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The Arctic is no longer put on ice: Evaluation of Polar cod (*Boreogadus saida*) as a monitoring species of oil pollution in cold waters

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ABSTRACT

The withdrawing Arctic ice edge will facilitate future sea transport and exploration activities in the area, which calls for the establishment of relevant cold water monitoring species. The present study presents first results of field baseline levels for core oil pollution biomarkers in Polar cod (*Boreogadus saida*) sampled from pristine, Arctic waters. Furthermore, biomarker response levels were characterized in controlled laboratory exposure experiments running over 2 weeks. Fish exposed to a simulated petrogenic spill (1 ppm dispersed, crude oil) exhibited elevated hepatic EROD activity, bile PAH-metabolites, and hepatic DNA-adducts, whereas male individuals exposed to simulated produced water (30 ppb nonylphenol) exhibited a strong induction of plasma vitellogenin. In conclusion, the results demonstrated low and robust biomarker baseline levels that were clearly different from exposure responses. In combination with its high abundance and circumpolar distribution, the Polar cod seems well qualified for oil pollution monitoring in Arctic waters.

1. Introduction

The Arctic Ocean encompasses about 6% of the Earth's surface and is largely covered by sea ice throughout the whole year. The harsh climate has made Arctic waters inaccessible for sea transport and spared the region from oil spills in the past. However, climate change is now opening the region. The Northwest Passage, a short cut seaway route between Europe and Asia through the Canadian Arctic, was ice-free for the first time in the summer of 2007 (Giles et al., 2008), raising the possibility that the Arctic region could become a prime trade route in the near future (Pietri et al., 2008). Furthermore, a recent report by the US Geological Survey suggested that the area north of the Arctic Circle (N 66°33′39″) accounts for about 22% of the world's undiscovered, technically recoverable oil and natural-gas resources (USGS fact sheet 2008-3049). So far, onshore exploration activities have pin-pointed more than 400 oil and gas fields north of the Arctic Circle. Nevertheless, 70% of Arctic petroleum resources are suspected to be found offshore where, however, the near-permanent sea ice has prevented acquisition of seismic data and drilling of exploratory wells. Thus, energy companies are now flocking northward, but whether or not recovery of oil and gas is desirable is of concern in the countries surrounding the Arctic. Under debate in particular are Arctic risk factors, such as rough weather conditions and drifting icebergs that will increase the threat of spills in the area. In general, oil pollution is more problematical in the Arctic because of the simple and highly seasonal ecosystems and the logistic challenges of cleaning up spills in remote regions. The low temperatures will also make hydrocarbons persist, making ice-edge communities particularly vulnerable (AMAP, 2008 report).

The growing industrial focus on the Arctic calls for the establishment of new and relevant monitoring species while the area is still relatively pristine. While current biomarker data on cold water fish species is very limited, it will be essential to have access to field baseline data and expected response levels for selected species and monitoring parameters in the event of a future pollution incident. This study has challenged the use of Polar cod (*Boreogadus saida*) as a monitoring organism of oil pollution in cold waters. Its high abundance and circumpolar Arctic distribution in combination with its association with the ice edge, a natural oil spill sink, makes Polar cod particularly relevant regarding effect monitoring of petroleum pollution. The aims of the study were to (i) generate preliminary field baseline levels of established biomarkers of oil exposure in individuals sampled from pristine, Arctic waters, and (ii) characterize biomarker response levels in relation to relevant hydrocarbon exposure situations. In this regard, we evaluated the robustness, and hence the suitability of using Polar cod as a monitoring species in controlled laboratory experiments. Fish were continuously exposed for 2 weeks to 1 ppm crude, dispersed oil, representing a petrogenic spill situation of mainly 2–3 ring PAHs, and to 30 ppb nonylphenol to simulate produced water. Following exposure, a suite of biomarkers recommended by ICES to monitor petroleum pollution were evaluated from fish biopsies; hepatic

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7-ethoxyresorufin-*O*-deethylase (EROD) activity, PAH-metabolites in bile, hepatic DNA-adducts, and plasma vitellogenin levels. Results obtained in exposed fish were related to unexposed control individuals as well as to field baseline data to highlight oil pollution biomarker response levels in Polar cod.

2. Materials and methods

2.1. Chemicals

Crude oil and nonylphenol (industrial grade; 85% of p-isomers) used in the laboratory exposure experiment were from Statfjord A, North Sea, and Fluka, respectively. Polyclonal rabbit-anti-trout-Vtg IgG was from Biosense Laboratories, Norway. The HRP-conjugate goat-anti-rabbit IgG and the protein assay solution were from Bio-Rad. Triphenylamine, 2,6-dibromophenol, BSTFA, OPD, BSA, NADPH, resorufin and 7-ethoxyresorfin were from Sigma–Aldrich. All other reagents were of analytical grade and purchased from Merck.

2.2. Collection of Polar cod

Adult Polar cod (16–96 g, 13.5–23 cm) for field baseline studies were collected during trawls in September 2001 and August 2002 (13–17.5 cm, weight not available) at locations given in Fig. 1. Fish to be used in the laboratory exposure experiment (80–100 g) were collected during a trawl in December 2001 near Bear Island, brought to the Norwegian College of Fishery Science (Tromsø) and kept in 5 °C seawater before transport to Stavanger. Fish were transported by plane from Tromsø to Stavanger (Norway) in polystyrene boxes topped with oxygen and put on ice. The total transport time was 6.5 h from tank to tank, and the water temperature was approximately 2 °C upon arrival. The fish were transferred to 4 °C tanks and acclimated for 12 days before exposure.

2.3. Laboratory exposure study

Seawater (salinity 34‰) was taken from 80 m depth, and passed through a sand filter prior to entering fish tanks (disinfected fiberglass tanks, 70 × 70 × 50 cm). The seawater was temperature controlled to 4 °C. Exposure to 1 mg/L dispersed, crude oil was made by means of a continuous flow system described in detail by Sanni et al. (1998). The 5 ppm oil dispersion header tank contained oil droplets of average size 10 μm^3, as evaluated from Coulter counter measurements (results not shown). Nonylphenol (NP) was dissolved in an acetone carrier to a 1.2 mg NP/ml stock solution. The NP and oil dispersion stock solutions were diluted with seawater using peristaltic pumps (Watson Marlow 505 U) equipped with Marprene tubing (Watson Marlow) to obtain nominal exposure concentrations of 1 ppm oil and 30 ppb NP. The acetone concentration was below the predicted no effect concentration (PNEC) in an aqueous environment (21 mg/L; UNEP) and there was, therefore, no separate carrier control. Tanks were fitted with surface outlets to avoid accumulation of oil film on the water surface. The two exposure tanks contained eight individuals, whereas the control tank contained seven individuals. Fish were not fed during the 2 weeks exposure experiment. Exposures did not give rise to any

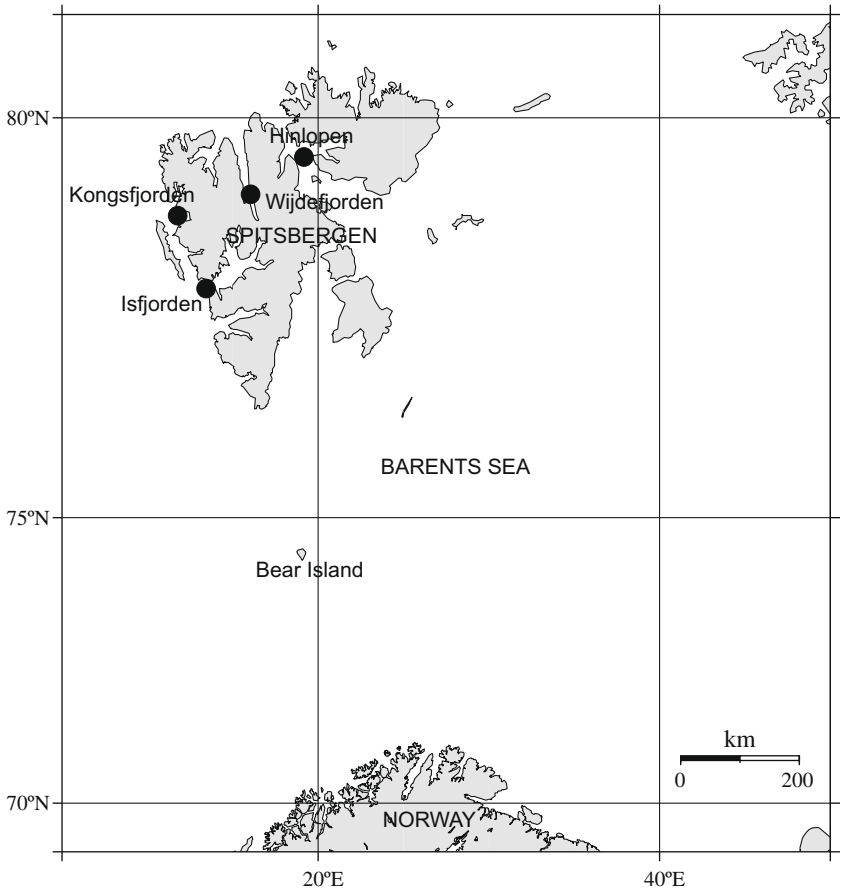

Fig. 1. Arctic field sampling locations. Polar cod were captured from four different sites outside Svalbard during two campaigns in September 2001 and August 2002; (from north to south) Hinlopen, Wijdefjorden, Kongsfjorden, Isfjorden. Additional fish were captured outside Bear Island in December 2001 and used in the laboratory exposure experiment.