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"Modern Marine Ecosystems Commons in Coastal Areas"

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Abstract/Summary

MODERN MARINE ECOSYSTEM COMMONS IN COASTAL ZONES

An increasing world population and raising living standard in many parts of the world requires increased food production. Demand for seafood and marine chemicals is thus rapidly growing while most wild marine resources have been overexploited for many decades. Aquaculture and mariculture has therefore been growing so that today it contributes almost half of food supplied from aquatic life. As a consequence, and as a response to the two global challenges of food security and job creation, the international policy agenda has identified aquaculture as a key strategy to support a Blue Growth that also include marine renewables, tourism and deep sea exploitation. Policies, R&D programs and incentives are designed to promote these developments, many of them targeting the coastal waters whose ecological status is already under threat (cfr. Horizon 2020)

Aquatic ecosystems are different from terrestrial ecosystems. In many ways they represent 3-dimensional commons where your harvesting or cultivation activities affects not only your co-harvesters and neighbours, but also all other marine organisms above or below your niche of operations. In a fluid environment any pollutant or pathogen, ecosystem imbalance, any bloom of algae or parasites will affect larger regions and eventually hit back at you and might thus ruin your operations more than in any terrestrial context. This is particularly true for coastal systems. Conservation issues also work differently and can be in conflict with many users' claim for free access to space and to natural resources and ecosystems. The collective dilemmas in such a complex coastal system are therefore far more challenging than in corresponding terrestrial mixed wild/domestic ecosystems. Property rights here cannot be thought of as just an extension of terrestrial rights, thus it is a major challenge to define and allocate access rights and user rights to coastal space, volumes and marine ecosystems for traditional dwellers or new-comers, while ensuring good environmental and good ecological status of coastal waters.

This paper will address different attempts to solve – or govern - such collective dilemmas. One is the multiple use Marine Protected Areas in France, where intact and highly biodiverse coastal ecosystems can produce vital ecosystem services for the surrounding coastal environments used for harvesting and cultivation activities. Another is the governing regime for aquaculture growth in Norway which aims at collective governing of growth (and reduction) in fish farming according to measures of "good ecological status". Both approaches adds important analytical tools to our toolbox for ecosystem based integrated coastal zone management.

1. Introduction

What has puzzled the resource governing research community during the later decennia is the challenges arising when analyzing complex commons with the conventional tools of institutional analysis. For a single forest, a single irrigation scheme or a single fish-stock, the IAD framework has for instance proved a useful and fruitful approach in analyzing local users' ability to handle their collective dilemmas and work out long-enduring institutional solutions – often known as "Commons" (Ostrom 1990, 2005). Many thousand such resource-governing regimes are analyzed and documented in the "Digital Library of the Commons" at the Indiana University Ostrom Workshop in Political Theory and Policy analysis (http://dlc.dlib.indiana.edu/dlc/).

But when it comes to complex resource systems with many inter-resource dependencies and multiple usages, it is widely believed that a basic institutional analysis does not yield results that appear useful for cross-sectoral policy making. As shown below, a number of different analytical frameworks have therefore been crafted to address such more complex resource governing situations. Although eagerly offered as the ultimate tools for policy-makers, none of these has so far been established as the canon of complex institutional analysis. One reason for this is of course the nature of policy-making; when the power and interests of different resource users are made relevant, the biological processes and the potential optimization between multiple harvests loose importance for the parties involved. In addition comes the fact that nature/human interactions are immensely unpredictable and might generate outcomes that are far beyond those of "natural" processes - where negative feedback mechanisms often ensure some form of long-term stability. Extinction, explosion of invasive species, tipping points etc. are examples of such outcomes that are difficult to forecast by any form of rational scientific analysis.

Coastal areas bear all the characteristic of complex resource systems with a high degree of connectedness between various species and ecosystem variables. The food chains are long and complex across many trophical layers, the terrestrial and the marine environments have complex interactions in the dynamic tidal zone and the wet elements are both fluid and 3-dimensional. The human users are a very diverse group, all the way from fishers, seaweed harversters, farmers and aquaculturalists – to recreationalists, tourists and city dwellers – harvesting from the high productivity of the coastal system and discharging waste into the same – or otherwise utilizing the ecosystem services of one or more of the ecosystems that together make up the coast. This interplay between geomorphological forces, biological processes and human socio-economic processes has often been termed a coastal socio-ecological system that can be analyzed for policy-making purposes by complex computerized models that take into account all the variables and all the interconnections one can possibly think up.

But the coast can also be imagined as a "Commons", a complex natural self-regulated system that left to itself will maintain its level of ecosystem services to a society. This requires a human use of the coast that balances the subtraction from the ecosystem and the provision of inputs, regulations and protection to maintain the "health" of the coasts in the foreseeable future. (Tett, Sandberg & Mette 2011). It also requires a view of the human nature as collectives that, given the chance, have a certain capacity to govern their own resource use and to learn from their mistakes Ostrom 2005). In this simpler image of a "Coastal Commons", a number of black boxes are not opened, but are assumed to function as we are used to, unless disturbed beyond critical thresholds.

In this paper we shall see how different ways to look at coastal systems can make possible interdisciplinary research that can be useful for policy making related to coastal areas. We shall use

examples from Northern Norway and Western France to illustrate this discussion. Here the various issues related to "Blue Growth" are the overarching challenges:

- How can the over-harvest and exhaustion of wild fish-stock be regulated without causing decay of coastal communities?
- How can the growth of coastal aquaculture be regulated so as to prevent deterioration of coastal ecosystems and restore the health of ecosystems that both wild fish regeneration and fish farming is so dependent on?
- How can the growth of the "Experience Economy" be designed so that it benefits both coastal ecosystems and coastal communities?
- How can Marine Protected areas be used as a governance tool to improve the ecosystem health of larger coastal areas?

2. Analytical concepts

A number of Social-Ecological analytical frameworks have recently been launched in order to provide improved tools for understanding coastal challenges and to supply possible solutions to policy makers.

One of these is focusing on the interaction between various Sustainable Development Goals, which might all be desirable, but not all attainable at the same time. This **Framework for understanding sustainable development goal interactions (ICSU-SDGF)** is based on a scoring method that identifies causal and functional relations underlying progress or achievement of the Development Goals and the targets (Nilson, Griggs, Visbeck, Ringler & McCollum 2017)

Another, and the most widely known, framework is the **Driver-Pressure State Impact Response (DPSIR)** framework for describing and analyzing the interactions between society and the environment – where environmental problems drives the search for more sustainable policies. This framework was initiated by the Organisation for Economic Cooperation and Development (OECD) and has been adopted by the European Environment Agency (EEA) and United Nations Environment Programme (UNEP). It has proved to be a useful tool, despite some limitations which are being addressed in recent developments (Gari & al 2015, Elliott, M., et al. 2017).

A less known, but related framework is the **System Approach Framework (SAF)** that was applied in the EU-SPICOSA project 2007-2011**.** This Systems Approach Framework (SAF) has three main elements, Systems Theory, Simulations of scenarios and Engagement of stakeholders at the science-policy interface. http://www.coastal-saf.eu/introduction/whatis.shtml). The SAF is a strategy for improving our understanding of how complex systems function. It allows us to investigate responses of complex systems *in situ* instead of analyzing them part by part. This reflects the systems theory caveat that understanding the structure (composition) does not necessarily permit an understanding of the function (dynamic purpose). Consequently, investigating a system's interactions can increase our understanding of its function beyond that gained by information only on the structure of its components. Treating coastal zones as complex systems therefore has to include all of the ecological, social and economic dimensions. Thus the SAF framework can be seen as a start-up methodology that addresses the "how to" gap between sustainable management goals and the information and actions needed to implement or modify them. The SAF framework could allow us to define **Sustainability** as the capability of an ecosystem to go on supplying humans with 'goods and services and **Efficiency** as the best use of those resources for the satisfaction of human needs; and **Equity** as the fair distribution of such satisfaction (Hopkins & al 2012).

A fourth framework is the **Socio-Ecological System (SES) diagnostic framework.** This can be seen as a potentially important extension of traditional institutional analysis. This analytical framework tries to map all possible linkages between the biophysical world and the social world by identifying crucial variables in 4 subsystems of an entire Socio-Ecological System: Resource Systems with Resource Units and Governance Systems with Actors. Variables can be organized in tiers – from higher levels to more detailed lower levels – and interactions between these can be modelled to produce predicted outcomes. Such variables can be resource reproduction rates, inter-specie dependency (e.g. predation), property rights, rules in use and capacity for stakeholder organizations. By changing crucial variables, such different outcomes can be produced and compared to real life situations. Although there will be no perfect resource governance situation – no panacea – this framework can through iterations be used as a powerful tool for finding and trying out different options for achieving sustainable policies. (Ostrom,2007, 2009).

Coastal Ecosystems and the Coastal Social systems poses challenges to all of these analytical frameworks. This is mainly because of the added complexity that stems from land/sea interactions and the dynamics of the tidal zone that interacts with both terrestrial and marine ecosystems. . In addition, the marine parts of the coast is 3-dimensional and highly fluid both horizontally and vertically. Crucial resources in the food chain interact with resources at various depths and sea currents quickly distribute beneficial nutrients, harmful discharge and pathogenic substance over large areas. Externalities are not only felt downstream, but can return with the tide and hit the source.

The "drivers" are therefore not one-dimensional, but interact with a multitude of other "forces" that can aggravate - or neutralize- the "pressure" - on the coastal ecosystem – or on the social system of coastal communities. A DPSIR analysis therefore has to make a conscious choice of which drivers to focus on in the analysis. The long debates on which "indicator organism" to use in implementing the EU Water Directive also illustrate the policy making challenges of the different system models. This is because such choices are often not neutral, but based on media's problem-reporting, political attention, funding opportunities or scientific fashions – like overfishing, climatic change, invasive species, algea blooms etc. Therefore, in many cases a wrong choice of indicators can result in a general ecosystem deterioration and a biodiversity reduction that can go undetected and lead to a long term collapse.

Most coasts are characterized by tidal actions; emitted pollutants can return to the waters of the polluter, nutrients produced by photosynthesis sink to the bottom – and upwell in distant places at later stages. A linear simulation of dynamic processes in a SAF framework can therefore miss the point of returning – or circular – dynamics, and interpret natural processes as unwanted externalities. Thus there is an inbuilt risk of misinterpreting traditional ecological knowledge of long-term cycles (TEK) and miss the chance of stimulating flexible adaptation and self-governing capability in coastal communities.

A SES framework analysis can be successful in listing all the variables that can be thought of as having an effect on a coastal system – from the macro-parameters of CO_2 content in sea water down to the minute details of the life cycle of an oyster. But ironically, this multiple-tier complete picture can appear unattractive for policy makers. There are simply too many variables to spread the political attention to, issues becomes blurred and thus it becomes virtually impossible to make policies that resonance with party platforms or with larger groups of voters. In addition, the complex Socio-Ecological System tend to be presented as a "machine" that functions smoothly, and dysfunctions and malfunctions does not show in the analysis. Thus the dynamics of both virtuous circles and vicious circles are often masked, and system-shifts through tipping points – or system self-repair – are missed. This weakness in predicting qualitative system changes is also hampering policy relevance of this

framework, since politics thrive to a large extent on hope and fear. There is some awareness of the lack of dynamic analytical capability in the SES framework, and progress towards improving this is being made. (McGinnis and Ostrom. 2014).

We shall in the following present two empirical cases of Coastal Systems, two coastal commons with their developmental and analytical challenges. One is from Bretagne on the French Atlantic Coast. The other one is from Northern Norway on the North Atlantic coast. They are both complex coastal Socio-Ecological Systems and we shall see how much analytical rigor is really needed in order to understand the policy challenges in these cases.

3. Governing Multiple Use of Marine Protected areas in Bretagne, France

Conservation and use/harvest has traditionally been seen as opposites and large areas of terrestrial land has been set aside as National Parks to preserve natural habitats and biodiversity. In coastal and fluid marine environments, this is not so simple, the dynamic character of these environments preclude conventional conservation strategies. The "Blue Growth" strategies of Europe is trying to bridge this contradiction and create an institutional base for a more sustainable growth in coastal areas rich in resources that are common to a large number of different users.

In Western France (Brittany) the Marine Natural Park of Iroise Sea was established in 2007 as a result of a long negotiation process between the French state and local territorial authorities and between local stakeholders and the authorities. This is an interesting case because multiple usages were incorporated into the governing regime of this complex Socio- Ecological system, and new legislation had to be enacted in order to facilitate this. The Iroise Sea was nominated as a biosphere reserve by UNESCO already in 1989 because, is a "remarkably well-preserved area, providing habitat for many sensitive species on fragile sites of national and even international significance for nature conservation". Thus, the area has vital ecosystem functions for a wider marine ecosystem and provide fundamental ecosystem services for a larger part of the French Atlantic coast. In the later decennia, the area has been put under great strain by the fishing industry and by tourists during the summer months. It is also a coastal area where water quality is threatened by runoff from heavy usage of the catchment areas and extremely heavy maritime traffic.

The concerns for the protection of the natural heritage of the Mer d'Iroise led to a proposal for creating a National Park there under the then existing French legislation. On September 25, 2001, the Prime Minister gave a ruling to study the project of creating a National Marine Park in the Mer d'Iroise (PNMI). In its first article, the proposal stated that *"the national marine park project in the Mer d'Iroise shall allow for the permanent protection of the area's outstanding natural beauty; the development of human activities compatible with this preservation will be taken into consideration"* (Sabourin and Pennanguer, 2003). The core zone for the PNMI would be 2000 km², and the buffer zone 2800 km² (Mission PNMI, 2003). However, the government took into account contests of the local population and the legitimate usages formulated during the consultation process. Already here a compromise between conservation and use is being formed in three strong recommendations made by the government: The conservation of fishing activities, of maritime and island tourism and of the economic development of the islands of Ouessant, Molène, and Sein. The future park should not be a closed-off sanctuary, but a vast area that will have to reconcile the protection of the environment with the further development of human activities. With such a multitude of different – and somewhat

conflicting - uses, the area is characterized by a series of collective dilemmas. Analytically we could say that it has the nature of a complex commons.

Within this context the whole idea of a coastal and marine area as National Park at sea was called into question and members of Parliament from the district used many arguments against such an implementation. They argued for a new governance tool with less restrictions on human activities and the idea of the new legal category "Marine Natural Park" came out. The law of Marine Natural Park discussed by the Parliament was heavily influenced by this debate around Iroise Sea Marine Protected Area. The new French law of 2006 defined the legal frame for this new conservation tool and established a new governing body with the name of National Agency of Marine Protected Areas. (Frangoudes, 2004).

From April 2006 to October 2007 the consultation process with all local stakeholders (users, citizens, scientists, etc.) for the establishment of the management plan was conducted. This resulted in a decision one year later. During this process the different users, especially fishers, seaweed harvesters, shellfish farmers and islands population acted in a way to secure that their particular interested was written into the management plan. All these stakeholders who initially had acted against the National Park now became the prime defenders of the Marine Natural Park - as their rights were taken in account by the management plan. The plan was now seen as an acknowledgement of their traditional right by higher authorities and as a protection of these from other and more aggressive outside users. These users definitely identified themselves as the "commoners" of the newly created park commons.

However, recreational fishers and divers were the losers because their historical rights were not recognized by the management plan of PNMI. Therefore, they reacted negatively towards the PNMI , and this attitude was supported by local politicians who decided to defend recreational fishers who represented a higher number of people than the local professional fishers. So, the management plan and the implementation of the PNMI did not satisfy all the users at the same level, but still all of them were invited to participate in the governing body of the MPA, the council.

The governing council for the Marine Natural Park is composed by 49 seats divided as follow to the different users and territorial authorities: Professional fishers considered as the most important users group occupies 12 seats, Recreational activities (fishers, divers, sailors, etc) got 8 seats, 11 seats are given to the 11 riparian municipalities, 2 to local NGO's, 9 seats to scientists, 1 seat to regional park and the last 6 to the state administration. An elected person chairs the council and from the beginning, this was the President of Finistère district. The park employs permanent administrative and patrol staff and its director is nominated by the State. Thus far- on the constitutional level – this governance system is to a large extent in line with the general design principles of commons (Ostrom 1990).

The council is the place where all issues concerning the implementation of the management plan, of the various action plans and different projects for specific users are discussing and decided upon. The minutes of the council show that decisions are taken only after many hours of discussions and a consensus is usually reached. The objective is to find an agreement in a way manage the different resources in a more sustainable way, to prevent conflict between users and to secure compliance to the user rules. The council does not have the full legal competency to manage fisheries and shellfish farming, although both these activities are planned for by the PNMI in their comprehensive Socio-ecological system plans.

To illustrate how the institutions of French MPA's are functioning we will have a closer look at the example of seaweed harvesting within the Iroise Sea. This is one of the main harvesting activities here because kelp forests are abundant and two main species are harvested, *Laminaria digitata* and *Laminaria hyperborea*. It must be said here that legally the park has limited competencies in fisheries management which is done by the fishers' regional organization - the Regional Fisheries Committee.

In the Iroise Sea kelp is also important as an ecosystem element, as crucial habitat for juvenile fish that later migrates to important fishing areas. It therefore renders important ecosystem services for other parts of the Park and for larger coastal areas outside the park. To practice commercial harvest from a keystone habitat of vital importance for other users is thus a classic collective dilemma that has to be solved at the collective choice level..

Even if the PNMI doesn't have any direct power in fisheries management, the PNMI conducts scientific studies aimed at increasing the knowledge about the marine ecosystem and about economic activities within its jurisdiction. The law gives powers to PNMI to exercise its veto if economic activities are likely to impact negatively on the ecosystem. But since its establishment, PNMI has exercised its veto only twice: (1) to oppose a Regional Committee of Fisheries decision to increase the number of purse seines permits for catching sardines and (2) to oppose the extension of a pig farm located near the marine park that would increase runoff and possible coastal eutrophication.

During this period, another external event modified the interactions between traditional stakeholders. An inspection undertaken by the General office of Concurrence, Consumption and Fraud, found that the setting of a seaweed price did not respect the principle of free competition. Prices were agreed upon between kelp harvesters and the processing industry at the beginning of each harvesting season and were common to all harvesters. This was seen as forming a cartel. A new system has now been implemented whereby each enterprise signs a contract with individual harvesters for a given quantity at a given price. The new system has considerably altered the role of the Kelp Commission of the Regional Committee of Fisheries. This was a case where decision making powers related to resource management were shifted from the Kelp Commission to a direct relationship between the harvesters and the processing industry. Kelp harvesters felt that the commission was no longer required as they could solve their problems directly with the industry and discuss the ecosystem consequences and precautions with other users in the PNMI governing system.

Not all governing of this coastal commons have been smooth. Tensions between fishers appeared rapidly because kelp harvesters unable to fulfill their contracts moved to other areas "belonging" to other harvesters. The Kelp Commission had to intervene to find collective solutions which would satisfy all kelp harvesters and avoid conflicts. In April 2014, new management rules were introduced to deal with this new situation. Kelp harvesters, participating at the Kelp Commission, voted for the following two rules: (1) harvesting areas would be based historical harvesting rights, and (2) moving to another harvesting zone required authorization from the Kelp Commission. These new management rules were approved by scientists and have been brought into law by the regional fisheries administration. Now the kelp harvesters demanded the intensification of *L. hyperborea* harvesting on an experimental basis. It would guarantee better incomes as demand for it was greater given new extraction and application possibilities for the processing industry. Harvesting of *L. hyperborea* would also reduce the pressure on *L. digitata* as this would guarantee better incomes especially to bigger boats.

While not against promoting the harvesting of *L. hyperborea*, PNMI ordered scientific studies to evaluate the impact of increasing harvest of *L hyperborea* on the species and secondly on associated species. The PNMI also tried to obtain data on the impact of fishing gear on other species such as dolphin and sharks. One study showed that the frequency of noise produced by the fishing gear used for *L. hyperborea* harvesting disturbed dolphins and sharks. Despite concerns by other stakeholders, traditional kelp harvesters tried to convince the park authority to accept intensified harvesting. The park authority tried its best to raise serious environmental concerns. However, the concerned scientist

working on population dynamics and management measures for seaweed supported the intensification of *L. hyperborea* harvesting on a rotation basis. He was inspired by the Norwegian management system that advocated closure of harvesting areas for five years (based on the species life cycle). The processing industry also pushed for the opening of *L. hyperborea* harvesting and increased their demand for *L. digitata* so as to maintain current employment levels. The local administration and political class in the riparian municipalities had only one objective in mind, namely "*the creation of new jobs in the area*" and hence they supported efforts at increased production of kelp.

Intensification of *L. hyperborea* harvesting was thus finally authorized by PNMI. In return, kelp harvesters accepted the closure of a dolphins' refuge areas and closure of the *L. digitata* forests to kelp harvesting. The Regional Fisheries Committee viewed the acceptance of these closures as "a sign of a good will"[1].

In general the governability of the kelp system has improved after the establishment of PNMI. Fishers' and kelp harvesters' organizations are both members of the park council and the PNMI participates in the Kelp Commission. Both the PNMI and the Kelp Commission are sensitive to the economic needs of the harvesters and the ecosystem value of the resource. Kelp harvesters are continuously informed about the findings of the studies aimed at increasing knowledge about kelp forests and are aware of management rules discussed by the Kelp Commission. Overall, research is used to improve the governing of the whole system. For example, the results of recent research undertaken by the PNMI on the location of kelp forests and the abundance of biomass in each area contributed to formulation of recent detailed management rules for *L. digitata*. The allocation to each boat of a specific harvesting zone was based on the fact that each boat is equipped with a Vessel Monitoring System (VMS/satellite recording).The mapping of *L. hyperborea* has also been done by the PNMI. The compliance by kelp harvesters to the closure of certain areas is most probably based on the fact that they have been informed by park authorities as to the reasons for it. The park authorities also support kelp harvesters to better manage the resources. The increased use of scientific ecological knowledge does however mean that traditional local ecological knowledge (TEK) is playing a different role than before, to some extent we can see a merger between the two when governing institutions is made more local and less sectorized.

The case of kelp exploitation in Brittany well illustrates how the natural eco-system, the social system and the governance system are changing over time. The natural system-to-be-governed is clearly part of a social construct. Initially concerned with sustainable exploitation of only one species of kelp, the natural system-to-be-governed now includes not only two key kelp species, but also a wide range of other ecosystem elements and social-ecological interactions. Change in the end product of kelp harvest and technical innovation in harvesting and processing have modified - sometimes at a rapid pace - the social system-to-be-governed. The governance system, both its formal institutions and its interactions, has also changed over time to respond to new needs. Despite doubts and criticism, there is a view among the leaders that the present governance - based on close collaboration between fishers, park authority and industry - has a potential to improve the overall governability of the system. This relates to the facts that there is more untapped governance capacity at the local level - as well as unused resources to produce knowledge about the socio-ecological system, its components, interactions and dynamics.

[1] Oral communication by the secretary of the District Fisheries Committee

4. Ecosystem management of aquaculture growth in Nordland, Norway.

There is an important emphasis on Blue Growth in the European Union and in the larger European Economic Area. In these strategies the marine sciences and biotechnology are to be used to stimulate a growth in both advanced biological production and in advanced technological solutions to coastal and off-shore challenges. A fundamental prerequisite here that it must be sustainable, and in line with the Sustainable Development Goals of UN, especially SDG # 14. Despite these commitments, there is little consensus regarding what really is sustainable Blue Growth, except that it has to be based on resources that are common to a large number of users. This EU Blue Growth Stategy is currently focused on 5 substrategies: Aquaculture, Coastal Tourism, Marine Biotechnology, Ocean Energy and Seabed Mining. For the aquaculture component of the Blue Growth Strategy, the emphasis is on 1) administrative simplification, (2) improving access to space and water, (3) increasing competitiveness and (4) exploiting the sustainable practices of EU aquaculture and high quality products (https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/swd-2017-128_en.pdf).

Although Norway is not a member of the EU, there are many parallels between the EU Blue Growth and the Norwegian Blue Growth strategy; Of the five EU-strategies the Blue Growth strategy in Northern Norway has particular emphasis on the growth potential in aquaculture (Salmon farming) and in Costal/MaritimeTourism, including local recreational tourism.

Compared to other parts of the Atlantic Coast, in this part of the North Atlantic, the problem of overfishing of major commercial fish-stocks is largely solved by more rational governance of wild-fish fisheries and a well functioning control and sanctioning regime. This has been achieved by long-term cooperation with Russian and EU fisheries authorities. With high fish-prices for stable volumes of catch, these fisheries are very valuable to the Norwegian economy and they have shown a long-term sustainability in accordance with the SDG #14. However, the biomass-fishing for fodder for the aquaculture industry has ecosystem effects that hits the large colonies of sea-birds on the coast, and on the whole, wild-fish fisheries are therefore not totally sustainable.

One monopolist international company (FMC), which claims to do this in a sustainable way, although critics point to local reduction of biodiversity and thus impoverishment of habitats for juvenile fish carry out kelp harvesting in Northern Norway. Therefore massive experiments with cultivation of micro-and macro algae is currently taking place all along these coasts, in the search for an increased supply of alginates and for new materials, new sources of energy and recently: new sustainable fodder types for salmon farming. Algea-cultivation in Integrated multi-trophic aquaculture (IMTA) is also seen as one possible solution to the problems of discharge from traditional cage-based fish farming plants.

The potential area conflict between oil-exploration and fisheries in the important cod-fishing grounds of Lofoten/Vesterålen is currently frozen by a political stalemate that implies non-exploration and non-protection. This situation is likely to remain so for a foreseeable future, but if any oil/gas should be "left in the ground" for climate-policy reasons, it would most probably be in these areas.

Thus aquaculture is the main "Blue Growth" strategy on the coasts of Western and Northern Norway as a major policy tool for the "nation's means of living after the oil époque is finished". Already, Norwegian Salmon aquaculture has since 1970 grown to be world's largest producer of farmed salmon and exported in 2016 more than 1 million tons to countries all over the world. Already in 2006 the value of aquaculture surpassed the value of wild-fish fisheries. A new government policy is therefore to increase the aquaculture production in a steady way so as to satisfy a growing consumer demand in emerging markets (e.g. China) and maintain a reasonable high price. (Gov. of Norway 2015). While new licensing through the last 40 years have been subject to political whims, the emphasis will now be on "increased predictability and removal of political uncertainty" (Kylland & Prescott 1977). But this

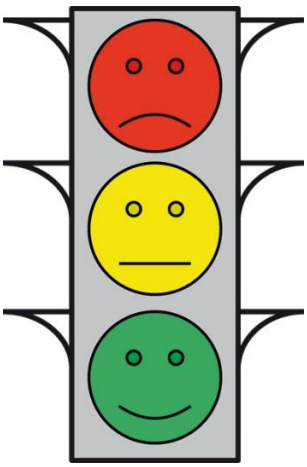
growth is only possible with a high standard of environmental quality and fish health. This is vital for a continued high reputation in the international food markets. In addition, in order to have a legitimate growth, the aquaculture industry must improve its performance in relation to a number of local factors:

- Local area conflicts in the coastal zone, especially in fjord areas.
- Sea water quality in areas with intensive aquaculture
- Contagious fish diseases and the spread of these
- Uncontrolled use of medicines and chemicals in open sea environments
- Discharge of fodder-spill (waste) and faeces from fish in open cages.
- Concentration of parasites (sea lice) in dense caged biomass
- Runaway salmon with harmful effects on wild salmon runs.

In a recent policy change the government and the major aquaculturalists' organizations have agreed on a new system for licensing that places the responsibility for sustainable growth on the aquaculturalists in a certain area as a collective (Government of Norway 2015). This system is based on two important elements:

- The division of the Norwegian coast in 11 Production zones, in each of which the "environmental status" of a large marine ecosystem can be monitored closely. .
- An "action rule" based on environmental indicators, where acceptable environmental impact ("Green light") implies a permission to increase production every 2nd year by 6 %; where moderate environmental impact ("yellow light") implies a "freeze" in production volume, and where unacceptable environmental impact ("red light") implies a forced reduction in production volumes. (see fig X)

Fig 1: Action rule for aquaculture growth as traffic lights.

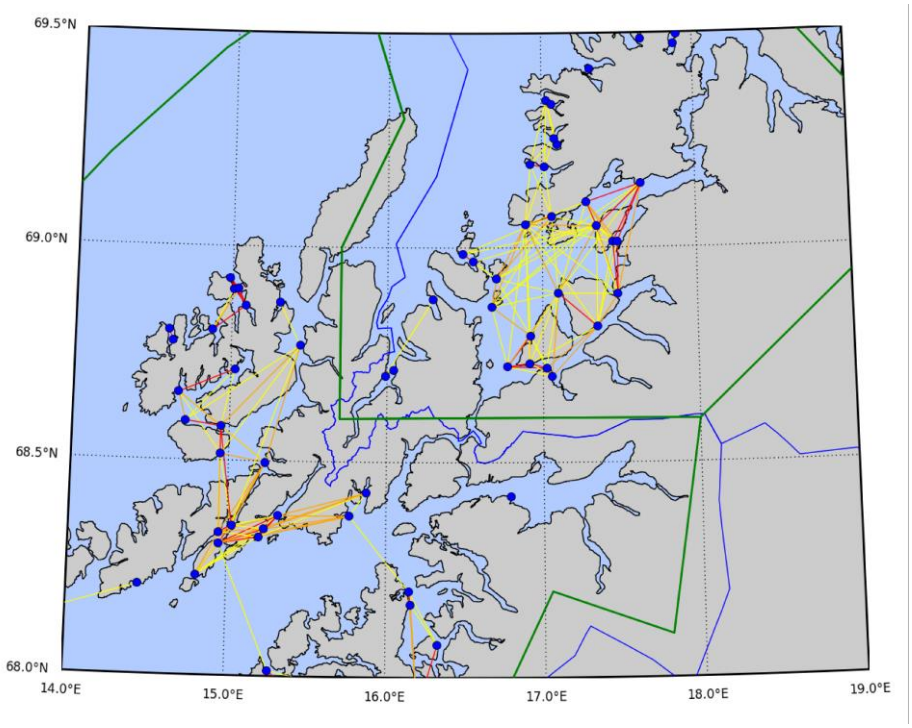


Source: Government of Norway, 2015

The production zones were designed on the basis of cluster analysis and analysis of environmental interaction between fish-farms by the use of an influence matrix. Between the clusters there should be sufficient "fire-lanes" to prevent contamination of diseases and parasites between the fish farms. Thus production zones with many aquaculturalists can in the years to come be analysed by social scientists

as collectives with common responsibility for achieving a "good environmental status" – the prize of which is increased production and increased profit.

Fig. 2. Example of aquaculture clusters in production zones Vestfjorden/Vesterålen and Andøya/Senja – with "fire lane" between.



Source: Ådlandsvik 2015

As mentioned above, the choice of environmental indicators is difficult and disputed, as a full set of ecological and social system parameters in a DPSIR-, SAF- or SES-analysis are hard to combine with administrative simplification. Here nearly all the performance factors above have been considered and rejected. In the end, the government settled with spread of sea-lice as the one measure to decide the environmental condition. In addition, the government has promised environmentalist organizations that a process will start on how to operationalize an indicator for measuring effects of discharge on the level of production zone, because discharge is an externality that can hit other fish-farms in addition to your own. All of this means that biodiversity reduction, biomass fishing, runaway salmon and a host of other systemic effects are not included in the model. Also the Norwegian Parliament has now agreed on an area license fee that goes to the municipality where the fish farms are located. This can dampen serious area conflicts to some extent, while smaller conflicts with other coastal users like fishers, recreational cabin owners and coastal tourist operators will still prevail.

Interesting for our analysis are some of the arguments used in the policy instrument design here: Fish health can be improved by replacing imported soya fat (causing hearth failure in salmon) and biomass marine fats with more use of cultivated algae in the fodder; Vaccinations can increase productivity as they are cheaper than large scale antibiotic treatment. Elimination of runaways will not only safeguard wild salmon, but will also decrease loss of production and increase profitability. As good fish health and cultivation productivity is believed to be in the aquaculturalist's own individual interests it is therefore not necessary to regulate.

How this simplified regulatory regime is going to work in empirical coastal setting is still to be seen. But it is interesting that an incentive based on collective performance within a production zone in relation to "good environmental status" (the traffic light model), will be the prerequisite for growth permissions. To analyse the workings of this model in the real world, the DPSIR-, SAF- or SES-frameworks seem unnecessary overburdened. Therefore, the analytical concepts in such a future research agenda could be quite simple, merely reflecting the dilemmas between individual and collective success, the costs of free-riding and the risk of under-provision of common-pool goods. This is the format of a traditional commons analysis (Ostrom 1990) with the conventional tools of IAD-analysis (Ostrom 2005).

5. The contribution of complex coastal studies to commons governance theory.

As shown in the preceding paragraphs, we have in recent years acquired vastly increased knowledge about coastal zones as important areas for biological production, recreation and basis for vital ecosystem services. Modern systems theory has in most cases enabled us to understand the complexity of elements in coastal social-ecological systems and a large number of the even more complex interrelations between these elements. The whole idea of sustainability has therefore changed dramatically through this deeper understanding of the connectedness and dynamics of coastal systems. It is no longer a question of a "maximum sustainable yield" from a certain population of wild commercial fish, but a question of the sustainability – or "health" - of entire coastal ecosystems – and of their dependencies – the coastal communities.

With this increased understanding through more comprehensive models, we should think that the accuracy of policy instruments available to policy makers are vastly improved so that the SDG goals are more attainable. But as we have shown in the two cases above, this is not the case. The governing system - in most western countries an interest-based and party-politics-based system – is not able – nor willing - to base regulations on predicted outcomes from complex models. Policy makers clearly wants "administrative simplification" and "political victories". Connectedness and probabilities blurs both "rights", "stands" and "fairness" and are thus less attractive in the face of upcoming elections. On the other hand policy makers are in favour of "getting the institutions right" and " reducing conflict over resource use" – removing noise is often interpreted as a political victory.

This is also what we have learned from our two cases. In Bretagne the PMNI brought the different resource users and local politicians together in a council where they were given the necessary tools to solve their own collective dilemmas. In Northern Norway, the government gives the operators in a "production zone" the responsibility for sustainable growth in aquaculture. In both cases, the choice of regulatory indicators is used both to simplify the governance of the coastal system and to maintain the sustainability of the coastal ecosystem. Both sea-lice frequency and kelp forest quality were such crucial indicators that the collectives of users could govern by. We have also learned that this choice process is crucial for the working of the system and that a number of potentially powerful indicators were not chosen, either because they were ambiguous in relation to "good environmental quality" or because they were superfluous. With the right institutional arrangements and the right incentives, it would be in the operators own interest to keep the values of these indicators at a low level.

The crucial point here is whether this "own interest" is of an individual or collective character. If the interest is individual, it will in most cases produce a sustainable development without any regulation,

in a few cases negligence will result in loss of license or criminal charges. If the "own interest" is of a collective character – or as in the Norwegian case designed as a collective responsibility – the self-regulatory capability of a certain area is important. We saw in Bretagne that such a self-self governing capacity was present also in highly sensitive policy issues. It still remains to see how the collective actions for growth will work on the coast of Northern Norway.

Therefore, these questions of which regulatory measures are efficient – and necessary – in an age of innovation in the public sphere, belongs more to the field of commons studies than to the field of complex systems modelling.

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