvesting industry. The fishery industry can also make use of our results to potentially adjust their fishing quotas in the North when kelp recovered. The coastal tourist industry and the new rising interest in kelp harvesting can also utilize our result directly in their planning. For example, our results will benefit future attention on tourism and word heritage area in Vega.

Conclusions

Our project provides the first knowledge on spatial and temporal harvesting advisories for sea urchin harvesting industry in Northern Norway. Our models and simulation on potential recovery of habitat, the kelp forest, and the ecosystem services it could provide to society provide a forefront modelling tool for habitat governance and the assessment of ecosystem service benefits of both the new industry and the habitat recovery to local communities.

From our project, we identified that kelp forests are habitats for sea urchin predators like the *Cancer Pagurus* that regulate sea urchin abundance by feeding on them. Kelp forests are also important habitats for coastal cod, particularly juvenile cod which feeds on *Cancer Pagurus* and king crabs, they indirectly regulate sea urchin abundance. The interactions between different parts of the food chain and the kelp habitat imply that targeting multiple species is likely to generate trade-off. And a regime shift between urchin barrens and kelp forest could lead to a surprising and relatively abrupt drop in some stock of targeted species. These issues motivate the need to plan multi species harvesting in an integrated and sustainable manner that accounts for food chain, kelp habitats recovery and ecosystem services interactions including the possibility of regime shift.