INSTITUTE OF MARINE RESEARCH

Risk assessment models considering effects of oil spills on fish

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Retrospect - Ocean analysis using optimal observation strategies

The knowledge obtained will contribute to (i) real-time integration of monitoring systems and operational ocean and oil spill drift models, and (ii) improving the modeling systems that are used to assess the environmental impact of petroleum-related activities.

Funded through the NFR-call PETROMAKS 2.

Political decissions wrt oil production in the Lofoten and Vesterålen (LoVe)

- The largest political party in Norway, Ap – the labour party, decided in April 2013 on their annual meeting to work for a Consequence Assessment of oil production in LoVe. Historically this has always resulted in an opening of a new area.

- But due to elections, the new government consisting of Høyre (the conservative party) and Frp (the progress party) with the support from Venstre (the liberal party) and Krf (the christian democracy party) decided on Sept 30th 2013 to await further development of petroleum resources in the Lofoten/Vesterålen area, despite the fact that Høyre and Frp are pro development.

- However, Frp (and Høyre?) "promises" a Consequence Assessment in the next governmental period (starting 2017) if they stay in position. If Ap wins they are likely to do the same.

Political decissions wrt oil production in the LoVe cont'

- High uncertainty in knowledge of risk with respect to oil spills and effects on marine biological resources makes the discussions of pros and cons quite open.

- It is expected that state funded research, along with funding from the industry preferably channeled through the Norwegian Research Council, should aid in reducing the uncertainties in risk assessments. However, there is limited time and resources available and it is therefore important that all scientific studies are aware of their responsibility.

- RETROSPECT is one key project that needs to contribute to improving risk assessment models through improved circulation models used to quantify exposure rates of vulnerable species and stages to toxic components of oil.

- It is, however, crucial to bear in mind how our priorities wrt research questions affect the ability to reduce uncertainties in risk assessments and future political decisions (Hauge et al. 2014; Blanchard et al. 2014).

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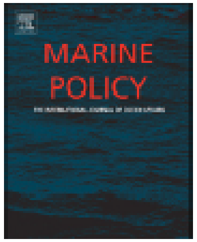

Inadequate risk assessments – A study on worst-case scenarios related to petroleum exploitation in the Lofoten area ☆

Kjellrun Hiis Hauge [a,*], Anne Blanchard [b], Gisle Andersen [c], Ragnhild Boland [b], Bjørn Einar Grøsvik [a], Daniel Howell [a], Sonnich Meier [a], Erik Olsen [a], Frode Vikebø [a]

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ABSTRACT

Heated debates are currently taking place on whether to open the area of Lofoten and Vesterålen in Northern Norway for petroleum production. Seismic explorations in this area have indicated promising petroleum resources. The area is known for its unique landscape and as a key spawning and nursery area for several economically important fish species. It hosts significant bird colonies and the world's largest-known deep-sea coral reef. New areas will be opened to petroleum production only if its high environmental value can be maintained. A risk analysis approach has become central to this decision, where the probability of a 'worst-case scenario' (a major oil spill) is assessed together with associated environmental impacts. This paper examines and characterises uncertainties associated with these risk assessments and some of the surrounding debates. Further, the paper reveals implications of these uncertainties: (1) potential values embedded in the risk assessments, (2) lack of validity of quantified worst-case scenarios and their probabilities and impacts, (3) limited prospects of filling addressed knowledge gaps and (4) how risk assessments restrict the debate on what issues and uncertainties are considered relevant. Taken together, this suggests that discussions on alternative approaches to decision making should be more prominent in public and political debates.

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Harmful routines? Uncertainty in science and conflicting views on routine petroleum operations in Norway

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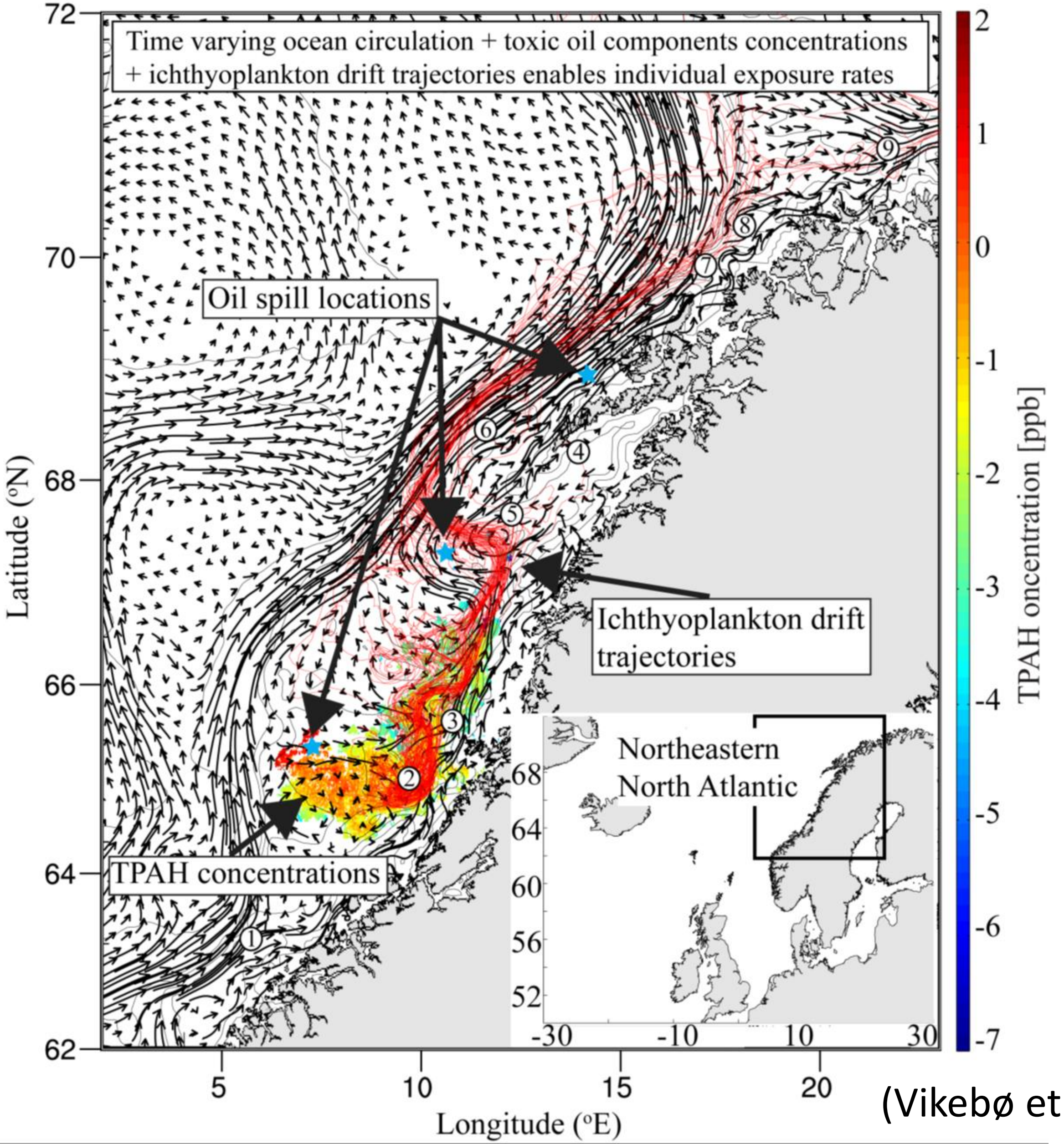
ABSTRACT

Offshore petroleum activities are the focus of highly politicised debates globally. Typically, public debate is sparked by catastrophic events, such as the 2010 oil spill in the Gulf of Mexico, and decision-making processes fuelled by the assessment of 'worst-case scenarios'. However, everyday 'routine' petroleum operations also impact the marine ecosystems and adjoining socio-economic sectors, but the extent and severity of the impacts are uncertain. This paper takes as its point of departure routine operations and their surrounding uncertainties. Particularly, it focuses on the debates of whether to extend routine petroleum operations in vulnerable and valuable parts of Norway, such as the Lofoten area and the Sula Ridge. These conflicts draw on important and for some, epistemological uncertainties that surround the impacts of routine operations. The paper argues that it is necessary to first highlight these uncertainties, rather than marginalise them, and second, recognise that uncertainties are not simply a scientific challenge, but can be a powerful political tool. This paper unpacks and explores uncertainties associated with three phases of routine operations, that are used to steer political actions: (i) the impacts of seismic surveys on fish and marine mammals; (ii) the impacts of drilling mud and drill cuttings on benthic communities such as deep-sea coral reefs; and (iii) the impacts of produced water on the marine environment. The paper discusses the importance of transparency in addressing these uncertainties, and emphasises the need to implement the precautionary principle in a more participatory way. It thus proposes participatory exercises in order to allow the recognition of the epistemological nature of uncertainties.

Three recent hot topics concerning risk assessment of oil spill in the LoVe

- There have been an erroneous notion that environmental risk assessment of potential impacts from oil spills on fish can be adequately addressed using a single representative species with NEC based on a limited subset of the ELS.
- Is it possible to combat oil with dispersants, so that human intervention may change the dispersal and fate of the oil and subsequently dampen the overall ecosystem impact?
- Spatiotemporal heterogeneity in natural mortality of early life stages in fish makes it difficult to integrate individual to population effects in fish following an accidental oil spill.

Risk assessment of oil spills on fish

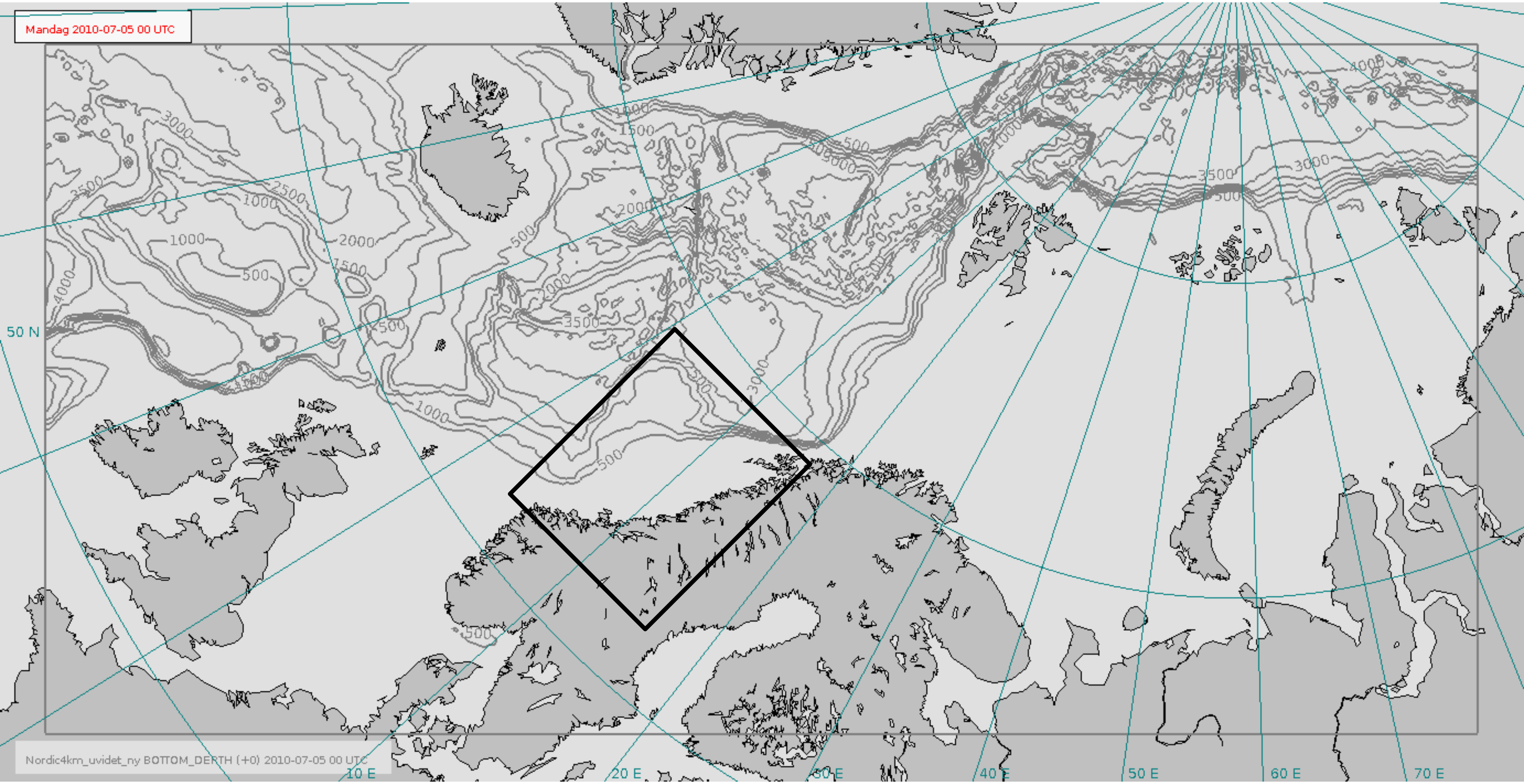


(Vikebø et al. 2015)

Model includes;

- state-of-the-art regional ocean model representing **physical processes at relevant temporal and spatial scales**
- oil spill and fate models including modules for applying dispersants
- individual-based biophysical models representing vulnerable marine species, stages and trophic interactions
- boby burden models for quantifying effects on species of exposure to toxins
- relate effects on individuals to populations

ROMS model domain 1958-2011



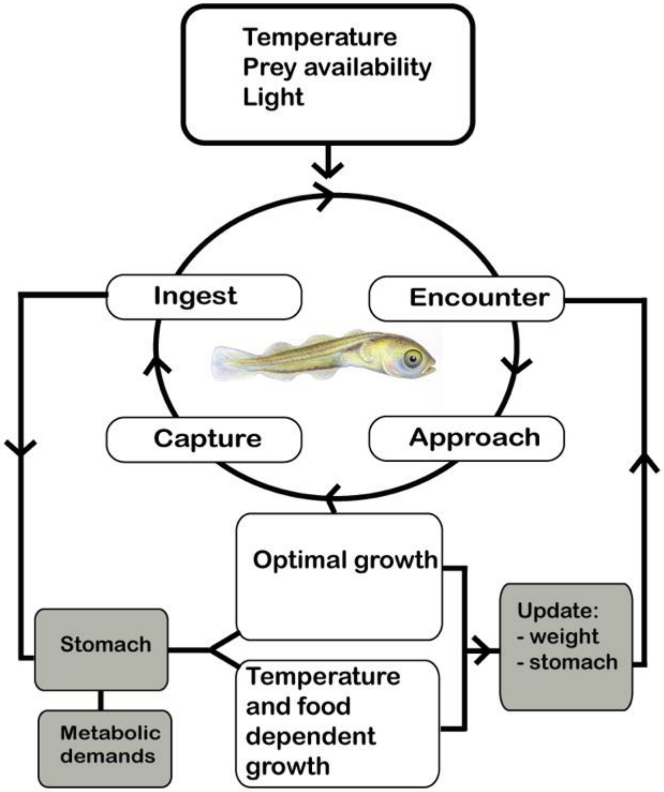
4x4 km resolution, daily means, 30 layers

Lien et al. 2013, 2014

NFR-project SWIM: HI, Met.no, CEES

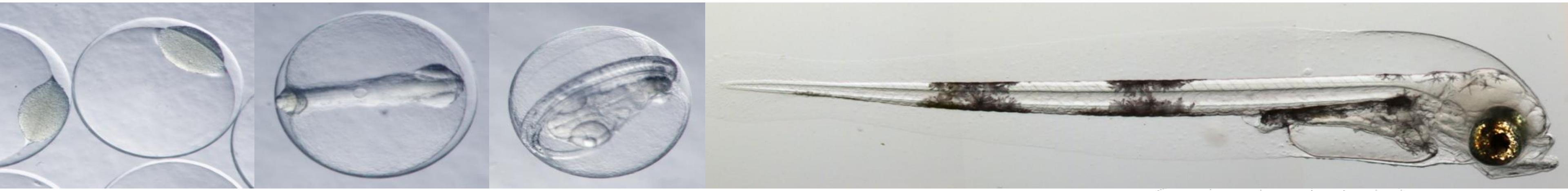
Individual-based biophysical models

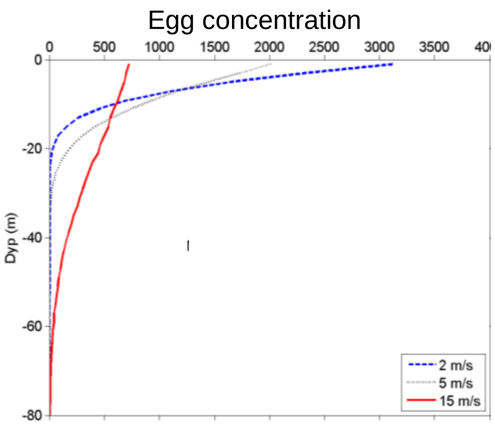
- Simple particle tracking models online or offline coupled to GCMs
- Exists many different models available for downloading; CMS (Paris et al.), LTRANS (North et al.), LADIM (Ådlandsvik).
- Build-in modules for handling physiology and behavior



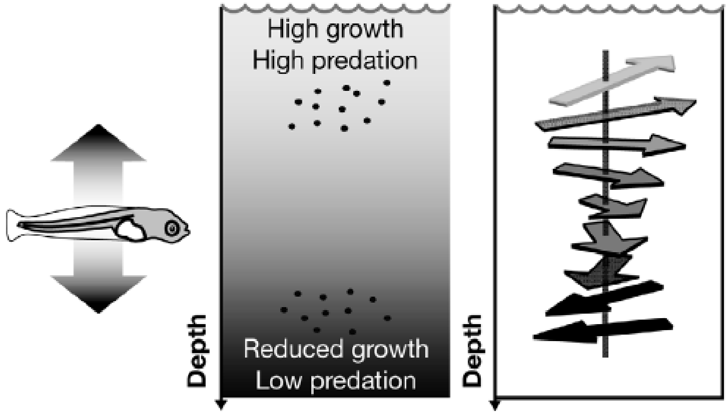
(Kristiansen et al. 2007)

Vertical distribution of fish eggs and larvae affects dispersal

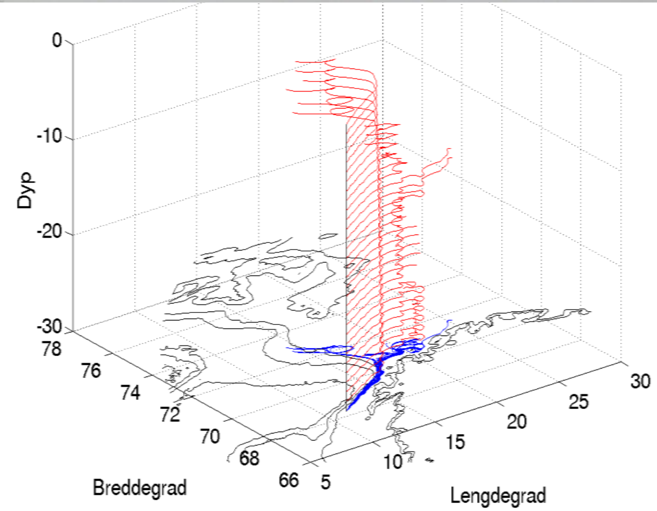




(Rohrs et al. 2014)

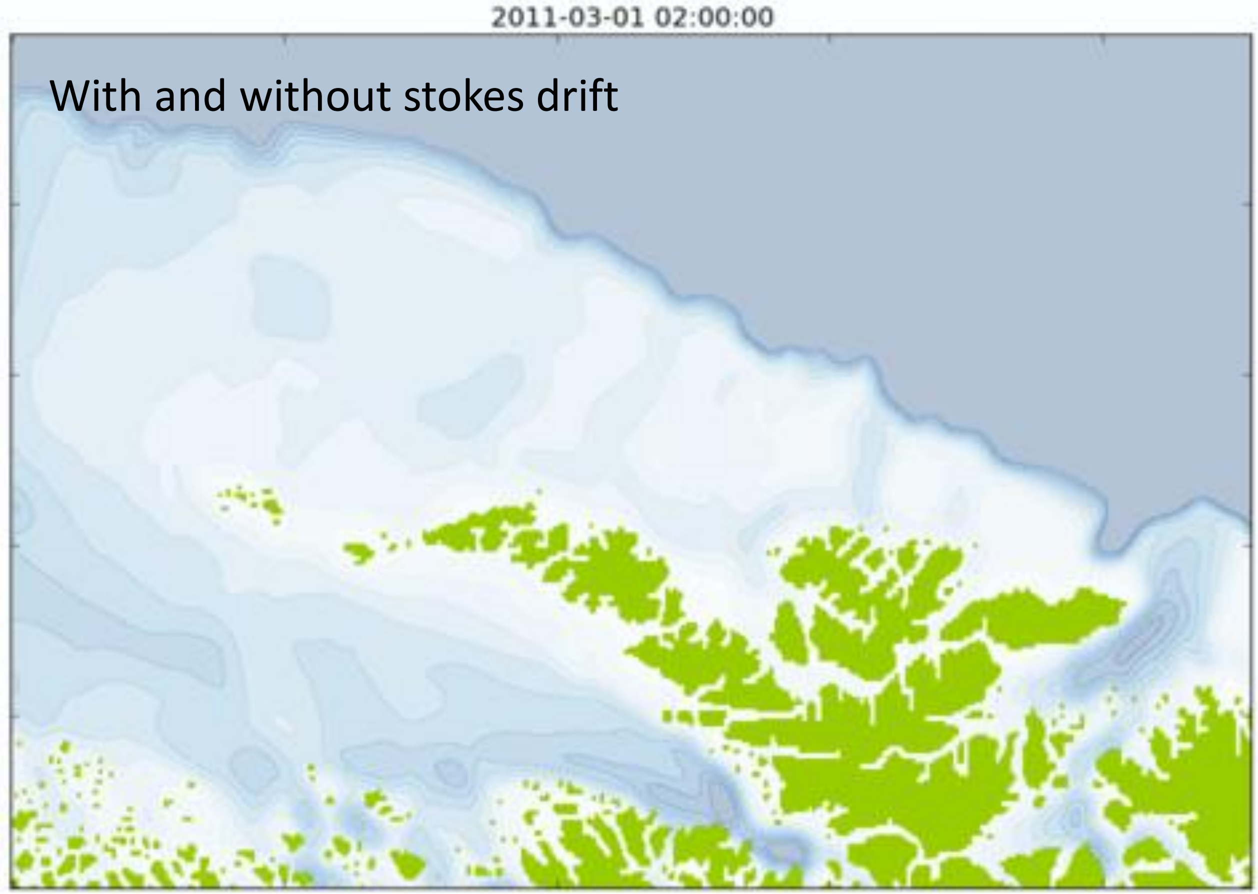


(Fiksen et al. 2007)



- Dynamic vertical distribution of eggs dependent on buoyancy
- Light decreases with. It affect the encounter rates of larval fish with both prey and visual predators. Hence, vertical positioning affects immediate growth and survival, but also large-scale and long-term drift and dispersal
- Feedback processes and high spatiotemporal resolution may change the vertical position of both larvae and prey as result of feeding and toxins

Tides and waves affect transport



(Rohrs et al. 2014)

- High temporal and spatial resolution may be critical to dispersal of plankton and toxins
- What other processes do we need to include to accurately represent dispersal and thereby exposure to toxins and a variable environment?

Three recent hot topics concerning risk assessment of oil spill in the LoVe

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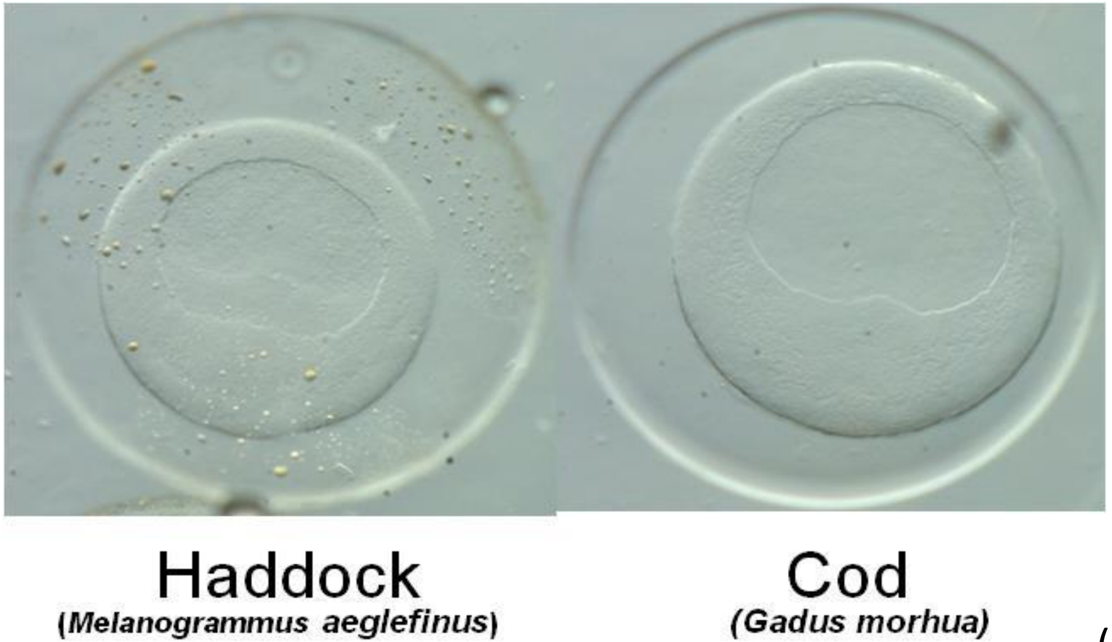
- Spatiotemporal heterogeneity in natural mortality of early life stages in fish makes it difficult to integrate individual to population effects in fish following an accidental oil spill.

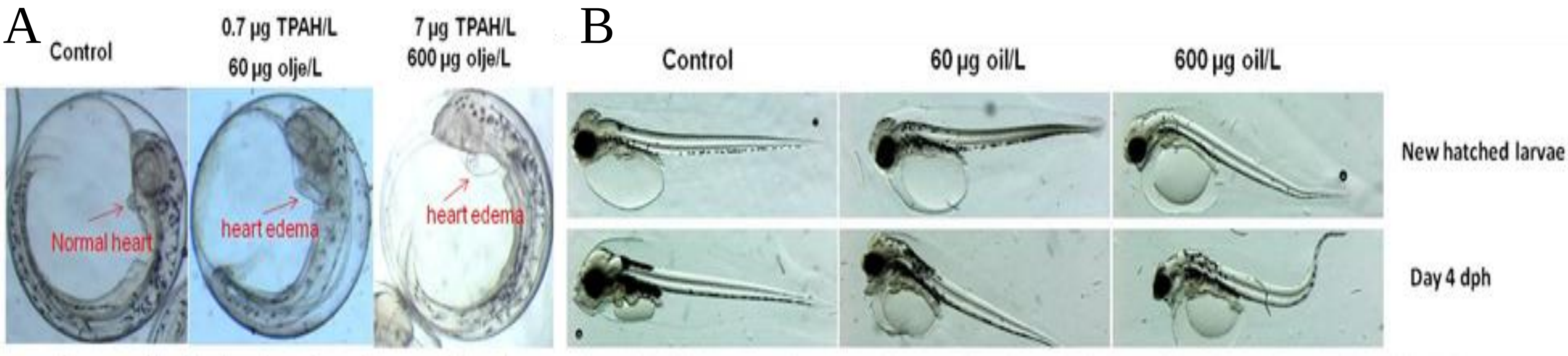
Exposure of haddock and cod embryos to oil droplets – the VISTA project



(Sørhus et al. 2014)

Haddock and cod embryos after 16 hours exposure to mechanical dispersed oil (600 µg/L). The haddock eggs accumulate microdroplets of oil on the surface, but the cod eggs do not. The direct contact between oil droplets and the fish egg results in high uptake of oil compounds by the haddock embryo.

Exposure of haddock and cod embryos to oil droplets – the VISTA project

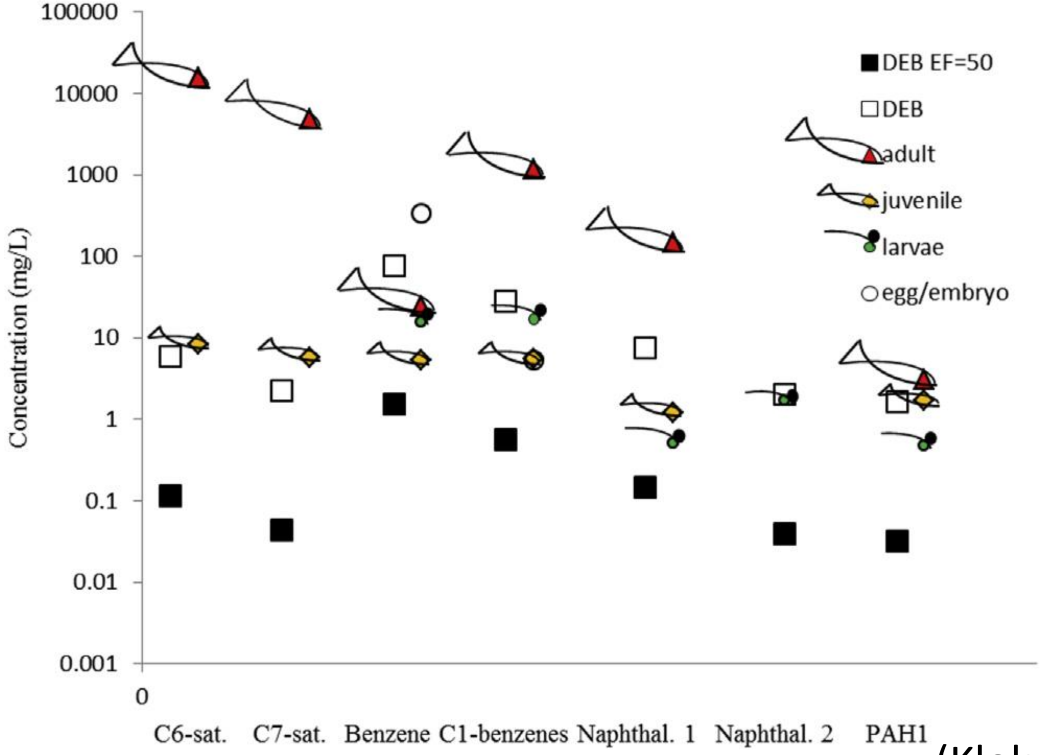


Haddock embryo exposed to different concentrations of oil dispersions for nine days compared to unexposed controls. A; The heart edema of exposed embryos is associated with irreversible heart malfunction associated with a number of secondary effects. B; Newly hatched larvae from the exposed groups have edema around the yolk sac. Four days after hatch, all larvae exposed to the high dose were severely deformed with malformations of the spine and cranium. The low dose group contained a mixture of deformed and apparently normal larvae.

Because cod do not stick to oil droplets at the egg stage they expect to have similar impacts but at ten times the concentrations?

What about sticky herring eggs that are attched to the seabed?

Extrapolation of effect thresholds from other species – SYMBIOSES project



(Klok et al. 2014)

Comparison of LC50 values calculated with DEB parameters with the lowest LC50 values found in literature for fish in life stage groups egg/embryo, larvae, juvenile and adult for eight pseudocomponent groups.

■ - with safety factor 50

In the lack of good data on cod sensitivity to oil exposure throughout the ELS juvenile Fathead minnow is used as a surrogate parameter set to parameterize a DEB model capturing body burden.

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Dispersants Have Limited Effects on Exposure Rates of Oil Spills on Fish Eggs and Larvae in Shelf Seas

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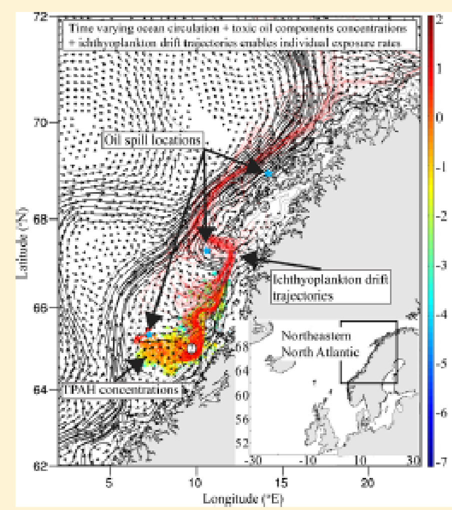
Supporting Information

ABSTRACT: Early life stages of fish are particularly vulnerable to oil spills. Simulations of overlap of fish eggs and larvae with oil from different oil-spill scenarios, both without and with the dispersant Corexit 9500, enable quantitative comparisons of dispersants as a mitigation alternative. We have used model simulations of a blow out of 4500 m^3 of crude oil per day (Statfjord light crude) for 30 days at three locations along the Norwegian coast. Eggs were released from nine different known spawning grounds, in the period from March 1st until the end of April, and all spawning products were followed for 90 days from the spill start at April first independent of time for spawning. We have modeled overlap between spawning products and oil concentrations giving a total polycyclic hydrocarbon (TPAH) concentration of more than 1.0 or 0.1 ppb (μg/l). At these orders of magnitude, we expect acute mortality or sublethal effects, respectively. In general, adding dispersants results in higher concentrations of TPAHs in a reduced volume of water compared to not adding dispersants. Also, the TPAHs are displaced deeper in the water column. Model simulations of the spill scenarios showed that addition of chemical dispersant in general moderately decreased the fraction of eggs and larvae that were exposed above the selected threshold values.

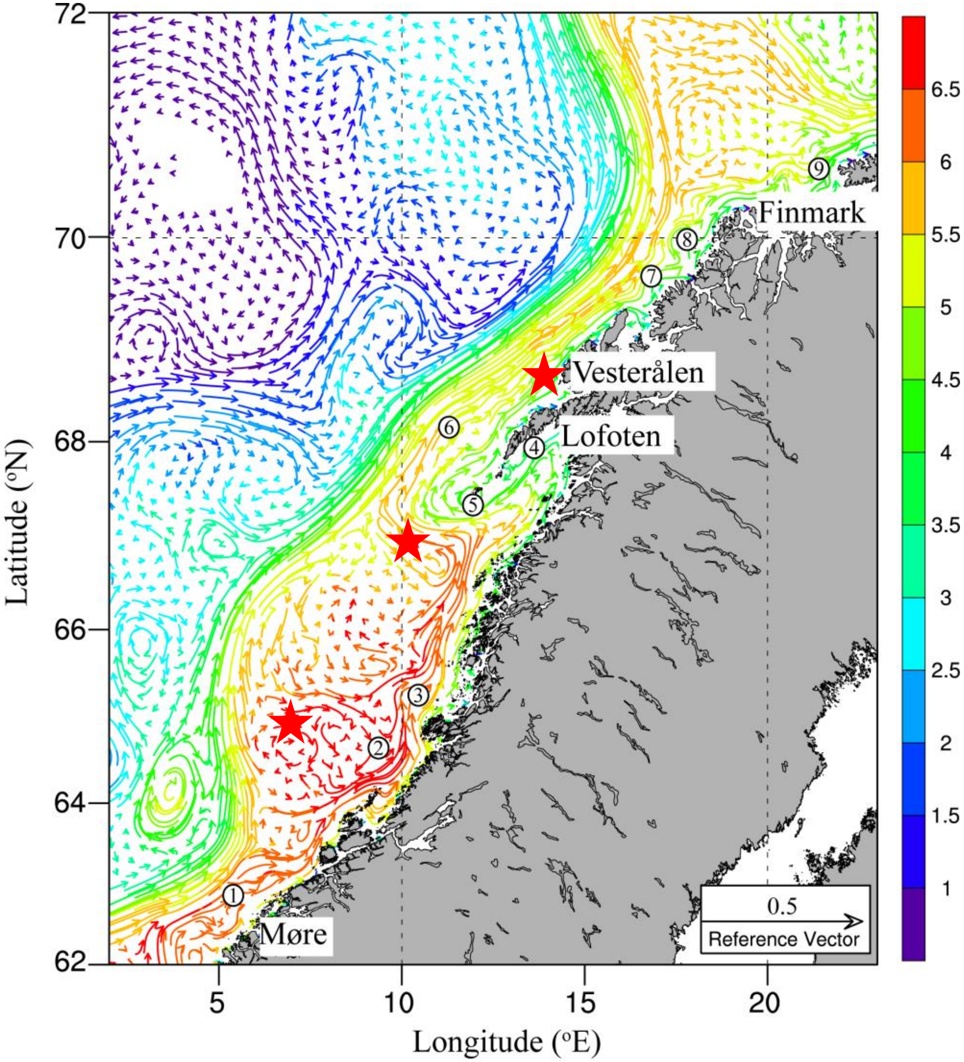


Ecosystem-effects of using dispersants

- Norwegian authorities reconsider the use of dispersants as a mean to mitigate acute oil spills following the Macondo blowout
- Dispersants shifts the oil droplets spectra towards smaller droplets and results in more dissolved oil
- Early life stages of fish have been identified to be particularly vulnerable to oil spills
- Simulate the overlap of fish eggs or larvae and an oil spill with or without use of the dispersant Coreexit 9500
- Utilize literature based thresholds for acute effects, ~1.0 ppb TPAH for acute effects and ~0.1 ppb TPAH for sublethal effects

Grøsvik et al. 2014

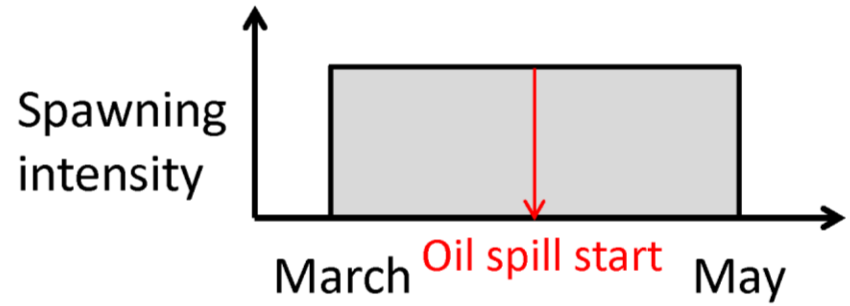
Overlap of oil and offspring



Oil spill

★ 1) N 65.00, E 7.00 (Haltenbanken)
★ 2) N 67.00, E 10.33 (Nordland V)
★ 3) N 68.67, E 13.92 (Vesterålen 1)

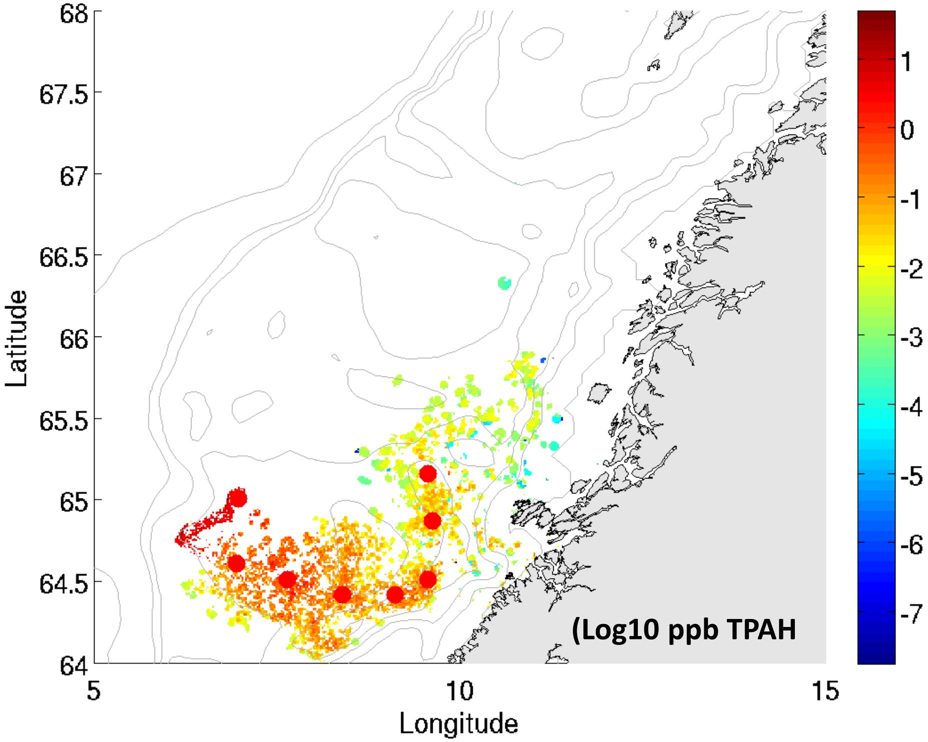
All scenarios include the same spill rate, 205 m^3/h (i.e., 4500 tons in 24 hours) for 30 days.

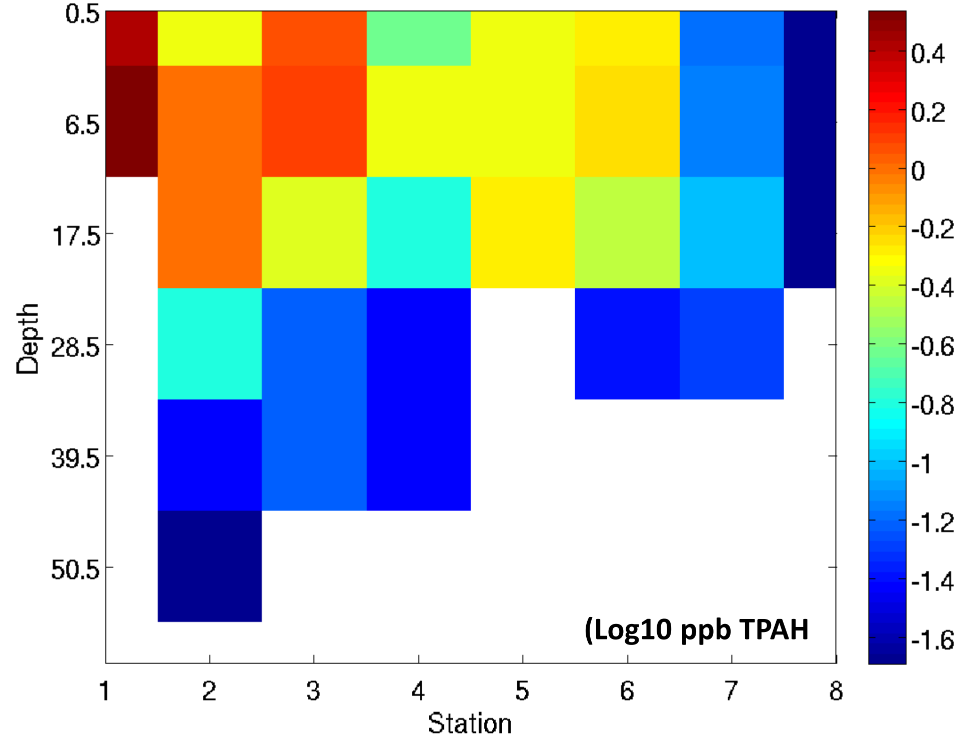


SG	1	2	3	4	5	6	7	8	9
SI(%)	5	5	5	20	10	20	15	10	10

(Vikebø et al. 2014)

Spill dispersal and fate

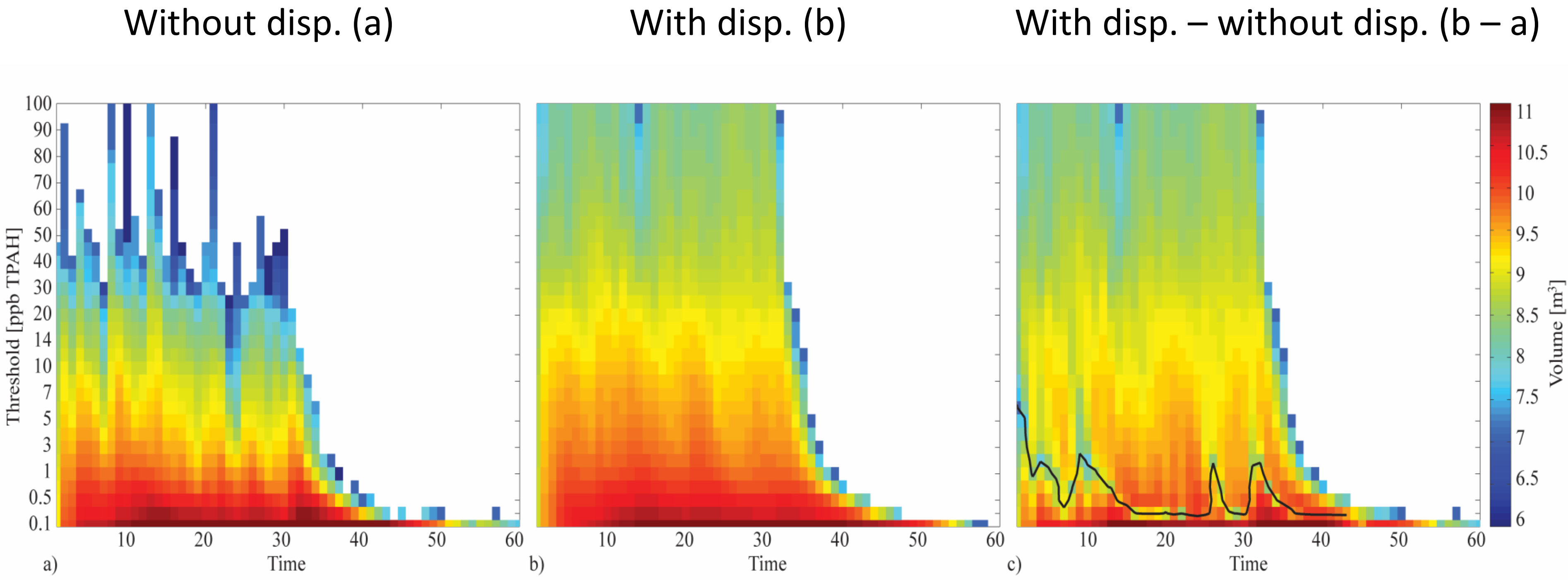




- Oil dispersal in OSCAR – 30 days of 4500 tonnes per day
- Spill location at Haltenbanken
- Horizontal and vertical distribution

(Vikebø et al. 2014)

Volume of water > threshold level of oil

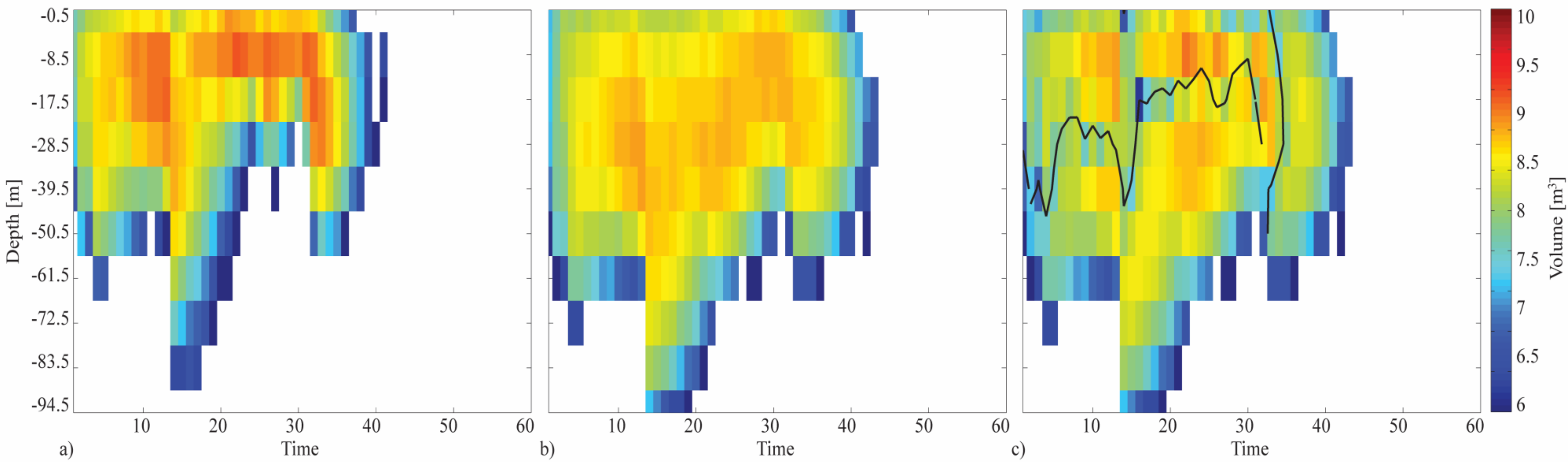


- Black line indicate threshold level with no difference in volume with or without dispersants
- Above the black line adding dispersants results in a greater volume of water with above threshold levels of PAHs for thresholds indicated at y-axis

(Vikebø et al. 2015)

Volume of water per depth > 1.0 ppb PAH

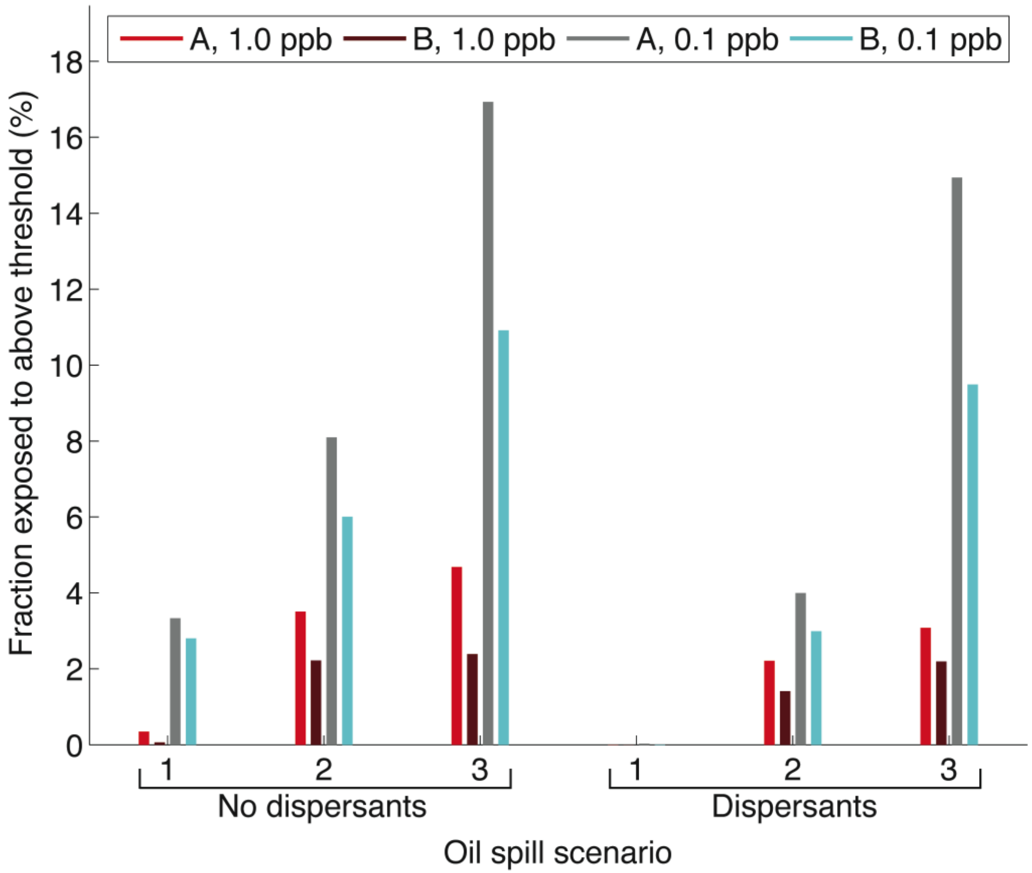
Without disp. (a) | With disp. (b) | With disp. – without disp. (b – a)



- Black line indicate depth level with no difference in volume with or without dispersants
- Adding dispersants results in a greater volume of water with more than 1.0 ppb PAHs in the lower part of the water column (below the black line)

(Vikebø et al. 2015)

Overlap with toxic levels of PAHs in different oil spill scenarios with and without dispersants



(Max PAH in water column, 1.0 ppb PAH

(PAH at larvae depth, 1.0 ppb PAH

(Max PAH in water column, 0.1 ppb PAH

(PAH at larvae depth, 0.1 ppb PAH

- Adding dispersants decreases the fraction of eggs and larvae exposed to above threshold level for acute (sublethal) effects of 1.0 (0.1) ppb PAHs
- However, the level of change is minor independent of oil spill scenario

(Vikebø et al. 2015)

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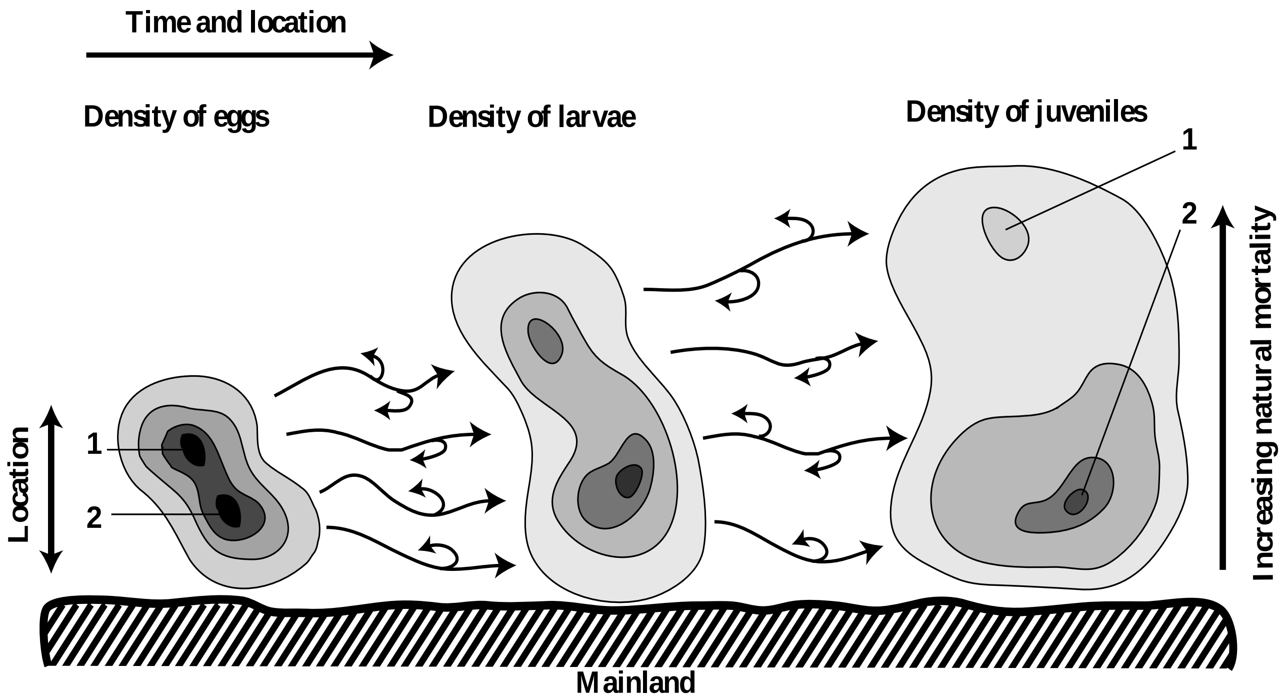
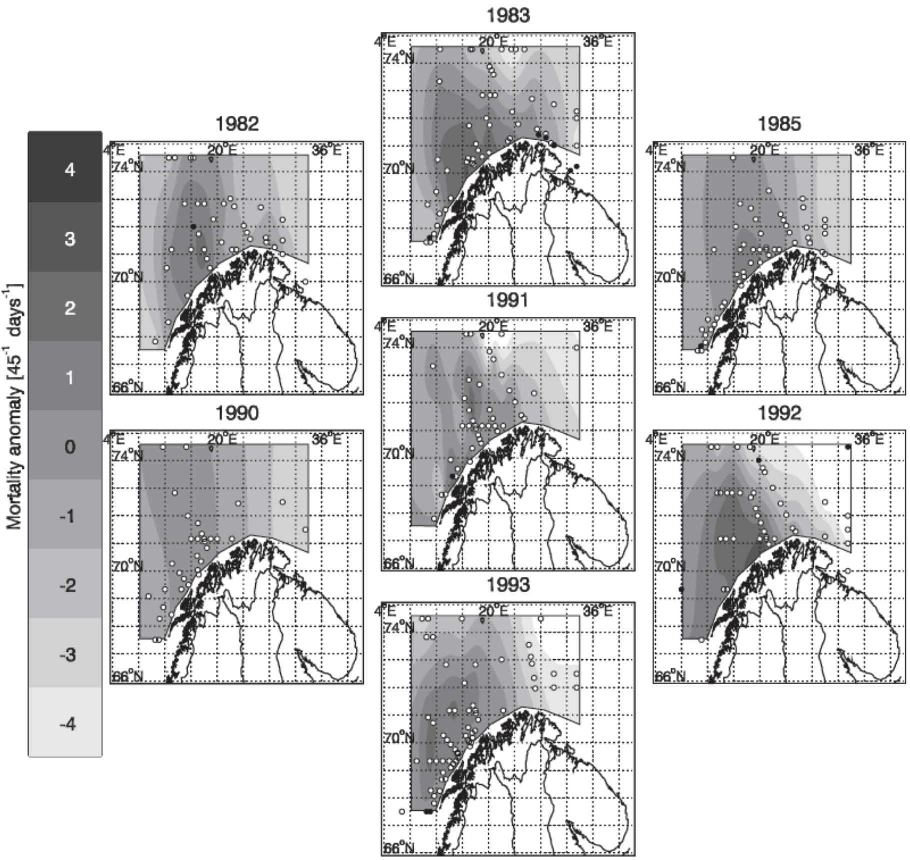
Spatial variation in natural mortality



(Langangen et al. In review)

- Conceptual model showing changes in density (darker shade = higher density) of early life stages of a fish with pelagic larvae drifting in a current (indicated by arrows) through a spatial differentiated natural mortality field with mortality assumed to be increasing with distance from the mainland.

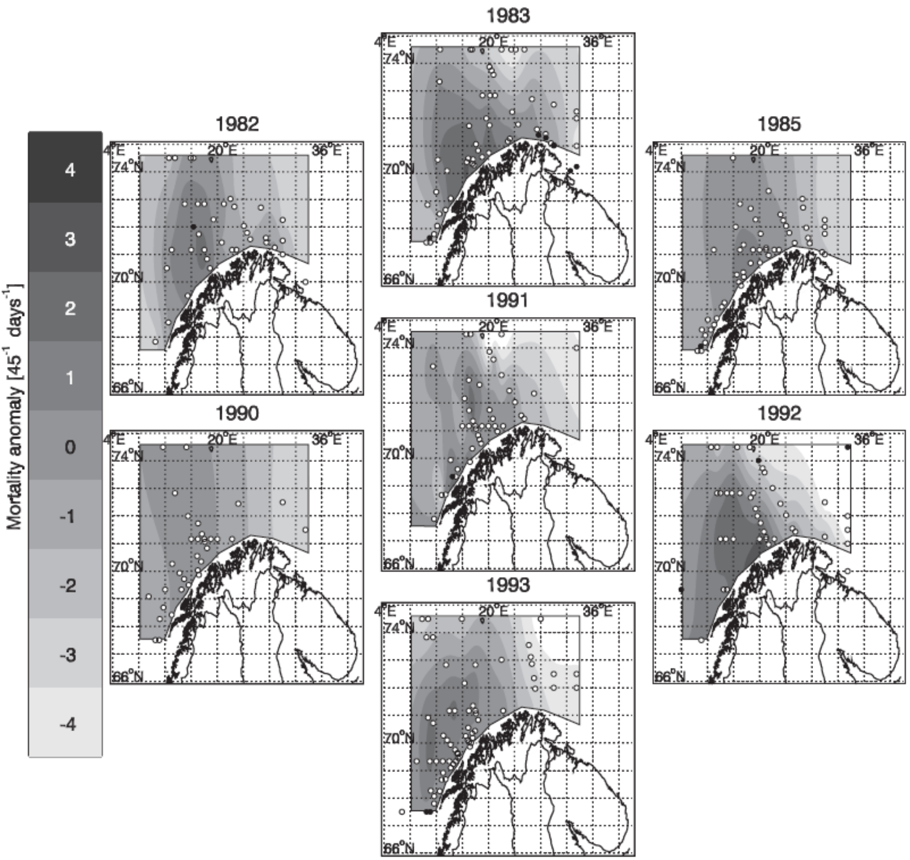
Natural mortality of eggs and larvae



Langangen et al. 2014

- Egg mortality are based on fixed rates (Langangen et al. 2013).
- Larvae mortality can either be fixed rates (Langangen et al. 2013) or a combination of size and light dependence (Vikebø et al. 2007).
- Starvation causes the larvae to shrink. Length based on weight. When shrunk below a threshold fraction of size according to length the larvae die (Fiksen et al. 2002; Kristiansen et al. 2009).
- A future possibility is to utilize estimates of spatial anomalies in mortality based on spring and summer observations of ELS of NEA cod in combination with a biophysical model (Langangen et al. 2014).

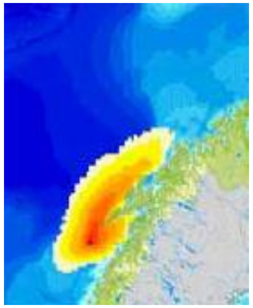
Natural mortality of eggs and larvae



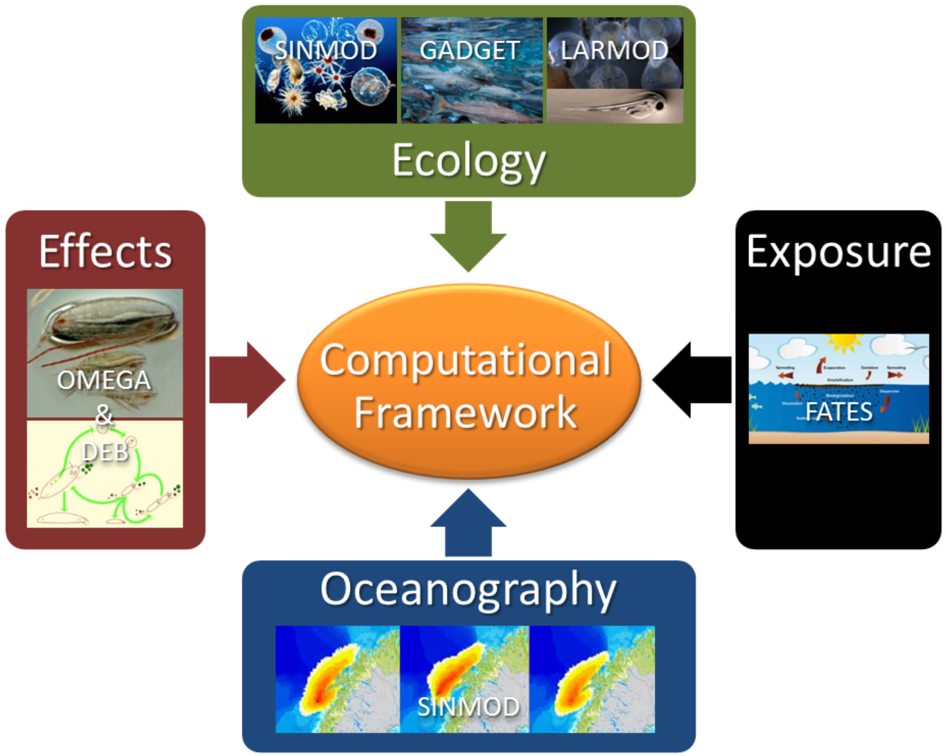
Langangen et al. 2014

- If initializing larval drift with observed larvae abundance, then comparing modeled and observed summer distribution and abundance allow estimation of natural mortality.
- This natural mortality is the sum of both starvation and predation (+ malformation, …).
- Utilizing modeled prey availability to estimate starvation allows for estimation of the fraction of natural mortality caused by predation.
- Modeled prey availability can be taken from the SYMBIOSES or from the NORWECOM.e2e model.

Attempts to build coupled models



ELS mortality in the biophysical model SYMBIOSES



- Alternatively, coupling NORWECOM E2E with an ELS fish IBM gives both modeled prey for the fish larvae and spatiotemporal distribution of some of their predators.

Summary

- Experimental work strongly suggest species and stage sensitivity to oil spill.
- Adding dispersants moderately decreases the exposure of Northeast Arctic cod eggs and larvae in three specific oil spill scenarios. However, Northeast Arctic haddock eggs attach to oil droplets – might the use of dispersants increase the contact rate with oil and therefore give opposite results as compared to cod?
- What is the overall ecosystem effect of combatting oil spill with dispersants if integrating across multiple species occupying different parts of the ecosystem?
- Spatiotemporal variability in natural mortality have the potential to significantly change the impact of oil spills on recruitment. Are we able to quantify this effect?
- All the above require high quality GCMs.