# *A Conceptual Framework for Evaluating the Effects of Disturbance on Marine Mammal Populations*

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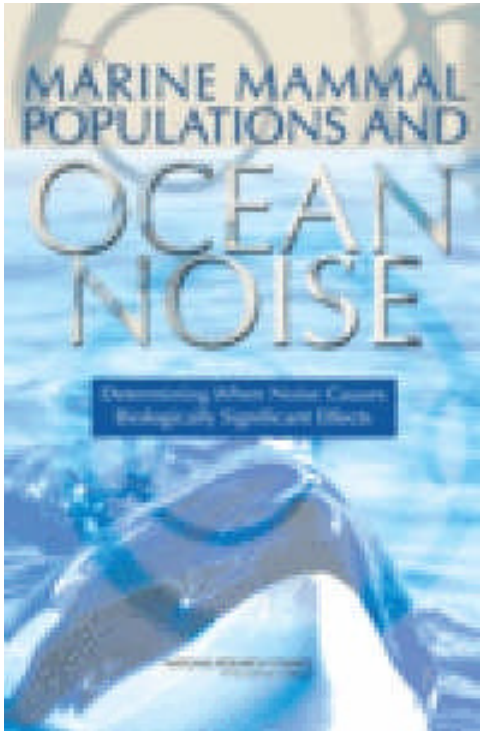
**Symposium:** ***Population Consequences of Acoustic Disturbance to Marine Mammals***

## 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
- All of these effects are likely to depend on the context in which disturbance occurs

# 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

+

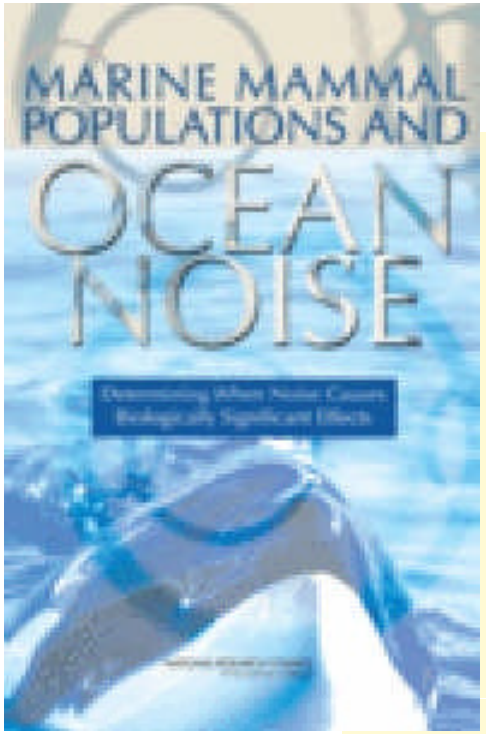
+ + +

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

+

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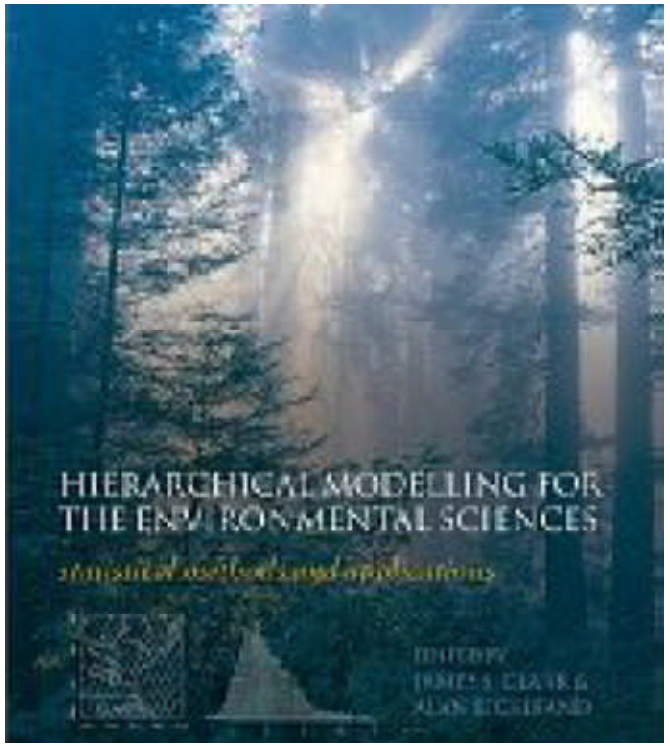
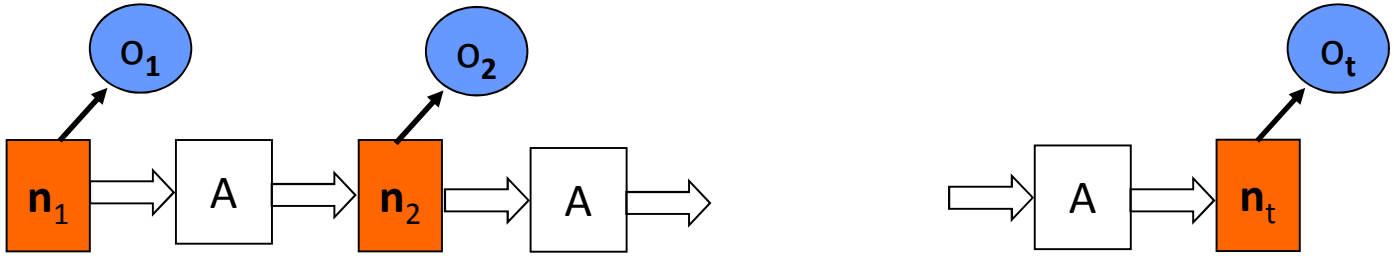
However, recent advances in statistical analysis and modelling have made this possible now.

# 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

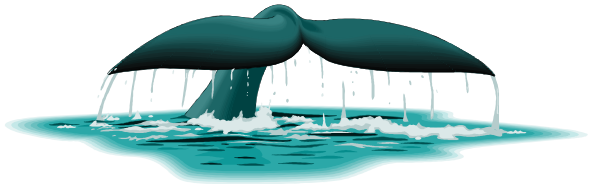


# PCAD Working Group

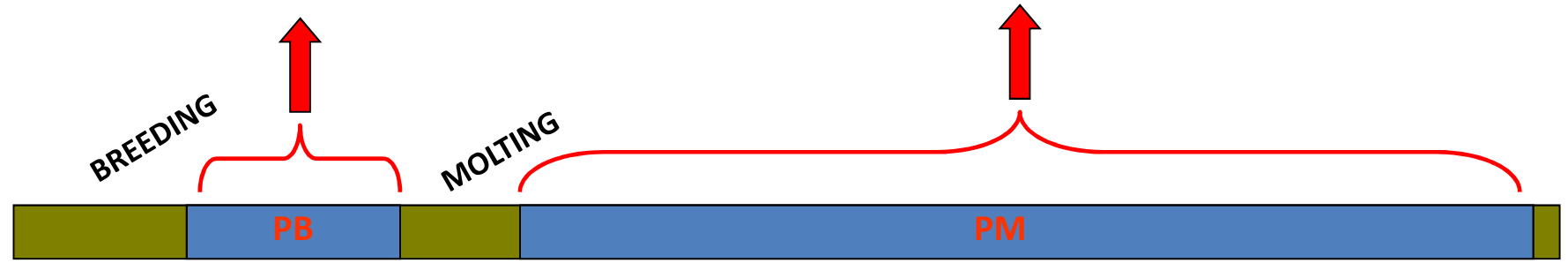
- Considered 4 case studies where there appears to be enough data to begin constructing suitable models and that cover the two major breeding strategies of marine mammals

## Capital Breeders

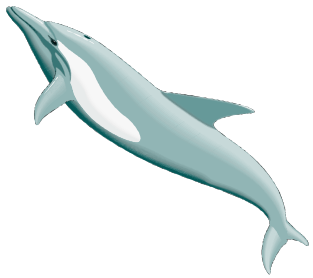


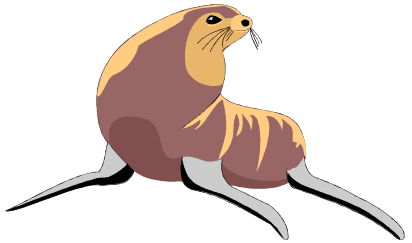
PB – Post Breeding foraging trip

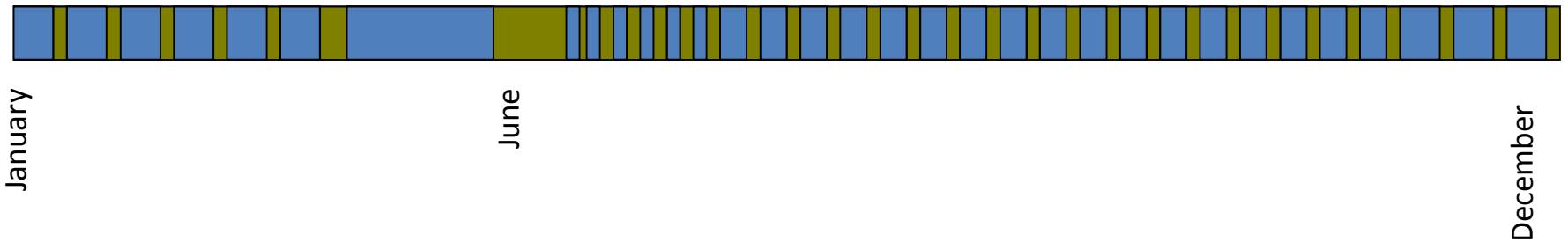
PM – Post Molt foraging trip




## Income Breeders



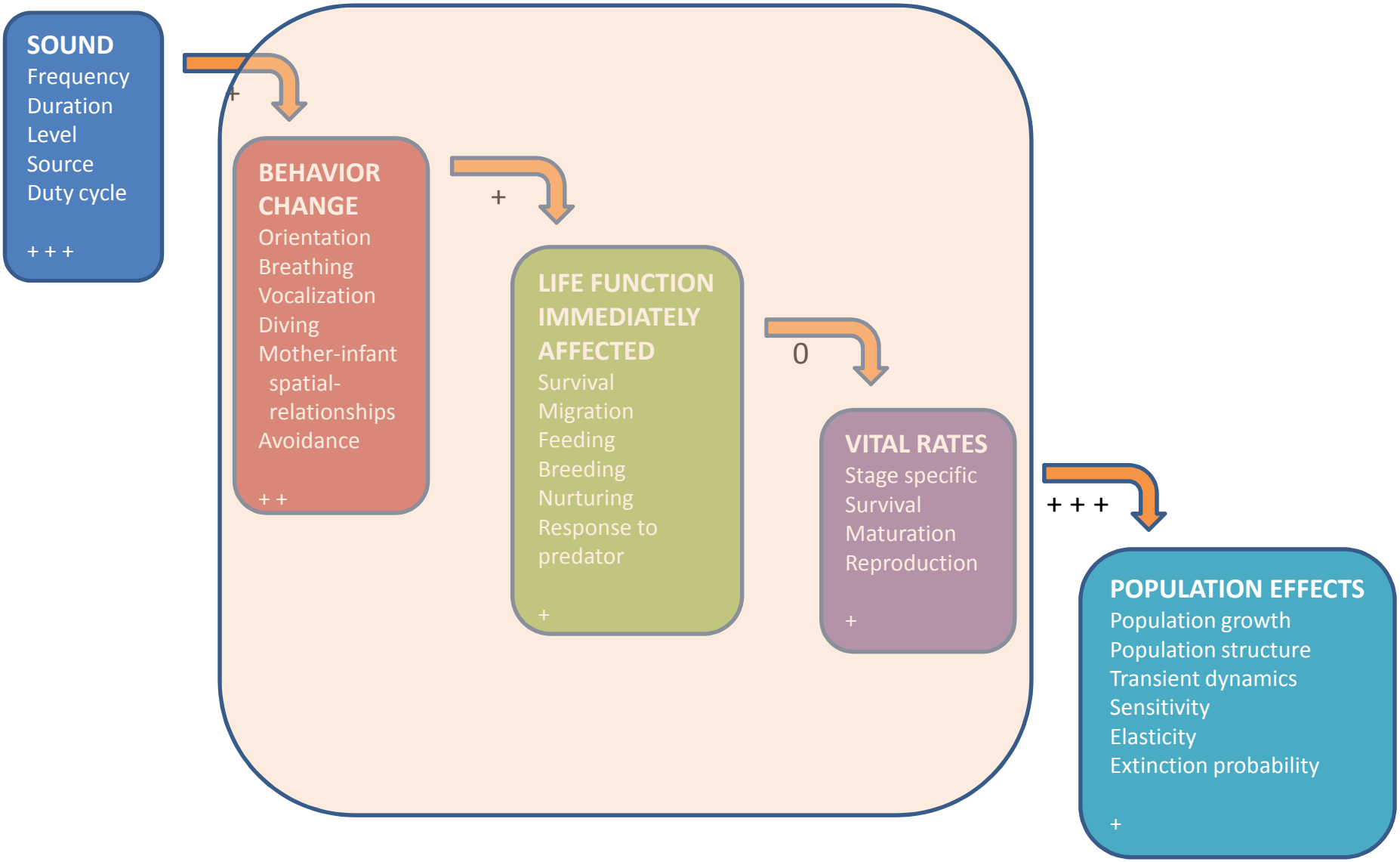




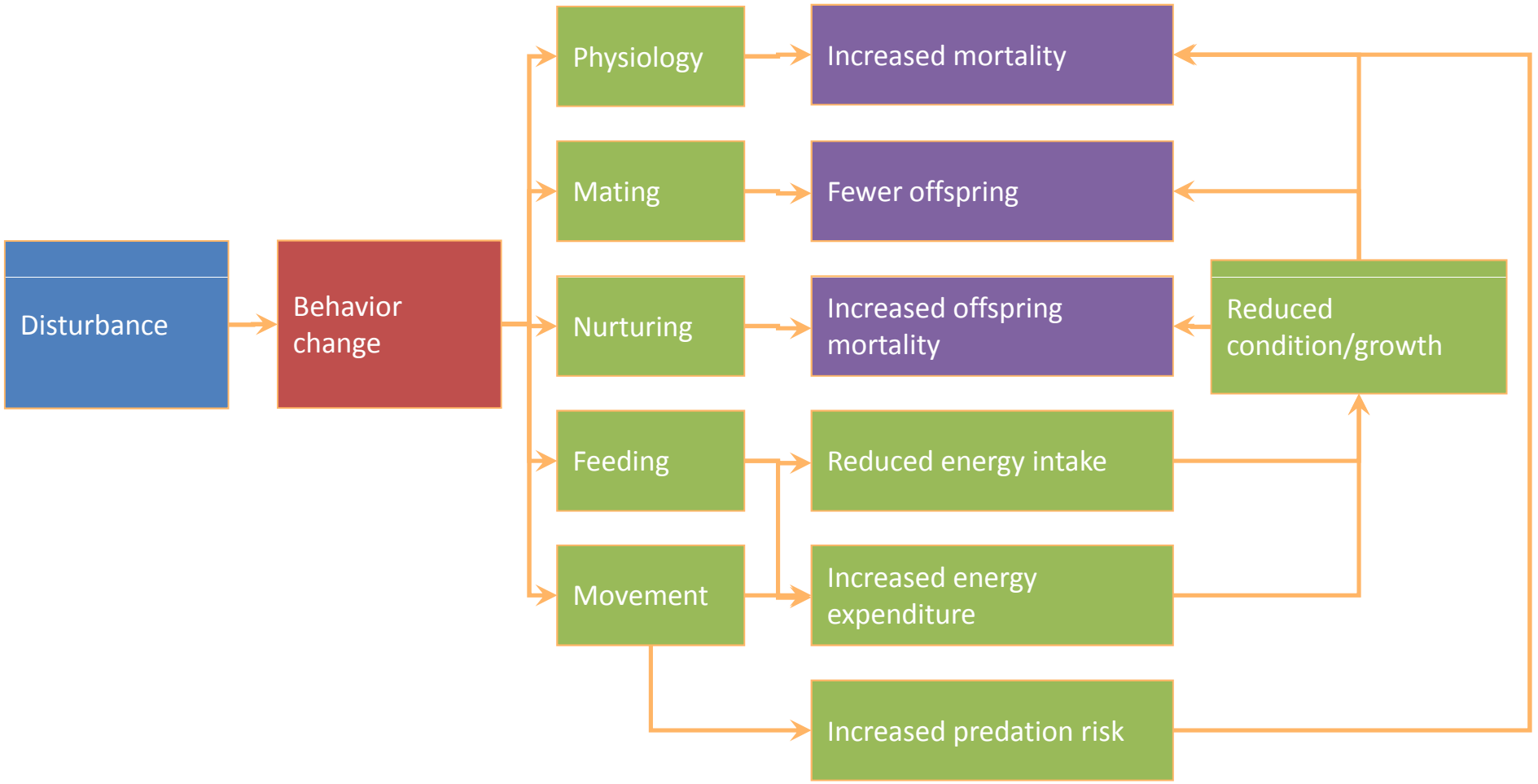
# PCAD Working Group

- 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



# PCAD model
# From behaviour to vital rates



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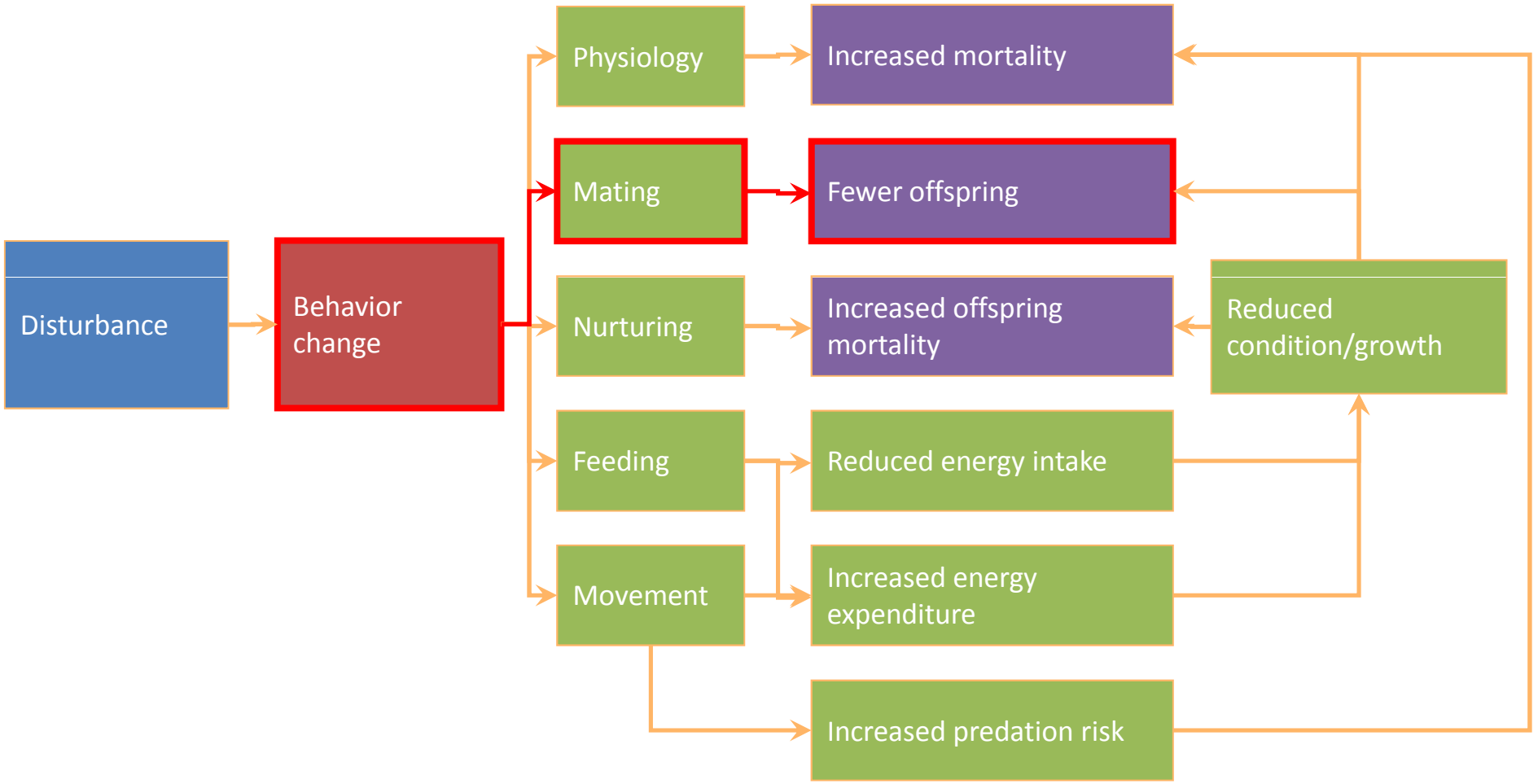
## Direct effects of behaviour on vital rates



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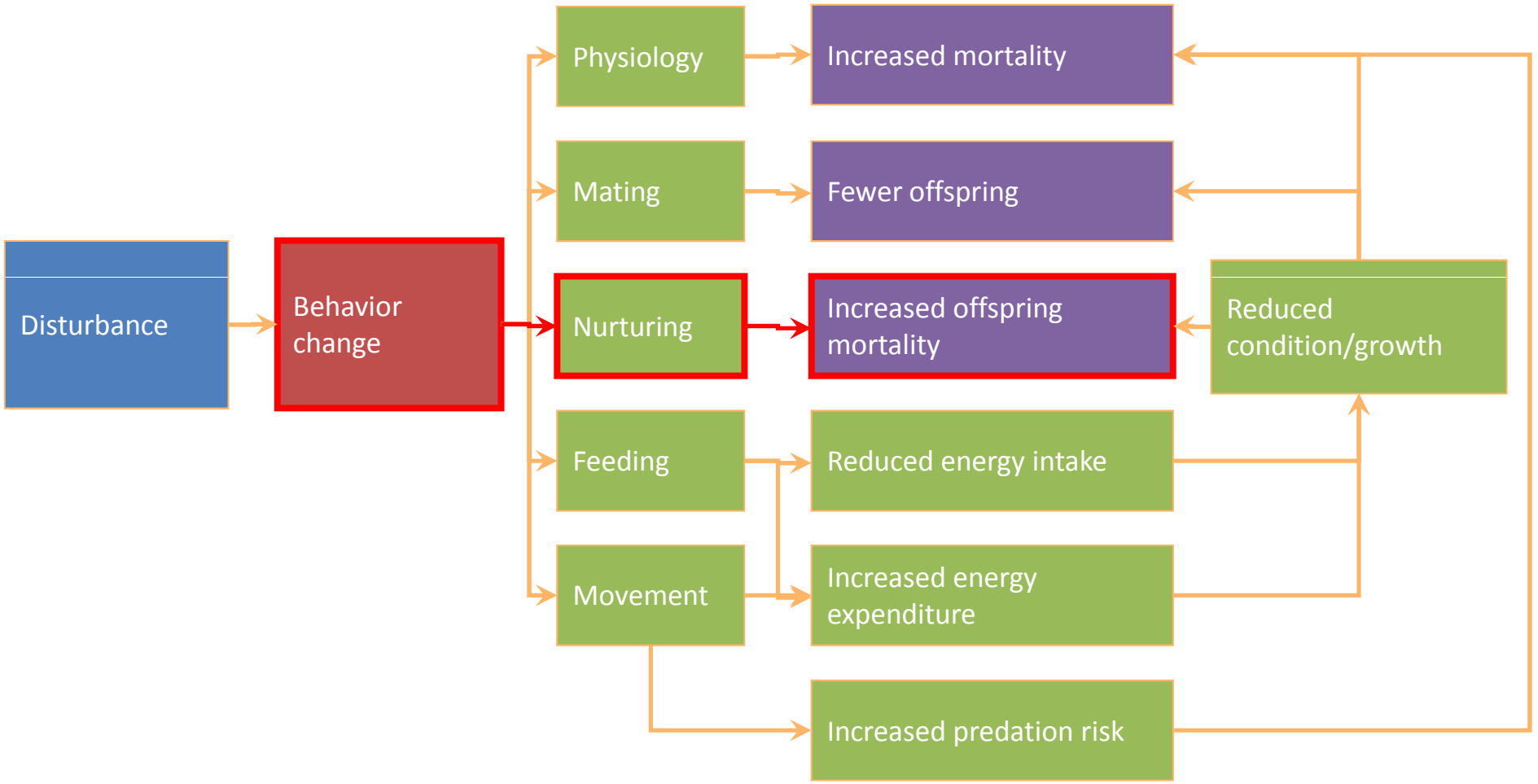
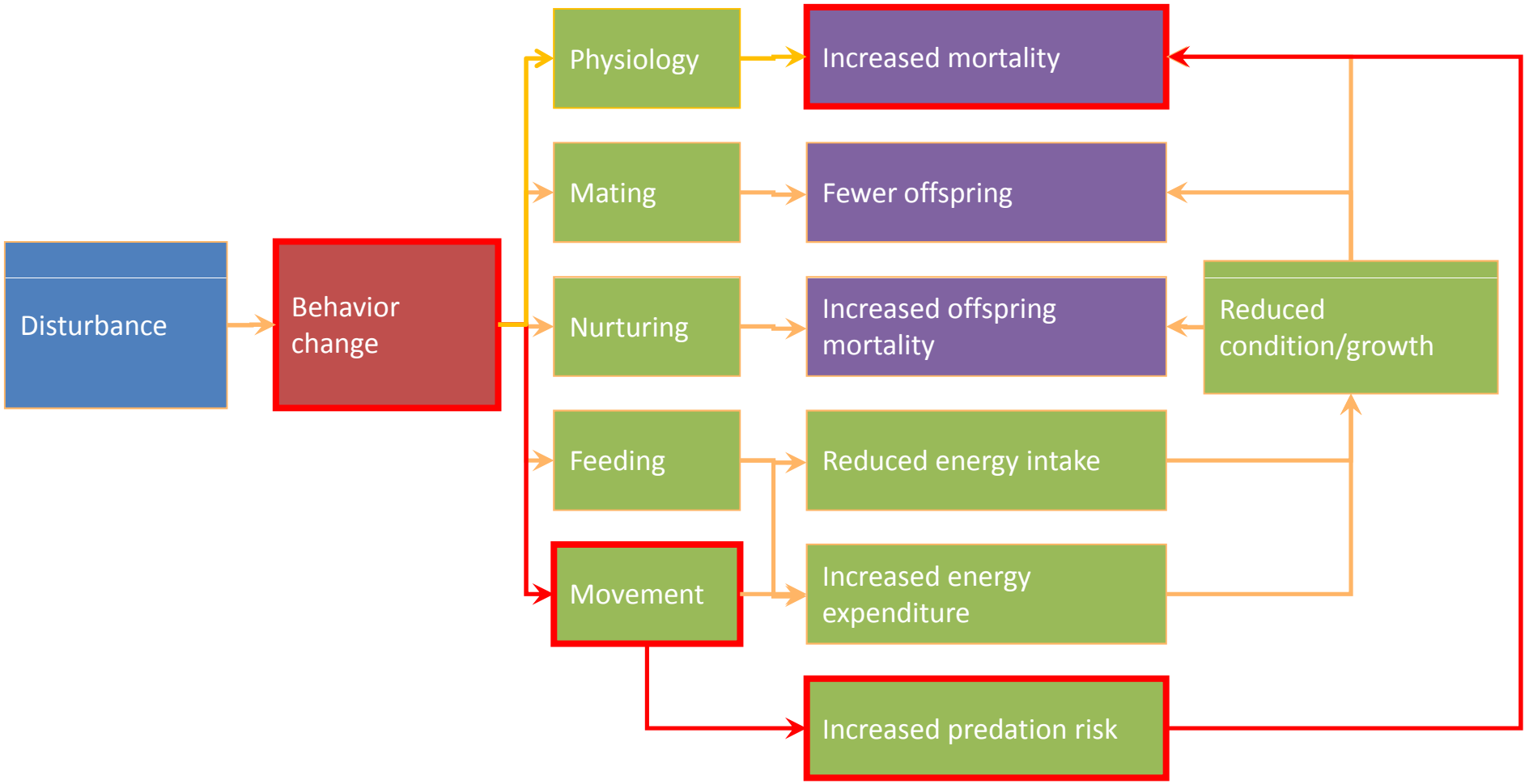
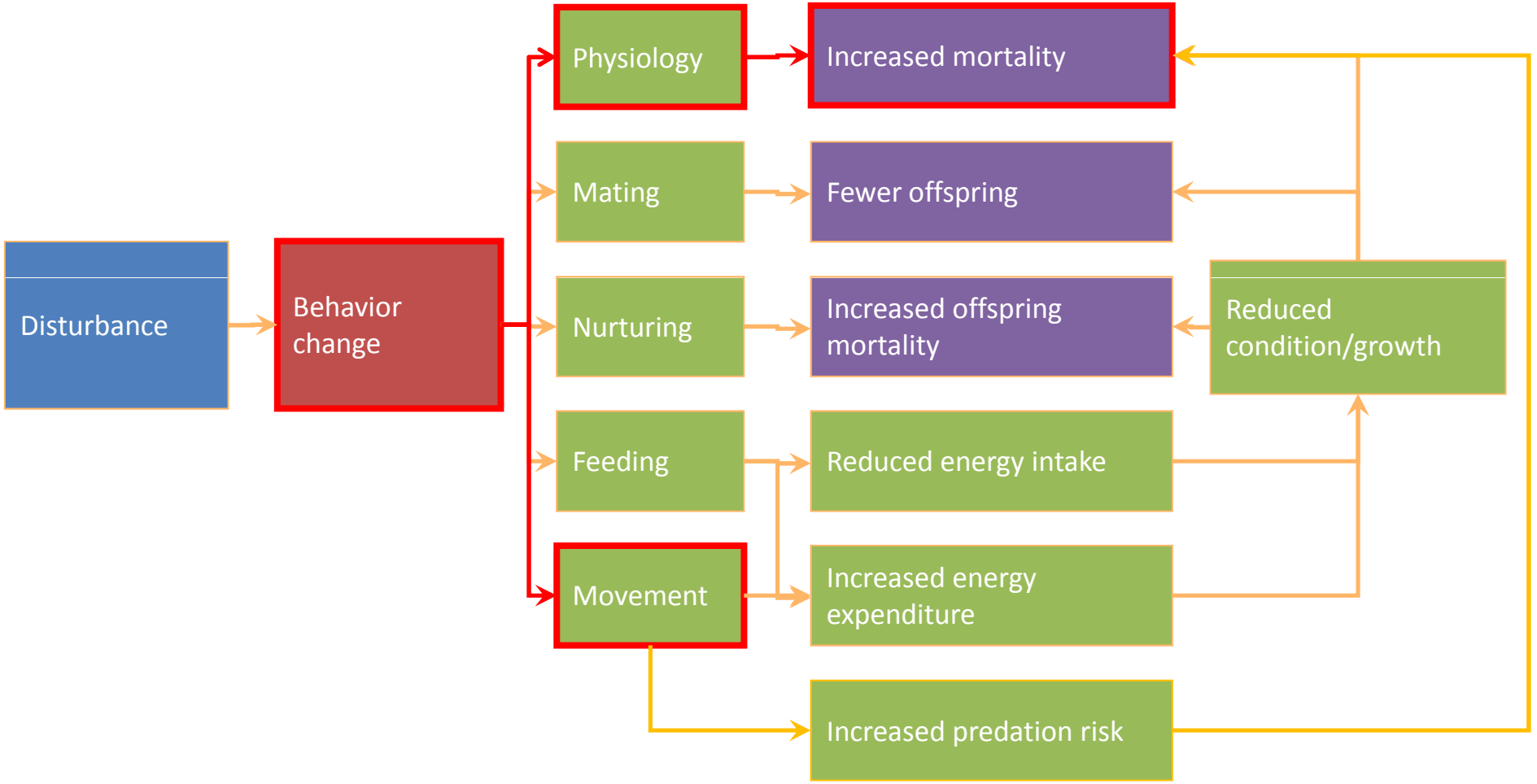


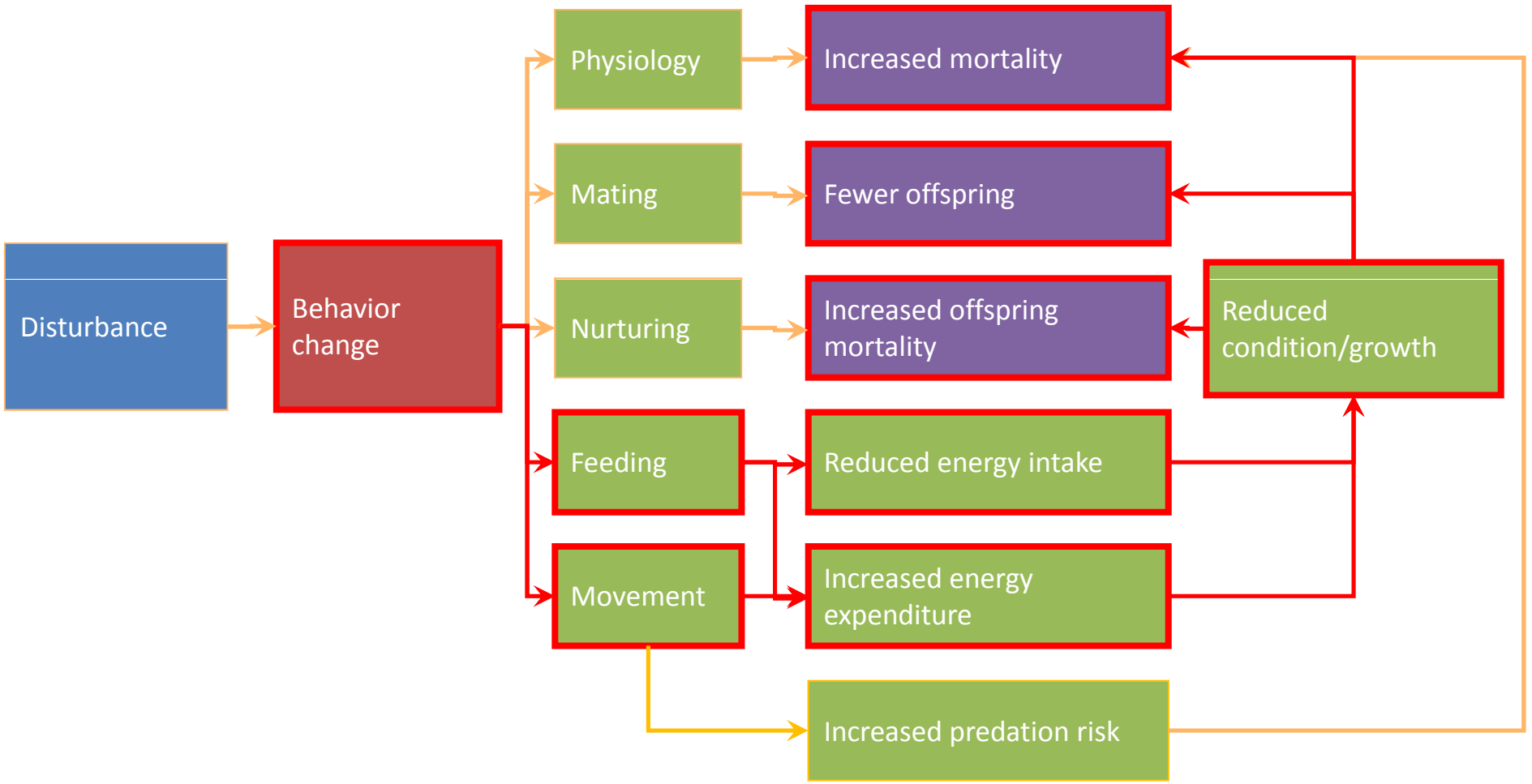
# PCAD model
# Increased predation risk



# PCAD model
# Trait-mediated effects



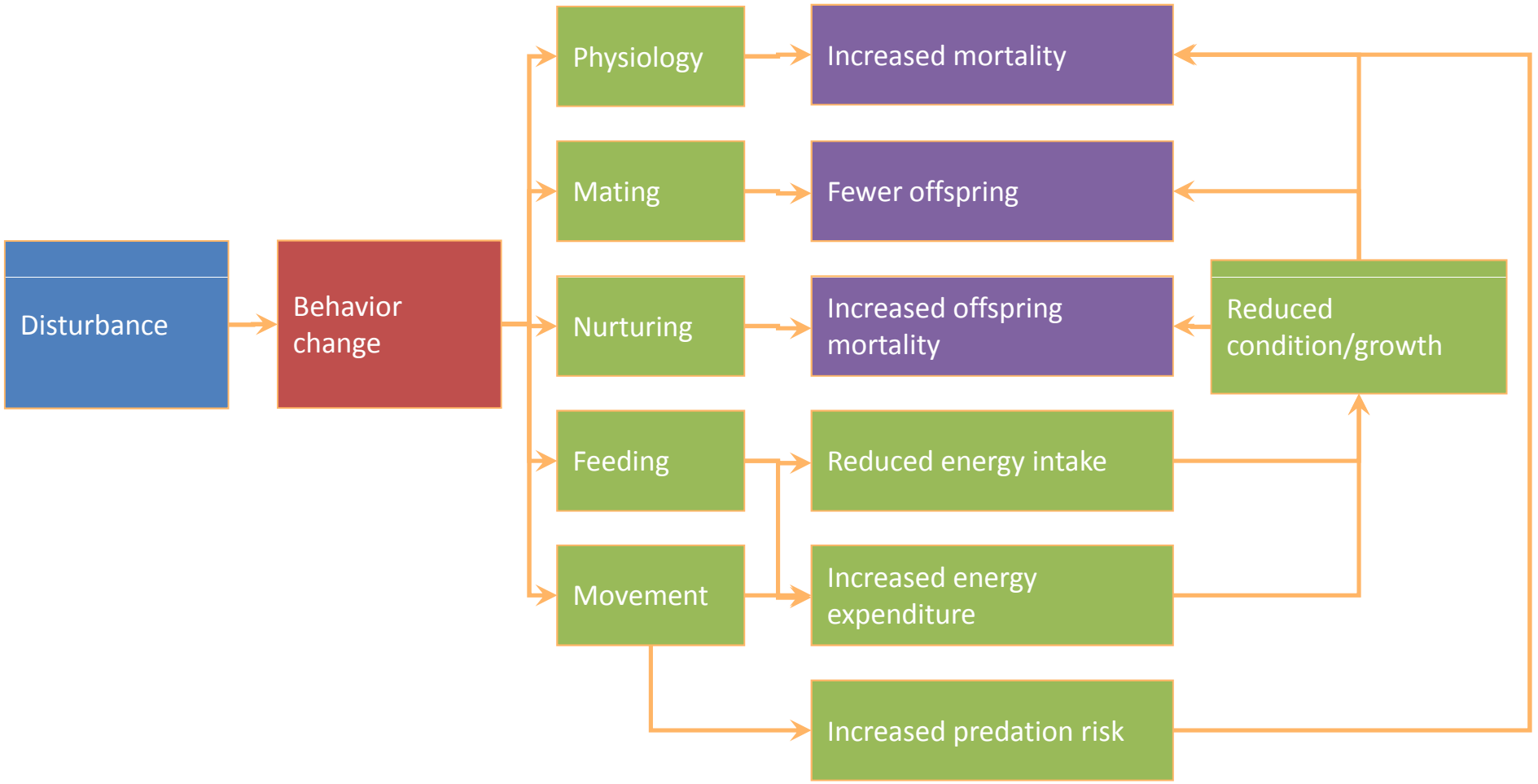
# PCAD model:
# Indirect effects of behaviour on vital rates



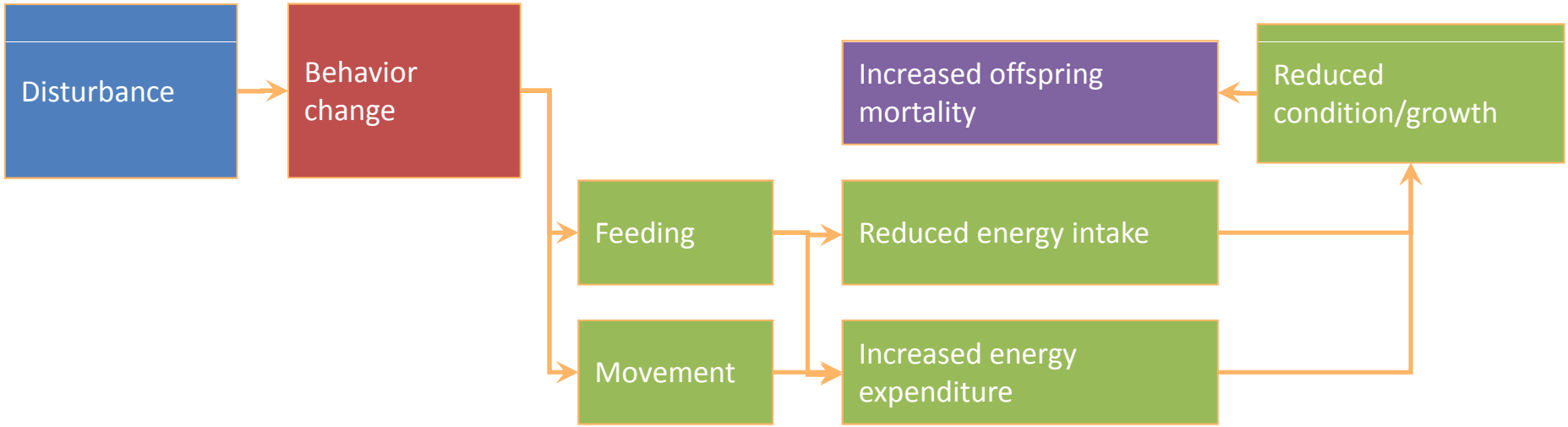
# What we did

1. **Identify the pathways by which the anticipated changes in behavior in response to disturbance may affect vital rates.**

# PCAD model
# From behaviour to vital rates



# PCAD model
# Northern elephants seals



# What we did

1. Identify the pathways by which the anticipated changes in behavior in response to disturbance may affect vital rates.

**2. Develop (stochastic) mathematical models of each pathway.**

**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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***(7. Assess what proportion of a local population might be impacted by each of these disturbances***

***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?

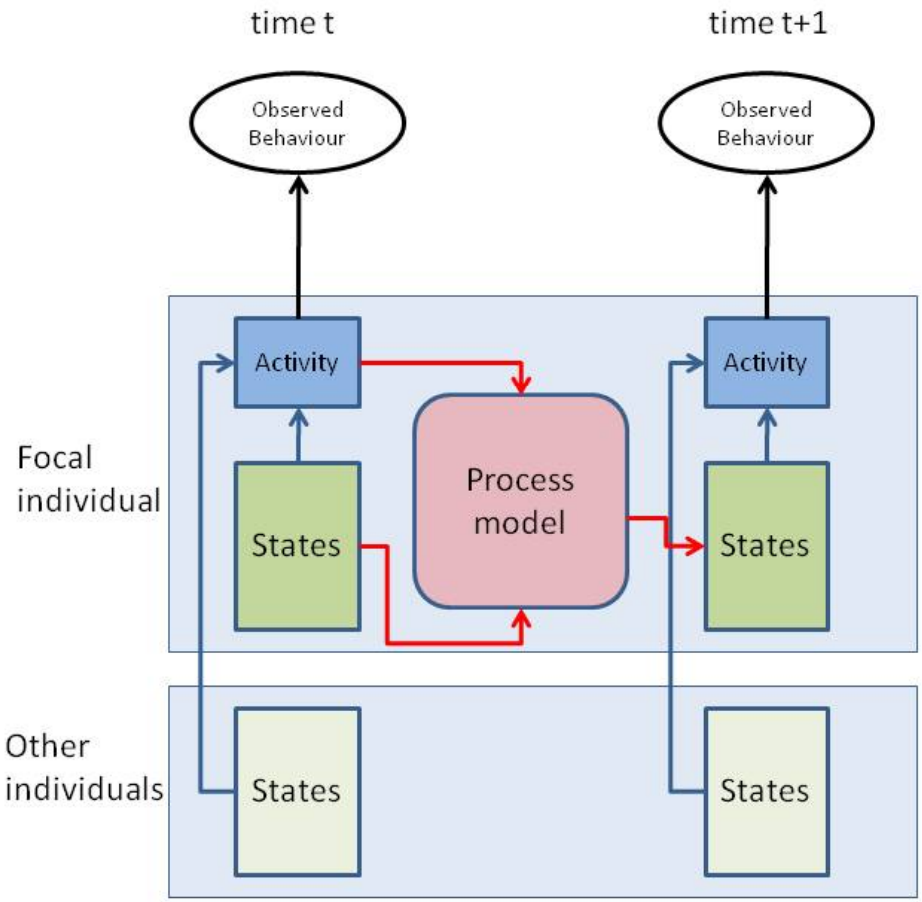
- Capital breeders
- Simple annual cycle for a colony: breed → leave to feed → return to molt → leave to feed → return to breed
- Satellite transmitters provide information on diving behavior, body condition and location for entire duration of feeding trip
- Pup survival strongly influenced by maternal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

- 1 manuscript submitted, 2 more in final stages of preparation.

# 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




1 manuscript submitted, several technical reports completed

# 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.

# Some 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.