WP2 Environment impact results

Kjetil Sagerup

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Environmental impact of shipping in Arctic
Petrozavodsk, Bjørnøya 11/5-2009

Photo:
Kystverket

Diesel from Petrozavodsk, Bjørnøya juni 2009

Photo:
Hallvard Strøm / NP

Photo: Ole Magnus Rapp, Aftenposten

Skjervøy 14-17.12.13

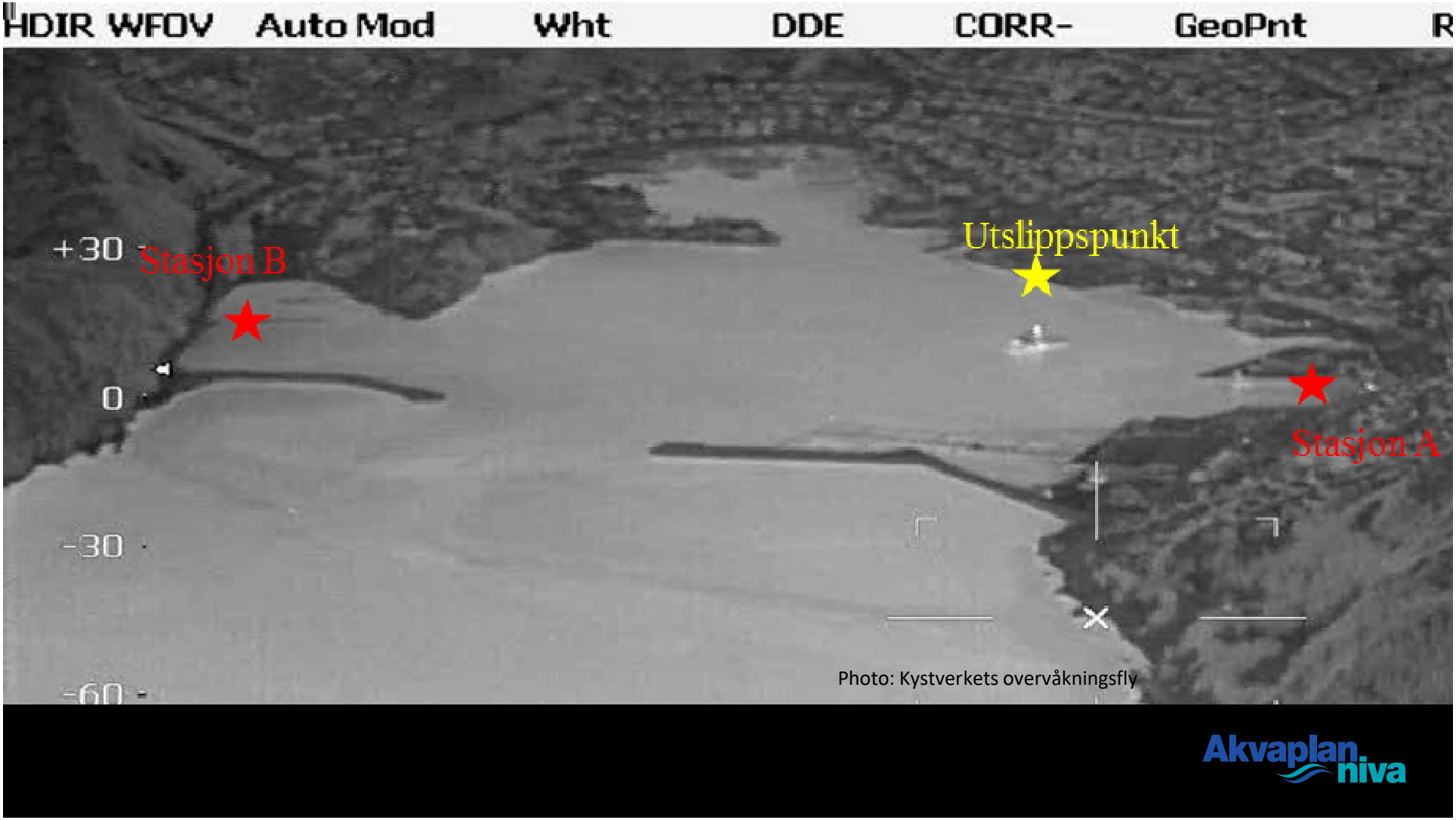
180.000 L spilled

Photo: www.framtidinord.no

Skjervøy 14-17.12.13

48.000 L retreived

Photo: www.framtidinord.no


HDIR WFOV Auto Mod Wht DDE CORR- GeoPnt R
+30
0
-30
-60
Stasjon B
Utslippspunkt
Stasjon A
Photo: Kystverkets overvåkningsfly
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Skjervøy 10.01.14
Photo: Kjetil Sagerup
niva

A-lex – Skjervøy - legacy

Inclusion in a PhD study

- **Case study Blue Mussel**
  - Growth effect of diesel
  - Reproductive effects
- **Laboratory experiment**
  - Blue mussels exposed under controlled conditions
  - Long time effects
    - Oxidative stress
    - Reproduction
    - Growth

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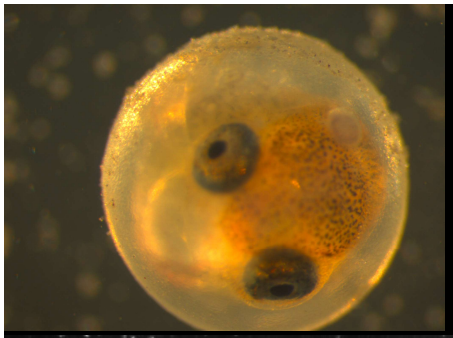

Cargo experiment
2,4,5-Trifluorobenzoic acid

Pilot – only experiment financed

Lump suckers eggs

5 exposure groups + control

1 – 975 µg/ml

Exposed for 48 hours

Endpoints	Preliminary results
Death of eggs	100 % in high group
Hatching success	Decreased w/ concentr.
Yolk sac oedema	+
Pericardia oedema	+
Haemorrhages	+
Spinal cord disorder	Increased with concentr.
Craniofacial abnorm.	+

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The mussel path – Using the contaminant tracer, Ecotracer, in Ecopath to model the spread of pollutants in an Arctic marine food web

Lars-Henrik Larsen *, Kjetil Sagerup, Silje Ramsvatn

Akvaplan-niva, Fram Centre, Postbox 6606, Langnes, 9296 Tromsø, Norway

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ABSTRACT

As the polar ice cap is receding, shipping in the Arctic seas becomes easier, and both destination and Atlantic–Pacific transit shipping is expected to increase. Thereby, the risk of accidents increase. Immediate negative impacts are expected from oil spills through the acute mortality for marine organisms, especially from heavy fuel oil (HFO). Marine Diesel oil (MDO) is therefore suggested as a preferable fuel for ships operating in Arctic waters. However, Polycyclic Aromatic Hydrocarbons (PAHs) are toxic components in both types of fuel, are highly bioavailable and can transfer up the food chain. A spill of MDO following a shipwreck could therefore have impacts beyond the spill site and long after the diesel has spread and evaporated. We model the spread of PAHs from a fictitious spill of MDO in the Pechora Sea (South Eastern Barents Sea) using the contaminant tracer module Ecotracer, in the Ecopath modelling software. We address the effects on the food-web including long term effects by combining toxicology and food-web modelling. Ecotracer assumes that pollutants follow the biomass passively through the system, and degradation of pollutants is following user specified rates. By combining in natura measurements of PAHs in seawater and in blue mussels (*Mytilus edulis*) recorded at an accidental MDO spill site, with experiments conducted on the red king crab (*Paralithodes camtschaticus*) and blue mussels, we derived values as inputs into the model. The Ecotracer predicted that the pollution in the mussels will spread throughout the food-web, especially to the top predators of mussels, king eider (*Somateria spectabilis*) and Atlantic walrus (*Odobenus rosmarus rosmarus*) and also from snow crab (*Chionoecetes opilio*) to seals and toothed whales.

1. Introduction

The Pechora Sea (67–71 °N, 44–60 °E) in the Russian Arctic is situated in the south-eastern Barents Sea (Fig. 1) and is considered to be a separate sea area because of marked differences in environmental conditions compared to the rest of the Barents Sea. The area is an important spawning ground for Arctic fish and is rich in seabirds and mammals that feed on benthic invertebrates (Boltunov et al., 2010). The Atlantic walrus (*Odobenus rosmarus rosmarus*) occur in the Pechora Sea, and one of very few population estimates indicates a summer population of 3943 animals (Lydersen et al., 2012). Walrus feed on benthic organisms in shallow waters, and haul out on either low elevation beaches, or on the sea ice. The Pechora sea is identified as an area of high ecological importance by the Arctic Monitoring and Assessment Programme (AMAP/CAFF/SDWG, 2013) based on criteria set by the International Maritime Organization (IMO, 2006). The coastline includes many low-level marshes and wetlands which are exposed to frequent and long-term flooding during spring and summer, as well the abrasive effects of sea ice. Muddy, shallow water coasts are characterized by high abundances of mussels. In the case of an oil-spill, shallow, soft sediment areas are known to accumulate oil, as seen, for example, after a spill on the coast of Massachusetts, USA in 1969 (Culbertson et al., 2008).

As the polar sea ice cap recedes, shipping and industrial activities become easier in the Arctic seas. Increased activities mean increased risk of accidents. The Pechora Sea is one of the areas expected to hold large sub-seabed deposits of hydrocarbons. The first offshore oilfield in the Pechora Sea, Prirazlomnoye, 60 km off the Siberian coast (Fig. 1) at a water depth of 20 metres started production in 2014. The oil from the Prirazlomnaya installation is exported by ice strengthened tankers.

This modelling exercise is based on a fictitious ship wreck (Larsen et al., in press) where the container vessel *MV "Oleum"* suffers an engine malfunction and runs aground on the north western corner of Vaygach (Fig. 1), thereby releasing approximating 200 tonnes of MDO. To assess the environmental impact of an oil

* Corresponding author. Tel.: +47 48 11 42 33.
E-mail address: Lars@apn.biz (L.-H. Larsen).

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0304-3800/

Outreach WP2

Peer-reviewed papers

- Larsen, L.-H., Kvamstad-Lervold, B., Sagerup, K., Gribkovskaia, V., Bambulyak, A., Rautio, R., Berg, T.E. (2016). Technological and environmental challenges of Arctic shipping - a case study of a fictional voyage in the Arctic. Polar Research 35 http://dx.doi.org/10.3402/polar.v35.27977.
- Larsen, L.-H., Sagerup, K., Ramsvatn, S. (2016). The mussel path–Using the contaminant tracer, Ecotracer, in Ecopath to model the spread of pollutants in an Arctic marine food web. Ecological Modelling 331, 77-85.
- Sagerup, K., Nahrgang, J., Frantzen, M., Larsen, L.-H., Geraudie, P. (2016). Biological effects of marine diesel oil exposure in red king crab (*Paralithodes camtschaticus*) assessed through a water and foodborne exposure experiment. Marine Environmental Research 119, 126-135.

In prep

- Larsen L-H, Eglund-Newby S, Cusa M, Berge J, Nahrgang J, Renaud PE, Falk-Petersen S, Varpe Ø (manuscript). Feeding activity and diet of three gadoid fish species in Svalbard waters during the polar night. (Target journal Polar Biology).
- Sagerup, K., Storhaug E., Geraudie P., Nahrgang J., Frantzen M. and Larsen L.H. (manuscript). Monitoring Polycyclic Aromatic Hydrocarbon in the Marine Environment after the Skjervøy Diesel Oil Spill. (Target journal Environmental Monitoring and Assessment)

Newspaper Chronicles

- Sagerup, K., Larsen, L.H. Blåskjell med nummerplate Dieselutslippet på Skjervøy. Kronikk, Fiskeribladet Fiskaren 17.06.2016.
- Larsen, L.H., Sagerup, K.. Hell i uhell? Fiskeribladet Fiskaren 05.09.2014.

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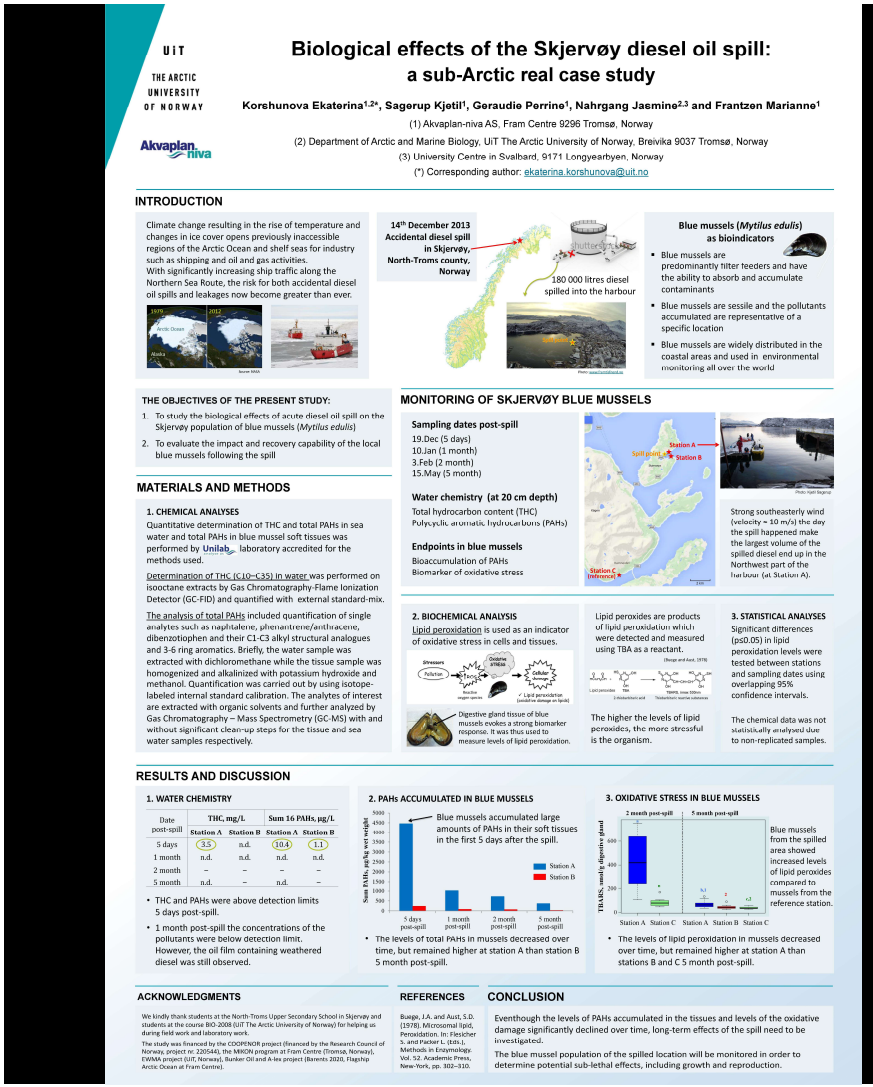

UiT THE ARCTIC UNIVERSITY OF NORWAY

Akvaplan-niva

Biological effects of the Skjervøy diesel oil spill: a sub-Arctic real case study

Korshunova Ekaterina[1,2*], Sagerup Kjetil[1], Geraudie Perrine[1], Nahrgang Jasmine[2,3] and Frantzen Marianne[1]

(1) Akvaplan-niva AS, Fram Centre 9296 Tromsø, Norway

(2) Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Breivika 9037 Tromsø, Norway

(3) University Centre in Svalbard, 9171 Longyearbyen, Norway

(*) Corresponding author: ekaterina.korshunova@uit.no

INTRODUCTION

Climate change resulting in the rise of temperature and changes in ice cover opens previously inaccessible regions of the Arctic Ocean and shelf seas for industry such as shipping and oil and gas activities.
With significantly increasing ship traffic along the Northern Sea Route, the risk for both accidental diesel oil spills and leakages now become greater than ever.

14th December 2013 Accidental diesel spill in Skjervøy, North-Troms county, Norway

180 000 litres diesel spilled into the harbour

Blue mussels (*Mytilus edulis*) as bioindicators

- Blue mussels are predominantly filter feeders and have the ability to absorb and accumulate contaminants
- Blue mussels are sessile and the pollutants accumulated are representative of a specific location
- Blue mussels are widely distributed in the coastal areas and used in environmental monitoring all over the world

THE OBJECTIVES OF THE PRESENT STUDY:

1. To study the biological effects of acute diesel oil spill on the Skjervøy population of blue mussels (*Mytilus edulis*)
2. To evaluate the impact and recovery capability of the local blue mussels following the spill

MATERIALS AND METHODS

1. CHEMICAL ANALYSES

Quantitative determination of THC and total PAHs in sea water and total PAHs in blue mussel soft tissues was performed by Unilab laboratory accredited for the methods used.

Determination of THC (C10–C35) in water was performed on isooctane extracts by Gas Chromatography-Flame Ionization Detector (GC-FID) and quantified with external standard-mix.

The analysis of total PAHs included quantification of single analytes such as naphtalene, phenantrene/anthracene, dibenzotiophen and their C1-C3 alkyl structural analogues and 3-6 ring aromatics. Briefly, the water sample was extracted with dichloromethane while the tissue sample was homogenized and alkalinized with potassium hydroxide and methanol. Quantification was carried out by using isotope-labeled internal standard calibration. The analytes of interest are extracted with organic solvents and further analyzed by Gas Chromatography – Mass Spectrometry (GC-MS) with and without significant clean-up steps for the tissue and sea water samples respectively.

MONITORING OF SKJERVØY BLUE MUSSELS

Sampling dates post-spill

19.Dec (5 days)
10.Jan (1 month)
3.Feb (2 month)
15.May (5 month)

Water chemistry (at 20 cm depth)

Total hydrocarbon content (THC)
Polycyclic aromatic hydrocarbons (PAHs)

Endpoints in blue mussels

Bioaccumulation of PAHs
Biomarker of oxidative stress

Strong southeasterly wind (velocity ≈ 10 m/s) the day the spill happened make the largest volume of the spilled diesel end up in the Northwest part of the harbour (at Station A).

2. BIOCHEMICAL ANALYSIS

Lipid peroxidation is used as an indicator of oxidative stress in cells and tissues.

Digestive gland tissue of blue mussels evokes a strong biomarker response. It was thus used to measure levels of lipid peroxidation.

Lipid peroxides are products of lipid peroxidation which were detected and measured using TBA as a reactant.

The higher the levels of lipid peroxides, the more stressful is the organism.

3. STATISTICAL ANALYSES

Significant differences (ps0.05) in lipid peroxidation levels were tested between stations and sampling dates using overlapping 95% confidence intervals.

The chemical data was not statistically analysed due to non-replicated samples.

RESULTS AND DISCUSSION

1. WATER CHEMISTRY

Date post-spill	THC, mg/L		Sum 16 PAHs, µg/L	
	Station A	Station B	Station A	Station B
5 days	3.5	n.d.	10.4	1.1
1 month	n.d.	n.d.	n.d.	n.d.
2 month	–	–	–	–
5 month	n.d.	–	n.d.	–

- THC and PAHs were above detection limits 5 days post-spill.
- 1 month post-spill the concentrations of the pollutants were below detection limit. However, the oil film containing weathered diesel was still observed.

2. PAHs ACCUMULATED IN BLUE MUSSELS

Blue mussels accumulated large amounts of PAHs in their soft tissues in the first 5 days after the spill.

- The levels of total PAHs in mussels decreased over time, but remained higher at station A than station B 5 month post-spill.

3. OXIDATIVE STRESS IN BLUE MUSSELS

Blue mussels from the spilled area showed increased levels of lipid peroxides compared to mussels from the reference station.

- The levels of lipid peroxidation in mussels decreased over time, but remained higher at station A than stations B and C 5 month post-spill.

ACKNOWLEDGMENTS

We kindly thank students at the North-Troms Upper Secondary School in Skjervøy and students at the course BIO-2008 (UiT The Arctic University of Norway) for helping us during field work and laboratory work.

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Buege, J.A. and Aust, S.D. (1978). Microsomal lipid. Peroxidation. In: Fleischer S. and Packer L. (Eds.), Methods in Enzymology. Vol. 52. Academic Press, New-York, pp. 302–310.

CONCLUSION

Eventhough the levels of PAHs accumulated in the tissues and levels of the oxidative damage significantly declined over time, long-term effects of the spill need to be investigated.

The blue mussel population of the spilled location will be monitored in order to determine potential sub-lethal effects, including growth and reproduction.

Outreach WP2

Abstracts and presentations

- Sagerup, K., Larsen, L.H., and Geraudie, P. Assessing the red king crab vulnerability of a diesel oil spill. Vulnerability symposium, Tromsø 3–4 November 2014.
- Biological effects of the Skjervøy diesel oil spill: a sub-Arctic case study. Poster. Arctic Change conference 2014, Ottawa, Canada. 8-12 December 2014.
- Biological effects of marine diesel on blue mussels (*Mytilus edulis*). Oral. Norwegian-Russian Research conference, NRC, Oslo 20.11.2014.
- Biological effects of the Skjervøy diesel oil spill: a sub-Arctic real case study. Korshunova E., Sagerup K., Geraudie P., Nahrgang J., Frantzen M. AF 2015.
- The Skjervøy diesel spill – a case study. Norske havforskers forening annual meeting, Bodø 13/10-2015
- Arctic Shipping Environmental Risk Assessment. Larsen, Sagerup. Sustainable Oceans Summit, Singapore November 2015.
- Ramsvatn, S., Sagerup, K., Larsen, L.H. The A-lex project: environmental effects of increased shipping in the arctic - a case study for the Pechora Sea. Ecopath 30 years – Modelling ecosystem dynamics: beyond boundaries with EwE, Barcelona, November 2014.

Coming

- Arctic: Ocean Business Scenarios and Responsible Artic Development. Larsen. WOC Sustainable Ocean Summit, Rotterdam, 30 Nov-2 Dec, 2016.

Teaching

- BIO-2008 at UiT The Arctic University of Norway in 2014, 2015 and 2016
- Skjervøy high school (Nord-Troms videregående skole). January 2014, April 2014, October 2015 and December 2015.

Other

- "Forskerne kommer 2016" Seminar and tradeshow in Finnsnes, Nordreisa and Skjervøy.
- Arctic Frontier young. "Forskerklassens fagdag" Lecture 26.10.2016.

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- Additional funding

- Bunker Oil
- COOPENOR prosjekt

NORRUSS - joint call with Russia

The Research Council of Norway

RFBR

- EWMA project (UiT)
- Flagship MIKON, Fram Centre
- Flaggskip miljøgifter, Fram Centre
- Nord-Troms videregående skole
- Akvaplan-niva own contribution

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Thank you for your attention!
Photo: Kjetil Sagerup