

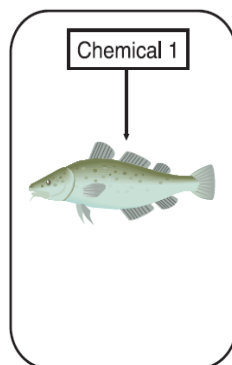
## Cumulative Effects

- Interactions with local environment
- Route of exposure
- Life stage effects
- Prior stress history
- Oxygen stress and osmotic relationships
- Trophic changes
- Energetic capacity
- .....

## Risk assessment

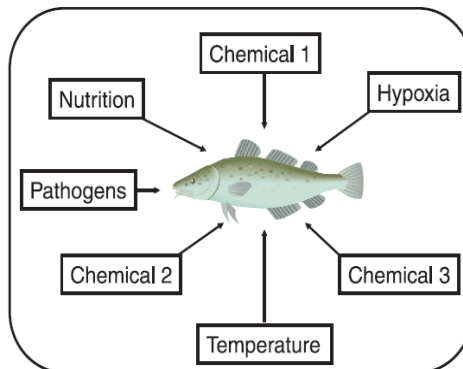
### Chemical oriented

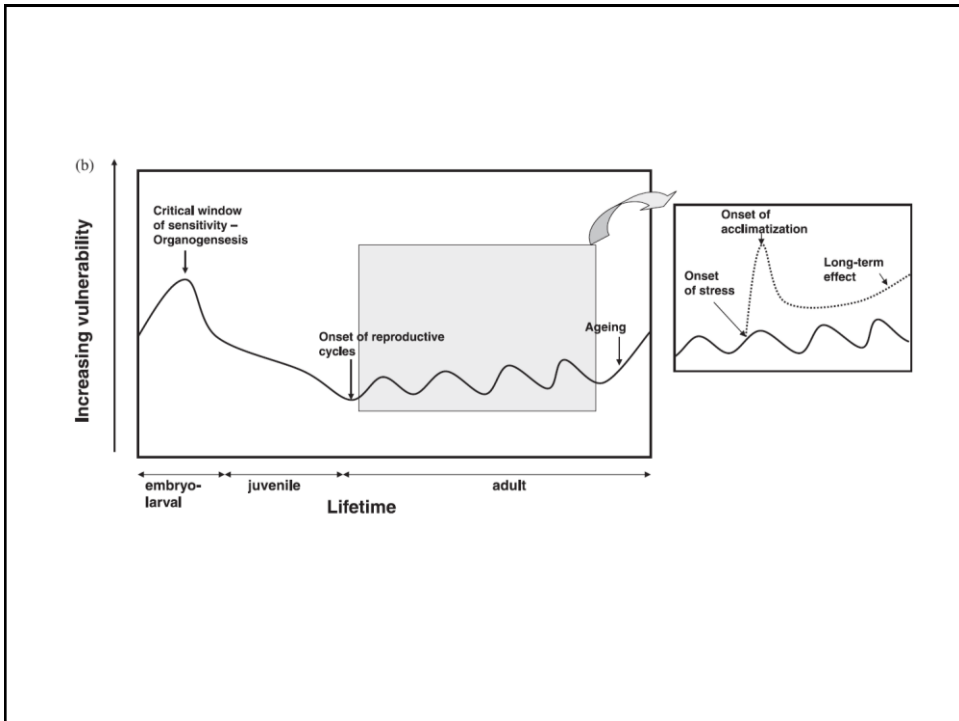
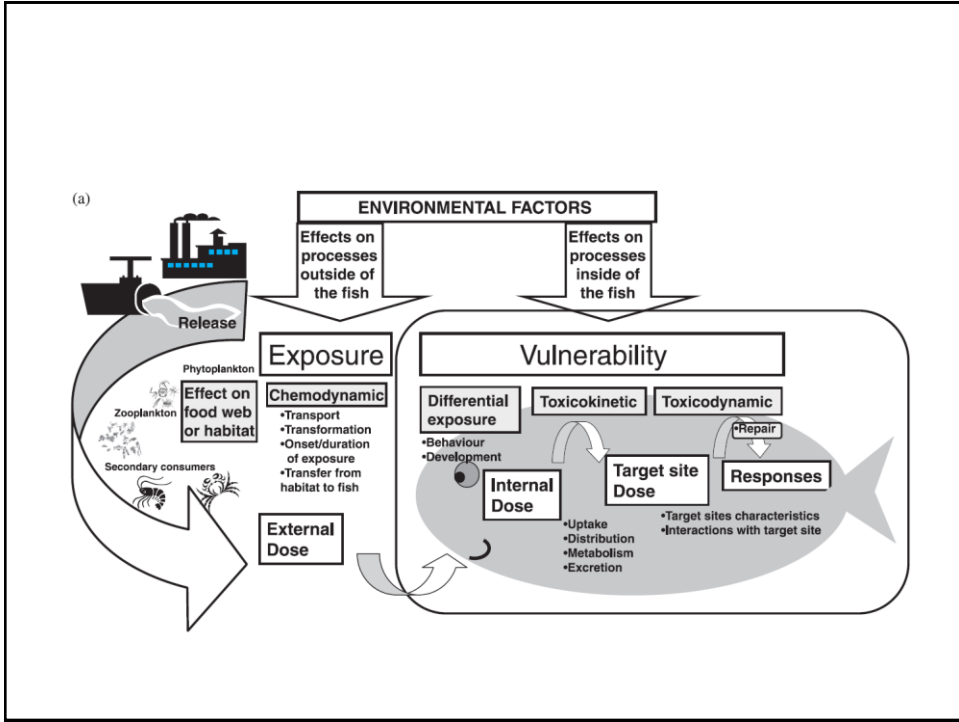
Goal: control source of pollution



### Fish oriented

Goal: protect fish or ecosystem health

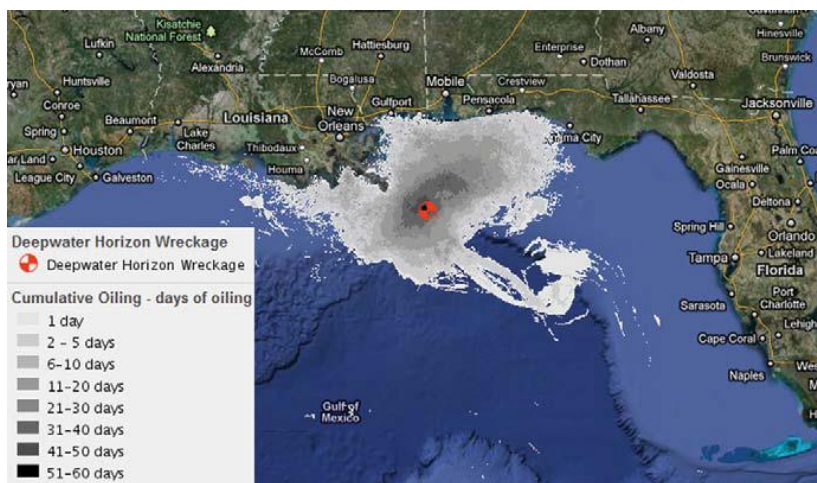




## Polycyclic Aromatic Hydrocarbons (PAHs)

Deepwater Horizon - DWH

## Exposure (days of oiling)

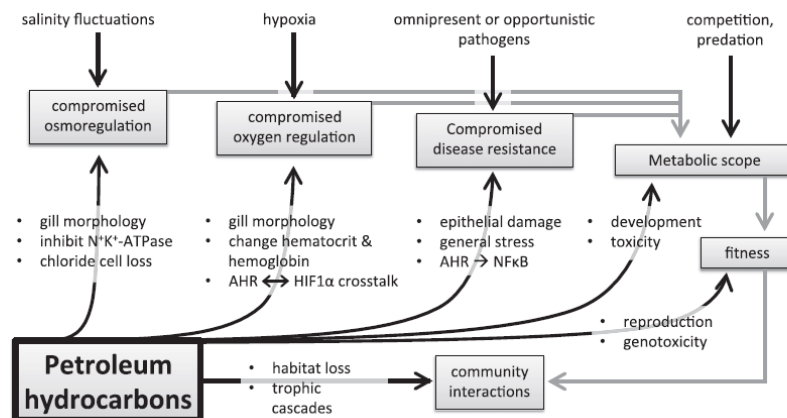


# PAH

Seawater vs freshwater environmental and risk differences

Drinking rates, elimination systems  
Micro habitat, etc.

## Hypothetical model

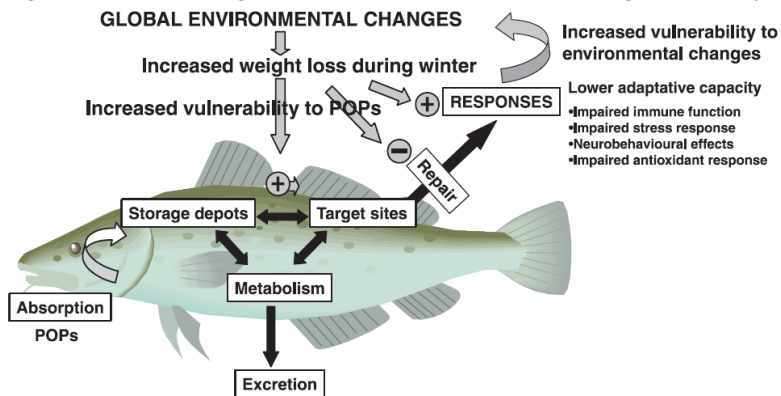


# Immunotoxicity

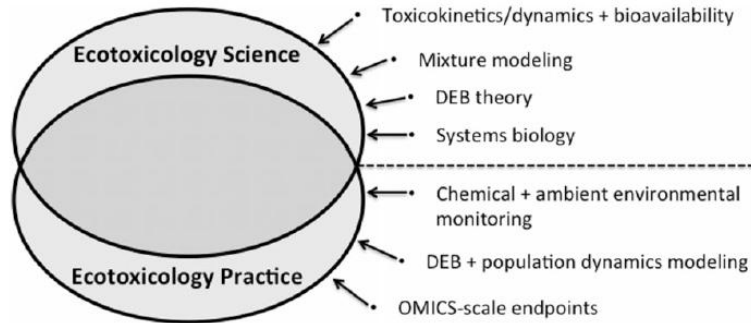
TABLE 3.—Example oil and polycyclic aromatic hydrocarbon (PAH) immunotoxicity in aquatic invertebrates, fish, birds and mammals.

Species	Exposure	Petroleum	Effects	Citation
<b>Aquatic invertebrates</b>				
Scallop (arctic)	Lab: oil in water	Crude oil	↓ Membrane stability ↓ Phagocytosis ↑ Hemocytes	Hannan et al. (2009)
Scallop (temperate)	Lab: PAH in water	Phenanthrene	↓ Membrane stability ↓ Phagocytosis ↑ Hemocytes	Hannan et al. (2010)
Oyster	Erika oil spill	Bunker C	↓ Hemocyte viability ↓ Phagocytic function Immunosuppression	Auffret et al. (2004)
<b>Fish</b>				
Flounder	Lab: oil in water	Bunker C	↑ Leukocytes Modulation of gene expression	Song et al. (2008); Nakayama et al. (2008)
Rainbow trout	Lab: sediment	Crude oil	↓ Liver Melanomacrophage centers	Payne and Fancey (1989)
Cod	Lab: oil in water	Diesel	Modulation of gene expression	Mos et al. (2008)
Sculpin	Exxon Valdez oil spill	Crude oil	↑ Gill parasites	Khan (1990)
			↓ Gut parasites ↑ Gill parasites ↓ Gut parasites	
<b>Birds</b>				
Seabird (guillemot)	Field: oiling	ND	Hemolytic anemia Heintz bodies Cachexia	Troisi et al. (2007)
Seabirds (multiple species)	Prestige oil spill	Bunker C	Hemolytic anemia	Balserio et al. (2005)
Mallard	Lab: intubation	Crude oil Bunker C Bunker C + Corexit	↓ Resistance to bacterial challenge No effect on antibody production	Rocke, Yuill, and Hinsdill (1984)
	Lab: intubation	Bunker C, crude oil	No effect on viral resistance	Goldberg, Yuill, and Burgess (1990)
<b>Mammals</b>				
Mink	Lab: dietary	Bunker C	↑ Lymphocytes Proinflammatory response	Schwartz et al. (2004)
	Lab: dietary	Crude oil	Anemia Hypoproteinemia	Beckett et al. (2002)
Sea otter	Lab: dietary	Bunker C	Modulation of gene expression	Bowen et al. (2007)

## Codfish Model from Couillard et al.



## Whitehead model and use of DEB



Do you remember our discussion paper???

Energy homeostasis as an integrative tool for assessing limits of environmental stress tolerance in aquatic invertebrates

Inna M. Sokolova<sup>a,\*</sup>, Markus Frederich<sup>b</sup>, Rita Bagwe<sup>a</sup>, Gisela Lannig<sup>c</sup>, Alexey A. Sukhotin<sup>d</sup>

## Monitoring and Mitigation

- Limitations of present monitoring systems?
- Dispersants?
- What do you think would work?

