Guidance for Dispersant Decision Making: Potential for Impacts on Aquatic Biota

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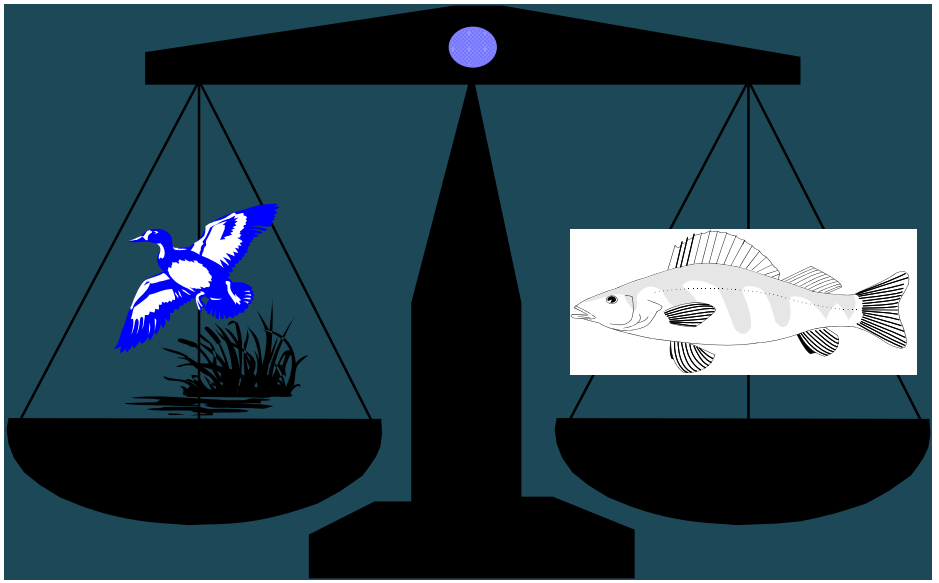
Problem Addressed

Spill Response – Biologically/Ecologically Driven:

Trade-off decisions in response based on expected level of resource injury

Use of chemical dispersants

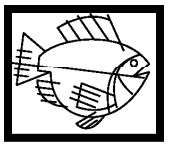
Quantify tradeoff



Oil Spill Impact Guide (OSIG)

Use oil fate and biological exposure modeling to quantify impacts

- **Area and Volume Indices**
  - **Surface area impacted by floating oil**
  - **Water volume adversely affected by dispersed oil and dissolved hydrocarbons**



- **Potential Impacts for Representative On-Shelf Locations**
  - **Birds (numbers)**
  - **Fish and invertebrates (biomass)**

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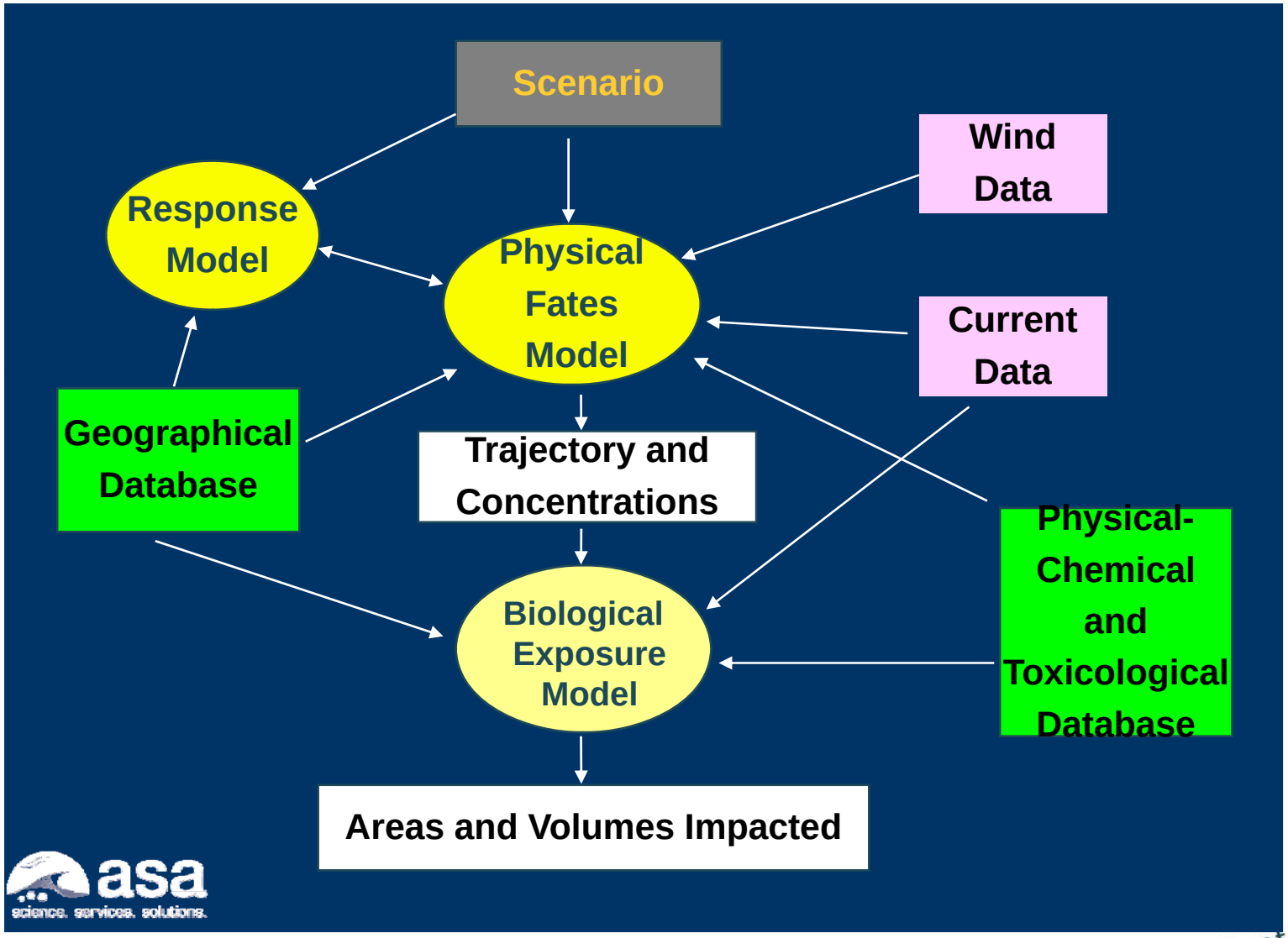
SIMAP



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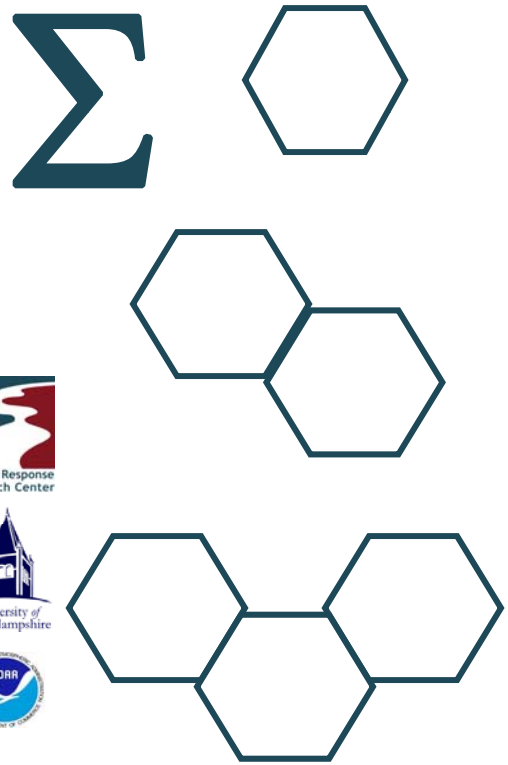
Toxic Components of Oil (Additive Effects)

Aliphatics = (e.g., alkanes) – more volatile than soluble



Monoaromatic Hydrocarbons (MAHs)

- **Benzene, Toluene, Ethylbenzene and Xylenes = BTEX – highly soluble, highly volatile, moderately toxic**
- **Alkyl-substituted Benzenes – soluble, less volatile, more toxic**

Polynuclear Aromatic Hydrocarbons (PAHs)

- **Naphthalenes (2-ring PAHs)**
  - **soluble, less volatile, more toxic**
  - **with more alkyl chains, less soluble but more toxic**
- **3 ring PAHs : Phenanthrenes, Fluorenes, Dibenzothiophenes**
- **4-ring PAHs – parent compounds bioavailable**
- **larger PAHs insoluble**

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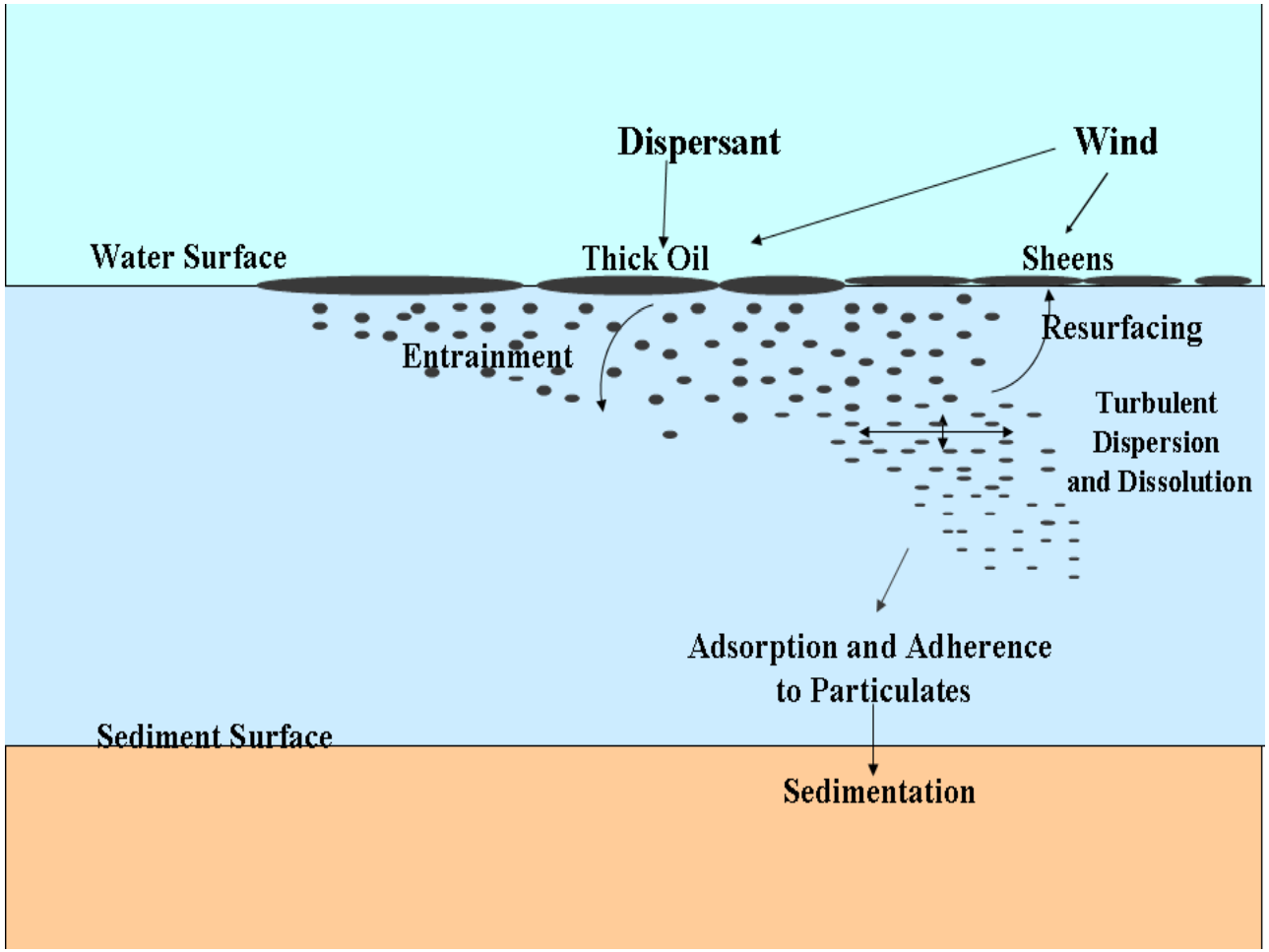
Important Fate Processes



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Biological Exposure Model

Organisms classified by behavior

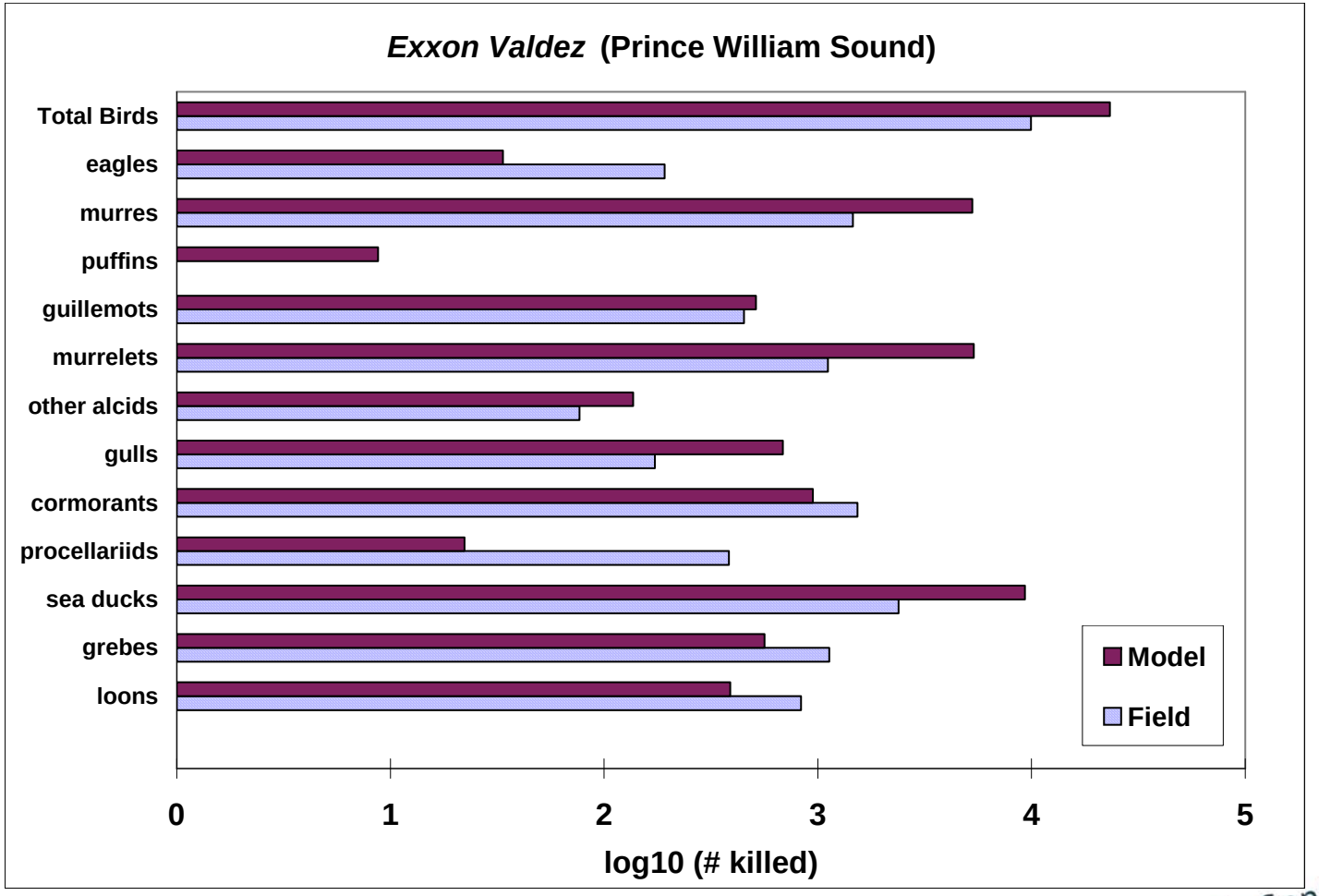
- Wildlife
  - % of time on water surface
  - Habitats used
  - Feathers & fur
- Fish and Invertebrates
  - Swimming
  - Drift with currents
  - Stationary

Movements of organisms are tracked to calculate exposure of individuals

Impact a function of dose

- Wildlife
  - Area swept
  - Slick thickness
- Fish and Invertebrates
  - Σ PAH Concentration (water, sediment pore water)
  - Exposure time
  - Temperature

Validation – Wildlife



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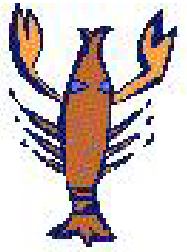
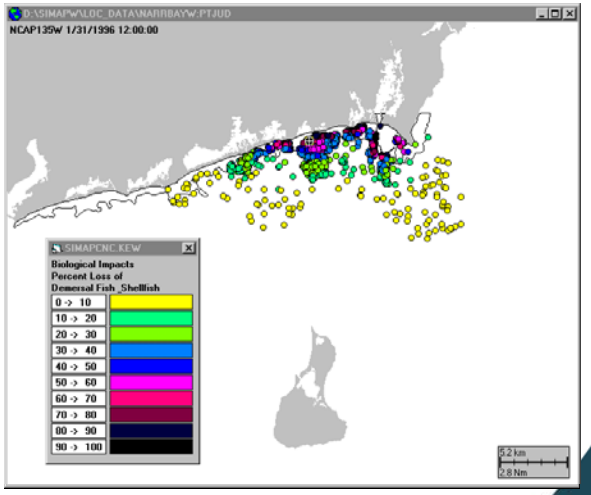
Validation – Fish and Invertebrate Toxicity

- **Oil bioassays**
  (French McCay, 2002; Envir. Tox & Chem Vol. 10)
  - **24 data sets (2 to 91 species tested)**
  - **For all data sets: model not significantly different from observed**



- ***North Cape* Oil Spill (RI, Jan 1996):**
  Lobsters
  - **Field estimate 9 million**
  - **Model estimate 8.3 million**
    - **(using best estimate of toxicity)**
  - **Strandings on beaches: 3 million**



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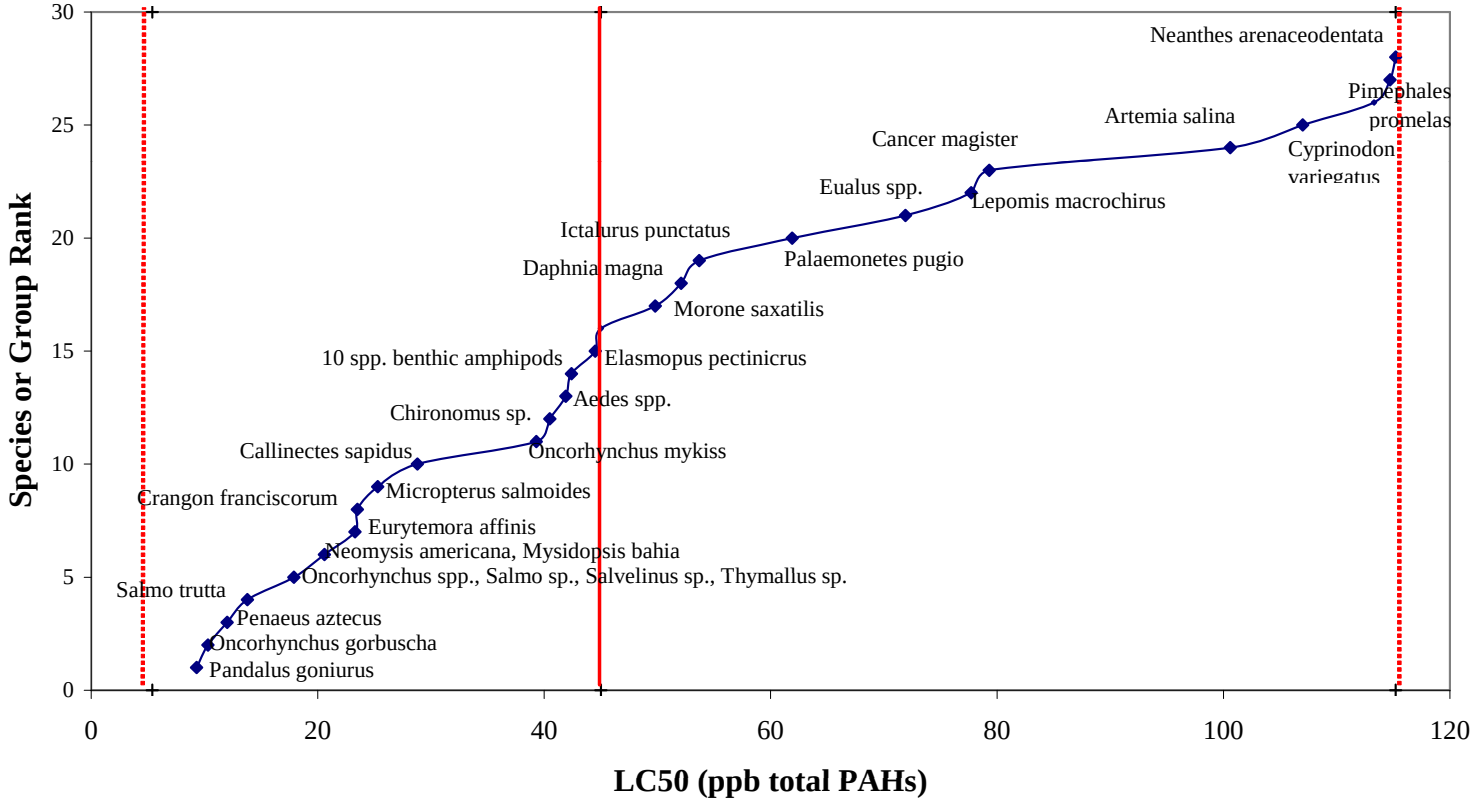
LC50 for >96hrs Exposure Time

Species Sensitivity Ranking -- PAHs in Crudes and Fuel Oils
Vertical Red Lines are Geometric Mean and Range for 95% of Species
(French McCay, 2002)



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Biological Impacts: Equivalent Areas of 100% Loss

Wildlife

(Birds primarily)

Area swept by >10 μm thick oil multiplied by probability of encounter with water surface:

[Area Swept] [Probability]

Water Column

(Plankton)

Weighted sum of volumes affected at λ% loss:

Σ [Volume] [λ/100]

Divide by mixed layer depth to calculate area of surface mixed layer affected

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Matrix of Model Runs

- Spills in open water
- Crude oils (which can be dispersed)
- Range of oil volumes (those likely to be dispersed in 1 location: < 100,000 gal)
- Vary key input variables determining impact
  - Temperature
  - Wind (light, moderate)
  - Time oil weathered before dispersed
  - Toxicity (range for 95% of species)

Model Run Matrix – Biological Data

Representative US Shelf Biological Data (used French et al. 1996 NRDAM/CME data sets)

- **Delmarva Shelf (province 15)**
- **No. Texas-LA Shelf (province 37)**
- **Central Calif. Shelf (province 44)**
- **Puget Sound and Straits (province 51)**
- **Prince Wm. Sound (province 55)**
- **Chukchi Sea (province 73)**

Product

- Results of model matrix:
  - Areas and volumes impacted
  - Injuries for example locations
- Presented in tabular and chart format (can look up order of magnitude of likely impact)
- Method of interpolation between results for intermediate spill volumes
  - Visually off chart or table
  - Regressions
  - Calculator in Excel

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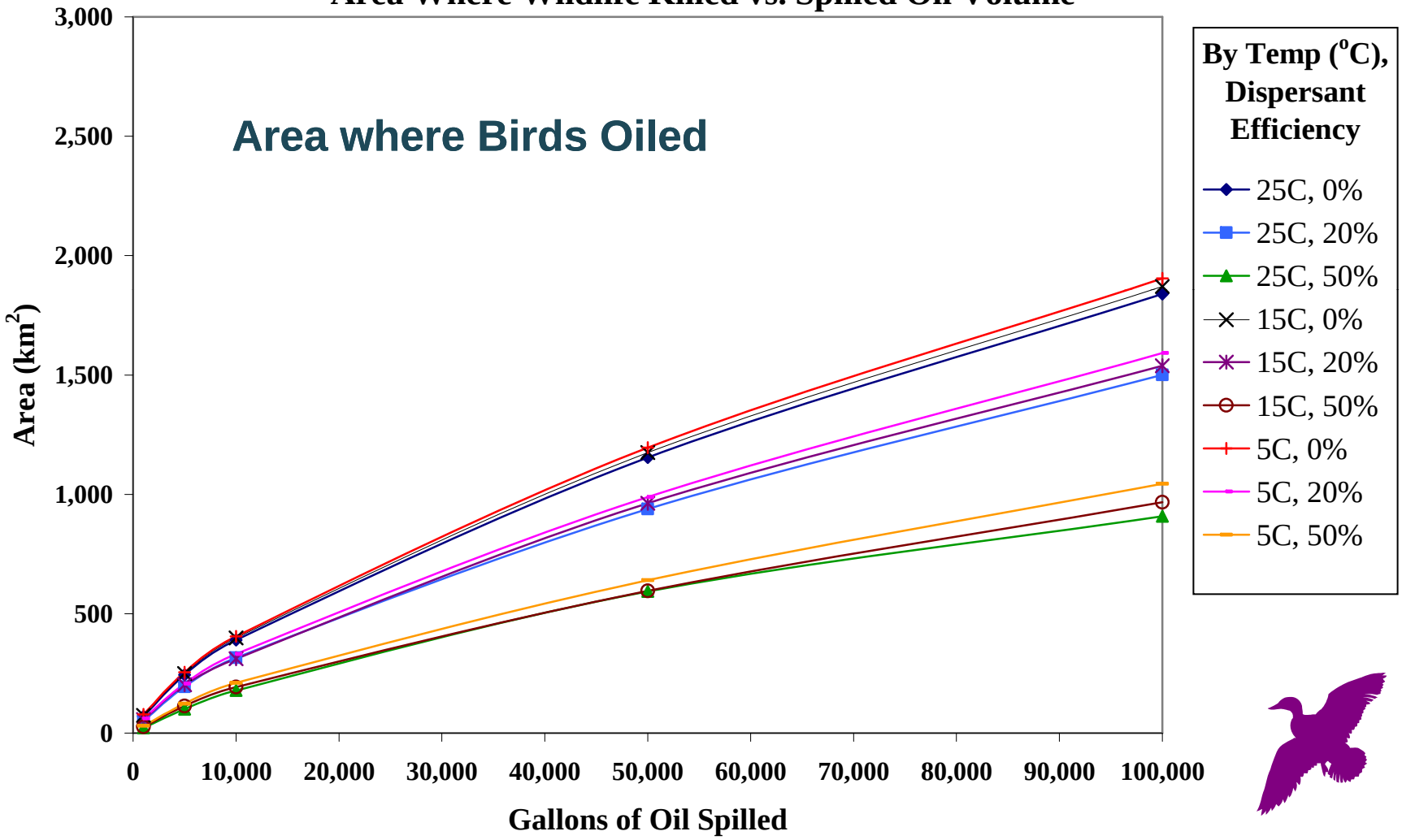
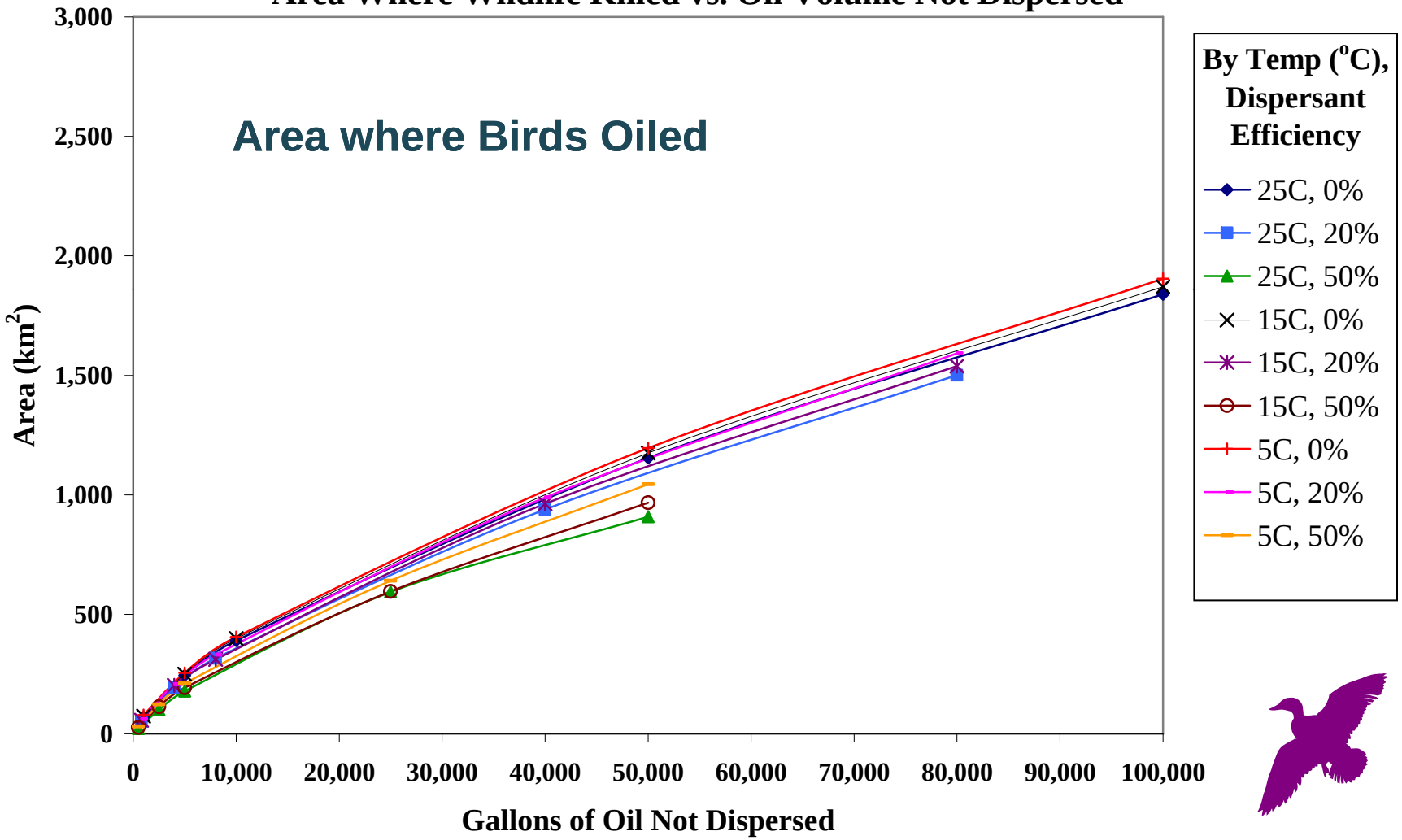
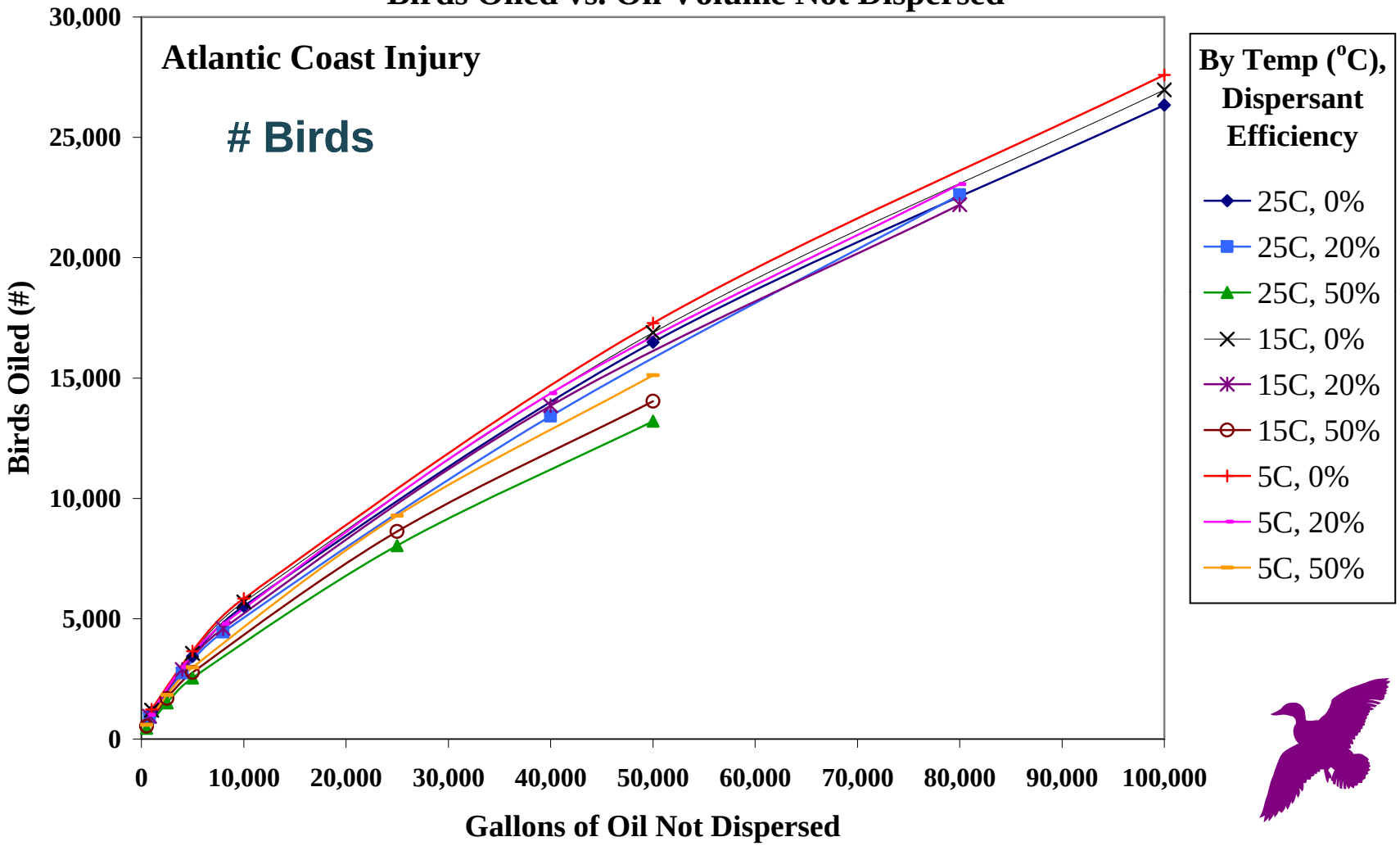
ANS Crude (Mid-Heavy), 5kt Wind, All Temperatures
Dispersant Applied after 12 hrs of Weathering:
Area Where Wildlife Killed vs. Spilled Oil Volume



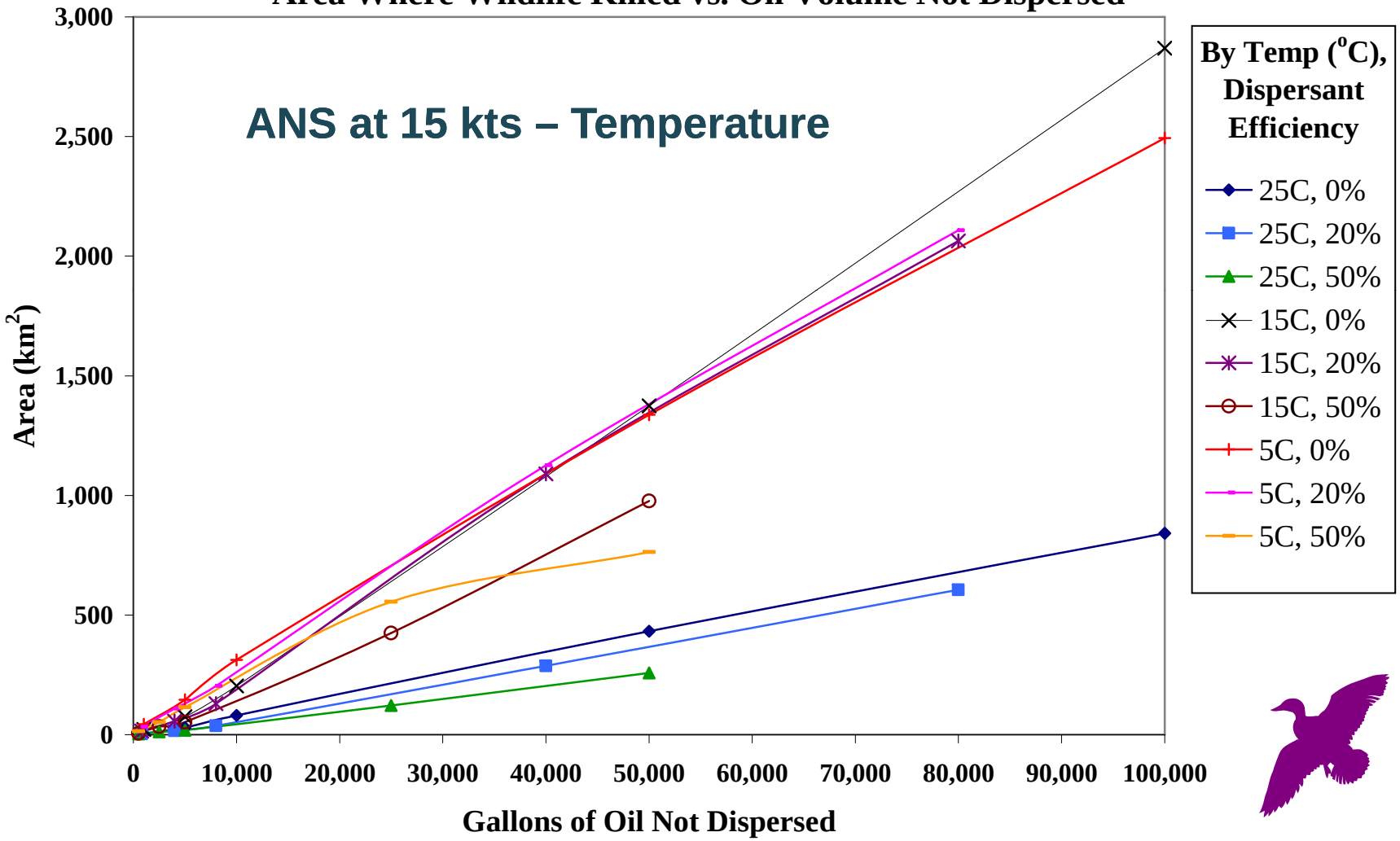
ANS Crude (Mid-Heavy), 5kt Wind, All Temperatures
Dispersant Applied after 12 hrs of Weathering:
Area Where Wildlife Killed vs. Oil Volume Not Dispersed



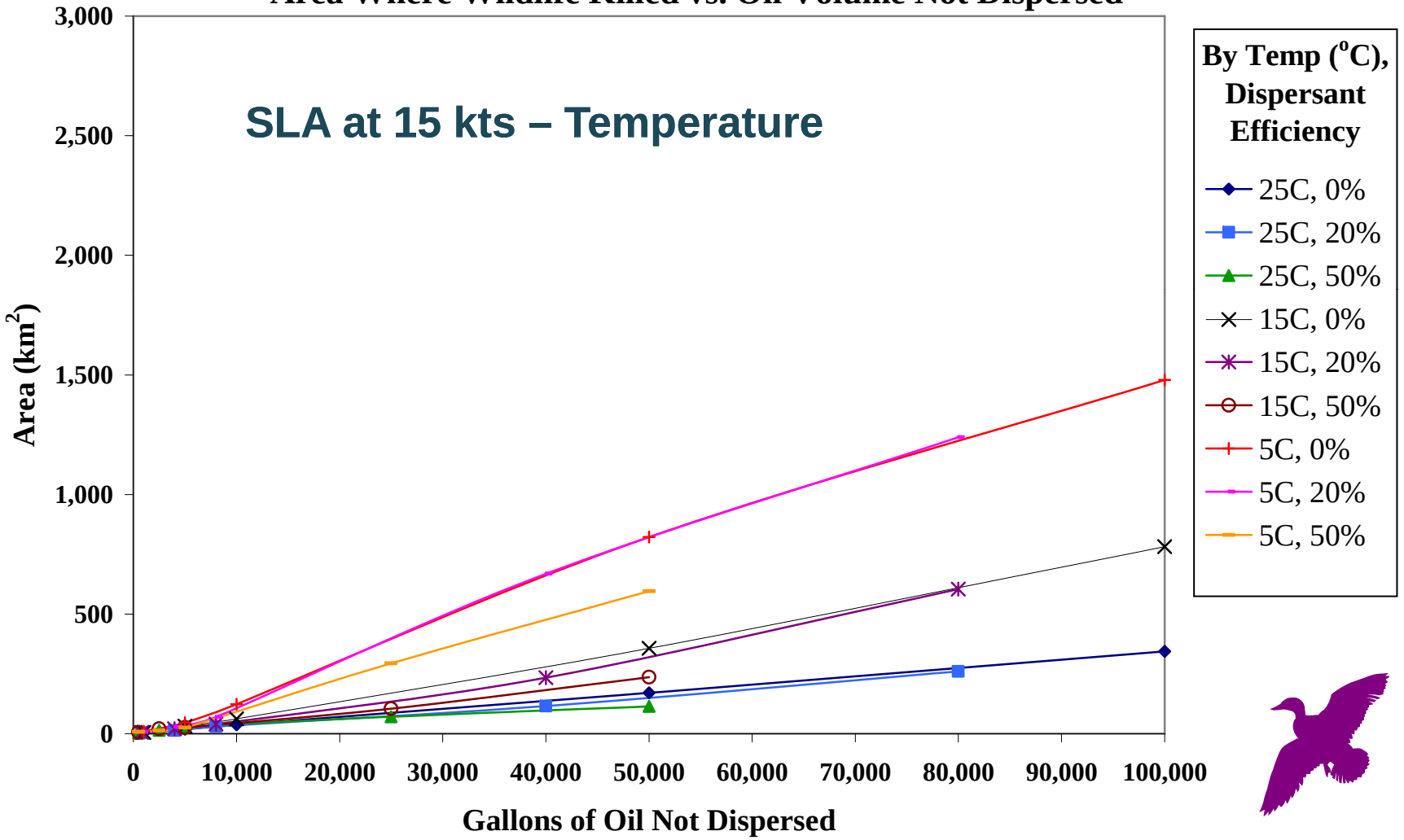
SLA Crude (Light), 5kt Wind, All Temperatures
Dispersant Applied after 12 hrs of Weathering:
Birds Oiled vs. Oil Volume Not Dispersed



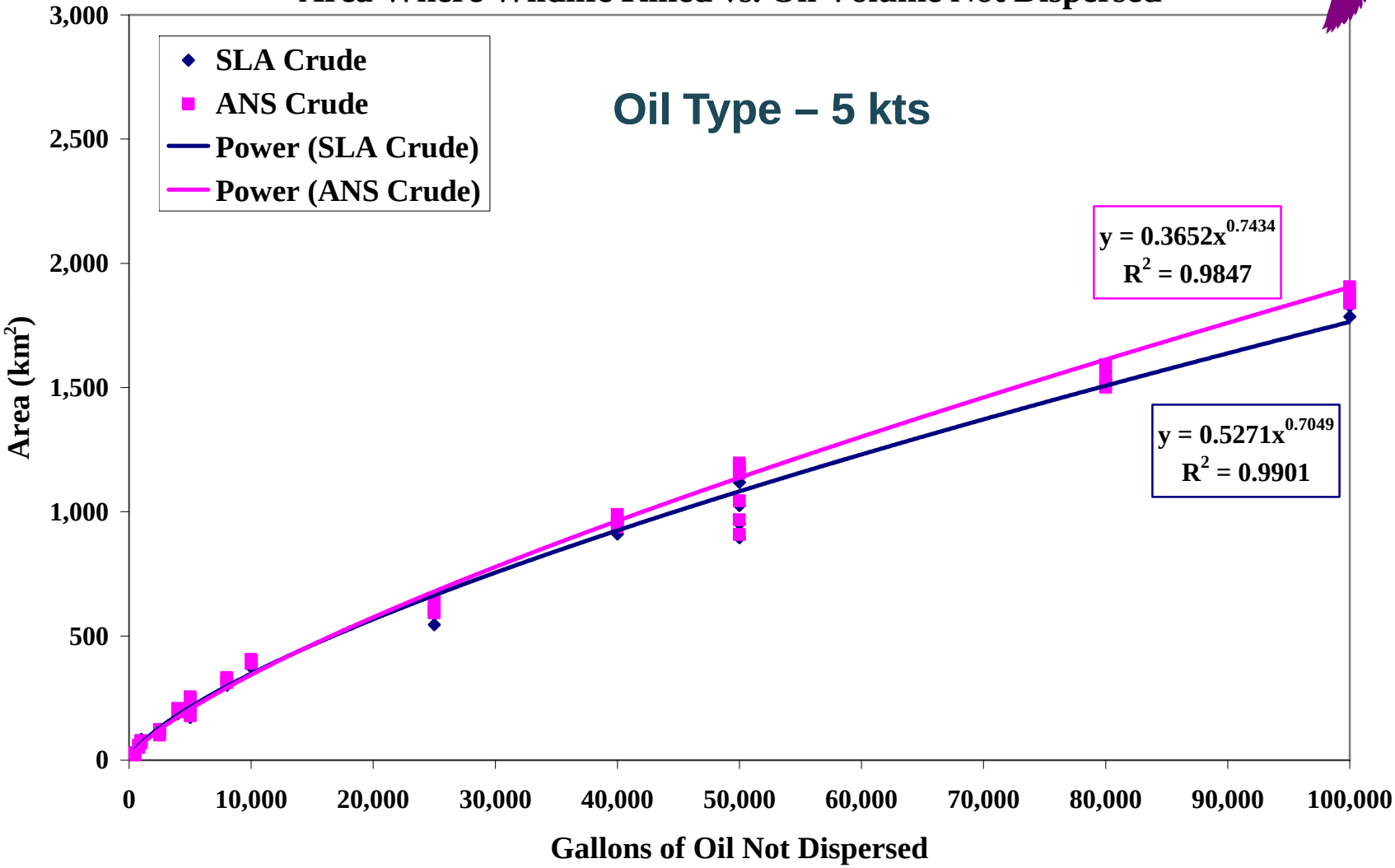
ANS Crude (Mid-Heavy), 15kt Wind, All Temperatures
Dispersant Applied after 12 hrs of Weathering:
Area Where Wildlife Killed vs. Oil Volume Not Dispersed



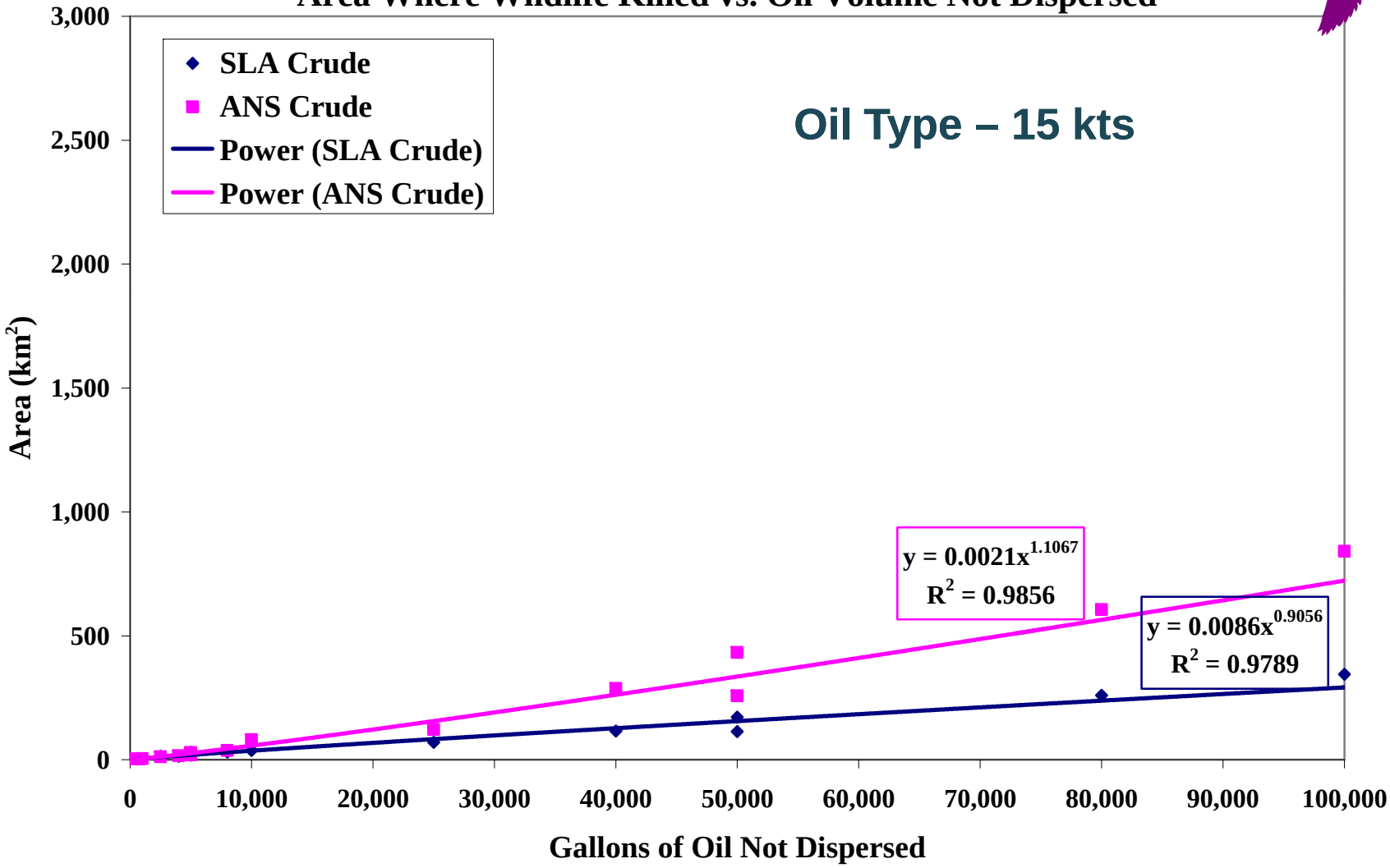
SLA Crude (Light), 15kt Wind, All Temperatures
Dispersant Applied after 12 hrs of Weathering:
Area Where Wildlife Killed vs. Oil Volume Not Dispersed



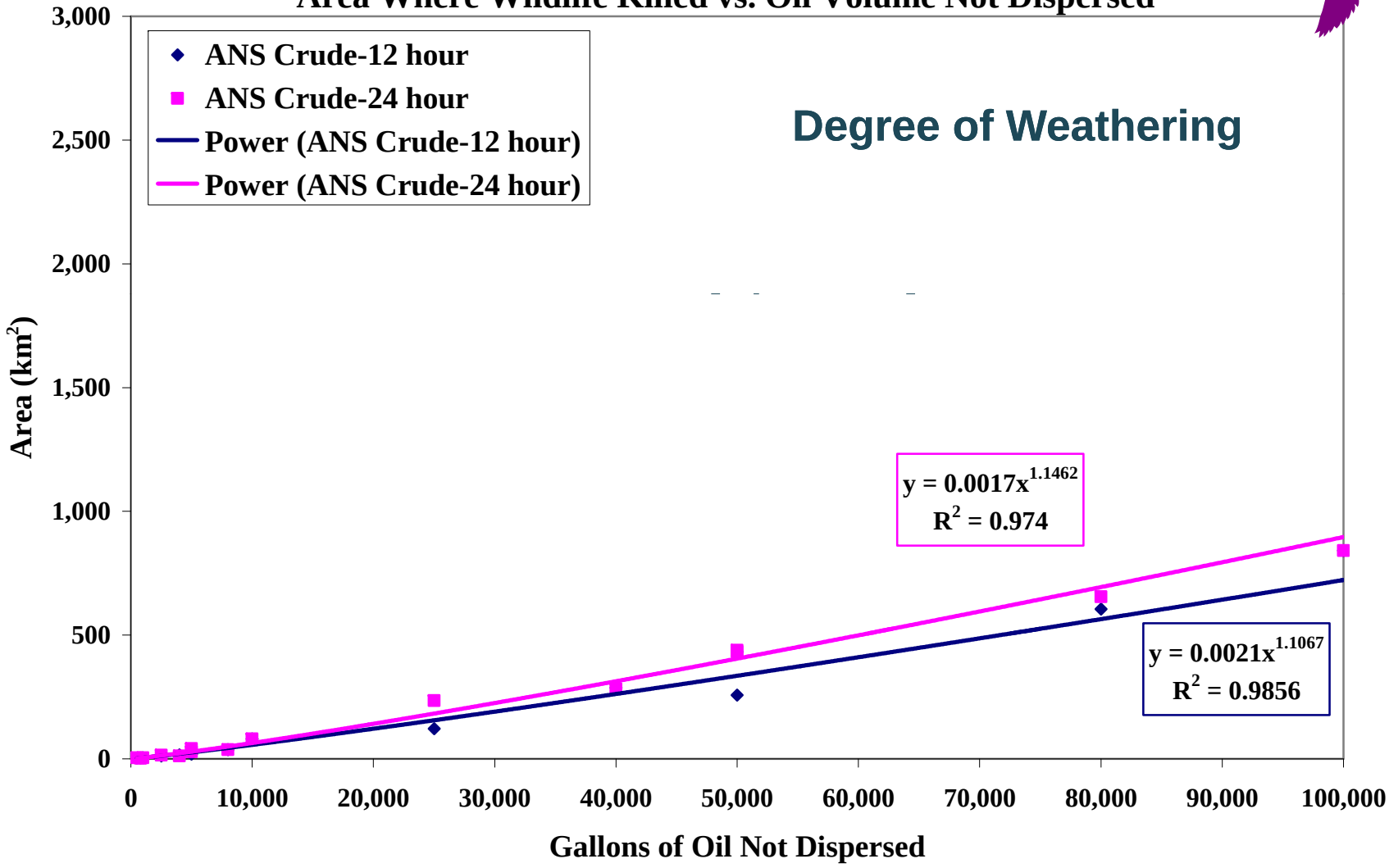
ANS vs. SLA Crude Oils, 5kt Wind, All Temperatures
Dispersant Applied after 12 hrs of Weathering:
Area Where Wildlife Killed vs. Oil Volume Not Dispersed



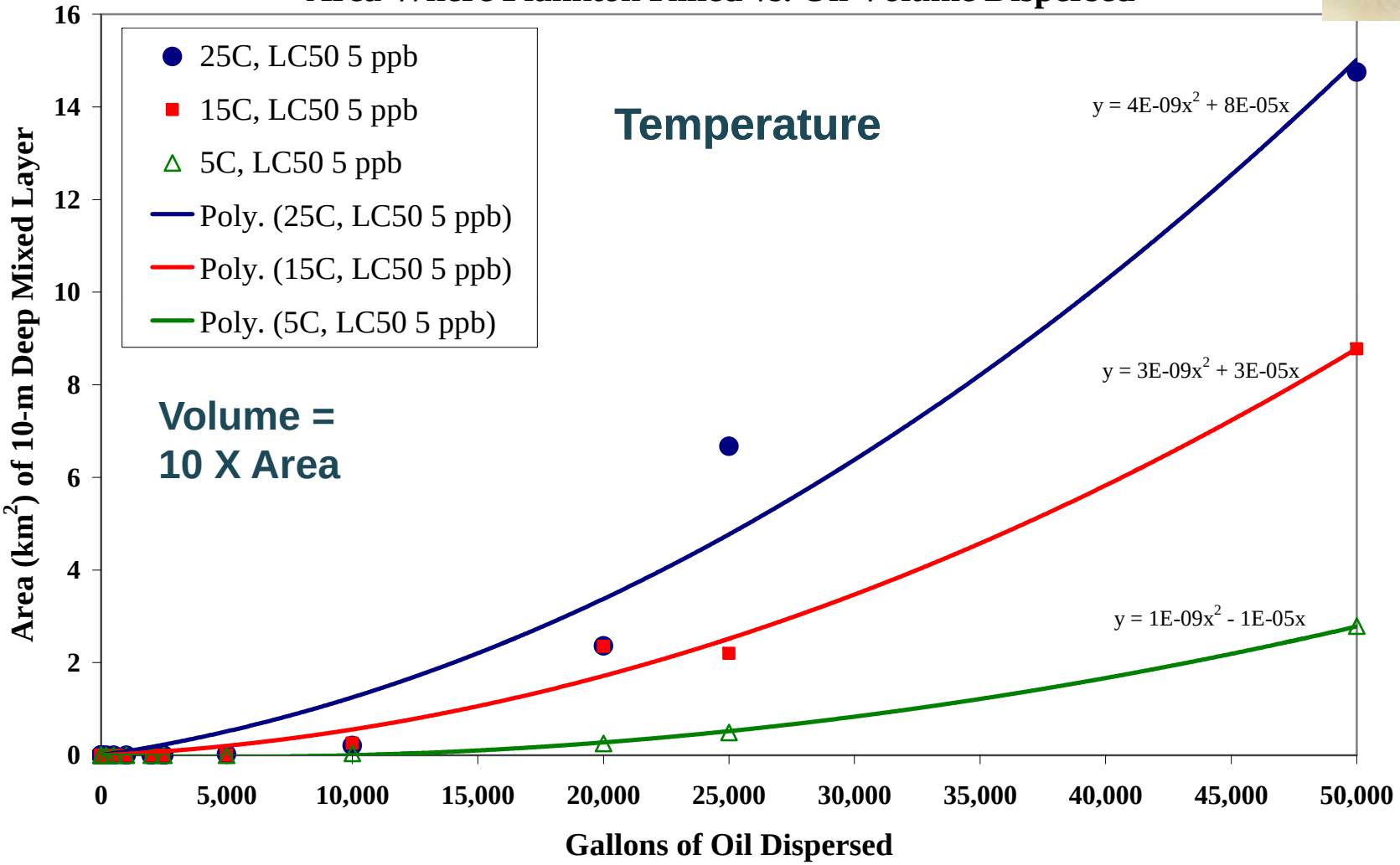
ANS vs. SLA Crude Oils, 15kt Wind, 25ºC
Dispersant Applied after 12 hrs of Weathering:
Area Where Wildlife Killed vs. Oil Volume Not Dispersed



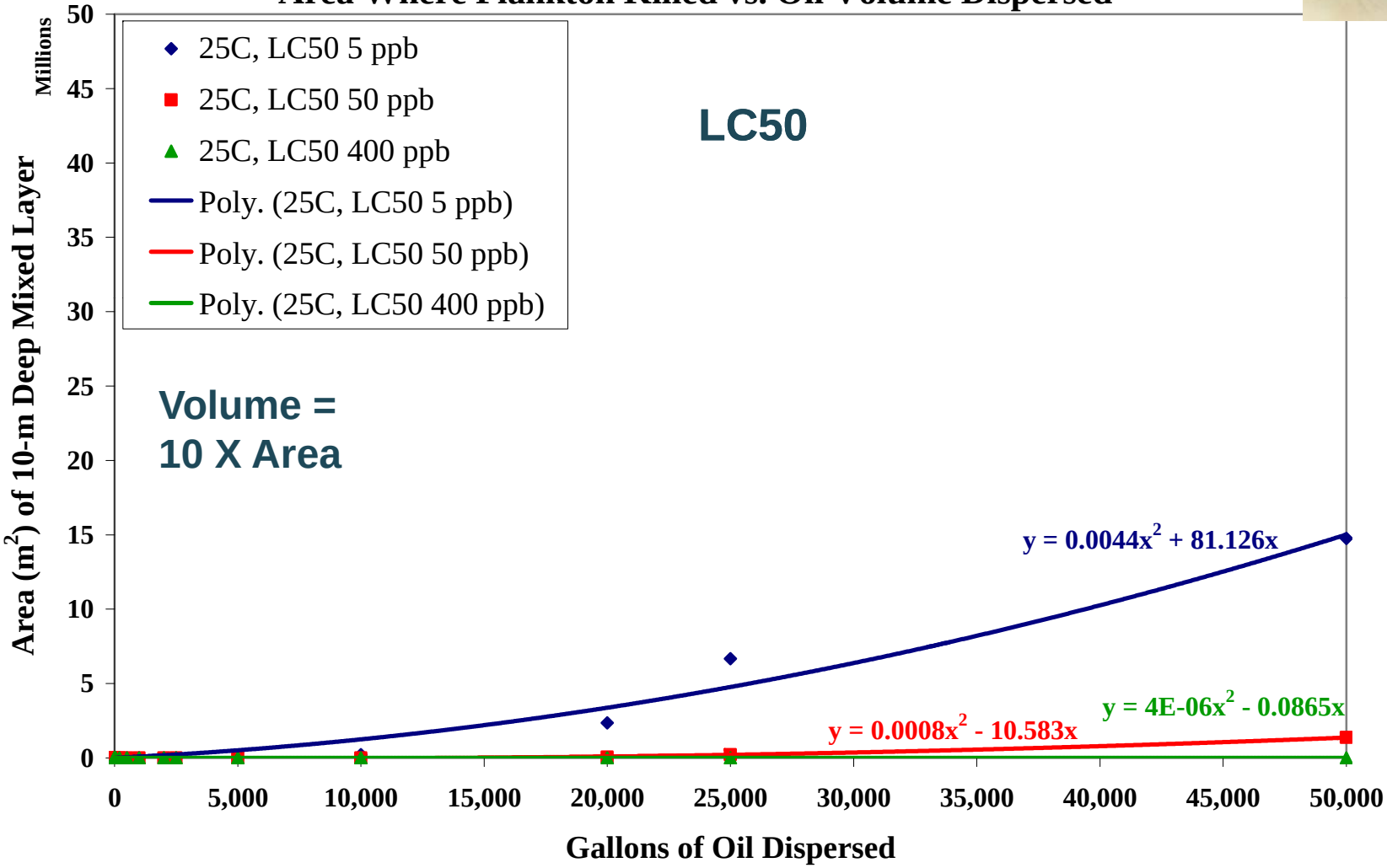
ANS Crude, 15kt Wind, 25ºC
Dispersant Applied after 12hrs vs. 24hrs of Weathering:
Area Where Wildlife Killed vs. Oil Volume Not Dispersed



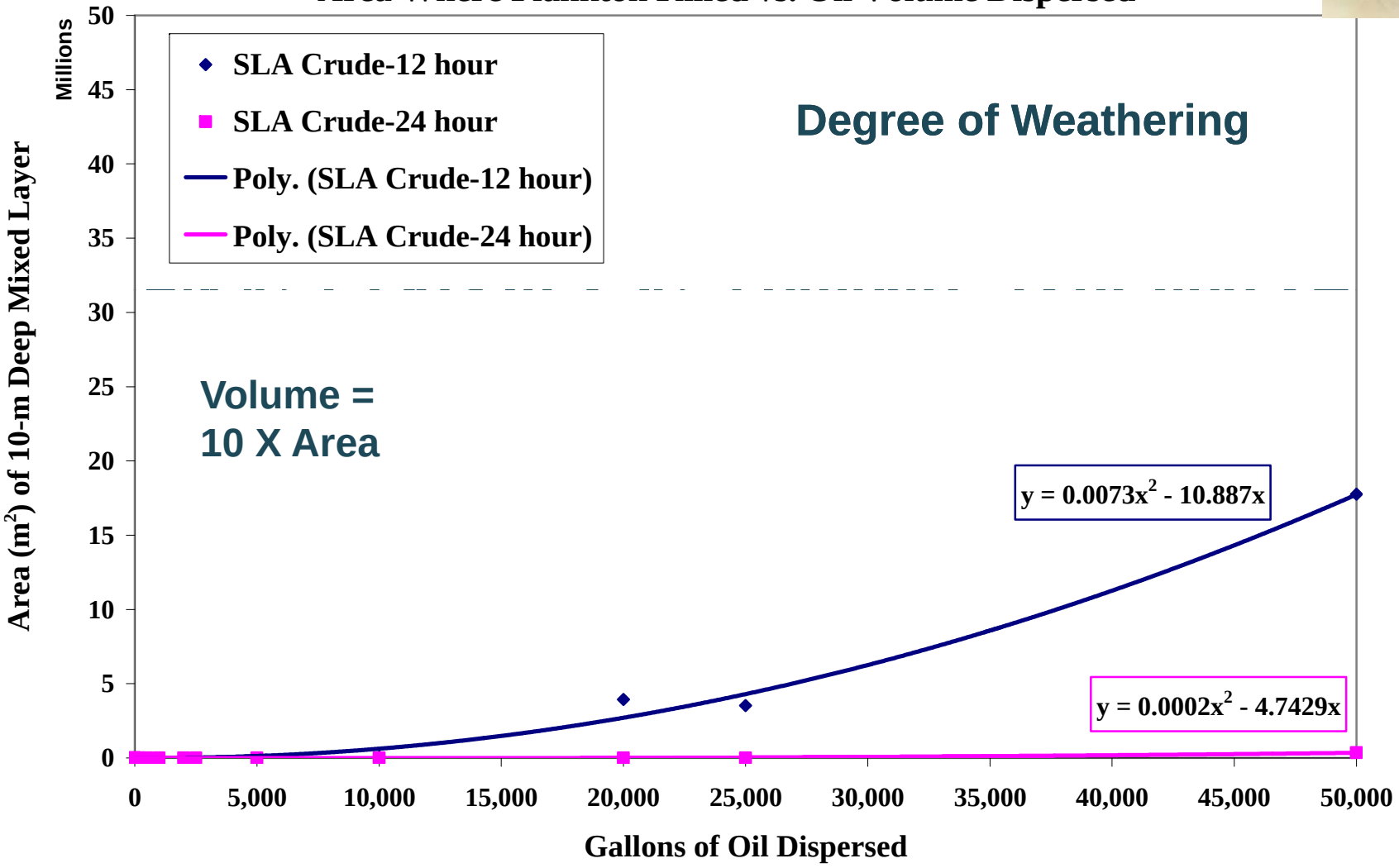
ANS Crude (Mid-Heavy), 5kt Wind, All Temperatures, Sensitive Species
Dispersant Applied after 12 hrs of Weathering:
Area Where Plankton Killed vs. Oil Volume Dispersed



ANS Crude (Mid-Heavy), 5kt Wind, 25°C
Dispersant Applied after 12 hrs of Weathering:
Area Where Plankton Killed vs. Oil Volume Dispersed



SLA Crude, 5kt Wind, 25°C, LC50 5 ppb
Dispersant Applied after 12hrs vs 24hrs of Weathering:
Area Where Plankton Killed vs. Oil Volume Dispersed



Spreadsheet-Calculator for Looking Up and Interpolating Results

User selects closest:

- Oil type
- Wind speed
- Hours Oil Weathered
- Temperature
- LC50 (fish/invert.)
- Biological Database

Impact Indices Calculated:

- Area (km^2) where wildlife would be oiled
- Total # Birds Oiled
- Equivalent volume (m^3) where 100% killed
- Equivalent area (km^2) where 100% killed
- Direct kill (kg)
- Production foregone (kg)
- Total biomass lost (kg)

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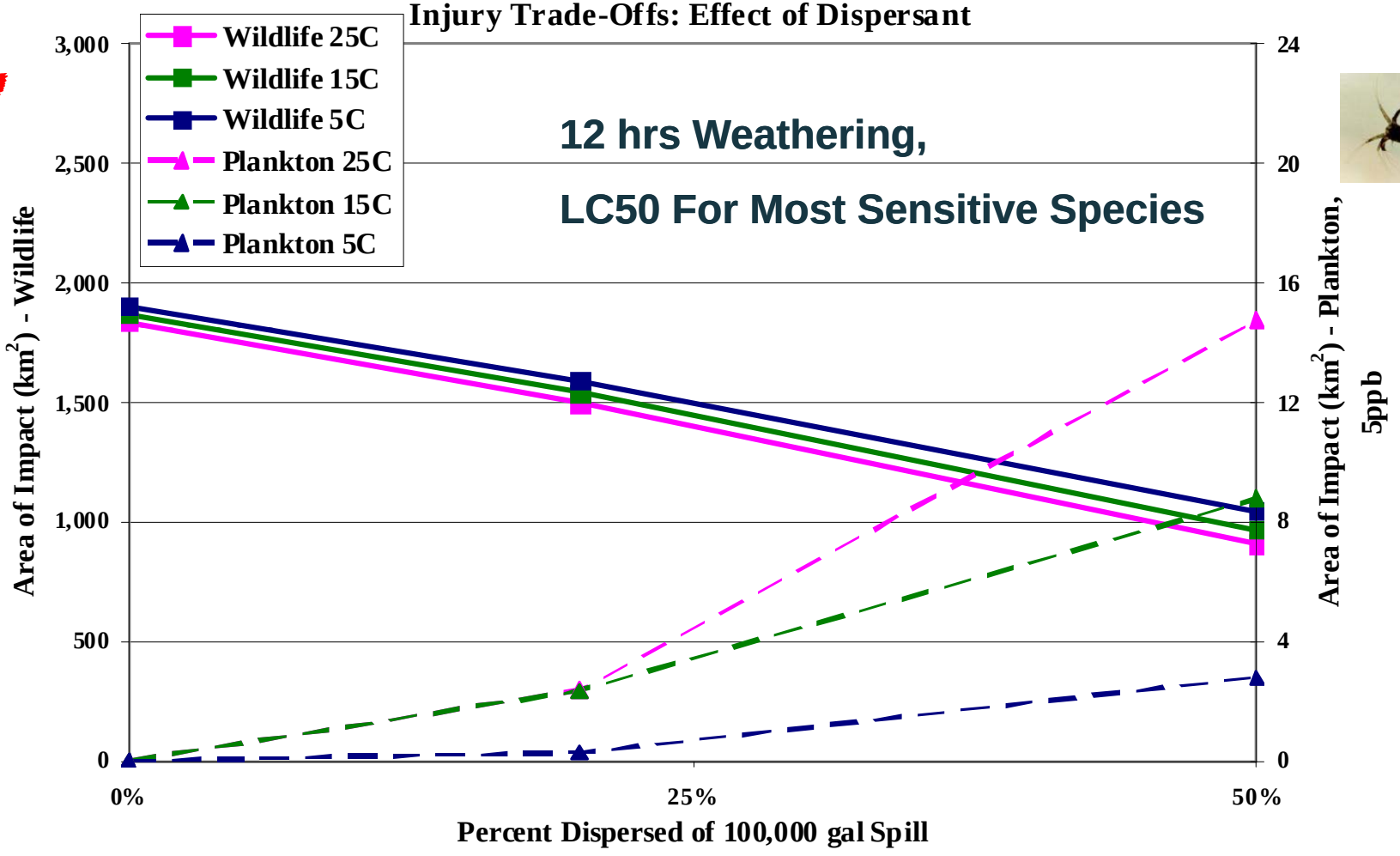
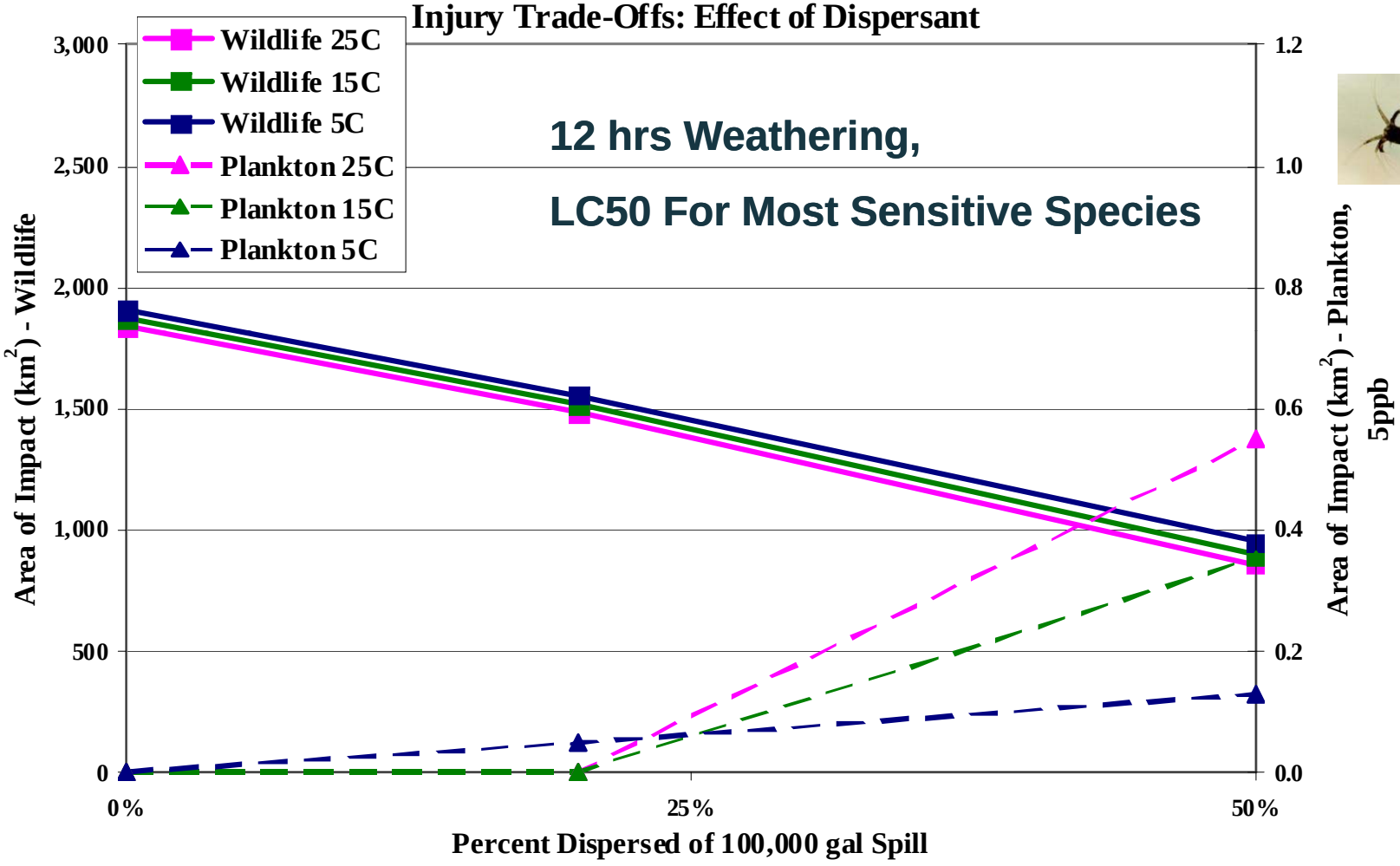
Injury Trade-Offs: Effect of Dispersant Applied after 12 hrs of Weathering
ANS Crude (Mid-Heavy), 5 kt Wind, 25°C, LC50 = 5 pppb

ANS Crude (Mid-Heavy), 5 kt Wind, All Temperatures,
Dispersant Applied after 12 hrs of Weathering:
Injury Trade-Offs: Effect of Dispersant



ANS Crude (Mid-Heavy), 5 kt Wind, All Temperatures, Dispersant Applied after 24 hrs of Weathering: Injury Trade-Offs: Effect of Dispersant



Conclusions

- Excel spreadsheet calculator
  - Easy to use, obtain results quickly
  - Freely Available
- Results useful as guidance for dispersant decision-making
- Results of dispersant tradeoffs
  - Dispersant use reduces wildlife and shoreline impacts
  - Do not have large impact to fish and invertebrates if:
    - Realistic smaller dispersed oil volumes considered
    - Oil dispersed after weathering removes toxicity

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Acknowledgement

Funding for this project is provided by the Coastal Response Research Center

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