

# WHALE, WHAT HAVE WE HERE? A META-ANALYSIS OF ORCA WHALE AND VESSEL INTERACTIONS

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## INTRODUCTION:

- *Orcinus orcas*; apex predators (Fisheries, 2024)
  - Protected under Marine Mammal Protection Act due to severe endangerment
  - Endangered Species Act: Southern Resident Killer Whales, Endangered Status
  - Pivotal role in marine ecosystems:
    - Influence prey populations
    - Contribute to ecosystem development during life and post-death
- Marine mammals, including *O. orcas*, are affected by boating vessel presence, thus a comprehensive understanding of the impacts is crucial
  - Boating Vessel-Mammal interactions can cause:
    - Differences in behaviors, impact survival and reproduction, and increase mortality rates, predation risk, and vulnerability
- Presently, the largest impact of boating vessels occurs on the behaviors and habitat use of orca whales



This study synthesizes the effect of controlled vessel exposure on the behavior/habitat use, physiology, and vocalization of *Orcinus orca*.

## METHODS:

- Paper Collection:
    - Followed PRISMA framework for systematic review (Mohner et al., 2015) with search via *Web of Science*
    - Selected all of the papers analyzing the impacts on *Orcinus orca*.
    - Original total of 35; after elimination 18 papers remained
  - Data Preparation/Extraction:
    - Location, methods, duration, numerical values, and significance
    - Annotated effect category and response including units, means, standard deviations, vessel counts for treatment and non-treatment groups
      - Example: vessel distance & travel/dive time
  - Response types:
    - The measured response of controlled vessel exposure was separated into three categories
      - Behavior and Habitat Use: behavioral response (e.g., swimming speed or direction) or movement related response (e.g., home range) was measured
      - Vocalization: vocalization response (e.g., whistle frequency) was measured
      - Physiology: physiological response (e.g., cortisol levels) was measured
  - Data Analysis & Statistic testing:
    - Log response ratio (LRR) (Hedges et al., 1999): natural logarithm of the response ratio and allows for outcomes to be measured on a ratio scale
      - A zero corresponds to the true absence of an outcome.
- LRR Equation:  $LRR = \ln(X_t/X_c)$
- X<sub>t</sub>: mean response when exposed to vessels  
X<sub>c</sub>: mean response when not exposed to vessels



Fig. 1: World map displaying locations of *O. orca* and boating vessel interaction studies. Two main locations include: San Juan Islands and surrounding areas (Canada, NW US: 48°N, -123°W) and Kvaenangen fjord/More coast (Norway: 67.5°N, 10.1°E).

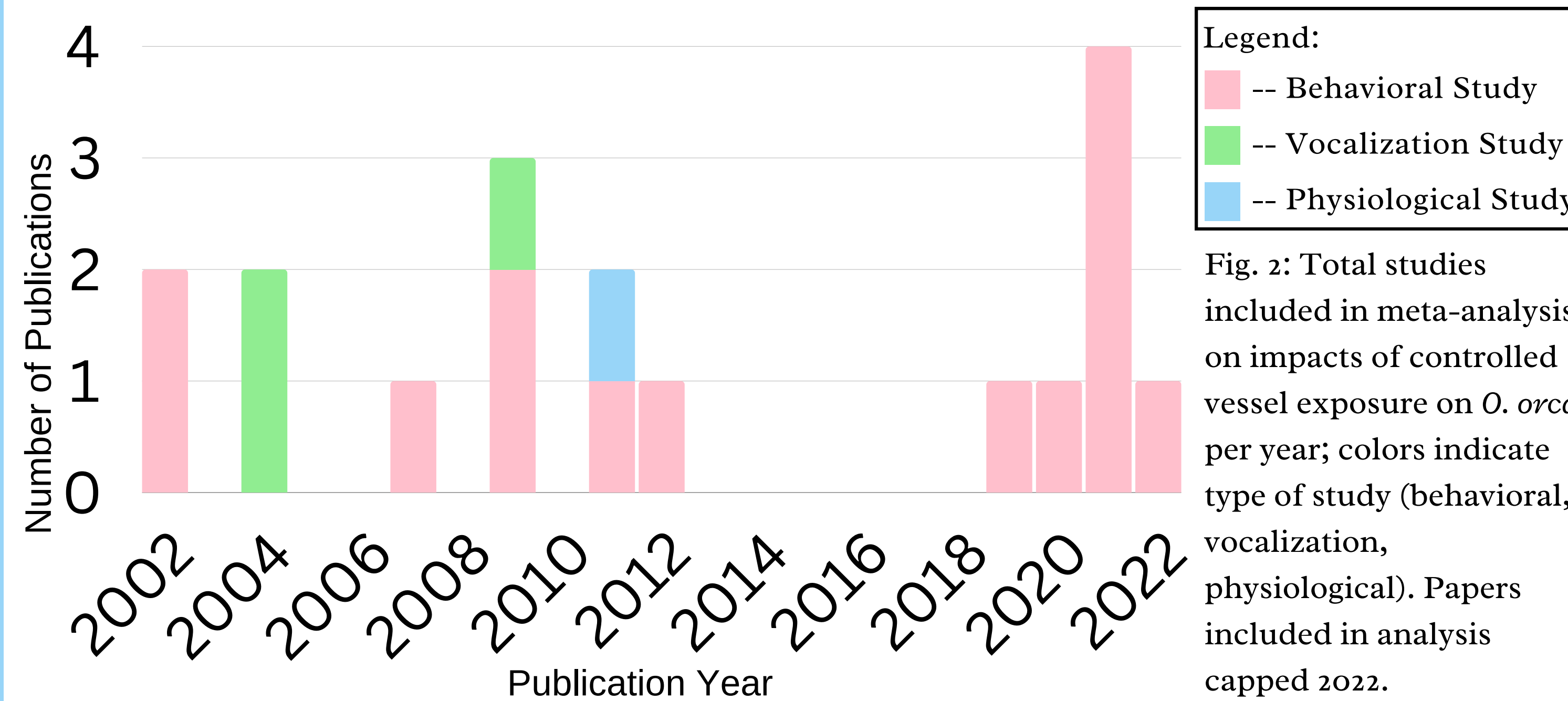


Fig. 2: Total studies included in meta-analysis on impacts of controlled vessel exposure on *O. orca* per year; colors indicate type of study (behavioral, vocalization, physiological). Papers included in analysis capped 2022.

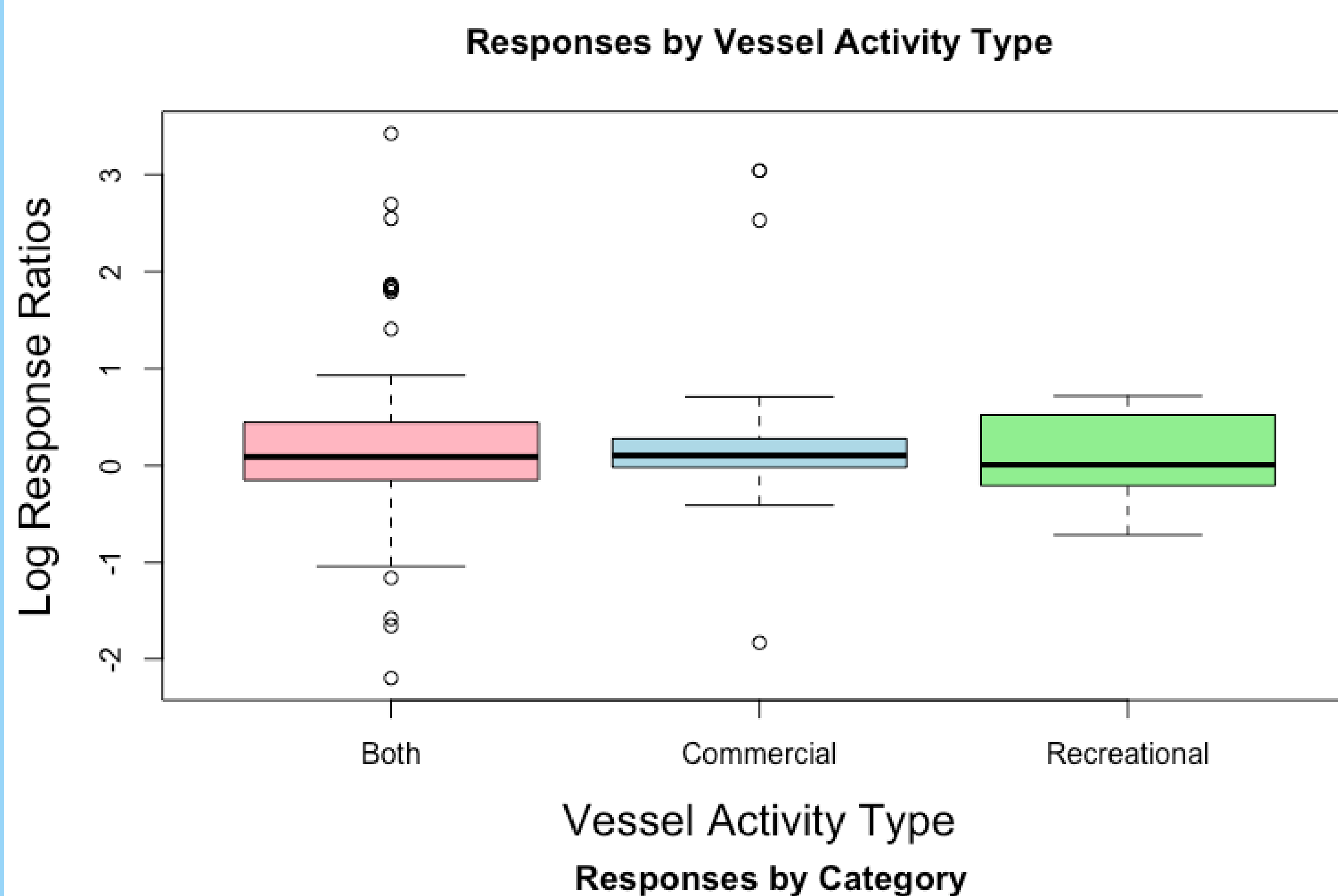


Fig. 3: Boxplot of the Log Response Ratio (LRR) regarding responses per boating vessel activity type: commercial, recreational, or both. Mean values include: 0.3481, 0.0744, and 0.3116, respectively.

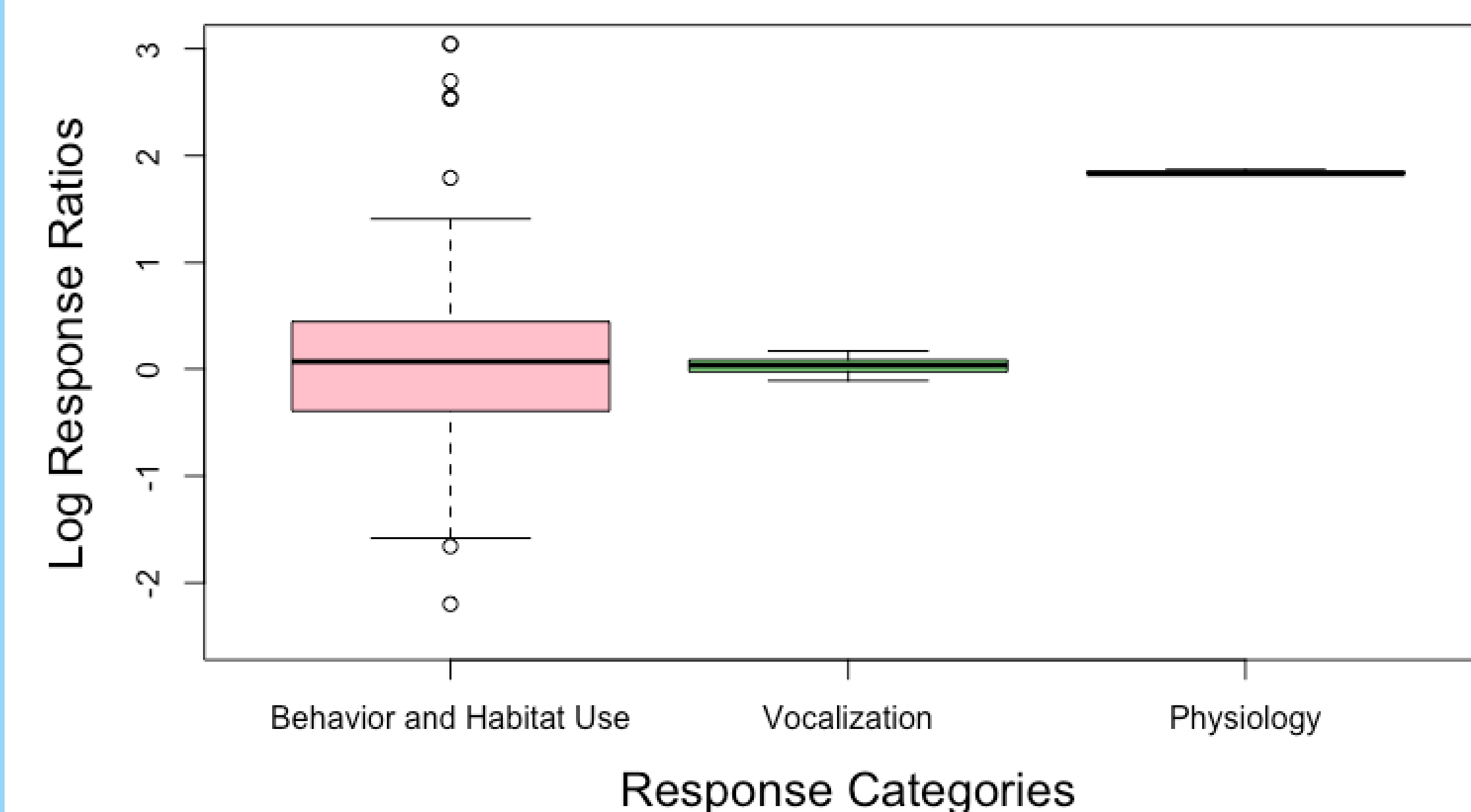


Fig. 4: Boxplot describing Log Response Ratio (LRR) of responses by the following categories: Behavior and Habitat Use, Vocalization, and Physiology. Mean values are 0.1734, 0.0391, and 1.8396 respectively.

## RESULTS:

- There are varying impacts on the behavior, vocalizations, and habitat use of orca whales when boating vessels are present, when compared with control
- Despite being a wide ranging species, most studies on orcas are concentrated in the two locations in Fig. 1
- The first study which met our inclusion criteria took place in 2002, after that, there was no clear trends related to frequency or type study in relationship to study year.
- There was no clear difference in LRR among vessel activity types
- The analysis of physiological and vocalization impacts are severely understudied in comparison to Behavior and Habitat Use

## CONCLUSIONS & DISCUSSION:

- Studies were geographically biased:
  - More research is necessary in locations beyond the USA and Norway
- Current publications focus on behavior/habitat use:
  - Physiology had the highest LRR mean value, however only one paper has analyzed it
- There is a lack of variation within subject of *O. orca* papers currently published, which met our inclusion criteria
  - It is difficult to develop policy framework when the overall impact of vessels cannot be quantified due to unequal analysis
- Obvious lack of information about the impacts of vessels on vocalizations and physiology of *O. orca*. underscoring the necessity for further research
  - Future research is necessary to inform environmental guidelines (e.g. MPAs, speed restrictions, and active monitoring of vessels)
- Controlled recreational and commercial vessel exposure appeared to have similar overall effects on orcas.
  - Future studies should compare the effects of commercial and recreational boating within the same population of orcas under controlled conditions
  - Management strategies are necessary for both commercial and recreational boaters, collaborative management will likely be most effective.
- The results of this study are largely consistent with previous work which has documented the impacts of controlled vessel exposure marine mammal physiology, behavior, habitat use, and vocalizations (e.g., Constantine *et al.* 2004; Allen & Read 2006; Stamation *et al.* 2009; Villagra *et al.* 2021)

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References

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