OSU~EmEA - 16

# Environmental Impact Assessment:

Evaluating impacts of oil spills.

# Exxon Valdez

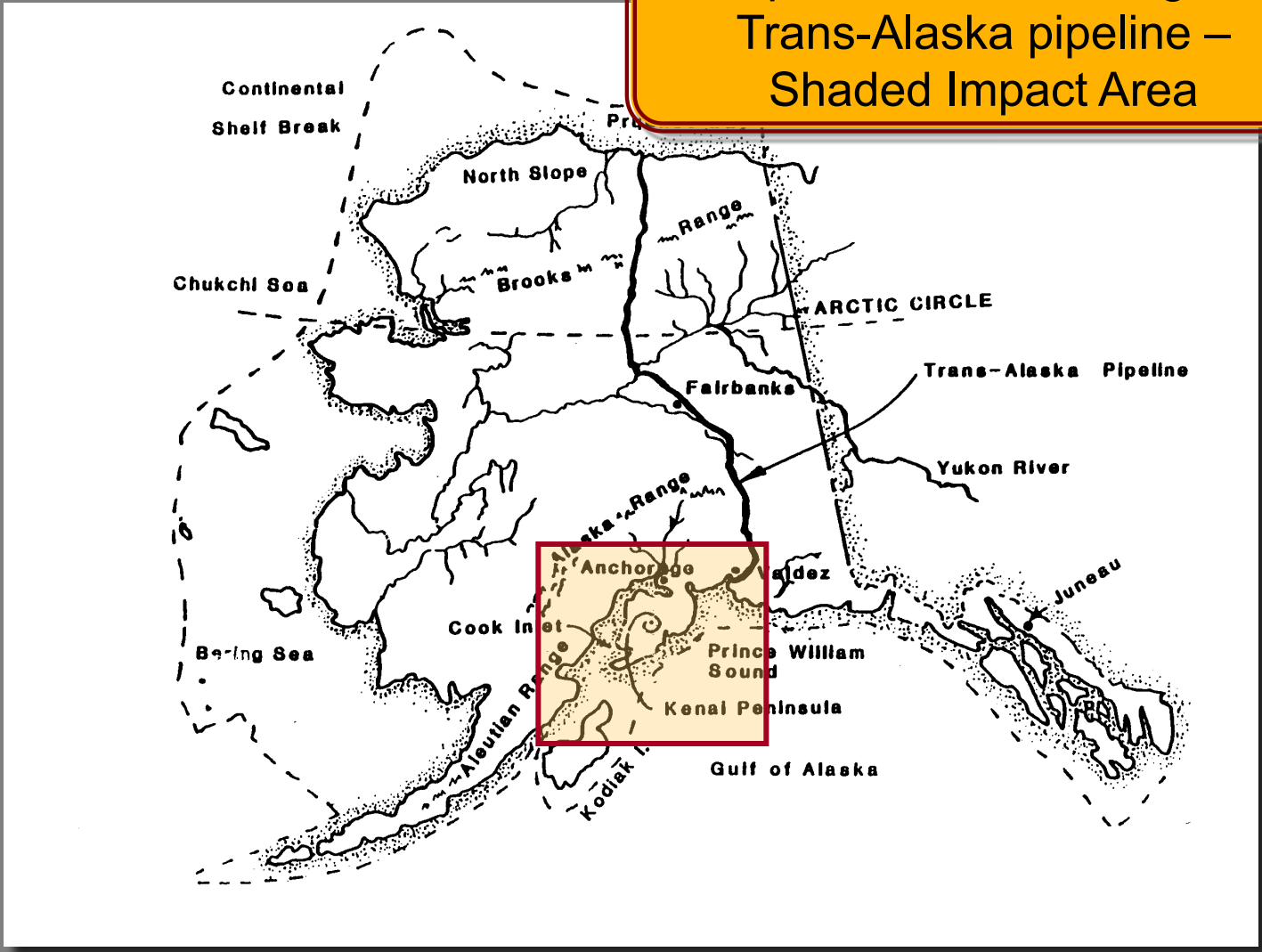
Example of environmental impact assessment of major oil “spill”

March 24, 1989

# Background...

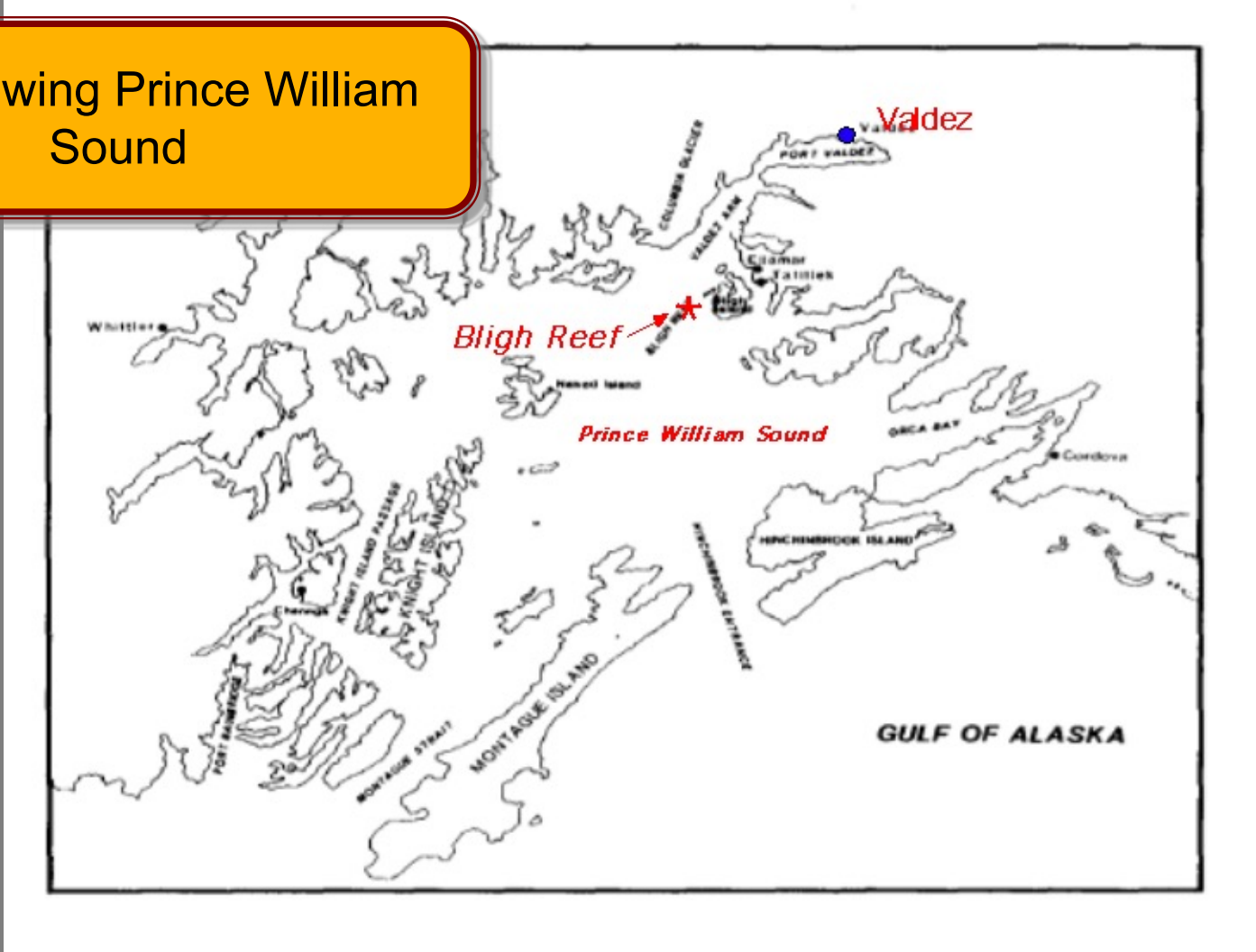
# Exxon Valdez...

Map of Alaska showing the Trans-Alaska pipeline – Shaded Impact Area



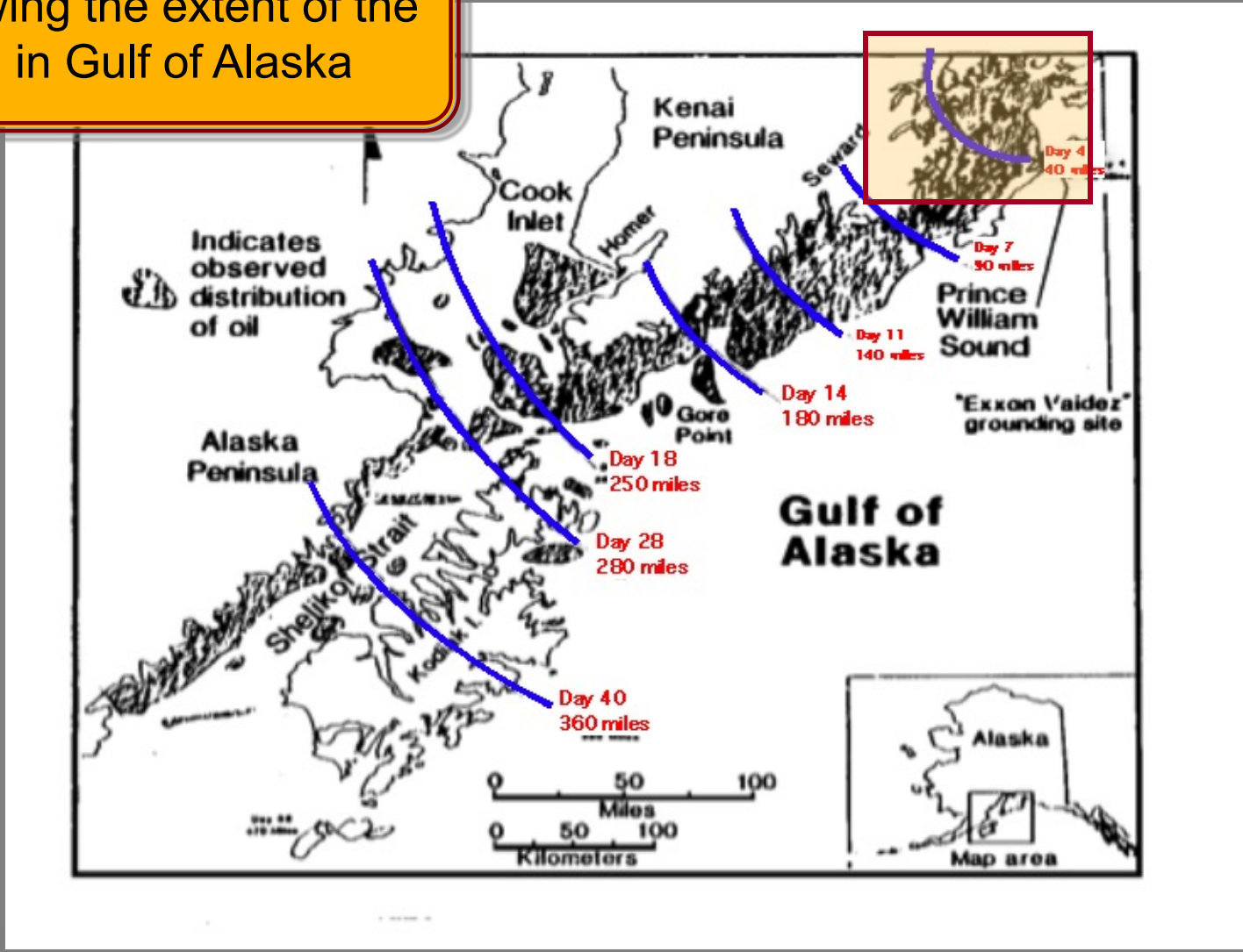
# Exxon Valdez...

Map showing Prince William Sound



# Exxon Valdez...

Map showing the extent of the oil spill in Gulf of Alaska



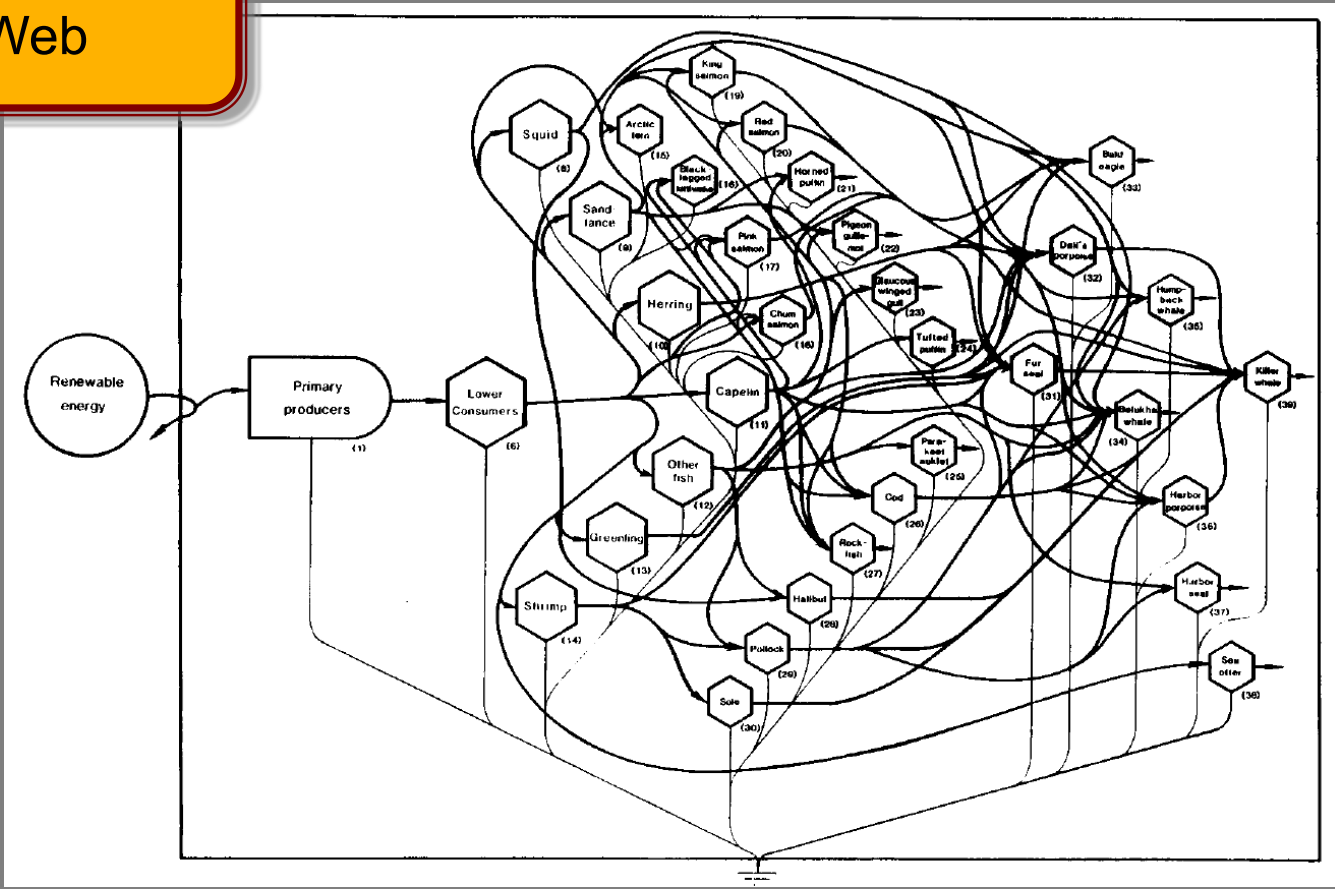
# Exxon Valdez...

## Ecological Impacts

- 250,000 Birds
- 250 Bald Eagles
- 2,800 Sea Otters
- 300 Harbor Seals
- Thousands of fish, herring eggs, and crabs
- At least 22 Killer Whales
- Intertidal plants and animals

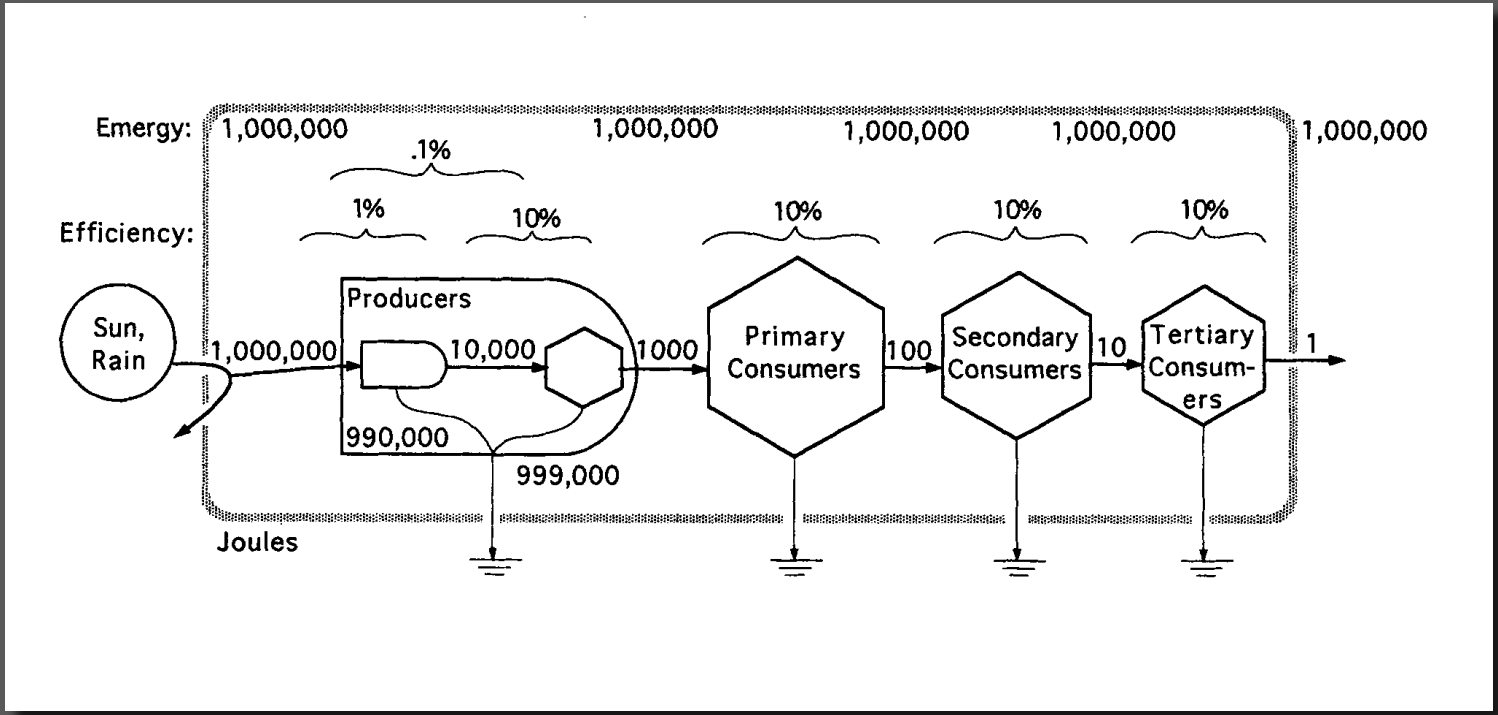
# Exxon Valdez...

Prince William Sound
Trophic Web



# Exxon Valdez...

Energy Chain...the food chain can be thought of as an energy transformation chain. At each transformation step some energy is degraded and some is passed to the next step in the chain.



# Exxon Valdez...

## Prince William Sound Trophic Web

| Component | NETWRK3 Trophic Level | Component | NETWRK3 Trophic Level |
|---|---|---|---|
| Squid | 3.0 | Tufted puffin | 4.0 |
| Sandlance | 3.0 | Parakeet anklet | 4.0 |
| Herring | 3.0 | Cod | 4.0 |
| Capelin | 3.0 | Rockfish | 4.0 |
| Other fish | 3.0 | Halibut | 4.0 |
| Greenling | 3.0 | Pollock | 4.0 |
| Shrimp | 3.0 | Sole | 4.0 |
| Arctic tern | 3.7 | Fur seal | 4.1 |
| Black-legged kittiwake | 3.5 | Dall's porpoise | 4.1 |
| Pink salmon | 3.4 | Bald eagle | 4.1 |
| Chum salmon | 3.4 | Belukha whale | 4.3 |
| King salmon | 4.0 | Humpback whale | 4.3 |
| Red salmon | 4.0 | Harbor porpoise | 4.4 |
| Homed puffin | 4.0 | Harbor seal | 4.5 |
| Pigeon guillemot | 4.0 | Sea olter | 3.0 |
| Glaucous-winged gull | 4.0 | Killer whale | 4.9 |

NETWRK3 (Ulanowicz, 1986)

# Exxon Valdez...

## Solar Transformities based on Trophic Web

| Component | Solar Transformity | Component | Solar Transformity |
|---|---|---|---|
| Squid | 1.10E+06 | Tufted puffin | 1.10E+07 |
| Sandlance | 1.10E+06 | Parakeet anklet | 1.10E+07 |
| Herring | 1.10E+06 | Cod | 1.10E+07 |
| Capelin | 1.10E+06 | Rockfish | 1.10E+07 |
| Other fish | 1.10E+06 | Halibut | 1.10E+07 |
| Greenling | 1.10E+06 | Pollock | 1.10E+07 |
| Shrimp | 1.10E+06 | Sole | 1.10E+07 |
| Arctic tern | 7.70E+06 | Fur seal | 2.80E+07 |
| Black-legged kittiwak | 6.10E+06 | Dall's porpoise | 2.30E+07 |
| Pink salmon | 5.10E+06 | Bald eagle | 2.50E+07 |
| Chum salmon | 5.10E+06 | Belukha whale | 3.60E+07 |
| King salmon | 1.10E+07 | Humpback whale | 3.10E+07 |
| Red salmon | 1.10E+07 | Harbor porpoise | 5.10E+07 |
| Homed puffin | 1.10E+07 | Harbor seal | 6.10E+07 |
| Pigeon guillemot | 1.10E+07 | Sea olter | 1.10E+06 |
| Glaucous-winged gul | 1.10E+07 | Killer whale | 1.70E+08 |

# Exxon Valdez...

Emergy losses of the Exxon Valdez oil spill

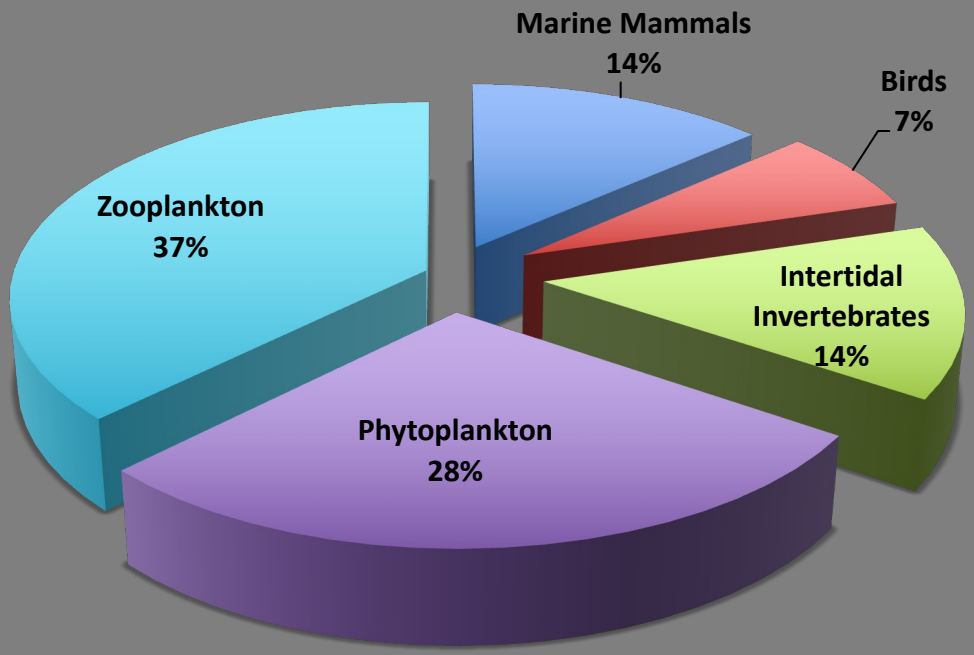
losses ($L_i$, $LPP_i$, and $M_i$) of the *Exxon Valdez* oil spill. Sources and descriptions for natural ource losses are given in Appendix D.

| | | Energy J | Solar Transformity scj/J | Solar Emergy 1E+19 scj | Macro-economic $ 1E+07 m$ |
|---|---|---|---|---|---|
| | **NATURAL RESOURCE LOSSES** | | | | |
| $M_2$ | Zooplankton | 0.53-16E+15 | 1.5E+05 | 5.8-170. | 3.6-110 |
| $M_{33}$ | Bald Eagles | 8.0E+10 | 2.5E+07 | 0.20 | 0.13 |
| $M_{37}$ | Harbor Seals | 6.0E+11 | 1.1E+07 | 0.66 | 0.41 |
| $M_{38}$ | Sea Otters | 5.3-8.4E+11 | 9.2E+07 | 4.9-7.6 | 3.1-4.8 |
| $M_{39}$ | Killer Whales | 0-5.3E+11 | 1.7E+08 | 0.0-8.9 | 0.0-5.6 |
| $M_{40}$ | Phytoplankton biomass | 0-2.9E+16 | 1.1E+04 | 0.0-32. | 0.0-20. |
| $LPP_{40}$ | Phytoplankton production | 0-3.7E+15 | 1.1E+04 | 0.0-4.1 | 0.0-2.6 |
| $M_{41}$ | Intertidal Producer biomass | 5.2-15E+15 | 1.1E+04 | 5.6-17. | 3.5-11. |
| $LPP_{41}$ | Intertidal Producer production | 1.4-7.5E+14 | 1.1E+04 | 0.14-0.83 | 0.09-0.52 |
| $M_{43}$ | Intertidal Herbivores | 2.7-5.3E+13 | 1.1E+05 | 0.30-0.58 | 0.19-0.36 |
| $M_{44}$ | Intertidal Meio- & Microfauna & Microflora | 0-2.3E+14 | 2.9E+05 | 0.0-6.8 | 0.0-4.3 |
| $M_{45}$ | Intertidal Macrofauna | 0-1.3E+14 | 8.1E+05 | 0.0-11. | 0.0-6.9 |
| $M_{46}+M_{46a}$ | Murres | 1.5-1.7E+12 | 4.7E+07 | 7.2-8.1 | 4.5-5.1 |
| $M_{47}$ | Procellarids | 1.6-1.8E+11 | 2.3E+07 | 0.36-0.41 | 0.23-0.26 |
| | **ECONOMIC SYSTEM LOSSES** | | | | |
| $L_{10}$ | Herring Fishery Harvest | 7.5E+13 | 1.1E+06 | 8.3 | 5.2 |
| $L_{AKNS}$ | AK North Slope Oil Production Loss | 7.8E+16 | 5.3E+04 | 410. | 260. |
| $L_{fuel}$ | Fuel | 5.9E+15 | 5.3E+04 | 31. | 19. |
| $L_{oil}$ | *Exxon Valdez* cargo | 1.6E+15 | 5.3E+04 | 8.5 | 5.3 |
| | | person-y | scj/person-y | | |
| $L_{people}$ | Social Disruption | 1.6E+04 | 1.9E+17 | 30. | 19. |
| | | $ | scj/$ | | |
| $L_{services}$ | Human Labor In Cleanup | 2.7E+09 | 1.6E+12 | 430. | 270. |
| | **EMERGY LOSS TOTALS** | | | | |
| | Primary Producers | | | 5.6-53. | 3.5-33. |
| | Intertidal Invertebrates | | | 0.30-18. | 0.19-11. |
| | Zooplankton | | | 5.8-170. | 3.6-110. |
| | Vertebrates | | | 13.-19. | 8.1-12. |
| VNRL | Natural Resource Losses: | | | 25.-260. | 16.-160. |
| VESL | Economic System Losses (excluding $L_{AKNS}$) | | | 508. | 320. |
| | Total Loss (excluding $L_{AKNS}$) | | | 533.-768. | 330.-480. |

# Exxon Valdez...

## Ecosystem Losses

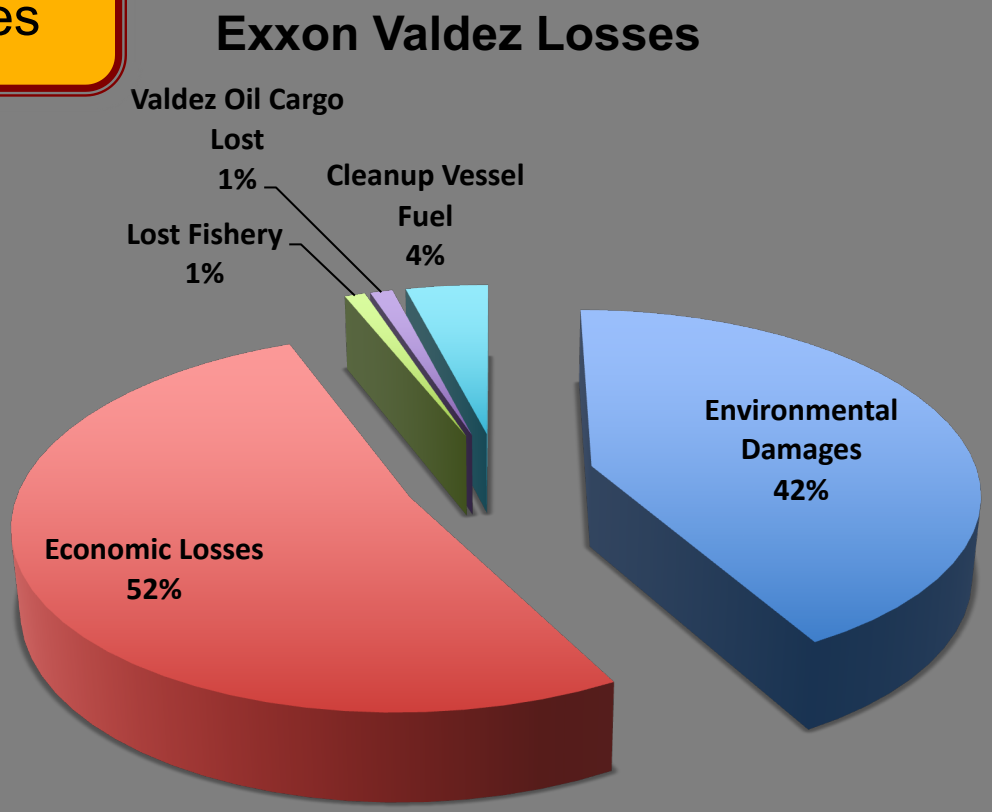
### Distribution of Ecosystem Losses




**Total losses (1990 USD)= $1.2 E9**

# Exxon Valdez...

## Economic & Ecosystem Losses




**Total losses (1990 USD)= em$2.86 E9**

(Oil flow interrupted = em$2.4 E9)

# Exxon Valdez...

## Economic facts of life...

Exxon spent an estimated $2 billion cleaning up the spill and $1 billion to settle related civil and criminal charges

In the case of Baker v. Exxon, an Anchorage jury awarded $287 million for actual damages and $5 billion for punitive damages.

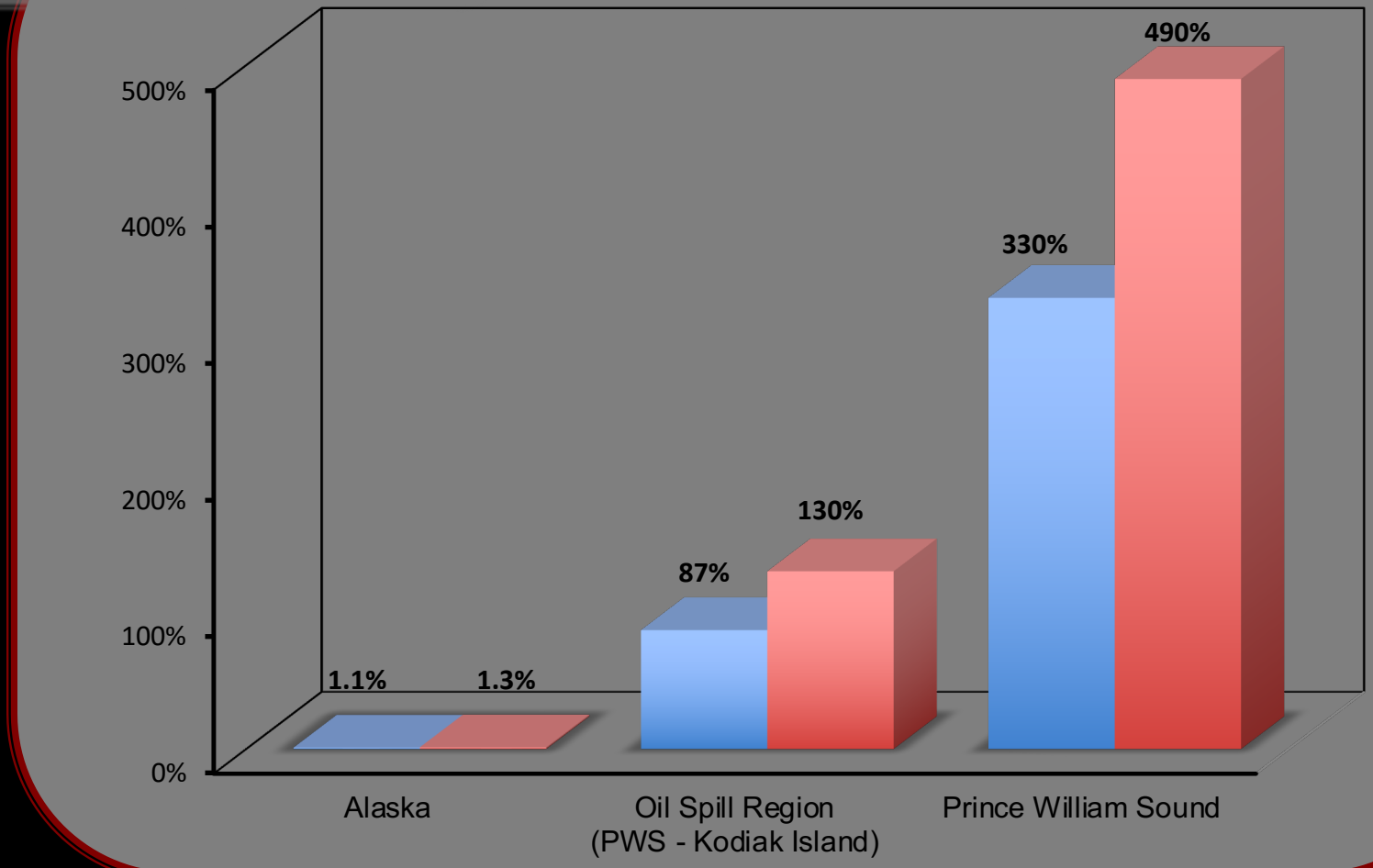
Which was reduced to $4 billion on appeal (2002)

Which was reduced to $2.5 billion on appeal (2006)

Which was reduced to “no more than $507.5 million by the Supreme Court (2008)

# Exxon Valdez...

## Total Losses as Percent of Region's Annual Emergy Support



# Exxon Valdez...

## Cost-Benefit Diagram

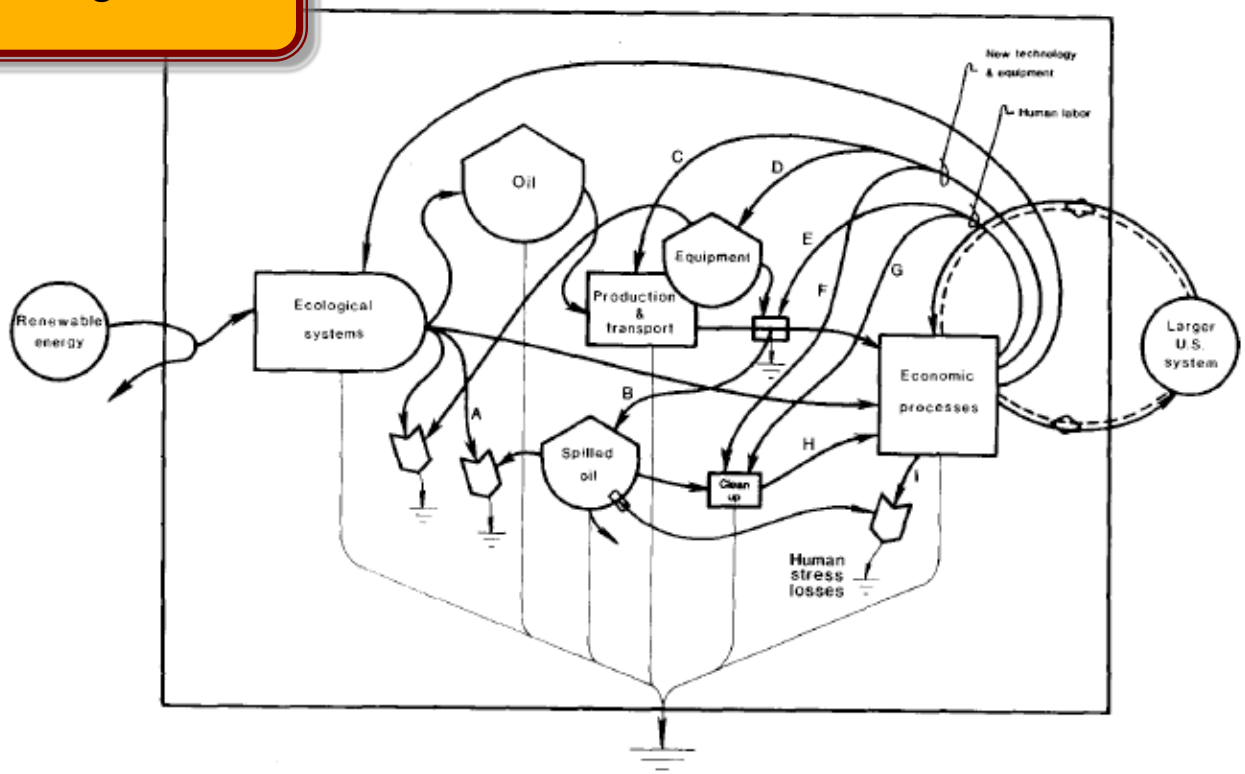
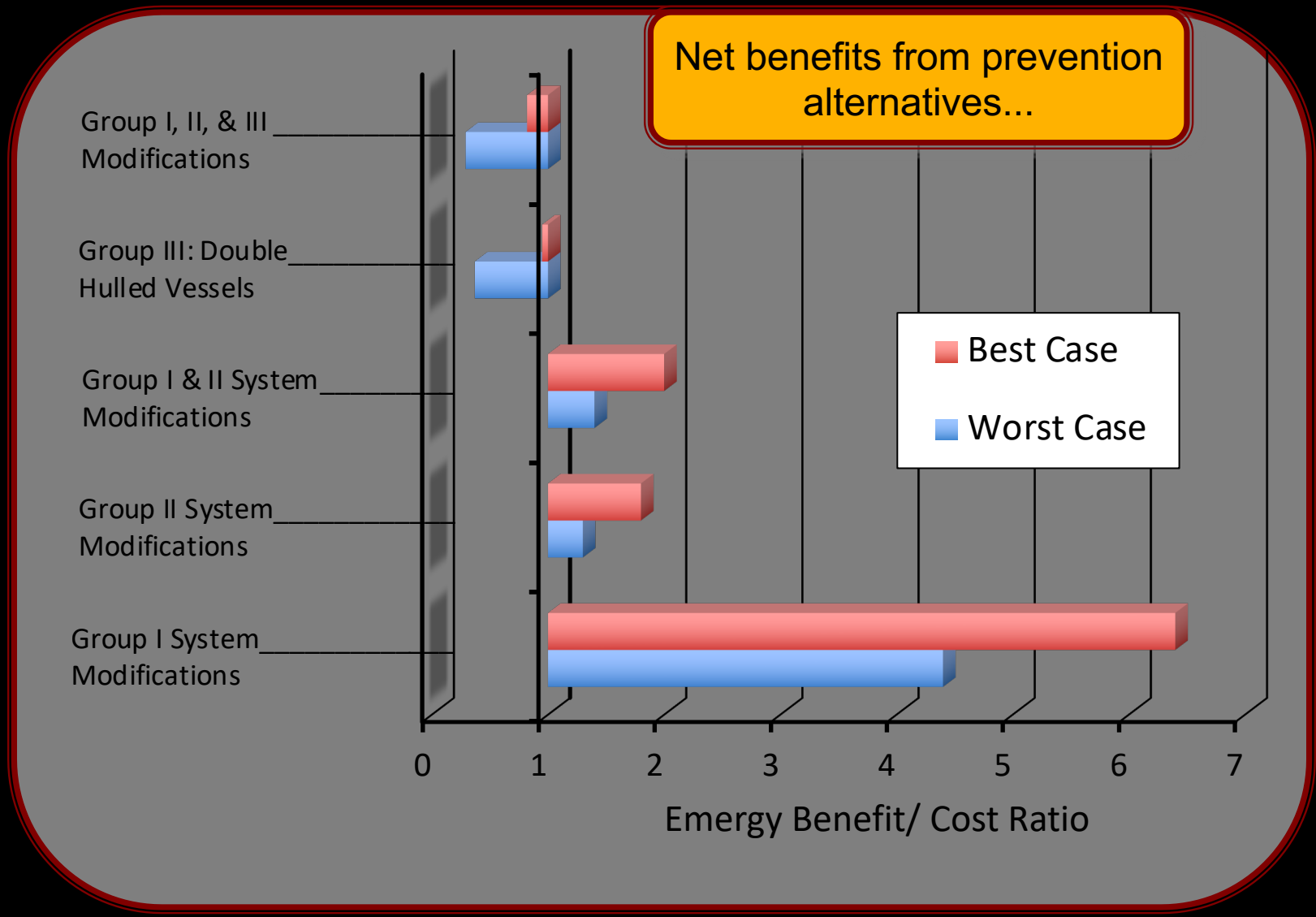



Figure II.4. A model of the costs and benefits of oil spill damage and oil spill prevention methods for the U.S. oil transportation system. the total loss from an oil spill is defined as: A + B + F + G + I - H, and the investment required to implement a prevention alternative is defined as: C + D + E, where, A = natural resource damage resulting from the oil spill, B = spilled oil, C = new technology invested in transport systems, D = new equipment invested in transport systems, E = additional human labor invested in transport systems, F = equipment and technology used in oil spill cleanup, G = human labor used in oil spill cleanup, H = spilled oil recovered during cleanup, I = human productivity losses due to stress as a result of the oil spill

# Exxon Valdez...

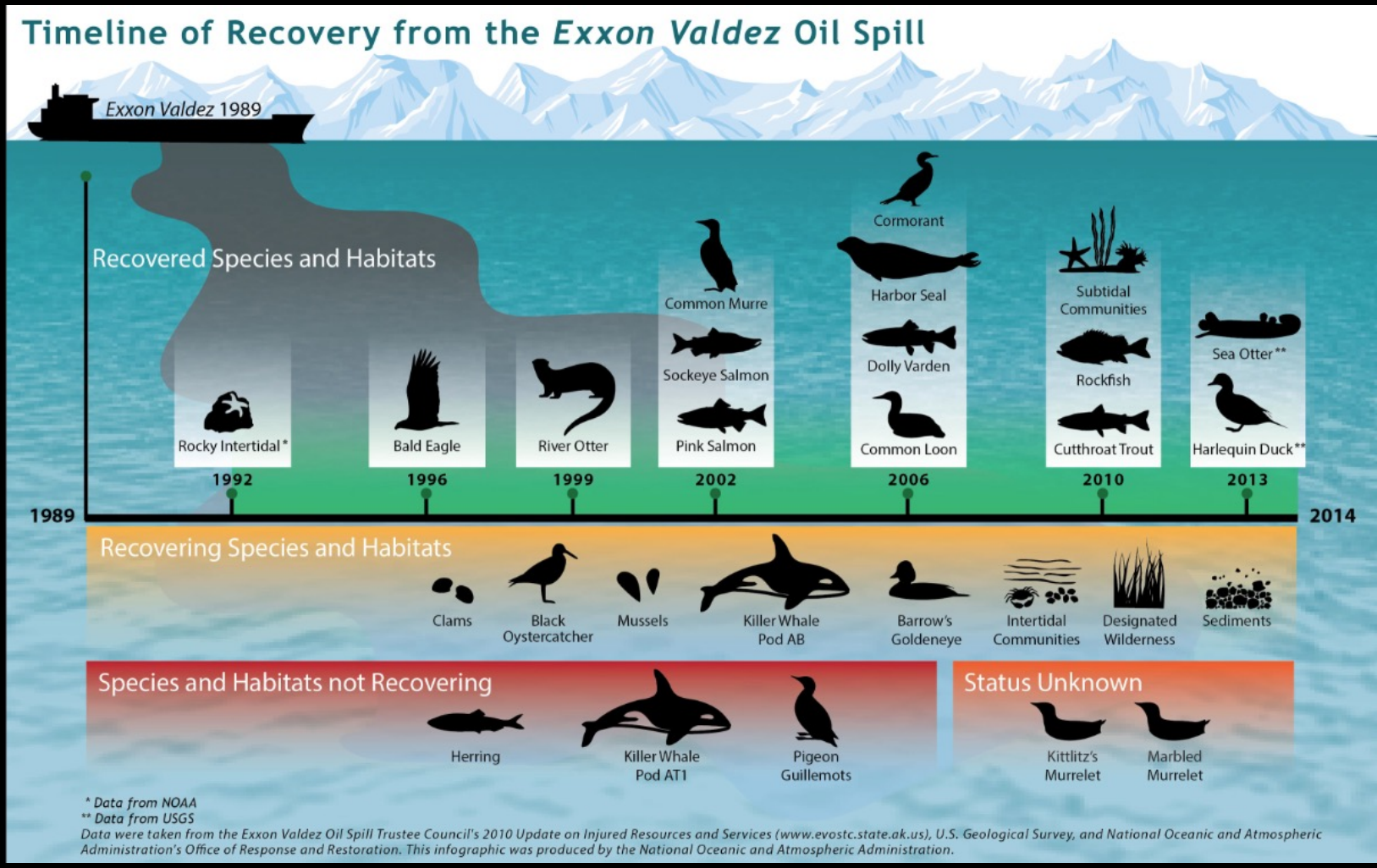


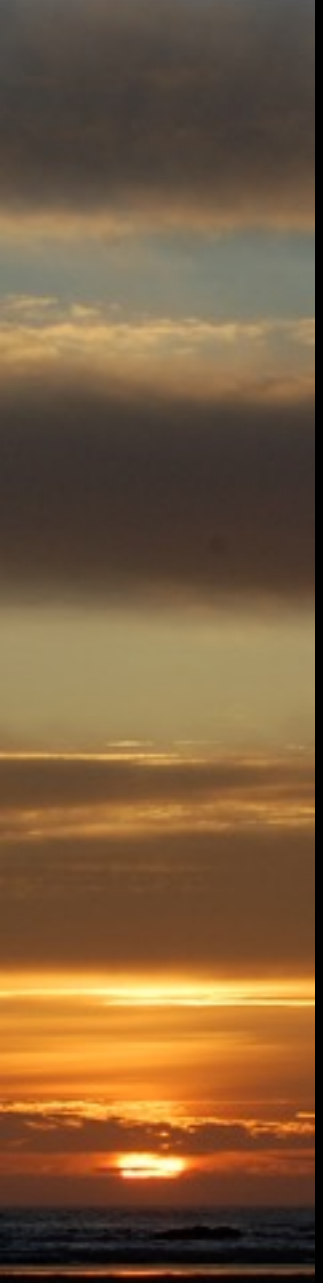
# Exxon Valdez...

## 25 YEARS LATER

The tanker *Exxon Valdez* spilled almost 11 million gallons of oil into Alaska's Prince William Sound on March 24, 1989, injuring 28 types of animals, plants, and marine habitats. How long has it taken them to recover from this spill? Twenty-five years later, which ones have not yet recovered?

Here is a timeline showing when natural resources were declared officially "recovered," though actual recovery could have occurred earlier than this official designation from the Exxon Valdez Oil Spill Trustee Council.





Valdez Oil Spill Research Team:
R.D. Woithe, H.T. Odum, C.L. Montague, and E.C. Odum

Funding provided by the Cousteau Society
Richard Murphy, project manager

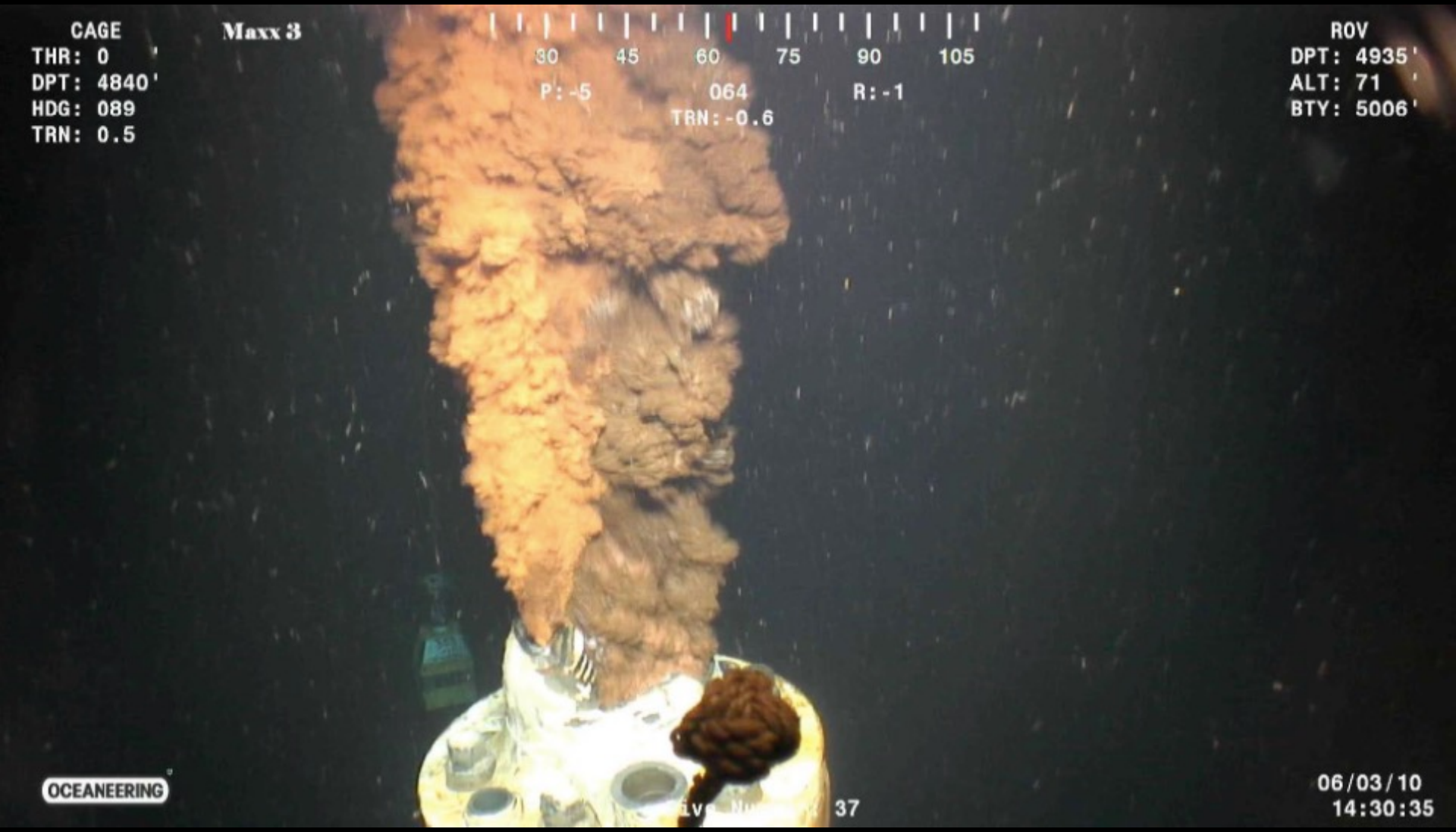
# Deepwater Horizon

Example of environmental impact assessment of major oil “spill”

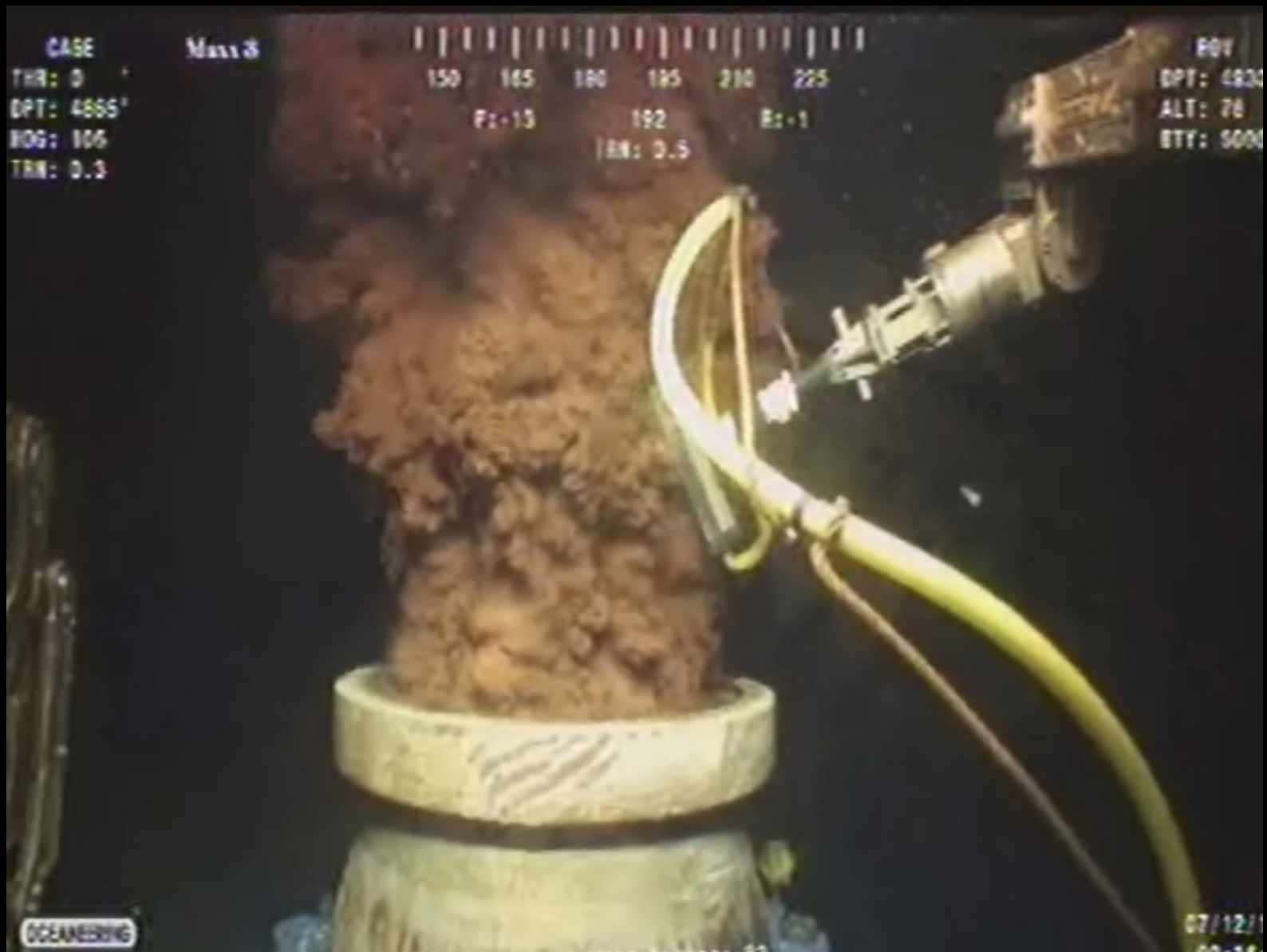
Lucia Zarba


20 April 2010
Deepwater Horizon...

# Deepwater Horizon...

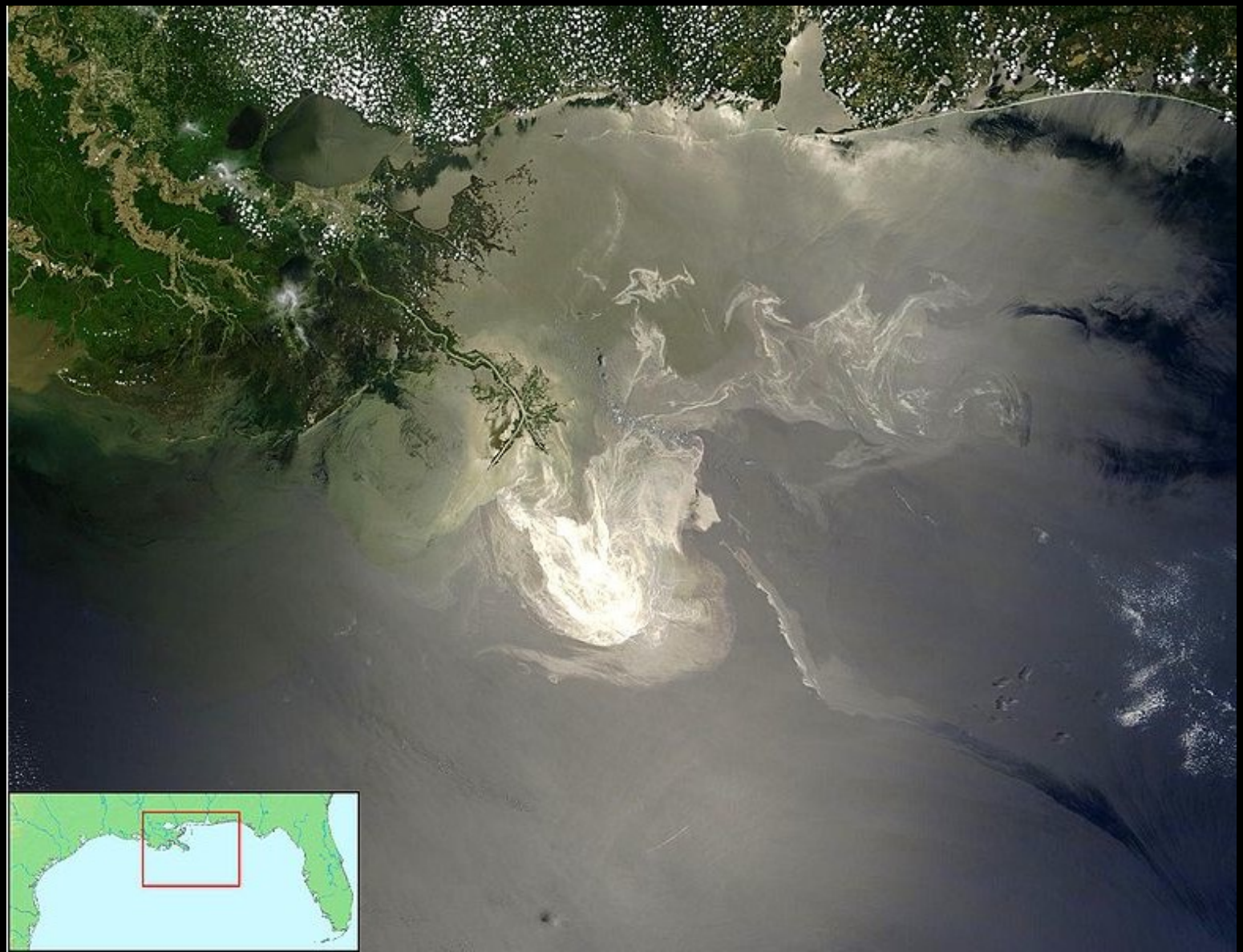


# Deepwater Horizon...



# Deepwater Horizon...

# Deepwater Horizon...



# Deepwater Horizon...

# Deepwater Horizon...

## DEEPWATER HORIZON SPILL: By the Numbers

2010 Deepwater Horizon Spill:
**206** MILLION GALLONS




1989 Exxon Valdez Spill:
**11** MILLION GALLONS

=

Miles of Coastline Affected:
**4,200** MILES
*(Length of 5 Californias)*

Wildlife Death Toll:

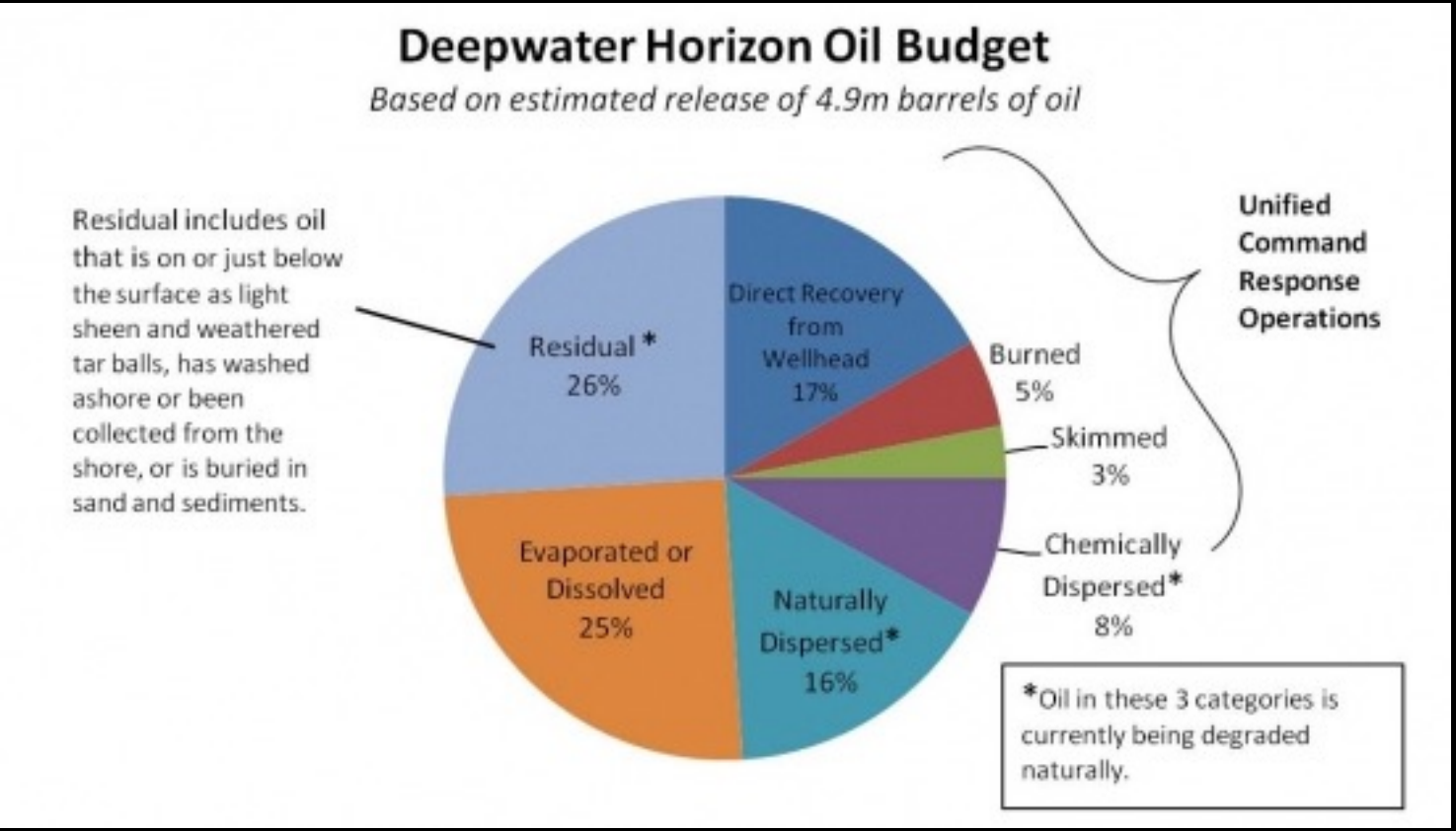
**6,104** BIRDS

**609** SEA TURTLES

**100** DOLPHINS & OTHERS

*Source: U.S. Government*

# Deepwater Horizon...



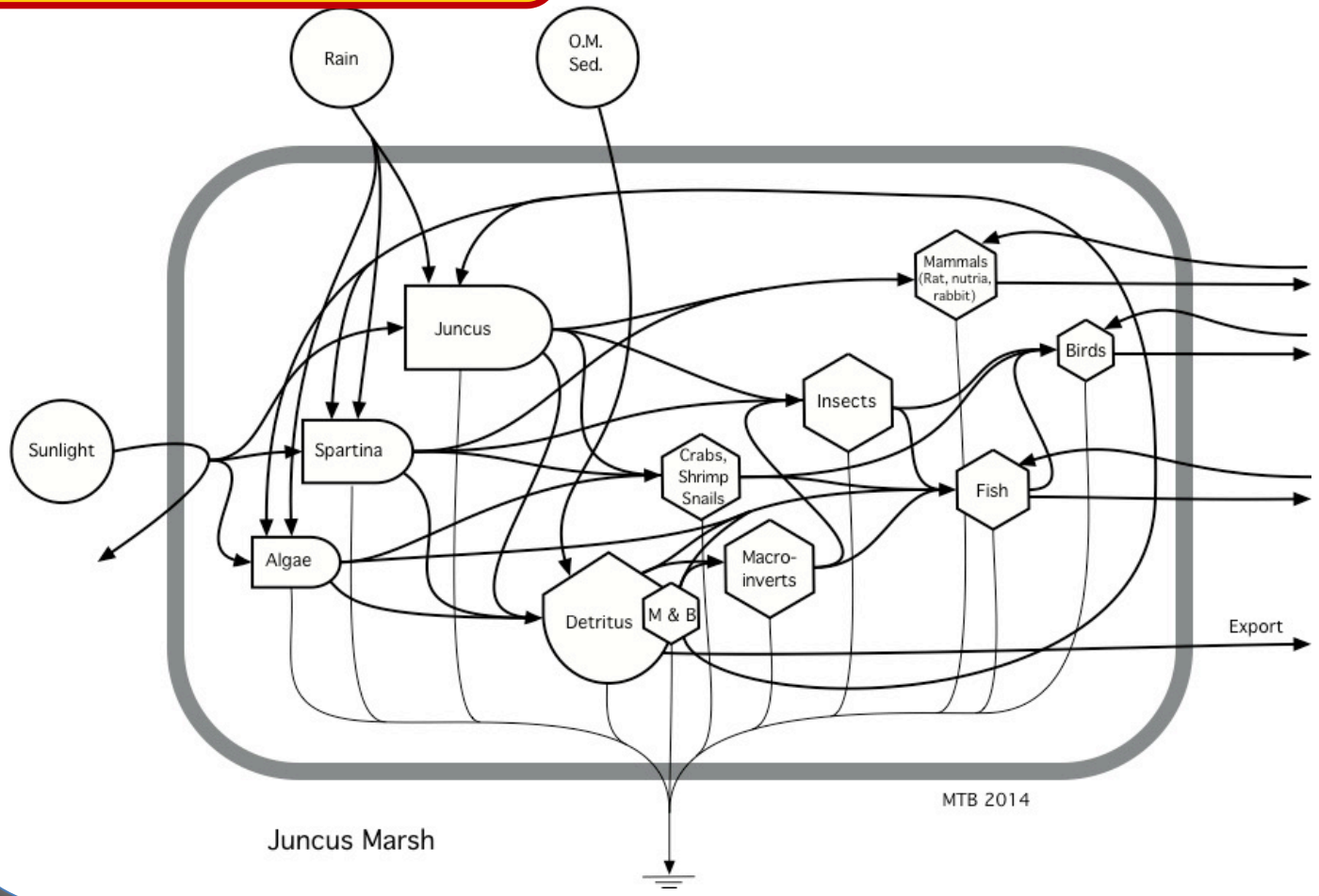
# Deepwater Horizon...

# Deepwater Horizon...

# Deepwater Horizon...

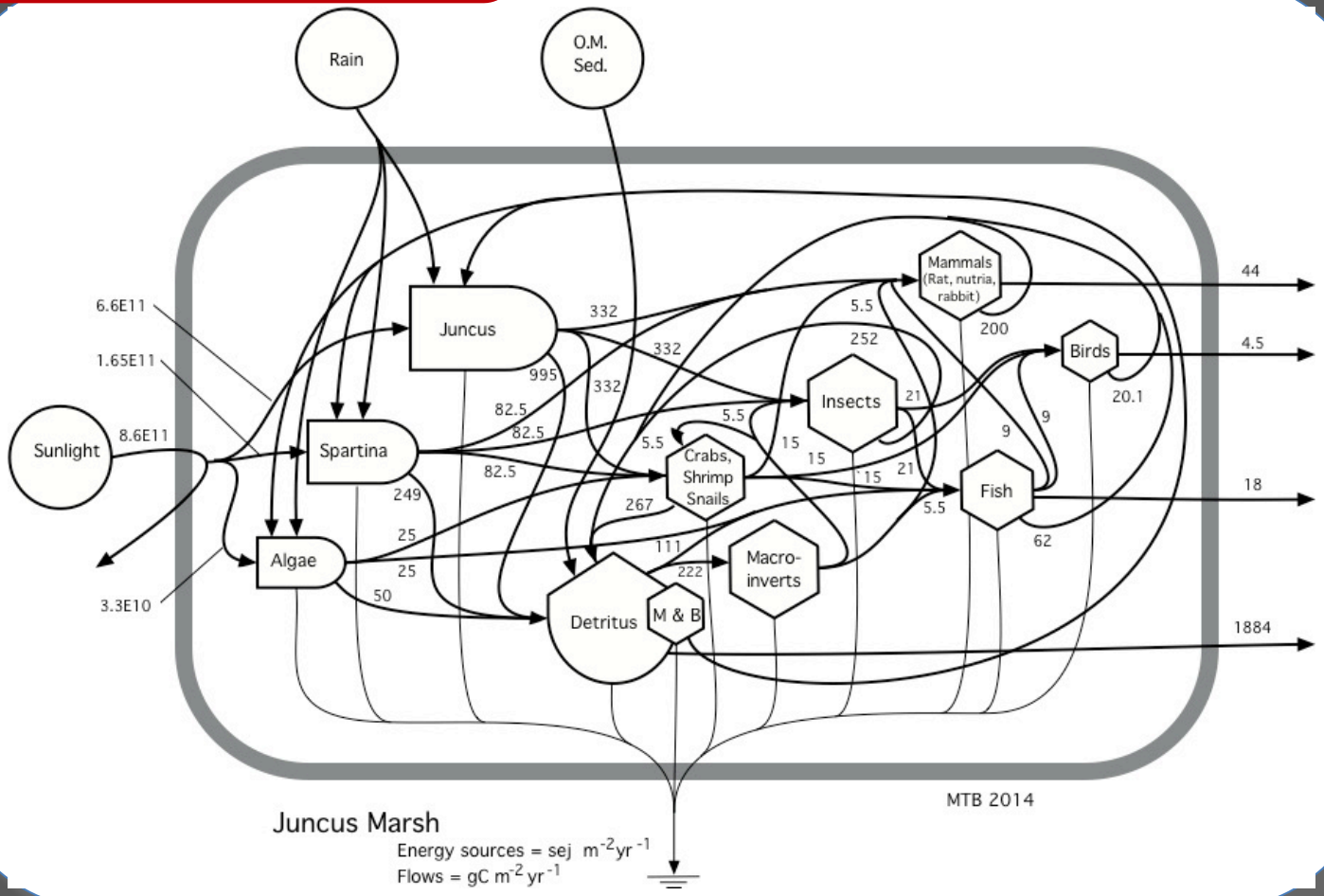
# Deepwater Horizon...

## Juncus Marsh Food Web



# Deepwater Horizon...

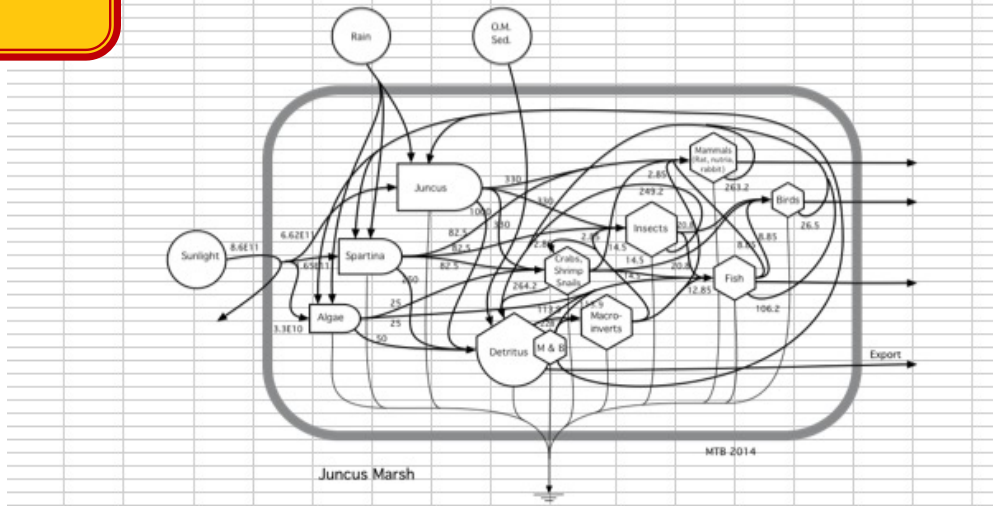
## Juncus Marsh Food Web



# Deepwater Horizon...

Juncus Marsh Food Web

| | | | 8.60E+11 | total (sej/m2/yr) | FROM | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| percent of total | Productivity (g/m2/yr) | | Input (sun) | Input (Sed) | Algae | Spartina | Juncus | Crabs, shrimp, snails | Detritus | Micr & Bac. | MacroInverts | Insects | Mammals | Fish | Birds |
| 3.85% | 1.00E+02 | Algae | 3.31E+10 | | | | | | | 1.01 | | | | | |
| 19.23% | 5.00E+02 | Spartina | 1.65E+11 | | | | | | | 5.04 | | | | | |
| 76.92% | 2.00E+03 | Juncus | 6.62E+11 | | | | | | | 20.16 | | | | | |
| | | Crabs, shrimp, snails | | | 25.00 | 82.50 | 330.00 | | | | 3.28 | | | | |
| | | Detritus | | | 50.00 | 250.00 | 1320.00 | 264.47 | | | 78.61 | 249.47 | 264.03 | 116.78 | 27.04 |
| | | Microbes & Bacteria | | | | | | | 262.04 | | | | | | |
| | | MacroInverts | | | | | | | 131.02 | | | | | | |
| | | Insects | | | | 82.50 | 330.00 | | | | 3.28 | | | | |
| | | Mammals | | | | 82.50 | 330.00 | 14.55 | | | 3.28 | | | 9.73 | |
| | | Fish | | | 25.00 | | | 14.55 | 131.02 | | 3.28 | 20.79 | | | |
| | | Birds | | | | | | 14.55 | | | | 20.79 | | 9.73 | |
| | | Export | | | | | | | 1.00E+03 | | | 41.58 | 43.03 | 19.46 | 4.51 |
| | | Column sum | 8.60E+11 | 0.00E+00 | 100.00 | 497.50 | 2310.00 | 308.10 | 1.52E+03 | 26.20 | 91.71 | 332.62 | 307.06 | 155.70 | 31.55 |
| | | Inputs | | | 3.31E+10 | 1.65E+11 | 6.62E+11 | 440.7755 | 2.62E+03 | 131.0195 | 131.0195 | 415.7755 | 440.0526 | 194.6294 | 45.06584 |
| | | Respiration | | | 3.31E+10 | 1.65E+11 | 6.62E+11 | 132.67 | 1.10E+03 | 104.82 | 39.31 | 83.16 | 132.99 | 38.93 | 13.52 |
| | | Respiration % inputs | | | 100% | 100% | 100% | 30% | 42% | 80% | 30% | 20% | 30% | 20% | 30% |



# Deepwater Horizon...

## Juncus Marsh Food Web Matrix

| | percent of total | Productivity (g/m2/yr) | | 8.60E+11 | total (sej/m2/yr) | ------ FROM ------ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Input (sun) | Input (Sed) | Algae | Spartina | Juncus | Crabs, shrimp, snails | Detritus | Micr & Bac. | MacroInverts | Insects | Mammals | Fish | Birds |
| | 3.85% | 1.00E+02 | Algae | 3.31E+10 | | | | | | | 1.01 | | | | | |
| | 19.23% | 5.00E+02 | Spartina | 1.65E+11 | | | | | | | 5.04 | | | | | |
| | 76.92% | 2.00E+03 | Juncus | 6.62E+11 | | | | | | | 20.16 | | | | | |
| | | | Crabs, shrimp, snails | | | 25.00 | 82.50 | 330.00 | | | | 3.28 | | | | |
| | | | Detritus | | | 50.00 | 250.00 | 1320.00 | 264.47 | | | 78.61 | 249.47 | 264.03 | 116.78 | 27.04 |
| | | | Microbes & Bacteria | | | | | | | 262.04 | | | | | | |
| | | | MacroInverts | | | | | | | 131.02 | | | | | | |
| | | | Insects | | | | 82.50 | 330.00 | | | | 3.28 | | | | |
| | | | Mammals | | | | 82.50 | 330.00 | 14.55 | | | 3.28 | | | 9.73 | |
| | | | Fish | | | 25.00 | | | 14.55 | 131.02 | | 3.28 | 20.79 | | | |
| | | | Birds | | | | | | 14.55 | | | | 20.79 | | 9.73 | |
| | | | Export | | | | | | | 1.00E+03 | | | 41.58 | 43.03 | 19.46 | 4.51 |
| | | | Column sum | 8.60E+11 | 0.00E+00 | 100.00 | 497.50 | 2310.00 | 308.10 | 1.52E+03 | 26.20 | 91.71 | 332.62 | 307.06 | 155.70 | 31.55 |
| | | | Inputs | | | 3.31E+10 | 1.65E+11 | 6.62E+11 | 440.77549 | 2.62E+03 | 131.01955 | 131.01955 | 415.77549 | 440.05255 | 194.6294 | 45.065836 |
| | | | Respiration | | | 3.31E+10 | 1.65E+11 | 6.62E+11 | 132.67 | 1.10E+03 | 104.82 | 39.31 | 83.16 | 132.99 | 38.93 | 13.52 |
| | | | Respiration % inputs | | | 100% | 100% | 100% | 30% | 42% | 80% | 30% | 20% | 30% | 20% | 30% |

TO

# Deepwater Horizon...

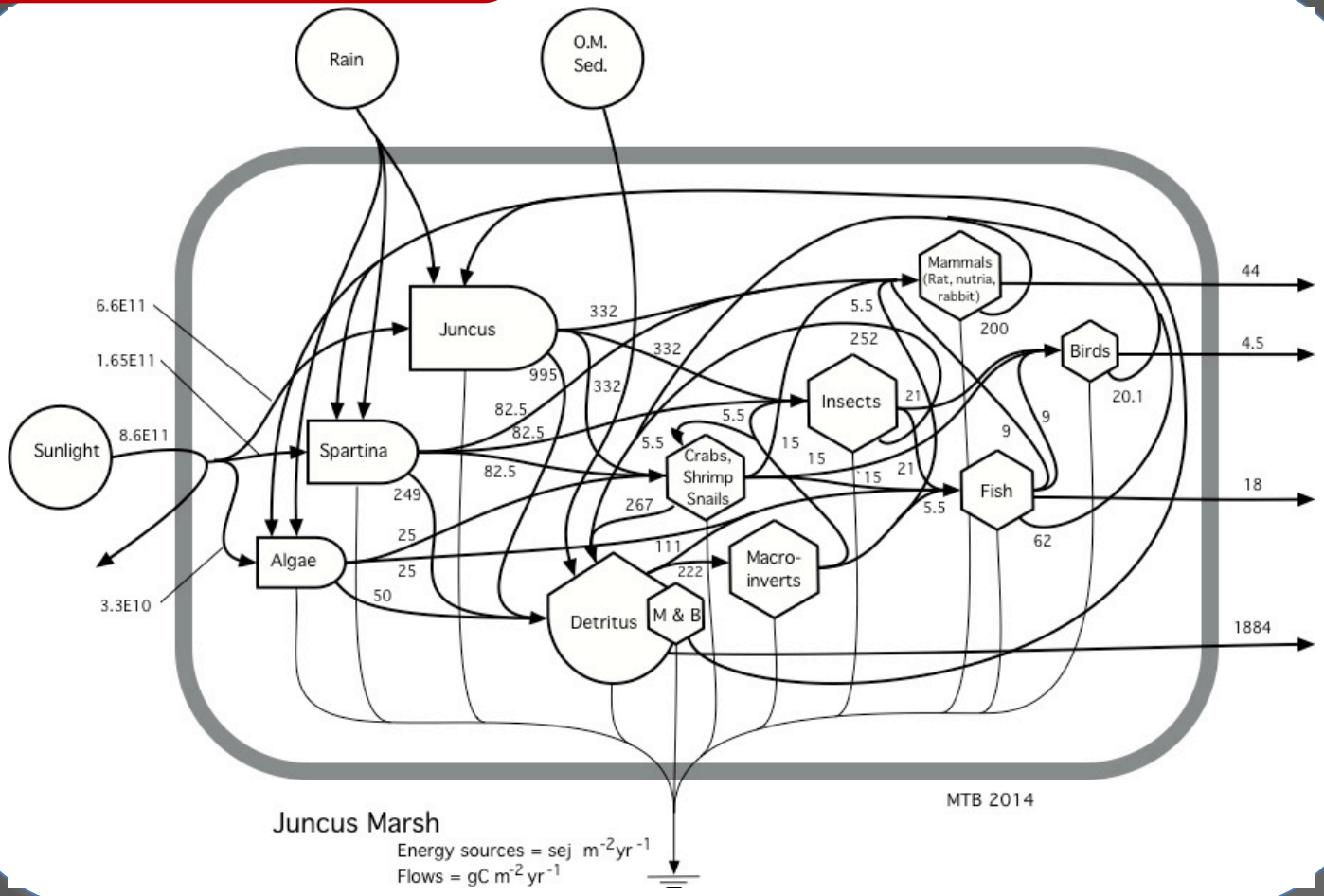
## Juncus Marsh Food Web UEV Matrix

Matrix inversion technique computes UEVs for each compartment

| Unit Emergy Value (sej/J) | 7.39E+04 | 5.18E+05 | 1.61E+05 | 9.25E+05 | 5.00E-03 | 1.40E+03 | 5.15E+05 | 5.15E+05 | 6.29E+06 | 1.18E+06 | 9.29E+05 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Input (sun) | Input $H_2O$ | O.Matter | Algae | Spartina | Juncus | Crabs, shrimp, snails | Detritus | Microbes & Bacteria | Macro-Invertebrates | Insects | Mammals | Fish | Birds |
| Algae | 3.31E+10 | 1.90E+11 | | -100 | | | | | 1.0 | | | | | |
| Spartina | 1.65E+11 | 4.80E+11 | | | -497.5 | | | | 5.0 | | | | | |
| Juncus | 6.62E+11 | 1.90E+12 | | | | -2310 | | | 20.2 | | | | | |
| Crabs, shrimp, snails | | | | 25.00 | 82.50 | 330.00 | -308.1 | | | 3.3 | | | | |
| Detritus | | | 2.69E+10 | 50.00 | 250.00 | 1320.00 | 264.5 | -1524.1 | | 78.6 | 249.5 | 264.0 | 116.8 | 27.0 |
| Microbes & Bacteria | | | | | | | | 262.0 | -26.2 | | | | | |
| MacroInvertebrates | | | | | | | | 131.0 | | -91.7 | | | | |
| Insects | | | | | 82.50 | 330.00 | | | | 3.3 | -332.6 | | | |
| Mammals | | | | | 82.50 | 330.00 | 14.5 | | | 3.3 | | -307.1 | 9.73 | |
| Fish | | | | 25.00 | | | 14.5 | 131.0 | | 3.3 | 20.8 | | -155.70 | |
| Birds | | | | | | | 14.5 | | | | 20.8 | | 9.73 | -31.6 |
| Export | | | | | | | | 1.00E+03 | | | 41.58 | 43.03 | 19.46 | 4.51 |

# Deepwater Horizon...

## Juncus Marsh Food Web



# Deepwater Horizon...

Q1 = Q1 + (J1 - J14 - J18 - Q1 * (D1 + E1 + R1) - 0.2 * Q1 * Sw1) * dt

Q2 = Q2 + (J2 - J24 - J26 - J27 - Q2 * (D2 + E2 + R2) - 0.25 * Q2 * Sw1) * dt

Q3 = Q3 + (J3 - J34 - J36 - J37 - Q3 * (D3 + E3 + R3) - 0.3 * Q3 * Sw1) * dt

Detritus = 0.2 * Q1 * Sw1 + 0.1 * Q2 * Sw1 + 0.4 * Q3 * Sw1

Q4 = Q4 + (J14 + J24 + J34 + J54 - J47 - J48 - J49 - Q4 * (D4 + E4 + R4)) * dt

Q5 = Q5 + (Jdet5 - J54 - J56 - J57 - J58 - Q5 * (D5 + E5 + R5) - 0.5 * Q5 * Sw1) * dt + MacroIn * SW2

Q6 = Q6 + (J26 + J36 + J56 - J68 - J69 - Q6 * (D6 + E6 + R6)) * dt '+ InsectsIn * SW2

Q7 = Q7 + (J27 + J37 + J47 + J57 + J87 - Q7 * (D7 + E7 + R7)) * dt '+ MammalsIn * SW2

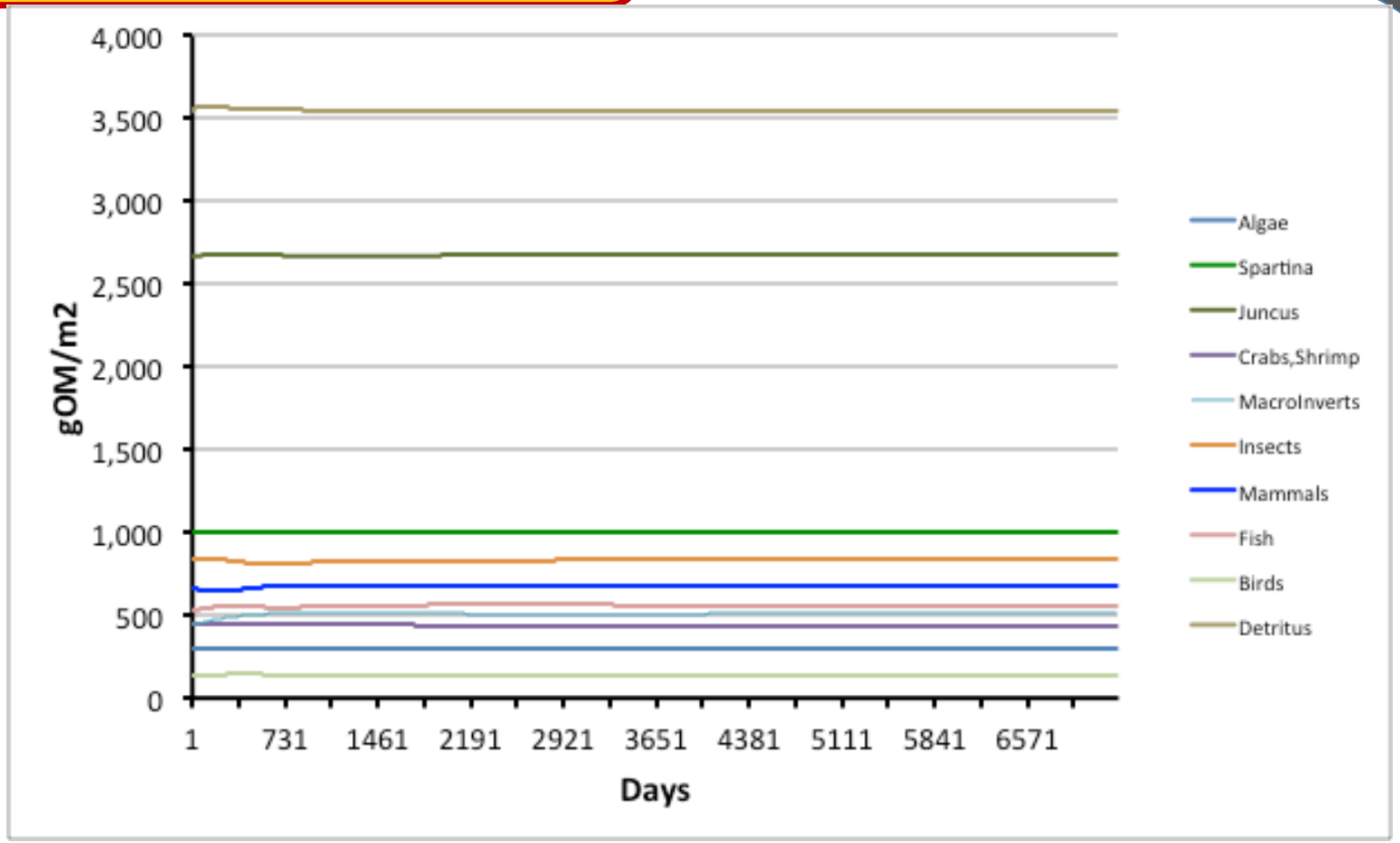
Q8 = Q8 + (J18 + J48 + J58 + J68 + Jdet8 - J87 - J89 - Q8 * (D8 + E8 + R8) - 0.3 * Q8 * Sw1) * dt '+ FishIn * SW2

Q9 = Q9 + (J49 + J69 + J89 - Q9 * (D9 + E9 + R9)) * dt + BirdsIn * SW2

q10 = q10 + (D1 * Q1 + D2 * Q2 + D3 * Q3 + D4 * Q4 + D5 * Q5 + D6 * Q6 + D7 * Q7 + D8 * Q8 + D9 * Q9 - Jdet5 - Jdet8 - e10 * q10 + Detritus) * dt

# Deepwater Horizon…

## Juncus Marsh Model
## "Steady State"



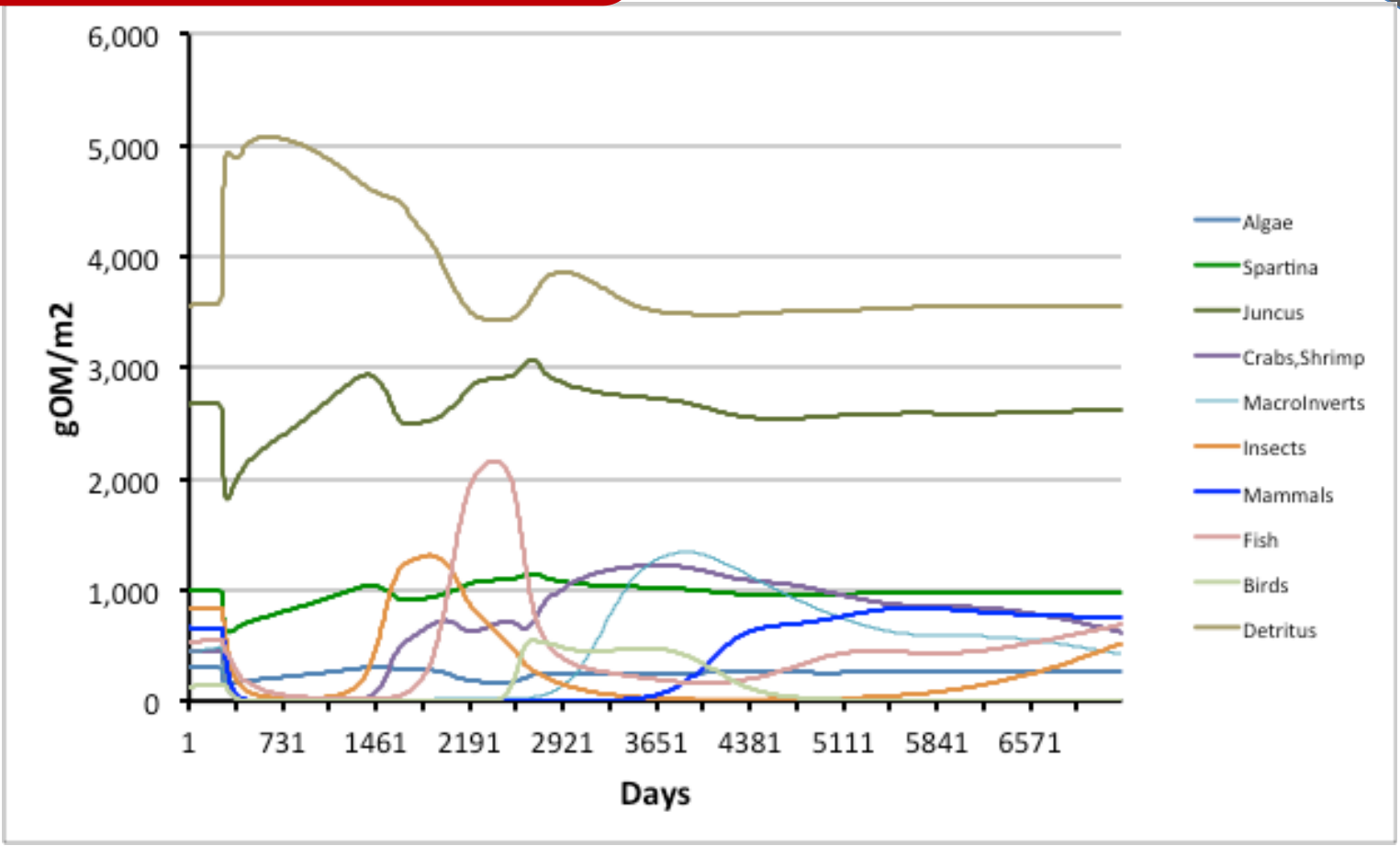
# Deepwater Horizon…

Set known direct level of impact on compartments

Q1 – Algae = 50%
Q2 – Spartina = 25%
Q3 – Juncus = 25%
Q4 - Crabs/Shrimp =?
Q5 – MacroInverts = 50%
Q6 – Insects = ?
Q7 – Mammals = ?
Q8 – Fish = 10%
Q9 – Birds = ?

# Deepwater Horizon…

## Juncus Marsh Model
## "Oiled"



# Deepwater Horizon...

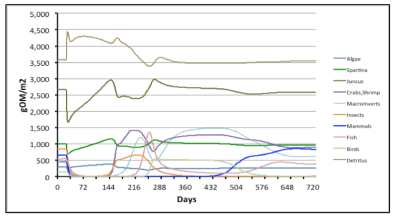
## Compute net change

| | Algae | Spartina | Juncus | Crabs, shrimp, snails | Macro Inverts | Insects | Mammals | Fish | Birds | Detritus |
|---|---|---|---|---|---|---|---|---|---|---|
| **Percent Dif.** | **-24%** | **-18%** | **-13%** | **-59%** | **-62%** | **-52%** | **-58%** | **-43%** | **-56%** | **26%** |
| Difference | 53597.0 | 135104.9 | 249287.0 | 194465.6 | 221593.8 | 315337.7 | 281844.4 | 172736.5 | 57867.7 | -675858.8 |
| Sum | 165183.3 | 596966.3 | 1704024.4 | 132685.7 | 134806.5 | 287307.1 | 200434.0 | 228439.5 | 45230.0 | 3276951.9 |
| | 301.8 | 1001.1 | 2669.6 | 445.1 | 443.5 | 840.3 | 663.2 | 531.5 | 134.1 | 3546.7 |
| | 301.8 | 1001.1 | 2669.7 | 445.1 | 443.5 | 840.3 | 663.1 | 531.5 | 134.1 | 3547.6 |
| | 301.8 | 1001.1 | 2669.7 | 445.1 | 443.5 | 840.3 | 662.9 | 531.5 | 134.1 | 3548.5 |
| | 301.8 | 1001.1 | 2669.8 | 445.1 | 443.5 | 840.3 | 662.7 | 531.5 | 134.1 | 3549.3 |
| | 301.8 | 1001.1 | 2669.9 | 445.1 | 443.5 | 840.3 | 662.6 | 531.5 | 134.1 | 3550.1 |
| | 301.8 | 1001.1 | 2669.9 | 445.1 | 443.5 | 840.3 | 662.4 | 531.5 | 134.1 | 3550.9 |
| | 301.8 | 1001.1 | 2670.0 | 445.1 | 443.6 | 840.3 | 662.2 | 531.5 | 134.1 | 3551.7 |
| | 301.8 | 1001.1 | 2670.0 | 445.1 | 443.6 | 840.3 | 662.1 | 531.5 | 134.1 | 3552.5 |
| | 301.8 | 1001.1 | 2670.1 | 445.2 | 443.6 | 840.3 | 661.9 | 531.6 | 134.1 | 3553.2 |
| | 301.8 | 1001.1 | 2670.2 | 445.2 | 443.7 | 840.3 | 661.8 | 531.6 | 134.1 | 3553.9 |
| | 301.8 | 1001.2 | 2670.2 | 445.2 | 443.7 | 840.3 | 661.6 | 531.6 | 134.1 | 3554.6 |

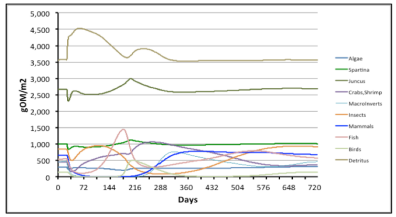
# Deepwater Horizon…

Many simulations changing impact conditions

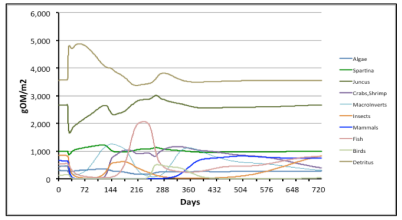
| Compartment | Net Difference (gOM) | UEV (sej/g) | Emergy (E9 sej) | Emdollars/acre | Percent Change |
|---|---|---|---|---|---|
| Q1 – Algae | 3380.7 | 73908.1 | -0.2 | -$0.5 | -24% |
| Q2 – Spartina | 91467.2 | 518321.7 | -47.4 | -$95.9 | -28% |
| Q3 – Juncus | 338894.5 | 160721.6 | -54.5 | -$110.2 | -13% |
| Q4 - Crabs/Shrimp | 195016.1 | 924530.1 | -180.3 | -$364.8 | -60% |
| Q5 – MacroInverts | 202798.4 | 1303347.4 | -264.3 | -$534.8 | -62% |
| Q6 – Insects | 324187.0 | 514566.5 | -166.8 | -$337.6 | -53% |
| Q7 – Mammals | 284349.8 | 857418.7 | -243.8 | -$493.3 | -59% |
| Q8 – Fish | 194189.4 | 1179540.7 | -229.1 | -$463.5 | -46% |
| Q9 – Birds | 58130.4 | 6290853.5 | -365.7 | -$740.0 | -56% |
| Q10 - Detritus | -327251.2 | 42371.2 | 13.9 | $28.1 | 23% |
| | | **Total** | **-1552.1** | **-$3,141** | |



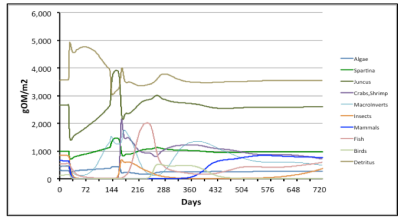

| Compartment | Net Difference (gOM) | UEV (sej/g) | Emergy (E9 sej) | Emdollars/acre | Percent Change |
|---|---|---|---|---|---|
| [illegible] | [illegible] | 73908.1 | -1.2 | -$2.5 | -24% |
| [illegible] | [illegible] | 518321.7 | -24.4 | -$49.5 | -28% |
| [illegible] | [illegible] | 160721.6 | -11.0 | -$22.3 | -13% |
| [illegible] | [illegible] | 924530.1 | -78.9 | -$159.6 | -60% |
| [illegible] | [illegible] | 1303347.4 | -268.4 | -$543.2 | -62% |
| [illegible] | [illegible] | 514566.5 | -39.6 | -$80.2 | -53% |
| [illegible] | [illegible] | 857418.7 | -199.9 | -$404.5 | -59% |
| [illegible] | [illegible] | 1179540.7 | -203.2 | -$411.1 | -46% |
| [illegible] | [illegible] | 6290853.5 | -340.4 | -$688.7 | -56% |
| [illegible] | [illegible] | 42371.2 | 17.3 | $34.9 | 23% |
| | | **Total** | **-1167.1** | **-$2,362** | |




| Compartment | Net Difference (gOM) | UEV (sej/g) | Emergy (E9 sej) | Emdollars/acre | Percent Change |
|---|---|---|---|---|---|
| Q1 – Algae | 6906.6 | 73908.1 | -0.5 | -$1.0 | -24% |
| Q2 – Spartina | -14822.8 | 518321.7 | 7.7 | $15.5 | -28% |
| Q3 – Juncus | 342981.8 | 160721.6 | -55.1 | -$111.5 | -13% |
| Q4 - Crabs/Shrimp | 193106.2 | 924530.1 | -178.5 | -$361.3 | -60% |
| Q5 – MacroInverts | 139933.1 | 1303347.4 | -182.4 | -$369.0 | -62% |
| Q6 – Insects | 314087.6 | 514566.5 | -161.6 | -$327.0 | -53% |
| Q7 – Mammals | 281416.5 | 857418.7 | -241.3 | -$488.3 | -59% |
| Q8 – Fish | 158920.9 | 1179540.7 | -187.5 | -$379.3 | -46% |
| Q9 – Birds | 57710.9 | 6290853.5 | -363.1 | -$734.6 | -56% |
| Q10 - Detritus | -588464.3 | 42371.2 | 24.9 | $50.5 | 23% |
| | | **Total** | **-1362.3** | **-$2,757** | |




| Compartment | Net Difference (gOM) | UEV (sej/g) | Emergy (E9 sej) | Emdollars/acre | Percent Change |
|---|---|---|---|---|---|
| Q1 – Algae | 5552.7 | 73908.1 | -0.4 | -$0.8 | -3% |
| Q2 – Spartina | 88732.7 | 518321.7 | -46.0 | -$93.1 | -12% |
| Q3 – Juncus | 490280.4 | 160721.6 | -78.8 | -$159.4 | -25% |
| Q4 - Crabs/Shrimp | 198224.4 | 924530.1 | -183.3 | -$370.8 | -61% |
| Q5 – MacroInverts | 154617.0 | 1303347.4 | -201.5 | -$407.8 | -43% |
| Q6 – Insects | 339602.0 | 514566.5 | -174.7 | -$353.6 | -56% |
| Q7 – Mammals | 289116.1 | 857418.7 | -247.9 | -$501.6 | -60% |
| Q8 – Fish | 167661.1 | 1179540.7 | -197.8 | -$400.2 | -42% |
| Q9 – Birds | 58524.3 | 6290853.5 | -368.2 | -$745.0 | -57% |
| Q10 - Detritus | -542598.7 | 42371.2 | 23.0 | $46.5 | 16% |
| | | **Total** | **-1498.6** | **-$3,032** | |



# Deepwater Horizon...

Net difference in each compartment * UEV = Emergy loss

To compute the emdollar value, use Emergy/$ ratio from the USA economy.... (2.0 E12 sej/$)

| Compartment | Net Difference (gC) | UEV (sej/J) | Emergy (E9 sej) | Emdollars/acre | |
|---|---|---|---|---|---|
| Q1 – Algae | 2140.1 | 73908.1 | -1 | -$2 | **-1%** |
| Q2 – Spartina | 364156.5 | 518321.7 | -974 | -$1,971 | **-20%** |
| Q3 – Juncus | 1110871.4 | 160721.6 | -921 | -$1,864 | **-19%** |
| Q4 - Crabs/Shrimp | 195636.6 | 924530.1 | -933 | -$1,889 | **-60%** |
| Q5 – MacroInverts | 214155.7 | 514566.5 | -569 | -$1,151 | **-60%** |
| Q6 – Insects | 327571.1 | 514566.5 | -870 | -$1,760 | **-54%** |
| Q7 – Mammals | 286670.6 | 6290853.5 | -9307 | -$18,833 | **-59%** |
| Q8 – Fish | 237677.0 | 1179540.7 | -1447 | -$2,928 | **-59%** |
| Q9 – Birds | 59038.3 | 929085.5 | -283 | -$573 | **-57%** |
| Q10 - Detritus | -933475.8 | 5000.0 | 24 | $49 | **12%** |
| | | **Total** | **-15281** | **-$30,922** | |

**~ $77,300/ ha.**

# Thank You...

Questions?

Comments?

Concerns?