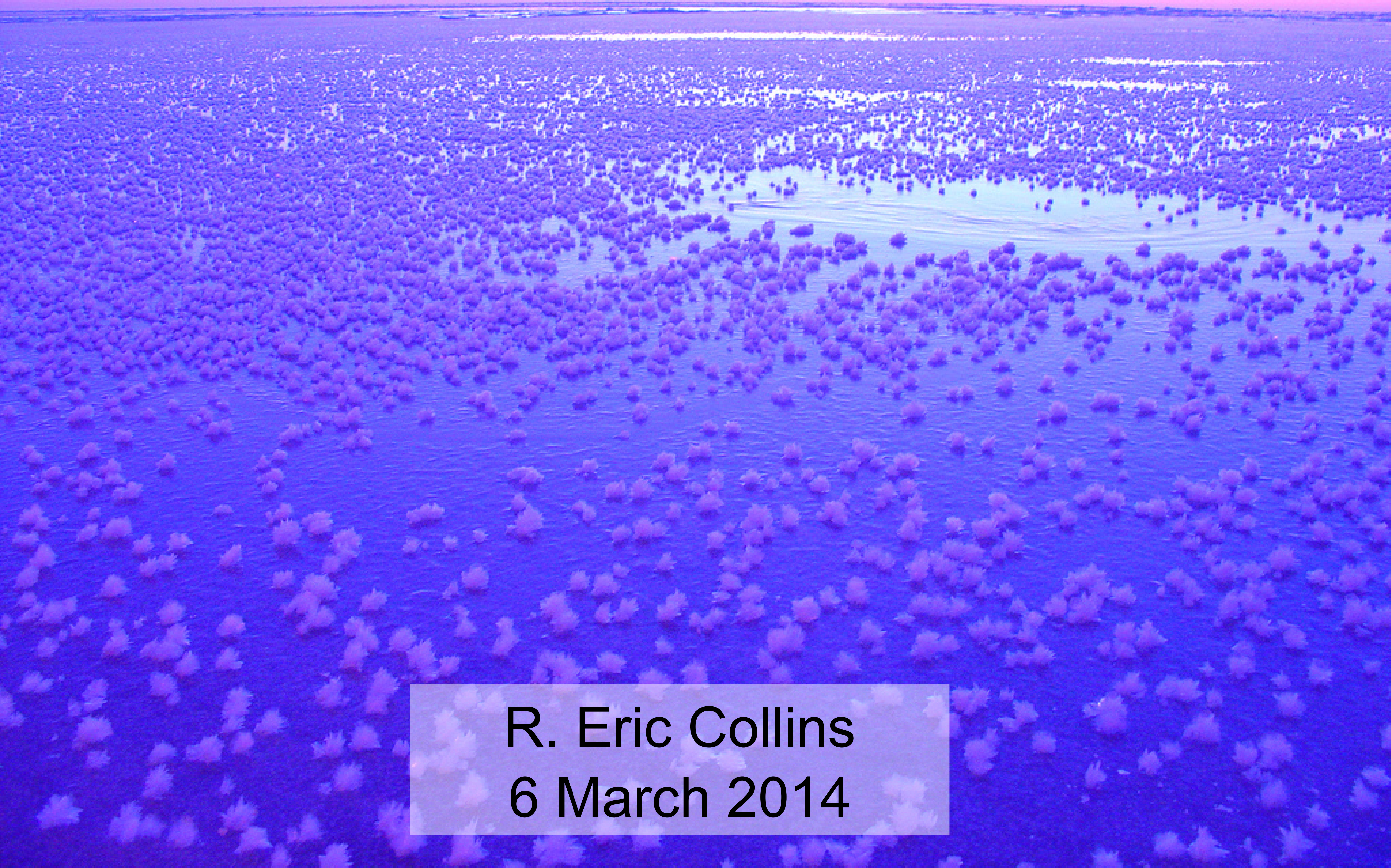
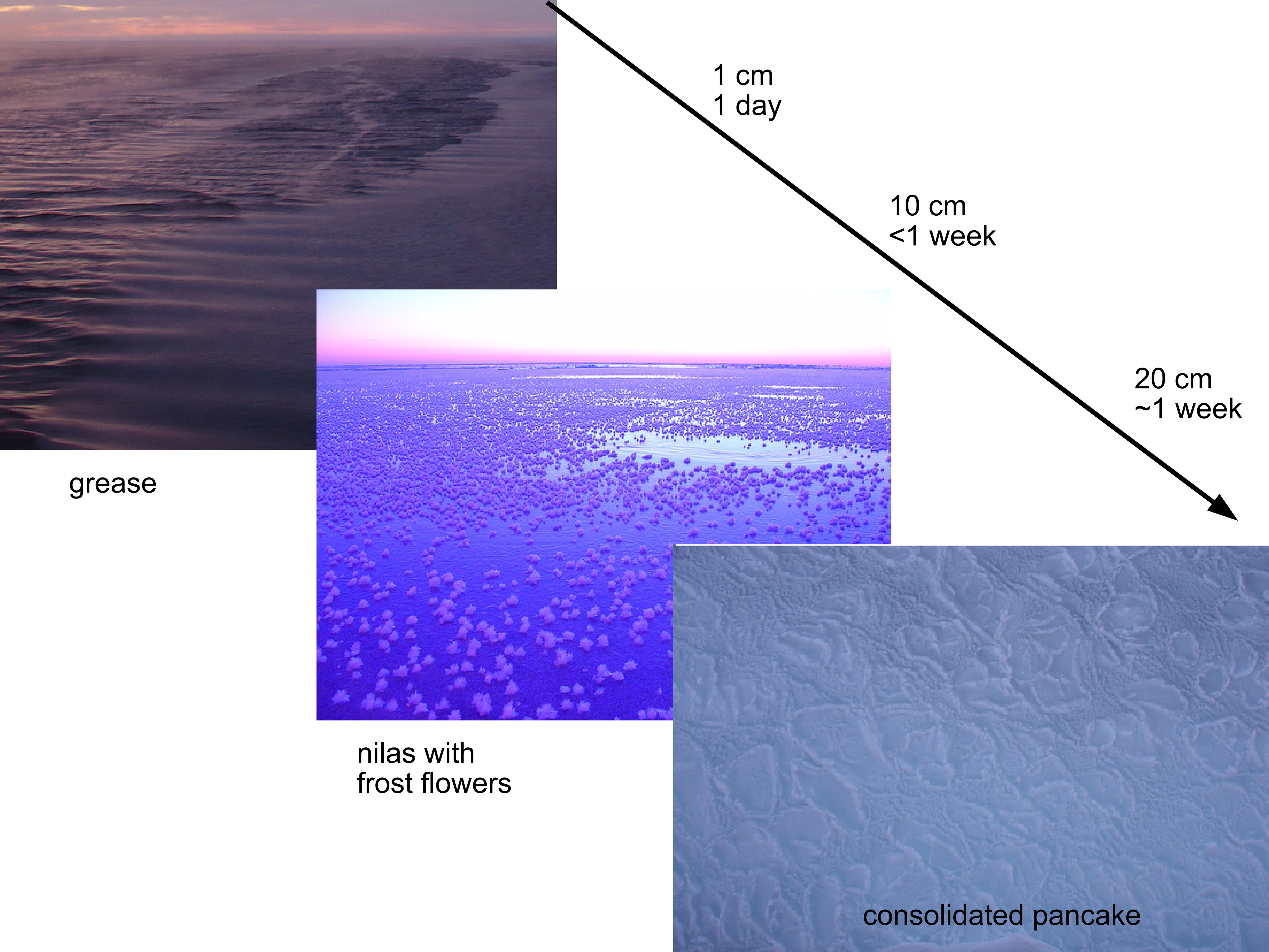
Oil Biodegradation Potential of Sea Ice Microbial Communities

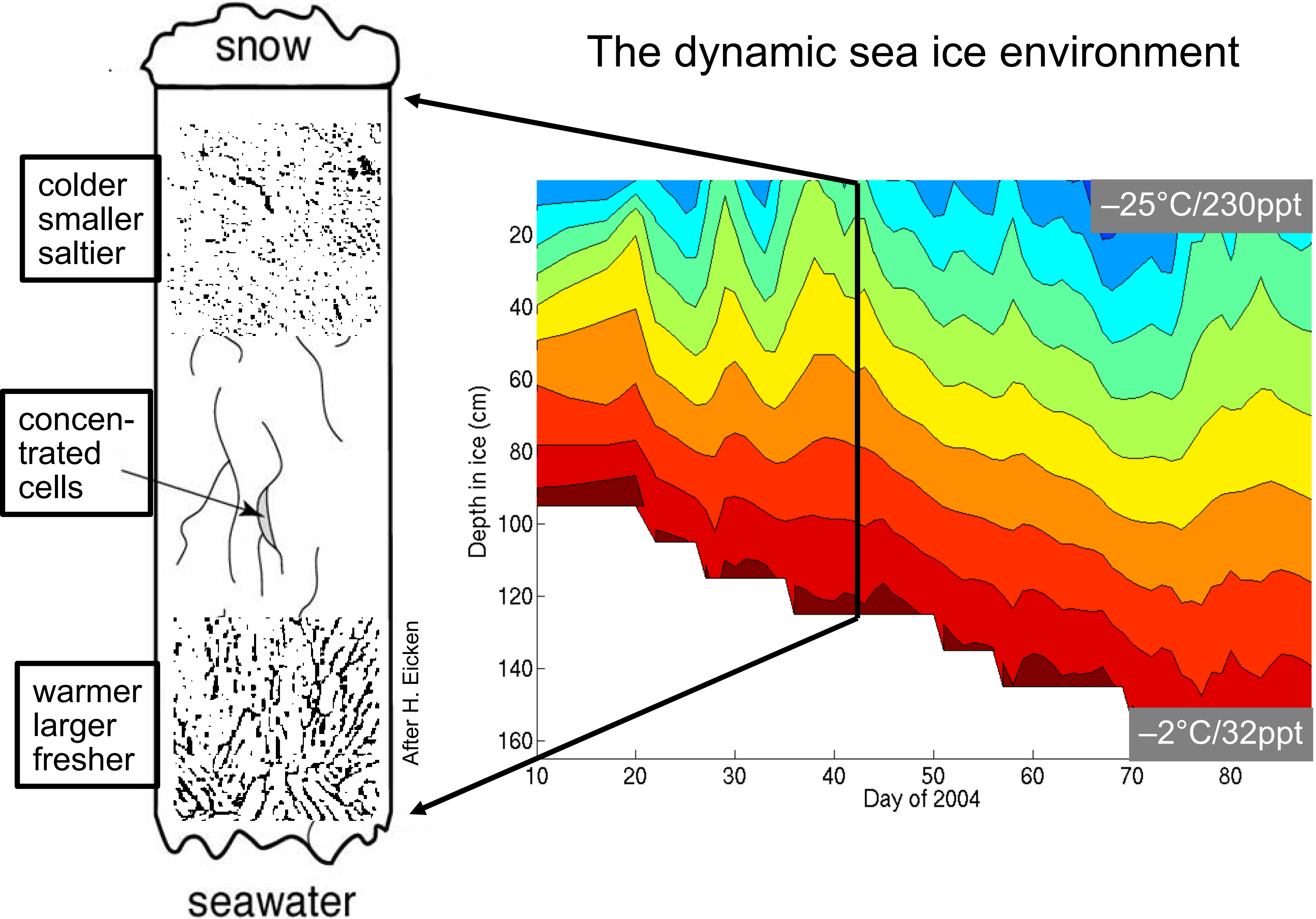


R. Eric Collins

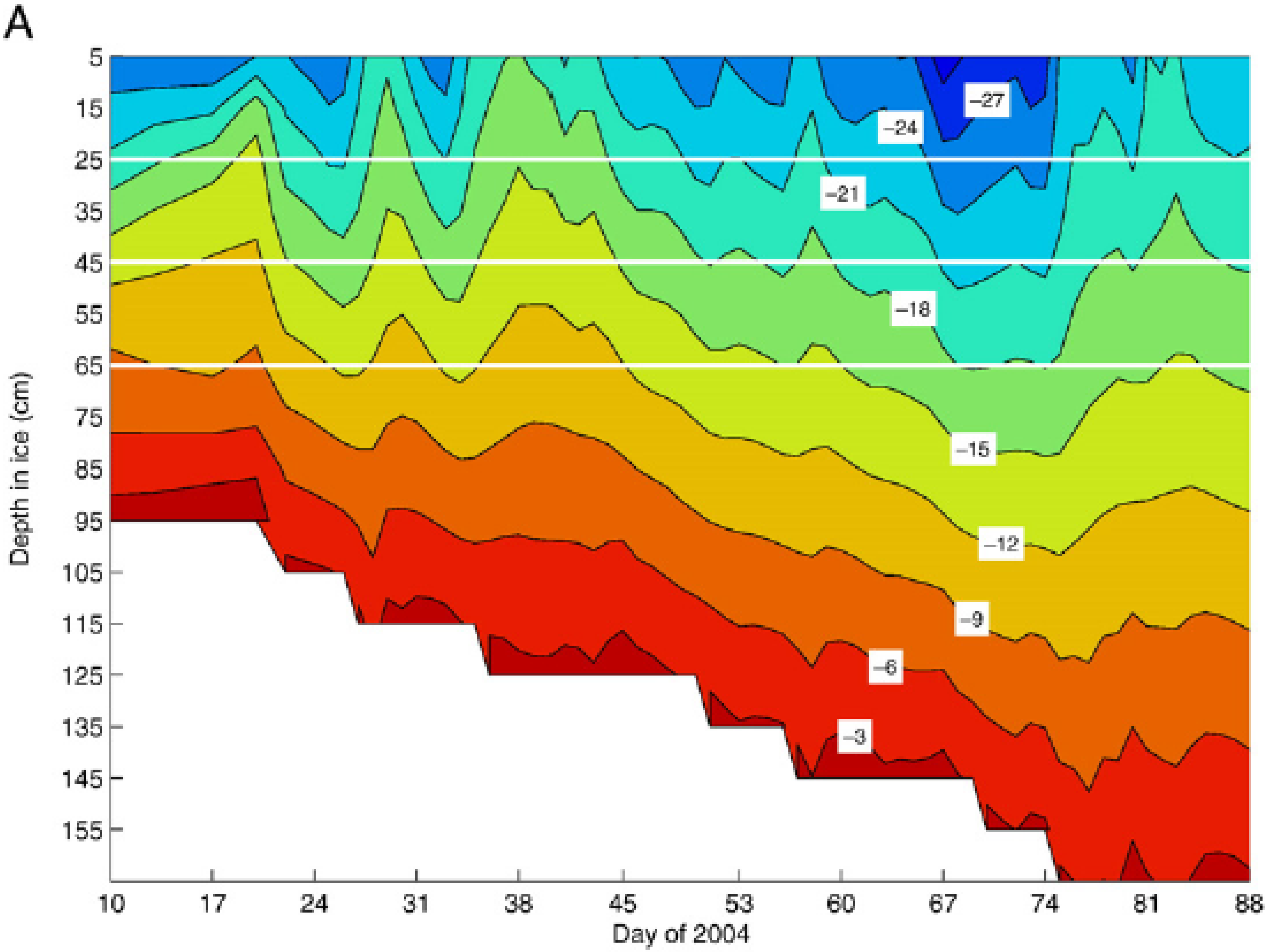
6 March 2014


1 cm
1 day
10 cm
<1 week
20 cm
~1 week
grease
nilas with
frost flowers
consolidated pancake

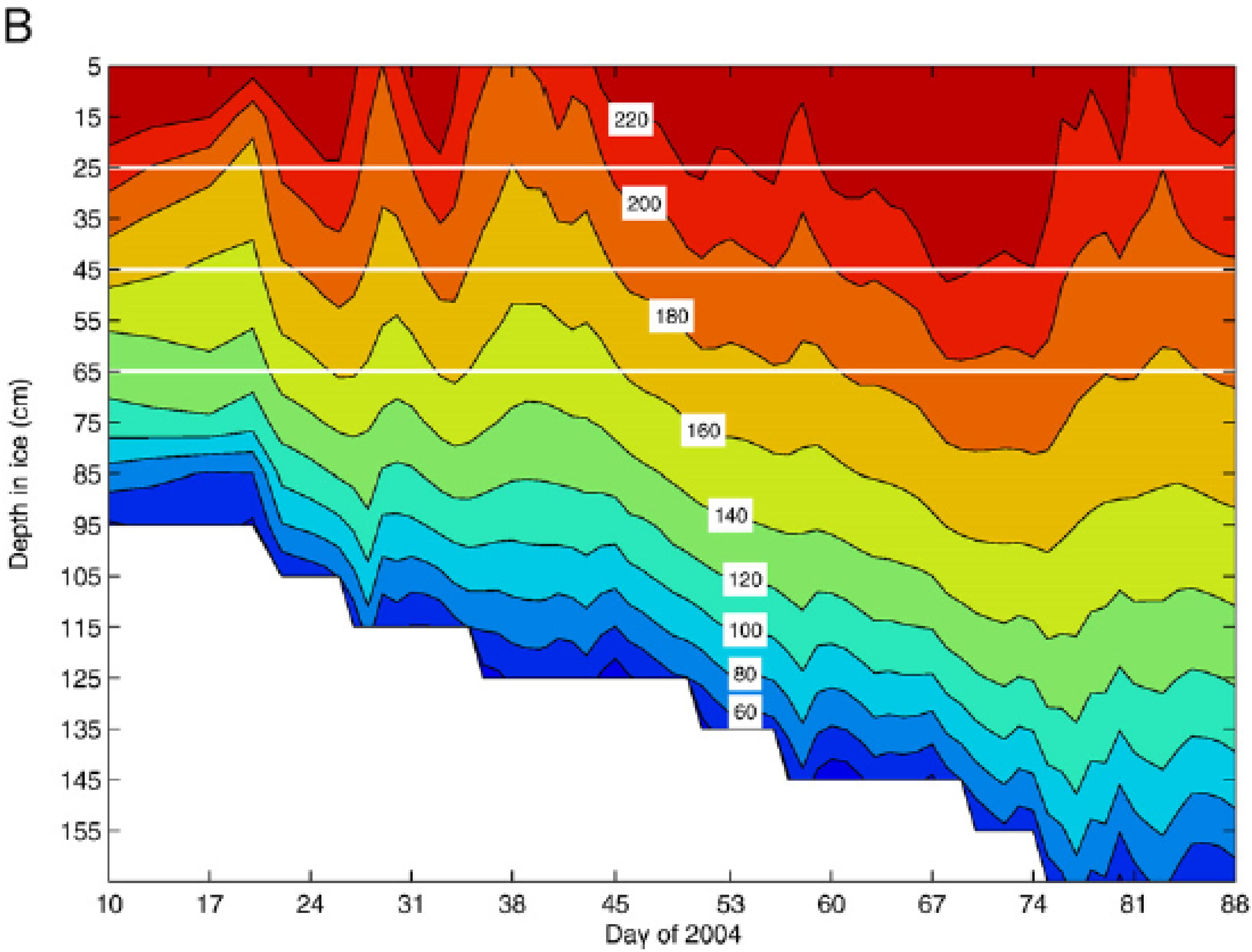
The dynamic sea ice environment



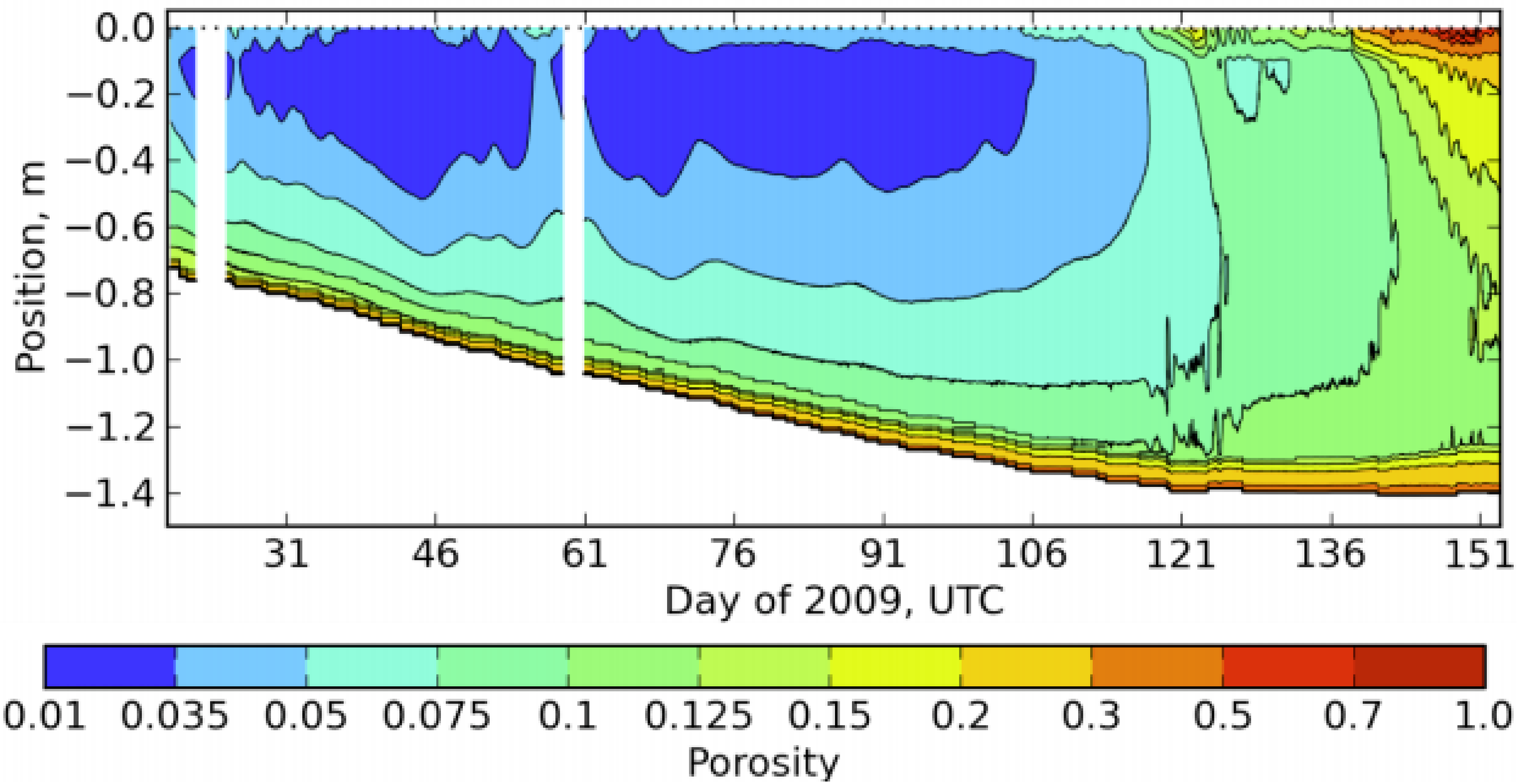
Ice temperature (measured, deg C)



In situ brine salinity (calculated, ‰)

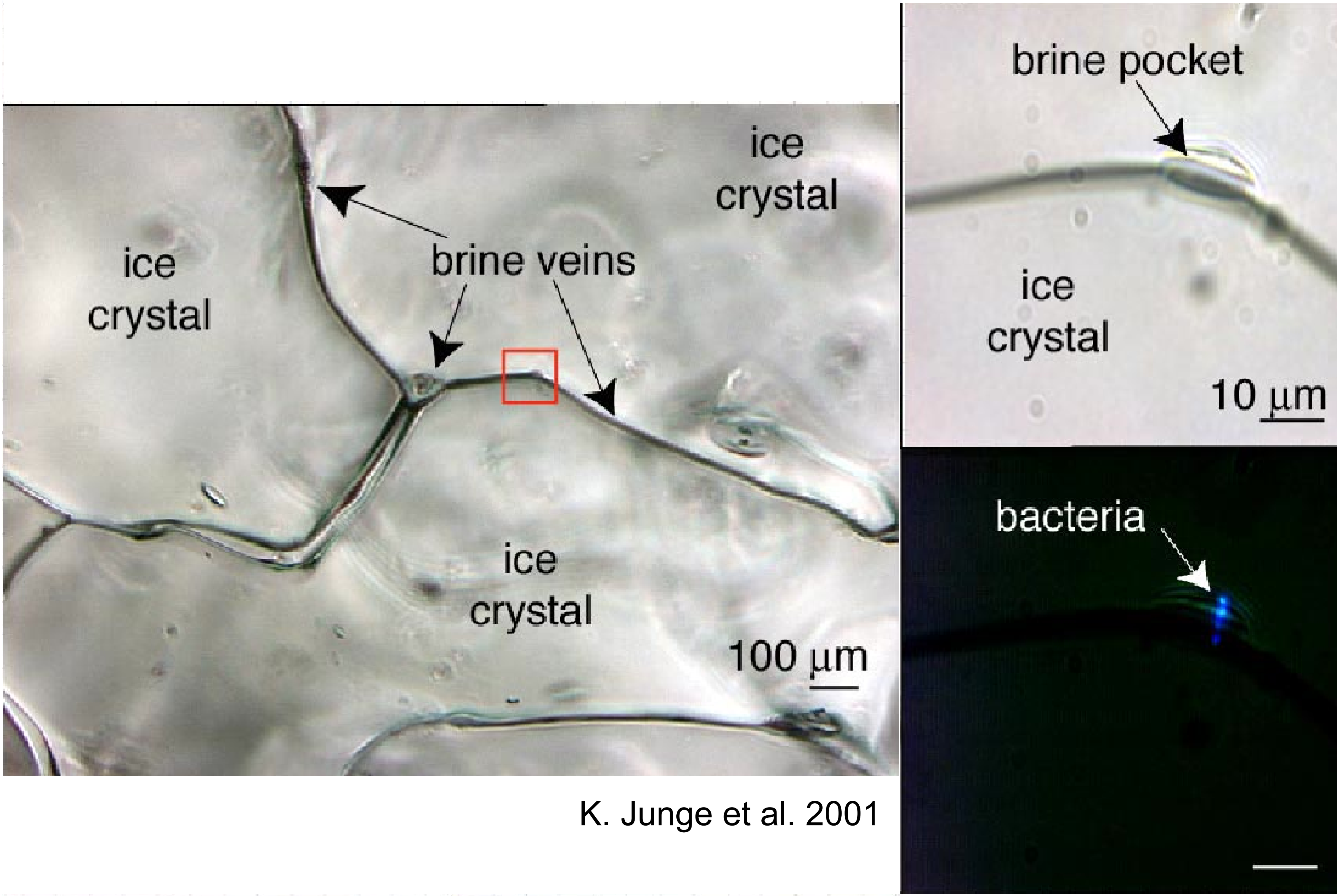


Brine volume fraction/porosity



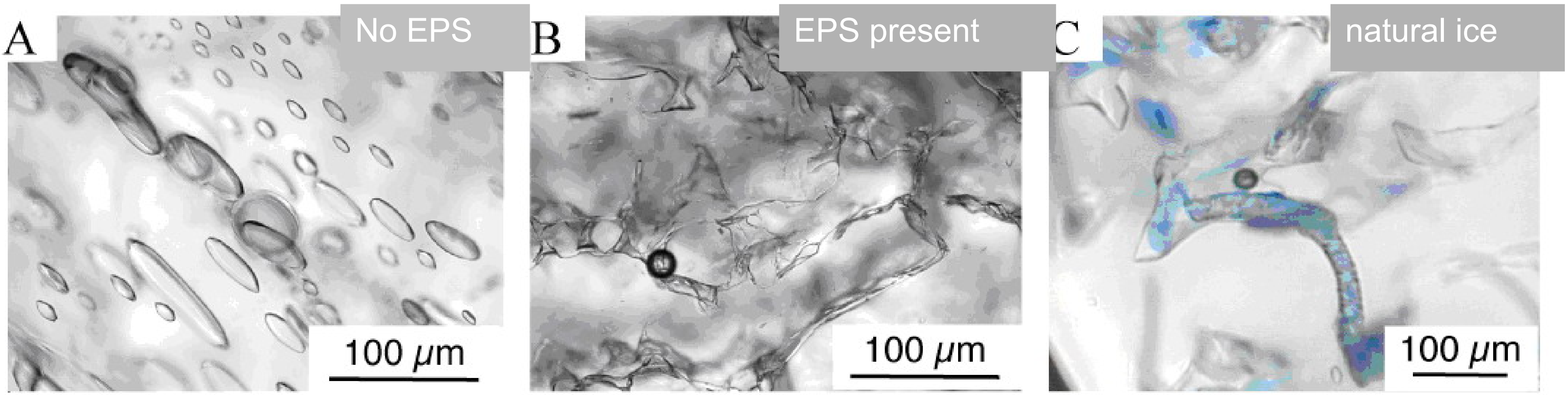
Karlsson *et al.* (2011)

Microbial habitats



K. Junge et al. 2001

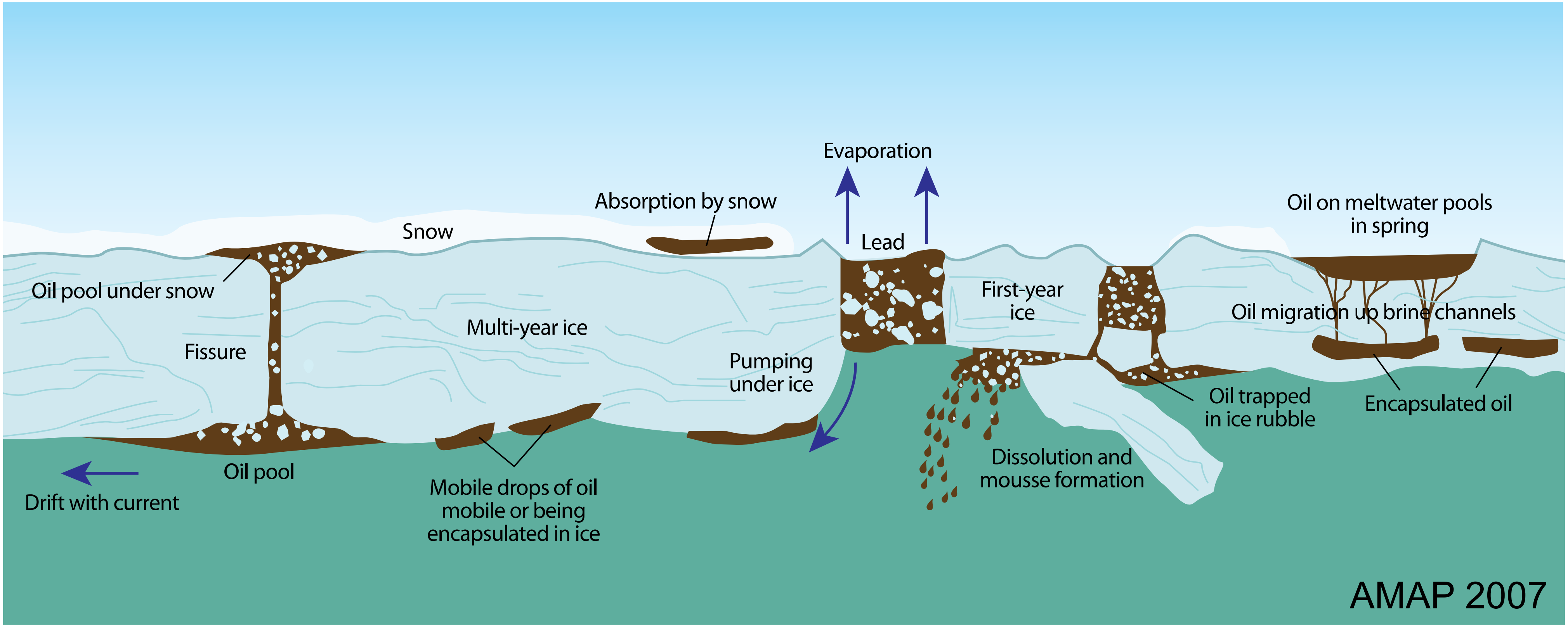
Microbial habitats



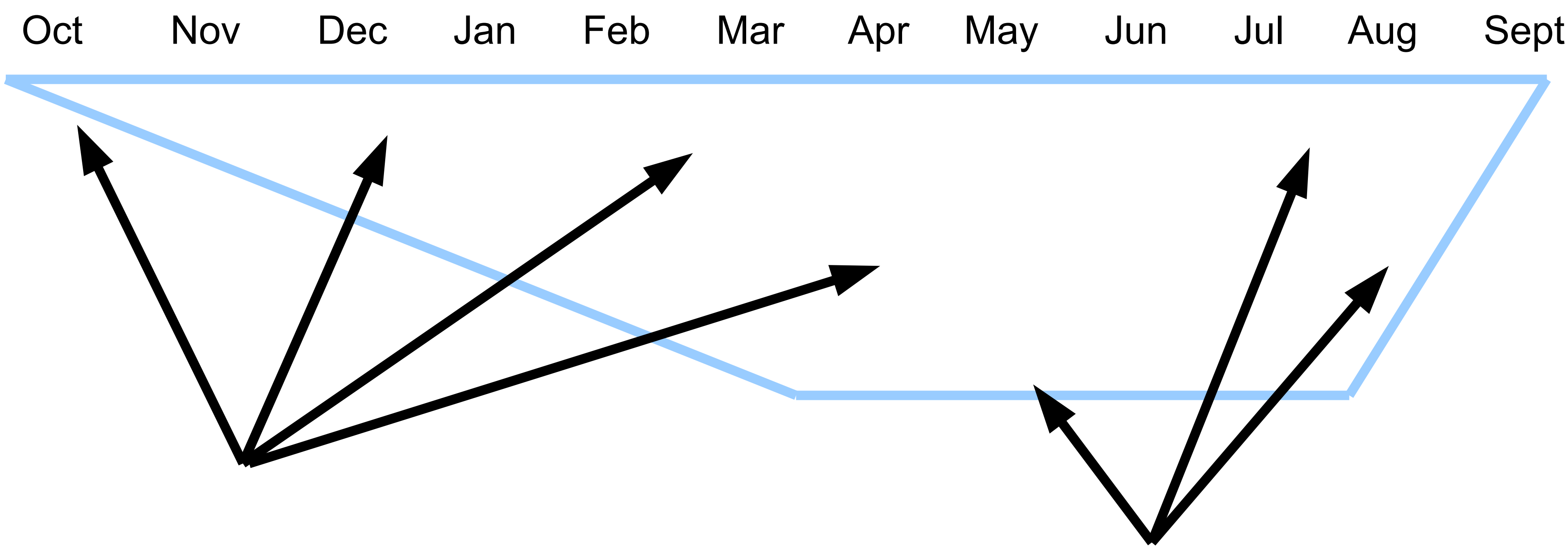
(Krembs et al. 2007; 2010)

Oil in Ice Scenarios

- Effects of oil on microbial communities?
- Effects of microbial communities on oil (biodegradation)?



Sea ice microbial community evolution



incorporated from seawater

prefer low nutrients

grow slowly

no algal production

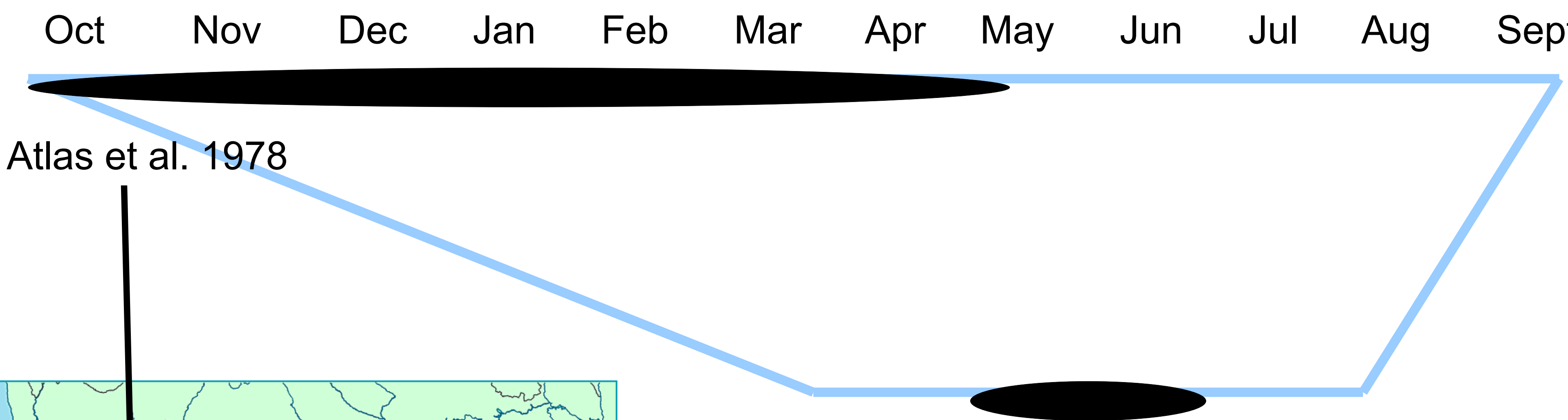
selective growth of 'weeds'

prefer high nutrients

grow quickly

intense algal production

Existing studies of oil biodegradation in Arctic sea ice



Only Alaskan study

Existing studies of oil biodegradation in Arctic sea ice

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

no biodegradation

Atlas et al. 1978

biodegradation observed but not quantified

change in community

Only Alaskan study

Existing studies of oil biodegradation in Arctic sea ice

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

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

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

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

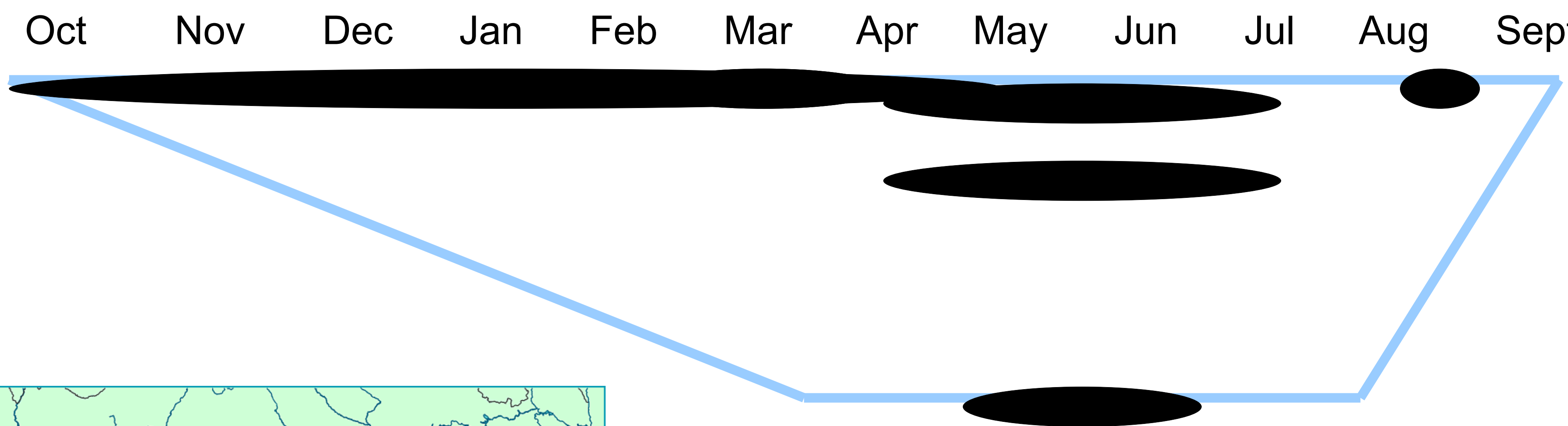
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sept

Gerdes et al. 2005

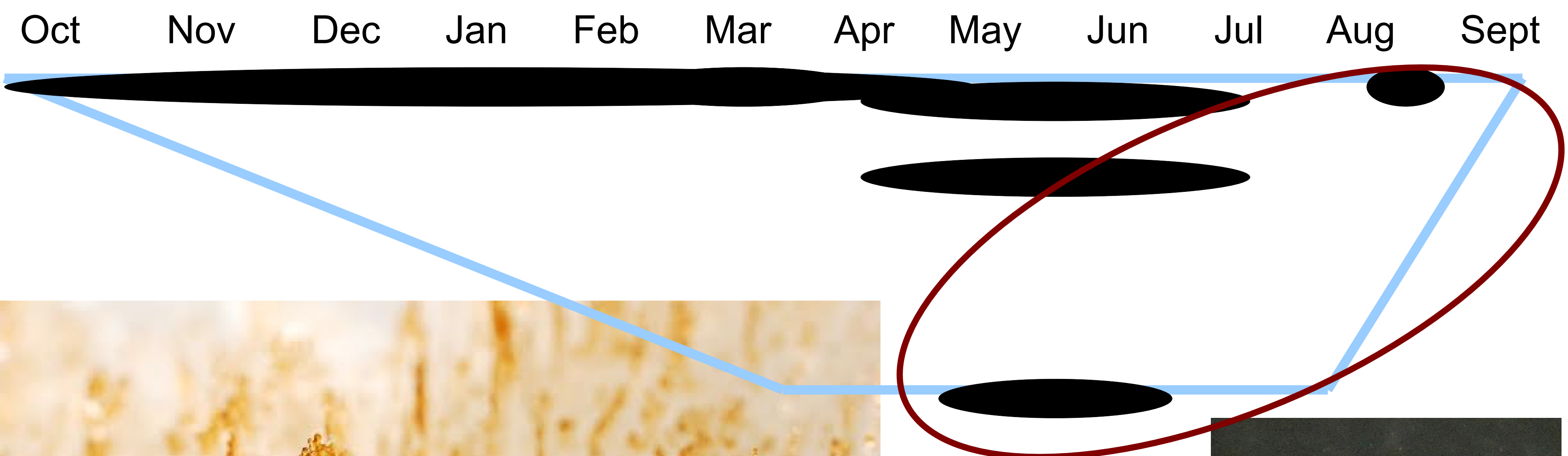
biodegradation not measured
community structure shifts
during 12-18 month incubations

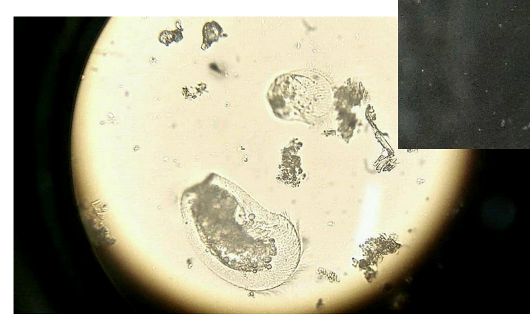
Svalbard studies

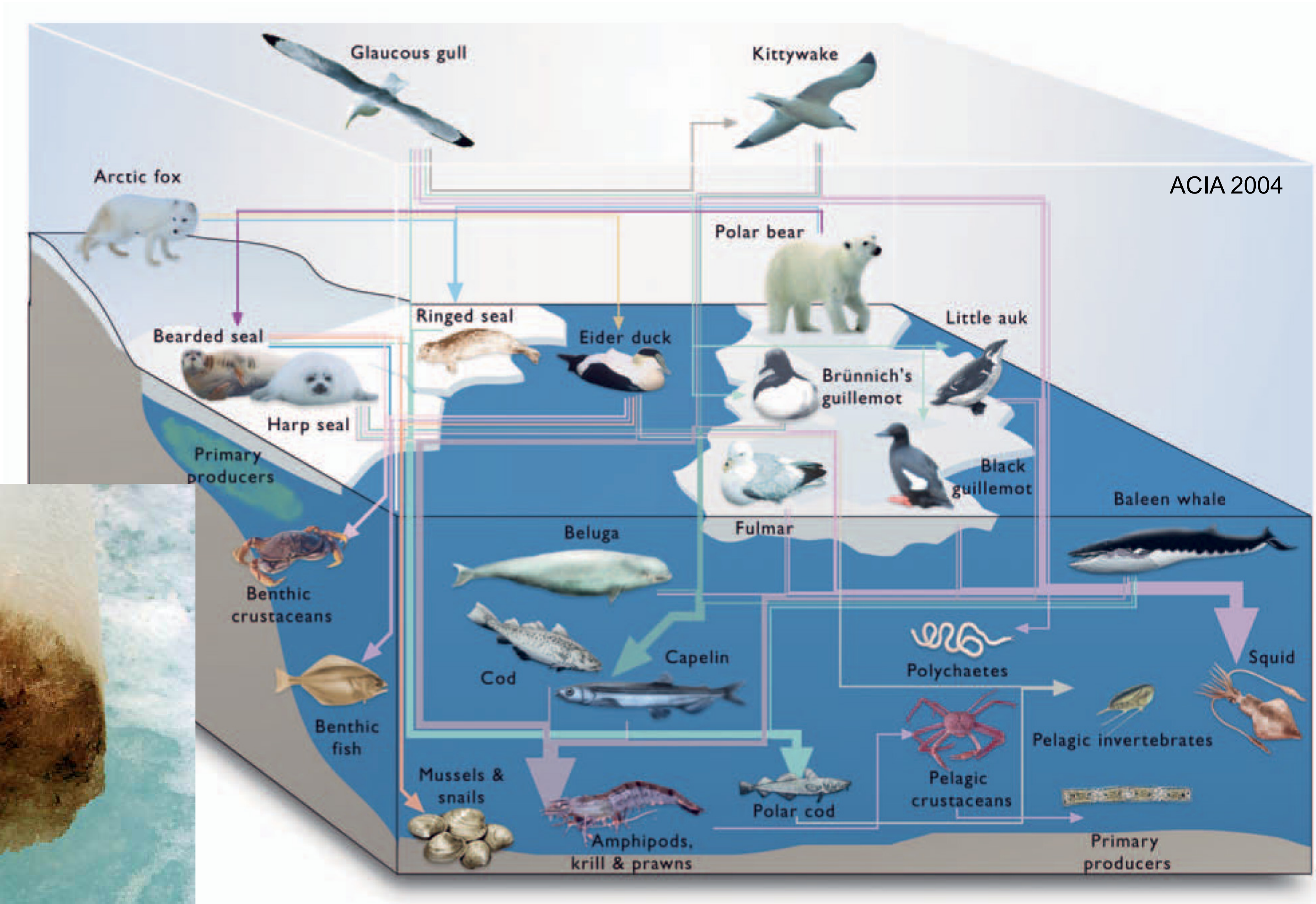
Existing studies of oil biodegradation in Arctic sea ice



Gap 1: Lack of studies on critical ice biota habitat (bottom of spring ice + summer ice)





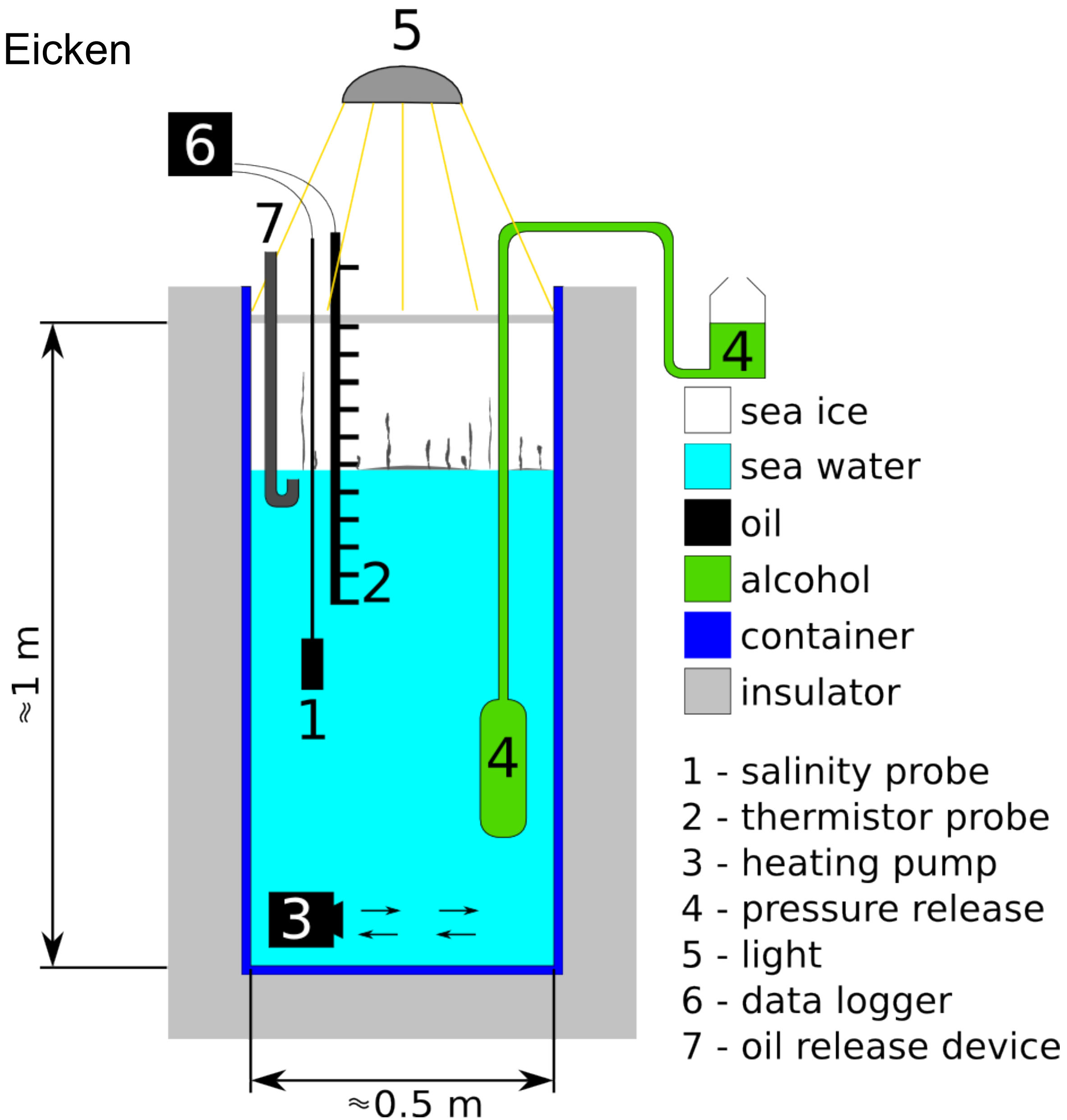

Glaucous gull
Kittywake
Arctic fox
ACIA 2004
Polar bear
Ringed seal
Eider duck
Little auk
Bearded seal
Brünnich's guillemot
Harp seal
Primary producers
Black guillemot
Fulmar
Baleen whale
Beluga
Benthic crustaceans
Cod
Capelin
Polychaetes
Squid
Benthic fish
Pelagic invertebrates
Mussels & snails
Pelagic crustaceans
Polar cod
Amphipods, krill & prawns
Primary producers


Bangor University

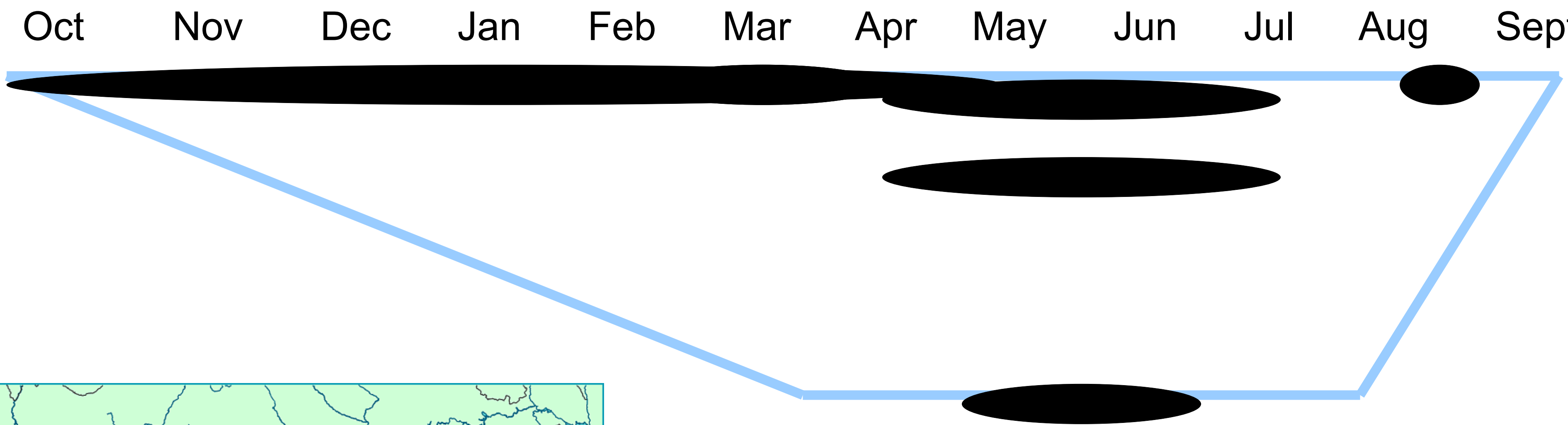
CMI: Crude oil infiltration and movement in first-year sea ice -- Impacts on ice-associated biota and physical constraints

Co-Investigators: Rolf Gradinger, Hajo Eicken

Students: Kyle Dilliplaine (poster),
Marc Oggier (talk)



Gap 2: Minimal spatial coverage



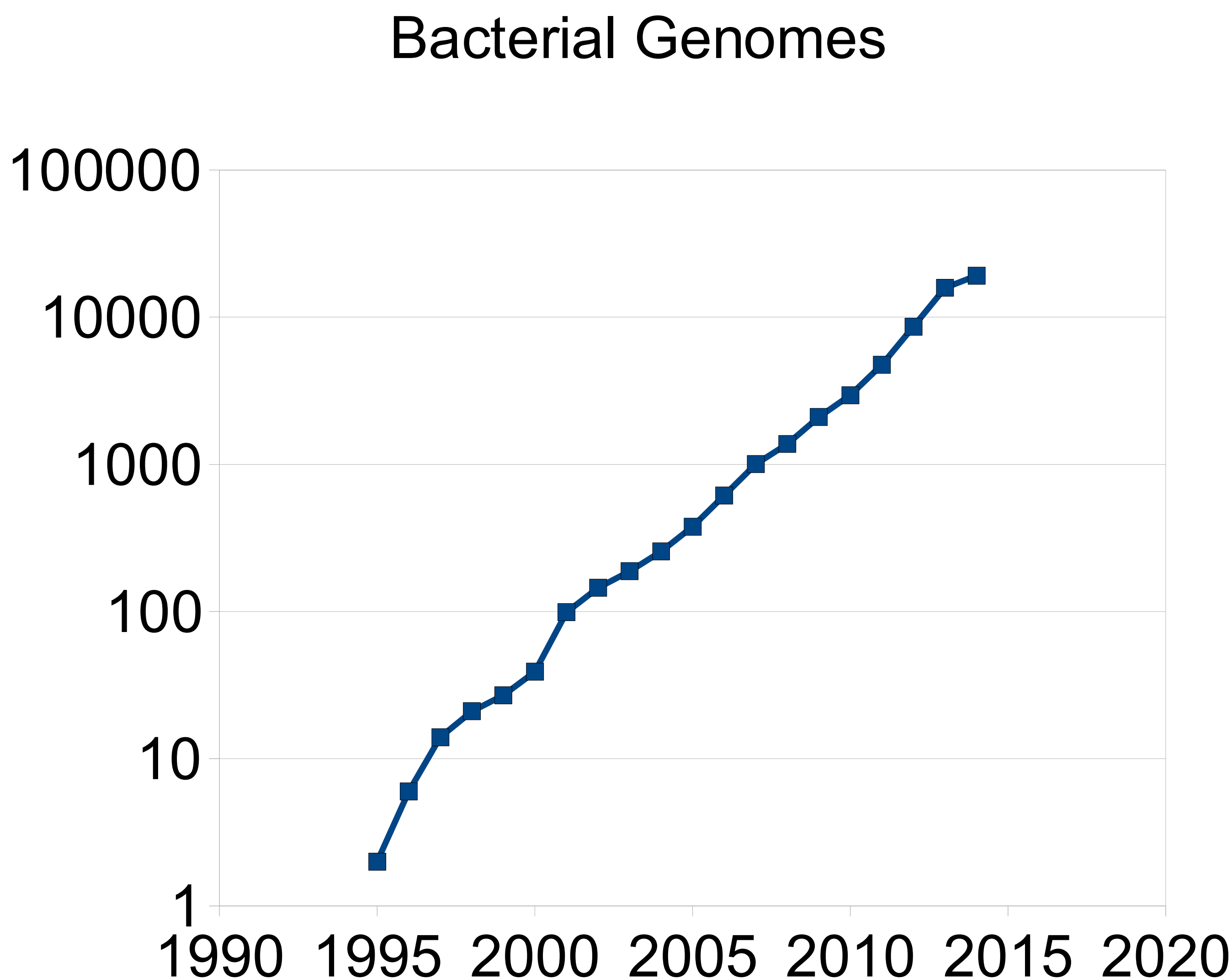
Recommendation:
More international collaboration

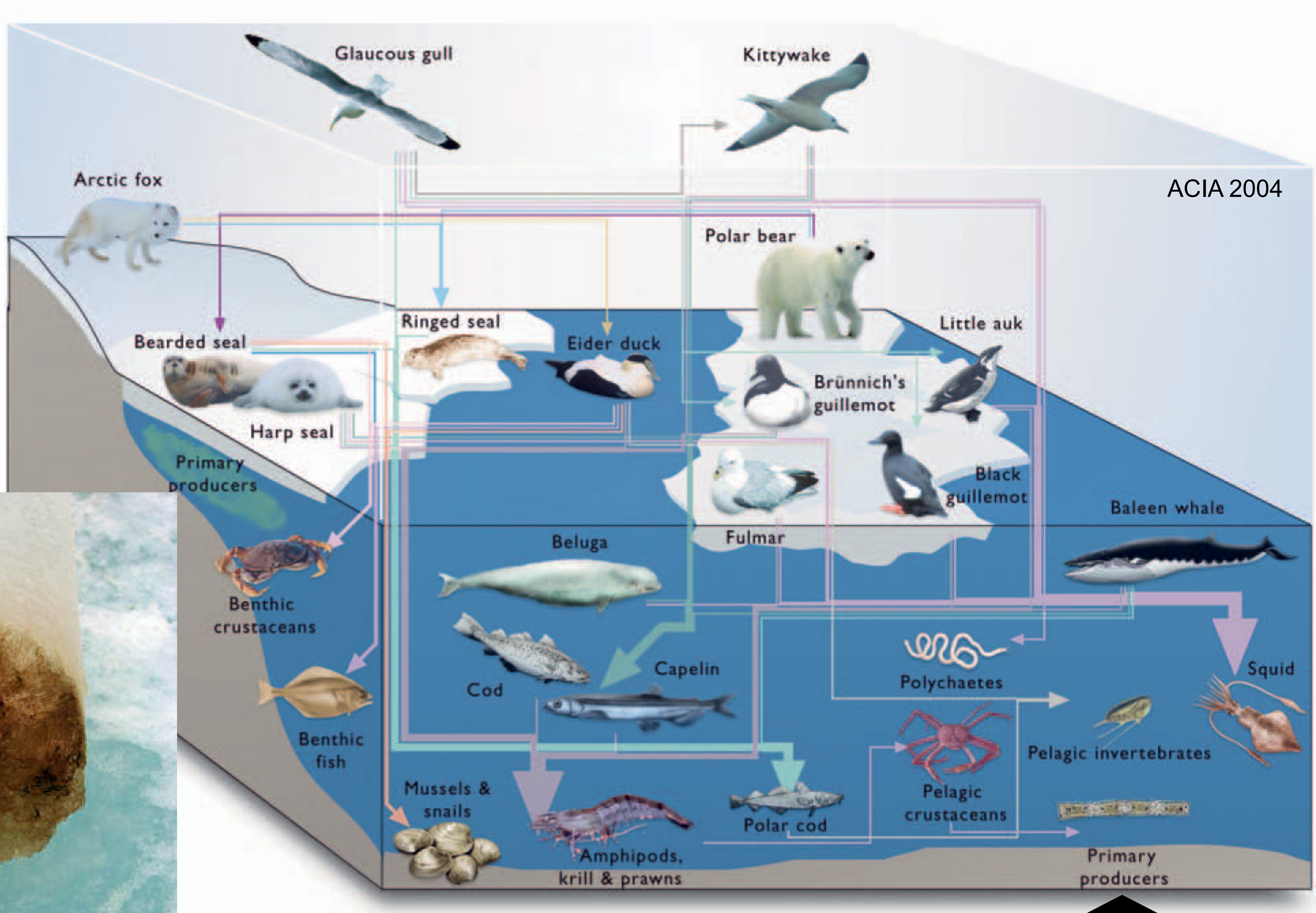
Gap 3: Absence of modern molecular methods (genomics and metagenomics)

Culturing:
Atlas et al. 1978

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

Sequencing:
none to date

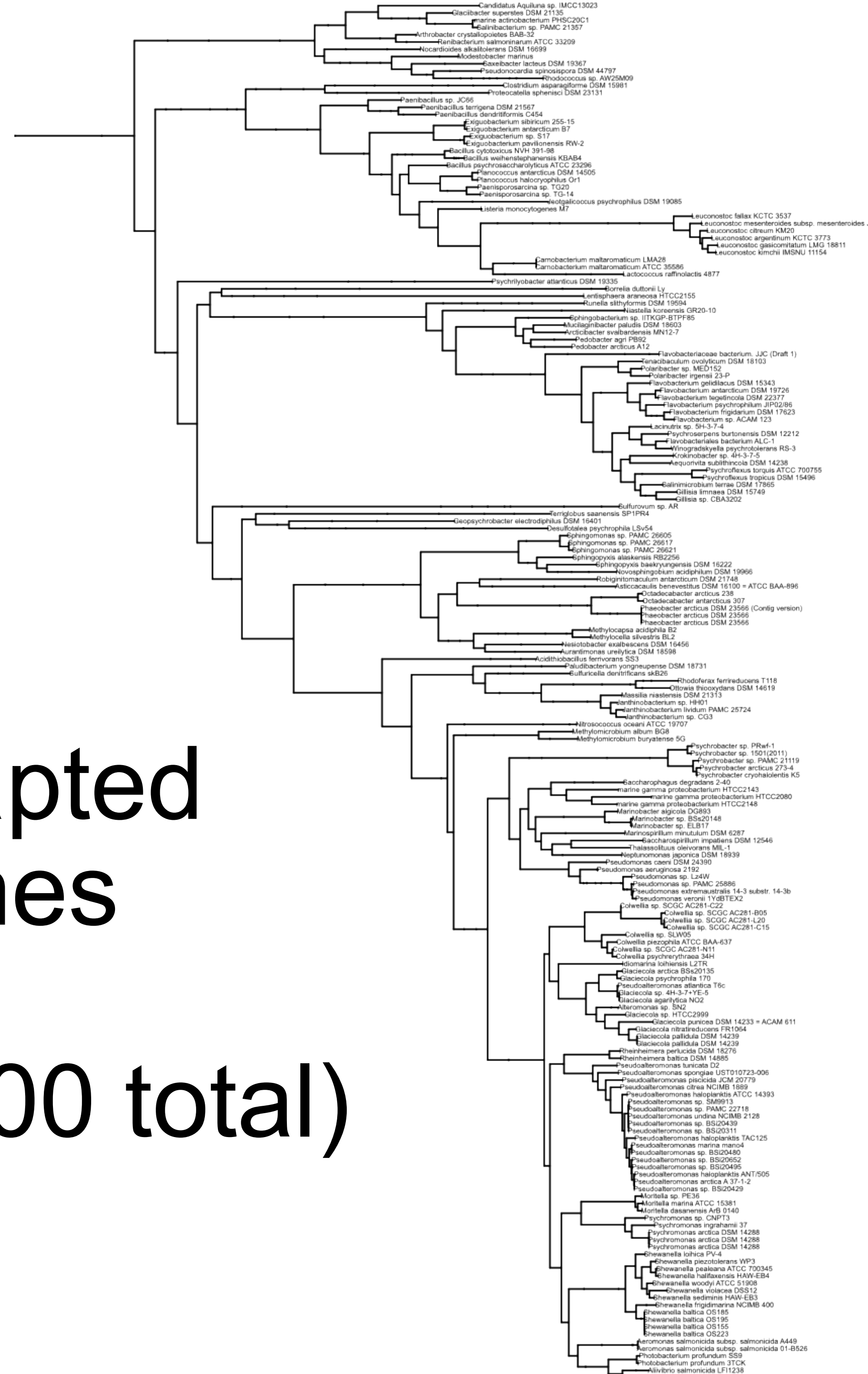




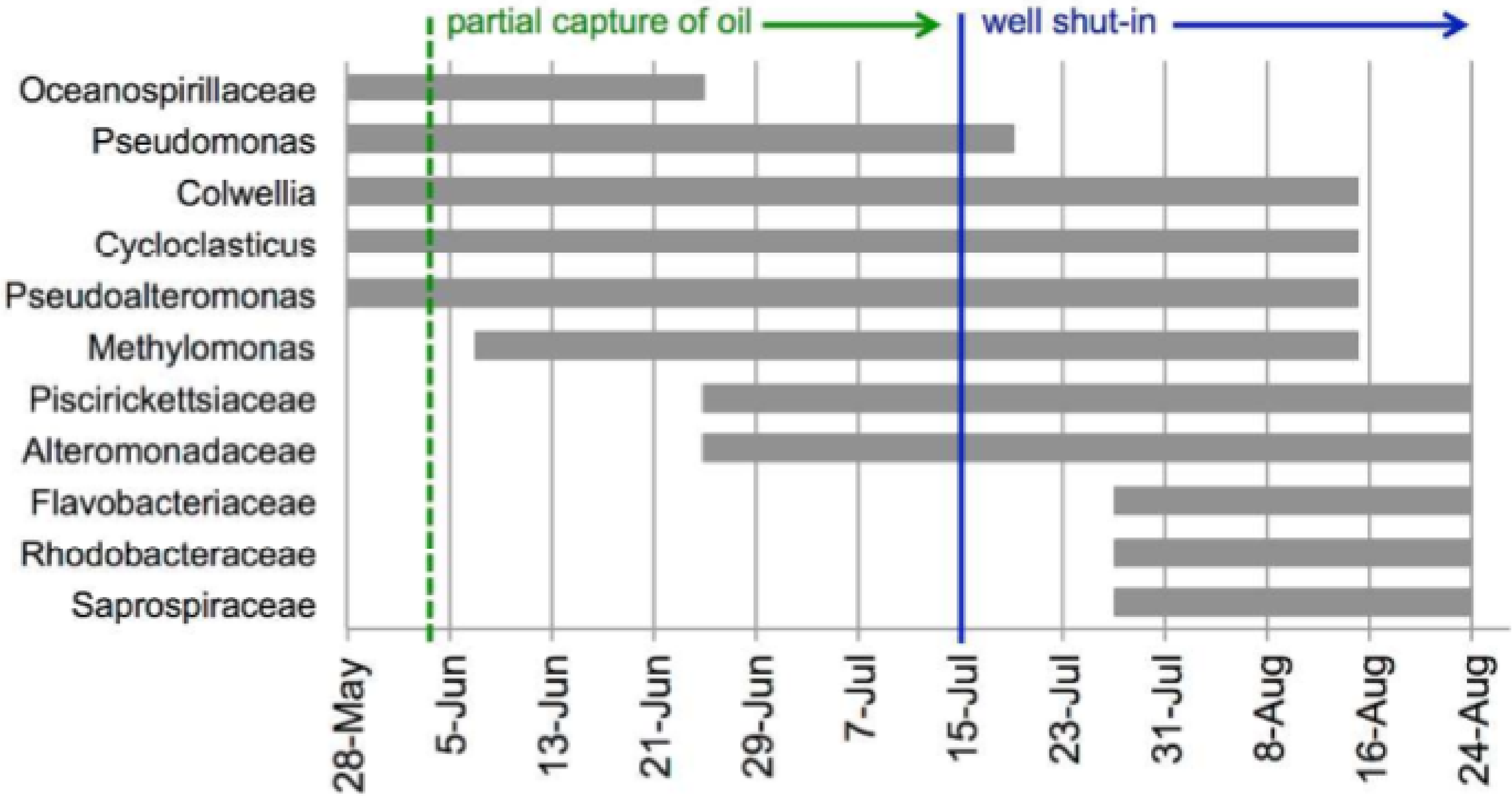
Microbial Loop =
Biodegradation

200
cold-adapted
genomes

(out of 20,000 total)

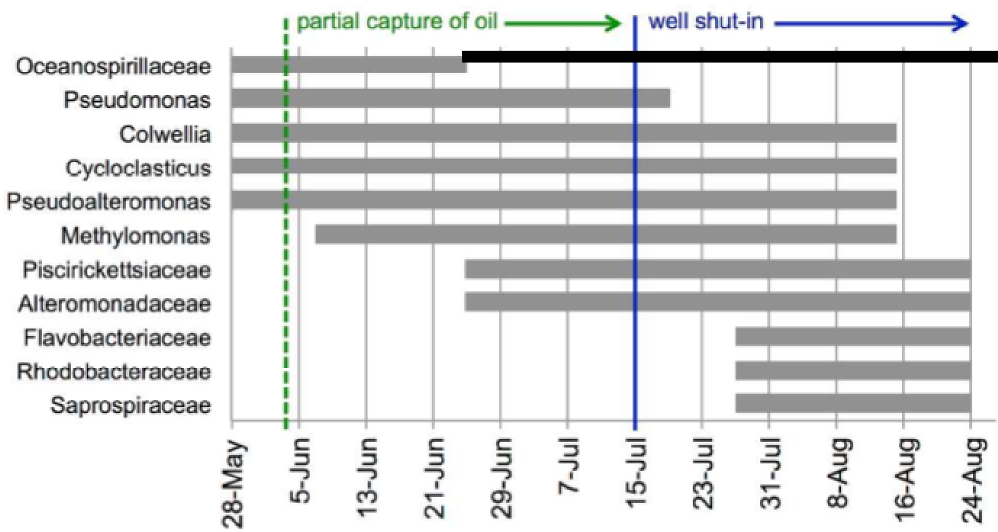


Deepwater Horizon Succession

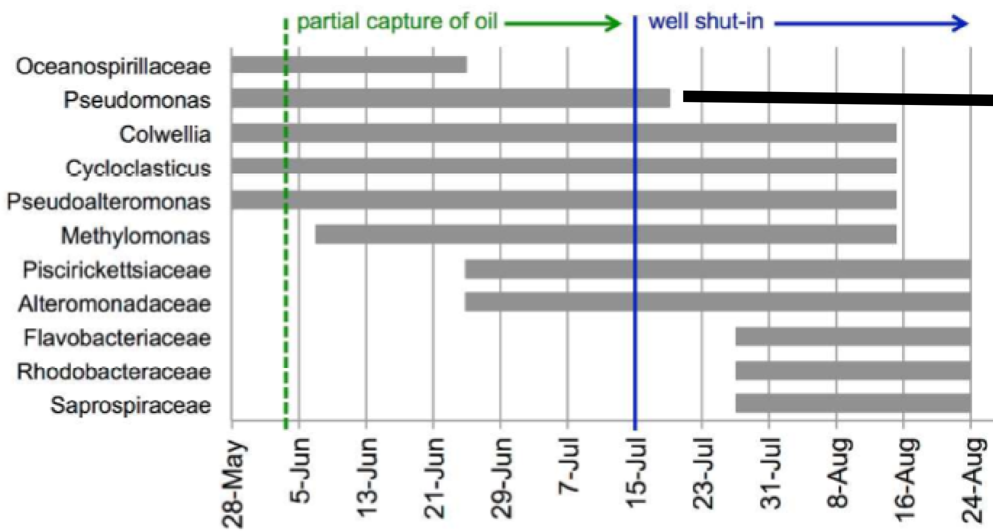


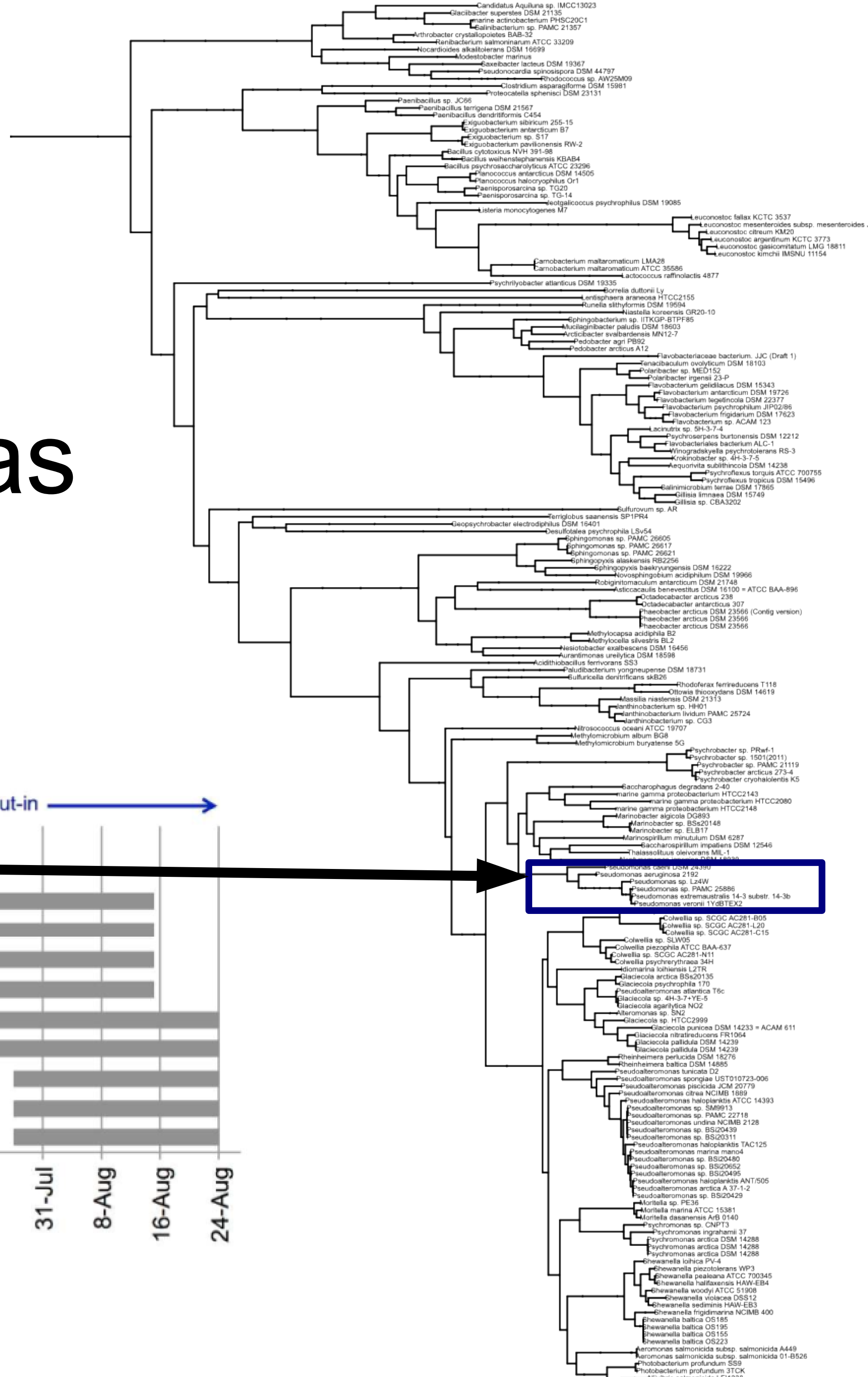
Dubinsky et al. (2013)

Oceanospirillales

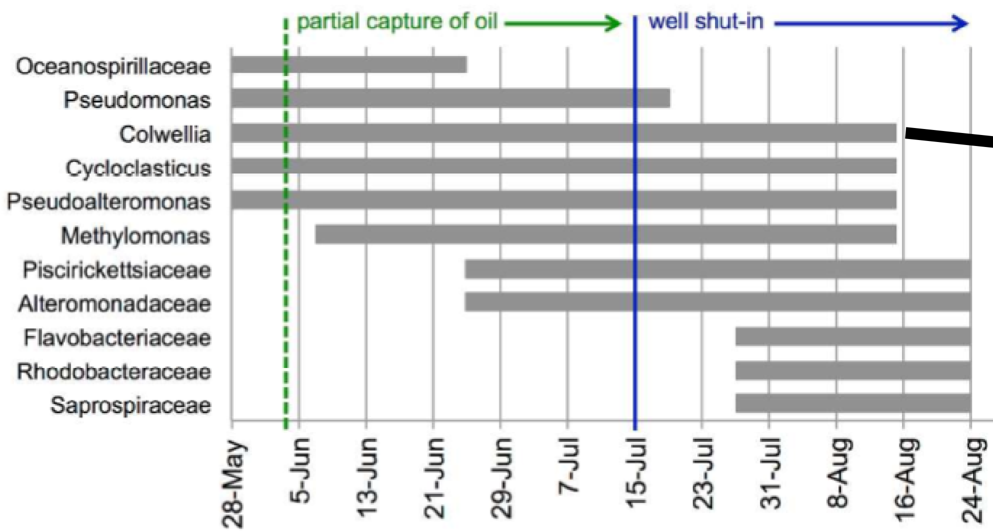


Pseudomonas

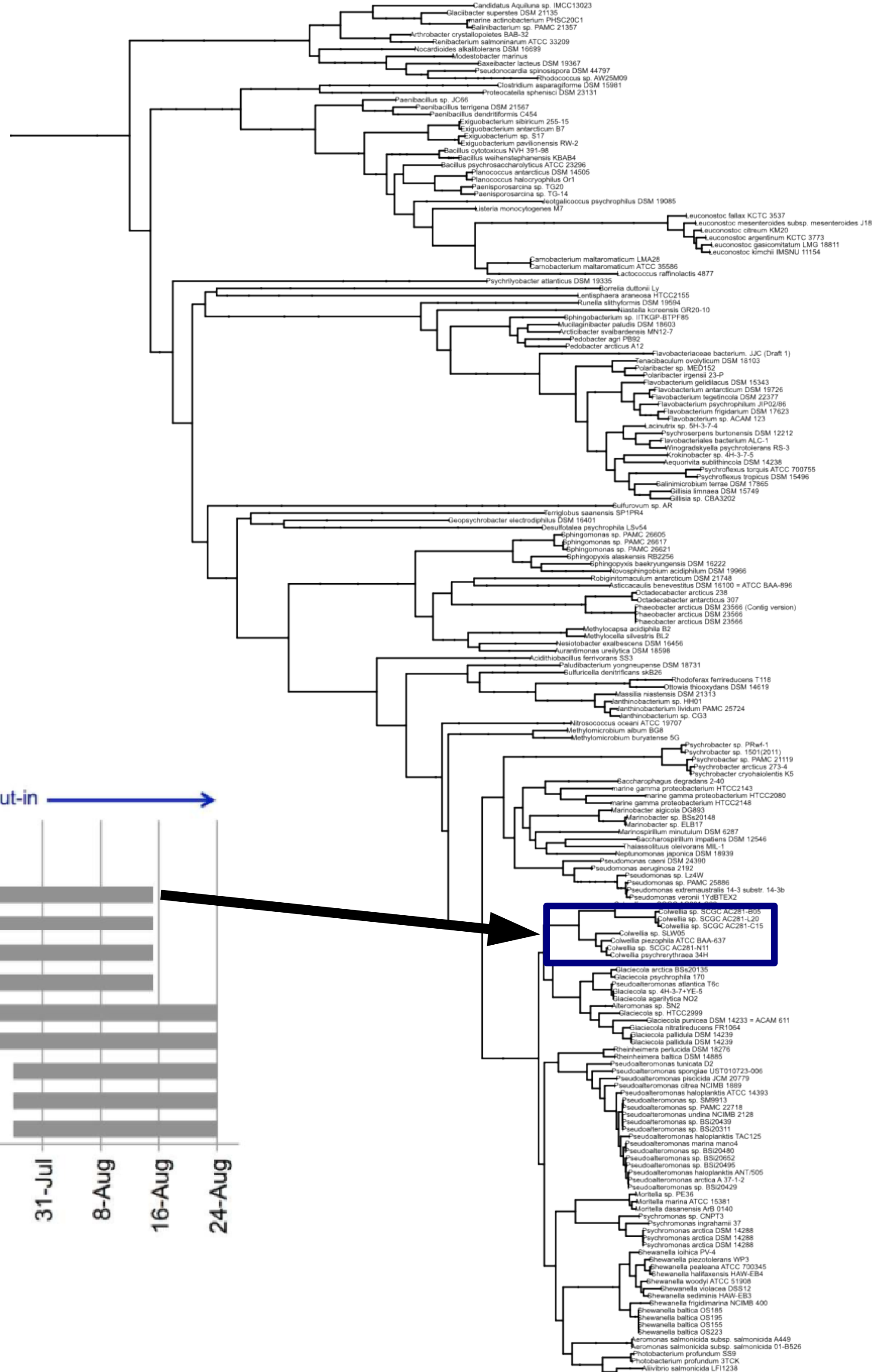




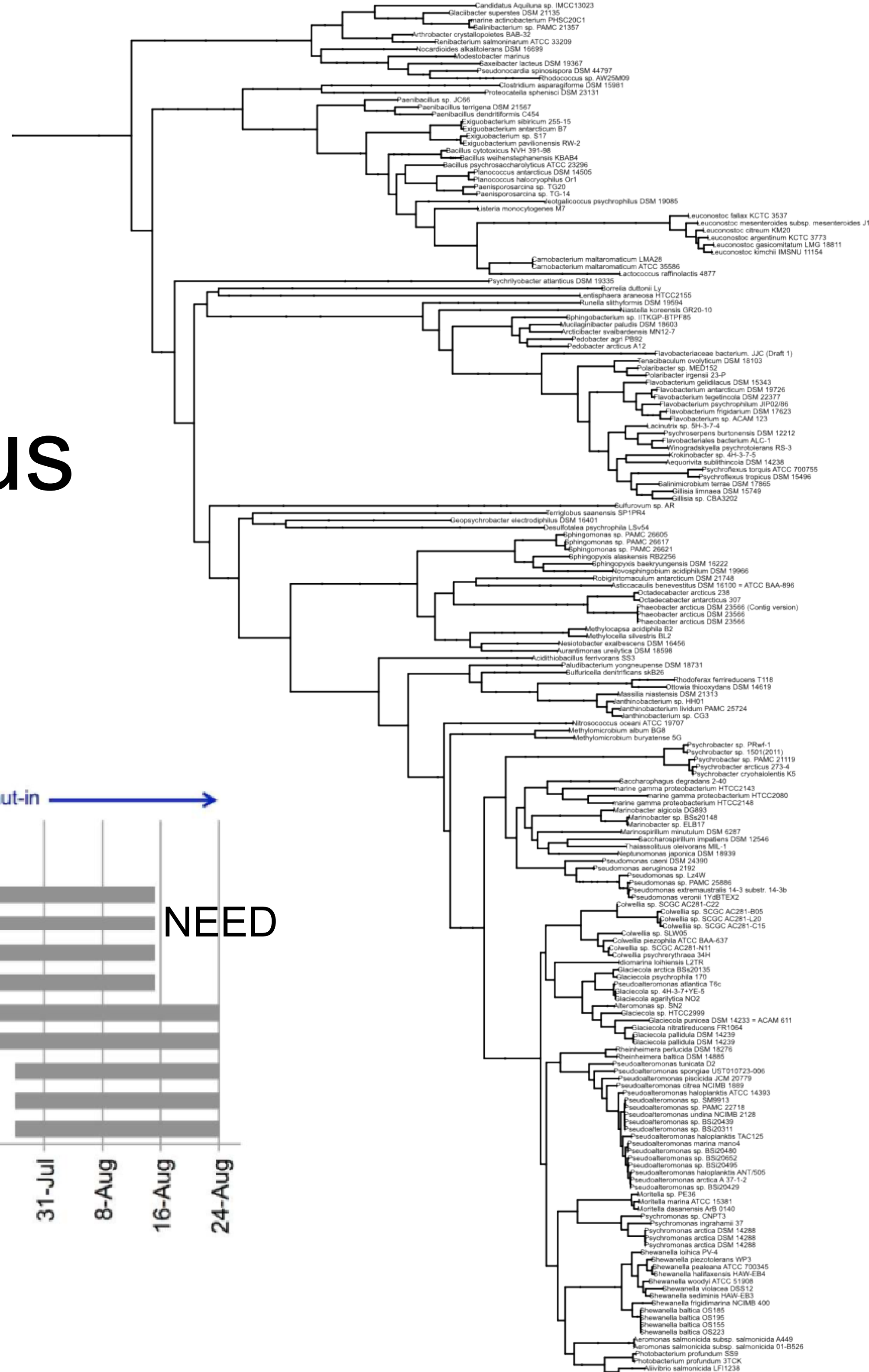
Colwellia

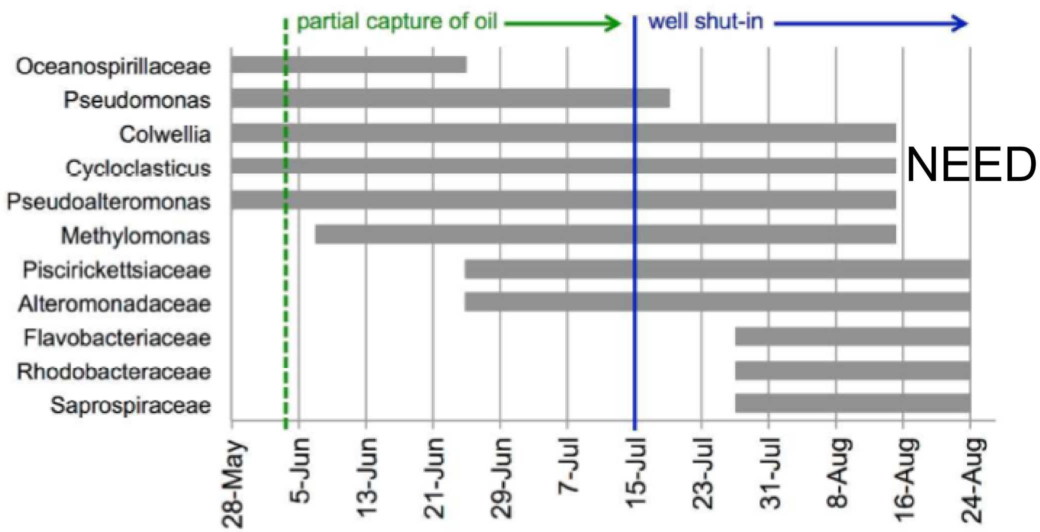


partial capture of oil
well shut-in
Oceanospirillaceae
Pseudomonas
Colwellia
Cycloclasticus
Pseudoalteromonas
Methylomonas
Piscirickettsiaceae
Alteromonadaceae
Flavobacteriaceae
Rhodobacteraceae
Saprospiraceae
28-May
5-Jun
13-Jun
21-Jun
29-Jun
7-Jul
15-Jul
23-Jul
31-Jul
8-Aug
16-Aug
24-Aug

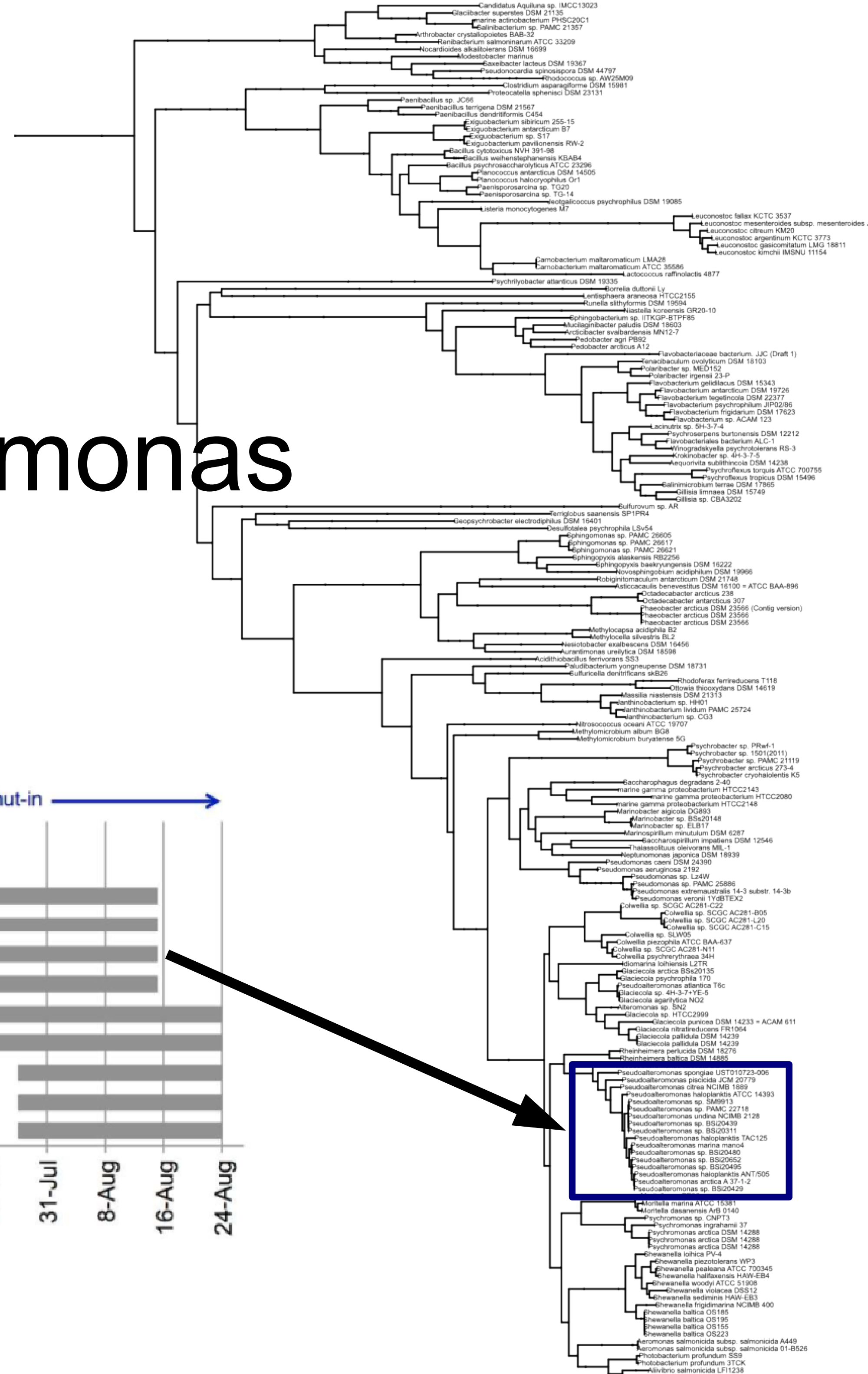


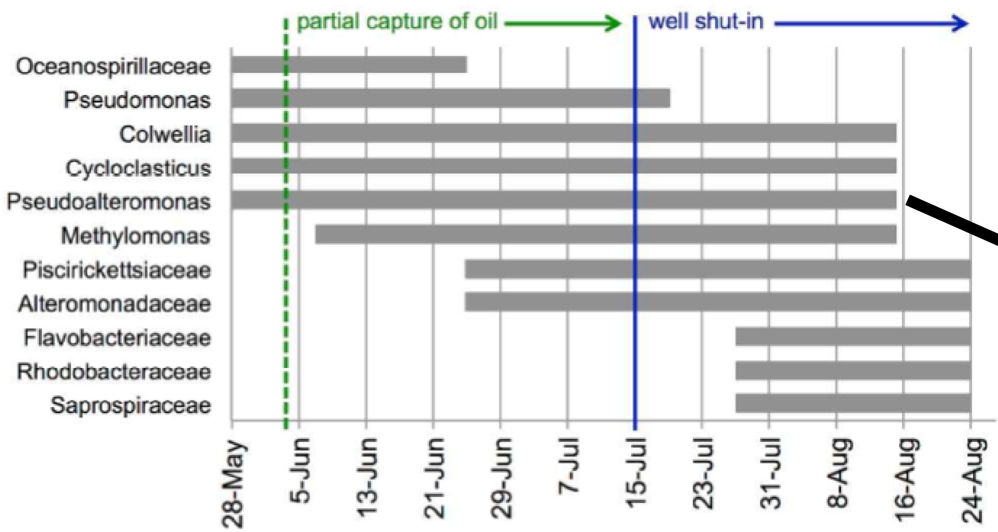
Cycloclasticus



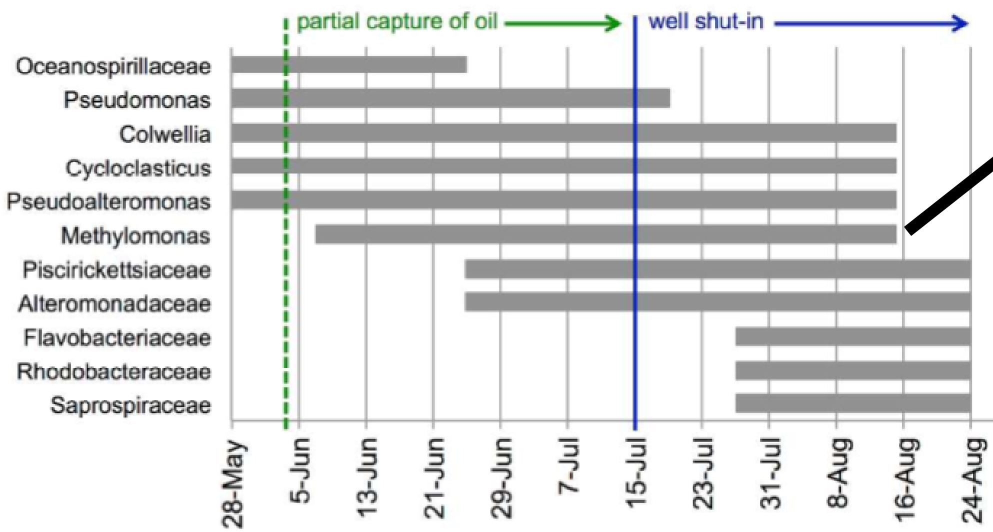


Pseudoalteromonas

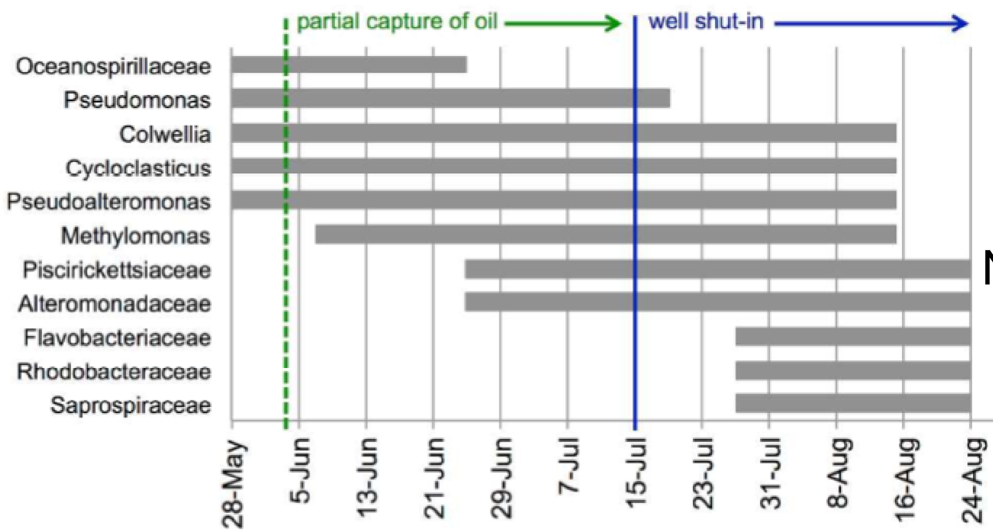




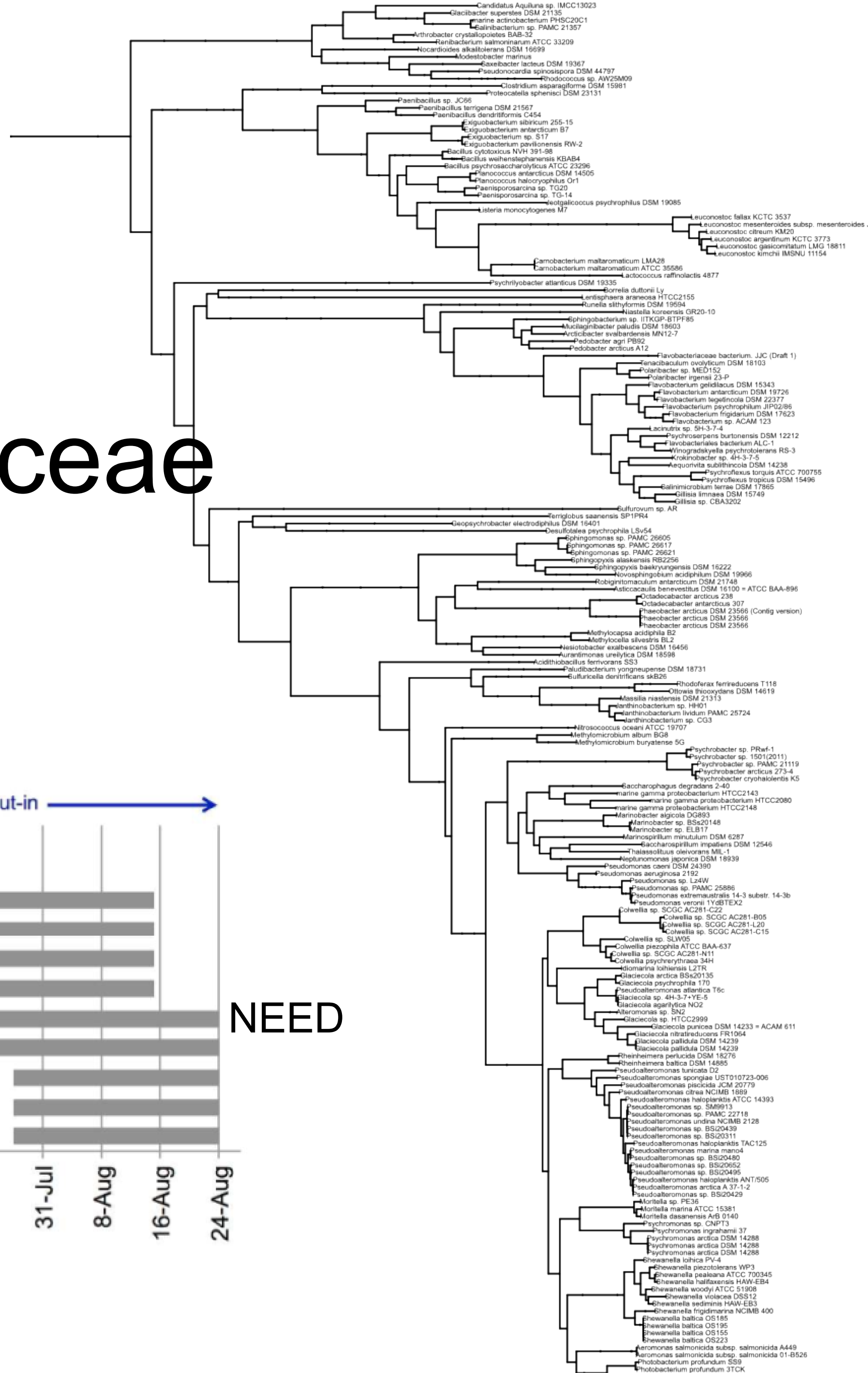
Methylomonas



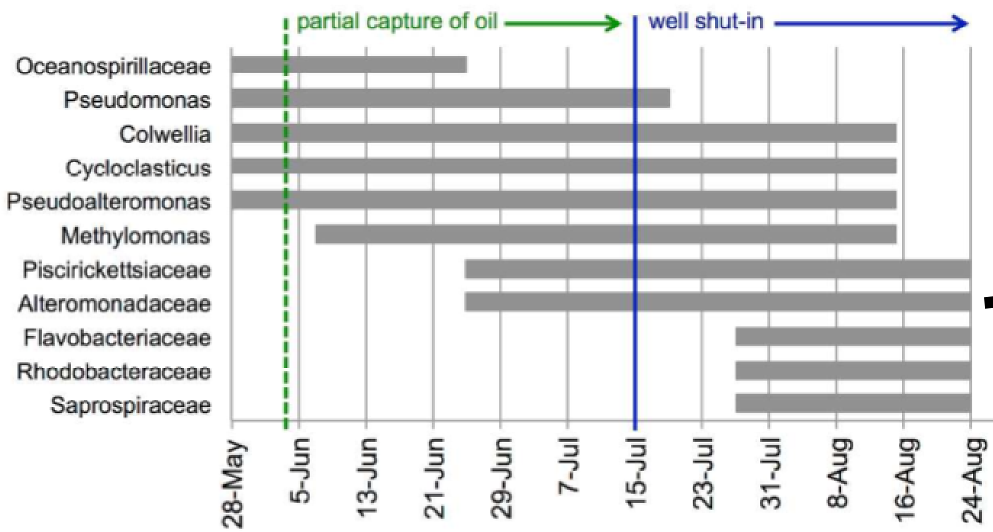
Piscirickettsiaceae



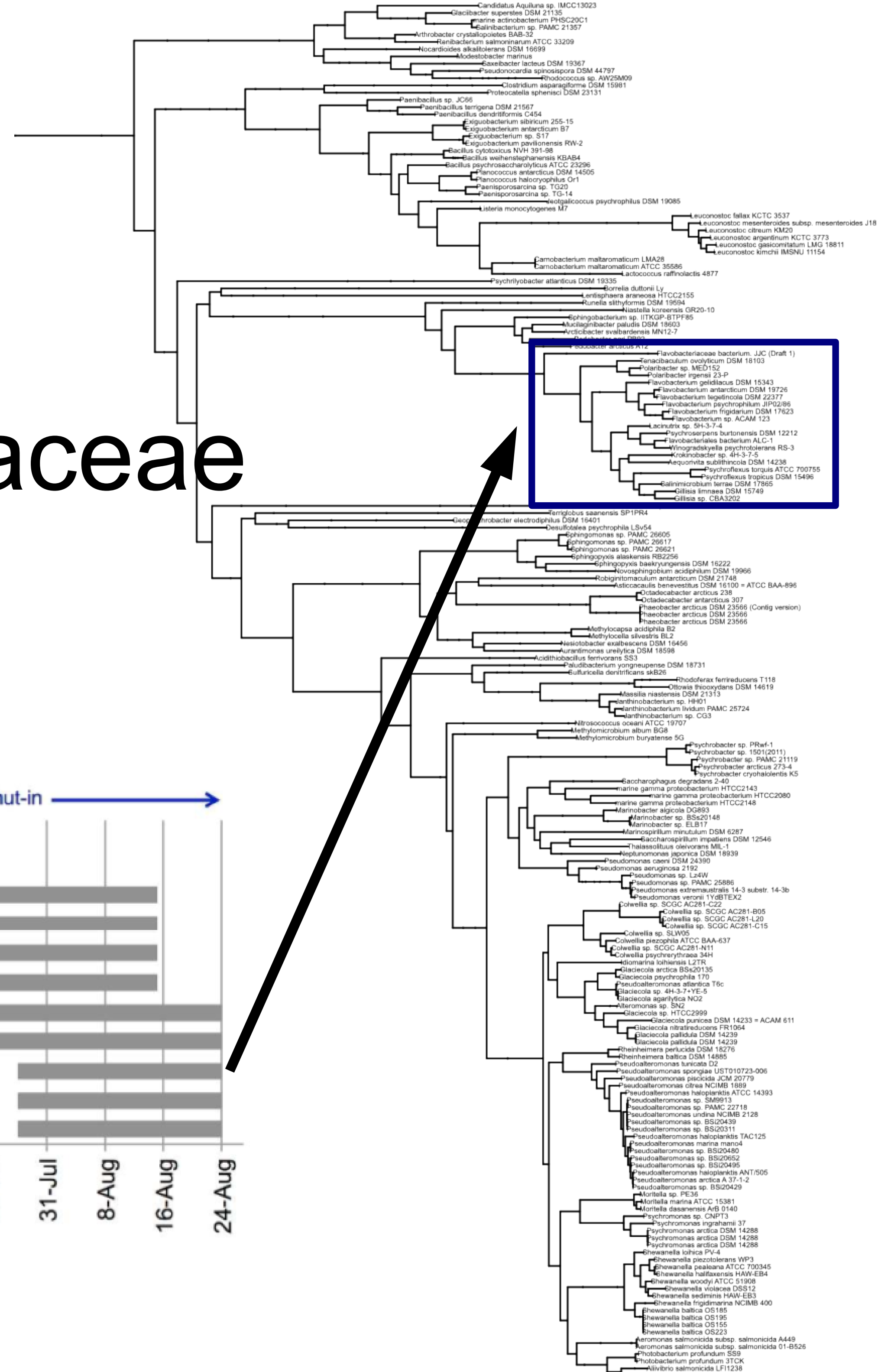
NEED

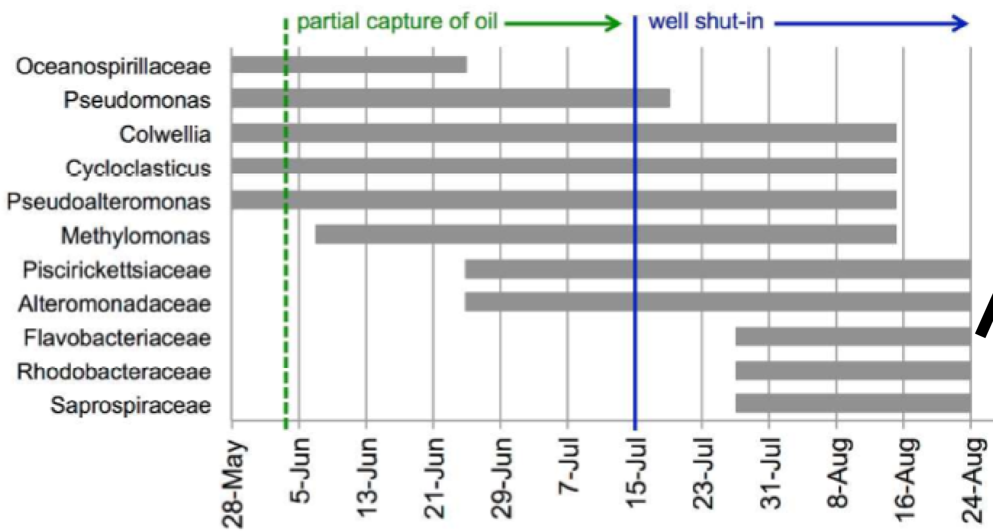


Alteromonadaceae

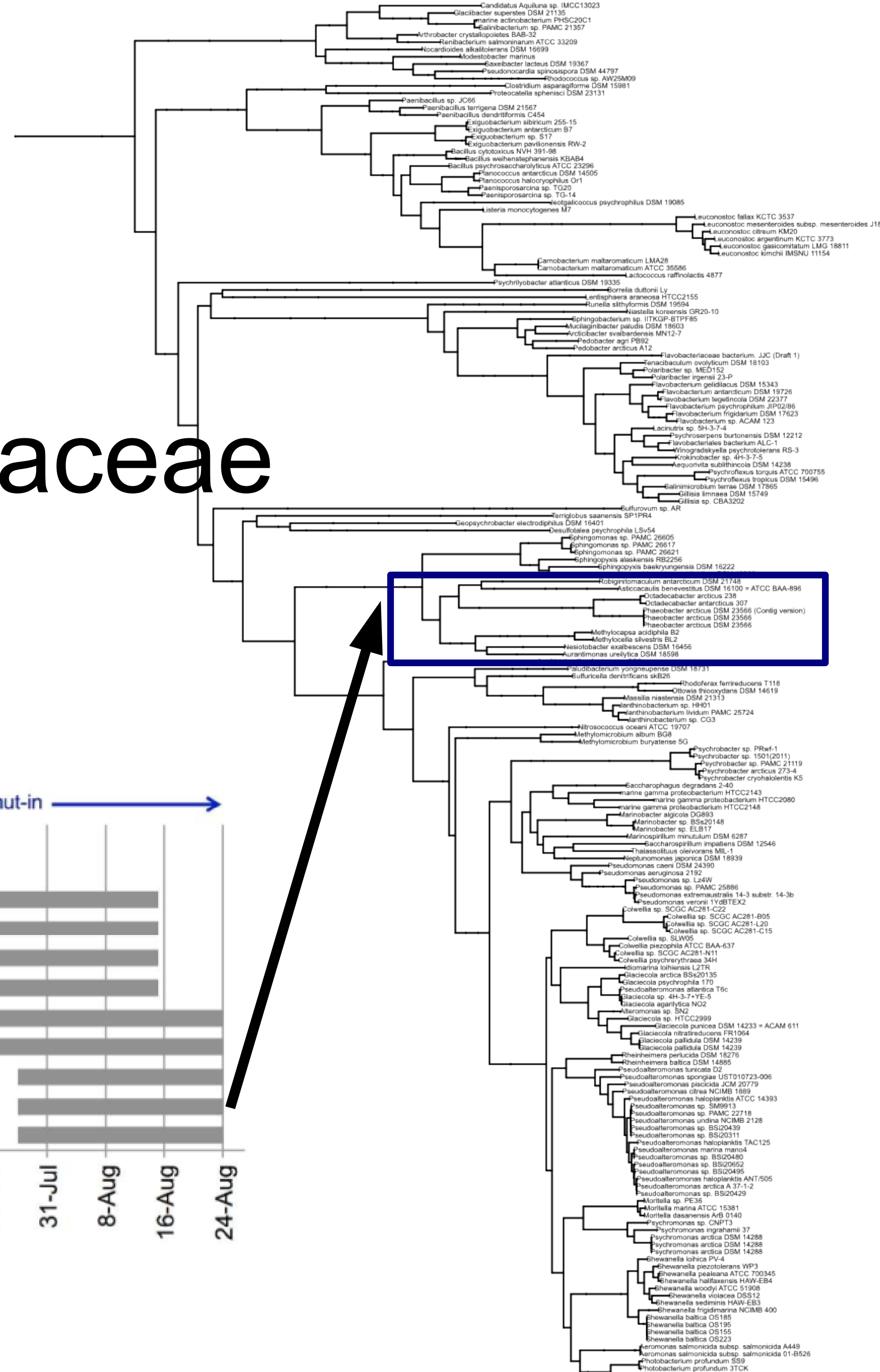


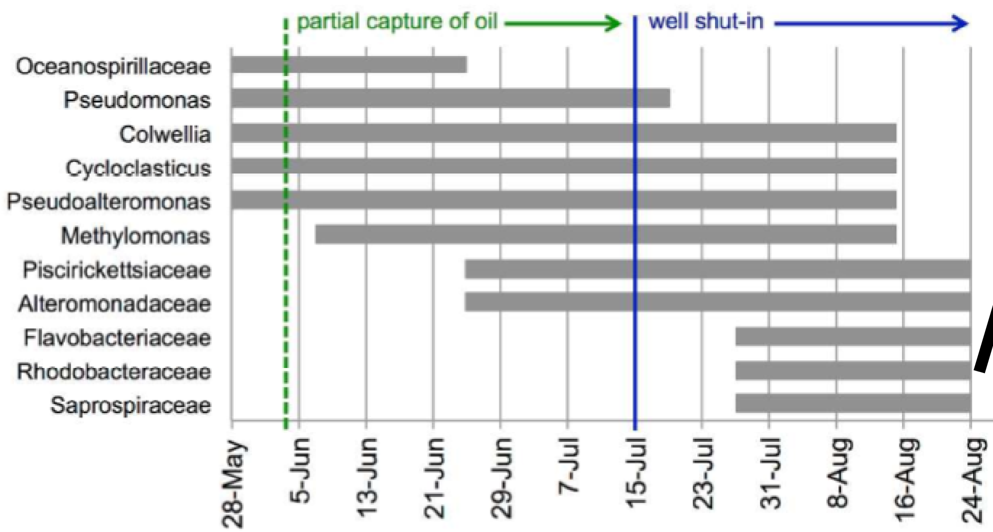
Flavobacteraceae



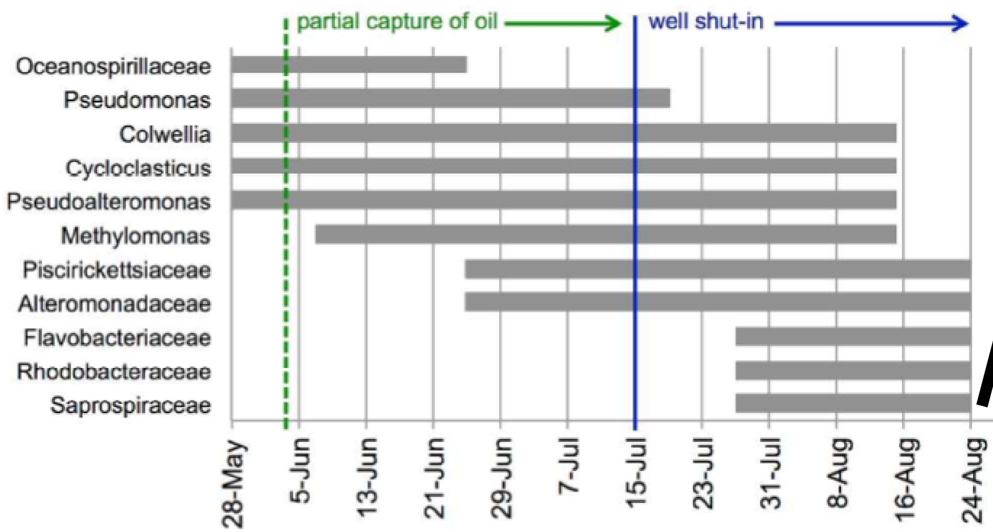


Rhodobacteraceae



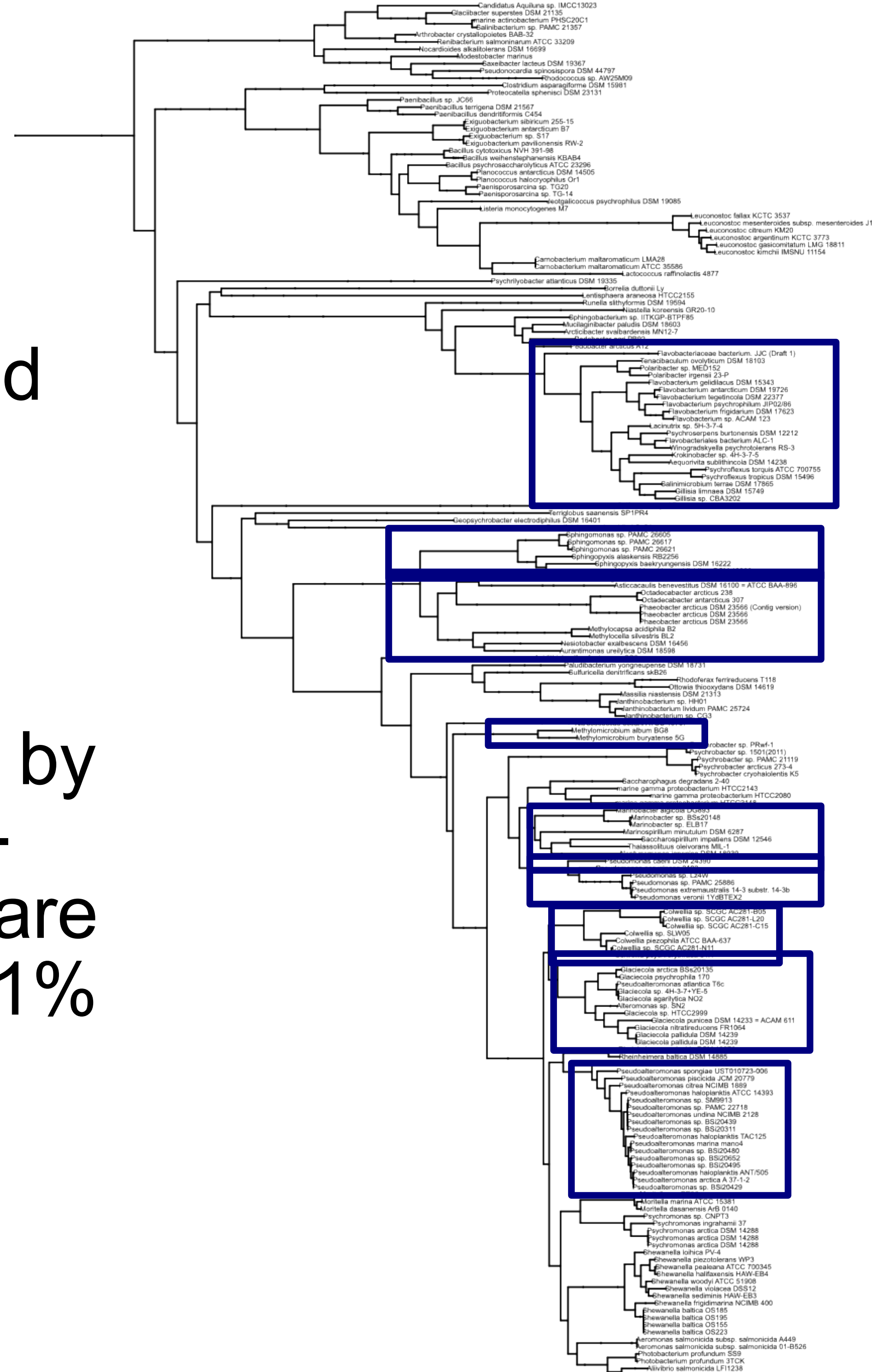


Saprospiraceae

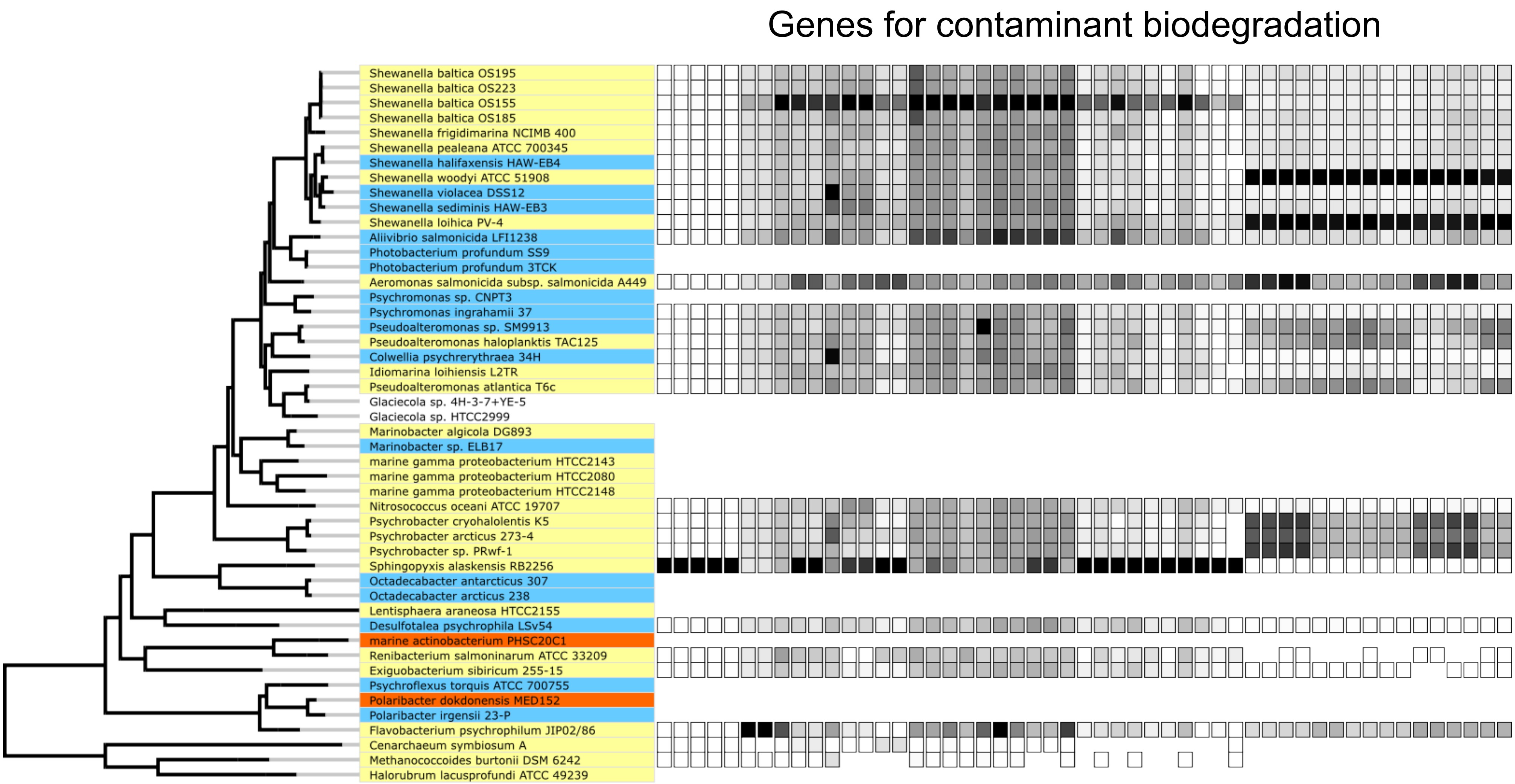


Most cold-adapted species are in oil-degrading groups

Cold ocean is 90% by volume but cold-adapted genomes are only **200/20,000** = 1%



Psychrophile Genome Biodegradation Potential



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