ENVIRONMENTAL EFFECTS OF ARCTIC OIL SPILLS AND ARCTIC OIL SPILL RESPONSE TECHNOLOGIES

PROJECT 1
ARCTIC RESPONSE CONSEQUENCE ANALYSIS TABLES and
ARCAT Analysis Tool
ACES Conference (December 2014)

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Consequence Analysis

Ecosystem consequences will occur during an oil spill

Ecosystems consequence analysis is complicated

The objective of Arctic Response Consequence Analysis Tables (ARCAT) is to support scientifically valid decisions for response actions that protect the less resilient EC and VECs from exposure to oil

Consequently these decisions then reduce the time to recovery

Response Actions

Response Action	Comment
Stop the Spill Event	**Stop the event and reduce the amount of spilled oil**
1. Monitor Physical Dispersion and Natural Recovery (MNR)	Active response not necessary or more damaging – MNR
2. Mechanical Recovery (MR)	Natural booms (ice, convergent zones), active placement of booms; oil capture during ice freeze-up may enhance mechanical recovery
2.1 Enhanced Mechanical (EMR)	Herding agent may concentrate oil at surface
	De-emulsifier may improve oil recovery or biodegradation of surfaced oil
3. In Situ Burning (ISB)	Ice capture during freezing can extend time for ISB application
4. Chemical Dispersant (CD)	Response time, weather conditions, and oil weathering controls the success of CD use for surface oil – deep water releases can be implemented over longer periods
4.1 Oil Mineral Aggregate (OMA) – non-chemical dispersant	Displaced into deeper water based on settling rates of OMA/oil particles

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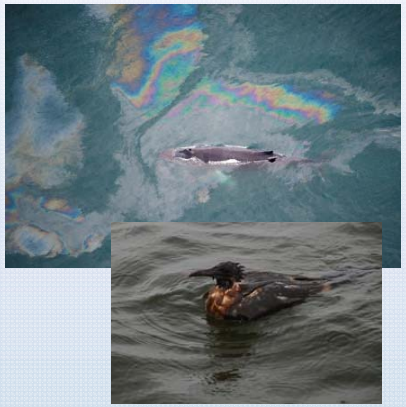
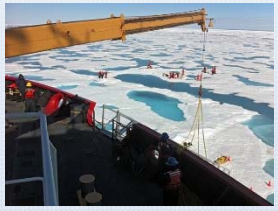
Environmental Compartments

Compartment assessment has been divided into 6 major categories for the Arctic:

1) **Atmosphere or Sea-Surface**



2) **Ice**



3) **Water Convergence Zones**

4) **Pelagic Waters**

5) **Sediment/Shorelines**

6) **Hard Substrate or Areas of Special Biological Significance**

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Valuable Ecosystem Component Factors

1. Numerically abundant prey resources critical to one or more food webs associated with EC
2. A key component supporting food sources used by subsistence harvesters
3. Similarly exposed to various oil spill response substances,
4. Taxa or populations concentrated to critical levels seasonally within an EC (*e.g.*, for feeding, breeding, resting), may be seasonal occupation
5. Taxa that create habitat used by other Arctic species (*e.g.,* ice algae, hard and soft corals)
6. Species that represent a functional role (*e.g.* bioturbation, scavenging, oil or gas utilizers)
7. Species that can be studied in the field or laboratory for individual responses that can represent rare or large species
8. Unique species or those with population sizes already at risk

Resilience (EC)

EC Resilience – factors that accelerate or delay removal of oil from exposed EC

- Volatilization
- Ice scour
- Waves – on beaches may accelerate cleansing by remobilization but in water may slow process by emulsification of oil)
- Currents – may flush system but may also re-aggregate oils on convergence zones.
- Fosters aerobic or anaerobic processes of microbial use/degradation
- Storage pockets (e.g., interstitial waters surrounding shoreline rocks; floating on interstitial water tables)

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Resilience (VEC)

VEC Resilience

- Age class and mortality rates (does a population have multiple breeding classes, is there a change in natural mortality rates among age classes, what is population size class variation among normal years, age class sensitivity to oil spill treatment residuals?
- Age to maturity (weeks to decades)
- Fecundity
  - Age related progeny production
  - Multiple or single year classes
  - Fitness of progeny following contaminant exposure
  - R or K reproductive strategies
- Spatial patterns of species distributions (world-wide or limited distribution)
  - Habitat specificity
  - Fragmented distributions (separate gene pools)
  - Spatial patterns of populations for different activities (e.g., feeding, resting, breeding)
  - Broadly distributed
- Production compared to population (subpopulation) sizes
  - Biomass assessments
  - Numerical assessments – resiliency is probably best evaluated using abundance as a key rather than biomass
- Migratory patterns
- Influences other trophic levels within or outside of EC
- Removal of tainting

Atmosphere, Sea-Surface, and Pelagic Compartments

Environmental Compartments		Exposure Components	Exposure Types
Atmosphere (ATM)		Volatiles ISB Residues Soluble compounds in aerosols	• Acute respiratory exposure to volatile or soluble aerosol components • Respiratory exposure to airborne ISB ash particles
Air Water Interface (SML)		Total oil ISB Residues Weathered, emulsified materials	• Fouling of exposed organism surfaces • Chronic toxicity of ingested components – skim feeding, particle picking • ISB ash particle deposition • Weathering alters bioavailability for exposure
Pelagic Open Water	Upper 1 m of sea surface	Soluble components Physically dispersed oil globules Chemically dispersed oil droplets OMA aggregates Hydrated Ash Residues Weathered, emulsified materials	• Acute exposure to soluble components via epithelial contact • Ingestion of globules, droplets, aggregates and ash residues with tissue uptake of contaminants • Chemical uptake to effects based concentrations • Weathering alters bioavailability for MOA
	Upper 10 m of sea surface	Chemically dispersed oil droplets OMA aggregates Globular mixtures of oil, organisms and debris under various weathering states	• Droplet exposure by ingestion and component uptake • Soluble exposure from increased droplet surface area • OMA aggregate ingestion and uptake of components • Ingestion or fouling and globular oil mixtures with natural products • Weathering alters bioavailability for MOA
	Upper 100 m of sea surface	OMA complexes with natural solids Weathered complexes CD treated deep water discharge Diel vertical migration transport	• Ingestion of OMA aggregates • Weathering and association with background suspended particulates alter bioavailability • Ingestion of diel vertical migrators or fecal pellets
	Upper 1000 m of sea surface		

Measurement Attributes for ARCAT (EC and VEC)

- Physical/chemical modifications and alteration in toxicity
- Exposure to treated or untreated oils
- Sensitivity to exposure type and mode of action
- Resiliency
- Biodegradation Potential

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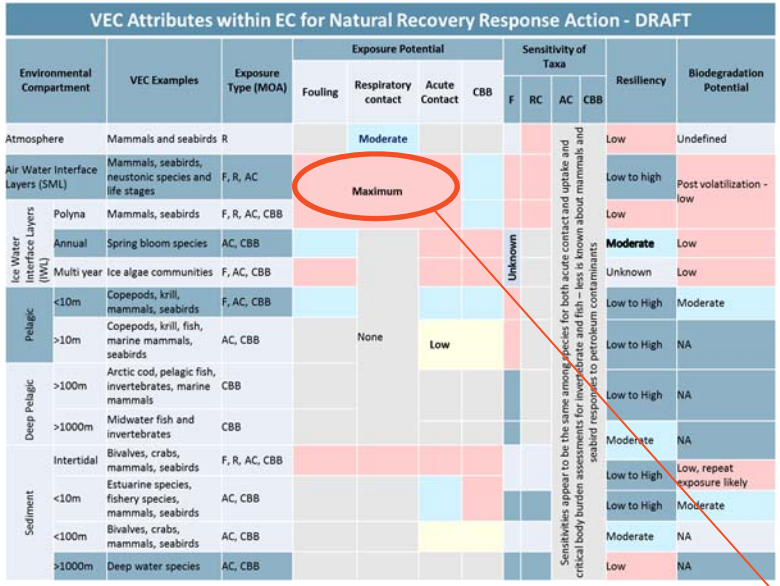
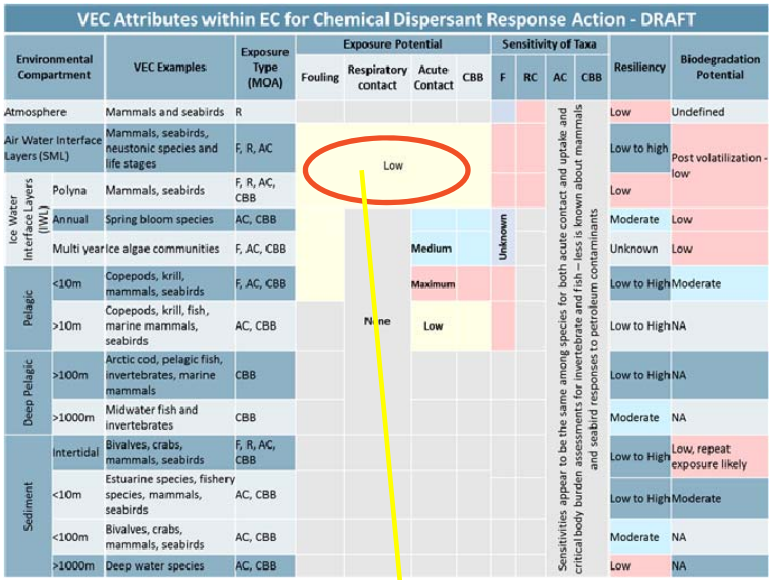
VEC Attributes within EC DRAFT EXAMPLE



VEC Attributes within EC for Natural Recovery Response Action - DRAFT

Environmental Compartment		VEC Examples	Exposure Type (MOA)	Exposure Potential: Fouling	Respiratory contact	Acute Contact	CBB	Sensitivity of Taxa: F	RC	AC	CBB	Resiliency	Biodegradation Potential
Atmosphere		Mammals and seabirds	R		Moderate							Low	Undefined
Air Water Interface Layers (SML)		Mammals, seabirds, neustonic species and life stages	F, R, AC		Maximum							Low to high	Post volatilization - low
Ice Water Interface Layers (IWL)	Polyna	Mammals, seabirds	F, R, AC, CBB									Low	
	Annual	Spring bloom species	AC, CBB					Unknown				Moderate	Low
	Multi year	Ice algae communities	F, AC, CBB									Unknown	Low
Pelagic	<10m	Copepods, krill, mammals, seabirds	F, AC, CBB									Low to High	Moderate
	>10m	Copepods, krill, fish, marine mammals, seabirds	AC, CBB		None	Low						Low to High	NA
Deep Pelagic	>100m	Arctic cod, pelagic fish, invertebrates, marine mammals	CBB									Low to High	NA
	>1000m	Midwater fish and invertebrates	CBB									Moderate	NA
Sediment	Intertidal	Bivalves, crabs, mammals, seabirds	F, R, AC, CBB									Low to High	Low, repeat exposure likely
	<10m	Estuarine species, fishery species, mammals, seabirds	AC, CBB									Low to High	Moderate
	<100m	Bivalves, crabs, mammals, seabirds	AC, CBB									Moderate	NA
	>1000m	Deep water species	AC, CBB									Low	NA

Sensitivities appear to be the same among species for both acute contact and uptake and critical body burden assessments for invertebrate and fish – less is known about mammals and seabird responses to petroleum contaminants



VEC Attributes within EC for Chemical Dispersant Response Action - DRAFT

Environmental Compartment		VEC Examples	Exposure Type (MOA)	Exposure Potential: Fouling	Respiratory contact	Acute Contact	CBB	Sensitivity of Taxa: F	RC	AC	CBB	Resiliency	Biodegradation Potential
Atmosphere		Mammals and seabirds	R									Low	Undefined
Air Water Interface Layers (SML)		Mammals, seabirds, neustonic species and life stages	F, R, AC		Low							Low to high	Post volatilization - low
Ice Water Interface Layers (IWL)	Polyna	Mammals, seabirds	F, R, AC, CBB									Low	
	Annual	Spring bloom species	AC, CBB							Unknown		Moderate	Low
	Multi year	Ice algae communities	F, AC, CBB			Medium						Unknown	Low
Pelagic	<10m	Copepods, krill, mammals, seabirds	F, AC, CBB			Maximum						Low to High	Moderate
	>10m	Copepods, krill, fish, marine mammals, seabirds	AC, CBB		None	Low						Low to High	NA
Deep Pelagic	>100m	Arctic cod, pelagic fish, invertebrates, marine mammals	CBB									Low to High	NA
	>1000m	Midwater fish and invertebrates	CBB									Moderate	NA
Sediment	Intertidal	Bivalves, crabs, mammals, seabirds	F, R, AC, CBB									Low to High	Low, repeat exposure likely
	<10m	Estuarine species, fishery species, mammals, seabirds	AC, CBB									Low to High	Moderate
	<100m	Bivalves, crabs, mammals, seabirds	AC, CBB									Moderate	NA
	>1000m	Deep water species	AC, CBB									Low	NA

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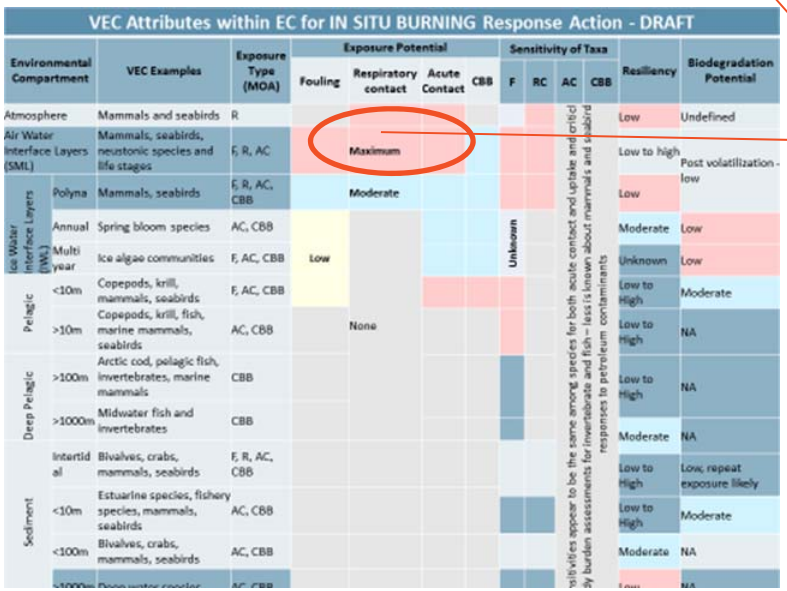

VEC Attributes within EC for IN SITU BURNING Response Action - DRAFT

Environmental Compartment		VEC Examples	Exposure Type (MOA)	Exposure Potential: Fouling	Respiratory contact	Acute Contact	CBB	Sensitivity of Taxa: F	RC	AC	CBB	Resiliency	Biodegradation Potential
Atmosphere		Mammals and seabirds	R									Low	Undefined
Air Water Interface Layers (SML)		Mammals, seabirds, neustonic species and life stages	F, R, AC		Maximum							Low to high	Post volatilization - low
Ice Water Interface Layers (IWL)	Polyna	Mammals, seabirds	F, R, AC, CBB		Moderate							Low	
	Annual	Spring bloom species	AC, CBB	Low				Unknown				Moderate	Low
	Multi year	Ice algae communities	F, AC, CBB									Unknown	Low
Pelagic	<10m	Copepods, krill, mammals, seabirds	F, AC, CBB									Low to High	Moderate
	>10m	Copepods, krill, fish, marine mammals, seabirds	AC, CBB		None							Low to High	NA
Deep Pelagic	>100m	Arctic cod, pelagic fish, invertebrates, marine mammals	CBB									Low to High	NA
	>1000m	Midwater fish and invertebrates	CBB									Moderate	NA
Sediment	Intertidal	Bivalves, crabs, mammals, seabirds	F, R, AC, CBB									Low to High	Low, repeat exposure likely
	<10m	Estuarine species, fishery species, mammals, seabirds	AC, CBB									Low to High	Moderate
	<100m	Bivalves, crabs, mammals, seabirds	AC, CBB									Moderate	NA
	>1000m	Deep water species	AC, CBB									Low	NA

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Optimum Recovery Potential = low exposure potential + high biodegradation + high resiliency and low sensitivity

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PROJECT 1 TASKS	DELIVERABLES	RESPONSIBLITY	Schedule (NTP-August 2014)	COMMENT
1	Oil Spill Response (OSR) options	Akvaplan Niva (A/N)	September	Established the options to be considered for ARCAT
2	Justify Environmental Compartments (EC) and Valuable Ecosystem Components (VEC)	ENVIRON less SML and Ice/Water Interface = A/N	October	Need EC and VEC information for SML and Ice/Water Interface from A/N
3	Map EC seasonal distribution	LGL	January	Basic framework of EC seasonality
4	Nearshore fishery GIS - seasonal	LGL	January	30 Year compilation and paper on nearshore fishery distributions
5	Marine mammal seasonal distribution	LGL	January	Marine mammal use of seasonal EC
6	Seabird seasonal distribution	LGL	March	Seabird seasonal use of EC
7	Pelagic fish and invertebrate seasonal distribution	LGL	March	VEC seasonal use of EC
8	Collation of OSR residual toxicity data	ENVIRON	January	Contribution to data base
9	Preliminary ARCAT	ENVIRON	October	Draft ARCAT distribution to Teams
10	Finalization of ARCAT	ENVIRON	May	Populate ARCAT with data and ID areas with minimal data
11	Resiliency Scale Development	ENVIRON	January	Provide to A/N for use with SML and Ice/Water Interface communities
12	Behavioral and physiological mammal and seabird factors	LGL/ENVIRON	February	Behavioral adaptations that alter exposure
13	Food web/chain complexity	ENVIRON	January	Structured versus unstructured food webs
14	NEBA/ECA scoring/visualization tool	ENVIRON	July	Visualization tool demonstration

ARCAT Analysis Tool for Evaluating the Ecological Consequences of Oil Spill Response