Project proposal to the Regional Research Fund Agder (RRF Agder), under the 'Regional public project' call, 16 October 2013.

Marine biodiversity 'hotspots' and connectivity in Skagerrak: implications for national park design and implementation in coastal Aust-Agder (MARINEPARK)

An exposé of the species diversity found in shallow water fish communities in Skagerrak, including the corkwing wrasse (Symphodus melops), Atlantic cod (Gadus morhua), greater pipefish (Syngnathus acus), and flounder (Platichthys flesus).

Project summary: Marine spatial planning is a tool to manage human use of the marine realm. Consequences of human use may include pollution, overharvesting, and habitat degradation– all drivers for loss of biodiversity and reduced recruitment to fisheries. Marine protected areas (MPAs) and no-take marine reserves are areas in the ocean where the human impact is, to varying degrees, limited or removed. Various types of protection levels can be nested within larger zoning plans, a management practice that is rapidly becoming an integral part of marine conservation. If properly designed, zoned networks may provide an array of local- as well as regional benefits to biodiversity and harvest of species, affected directly or indirectly, by human activities. We propose a multidisciplinary study that will address the design of a coherent network of protected biodiversity 'hotspots' along the Skagerrak coast, with primary focus on the Agder coastline. We envisage a two-part study, each part resulting in major findings in their own: primarily by giving timely advice on ecosystem-based management of marine resources, and secondarily by contributing to our understanding of the variation in biodiversity and fish recruitment observed along the Skagerrak coast. The results obtained will contribute to science based decision-making when designing marine conservation measures within the planned 'Raet National Park' along the coast of Aust-Agder county. Moreover, the proposed project will (1) enhance collaboration between the partners involved, and (2) reinforce the ongoing capacity building in marine conservation science within the region. We are confident that we have gathered the ideal team for this project, covering all theoretical and practical aspects of the proposed R&D effort.

PART 1: Innovation

1. General idea

The County Governor of Aust-Agder's Department of Environment is leading an initiative aiming to establish a national park (Raet National Park) encompassing the marine areas of Tvedestrand, Arendal, and Grimstad municipalities (Figure 1) by 2016 (Fylkesmannen i Aust-Agder 2013). The present proposal describes a project designed to support decision making in the process towards implementation of the park and its subcomponents. Generally, we aim to (1) generate knowledge on how to design a coherent network of marine reserves in Skagerrak, and specifically, (2) explore the potential role of the proposed Raet National Park in such a network.

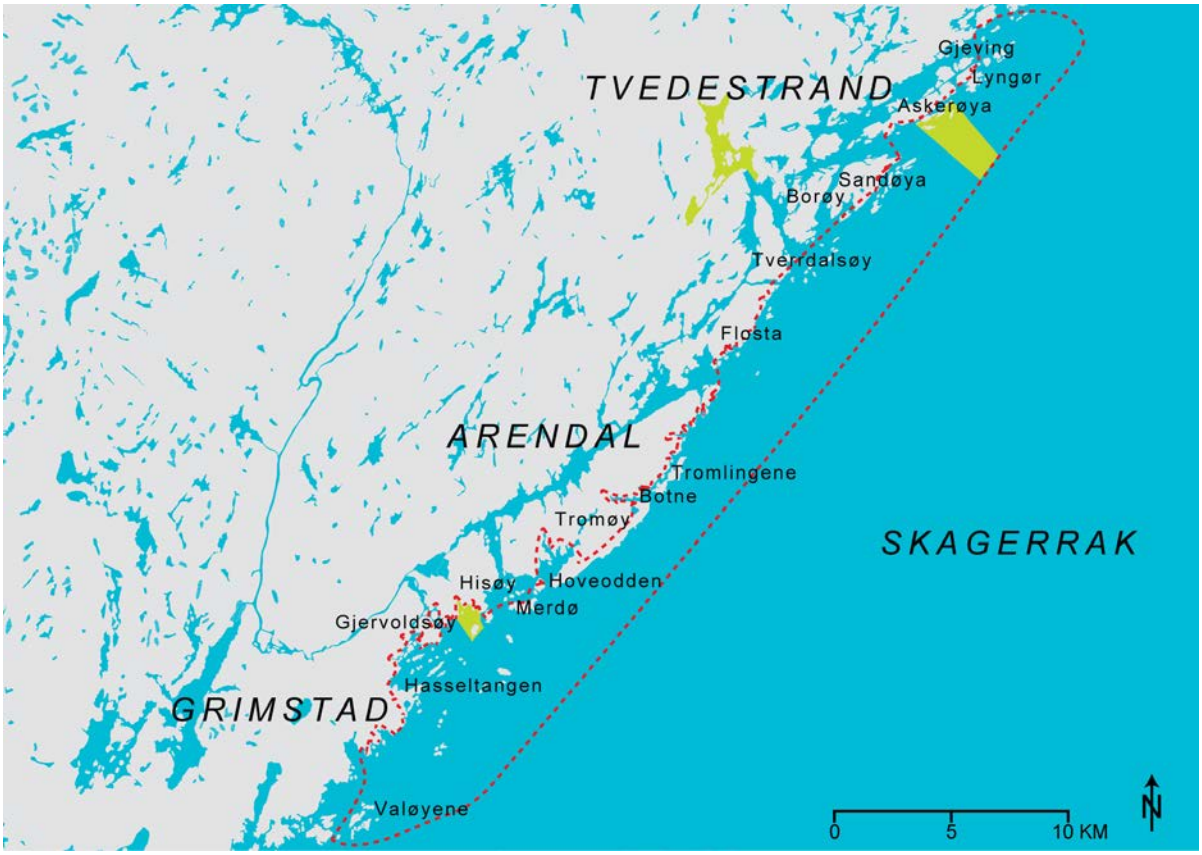

Figure 1 Map of the focal area of the study, the proposed Raet National Park (red stipled line), encompassing the marine areas of Tvedestrand, Arendal, and Grimstad municipalities, in total an area of roughly 185 km^2. The green zones indicate existing marine protected areas (MPAs) in the region.

2. Degree of innovation

The present project will provide urgently needed knowledge for science based marine spatial planning and management of coastal areas. In particular we will develop a set of design criteria that will be highly relevant to implementation of marine conservation measures in Skagerrak, including Aust-Agder, such as the Raet National Park. To date, a lack of cross sectoral cooperation has seen the creation of national parks in Skagerrak without specific marine content in terms of conservation measures. This project represents an opportunity to pinpoint tangible measures with potential to foster cross sectoral collaboration with the Directorate of Fisheries to develop and enable science based management of coastal marine resources by means of spatial management on multiple scales.

3. Potential for value creation

Improved science based management of our coastal areas and marine life has a number of ecosystem- and societal benefits. From a well managed marine coastal ecosystem we may derive ecosystem services such as healthy stocks of fish and crustaceans. Moreover, well managed marine components within the planned Raet National Park may create opportunities for sustainable commercial- and recreational fishing activities; while simultaneously improve the potential for eco-tourism in the region. Outcome from this project will be highly suitable for information/ public relations material (posters, leaflets etc.) to be produced in relation to the park.

Additionality: the knowledge obtained through this project will be highly transferrable to other similar spatial management efforts within and beyond Skagerrak. As such, it will provide the County Governor of Aust-Agder with sought after tools and expertise that may be shared within the public sector and among its management bodies, e.g. the Directorate of fisheries, Norwegian Environment Agency, County Governors of Telemark (Jomfruland National Park), Vestfold (Færder National Park), Østfold (Ytre Hvaler National Park) and managers of Kosterhavet National Park in Sweden.

4. Research needs

Two central knowledge gaps have to be addressed and a computer model must be developed to realise our innovation:

Variation in biodiversity and recruitment in Skagerrak: A promising approach to conserving the highest number of species by the least effort and cost is to identify biodiversity 'hotspots' (e.g. areas of high biodiversity) for potential reserve designation (Myers *et al.* 2000). Further, identifying which activities that cause biodiversity loss or reduced recruitment is paramount. For example, if habitat degradation and pollution are among the main reasons for loss of biodiversity, a national park that bans such activities may mitigate their detrimental effects. By contrast, if overharvesting is the main factor that reduces biodiversity and recruitment success to important fished stocks, no-take reserve components (i.e., areas where fishing is banned) has to be considered for areas of unsustainably high fishing activity. Presently, there are few up to date empirical studies that have identified contemporary drivers of variation in biodiversity and recruitment at a Skagerrak scale. *To support the Raet National Park project in science based decision making towards establishing a sustainable national park, we need to perform new research on the drivers of local as well as large scale variation in biodiversity and recruitment.*

Marine reserve design and connectivity: Typically, marine reserves display a marked increase in biodiversity, biomass, density, and size of species that are affected by harvesting outside reserves (Lester *et al.* 2009, Fenberg *et al.* 2012). From a fisheries perspective, a measurable effect of a marine reserve is spillover of adults and juveniles from reserves and into adjacent, fished areas (Huserbråten et al. 2013). Protecting large, highly fecund individuals within reserves may also lead to subsidies of pelagic eggs and larvae to unprotected, fished areas (Gell & Roberts 2003). At the same time, where larvae exported from reserves end up, is unknown for most species of commercial interest (Sale *et al.* 2005). *If estimates of larval dispersal kernels can be obtained, they can be used to optimise reserve placing within a network, ensuring connectivity among reserves (Palumbi 2004), which in turn increases sustainability of reserves (Gaines et al. 2010).*

Biophysical modelling: Fjord and coastal ocean dynamics are complicated and hence it is necessary to use sophisticated methods to reproduce realistic drift patterns. Environmental conditions in the ocean influence ecology in a number of ways (Sundby & Nakken 2008),

and knowledge of the environment and environmental variability is crucial to understand variability of the ecosystem. The most basic parameters defining the oceanic environment are water currents (-speed and -direction with depth), temperature, and salinity. These parameters are dynamically linked and usually vary in concert. Obvious effects of these parameters on the ecosystem are temperature dependent growth of individuals (affecting pelagic larval duration) and dispersal of early pelagic life stages (EPLSs). Generally, variability on shorter time scales affect individuals while longer-term variability affect populations. Moreover, individual based models (IBMs) are flexible and powerful tools to integrate existing knowledge on demography and behaviour of a particular species or life history stage. IBMs also allow for exploration of consequences of knowledge gaps by contrasting alternative model assumptions and comparing corresponding model outputs to a set of patterns identified in real populations. In combination with high-resolution ocean circulation models, biological and behavioural subroutines constitute powerful tools to address relevant scales of larval dispersal and population connectivity in Skagerrak. *To address the knowledge gaps that our study intends to fill, we need to simulate Skagerrak scale connectivity, and to do this we need to develop a computer model that integrates behaviour of Skagerrak coastal water masses and movement of different life stages of focal organisms (biophysical model).*

PART 2: R&D activities

5. Aims

Principal objective: We propose a two-part study, where both parts will significantly strengthen the science based decision-making process of implementing the Raet National Park in Aust-Agder, and similar projects within Skagerrak. First, we aim to generate new insight into variation in biodiversity and recruitment of important harvested species. Second, we will apply the knowledge generated on species diversity to design a coherent network of marine reserves in Skagerrak.

Sub-goals:

- To explore the variation in biodiversity and recruitment to important fish stocks in Skagerrak over the past century and identify the chief drivers of this variation (Task 1)
- To develop a biophysical model that realistically simulates dispersal of early pelagic stages of key species in Skagerrak (Task 2)
- To quantify connectivity within a proposed network of reserves, protecting biodiversity ‘hotspots’ in Skagerrak (Task 3)

6. R&D challenges and methods

Task 1: “The Flødevigen data set” is a unique data set that contains beach seine sampling data from all over coastal Skagerrak, sampled every year from 1919 and until today (Johannessen & Sollie 1994). We will analyse this data set to reveal any patterns in species variation and recruitment. We will gather all readily available variables that may explain this variation, such as for example: fishing pressure, release of pollutants into fjords, cover of benthic flora at sampling stations (i.e., eelgrass and macro algae), temperature, wind stress, the North Atlantic Oscillation index, and distance of sample site to major currents (i.e., the Norwegian coastal current). Novel analyses of the data will provide an interesting vista on how species diversity and abundance has developed the past decades. This task will also provide important insights on how the changing climate has affected biodiversity and recruitment to fish communities in Skagerrak.

Task 2: To quantify fjordic and coastal scale connectivity of fish communities in Skagerrak, we suggest incorporating the best available science on the larval ecology of key species into IBMs, and implement the IBMs into the newly established ocean circulation model NorKyst-800. The NorKyst800 model has already shown merit when predicting important physical parameters such as currents, temperature, and salinity along the Norwegian coast (Albretsen *et al.* 2011). The model has a resolution of 800 meters, with the possibility of expanding the resolution even further (e.g., 160 meters). We will employ one of NOTUR's (Norwegian Metacenter for Computational Science) High Performance Computer Facilities for the CPU-demanding simulations.
The key species we will focus our modelling study on is the Skagerrak coastal cod. Cod is broadcast spawner (i.e., it releases eggs into the water column), cod has EPLSs lasting for several months, Skagerrak coastal cod show restricted movement of adult life stages, and they show a moderate level of genetic differentiation in Skagerrak suggesting that dispersal of cod EPLSs is restricted to fjordic scales (Knutsen et al. 2003). Additionally, we will use the European lobster as a 'null model' in the connectivity study to which the cod will be contrasted, as there appears to be little or no restriction to dispersal of lobster EPLSs in Skagerrak (Huserbråten et al. 2013).
Besides, obtaining good estimates on Skagerrak scale connectivity will add substantially to our knowledge on recruitment dynamics of important fished species in Skagerrak (Stenseth *et al.* 1999). Estimates of dispersal will also augment our understanding of community dynamics in Skagerrak coastal areas (Stenseth *et al.* 2002).

Task 3: To identify and estimate biodiversity 'hotspots' in Skagerrak, we will use "the Flødevigen data set". Identifying such hotspots will yield solid advice on where efforts should be made for protecting biodiversity in Skagerrak. Using the biophysical model developed in task 2, and the hotspots identified herein as tentative release sites for the IBMs developed in task 2, we will quantify the connectivity among hotspots. Placing reserves to maximise connectivity within the network will be key for the sustainability of future reserves. We will also explore alternative scenarios for reserve placing, balancing connectivity among reserves and species richness of the designated reserves. An important aspect will also be to what extent the tentative reserves encompass spawning sites and important nursery grounds such as eelgrass beds. The results from this task will be of particularly high relevance for potential marine conservation measures to be evaluated within the Raet National Park plan.

7. Organisation and project plan

Applicant/ Partner I: Department of Environment, County Governor of Aust-Agder.

Partner II: Institute of Marine Research (IMR), Flødevigen.

Partner III: University of Agder.

Project administrator: *T. K. Langeland,* Assistant Director, Department of Environment, County Governor of Aust-Agder.

County Governor of Aust-Agder participants: *J.A. Knutsen*, Chief officer, Department of Environment, *G. A. Homme*, National Park coordinator, Department of Environment.

Project leader: *J. Albretsen*, Senior Scientist, IMR Flødevigen.

IMR participants: *E. Moland*, Research Scientist, IMR Flødevigen, *S.H. Espeland*, Research Scientist, IMR Flødevigen, *A.R. Kleiven*, Research Scientist, IMR Flødevigen, *E.M. Olsen*, Principal Scientist IMR Flødevigen and Professor II UiA, *H. Knutsen*, Principal Scientist IMR Flødevigen and Professor II UiA.

University of Agder participant: *D.O. Andersen*, Department leader, Department of Natural Sciences.

PhD candidate: *M. Huserbråten* (see attached CV and M.Sc. diploma). Duration: 2014-2015-2016.

Partner roles: The County Governor of Aust-Agder (CGAA) is the project owner and main user of project results in development of the Raet National Park initiative. The CGAA Department of Environment will contribute to the project by communicating its knowledge needs and thus, in a realistic way, tune the scientific project to a real world, applied marine spatial planning example. Biannual seminars will be hosted and led by CGAA participants, and this will provide the forum for collaborative efforts. IMR Flødevigen is the institution responsible for all scientific aspects, project leadership and provider of a learning environment for the PhD-candidate through the established UiA/ IMR Flødevigen Marine Centre. UiA will be the hosting academic institution and employer for the PhD candidate. The PhD project is the pivotal point in this proposal. Moreover, with the structure in which a PhD project is conducted, it will ensure optimal outcome of the project in terms of high-quality scientific output.

The PhD candidate, Mr. M. Huserbråten is considered highly suited for the tasks at hand in the present project. He graduated from University of Oslo in 2012, and figured as lead author of an article recently published in PLoS ONE, in which he and co-authors empirically assessed the design of a marine reserve network in Skagerrak (Huserbråten et al. 2013).

8. Central milestones for R&D activities

No.	Milestones and deliveries	Period* (quarter)	Responsible partner	Participating partner
1	Identify knowledge gaps	1-2	CGAA	IMR/UiA
2	Identify chief drivers of variation in biodiversity and recruitment	3-4	IMR	UiA
3	Development of the biophysical model	5-6	IMR	UiA
4	Design criteria for a coherent network of MPAs in Skagerrak	7-8	IMR	CGAA/UiA
5	Writing of scientific and popular articles	3-12	IMR	CGAA/UiA
6	Writing of the MARINEPARK end report	10-12	IMR	UiA/CGAA
7	Biannual MARINEPARK seminars	2-12	CGAA	IMR/UiA

*The project period consists of 12 quarters from 1 February 2014 to 31 December 2016.

9. Costs per participating partner (in 1 000 NOK)

Partner	Pers.- and indir. cost	Equipment	Other costs	Total
County Governor of Aust-Agder	300		48†	348
Institute of Marine Research (IMR)	700		50†	750
University of Agder (UiA)	2902*			2902
Sum	3902		98†	4000

*The PhD position placed with UiA will require the bulk of the funding allocated from RRF Agder. Research Council of Norway doctoral position round sum rates for 2014 = 936 000 NOK, 2015 = 967 000 NOK, 2016 = 999 000 NOK (sum: 2 902 000 NOK).
†Other costs allocated to meetings and travel.

10. Financing per partner (in 1 000 NOK)

Partner	Own funding*		Total
County Governor of Aust-Agder	300		300
IMR/ UiA affiliated personnel	700		700
From Regional Research Fund Agder		3000	3000
Total financing (= total costs)	1000	3000	4000

*Own funding represents hours (hourly wages) to be allocated to the project by project participants within each partner institution throughout the project period.

11. Other partnerships for R&D-activites
The proposed project will interact with and reinforce other relevant ongoing projects involving the County Governor of Aust-Agder/ IMR ("*Active Management*") and the RFF Agder funded IMR/ UiA project "*CROSCON*", and thus add to regional project synergy.

PART 3: Use of innovation and results

12. Innovation realisation plan
Results from the proposed project will be communicated within the group of partners through biannual seminars (see 2.8 *Milestones and deliveries*). This will ensure that the Raet National Park planning process will be informed by any recent development in this and other relevant projects throughout the project period, which overlaps with the time frame proposed for the implementation of the park (Fylkesmannen i Aust-Agder 2013). For realisation of innovation in terms of dissemination of scientific results, see 3.15 *Dissemination and communication of results* (below).

13. Risks
We consider the present project as "low risk – high gain", meaning that we consider the outlined work highly feasible with guaranteed outcome. Here, we briefly discuss the risk categories relevant to this project: *Organisation risk*: by organisation risk we mean the need to overcome the challenges of cross sectoral collaboration. We acknowledge this risk, and to mitigate it we have scheduled biannual project seminars. These well be held to ensure optimal outcome for all projects partners. We deem this especially important for continuous transferral of scientific findings throughout the parallel project time frames for the present

project and the implementation of the proposed Raet National Park. *Implementation risk*: we deem this less acute as the partners involved have considerable experience in project based processes. *Financial risk*: the present project represents a sound investment to RRF Agder. It represents an opportunity to fund a project from which the outcome will be used in planning a substantial regional project. Also, it will support a doctoral position in marine science within the region, at the lowest possible cost, while at the same time ensuring optimal regional outcome due to the framework in which this doctoral position is placed (see section 19. *Other aspects specific to the call*, below).

14. Other benefits to society

There is a burgeoning interest in the use of marine spatial planning and marine reserves as management tools on national, regional and municipality level. Therefore, our results will be a timely resource for managers involved in establishing coherent networks of marine protected areas in northern waters. If reserves and reserve networks are properly designed, they may provide significant local benefits in areas surrounding reserves through the spillover effect, and long-term benefits through recruitment subsidy outside reserves (recruitment effect).

15. Dissemination and communication of results

Main findings from this project will be communicated to all relevant parties in the Raet National Park planning and implementation process such as the Directorate of fisheries, the Norwegian Environment Agency, County Governors of Telemark (Jomfruland Natinoal Park), Vestfold (Færder National Park), Østfold (Ytre Hvaler National Park) and managers of Kosterhavet National Park in Sweden. On the scientific arena, findings will primarily be disseminated to the international scientific community, through publication in peer-revived, high-ranking scientific journals. We believe this study will generate interest among a range of stakeholders in Skagerrak, for example, commercial and recreational fishers. Therefore we will strive to communicate and interact, directly with interested parties through talks/ lectures, but also indirectly through publications in their primary journals. To other stakeholders and the general public, we will communicate findings through meetings arranged for the interested public, through local TV, radio and newspapers, as well as nationwide through popular articles in the scientific (e.g., www.forskning.no) and non-scientific media. Recent research conducted by our IMR Flødevigen participants has featured on national television news on eight occasions over the last five years, as well as twice on the natural history programme ‘Ut i Naturen’ (Out in the wild) on national television (NRK 1) and on three occasions in the natural history programme ‘Naturens Verden’ (The natural world) on national radio (NRK P1).

PART 4: Other information relating to the project

16. Environmental aspects and consequences

Results obtained through this project may be used as scientific basis in marine spatial planning or in implementation of networks of marine protected areas in the future. Marine protected areas are considered to have a positive impact on the environment by increasing resilience and potentially restoring ecosystems to ‘natural’ states.

17. Ethical perspectives

We see no ethical issues worthy of discussion in relation to the proposed project.

18. Gender issues

All institutions involved in the present project aim for equal opportunities for males and females. We will aim to recruit master students in this project, and female and male students will be equally encouraged.

19. Other aspects specific to the call

The project described herein is relevant to several sections and subsections of the document 'Research and development strategy for Agder', from 2009. Firstly, it is relevant to the focal area 5.2.3 ('Food, agriculture, fisheries and biotechnology') as it aims to provide knowledge and innovation with potential to ensure long term sustainability for coastal ecosystems in the region, from which the fishing sector derives its goods. Secondly, it is relevant to focal area 5.2.6 ('Culture- and experience based industries') as well designed marine conservation measures within the planned Raet National Park is likely to enhance opportunities for ecotourism in the region. Thirdly, by the inclusion of the research institution partners IMR and UiA, it is relevant to subsection 4.1 ('Overall vision for the region') through contributing to reinforcement of a strong university (by providing a new doctoral position in marine science at UiA), and strengthening competitive research groups in subjects relevant to the region (marine spatial planning and marine conservation science). Importantly, the proposed partnership and project will strengthen the aim of two of the partners (IMR and UiA) in applying for status as a Research Council of Norway Centre of Excellence in 2016.

References

Albretsen J, Sperrevik AK, Staalstrøm A, Sandvik A, Vikebø F, Asplin L (2011) Norkyst-800 Report No. 1: User Manual and Technical Descriptions. Fisken og Havet, Institute of Marine Research 2/2011

Fenberg PB, Caselle JE, Claudet J, Clemence M, Gaines SD, Garcia-Charton JA, Goncalves EJ, Grorud-Colvert K, Guidetti P, Jenkins SR, Jones PJS, Lester SE, McAllen R, Moland E, Planes S, Sorensen TK (2012) The Science of European Marine Reserves: Status, Efficacy, and Future Needs. Marine Policy 36(5)**:**1012-1021

Fylkesmannen i Aust-Agder (2013) Raet Nasjonalpark. Melding om oppstart av plan- og utredningsarbeid, juli 2013 15 pp. (in Norwegian)

Gaines SD, White C, Carr MH, Palumbi SR (2010) Designing Marine Reserve Networks for Both Conservation and Fisheries Management. Proceedings of the National Academy of Sciences of the United States of America 107(43)**:**18286-18293

Gell FR, Roberts CM (2003) Benefits Beyond Boundaries: The Fishery Effects of Marine Reserves. Trends in Ecology & Evolution 18(9)**:**448-455

Huserbråten MBO, Moland E, Knutsen H, Olsen EM, André C, Stenseth NC (2013) Conservation, Spillover and Gene Flow within a Network of Northern European Marine Protected Areas. PLoS ONE 8(9)

Johannessen T, Sollie A (1994) Overvåking Av Gruntvannsfauna På Skagerrakkysten - Historiske Forandringer I Fiskefauna 1919-1993, Og Ettervirkninger Av Den Giftige Algeoppblomstringen I Mai 1988. Fisken og Havet 10**:**91 pp (in Norwegian)

Knutsen H, Jorde PE, Andre C, Stenseth NC (2003) Fine-Scaled Geographical Population Structuring in a Highly Mobile Marine Species: The Atlantic Cod. Molecular Ecology 12(2)**:**385-394

Lester SE, Halpern BS, Grorud-Colvert K, Lubchenco J, Ruttenberg BI, Gaines SD, Airame S, Warner RR (2009) Biological Effects within No-Take Marine Reserves: A Global Synthesis. Marine Ecology-Progress Series 384**:**33-46

Myers N, Mittermeler RA, Mittermeler CG, Da Fonseca GAB, Kent J (2000) Biodiversity Hotspots for Conservation Priorities. Nature 403(6772)**:**853-858

Palumbi SR (2003) Population Genetics, Demographic Connectivity, and the Design of Marine Reserves. Ecological Applications 13(1)**:**S146-S158
Palumbi SR (2004) Marine Reserves and Ocean Neighborhoods: The Spatial Scale of Marine Populations and Their Management. Annual Review of Environment and Resources 29**:**31-68
Sale PF, Cowen RK, Danilowicz BS, Jones GP, Kritzer JP, Lindeman KC, Planes S, Polunin NVC, Russ GR, Sadovy YJ, Steneck RS (2005) Critical Science Gaps Impede Use of No-Take Fishery Reserves. Trends in Ecology & Evolution 20(2)**:**74-80
Stenseth NC, Lekve K, Gjøsæter J (2002) Modeling Species Richness Controlled by Community-Intrinsic and Community-Extrinsic Processes: Coastal Fish Communities as an Example. Population Ecology 44(3)**:**165-178
Stenseth NC, Bjørnstad ON, Falck W, Fromentin JM, Gjøsæter J, Gray JS (1999) Dynamics of Coastal Cod Populations: Intra- and Intercohort Density Dependence and Stochastic Processes. Proceedings of the Royal Society B: Biological Sciences 266(1429)**:**1645-1654
Sundby S, Nakken O (2008) Spatial Shifts in Spawning Habitats of Arcto-Norwegian Cod Related to Multidecadal Climate Oscillations and Climate Change. ICES Journal of Marine Science 65(6)**:**953-962