Assessing the population level impacts of acoustic disturbance associated with marine energy devices on marine organisms

John Harwood, University of St Andrews and the ONR Working Group on the Population Consequences of Acoustic Disturbance

Marine mammals and Marine & Hydrokinetic Devices in the UK

- UK already has one operational tidal energy device –
- Carol Sparling described the marine mammal monitoring that has been carried out around this device in her August 29 Webinar.
- Several others will almost certainly be installed over the next 2-3 years
- Many more have been licenced
- Primary concern for marine mammals is injury associated with the moving parts of these devices
- However, disturbance associated with noise during construction and operation could be an issue.

Disturbance causes changes in the behaviour of individuals. How do these affect their vital rates? What are the population-level consequences?

- Disruption of mating
- Separation of mothers and offspring
- Death or injury through inappropriate behavior (particularly important in species that undertake “dangerous” activities like deep diving)
- Shifts in migration
- Increased risk of predation
- Altered energy expenditure
- Reduced food intake
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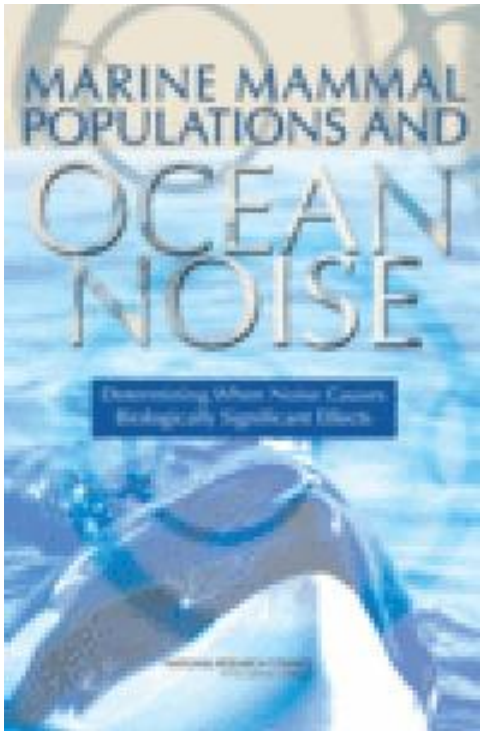
The NRC "conceptual model" for the impacts of ambient noise on marine mammals



SOUND
Frequency
Duration
Level
Source
Duty cycle

+ + +

+

BEHAVIOR CHANGE
Orientation
Breathing
Vocalization
Diving
Mother-infant spatial-relationships
Avoidance

+ +

+

LIFE FUNCTION IMMEDIATELY AFFECTED
Survival
Migration
Feeding
Breeding
Nurturing
Response to predator

+

0

VITAL RATES
Stage specific
Survival
Maturation
Reproduction

+

+ + +

POPULATION EFFECTS
Population growth
Population structure
Transient dynamics
Sensitivity
Elasticity
Extinction probability

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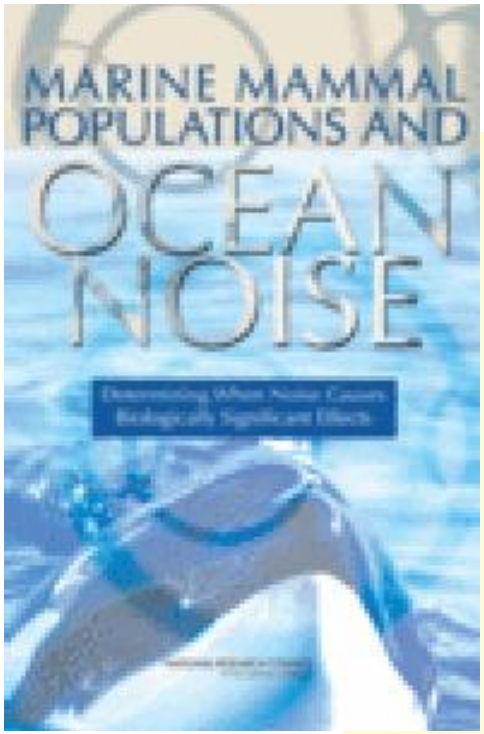
"... designed to serve as a roadmap for developing a predictive model that will relate behavioral responses caused by anthropogenic sound to **biologically significant**, population-level consequences"."

The NRC committee concluded: "consensus [is] we are a decade or more away from having the data and understanding of the transfer functions needed to turn such a conceptual model into a functional, implementable tool."



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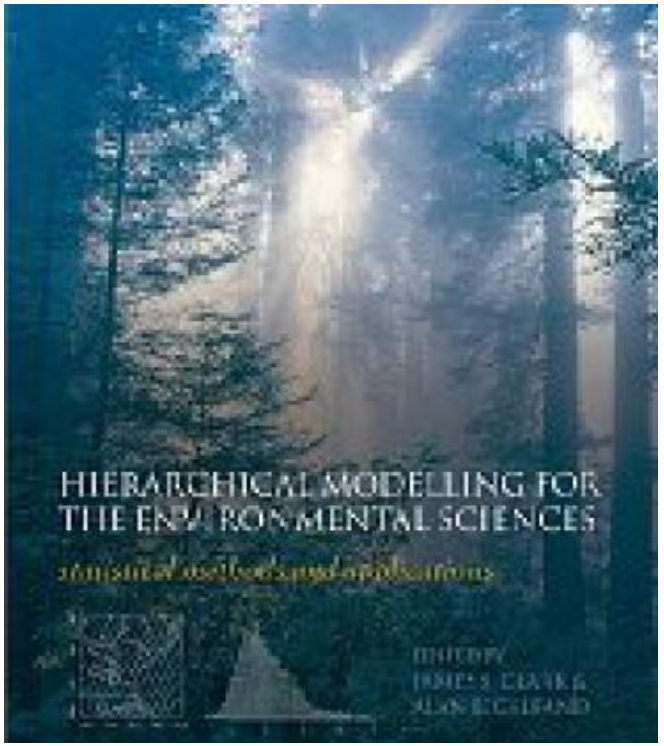
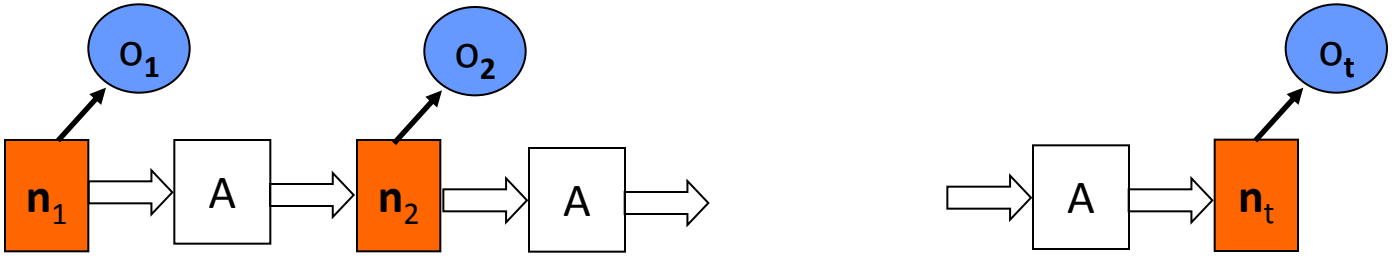
However, recent advances in statistical analysis and modelling have made this possible now.

Conceptual and statistical approaches for investigating the population consequences of disturbance

- Understanding of trait-mediated effects
- State-space (or hidden process) modelling framework
- A key assumption of most implementations: all individuals in a population (or some population unit – e.g. all females) are identical
- Known as "**the ecological fallacy**" in public health science (courtesy of Jim Clark)
- A variety of relatively new statistical techniques (particularly **Hierarchical Bayesian analysis**) can account for individual variation without resorting to individual-based models

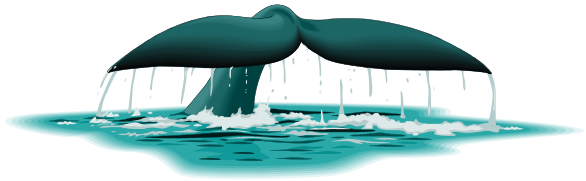




US Office of Naval Research has supported a PCAD Working Group to implement this approach

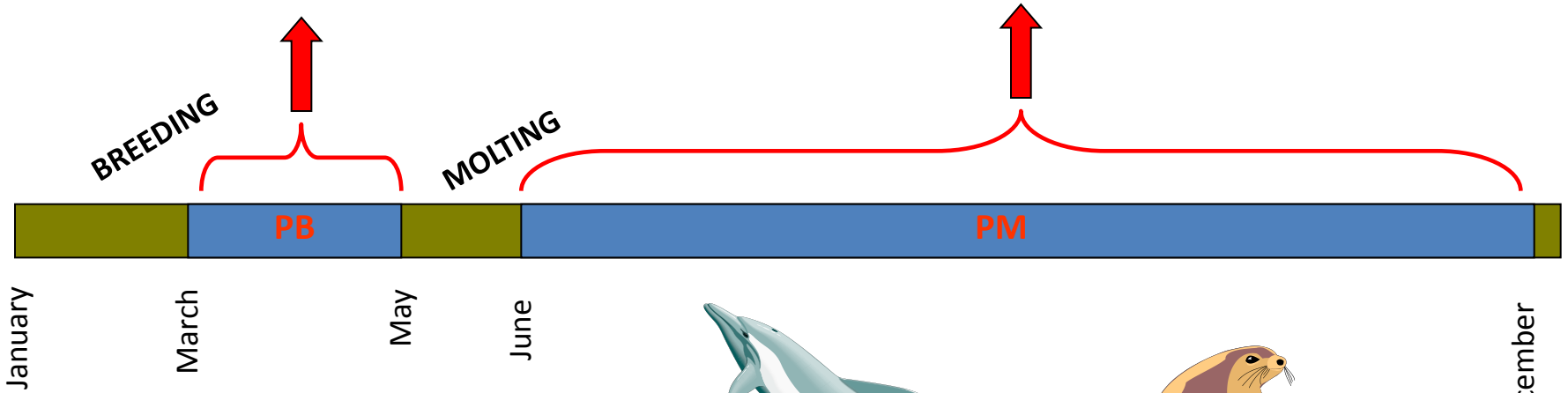
- Considered 4 case studies where there appears to be enough data to begin constructing suitable models and that cover the two major breeding strategies of marine mammals

Capital Breeders

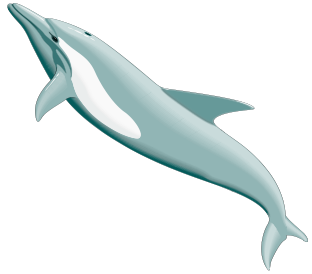


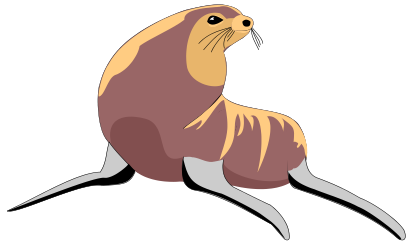
PB – Post Breeding foraging trip

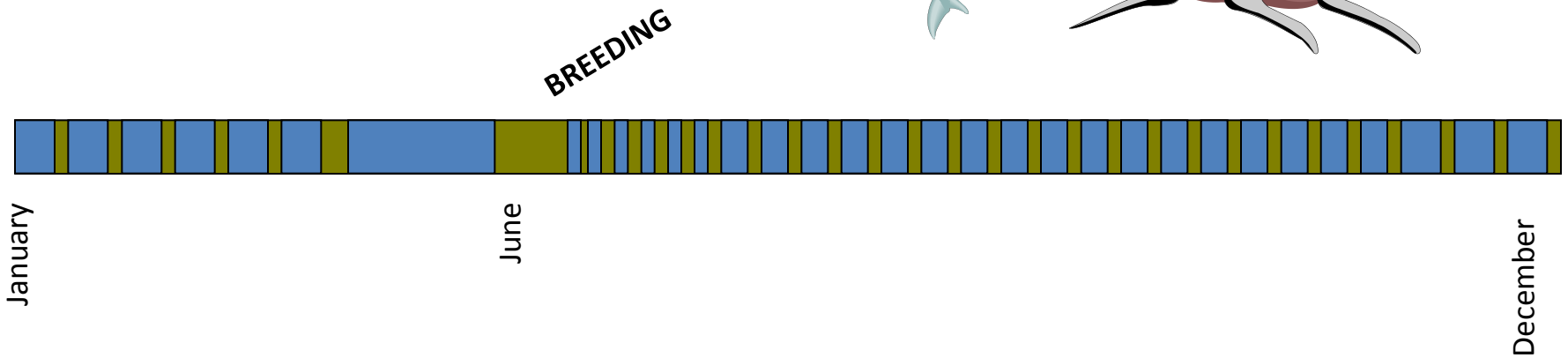
PM – Post Molt foraging trip



Income Breeders



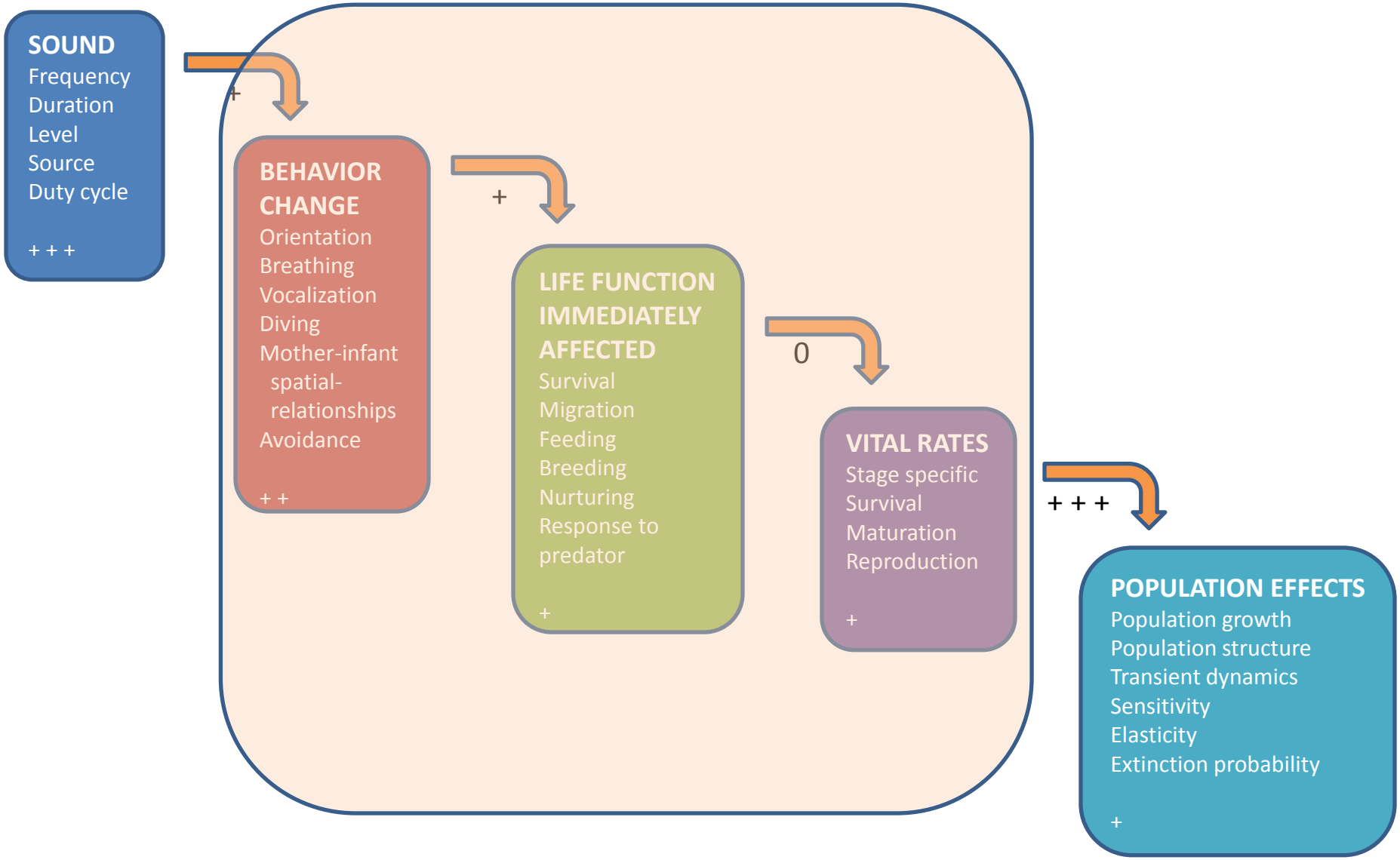




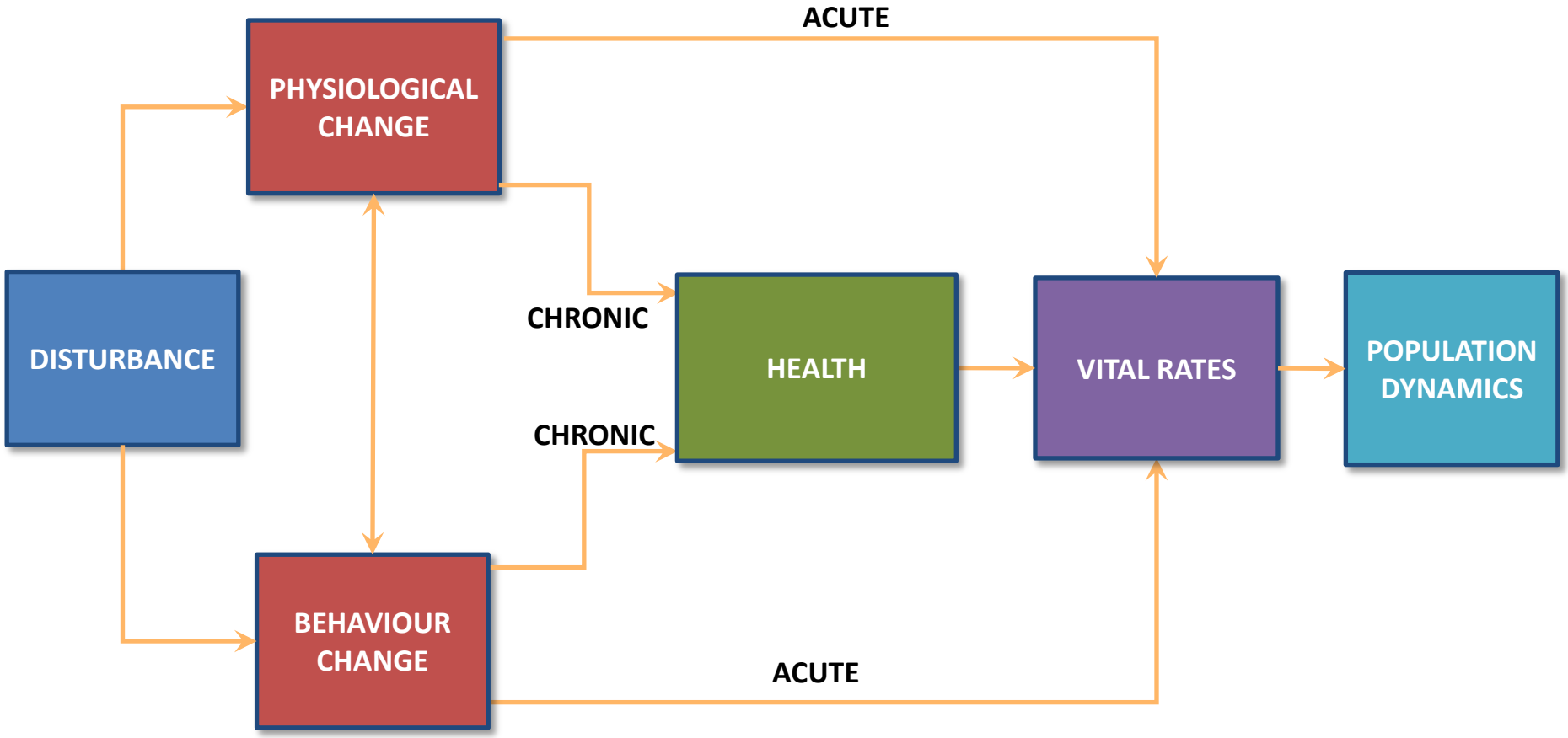
PCAD Working Group

- Considered 4 case studies where there appears to be enough data to begin constructing suitable models and that cover the two major breeding strategies of marine mammals
- Work closely with data owners to develop these models
- First meeting: seals, fur seals, & sea lions. Focused on elephant seals.
- Second meeting: coastal populations of bottlenose dolphins
- Third meeting: North Atlantic right whales
- Fourth meeting: beaked whales

PCAD conceptual framework



The new PCoD (Population Consequences of Disturbance) framework



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3. Determine what data are available to estimate the parameters of these models.

4. Create simulated data sets to determine whether state space modeling can provide robust estimates of model parameters.

5. If state space modelling works, proceed to a full fitting exercise. If it doesn't, use the underlying process models developed in step 2. as the basis for a simulation study.

6. Use models resulting from steps 2-5 to investigate the implications of a range of disturbance scenarios for individual vital rates.

(7. Assess what proportion of a local population might be impacted by each of these disturbances and use this in combination with the results from step 6. to determine the consequences for population-level demographic rates and population viability.)

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8. Use this, with the results from step 6. to determine the consequences at the population level.)

Why use elephant seals as a case study?

- Capital breeders
- Simple annual cycle for a colony: breed → leave to feed → return to molt → leave to feed → return to breed
- Satellite transmitters provide information on diving behavior, body condition and location for entire duration of feeding trip
- Pup survival strongly influenced by maternal body condition

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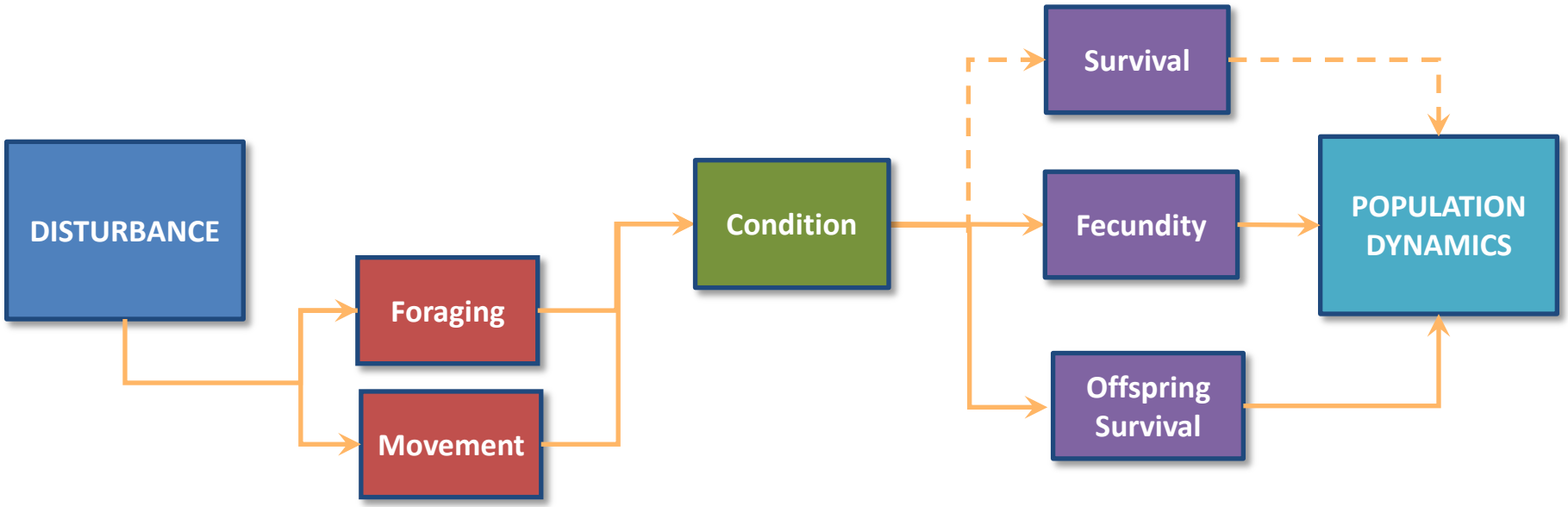
Elephant seals in the PCoD framework

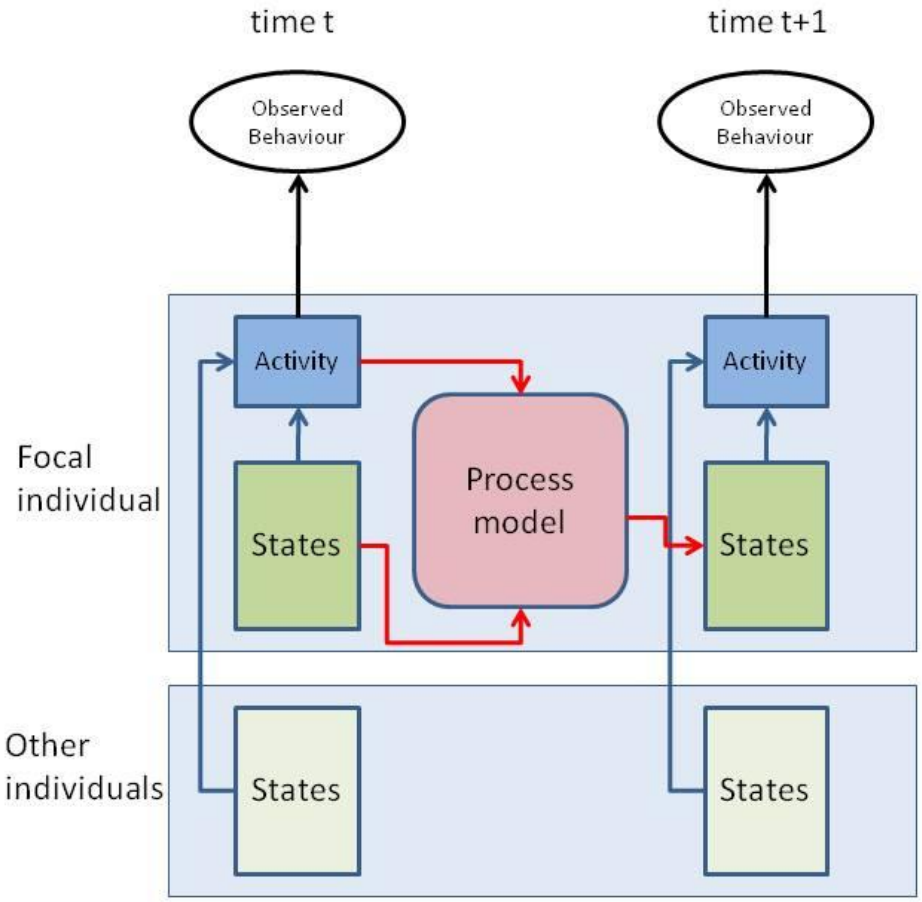


Gitte McDonald

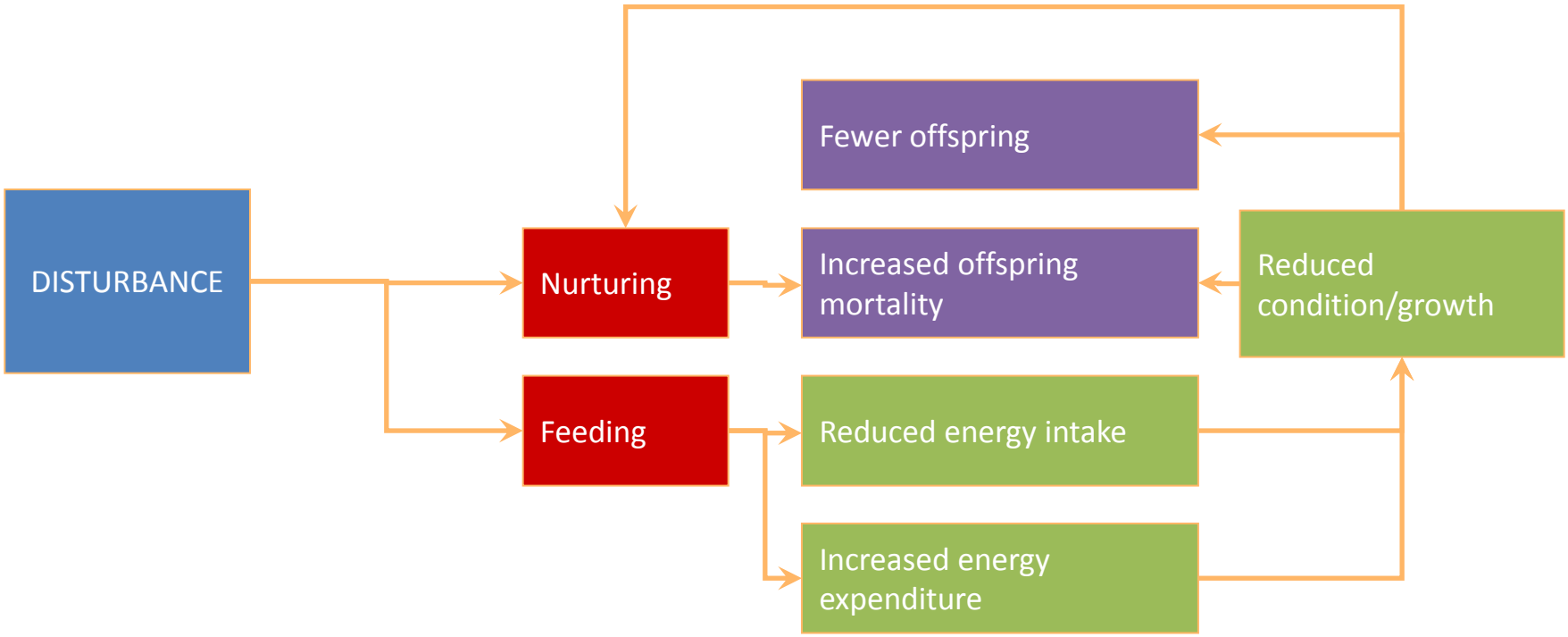
Why use coastal bottlenose dolphins as a case study?

- Income breeders
- Long term studies of population structure, individual life histories, behavioural time budgets, etc. from a number of sites, particularly Sarasota Bay, Florida
- Data from two sites (Doubtful Sound New Zealand and Shark Bay, Australia) suggest that animals' main preoccupation is to avoid predation by sharks

The state space model developed for coastal bottlenose dolphins



PCoD model
Coastal bottlenose dolphins



Why use North Atlantic Right Whales as a case study?

- Capital breeders
- Critically endangered – but a useful comparison can be made with rapidly recovering South Atlantic Right Whale
- Multiple databases of a wide range of detailed observations, paticulaly individual health, curated by the Northern Right Whale Consortium

Why use beaked whales as a case study?

- Primarily income breeders
- Detailed data on response of individual animals and local populations to acoustic disturbance
- Long term studies of population structure in areas where there is and isn't regular disturbance.

Two take-home messages

- Avoiding predation is a high priority in all case studies
- As a result, disturbance generally results in a reduction in energy intake, or an increase in energy expenditure.