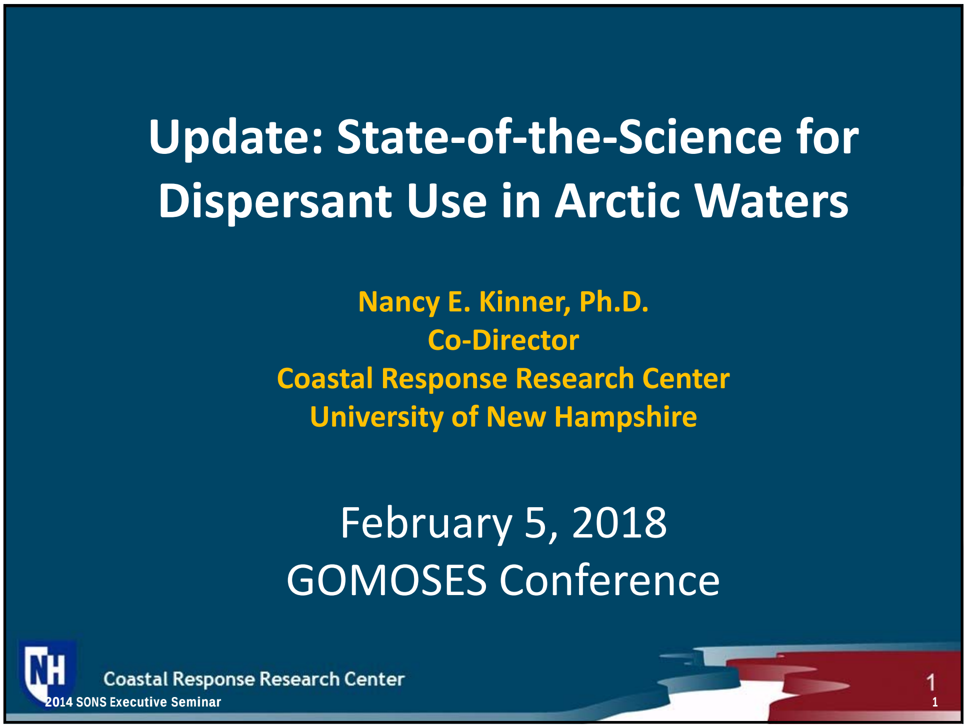
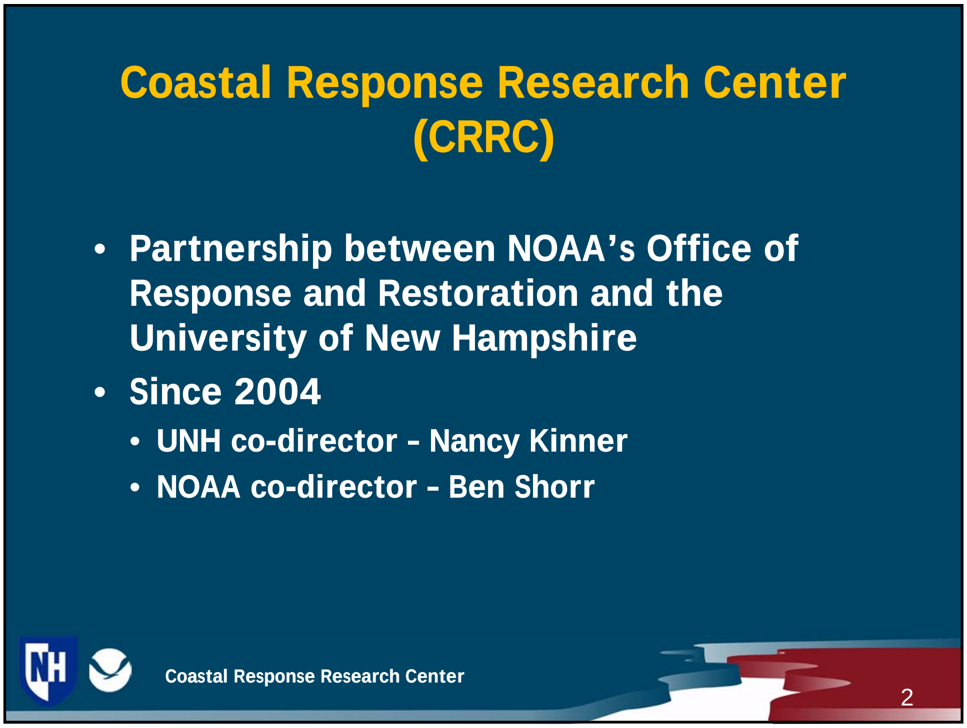


Update: State-of-the-Science for Dispersant Use in Arctic Waters

Nancy E. Kinner, Ph.D.
Co-Director
Coastal Response Research Center
University of New Hampshire

February 5, 2018
GOMOSES Conference



Coastal Response Research Center (CRRC)

- **Partnership between NOAA’s Office of Response and Restoration and the University of New Hampshire**
- **Since 2004**
  - **UNH co-director - Nancy Kinner**
  - **NOAA co-director - Ben Shorr**

Coastal Response Research Center

- Conduct and Oversee **Basic** and **Applied** Research and Outreach on Spill Response and Restoration
- Transform Research **Results into Practice**
- Serve as **Hub for Oil & Environmental Spill R&D**
  - ALL Stakeholders: Federal, State, NGOs, Academia, Industry
- **Facilitate Collaboration** on R&D Among Stakeholders
- Application to All Hazards

NOVEMBER 20, 2014

2014 SONS Executive Seminar

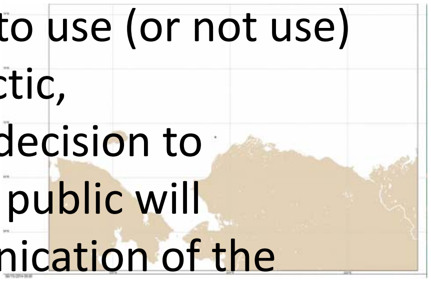
USCG Headquarters
St. Elizabeth’s Campus
Washington, DC

SONS
SPILL OF NATIONAL SIGNIFICANCE

2013 Lesson Learned

2013 Late Summer Scenario

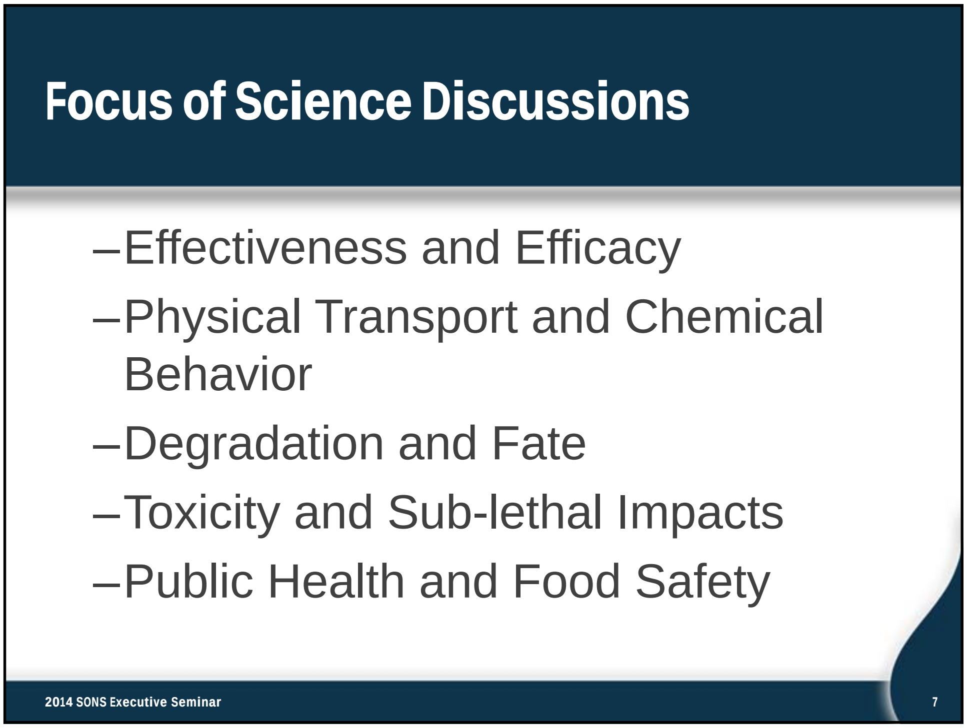
2014 Late Summer Scenario



If a decision is made to use (or not use) dispersants in the Arctic, communicating that decision to stakeholders and the public will require clear communication of the science contributing to that decision.

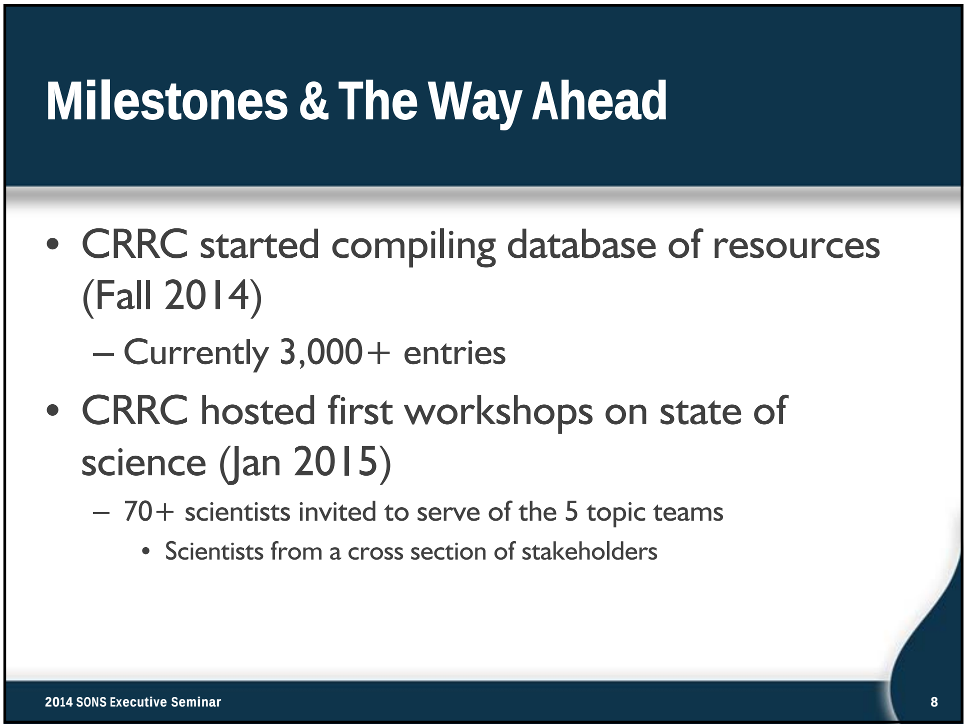
Corrective Action

- Develop Summary of the State of Dispersant Science
  1) What we know
  2) What we don’t know
  3) Key issues of which senior leadership should be aware
- Provide Recommendations on Outreach and Educational Materials
- Collaborate with ongoing efforts in Alaska



Focus of Science Discussions

- Effectiveness and Efficacy
- Physical Transport and Chemical Behavior
- Degradation and Fate
- Toxicity and Sub-lethal Impacts
- Public Health and Food Safety



Milestones & The Way Ahead

- CRRC started compiling database of resources (Fall 2014)
  - Currently 3,000+ entries
- CRRC hosted first workshops on state of science (Jan 2015)
  - 70+ scientists invited to serve of the 5 topic teams
    - Scientists from a cross section of stakeholders

Each Participant's Assignment

- 3-5 Knowns about topic supported by literature
- 3-5 Uncertainties about topic supported by literature

Each Group’s Starting Document

Degradation and Fate

The following points were submitted by workshop participants at the request of organizers to provide starting points for discussion. These statements are not necessarily supported by all workshop participants or sponsoring organizations and should not be attributed to individual participants or organizations.

Points that you believe are known about the degradation and fate of dispersants and dispersed oil that can be supported in the scientific literature.

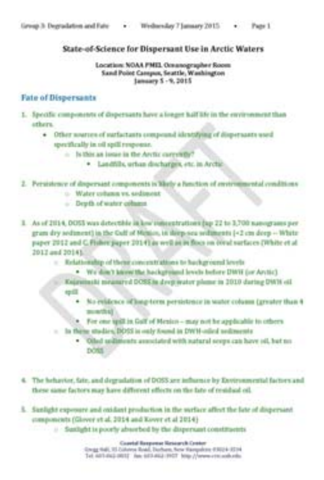
Fate of Dispersants

- Persistence of dispersants in the Gulf of Mexico region.
- DOSS persisted in the Gulf of Mexico following application to the DWH oil spill, in the oil/gas plume and in deep-sea sediments (<2 cm deep) as well as in flocs on coral surfaces.
- Background water matrix (ocean/fresh) affects the fate of dispersant via generation of reactive oxygen species.
- Hydroxyl radical is a major contributor to decay of Corexit constituents.
- Direct photolysis of chemical species is limited by molar absorbance and low quantum yields.

Droplet Size Impact on Degradation

- All water bodies contain naturally occurring microbes which feed on and breakdown hydrocarbons, and dispersants aid the microbial degradation by increasing the oil's surface area, and thereby making it more readily available to microbial degradations.

Final Workshop Document



Group 3: Degradation and Fate • Wednesday 7 January 2015 • Page 1

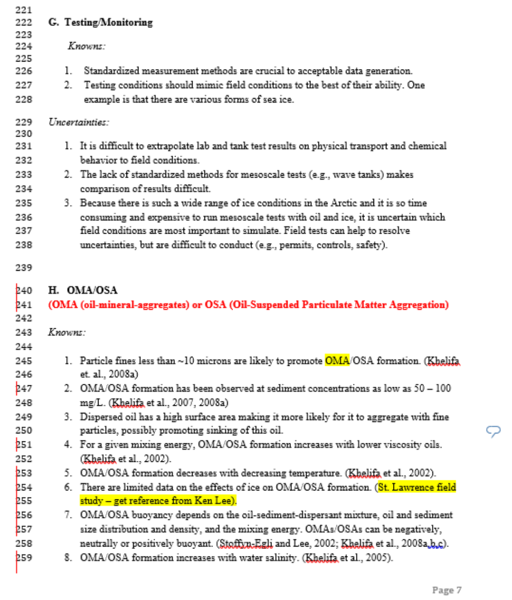
State-of-Science for Dispersant Use in Arctic Waters

Location: NOAA PMEL Oceanographer Room
Sand Point Campus, Seattle, Washington
January 5 - 9, 2015

Fate of Dispersants

1. Specific components of dispersants have a longer half life in the environment than others.
   - Other sources of surfactants compound identifying of dispersants used specifically in oil spill response.
     - Is this an issue in the Arctic currently?
       - Landfills, urban discharges, etc. in Arctic
2. Persistence of dispersant components is likely a function of environmental conditions
     - Water column vs. sediment
     - Depth of water column
3. As of 2014, DOSS was detectible in low concentrations (up 22 to 3,700 nanograms per gram dry sediment) in the Gulf of Mexico, in deep-sea sediments (<2 cm deep – White paper 2012 and C. Fisher paper 2014) as well as in flocs on coral surfaces (White et al 2012 and 2014).
     - Relationship of these concentrations to background levels
       - We don't know the background levels before DWH (or Arctic)
     - Kujawinski measured DOSS in deep water plume in 2010 during DWH oil spill
       - No evidence of long-term persistence in water column (greater than 4 months)
       - For one spill in Gulf of Mexico – may not be applicable to others
     - In these studies, DOSS is only found in DWH-oiled sediments
       - Oiled sediments associated with natural seeps can have oil, but no DOSS
4. The behavior, fate, and degradation of DOSS are influence by Environmental factors and these same factors may have different effects on the fate of residual oil.
5. Sunlight exposure and oxidant production in the surface affect the fate of dispersant components (Glover et al. 2014 and Kover et al 2014)
     - Sunlight is poorly absorbed by the dispersant constituents

Coastal Response Research Center



G. Testing/Monitoring

Knowns:

1. Standardized measurement methods are crucial to acceptable data generation.
2. Testing conditions should mimic field conditions to the best of their ability. One example is that there are various forms of sea ice.

Uncertainties:

1. It is difficult to extrapolate lab and tank test results on physical transport and chemical behavior to field conditions.
2. The lack of standardized methods for mesoscale tests (e.g., wave tanks) makes comparison of results difficult.
3. Because there is such a wide range of ice conditions in the Arctic and it is so time consuming and expensive to run mesoscale tests with oil and ice, it is uncertain which field conditions are most important to simulate. Field tests can help to resolve uncertainties, but are difficult to conduct (e.g., permits, controls, safety).

H. OMA/OSA

(OMA (oil-mineral-aggregates) or OSA (Oil-Suspended Particulate Matter Aggregation)

Knowns:

1. Particle fines less than ~10 microns are likely to promote OMA/OSA formation. (Khelifa et. al., 2008a)
2. OMA/OSA formation has been observed at sediment concentrations as low as 50 – 100 mg/L. (Khelifa et al., 2007, 2008a)
3. Dispersed oil has a high surface area making it more likely for it to aggregate with fine particles, possibly promoting sinking of this oil.
4. For a given mixing energy, OMA/OSA formation increases with lower viscosity oils. (Khelifa et al., 2002).
5. OMA/OSA formation decreases with decreasing temperature. (Khelifa et al., 2002).
6. There are limited data on the effects of ice on OMA/OSA formation. (St. Lawrence field study – get reference from Ken Lee).
7. OMA/OSA buoyancy depends on the oil-sediment-dispersant mixture, oil and sediment size distribution and density, and the mixing energy. OMAs/OSAs can be negatively, neutrally or positively buoyant. (Stoffyn-Egli and Lee, 2002; Khelifa et al., 2008a,b,c).
8. OMA/OSA formation increases with water salinity. (Khelifa et al., 2005).

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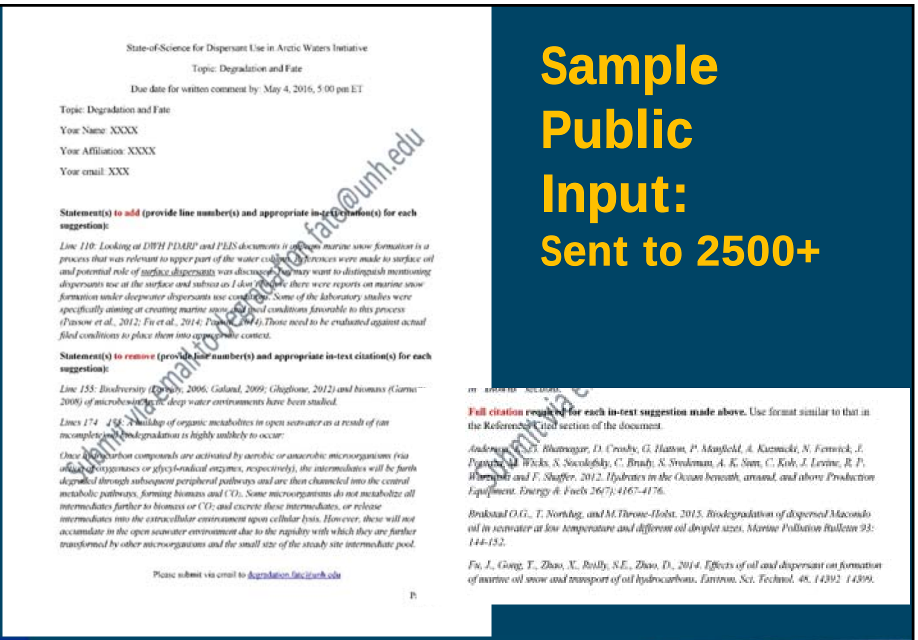
Each group had > 40 hours of conference calls of discussion subsequent to initial workshop



State-of-Science for Dispersant Use in Arctic Waters Initiative

Topic: Degradation and Fate

Due date for written comment by: May 4, 2016, 5:00 pm ET

Topic: Degradation and Fate

Your Name: XXXX

Your Affiliation: XXXX

Your email: XXX

Statement(s) to add (provide line number(s) and appropriate in-text citation(s) for each suggestion):

Line 110: Looking at DWH PDARP and PEIS documents it [illegible] marine snow formation is a process that was relevant to upper part of the water column. References were made to surface oil and potential role of surface dispersants was discussed. You may want to distinguish mentioning dispersants use at the surface and subsea as I don't [illegible] there were reports on marine snow formation under deepwater dispersants use conditions. Some of the laboratory studies were specifically aiming at creating marine snow and used conditions favorable to this process (Passow et al., 2012; Fu et al., 2014; Passow, 2014).Those need to be evaluated against actual filed conditions to place them into appropriate context.

Statement(s) to remove (provide line number(s) and appropriate in-text citation(s) for each suggestion):

Line 155: Biodiversity ([illegible], 2006; Galand, 2009; Ghiglione, 2012) and biomass (Garn 2008) of microbes in Arctic deep water environments have been studied.

Lines 174 – 175: A buildup of organic metabolites in open seawater as a result of (an incomplete) [illegible] biodegradation is highly unlikely to occur:

Once hydrocarbon compounds are activated by aerobic or anaerobic microorganisms (via action of oxygenases or glycyl-radical enzymes, respectively), the intermediates will be furth degraded through subsequent peripheral pathways and are then channeled into the central metabolic pathways, forming biomass and CO₂. Some microorganisms do not metabolize all intermediates further to biomass or CO₂ and excrete these intermediates, or release intermediates into the extracellular environment upon cellular lysis. However, these will not accumulate in the open seawater environment due to the rapidity with which they are further transformed by other microorganisms and the small size of the steady site intermediate pool.

Please submit via email to degradation.fate@unh.edu

Full citation required for each in-text suggestion made above. Use format similar to that in the References Cited section of the document.

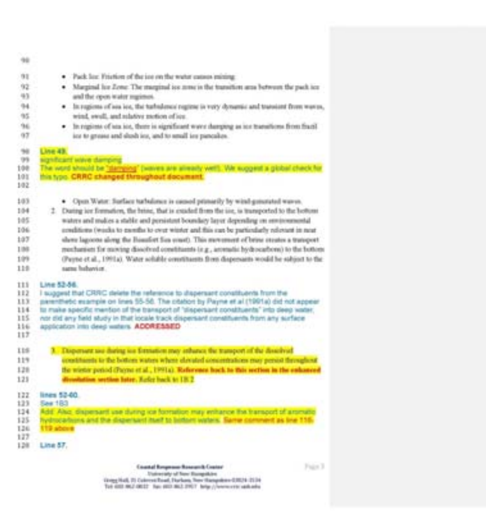
Anderson, K., G. Bhatnagar, D. Crosby, G. Hatton, P. Manfield, A. Kuzmicki, N. Fenwick, J. Pontaza, M. Wicks, S. Socolofsky, C. Brady, S. Svedeman, A. K. Sum, C. Koh, J. Levine, R. P. Warzinski and F. Shaffer. 2012. Hydrates in the Ocean beneath, around, and above Production Equipment. Energy & Fuels 26(7):4167-4176.

Brakstad O.G., T. Nordtug, and M.Throne-Holst. 2015. Biodegradation of dispersed Macondo oil in seawater at low temperature and different oil droplet sizes. Marine Pollution Bulletin 93: 144-152.

Fu, J., Gong, Y., Zhao, X., Reilly, S.E., Zhao, D., 2014. Effects of oil and dispersant on formation of marine oil snow and transport of oil hydrocarbons. Environ. Sci. Technol. 48, 14392–14399.

Sample Public Input:

Sent to 2500+



- Pack Ice: Friction of the ice on the water causes mixing.
- Marginal Ice Zone: The marginal ice zone is the transition area between the pack ice and the open water regimes.
- In regions of sea ice, the turbulence regime is very dynamic and transient from waves, wind, swell, and relative motion of ice.
- In regions of sea ice, there is significant wave damping as ice transitions from frazil ice to grease and slush ice, and to small ice pancakes.

Line 49.
significant wave damping
The word should be "damping" (waves are already wet). We suggest a global check for this typo. **CRRC changed throughout document.**

- Open Water: Surface turbulence is caused primarily by wind-generated waves.

2. During ice formation, the brine, that is exuded from the ice, is transported to the bottom waters and makes a stable and persistent boundary layer depending on environmental conditions (weeks to months to over winter and this can be particularly relevant in near shore lagoons along the Beaufort Sea coast). This movement of brine creates a transport mechanism for moving dissolved constituents (e.g., aromatic hydrocarbons) to the bottom (Payne et al., 1991a). Water soluble constituents from dispersants would be subject to the same behavior.

Line 52-56.
I suggest that CRRC delete the reference to dispersant constituents from the parenthetic example on lines 55-56. The citation by Payne et al (1991a) did not appear to make specific mention of the transport of "dispersant constituents" into deep water, nor did any field study in that locale track dispersant constituents from any surface application into deep waters. **ADDRESSED**

3. Dispersant use during ice formation may enhance the transport of the dissolved constituents to the bottom waters where elevated concentrations may persist throughout the winter period (Payne et al., 1991a). **Reference back to this section in the enhanced dissolution section later.** Refer back to 18.2

lines 52-60.
See 183
Add: Also, dispersant use during ice formation may enhance the transport of aromatic hydrocarbons and the dispersant itself to bottom waters. Same comment as line 118-119 above

Line 57.

Coastal Response Research Center
University of New Hampshire

Group's Review of Public Input

CRRC Website

The State of the Science for Dispersant Use in Arctic Waters

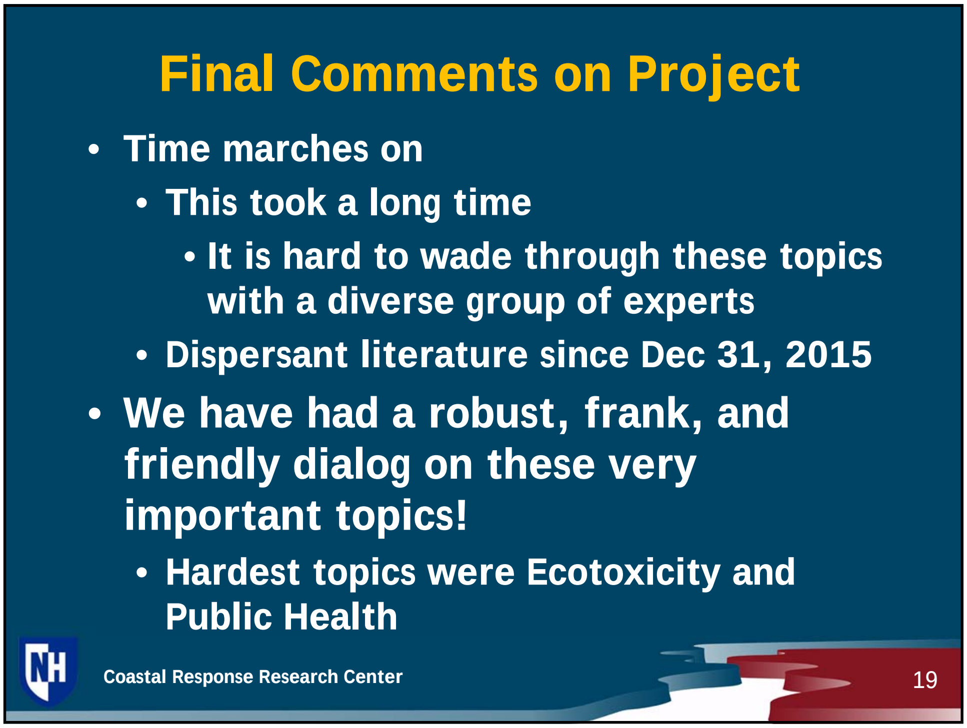
- Process Described
- Literature Databases
  - LUMCON prior to June 2008
  - CRRC after that
- Final Documents for Each Group

Still to Come on Documents

- Final on Ecotoxicity and Sublethal Impacts
- Public Health and Food Safety
  - Finish Draft for Public Release
  - Receive Public Input
  - Panel Reviews Input
  - Panel Finishes Document

Still to Come on Project

- Workshop – communicating the state of science to the public & others
  - Will follow completion of state of science papers
  - Small workshop with scientists and communication experts
  - Recommend types of material that would be most effective for communications to public



Final Comments on Project

- Time marches on
  - This took a long time
    - It is hard to wade through these topics with a diverse group of experts
  - Dispersant literature since Dec 31, 2015
- We have had a robust, frank, and friendly dialog on these very important topics!
  - Hardest topics were Ecotoxicity and Public Health

Final Comments on Project

- **Agreement possible** on the knowns vs. uncertainties among diverse group of scientists
  - **TAKES LOTS OF DISCUSSION!!!!**

Huge Thanks to the Panelists

Their volunteer efforts, patience and commitment is amazing!!!!!

Detailed Overview of Completed Documents:

Efficacy and Effectiveness

Physical Transport and Chemical Behavior

Degradation and Fate

Caveats

- Mostly focused on surface application
- Focus is U.S. Arctic waters
- Conditions considered:
  - Ice free water
  - Ice infested water
  - Full ice cover
- No operations evaluation
- Primarily Corexit 9500/9527 in U.S. and post-DWH research

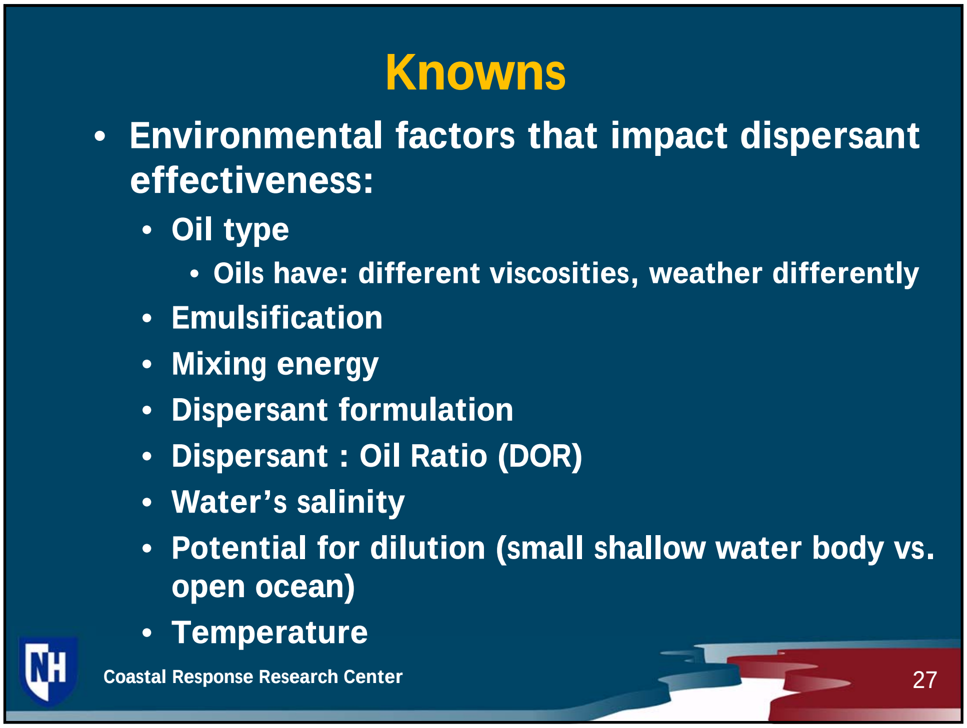
Efficacy and Effectiveness

Efficacy vs. Effectiveness

- **Efficacy = how well dispersants work in ideal/controlled setting (e.g., laboratory trial)**
- **Effectiveness = how well dispersants work under "real-world" conditions**

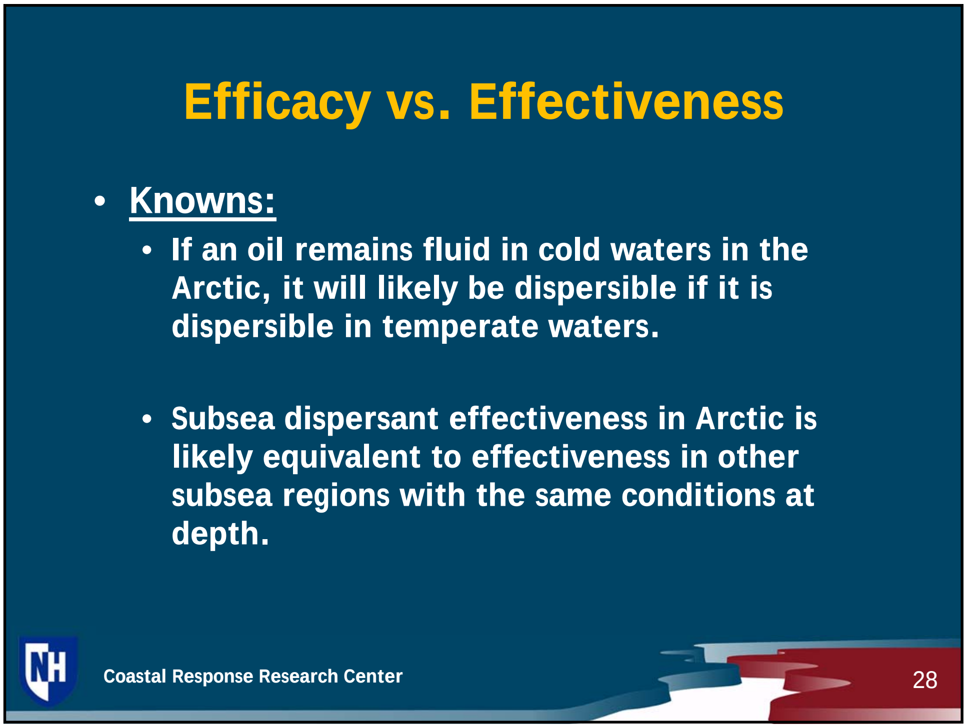
Goals of Dispersant Application

- **Reduce surface slicks**
  - **Break-up into small droplets that enter water column**
    - **Less contact for surface species (e.g., birds, marine mammals, turtles)**
    - **Speed dissolution**
    - **Speed biodegradation**
    - **Reduce oil toxicity by dilution**
  - **For subsea, disperse oil into droplets, so it does not reach surface**



Knowns

- Environmental factors that impact dispersant effectiveness:
  - Oil type
    - Oils have: different viscosities, weather differently
  - Emulsification
  - Mixing energy
  - Dispersant formulation
  - Dispersant : Oil Ratio (DOR)
  - Water’s salinity
  - Potential for dilution (small shallow water body vs. open ocean)
  - Temperature



Efficacy vs. Effectiveness

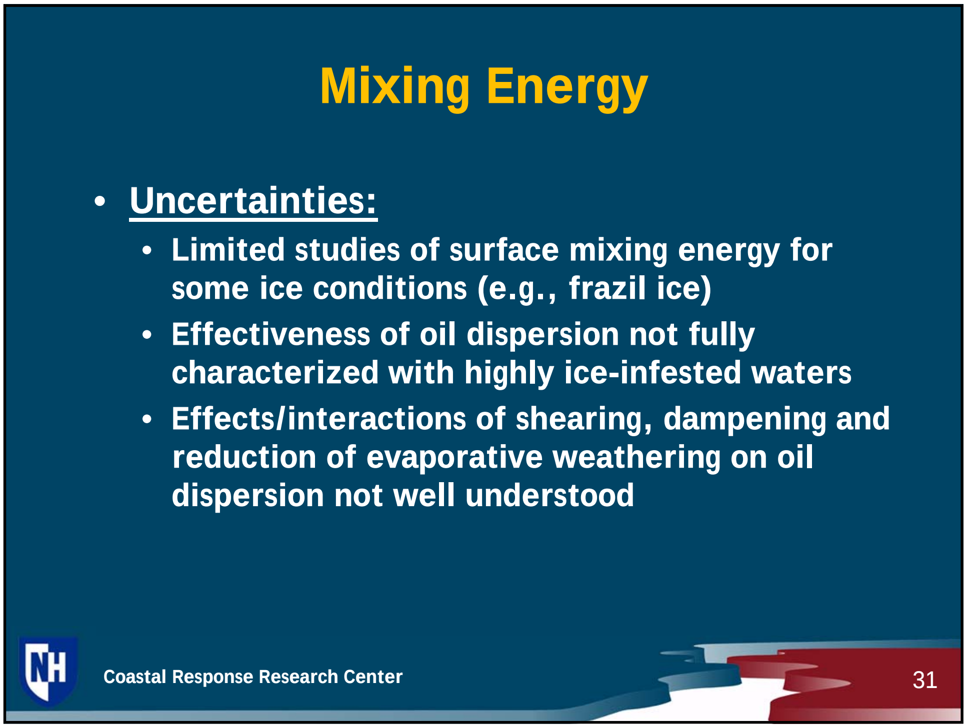
- Knowns:
  - If an oil remains fluid in cold waters in the Arctic, it will likely be dispersible if it is dispersible in temperate waters.
  - Subsea dispersant effectiveness in Arctic is likely equivalent to effectiveness in other subsea regions with the same conditions at depth.

Efficacy vs. Effectiveness

- **Uncertainties:**
  - The environment, oil and water systems are very complex, so applying general rules about dispersibility to the Arctic must be done carefully.
    - Ice is a big complicating factor
  - Dispersibility of higher viscosity oils

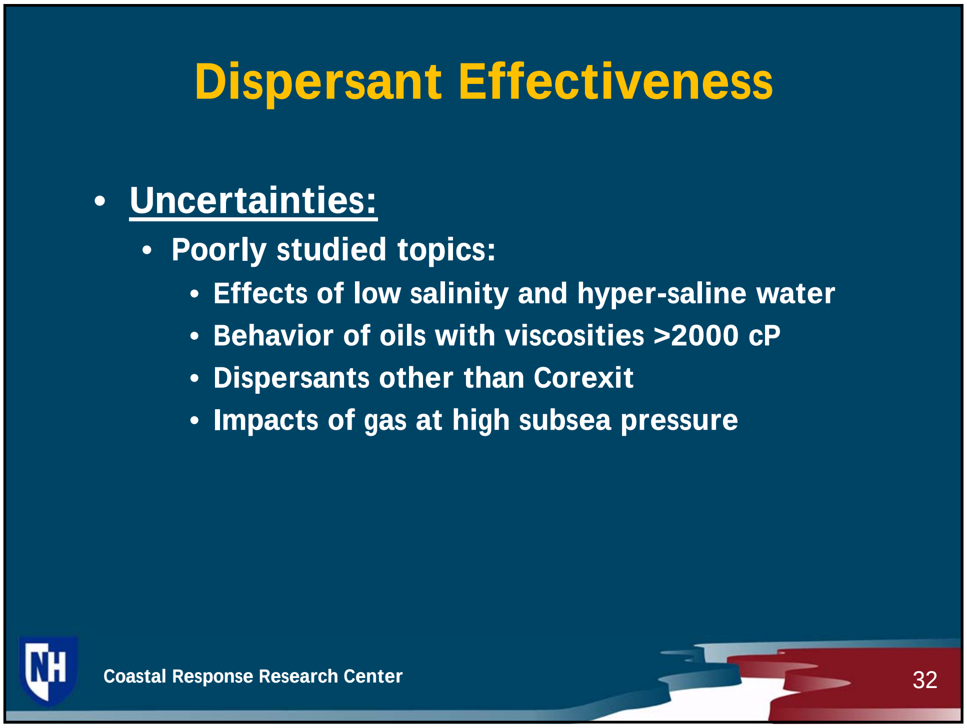
Mixing Energy

- **Knowns:**
  - Ice-free waters: mixing energy impacts equivalent to those in temperate waters
  - Ice-infested waters: ice dampens surface waves energy, slowing dispersion kinetics
  - Propeller wash from ships, including ice breakers, can enable dispersion of oil + dispersant



Mixing Energy

- **Uncertainties:**
    - Limited studies of surface mixing energy for some ice conditions (e.g., frazil ice)
    - Effectiveness of oil dispersion not fully characterized with highly ice-infested waters
    - Effects/interactions of shearing, dampening and reduction of evaporative weathering on oil dispersion not well understood



Dispersant Effectiveness

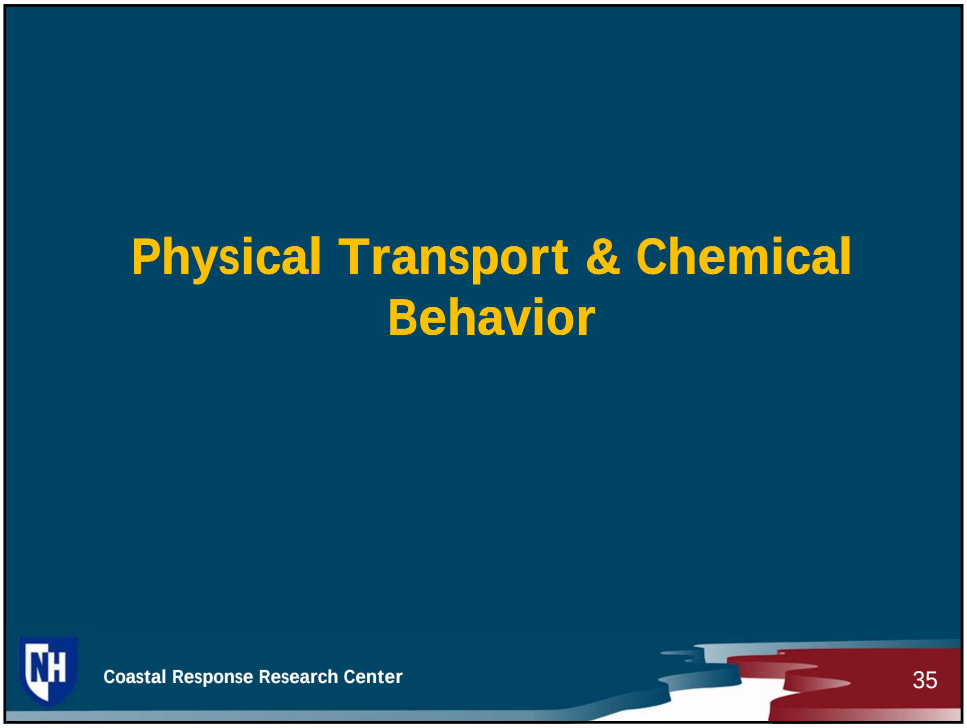
- **Uncertainties:**
    - Poorly studied topics:
        - Effects of low salinity and hyper-saline water
        - Behavior of oils with viscosities >2000 cP
        - Dispersants other than Corexit
        - Impacts of gas at high subsea pressure

Detection & Monitoring of Effectiveness

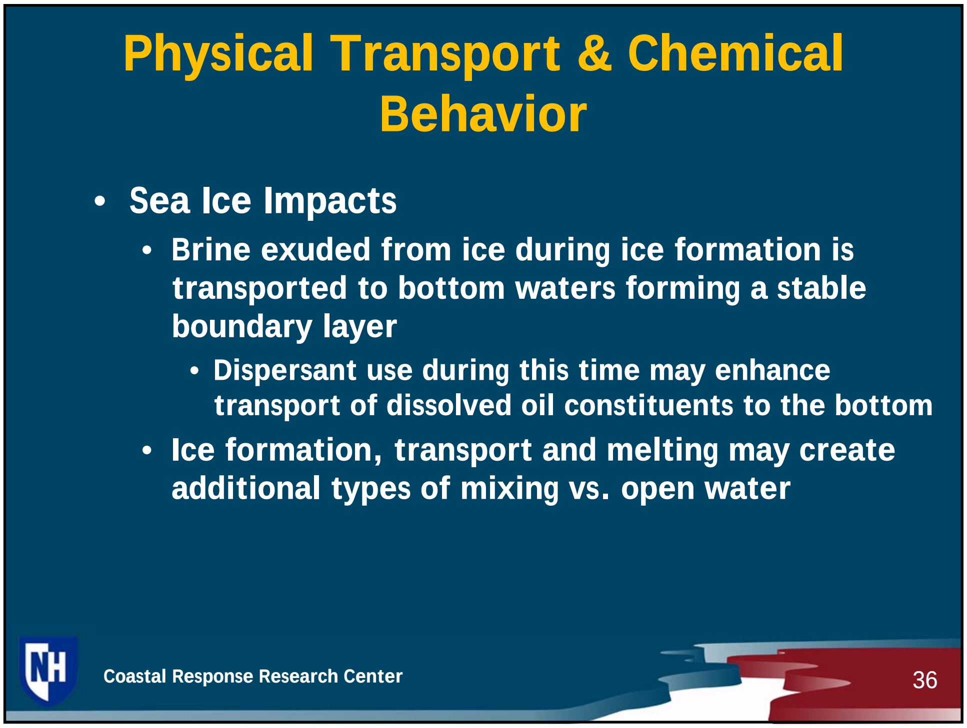
- No standard dispersant effectiveness monitoring protocols for ice-infested waters
- Existing quantitative assessment techniques for measuring overall effectiveness have lots of uncertainty

Overall Conclusions on State of Science of Efficacy & Effectiveness of Dispersant Use in Arctic Waters

- Subsea efficacy & effectiveness should be similar in Arctic to elsewhere if same conditions at depth
- Ice in Arctic waters changes the conditions for oil dispersant interactions in ways we do not fully understand



Physical Transport & Chemical Behavior



Physical Transport & Chemical Behavior

- Sea Ice Impacts
  - Brine exuded from ice during ice formation is transported to bottom waters forming a stable boundary layer
    - Dispersant use during this time may enhance transport of dissolved oil constituents to the bottom
  - Ice formation, transport and melting may create additional types of mixing vs. open water

Physical Transport & Chemical Behavior

- **Knowns:**
  - Key point: dispersants do not change oil or its constituents chemically
    - Dispersants impact formation of oil droplets
  - Lots known about droplet size as a function of dispersant use, particularly regarding dissolution of hydrocarbon constituents from droplets
  - Dispersants help reduce droplet size
  - Smaller droplet sizes = higher dissolution and degradation = longer residence time in water column vs. being on surface as a slick

Physical Transport & Chemical Behavior

- **Uncertainties: Droplet size/formation**
  - No models of near surface droplet size distribution for naturally vs. chemically dispersed oil in ice infested waters
  - Lab studies of mixing energy’s impact on droplet size distribution do not scale up well to the field
  - Turbulence regimes under ice are not well understood
  - Difficult to predict droplet rise under ice
  - Unknown if resurfaced chemically dispersed oil can be dispersed again when mixing energy added

Physical Transport & Chemical Behavior

- **Knowns:**
  - Open water conditions follow same hydrodynamic principles observed in other regions
  - Unique Arctic factor is when oil frozen in ice
  - Capacity of ice to pool non-dispersed oil increases with under-ice roughness
  - Transport of dispersed oil depends on droplet size, cross-currents, in situ conditions (e.g., density gradient)
  - 3D decrease in concentration (for droplets and dissolved constituents) over time with distance from spill

Transport

- **Uncertainties:**
  - Pooling capacity and transport under ice difficult to predict
  - Transport of surface oil in water with intermediate ice coverage is uncertain
  - Difficult to predict transport and mixing in frazil, grease and slush ice
  - Spreading of dispersant treated oil in ice-infested water is difficult to predict

Oil-in-Ice

- **Knowns:**
  - Experimental field releases have increased understanding of behavior of oil-in-ice
  - Spreading (movement of oil within ice field) is constrained by ice
  - Oil in pack ice will move with the ice unless pack ice is at low concentrations
    - Then may move independently of ice
  - Secondary release of oil entrapped in ice occurs at site where ice melts

Oil-in-Ice

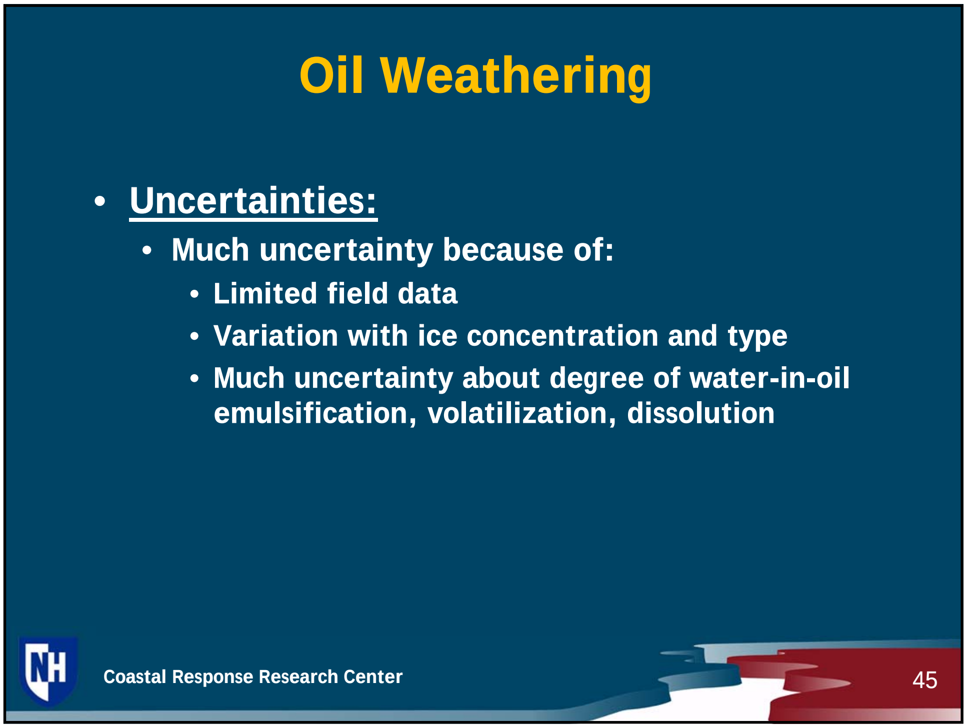
- **Knowns (continued):**
  - Fresh oil in leads may emulsify due to wave action; this oil may not be as readily dispersed by chemical dispersants
  - Window of opportunity for surface application of chemical dispersants increases with high ice cover and low air and sea temperature (e.g., less weathering)

Oil-in-Ice

- **Uncertainties:**
  - Uncertain how oil is transported when 3/10ths to 8/10ths ice cover
  - Uncertain if oil dispersant mixtures trapped in ice will be dispersed when ice is melted

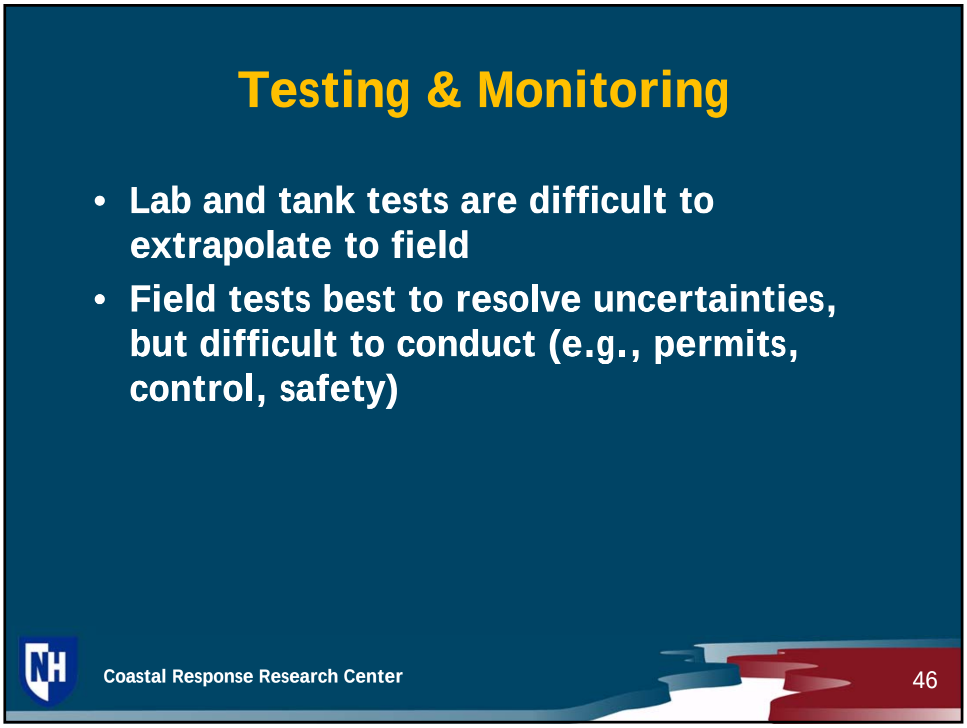
Oil Weathering

- **Knowns:**
  - Bulk properties of oil frozen into first year ice are much the same as when oil first encapsulated
    - When temperature warms, oil can migrate to surface of ice through brine channels forming melt pools
    - Water soluble oil constituents released into brine and transported with brine to water underneath ice
  - Field trials show weathering in Arctic is slow; dispersant window as long as 7 days



Oil Weathering

- **Uncertainties:**
  - Much uncertainty because of:
    - Limited field data
    - Variation with ice concentration and type
    - Much uncertainty about degree of water-in-oil emulsification, volatilization, dissolution



Testing & Monitoring

- Lab and tank tests are difficult to extrapolate to field
- Field tests best to resolve uncertainties, but difficult to conduct (e.g., permits, control, safety)

Oil-Mineral Aggregate (OMA)

- **Knowns:**
  - Arctic river outputs and glacial till can be significant in OMA formation
  - OMA occurs in cold waters and presence of ice
  - In lab studies, chemical dispersants enhance OMA formation
  - OMA will sink similar to sediment
    - Observed during Deepwater Horizon spill when drilling mud injected as a well control method
  - Lots of work on OMA done by Khelifa (Environment Canada) and Lee (Canada Dept. of Fisheries and Oceans)

OMA

- **Uncertainties:**
  - Formation, behavior and fate of OMA in ice-infested water

Mathematical Modeling

- **Uncertainties/Issues:**
  - Limited empirical data to develop improved predictive models of dispersed oil droplet sizes, dissolution, OMA formation, water-in-oil emulsification for oil spills in ice
  - Modeling movement of oil through brine channels
  - Modeling of oil movement under ice
  - Modeling with higher concentrations of ice

Subsea Release

- **Knowns:**
  - Many aspects of Arctic subsea conditions may be similar to conditions elsewhere
  - In shallow waters, force of rising gas from blowout could break ice
- **Uncertainties:**
  - Effect of gas bubbles from subsea spill and hydrate formation on oil droplet size formation
  - In shallow release, uncertain if oil-water plume will melt ice

Degradation & Fate

Fate of Dispersants Alone

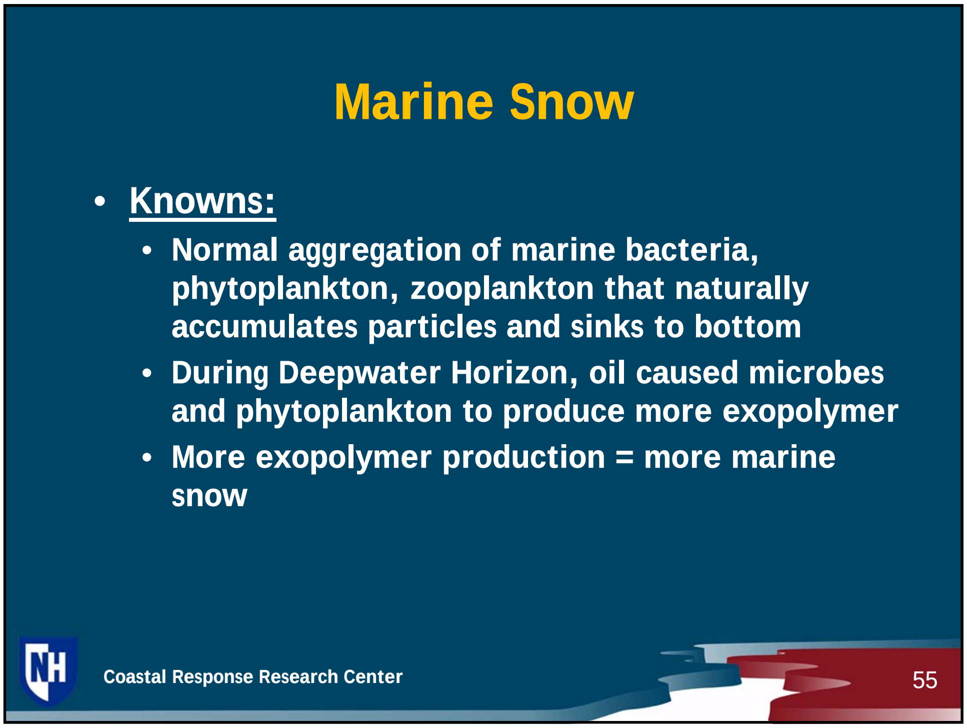
- **Knowns:**
  - Dispersant components have different half lives in the environment
    - Affected by environmental conditions
  - Anionic surfactants (e.g., DOSS) biodegrade under aerobic conditions and more slowly anaerobically
    - Most studies are surfactants alone, not dispersant mixtures

Fate of Dispersants Alone

- Knowns (continued):
  - DOSS is most studied anionic surfactant and is a constituent of the dispersant Corexit
    - In DWH, found in water column up to 4 months after last use
    - In sediments, still present in DWH-oiled sediments (not in natural seep sediments)
  - Direct absorption of sunlight by dispersants is poor
    - Some decay over days by photolysis
    - Natural organic matter (NOM) + sunlight = reactive oxygen species → may impact dispersant abiotic degradation

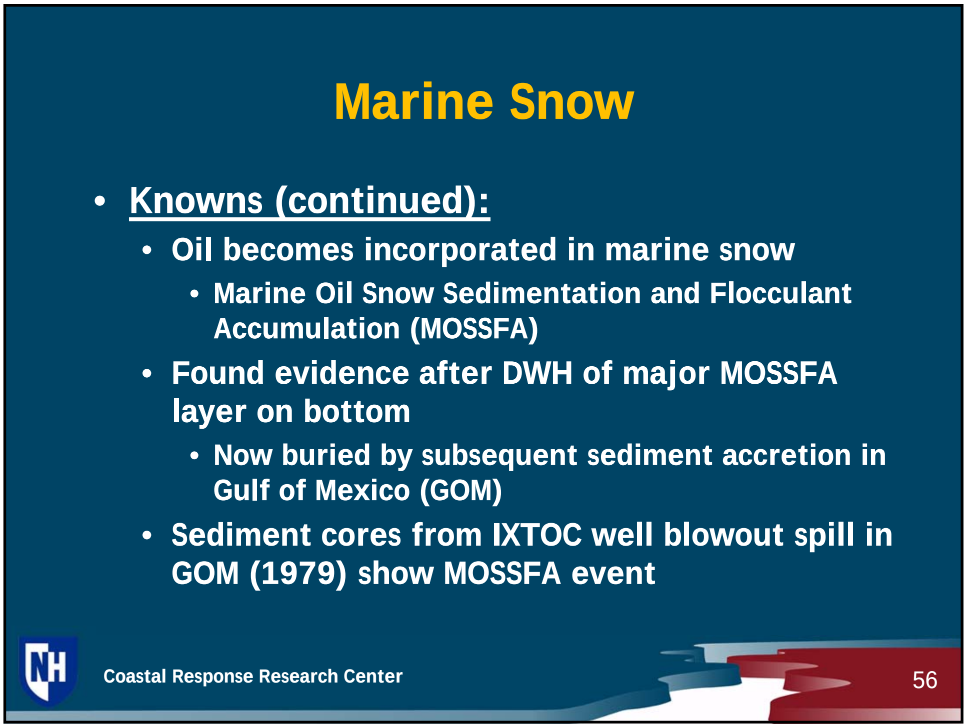
Fate of Dispersants Alone

- Uncertainties:
  - Because dispersants vary in composition, degradation and fate are not well known
  - Do other sources of surfactants (non-oil spill related) exist in the Arctic?
  - Effect of sunlight, low temperatures, and natural organic matter on dispersant decay/degradation not well understood



Marine Snow

- **Knowns:**
  - Normal aggregation of marine bacteria, phytoplankton, zooplankton that naturally accumulates particles and sinks to bottom
  - During Deepwater Horizon, oil caused microbes and phytoplankton to produce more exopolymer
  - More exopolymer production = more marine snow



Marine Snow

- **Knowns (continued):**
  - Oil becomes incorporated in marine snow
    - Marine Oil Snow Sedimentation and Flocculant Accumulation (MOSSFA)
  - Found evidence after DWH of major MOSSFA layer on bottom
    - Now buried by subsequent sediment accretion in Gulf of Mexico (GOM)
  - Sediment cores from IXTOC well blowout spill in GOM (1979) show MOSSFA event

Marine Snow

- **<u>Uncertainties:</u>**
  - How does dispersant use affect marine snow formation in Arctic?

Biodegradation of Oil

- **<u>Knowns:</u>**
  - Hydrocarbon-degrading (HD) microbes are ubiquitous
    - McFarlin et al. (2014) Arctic near-shore waters crude oil biodegradation at -1°C
    - Microbial community structure may differ geographically
    - HD microbes found in Arctic waters
  - Microbes degrade <u>dissolved</u> oil constituents and also at <u>oil-water interface</u>

Biodegradation of Oil

- **Uncertainties:**
  - What actually happens in the field?
    - Few studies
    - Most based on lab not field

Oil Biodegradation Pathways

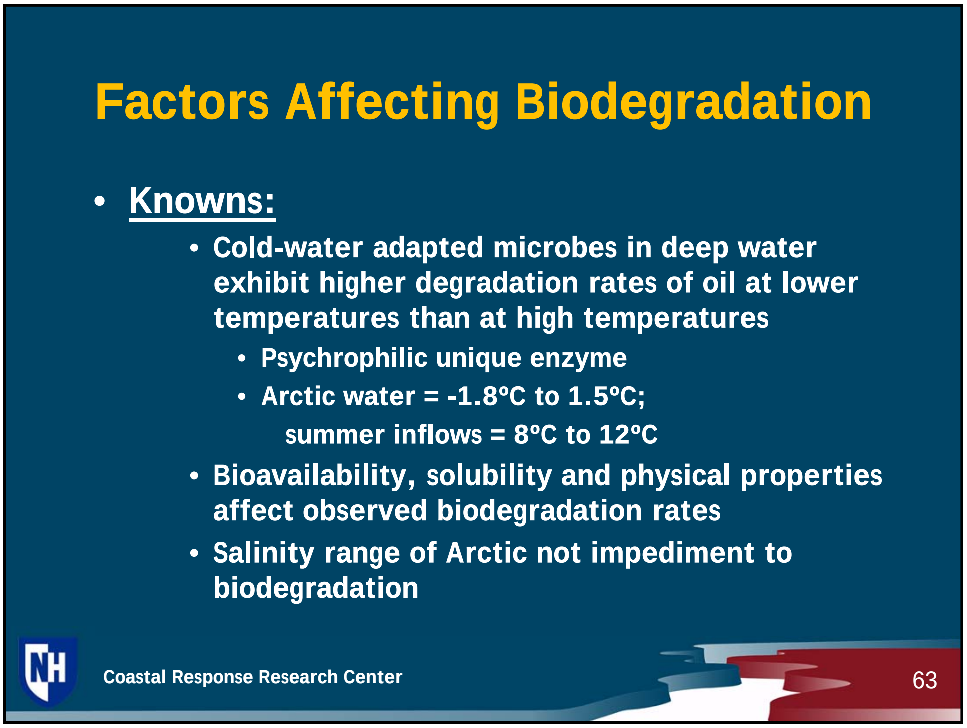
- **Knowns:**
  - Oil constituents degrade at different rates
    - Arctic biodegradation pathways follow typical pattern observed in temperate waters
    - Complex microbial consortia degrade different oils (and their constituents) with complementary metabolic pathways
      - Live vs. dead oils
      - Light vs. heavy oils
  - Lab studies show no change in biodegradation sequence with dispersants present

Oil Biodegradation Pathways

- **Uncertainties:**
  - Is biodegradation sequence in anaerobic marine environment consistent?

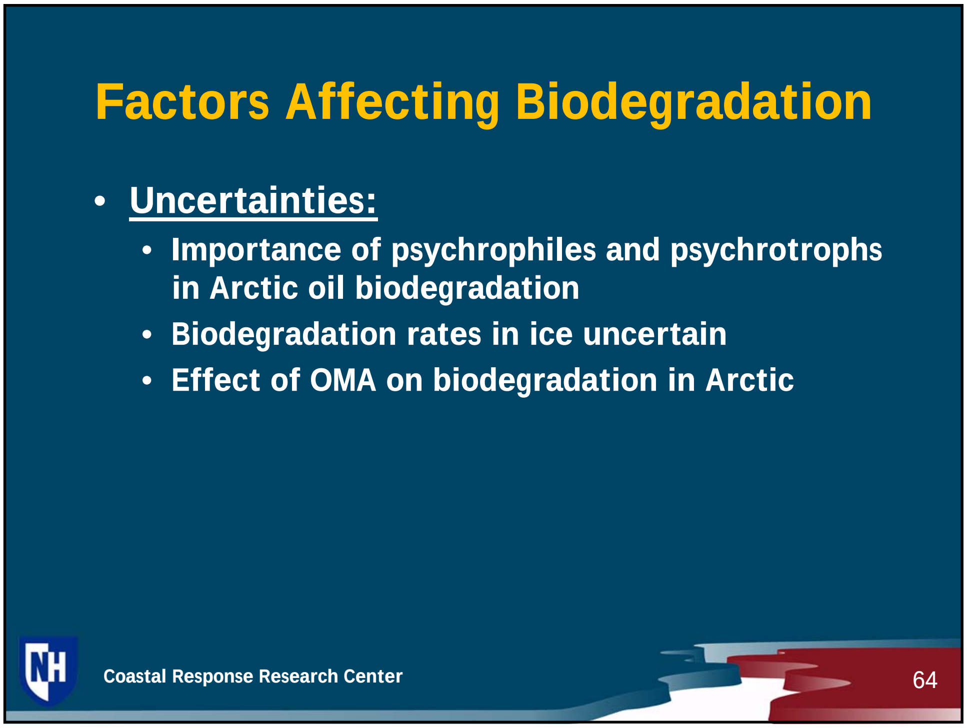
Factors Affecting Biodegradation

- **Knowns:**
  - Nutrients and trace metal availability important in oil biodegradation rates
    - Lab studies suggest oil biodegradation can become nutrient limited
    - At low oil concentration (dispersed oil), there should be sufficient micronutrients



Factors Affecting Biodegradation

- **Knowns:**
  - Cold-water adapted microbes in deep water exhibit higher degradation rates of oil at lower temperatures than at high temperatures
    - Psychrophilic unique enzyme
    - Arctic water = -1.8ºC to 1.5ºC;
      summer inflows = 8ºC to 12ºC
  - Bioavailability, solubility and physical properties affect observed biodegradation rates
  - Salinity range of Arctic not impediment to biodegradation



Factors Affecting Biodegradation

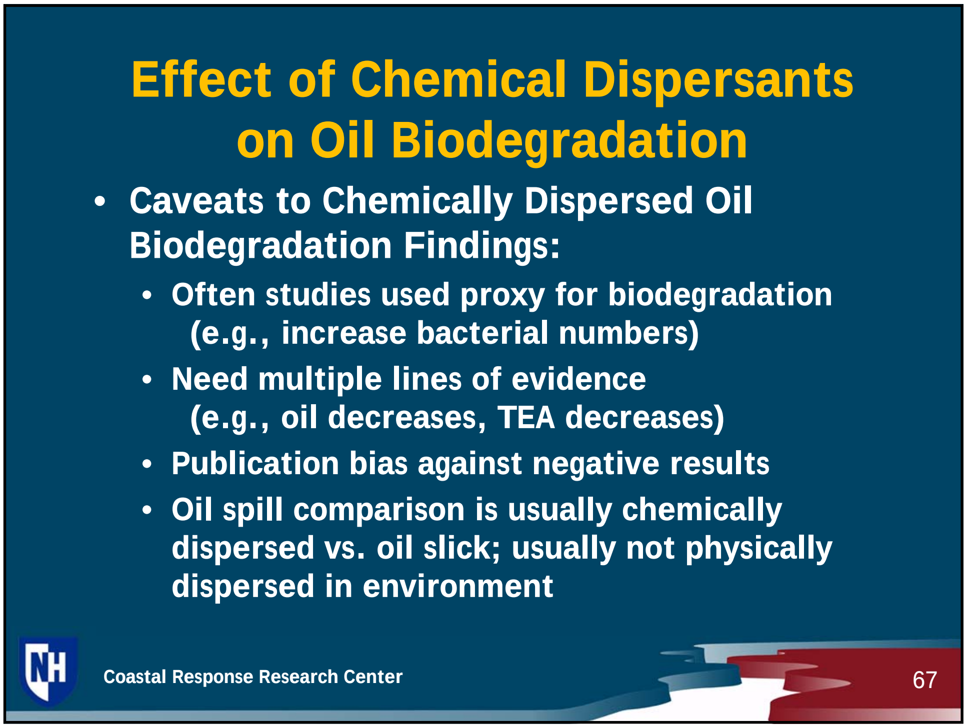
- **Uncertainties:**
  - Importance of psychrophiles and psychrotrophs in Arctic oil biodegradation
  - Biodegradation rates in ice uncertain
  - Effect of OMA on biodegradation in Arctic

Effect of Chemical Dispersants on Oil Biodegradation

- Lots of papers published on this topic, some not scientifically sound and some not representative of environmental conditions
  - Examples:
    - Nominal initial oil concentration (not actually measured)
    - Dispersant concentrations very high >1,000 ppm

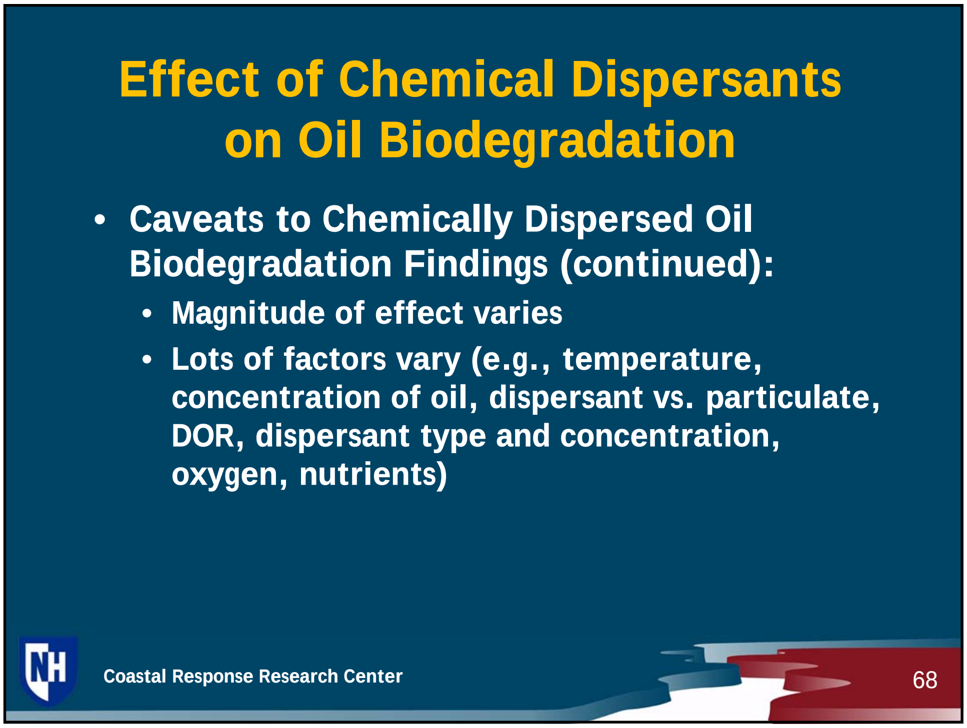
Effect of Chemical Dispersants on Oil Biodegradation

- <u>Knowns:</u>
  - 10 µm oil droplets degrade faster than 30 µm oil droplets (Brakstad et al., 2015)
  - Dispersants increase oil-water interfacial area, thus increasing biodegradation of oil droplets vs. slick
  - Chemical dispersion most frequently increased oil biodegradation rates vs. physically dispersed oil
    - Most studies with Corexit



Effect of Chemical Dispersants on Oil Biodegradation

- Caveats to Chemically Dispersed Oil Biodegradation Findings:
  - Often studies used proxy for biodegradation (e.g., increase bacterial numbers)
  - Need multiple lines of evidence (e.g., oil decreases, TEA decreases)
  - Publication bias against negative results
  - Oil spill comparison is usually chemically dispersed vs. oil slick; usually not physically dispersed in environment



Effect of Chemical Dispersants on Oil Biodegradation

- Caveats to Chemically Dispersed Oil Biodegradation Findings (continued):
  - Magnitude of effect varies
  - Lots of factors vary (e.g., temperature, concentration of oil, dispersant vs. particulate, DOR, dispersant type and concentration, oxygen, nutrients)

Effect of Chemical Dispersants on Oil Biodegradation

- <u>**Uncertainties:**</u>
  - **Impacts of droplet size; only 10 µm vs. 30 µm studied**
  - **Impact of dispersants/dispersion on microbial activity**
    - **Degrading short-term vs. long-term release and adaptation**
  - **Lack of realistic field conditions**
    - **DWH oil concentrations in water typically < 10 ppm**

Effect of Chemical Dispersants on Oil Biodegradation

- <u>**Uncertainties (continued):**</u>
  - **Order of biodegradation of dispersant components vs. oil constituents**
    - **Preferential biodegradation?**

Still to Come on Documents

- Final on Ecotoxicity and Sublethal Impacts
- Public Health and Food Safety
  - Finish Draft for Public Release
  - Receive Public Input
  - Panel Reviews Input
  - Panel Finishes Document

Still to Come on Project

- Workshop – communicating the state of science to the public & others
  - Will follow completion of state of science papers
  - Small workshop with scientists and communication experts
  - Recommend types of material that would be most effective for communications to public

Thank You for Listening

Questions???

- nancy.kinner@unh.edu
- 603-479-3777
- www.crrc.unh.edu

Coastal Response Research Center

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Organizing Committee

- Lt CDR Stacey Crecy, USCG
- Mark Everett, USCG District 17
- Doug Helton and Gary Shigenaka, NOAA ORR
- Leslie Holland-Bartels, USGS
- Phil Johnson, US DOI-Alaska
- Lee Majors, Alaska Clean Seas
- Kristin Ryan, Alaska DEC
- Greg Wilson and Vanessa Principe, USEPA
- Susan Saupe, Cook Inlet RCAC
- Mark Swanson, PWSRCAC

2014 SONS Executive Seminar

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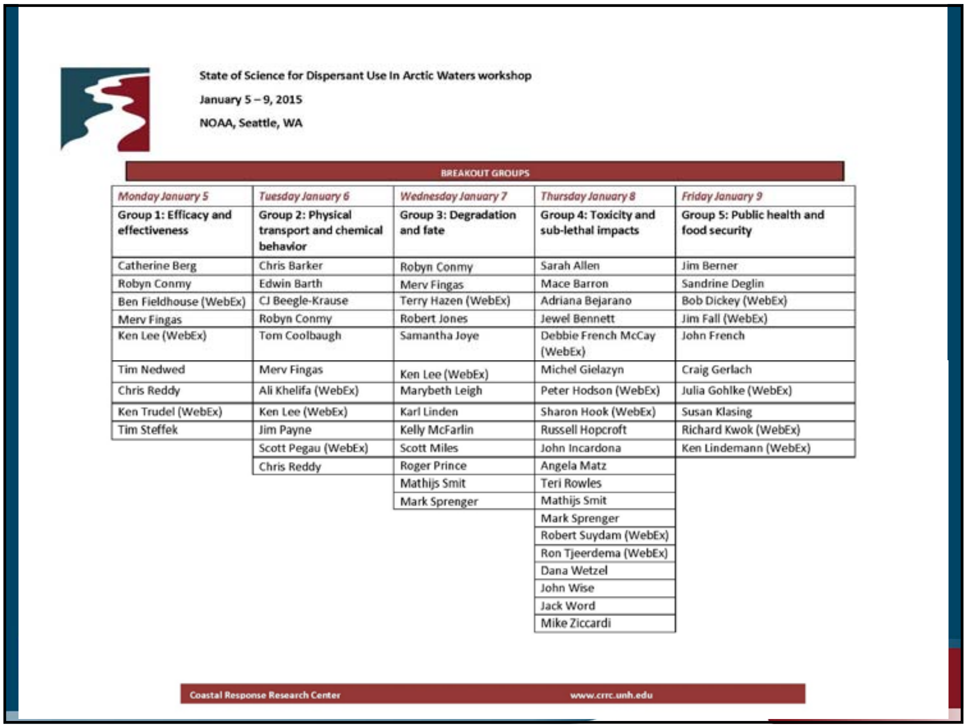

State of Science for Dispersant Use In Arctic Waters workshop
January 5 – 9, 2015
NOAA, Seattle, WA

BREAKOUT GROUPS

Monday January 5	*Tuesday January 6*	*Wednesday January 7*	*Thursday January 8*	*Friday January 9*
Group 1: Efficacy and effectiveness	**Group 2: Physical transport and chemical behavior**	**Group 3: Degradation and fate**	**Group 4: Toxicity and sub-lethal impacts**	**Group 5: Public health and food security**
Catherine Berg	Chris Barker	Robyn Conmy	Sarah Allen	Jim Berner
Robyn Conmy	Edwin Barth	Merv Fingas	Mace Barron	Sandrine Deglin
Ben Fieldhouse (WebEx)	CJ Beegle-Krause	Terry Hazen (WebEx)	Adriana Bejarano	Bob Dickey (WebEx)
Merv Fingas	Robyn Conmy	Robert Jones	Jewel Bennett	Jim Fall (WebEx)
Ken Lee (WebEx)	Tom Coolbaugh	Samantha Joye	Debbie French McCay (WebEx)	John French
Tim Nedwed	Merv Fingas	Ken Lee (WebEx)	Michel Gielazyn	Craig Gerlach
Chris Reddy	Ali Khelifa (WebEx)	Marybeth Leigh	Peter Hodson (WebEx)	Julia Gohlke (WebEx)
Ken Trudel (WebEx)	Ken Lee (WebEx)	Karl Linden	Sharon Hook (WebEx)	Susan Klasing
Tim Steffek	Jim Payne	Kelly McFarlin	Russell Hopcroft	Richard Kwok (WebEx)
	Scott Pegau (WebEx)	Scott Miles	John Incardona	Ken Lindemann (WebEx)
	Chris Reddy	Roger Prince	Angela Matz	
		Mathijs Smit	Teri Rowles	
		Mark Sprenger	Mathijs Smit	
			Mark Sprenger	
			Robert Suydam (WebEx)	
			Ron Tjeerdema (WebEx)	
			Dana Wetzel	
			John Wise	
			Jack Word	
			Mike Ziccardi	

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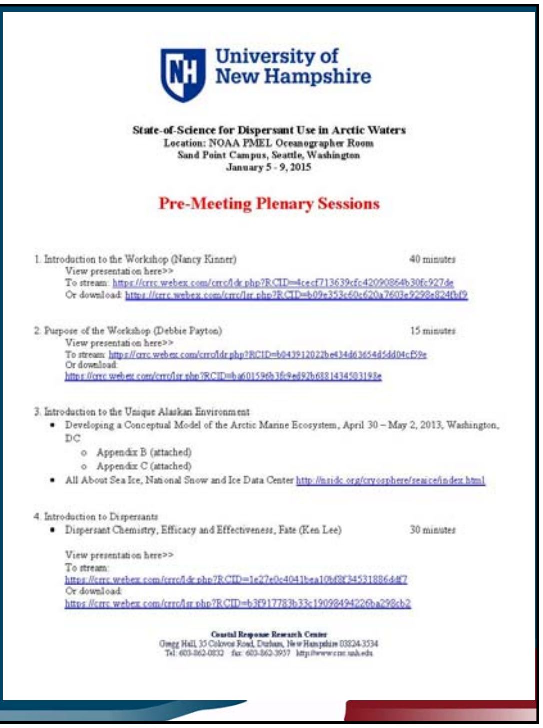
Pre-Meeting Plenary Sessions



University of New Hampshire

State-of-Science for Dispersant Use in Arctic Waters
Location: NOAA PMEL Oceanographer Room
Sand Point Campus, Seattle, Washington
January 5 - 9, 2015

Pre-Meeting Plenary Sessions

1. Introduction to the Workshop (Nancy Kinner) 40 minutes
   View presentation here>>
   To stream: https://crrc.webex.com/crrc/ldr.php?RCID=4cecf713639cfc42090864b30fc927de
   Or download: https://crrc.webex.com/crrc/lsr.php?RCID=b09e353c60c620a7603e9298e824fbf9

2. Purpose of the Workshop (Debbie Payton) 15 minutes
   View presentation here>>
   To stream: https://crrc.webex.com/crrc/ldr.php?RCID=b043912022be434d63654d5dd04cf59e
   Or download:
   https://crrc.webex.com/crrc/lsr.php?RCID=ba601596b3fc9ed92b6381434503198e

3. Introduction to the Unique Alaskan Environment
   - Developing a Conceptual Model of the Arctic Marine Ecosystem, April 30 – May 2, 2013, Washington, DC
     - Appendix B (attached)
     - Appendix C (attached)
   - All About Sea Ice, National Snow and Ice Data Center http://nsidc.org/cryosphere/seaice/index.html

4. Introduction to Dispersants
   - Dispersant Chemistry, Efficacy and Effectiveness, Fate (Ken Lee) 30 minutes

   View presentation here>>
   To stream:
   https://crrc.webex.com/crrc/ldr.php?RCID=1e27e0c4041bea10bf8f34531886d4f7
   Or download:
   https://crrc.webex.com/crrc/lsr.php?RCID=b3f917783b33c19098494226ba298cb2

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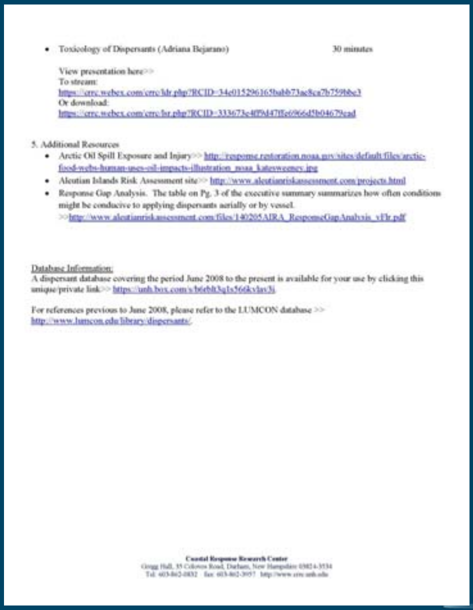
Coastal Response Research Center



- Toxicology of Dispersants (Adriana Bejarano) 30 minutes

  View presentation here>>
  To stream:
  https://crrc.webex.com/crrc/ldr.php?RCID=34e015296165babb73ae8ca7b759bbe3
  Or download:
  https://crrc.webex.com/crrc/lsr.php?RCID=333673e4ff9d47ffe6966d5b04679ead

5. Additional Resources
- Arctic Oil Spill Exposure and Injury>> http://response.restoration.noaa.gov/sites/default/files/arctic-food-webs-human-uses-oil-impacts-illustration_noaa_katesweeney.jpg
- Aleutian Islands Risk Assessment site>> http://www.aleutianriskassessment.com/projects.html
- Response Gap Analysis. The table on Pg. 3 of the executive summary summarizes how often conditions might be conducive to applying dispersants aerially or by vessel. >>http://www.aleutianriskassessment.com/files/140205AIRA_ResponseGapAnalysis_vFIr.pdf

Database Information:
A dispersant database covering the period June 2008 to the present is available for your use by clicking this unique/private link>> https://unh.box.com/s/b6rblt3q1s566kvlav3i

For references previous to June 2008, please refer to the LUMCON database >> http://www.lumcon.edu/library/dispersants/.

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Panel Experts Efficacy and Effectiveness

- Catherine Berg, NOAA
- Robyn Conmy, USEPA
- Ben Fieldhouse, Environment Canada
- Merv Fingas, Spill Science
- Tim Nedwed, ExxonMobil
- Christopher Reddy, Woods Hole Oceanographic Institution
- Ken Trudel, SL Ross Environmental Research Ltd
- Timothy Steffek, US Bureau of Safety & Environmental Enforcement

Panel Experts: Physical Transport and Chemical Behavior

- Christopher Barker, NOAA
- CJ Beegle-Krause, SINTEF
- Robyn Conmy, US EPA
- Thomas Coolbaugh, ExxonMobil
- Merv Fingas, Spill Science
- Ali Khelifa, Environment Canada
- James R. Payne, Payne Environmental Consultants, Inc.
- W. Scott Pegau, Alaska Oil Spill Recovery Institute

Panel Experts: Degradation and Fate

- Robyn Conmy, US EPA
- Thomas Coolbaugh, ExxonMobil
- Merv Fingas, Spill Science
- Terry Hazen, University of Tennessee and Oak Ridge National Laboratory
- Robert Jones, NOAA
- Samantha (Mandy) Joye, University of Georgia Athens
- Mary Beth Leigh, University of Alaska Fairbanks
- Karl Linden, University of Colorado Boulder
- Kelly McFarlin, University of Alaska Fairbanks
- Scott Miles, Louisiana State University
- Mathijs Smit, Shell Global Solutions International BV
- Mark D. Sprenger, US EPA