Energetic Consequences of SONAR Exposure

Max Czapanskiy

Abstract

This is a tool intended for resource managers to understand some of the sub-lethal effects of SONAR on cetaceans. The model makes a first order approximation by estimating (1) the energy intake lost to foraging cessation and (2) the additional locomotor costs from increased swim speeds. Energetic parameters for the model come from empirical data and theoretical scaling relationships.

We present the model derivation and apply it to four case studies of typical behavioral responses. *SUMMARY OF RESULTS HERE.*

Energetic model

The energetic consequences of SONAR exposure, as modeled here, take the form:

$$E_{sonar} = P_{in} \times t_d + P_{out}(U_f) \times t_f$$

Where $\mathrm{E_{sonar}}$ is the energy cost of sonar exposure, $\mathrm{P_{in}}$ is the rate of energy consumption during undisturbed foraging, $\mathrm{t_d}$ is the time displaced from foraging, $\mathrm{P_{out}}$ is the increased rate of locomotor costs during the flight response relative to undisturbed movement, $\mathrm{U_f}$ is the animal's speed during flight, and $\mathrm{t_f}$ is the flight time.

The first term ($P_{in} \times t_d$) is the energy the animal would have consumed during foraging. The second term ($P_{out}(U_f) \times t_f$) is the additional energy spent in elevated locomotion.

Rate of consumption (P_{in})

The rate of consumption is the product of feeding rates and prey quality. We estimated feeding rates from tag data (lunges for rorquals, buzzes for odontocetes) and prey quality from active acoustics (rorquals) or stomach contents (odontocetes).

$$P_{in} = r_f \times E_p$$

Where $\mathrm{r_f}$ is the feeding rate and $\mathrm{E_p}$ is the energy from prey consumed per feeding event.

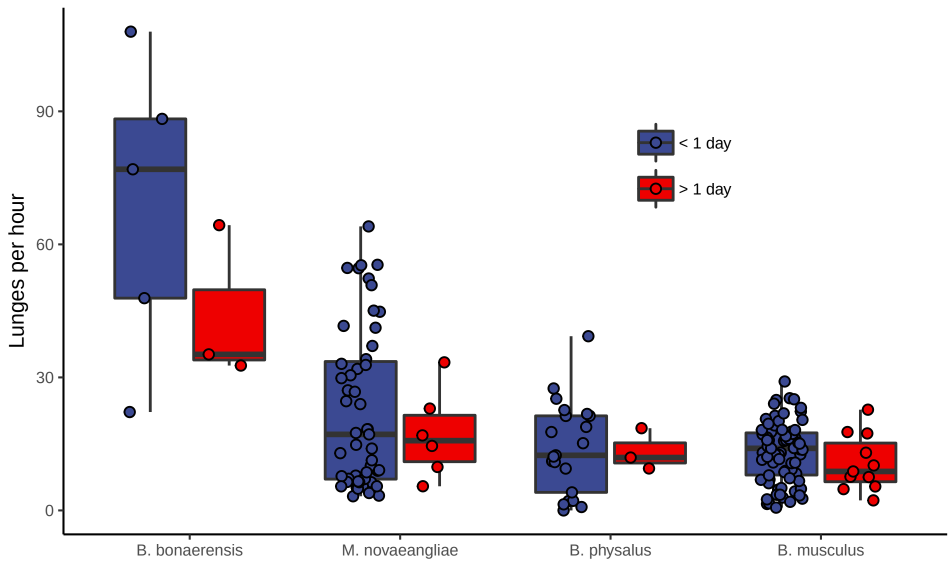
Empirical feeding rates (r_f)

Feeding rates were empirically derived from tag data. Lunges for mysticetes (rorquals only) and buzzes for odontocetes.

Mysticetes

The mysticete feeding rate is defined as the mean number of lunges per hour of deployment for deployments exceeding 24 hours. Shorter deployments tend to have higher lunge rates due to diel foraging patterns. Overall, lunge rates decrease with body size.

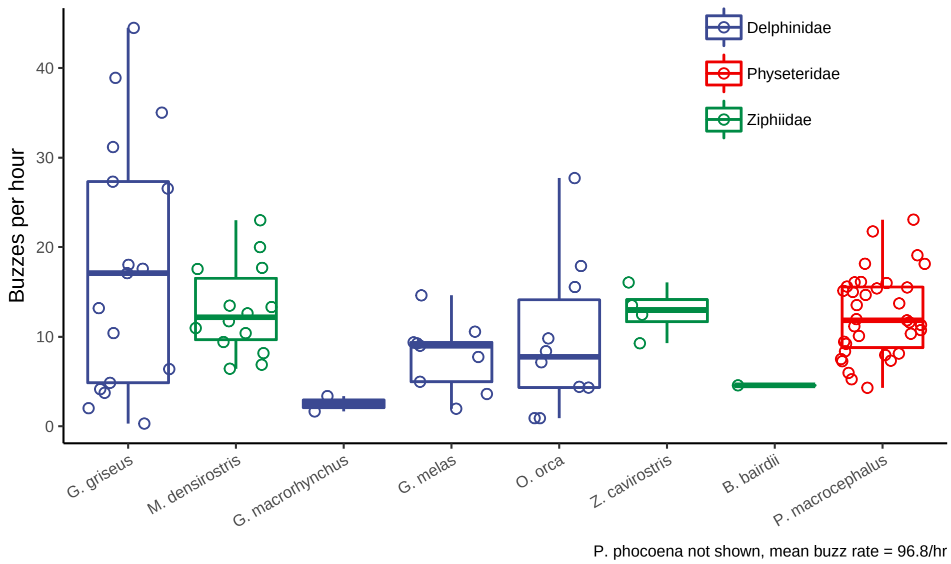
Species	N	Lunge rate
B. bonaerensis	3	44.1
M. novaeangliae	6	17.2
B. physalus	3	13.3
B. musculus	11	10.7



Odontocetes

Odontocetes forage with echolocation so feeding events are identifiable by an acoustic signature. Feeding rates are estimated as buzzes per hour. The tagging durations on odontocetes were not as long as mysticetes, so I used all available data. The relationship between feeding rates and body size is more variable than for mysticetes. This makes sense given the wider range of prey and dive depths for odontocetes.

Species	N	Buzz rate (per hour)
P. phocoena	8	96.8
G. griseus	17	17.7
M. densirostris	14	13.0
G. macrorhynchus	2	2.5
G. melas	9	7.9
O. orca	10	9.7
Z. cavirostris	4	12.8
B. bairdii	1	4.6
P. macrocephalus	36	12.5



Empirical prey energy (E_p)

Prey energy was empirically derived from acoustic backscatter (mysticetes) and stomach samples (odontocetes). Filter feeders consume the most energy per feeding event. Delphinids target more energy-rich prey than Ziphids.