

Energetic Consequences of Sonar Exposure

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What are the energetic consequences for cetaceans when exposed to sonar? The following model makes a first order approximation by estimating (1) the energy intake lost to foraging cessation and (2) the additional energy expenditure from increased swim speeds. We considered these two factors in four potential scenarios:

1. No response
2. Cessation of foraging without flight
3. Cessation of foraging with flight
4. Extreme response

The model will be parameterized using data and models from other sources (see table at the end of this document). Functional responses (e.g. displacement distance and duration) will come from the literature. The energy cost of lost feeding opportunities will be estimated with the scaling relationships in Jeremy's scaling paper. The energy cost of increased swim speeds during flight will be estimated using models from Williams et al. 2017. Thus:

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

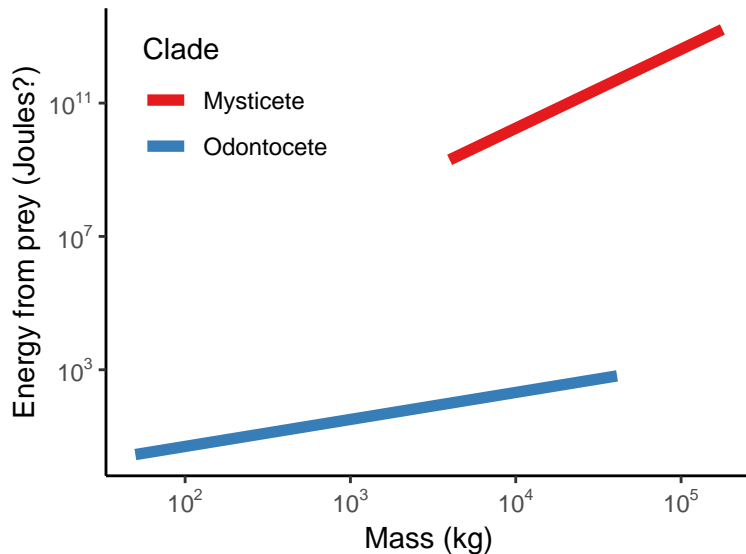
Where E_{sonar} is the energy cost of sonar exposure, P_{in} is the rate of energy intake when foraging, t_d is the displacement time, P_{out} is the rate of energy expenditure at the flight velocity (v_f), and t_f is the flight time.

Functional responses

In progress

Energetic parameters

I'm estimating P_{in} as the product of energy acquired per feeding event (E_p) and feeding rate (r_f). Energy acquired from prey scales sublinearly among odontocetes [$E_p = 0.12M_c^{0.81}$] but superlinearly among mysticetes [$E_p = 5.83M_c^{2.37}$]. *Note: Jeremy's paper has a negative coefficient for mysticete E_p scaling (v8.3:115) but I think that's a mistake.*



If I understand correctly, E_p is energy per feeding event. But how do I get feeding rate? Figure 2 in Jeremy's paper has $[feeding\ events / dive] \sim [dive\ time - TADL]$. Can we get feeding rates from something like that?

Literature

Reference	Species	Tags	Notes
Tyack et al. 2011	Mesoplodon densirostris	1	Only 1 tag, but other data from sonar array
DeRuiter et al. 2017	Balaenoptera musculus	37	How did the transition probability from deep feeding to other states change in CEEs?
DeRuiter et al. 2013	Ziphius cavirostris	2	Reduced time foraging in response to proximal sonar, but not distant
Friedlaender et al. 2016	Balaenoptera musculus	9	Includes prey data
Goldbogen et al. 2013	Balaenoptera musculus	17	Basis for Friedlaender et al. 2016 and DeRuiter et al. 2017
Kvadsheim et al. 2017	Balaenoptera acutorostrata	4	SoCal + Norway. 1 CEE + 1 control in each location
Southall et al. 2019	Ziphius cavirostris	0	Prey distribution in SoCal sonar array