Efficacy and Effects of Dispersants in Oil Spill Response: Progress Since the 2005 NRC Report

Coastal Response Research Center

May 4th, 2008
IOSC - Savannah, GA

Course Organizers

- **Amy Merten – NOAA ORR & Co-Director of the Coastal Response Research Center**
- **Nancy Kinner – University of New Hampshire & Co-Director of the Coastal Response Research Center**

Speakers

- Victoria Broje, Shell
- Balaji Gopalan, John Hopkins University
- Ken Lee, Bedford Institute of Oceanography
- Bruce Hollebone, Environment Canada
- Ali Khelifa, Environment Canada
- Bill Lehr, NOAA ORR, Emergency Response Division
- Jordan Stout, NOAA ORR, Emergency Response Division
- Nick Nichols, US Environmental Protection Agency
- Charlie Henry, NOAA ORR Emergency Response Division
- Troy Baker, NOAA ORR Assessment & Restoration Division
- CJ Beegle-Krause, Applied Sciences Associates, Inc

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Course Participants

- **Name**
- **Affiliation**
- **Reason for participating in course**

Course Objectives

- Overview of Research Findings on Dispersants in Oil Spill Response
- Practical Implications of Research on Dispersant Use
  - When and how to use
  - How to minimize effects on natural resources

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Caveat

- **Efficacy of dispersants will not be covered in course**

Agenda

- History of Dispersants and Dispersants Use
- Documented Research Needs on Dispersants
  - Fate
  - Effects
  - Cold Water
- *Break*
- Fate of Dispersants
  - Mixing
  - Chemistry
  - Particulate
  - Reactions
- *Lunch Break*

Agenda

- **Effects on Organisms**
  - **Reactions**
- *Break*
- **Tying it All Together**
  - **Modeling**
  - **Biological**
  - **Practice**
- **Wrap Up / Closing**

List of Acronyms

CEWAF	Chemically-Enhanced Water-Accommodated Fraction
CI	Confidence Interval
CROSERF	Chemical Response to Oil Spills: Ecological Research Forum
CRRC	Coastal Response Research Center
DWG	Dispersants Working Group
ERA	Environmental Risk Assessment
LC50	Lethal Concentration where 50% organisms die
LOEC	Lowest Observed Effect Concentration
MMS	United States Minerals Management Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
ORR	Office of Response and Restoration
PAH	Polycyclic Aromatic Hydrocarbon
PIs	Project Investigators
PWS RCAC	Prince William Sound Regional Citizens' Advisory Council
QSAR	Quantitative Structure Activity Relationship
RFP	Request for Proposals
SMART	Special Monitoring of Applied Response Technologies
TLM	Target Lipid Model
TPH	Total Petroleum Hydrocarbons
TU	Toxic Unit
USCG	United States Coast Guard
USEPA	United States Environmental Protection Agency
WAF	Water-Accommodated Fraction
WSF	Water Soluble Fraction

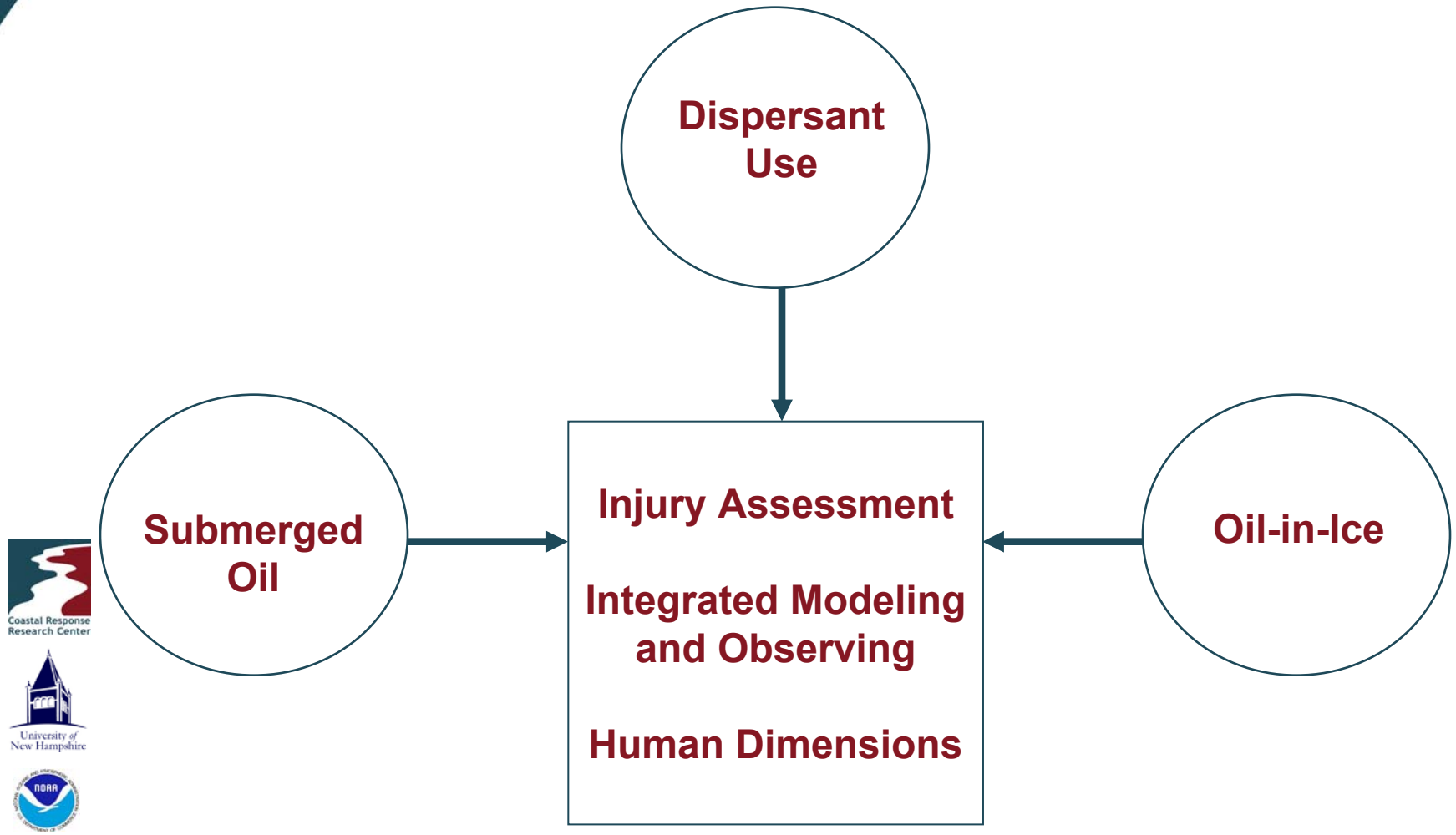
Overall CRRC Mission

- Develop new approaches to spill response and restoration through research/synthesis of information
- Serve as a resource for ORR and NOAA
- Serve as a hub for spill research, development, and technical transfer
  - Oil spill community (e.g., Regional Response Teams, National and International R&D efforts, multi-organizational partnerships)

CRRC's Strategic Plan

- 3-5 year horizon starting in 2007
- Three topics of CRRC focus
  - Dispersant use
  - Submerged oil
  - Oil-in-Ice
- Within each topic, three areas of emphasis
  - Injury Assessment
  - Integrated Modeling and Ocean Observing
  - Human Dimensions

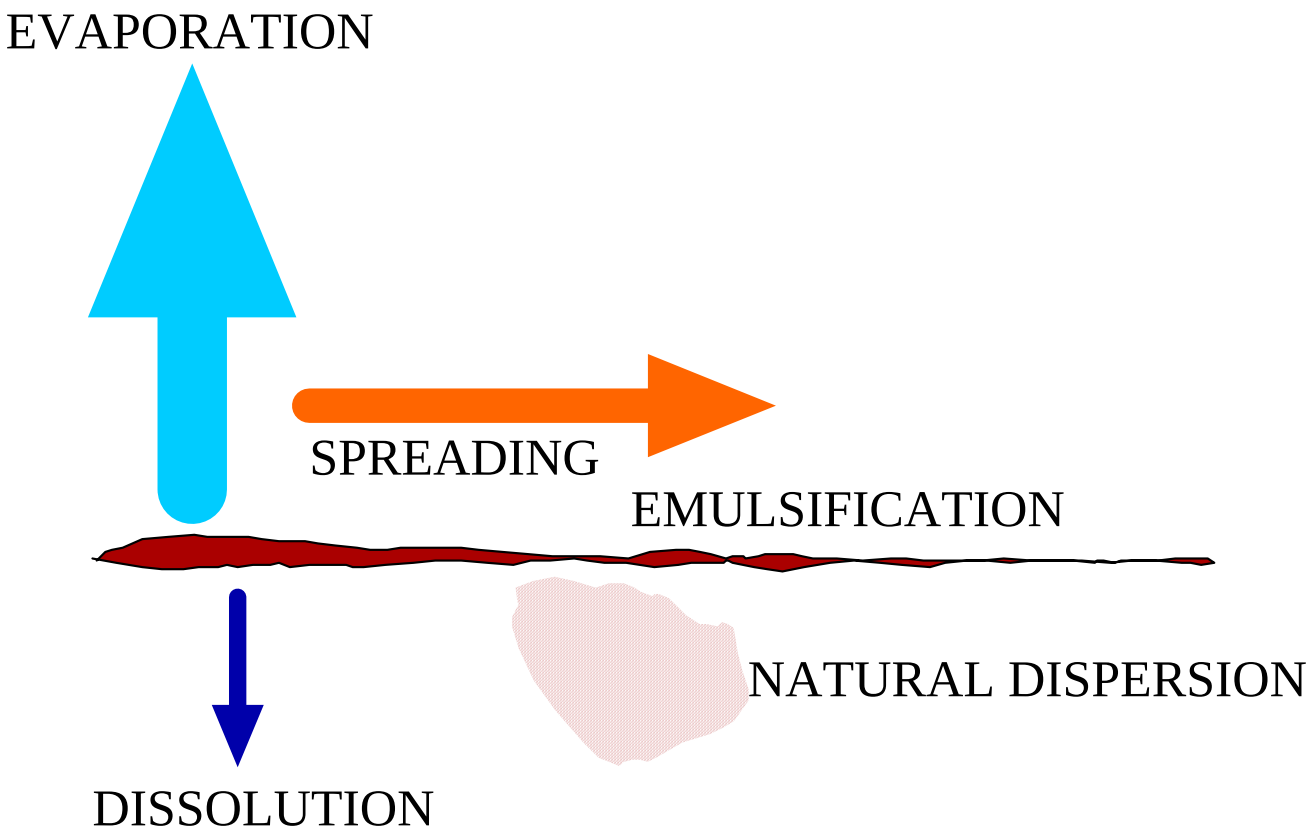
Focus Topics



Dispersants Reminder

- **Why consider using dispersants in the first place?**
- **Chemistry**
- **Exposure-Effects**
- **History**

Physical Oil Weathering



Why Treat Oil Spills in Open Water?

Response Options?

Surfactants

- **Dispersants are simply surfactants dissolved in solvent**
  - **Surfactants reduce interfacial tension between water and oil, permitting oil to break into tiny droplets**
- **Dispersants enhance natural processes**
- **Ultimate fate of oil spilled in marine environment is biodegradation**
  - **Dispersion is thought to enhance rate of natural biodegradation by significantly increasing the surface area of spilled oil**

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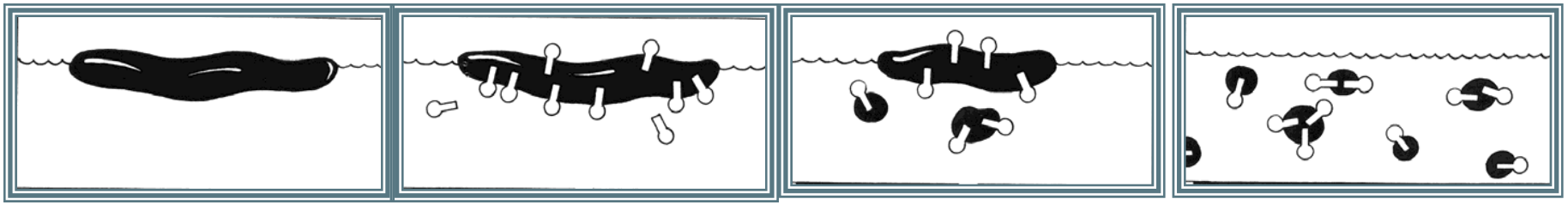
Dispersant Mechanism

Surfactant molecule (in solvent)

Water-loving (hydrophilic) end

Oil-loving (oleophilic) end



Dispersible Slick

Dispersant Applied

Droplets Form

Oil Dispersed

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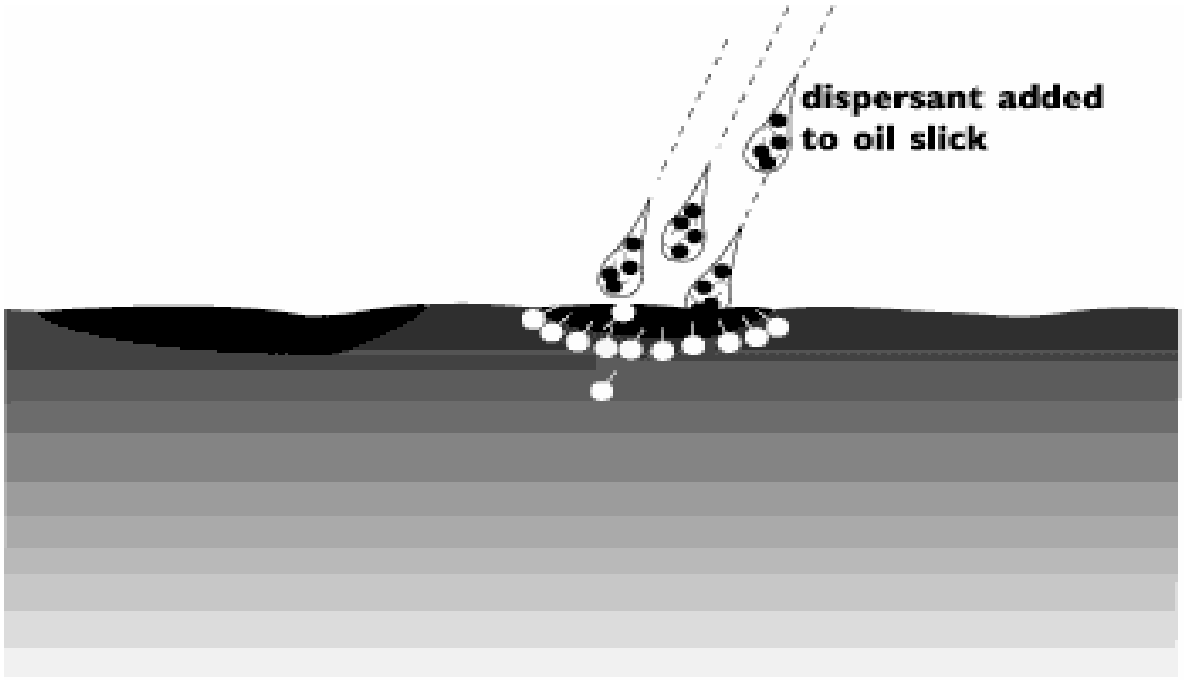
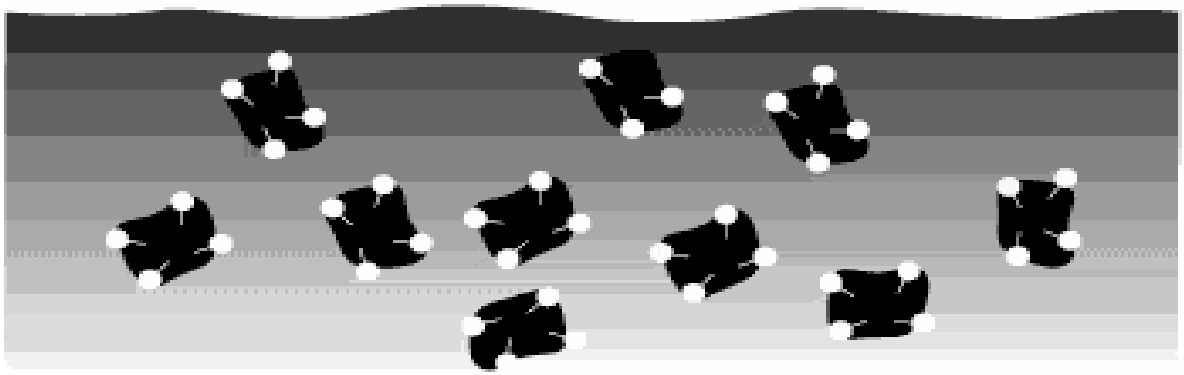
How Do Dispersants Work?



One end of each dispersant molecule 'chain' attaches to water molecules while the other end of the 'chain' attaches to the oil droplets.



A little energy from wind and waves breaks the oil slick into smaller oil droplets surrounded by dispersant molecules as shown.

From NRC 2005. Oil Spill Dispersants: Efficacy and Effects

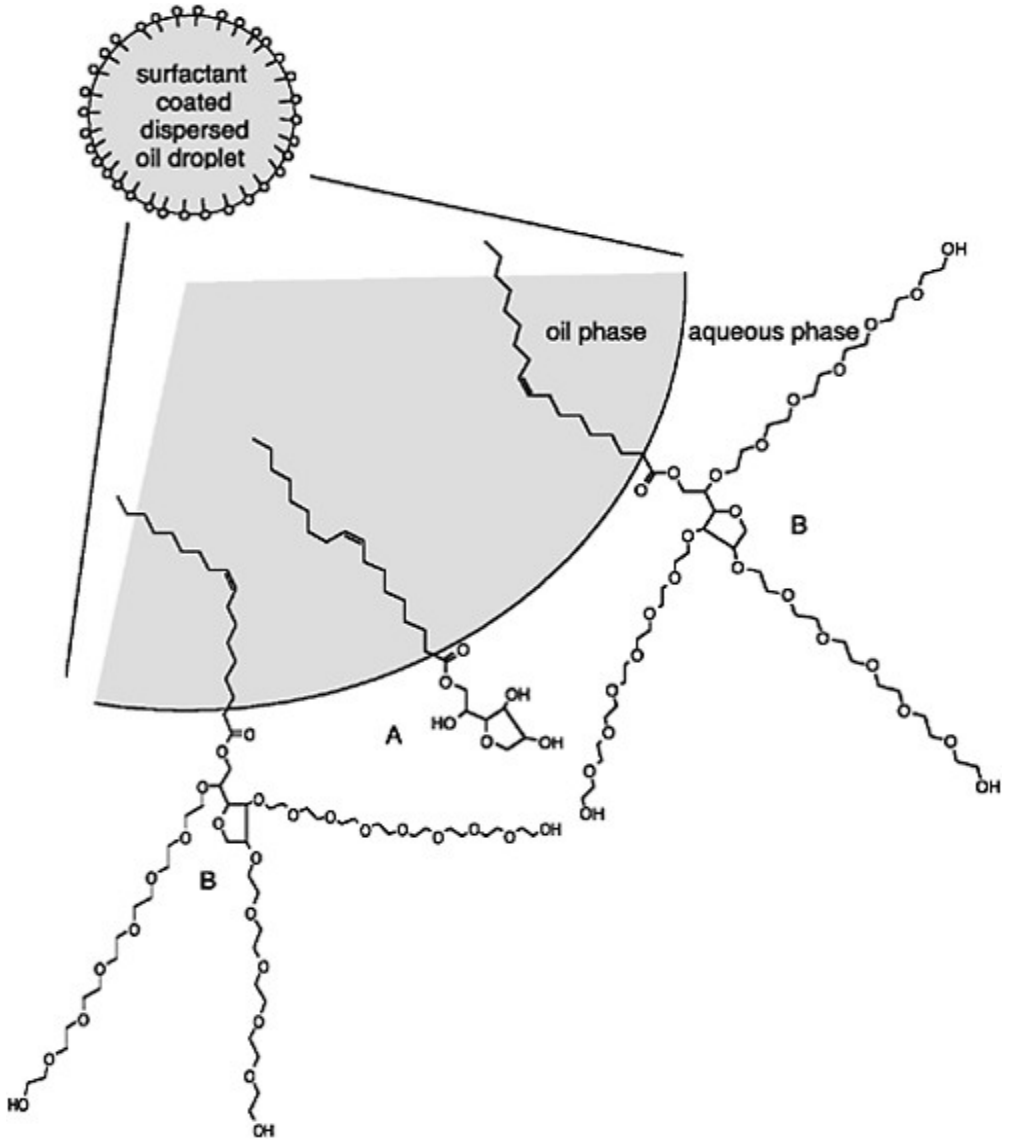
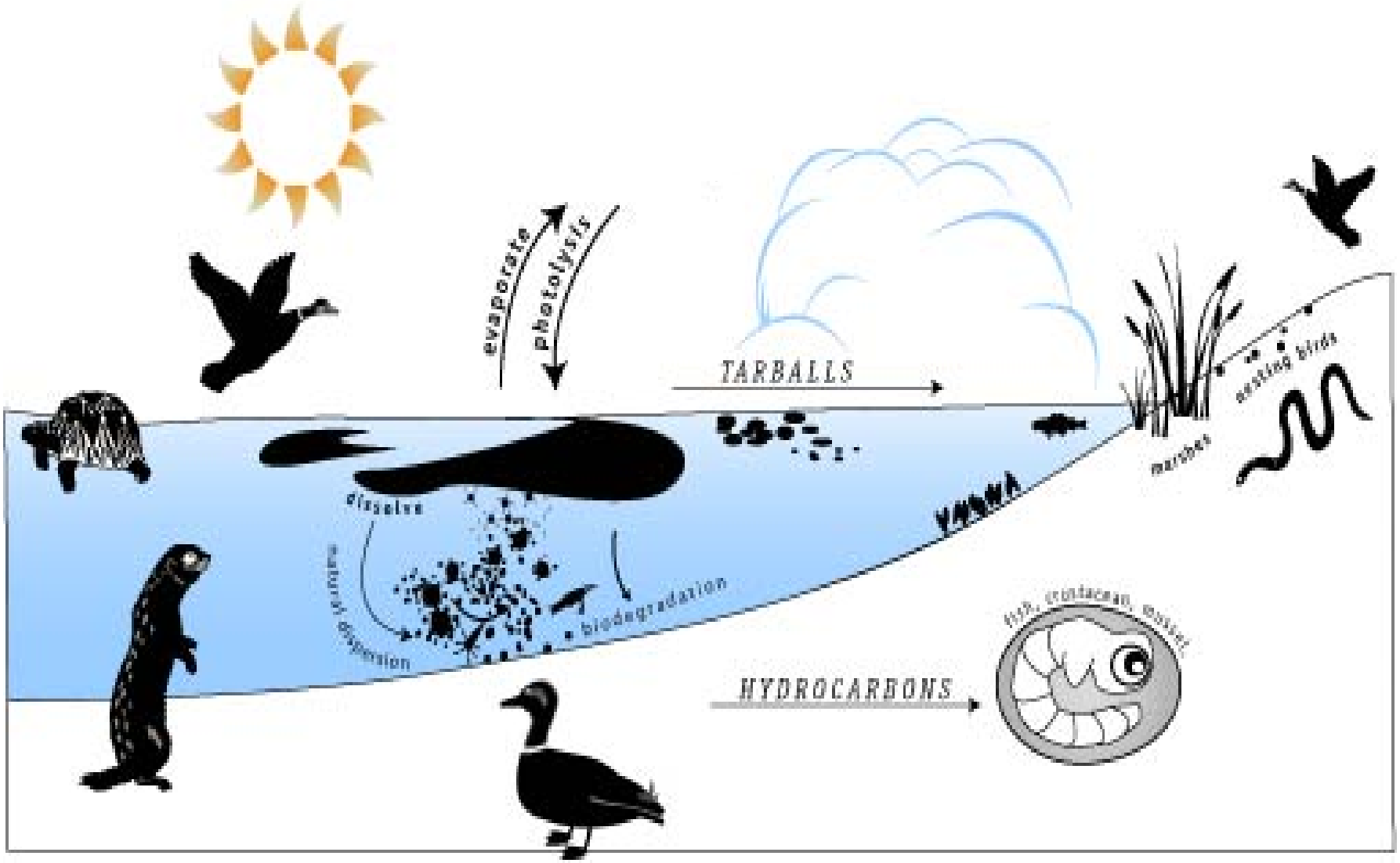


FIGURE 3-2 Orientation of surfactants at oil-water interface in dispersed oil droplets. Surfactant A is sorbitan monooleate (a.k.a., Span 80; HLB ≈ 4.3); surfactant B is ethoxylated (E20) sorbitan monooleate (a.k.a., Tween 80; HLB ≈ 15).

Fate of Oil


evaporate
photolysis
TARBALLS
nesting birds
marshes
dissolve
natural dispersion
biodegradation
HYDROCARBONS
fish, crustacean, oyster

Exposure Pathways

- Location of resources at risk (water depth, oil type, duration)
- Direct physical contact or chemical toxicity (bioassimilation of contaminants through ingestion or water exposure)
- Oil type
- Sea conditions
- Three phases: particulate, oil droplets, and dissolved water accommodated fraction (WAF)
  - Concentration
  - Duration

Interpreting Toxicity Difficult Task

- Laboratory studies
  - Nominal concentrations
  - Exposure regime
    - Continuous
    - Spiked
    - Phase of Oil
  - Lethal and sublethal impacts
- Test species – different sensitivities
- Field-scale studies
  - Expensive
  - Demonstrate sublethal effects and delayed mortality

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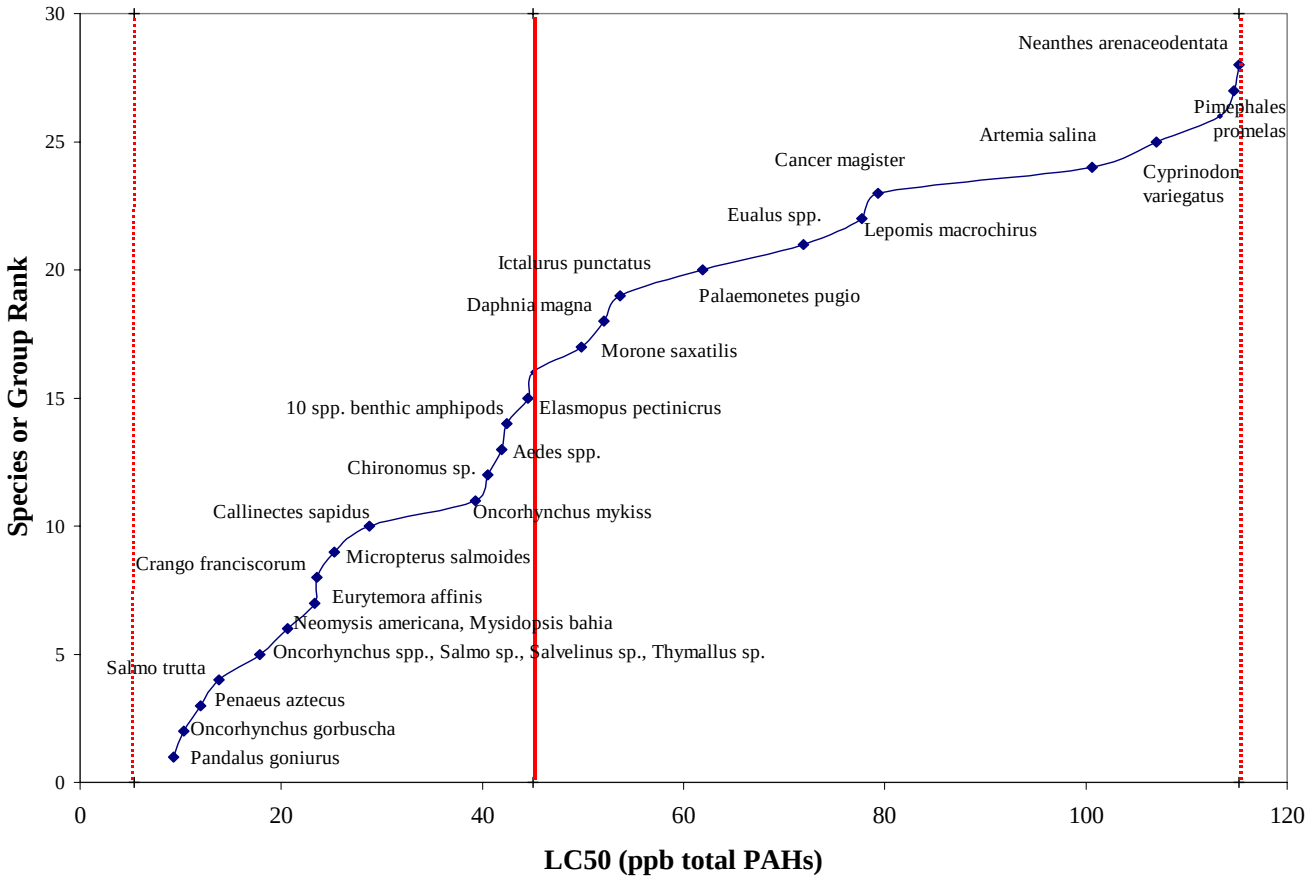
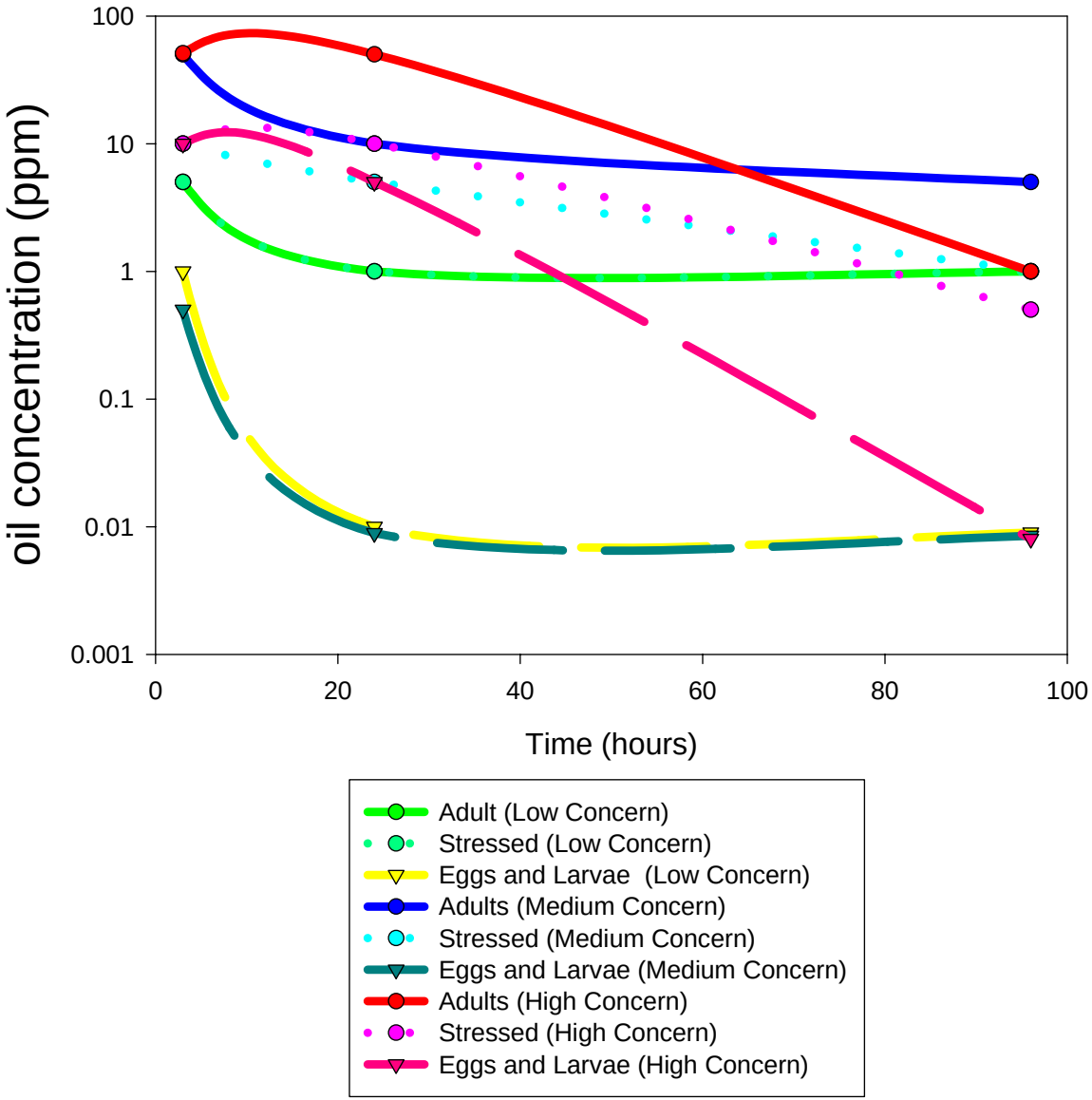
Species Sensitivities to Oil

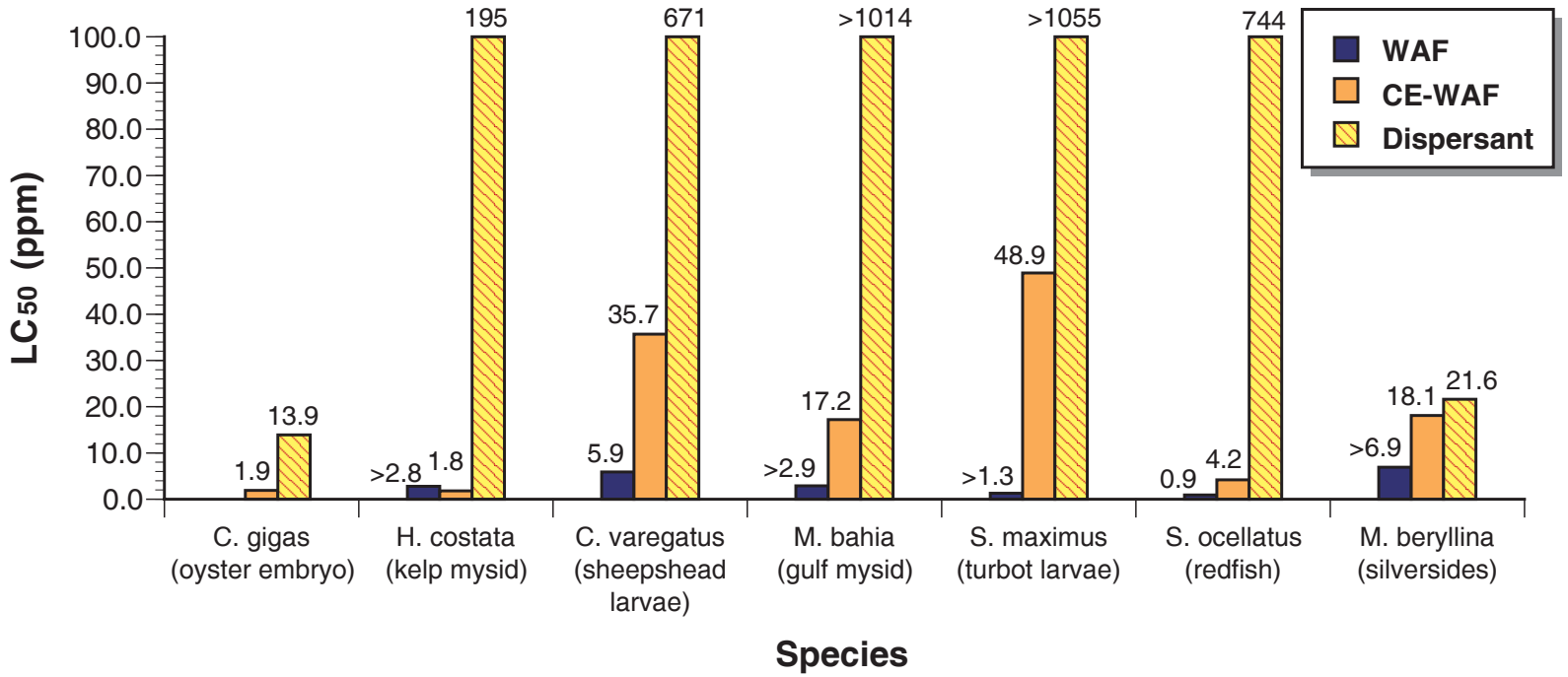


French McCay 2002

Levels of Concern for Oil Exposure to Corals



From Draft Tropical Dispersant Guide, J. Michel, B. Benggio, A. Mearns, and G. Watabayashi



-Comparison of the toxicity (mean LC50 for 96-hour exposures, except for oyster larvae which is a 48-hour exposure) for spiked exposure regimes using fresh crude oil (Kuwait, Forties, Prudhoe Bay, and Venezuela) and Corexit 9500. Data are from Clark et al. (2001), Fuller and Bonner (2001), and Wetzel and Van Fleet (2001).

Source: EVALUATING DISPERSANT USE FOR TROPICAL ENVIRONMENTS – Draft: J. Michel, B. Benggio, A. Mearns & G. Watabayashi.

Chronic Toxicity and Delayed Effects

- Areas of current research
- Environmentally realistic exposures
- Measurements of individual PAH analytes and TPH instead of nominal concentrations
  - better links exposure to effects
- Three phases of oil exposure: is this important?
- Measurements of bioaccumulated PAHs
- Mechanisms of toxicity
- Extrapolating laboratory studies to population-level effects

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History of Dispersant Use

- **Early generation: degreasers, highly toxic** *Torrey Canyon* **(1967) and** *Amoco Cadiz (1978*)
- **Newer formulations, "less toxic"**
- **1989 First NRC Study, research recommendations**
- **1990's SMART Protocol Developed**
- **1994 - 2000; CROSERF**
- **Ecological Risk Assessments (ERA) 1998 - Today**
- **2005 Update to 1989 Study**
- **2006 – PWSRCAC Ban on Dispersants**
- **1998 to Date: USCG Dispersant Use Rulemaking Process**

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Recent Dispersant Use - US

- *Exxon Valdez* – **1989**
- **Gulf of Mexico (1998 – 2004) – 7 uses in "pre-approval zone" - > 3 nm from shore, water depth > 10 m**
  - **Pipeline Spill, 2500 bbls (360 tonnes) of S. Louisiana Crude (SLC) (API 38.2)**
  - **Pipeline Spill, 3700 – 7500 bbls (530 – 1070 tonnes) SLC (API 28.6)**
  - **Tanker Collision, 100 bbls (17 tonnes) IFO 180 (API 11.7)**
  - **Pipeline Spill, 2000 bbls (290 tonnes) SLC (API 31.5)**
- **Very limited "effectiveness" monitoring other than visual observation.**

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From NRC 2005. Oil Spill Dispersants: Efficacy and Effects

Recent Dispersant Use (1995 – 2000): Non-US Spills

By Region

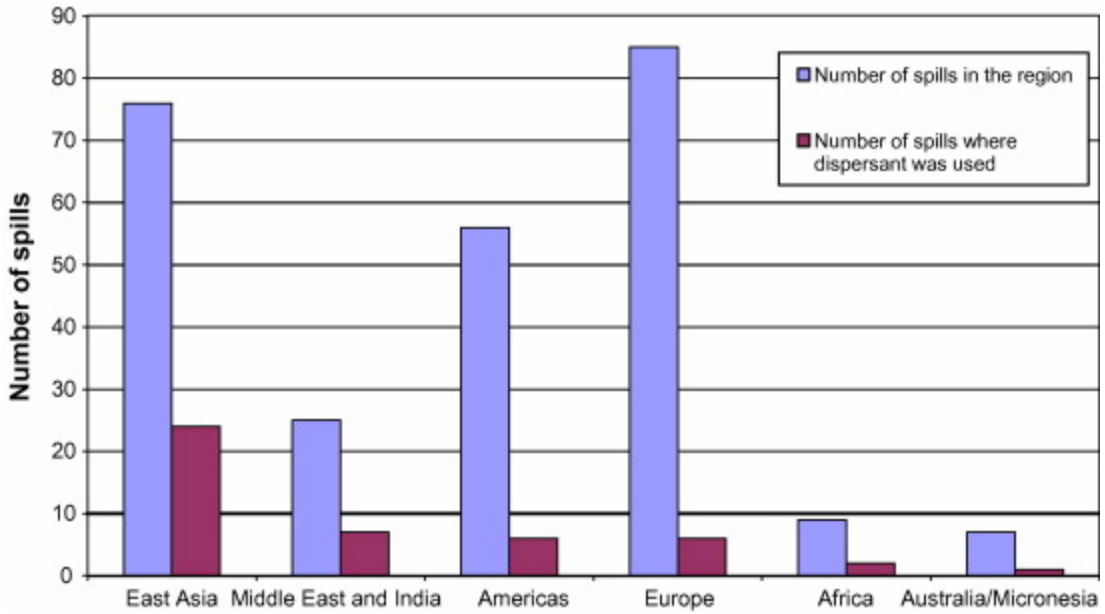

Fig. 1. Regional distribution of spills and dispersant use.
(Chapman et al., 2007, MPB)

Recent Dispersant Use (1995 – 2000): Non-US Spills

By Fuel Type

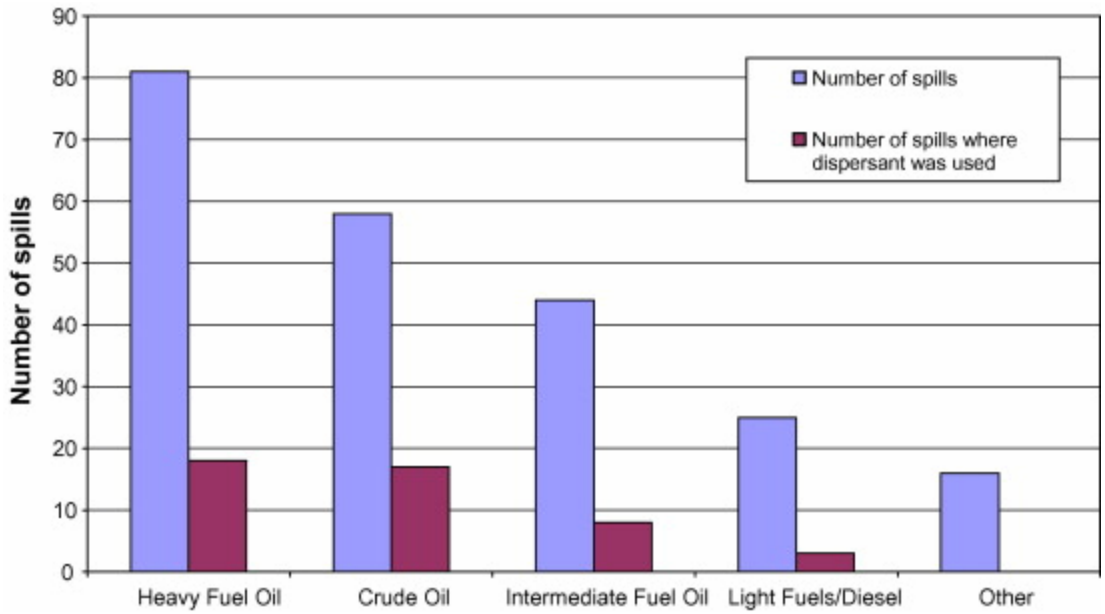

Fig. 2. Oil-type distribution of spills and dispersant use. **(Chapman et al., 2007, MPB)**

NRC Report 2005

Dispersants Initiative

- NRC report on dispersants efficacy and effects recommended:
  - Integration of research plans
  - Need for peer-reviewed information and environmentally-meaningful studies
  - CRRC's mission to address national issues related to spills
    - Act as a hub for oil spill research
    - Foster collaboration

Efficacy/Effects of Dispersant Use

- Dispersant-related issues CRRC focus since inception
  - NRC Report - 2005
  - Annual Request for Proposal (RFP) topic
  - Sept 2005 workshop
  - CRRC leads Dispersants Working Group (DWG)
- Dispersants emphasis continues because of:
  - Continued DWG efforts because of USCG near-shore dispersant regulations
  - Questions remain

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Coordinated Dispersants Initiative

- **July 2005: CRRC and NOAA convened meeting of U.S. funding entities: USEPA, MMS, USCG, TXGLO, OSRI, LA OSRADP, CAOSPR, API and other Industry reps**
- **Unanimous agreement to participate in integrated research plan**
  - **Formed Dispersants Working Group (DWG) in Fall 2005, with expanded membership**
  - **Expanded in 2006 to include international funding entities**

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Dispersants Workshops

- CRRC Workshop on Sept 20-21,2005
  - Outcome of workshop = report of research needs, RFP topics and brief descriptions
  - DWG members use these as basis for their RFPs
- February 1-2, 2007: Dispersants Research Forum in New Jersey, USA
  - DWG PIs presented current research findings
  - Included international participation
  - DWG continually determines which research needs have been addressed and what remains to be answered

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Matrix of Current Dispersed Oil Research

- Organized by topic areas identified in CRRC workshop report: “R&D Needs for Making Decisions Regarding Dispersing Oil.”
- Funding entities provided data for the matrix
- Includes project title/PIs, coverage of research topic, completion date, funding, and manuscripts/contact information
- Demonstrates impressive, collaborative effort in filling research gaps

Major Topic Areas

1) Efficacy 1: Chemical parameters
2) Efficacy 2: Operational & hydrodynamic parameters
3) Efficacy 3: Modeling integration of chemical, operational & hydrodynamic parameters
4) Effects 1: Fate of oil and dispersed oil in the water column & other habitats
5) Effects 2: Realistic Exposure Regimes/Toxicity Testing
6) Effects 3: Integration to improve short & long-term predictions of effects

Dispersed Oil Research Forum

- **All presentations and panel discussion notes on CRRC website**

http://www.crrc.unh.edu/workshops/dispersants_forum/index.htm