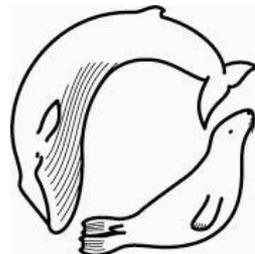


Approaches to Understanding Cumulative Effects of Stressors on Marine Mammals

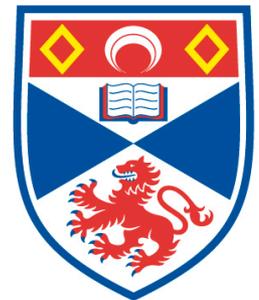
State of the Science Workshop on
Wildlife and Offshore Wind Energy
2020: Cumulative Impacts

Peter L. Tyack

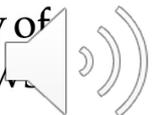
20 November 2020



**Sea Mammal
Research
Unit**



University of
St Andrews



The National Academies of
SCIENCES • ENGINEERING • MEDICINE



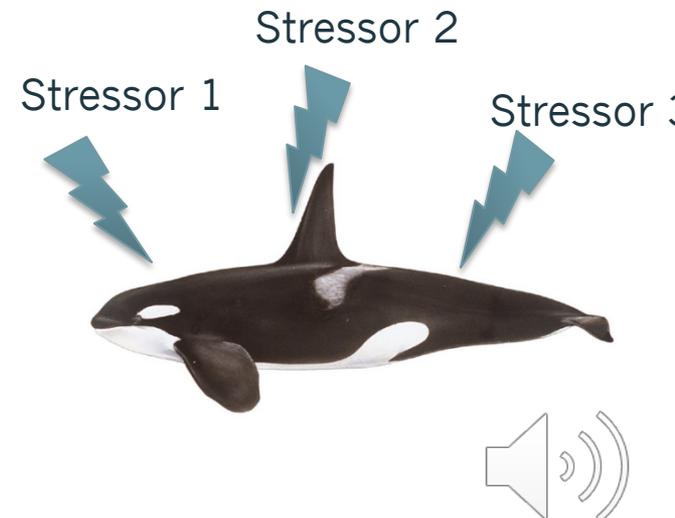
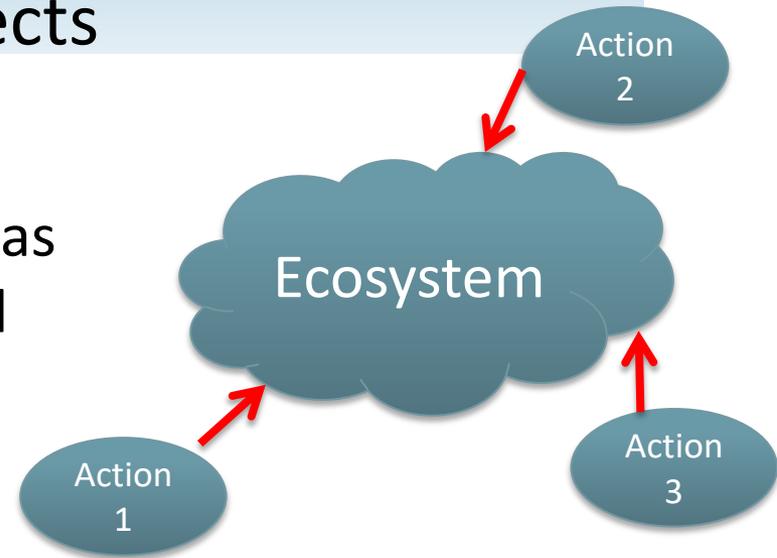
Parts of Talk Based on US National Academies
Report Entitled:
Approaches to Understanding the Cumulative
Effects of Stressors on Marine Mammals

Available for Free Download at www.nap.edu 

Contrasting regulatory vs biological definitions of cumulative effects

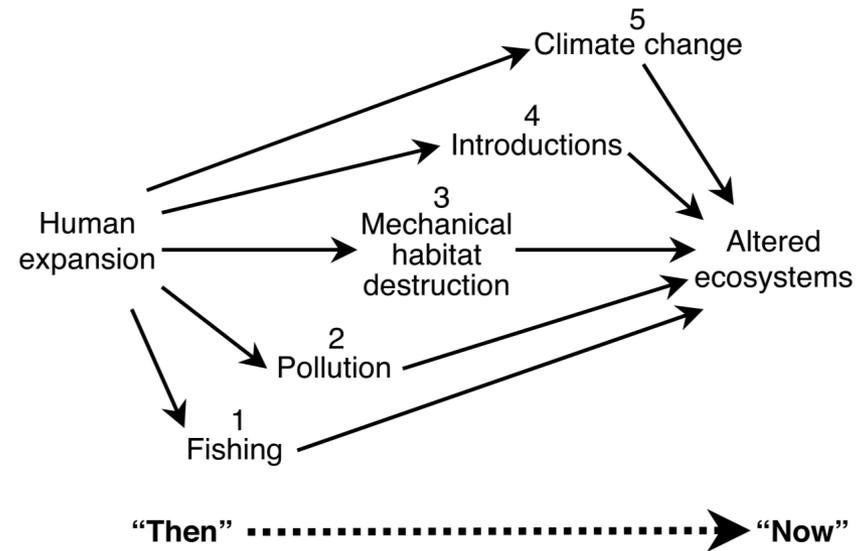
Cumulative effects are defined by the U.S. Council on Environmental Quality as “the incremental impact of a proposed action when added to the other past, present and reasonably foreseeable actions.”

Biologists focus on the individual animal or population, with effects accumulating when animals are repeatedly exposed to the same or different stressors.



Lots of Stressors on Marine Ecosystems

- Ocean Climate and Conditions
- Pollution
 - Chemical
 - Noise
- Fisheries
- Parasites/Pathogens
- Resource Limitation
- Physical Injury
- Invasive Species



Jackson et al. 2001 Science 293:635



Scientific Progress on Studying Cumulative Effects of Stressors

- Environmental Assessments usually state that effects can be additive, synergistic or antagonistic
- Meta-analyses of hundreds of studies on effects of multiple stressors on marine systems conclude that you cannot predict which will occur
- **The state of the science of cumulative effects has low predictive power compared to regulatory demands to assess these effects.**

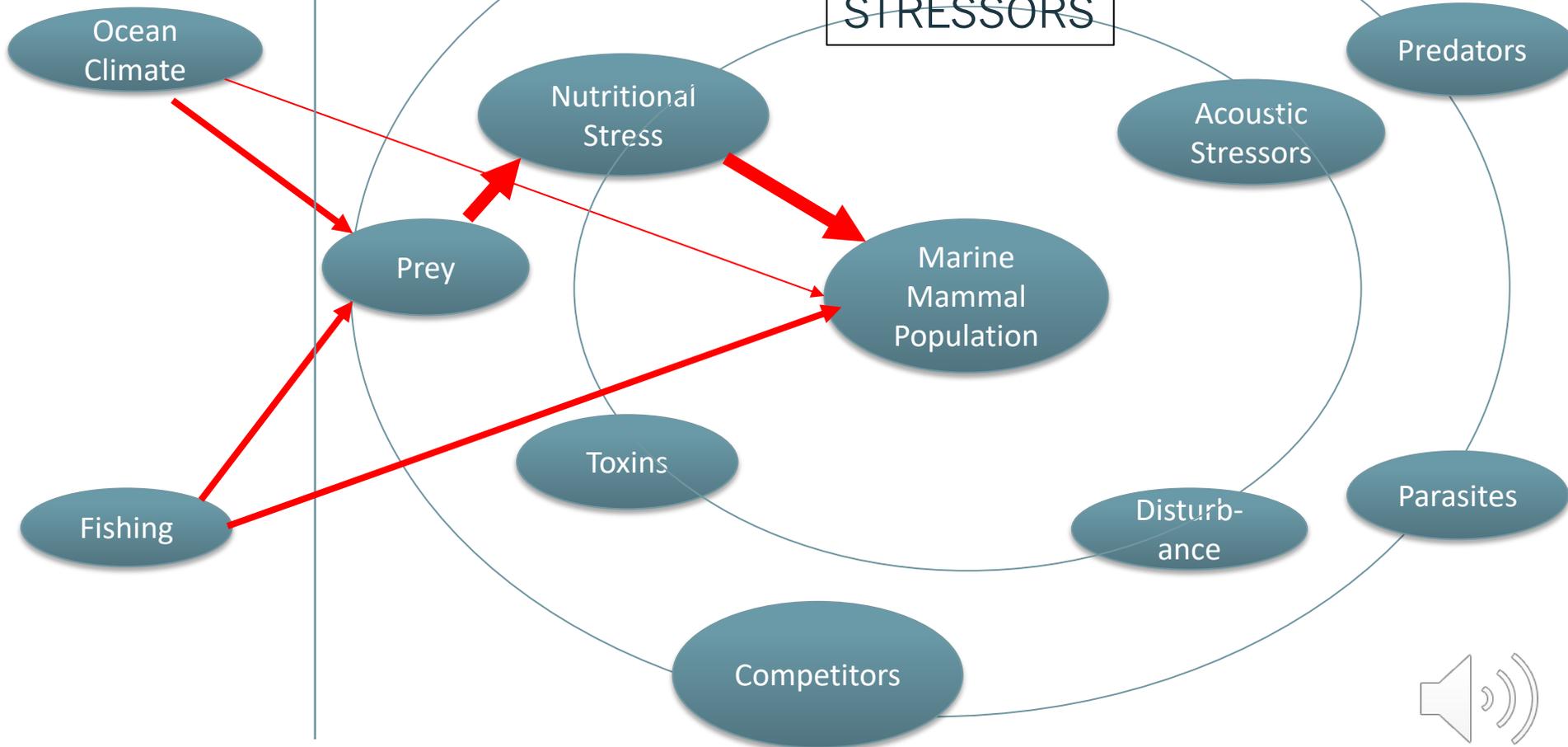


Ecological Interaction Web

Ecological Drivers

ECOSYSTEM COMPONENTS

STRESSORS

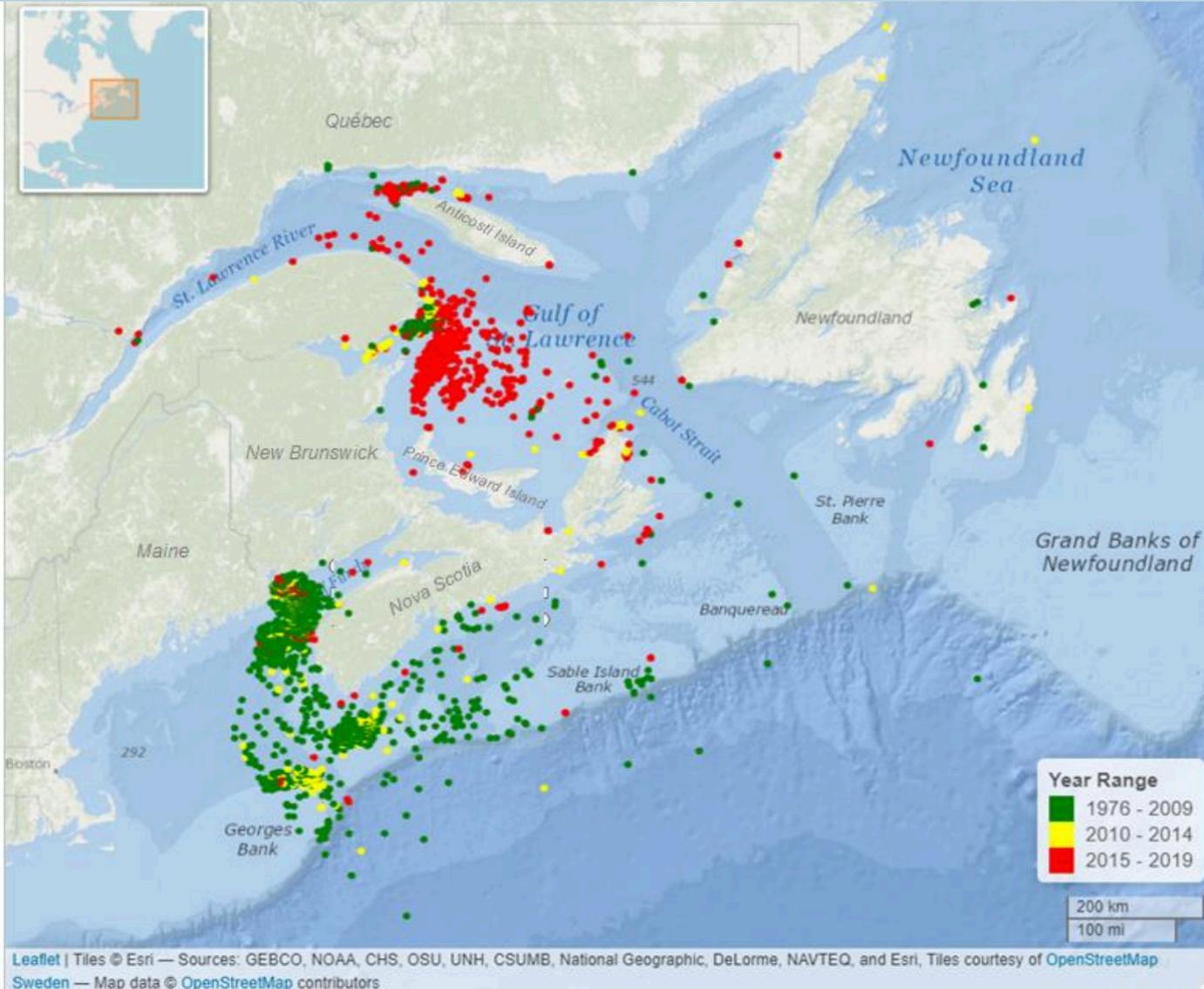


Importance of Indirect Effects

- Any two species may link together in the interaction web via direct or indirect interactions.
- **Direct interactions** are those in which there are no intervening species whereas indirect interactions are those in which there is one or more intervening species.
- **Indirect effects** can link species with stressors via long interaction chains that may involve both bottom-up and top-down forcing processes.



Climate Changes Distribution of Right Whales in Canada: 1976-2009, 2010-2014, 2015-2019



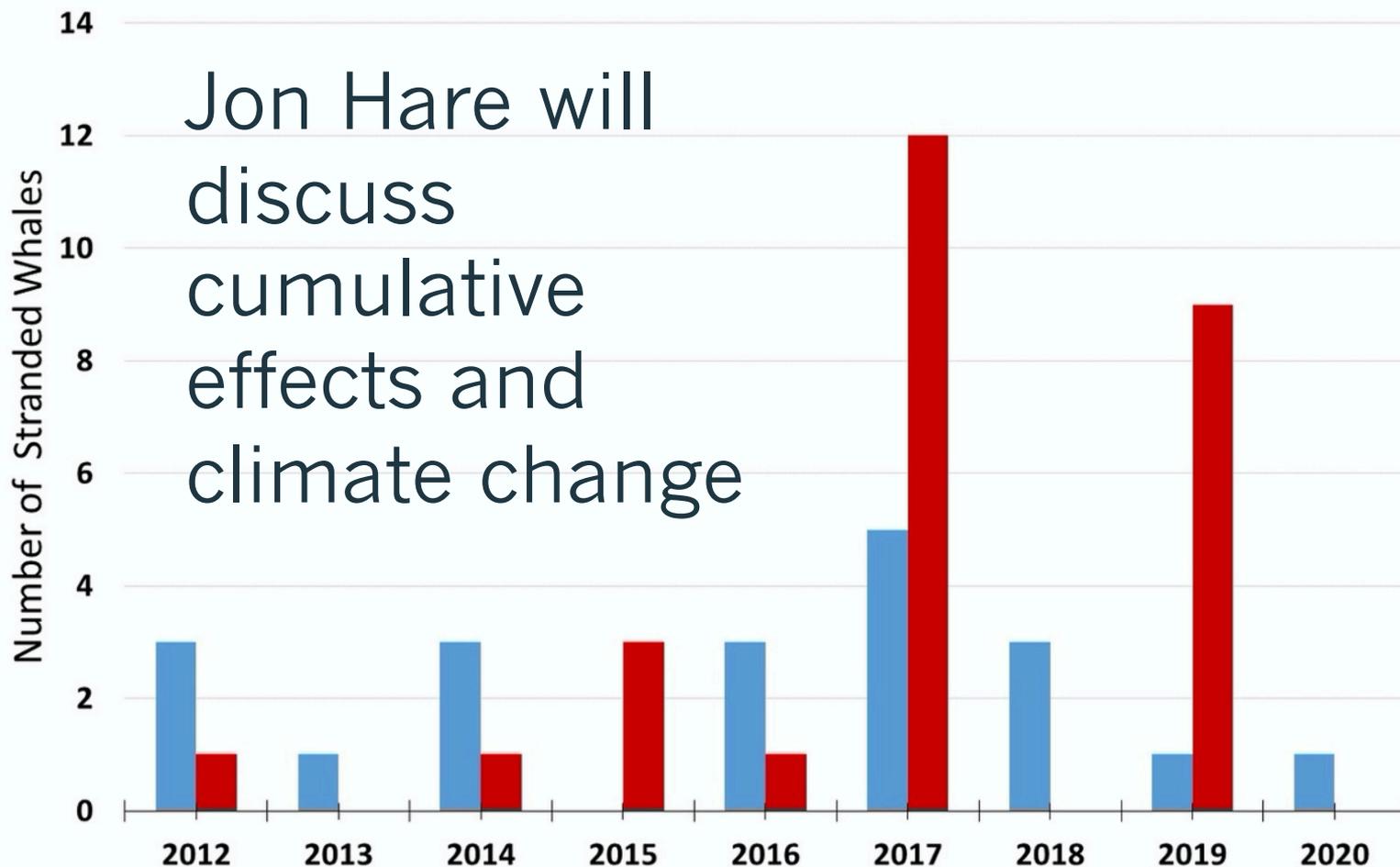
Bourque, L., Wimmer, T., Lair, S., Jones, M., Daoust, P.-Y. 2020. Incident Report: North Atlantic Right Whale Mortality Event in Eastern Canada, 2019. Canadian Wildlife Health Cooperative and Marine Animal Response Society. 210 pp.



Spike in Right Whale Mortality When Feeding Whales Moved to Canada

Annual North Atlantic Right Whale Mortalities

■ All U.S. Mortalities ■ All Canadian Mortalities



Jon Hare will discuss cumulative effects and climate change

U.S. National Marine Fisheries Service (2020) 2017-2020 North Atlantic Right Whale Unusual Mortality Event



Definition of Cumulative Effects from One or More Stressors

Cumulative Effects Are Defined As Stemming From:

Aggregate Exposure: Repeated Exposure to One Stressor Over Time, Potentially from Several Sources

OR

Cumulative Risk: Exposures to Multiple Stressors That Can Come From Many Sources At Different Times and Have Different Effects



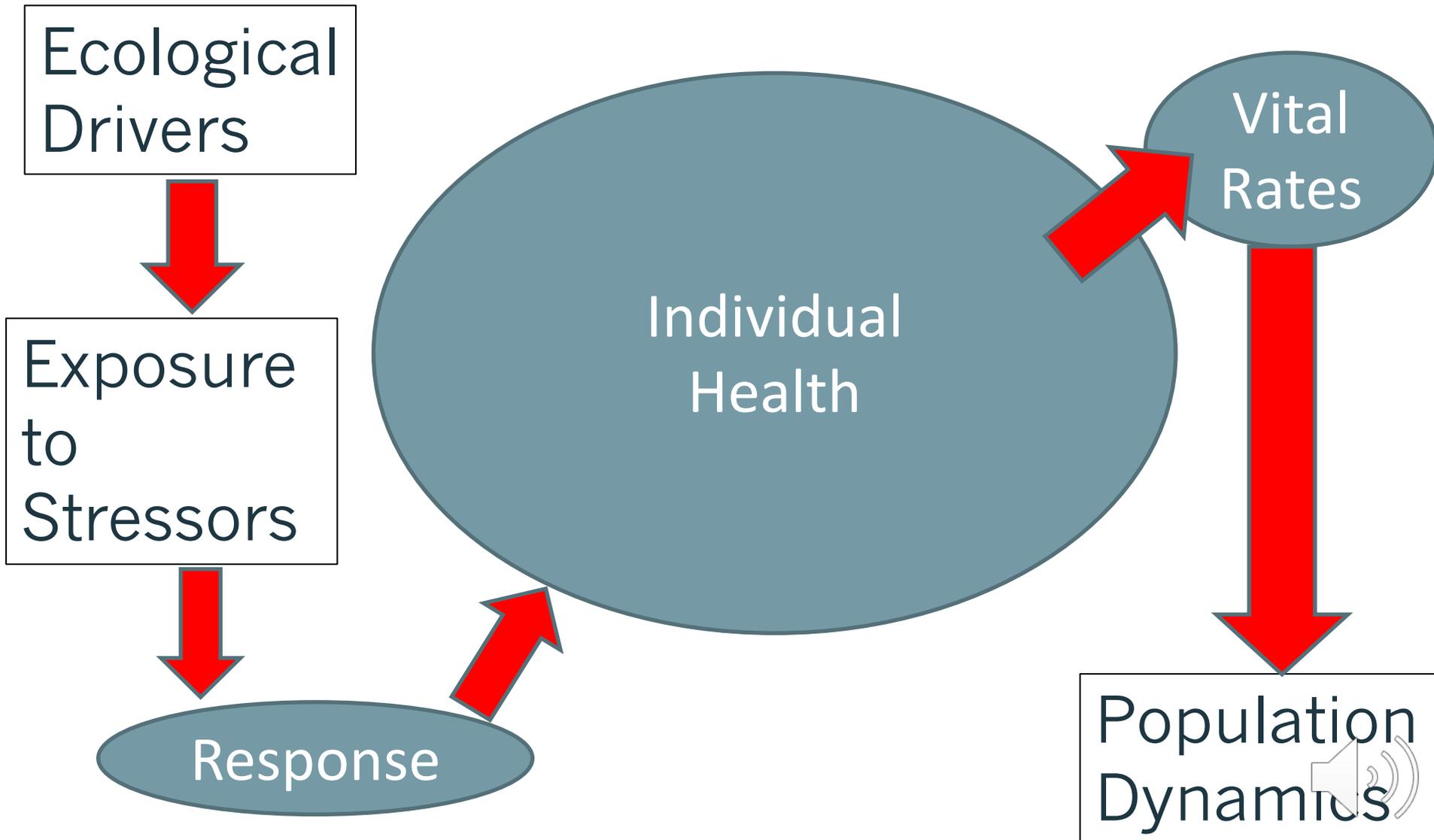
Bridging the Gap Between Short Term Responses and Lifetime Effects

The National Academies Committee developed a conceptual framework that uses an **intermediate health parameter** to:

- integrate effects of short-term responses to stressors
- link to long-term changes in survival and reproduction of individuals.



Population Consequences of Multiple Stressors

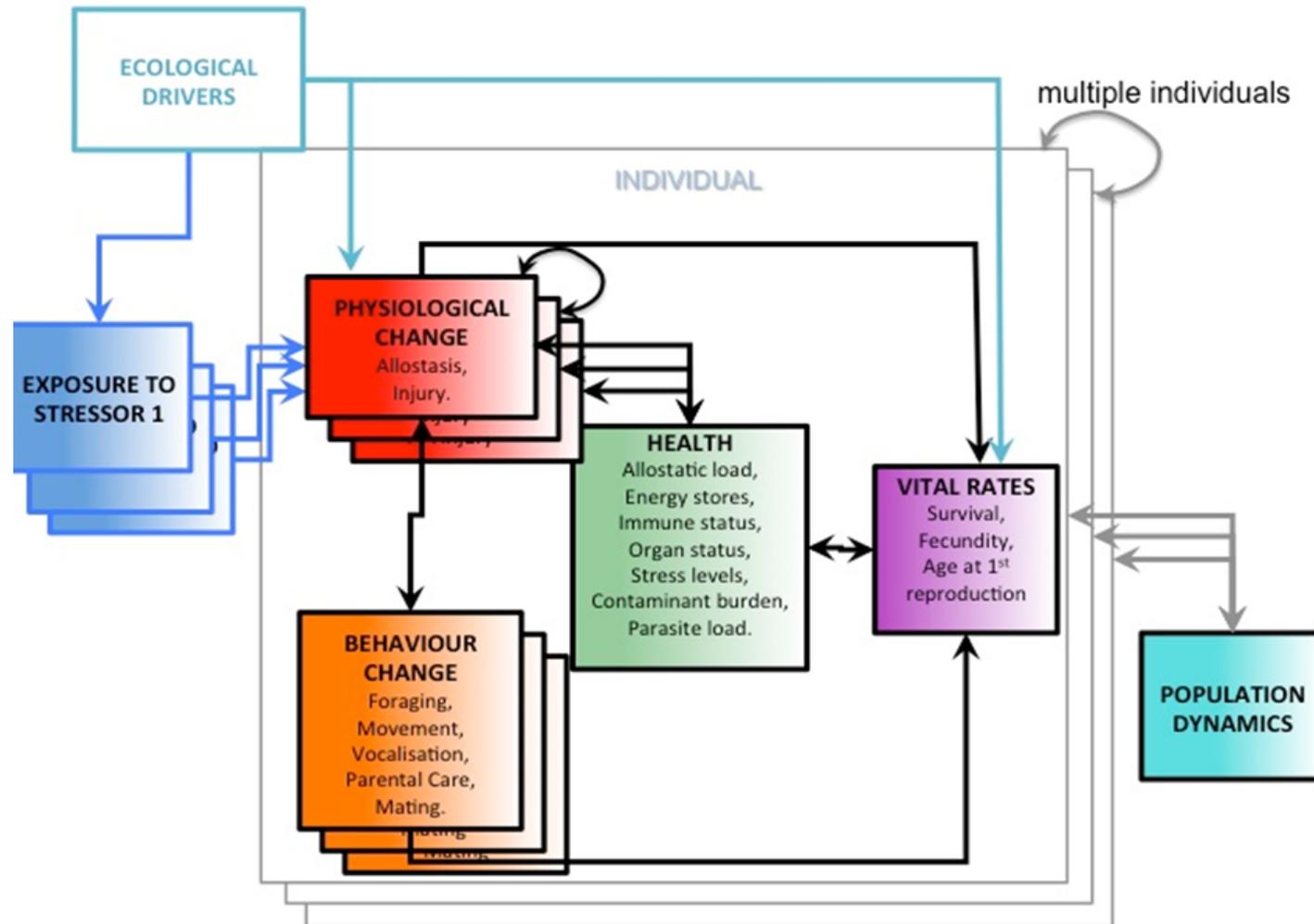


Measures for Assessing Health

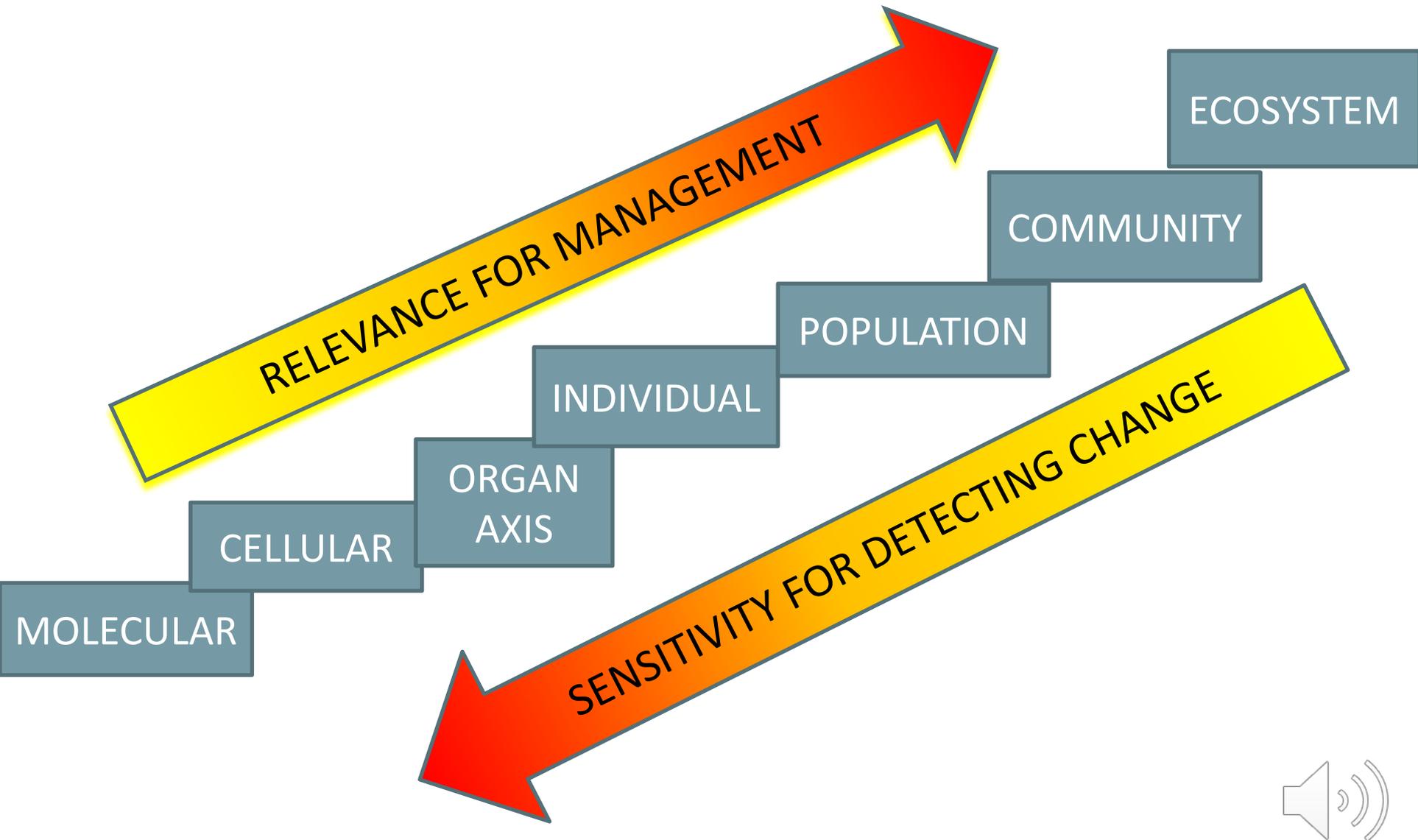
- Body Condition: imaging, buoyancy
- Organ Status: usually requires blood for hematology and serum chemistry, ultrasound
- Immune Status: many sophisticated markers have been developed for mammals, but require large cross-sectional datasets
- Stress: has chronic stress dysregulated the stress response? Need to characterize baseline and study dynamic response to acute stressor



Population Consequences of Multiple Stressors (PCoMS) model



Responses to Stressors Across Levels



Between Experiment and Monitoring

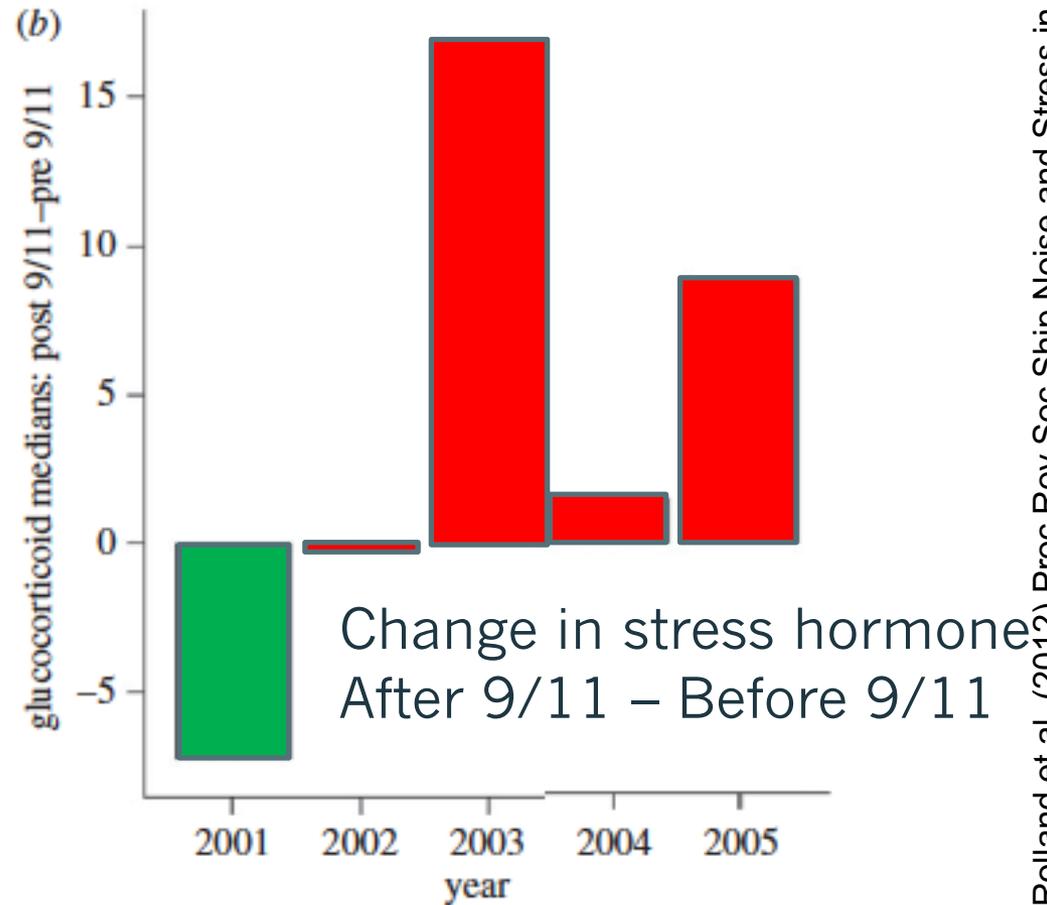
- Controlled experiments are the most rigorous way of testing for the influences of potential stressors on any species.
- For marine mammals, such experimental approaches are often not possible, in which case inferences must be based on quasi-experiments.
- Although quasi-experimental data are subject to confounding and thus multiple interpretations, reasonably strong inferences are often possible from time series analyses and weight of evidence approaches.





Stress Hormones
in Right Whale
Feces Dropped
After 9/11 in 2001
but not Later Years

Quasi-Experiments



Recommendation re Adaptive Management

- Adaptive management should be used to identify which combinations of stressors pose risks to marine mammal populations, and to select which stressors to reduce once a risk is identified.
- In this approach, hypotheses are developed which guide management actions, and data are collected to assess the strength and impact of individual stressors and their cumulative effects.
- This approach could suggest quasi-experiments applying different management actions in different sites to evaluate effectiveness and cost/benefit



Approach Based On Ecosystem Effects Rather Than Human Actions

- Regulation of environmental impacts often focuses on one proposed activity at a time, analyzing the cumulative effect of one proposed action when added to other actions
- Reduction of risk may be limited to the proposed action
- An alternate ecosystem-focused approach would regularly test whether cumulative effects risk adverse impacts
- If so, identify a practical reduction in stressors to reduce the risk



Closing points

- The state of the science of cumulative effects has low predictive power compared to regulatory demands to assess these effects.
- The most important goals for managing cumulative effects are (1) identifying when the cumulative effects of stressors risk transitioning a population or ecosystem to an adverse state; and (2) identifying practical reductions in stressors to reduce this risk



Thank you!

Approaches to Understanding the
Cumulative Effects of Stressors on
Marine Mammals
Download the report at nap.edu

