Oil Biodegradation Potential of Sea Ice Microbial Communities

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grease

nilas with frost flowers

consolidated pancake

1 cm 1 day

10 cm <1 week

20 cm ~1 week
The dynamic sea ice environment

colder
smaller
saltier

warmer
larger
cleaner

concen-
trated
cells

After H. Eicken

seawater

snow

–2°C/32ppt

–25°C/230ppt
Ice temperature (measured, deg C)
In situ brine salinity (calculated, ‰)
Brine volume fraction/porosity

Karlsson et al. (2011)
Microbial habitats

K. Junge et al. 2001

brine pocket

ice crystal

brine veins

ice crystal

bacteria

10 μm

100 μm
Microbial habitats

(Krembs et al. 2007; 2010)
Oil in Ice Scenarios

• Effects of oil on microbial communities?
• Effects of microbial communities on oil (biodegradation)?
Sea ice microbial community evolution

- Oct
- Nov
- Dec
- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sept

- incorporated from seawater
- prefer low nutrients
- grow slowly
- no algal production

- selective growth of 'weeds'
- prefer high nutrients
- grow quickly
- intense algal production
Existing studies of oil biodegradation in Arctic sea ice

Atlas et al. 1978

Only Alaskan study
Existing studies of oil biodegradation in Arctic sea ice

- Oct        Nov       Dec      Jan      Feb      Mar      Apr     May      Jun      Jul      Aug      Sept
- Atlas et al. 1978
  - no biodegradation

biodegradation observed but not quantified
change in community

Only Alaskan study
Existing studies of oil biodegradation in Arctic sea ice

Gerdes et al. 2006

- no biodegradation detected over 2 months in situ
- no community change
- no influence of nutrients

Svalbard studies
Existing studies of oil biodegradation in Arctic sea ice

Brakstad et al. 2008

no biodegradation in surface
slow biodegradation at depth
change in community structure

Svalbard studies
Existing studies of oil biodegradation in Arctic sea ice

Gerdes et al. 2005

biodegradation not measured community structure shifts during 12-18 month incubations

Svalbard studies
Existing studies of oil biodegradation in Arctic sea ice
Gap 1: Lack of studies on critical ice biota habitat (bottom of spring ice + summer ice)
CMI: Crude oil infiltration and movement in first-year sea ice -- Impacts on ice-associated biota and physical constraints

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Students: Kyle Dilliplaine (poster), Marc Oggier (talk)
Gap 2: Minimal spatial coverage

Recommendation: More international collaboration
Gap 3: Absence of modern molecular methods (genomics and metagenomics)

Culturing:
Atlas et al. 1978

Fingerprinting:
Gerdes et al. 2005
Gerdes et al. 2006
Brakstad et al. 2008

Sequencing:
none to date
Microbial Loop = Biodegradation
200 cold-adapted genomes
(out of 20,000 total)
Deepwater Horizon Succession

 Dubinsky et al. (2013)
Pseudomonas
Cycloclastisicus
Pseudoalteromonas
Methylomonas
Piscirickettsiaceae
Alteromonadaceae
Flavobacteraceae
Rhodobacteraceae
Saprospiraceae
Most cold-adapted species are in oil-degrading groups.

Cold ocean is 90% by volume but cold-adapted genomes are only \( \frac{200}{20,000} = 1\% \)
Psychrophile Genome Biodegradation Potential

Genes for contaminant biodegradation
Recommendations:

- Application of modern **sequencing & bioinformatics** techniques to determine biodegradation potential of sea ice communities
- Integration of **biodegradation rate measurements** with biological community analysis
- Increase the relevance of lab experiments to **natural communities**
- Rigorous analysis of natural **variability and uncertainty** in environmental conditions
- Forecast of future changes in microbial community structure as a result of global warming-induced sea ice loss