Marine Pollution Bulletin 202 (2024) 116309

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Not so silent spectators: How spectator vessels at international sailing regattas alter marine soundscapes

Matthew K. Pine [a,b,*], Emily Hague [a], Anna Kebke [c], Lauren McWhinnie [a,d], Charlotte R. Findlay [e]

[a] Institute of Life and Earth Sciences, Heriot-Watt University, Edinburgh, United Kingdom
[b] Juanes Lab, Department of Biology, University of Victoria, Victoria, BC V8W 3R4, Canada
[c] School of Biodiversity, One Health and Veterinary Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow, Glasgow, United Kingdom
[d] Department of Geography, University of Victoria, Victoria, BC V8W 3R4, Canada
[e] Department of Biology, Section for Zoophysiology, Aarhus University, Aarhus 8000, Denmark

ARTICLE INFO

Keywords:
America's cup
Marine life
Vessels
Regatta
Sailing
Soundscapes
Underwater noise

ABSTRACT

International sailing regattas are major sporting events often held within coastal marine environments which overlap with the habitats of marine species. Although races are confined to courses, the popularity of these events can attract large spectator flotillas, sometimes composed of hundreds of motorized vessels. Underwater noise from these flotillas can potentially alter soundscapes experienced by marine species. To understand how these flotillas may alter soundscapes, acoustic recordings were taken around racecourses during the 36th America's Cup in the Hauraki Gulf, New Zealand in 2021. Sustained increases in broadband underwater sound levels during the regatta (up to 17 dB re 1 μPa rms; 0.01–24 kHz) that extended beyond racecourse boundaries (>8.5 km) and racing hours were observed; very likely attributable to the increase in regatta-related vessel activity. Underwater noise pollution from spectator flotillas attending larger regattas should be considered during event planning stages, particularly when events occur in ecologically significance areas.

1. Introduction

Competitive sailing regattas are major sporting events that are commonly held in coastal areas which are biologically important habitats for many marine species (Halpern et al., 2008). Common examples of such events are the *America's Cup*, and *SailGP*, or the *Ocean Race*, and the *Sydney to Hobart Yacht Race* where at least part of the event occurs closer to shore (i.e., within 15 km). These events can attract substantial public interest, with large numbers of spectator vessels forming flotillas that travel to and from race locations, surround the boundaries of racecourses in some events, or accompany competitors as they enter or depart race-checkpoints (such as the Ocean Race or Sydney to Hobart). In some cases, these spectator flotillas can comprise up to several hundred individual motorized vessels, such as during the 36th America's Cup where up to 1300 spectator vessels were recorded in one day (America's Cup Event Ltd., 2021).

Underwater radiated noise from recreational motorized vessels is known to acoustically degrade coastal marine habitats (Hermannsen et al., 2019; Pine et al., 2016, 2021; Wilson et al., 2022, 2023). Evidence indicates that noise from these vessels can increase median background sound levels by as much as 2 dB for every 10 % increase in vessel traffic (Pine et al., 2021). It is also broadband, exceeding 50 kHz in some cases (Hermannsen et al., 2019; Li et al., 2015), making this source audible to several marine mammals (Southall et al., 2019), fishes (Popper et al., 2014) and invertebrates (Putland et al., 2017; Wilson et al., 2023). Many marine species have sensitive and intricate hearing systems that are vital for life history processes, such as foraging, communication, reproduction, orientation, and predator avoidance (Richardson et al., 1995; Slabbekoorn et al., 2010). Rising noise levels from motorized vessel traffic has been shown to affect animal behavior and physiology (see reviews by: Erbe et al., 2019; Weilgart, 2017), thereby causing concerns about reduced individual fitness and the potential for population level consequences if disturbances are prolonged or experienced repeatedly.

With our increased understanding of the potential impacts of motorized vessel noise on marine species, there are increasing obligations to reduce and mitigate noise from commercial vessel activity in many countries (Chou et al., 2021; European Commission, 2008; HELCOM, 2021; IMO, 2023; OSPAR, 2022). However, the contribution to underwater noise from smaller recreational boats has so far received less attention by regulators, despite evidence indicating that the noise from

* Corresponding author at: Institute of Life and Earth Sciences, Heriot-Watt University, Edinburgh, United Kingdom.
E-mail address: m.pine@hw.ac.uk (M.K. Pine).

https://doi.org/10.1016/j.marpolbul.2024.116309
Received 15 December 2023; Received in revised form 26 March 2024; Accepted 26 March 2024
Available online 1 April 2024

these vessels can pose a potential threat to coastal ecosystems (Hermannsen et al., 2019; McWhinnie et al., 2021; Merchant et al., 2014; Wilson et al., 2022). This issue is particularly relevant to competitive sailing regattas that can attract significant on-water spectator vessel presence. Here, we present acoustic data that quantifies how a globally renowned sailing regatta, the 36th America's Cup, caused changes to a regional soundscape; highlighting the need to consider early in the planning phases how these events may alter underwater noise levels to ensure appropriate mitigation measures can be enacted.

2. Materials and methods

Seafloor mounted SoundTrap 300HF (with external battery packs) or 600HF recorders (Ocean Instruments NZ) were deployed at the boundaries of three racecourses off Auckland's North Shore, within the inner Hauraki Gulf, New Zealand, between 9th January and 12th April 2021 (Fig. 1; Supplementary Materials Table S1). During this time, the Prada Cup and 36th America's Cup (AC36) took place and together comprised the AC36 'tournament' referred to in this study. The hydrophones were secured 1 m above the seafloor with no subsurface or surface floats, in water depths between 11 m and 16 m at mean low water spring. Recorders continuously captured audio at a sampling rate of 96 kHz and high gain setting. To ensure accuracy in noise measurements, field-calibration checks were conducted for all hydrophones before and after deployment using a calibrated piston phone (G.R.A.S. Type 42AA, 250 Hz @ 114 dB) and a sound level meter (Brüel & Kjaer 2250 Type 1 SLM with a Brüel & Kjaer ½ condenser microphone Type 4189 and calibrated with a Brüel & Kjaer Type 4231 sound calibrator). This also ensured similar detection ranges for all SoundTrap recorders used.

Power spectral densities (PSD, 1 s Hamming windows and 50 % overlap) were calculated for every 1 min of data using codes extracted from PAMGuide (Merchant et al., 2015). Broadband sound pressure levels (L_p, 10 Hz – 24 kHz) were computed over the same 1 min periods via an energy summation across all frequencies, providing a single L_p value for every 1 min and their corresponding time stamps. Frequencies above 24 kHz were not included in the analysis to align outputs with measurements made in this area during previous research.

Processed data were sorted into race days and non-race days. Race days were determined as any days when competitive races took place (including the round-robin races during the Prada Cup) and did not include days when teams were practicing, as spectator flotillas were not present on practice days. Descriptive comparisons of the ambient sound levels between these two categories were then undertaken to assess potential differences in the regional marine soundscape caused by on-water spectators attending the AC36 tournament.

3. Results

Sustained increases in the broadband L_p on the days when racing occurred were observed. For example, on the 17th March 2021, racing occurred between 16:00 and 18:00 h (America's Cup Event Ltd., 2021), although the ambient L_p at ST3 began increasing approximately 3.5 h beforehand, as spectator vessels arrived at racecourse A (Fig. 2B & 2C). During the afternoon on that race day, the 1 min averaged L_p around racecourse A increased from 3 dB re 1 μPa rms as spectator vessels began arriving at the course boundary, to as much as 17 dB re 1 μPa rms upon their return to Auckland city just before 18:00 h (Fig. 2C). Ambient L_p at ST3 did not return to pre-racing levels until 3 h post-racing. These increases were sustained long enough to raise the mean daily broadband ambient L_p over the whole daytime period (06:00 h – 21:00 h) by 5 dB re 1 μPa rms (Fig. 2C). When compared with a day one week later, when no racing was scheduled (24th March 2021), median daily L_p were 1–2 dB higher on race days than non-race days.

Substantial increases to ambient L_p across the measured spectrum were also recorded several kilometers from the racecourses. For example, on the 16th March 2021 when racing occurred at Racecourse C, the broadband ambient sound levels were 8 and 19 dB re 1 μPa rms higher than pre-racing hours at approximately 4.5 km (ST2) and 8.5 km (ST3) away, respectively (Fig. 3C). Over the 46 min it took the spectator flotilla to round North Head and exit Rangitoto Channel on return to Auckland after racing had concluded, the ambient L_p at ST3 (approximately 8.5 km away from the racecourse) was 4 dB re 1 μPa rms higher than the same time period during the race (when spectator vessels were more likely to remain stationary) (Fig. 3).

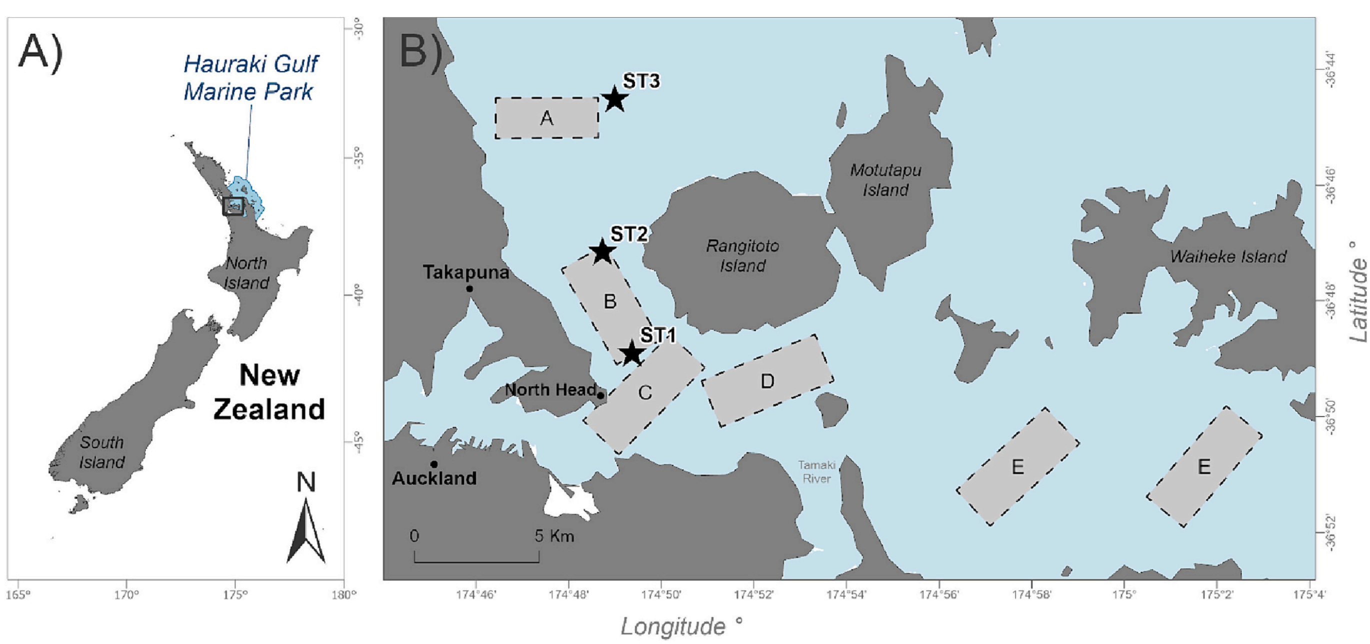

Fig. 1. (A) Map of New Zealand with black box highlighting the inner Hauraki Gulf, New Zealand, where the AC36 tournament was held, and the extent of the Hauraki Gulf Marine Park. (B) Map of the inner Hauraki Gulf, including the AC36 racecourses (labeled A to E), the locations of the seafloor mounted SoundTraps (denoted by stars), and the blue area indicates the extent of the Hauraki Gulf Marine Park in this region. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

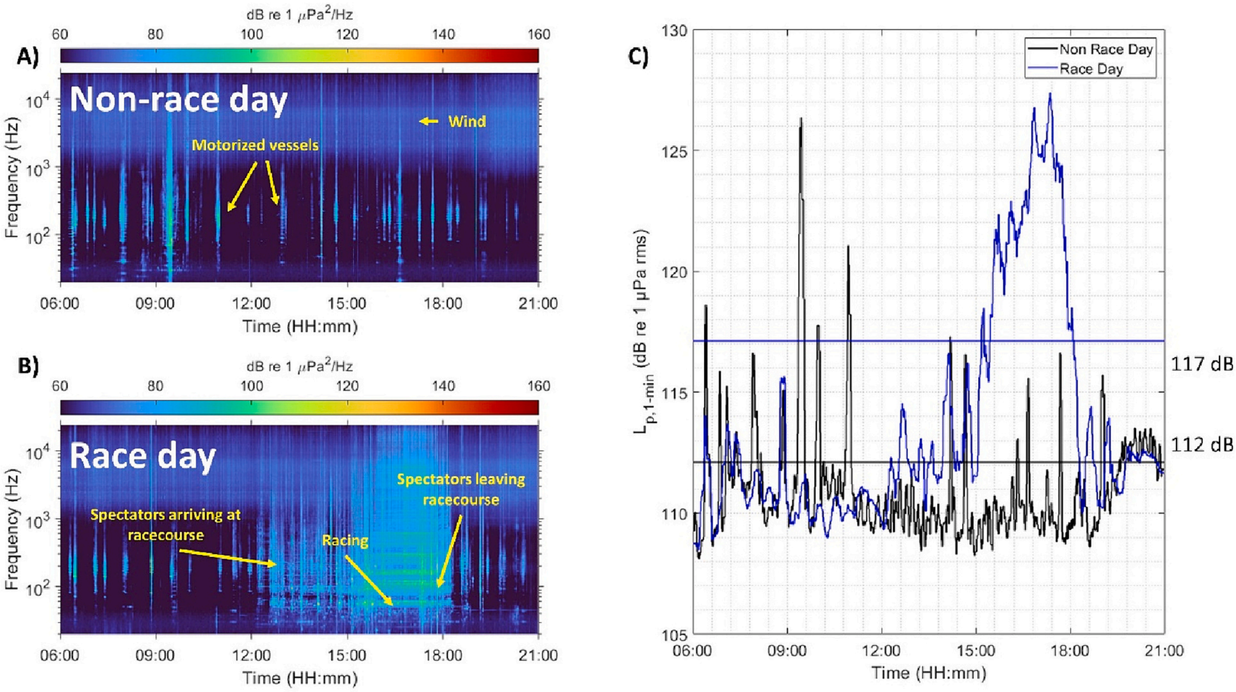

Fig. 2. Spectrograms showing the ambient soundscape recorded at ST3 located next to Racecourse A (16–19 m depth) in the inner Hauraki Gulf on (A) a 'typical' day without scheduled racing (24th March 2021), compared to (B) a race day (17th March 2021). The line plot (C) shows the corresponding broadband (10 Hz – 24 kHz) 1 min sound pressure levels (L_p) where the log-average L_p on that race day (17th March) was 117 dB re 1 μPa rms compared to 112 dB re 1 μPa rms on the non-race day (24th March). N.B. The sharp increases in 1 min L_p recorded on the non-race day (24th March) in subplot C (e.g., just after 09:00 h) are due to vessels passing close to the hydrophone as can be seen for the same period in the spectrogram of subplot A.

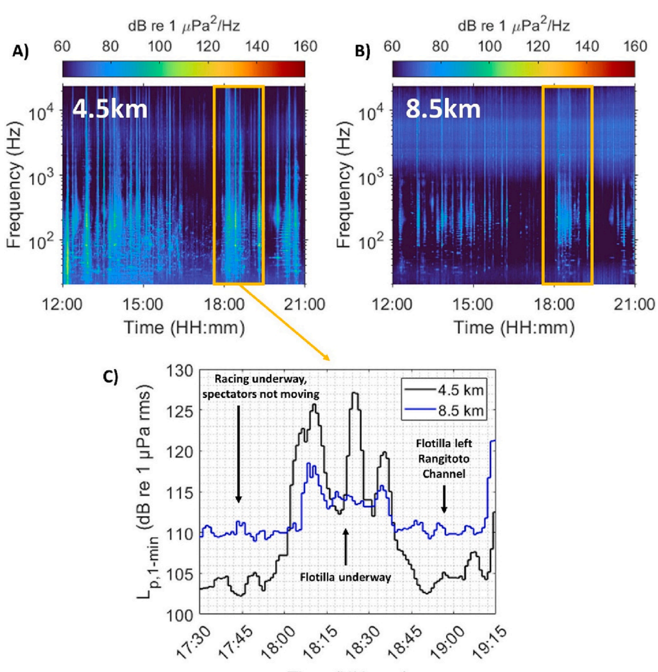

Fig. 3. Spectrograms showing the ambient soundscape at (A) ST2 and (B) ST3 (approximately 4.5 km and 8.5 km from the edge of Racecourse C, respectively) in the inner Hauraki Gulf during the afternoon with scheduled racing at Racecourse C (16th March 2021). The line plot (C) shows the corresponding broadband (10 Hz – 24 kHz) 1 min sound pressure levels (L_p) post-racing as the spectator flotilla left the racecourse area.

4. Discussion

This study demonstrates the possibility of competitive international sailing regattas, which attract considerable on-water spectator presence, increasing ambient sound levels in marine habitats. The most notable observation from the AC36 tournament was that sound pressure levels increases were observed several kilometers beyond the racecourses boundaries and remained high well beyond the duration of the races themselves. The America's Cup is the world's oldest sporting trophy with a 172-year history and is the largest competitive sailing event in the world. As such, it is a very popular regatta, attracting a considerable spectator presence (America's Cup Event Ltd., 2021). The effects of this event on the underwater soundscape are further compounded by its location, given that 36 % of Auckland City's population alone are involved in recreational boating (Maritime New Zealand, 2020). It is therefore important to note that the results shown here may not be applicable to smaller events or those with less on-water spectator presence and that the composition of the flotillas at these events (e.g., vessel numbers, sizes, engine types, etc.) may alter the local noise levels. Notwithstanding, however, this study illustrates that large sporting events have the potential to substantially alter underwater soundscapes when on-water spectator presence is numerous.

On a typical race day during AC36, the mean ambient sound pressure levels (between 06:00 h and 21:00 h) around the racecourse was 5 dB higher than on a 'control day' when no racing took place (for example the 24th March 2021; Fig. 2C). These findings imply that the change in ambient sound levels can be attributed to large increases in vessel activity on race days, which is uncharacteristic of what can be expected within the inner Hauraki Gulf Marine Park (Pine et al., 2021; Wilson et al., 2022). Small boats are a ubiquitous source of anthropogenic underwater noise around the Gulf (Wilson et al., 2022), with vessel noise being present between 50 % and 70 % of the time over a 24-h period during the summer months (Pine et al., 2021). However, these vessels tend to occur randomly over space and time and are generally spaced throughout the day (see Fig. 2A). This is substantially different to what was observed during the AC36 tournament, where an estimated 10,468 vessels attended the three different race events between December 2020 and March 2021, and up to 1300 vessels transited to and from the racecourses within this region at regular intervals each day (America's Cup Event Ltd., 2021).

The atypical nature of this vessel activity during AC36 caused an increase in the 1 min sound pressure levels to over 6 dB re 1 μPa rms up to 8.5 km away from where the races were taking place (Fig. 3). In other events akin to the America's Cup, such as SailGP, similar increases in noise could be plausible, assuming on-water spectators are numerous. Increases in broadband underwater noise from motorized vessels are particularly problematic, as this source has been found to increase physiological stress levels (Kight and Swaddle, 2011; Rolland et al., 2012; Weilgart, 2017), reduce reproductive success rates (Nedelec et al., 2022), foraging success (Wisniewska et al., 2018) and social interactions (Marley et al., 2017), or result in avoidance behaviors (Frankish et al., 2023) and displacement from habitats (Bejder et al., 2006) in several marine species. Furthermore, our results indicate sustained increases in underwater noise levels in frequencies that overlap with delphinid vocalizations (between 3 and 24 kHz; Frankel et al., 2014). Utilizing the generalized linear model (GLM) from Pine et al. (2021), the increase in daily median sound pressure levels between 1 and 2 dB found on race-days in this study, equated to an approximately 23–46 m reduction in delphinid communication ranges within the Rangitoto Channel (where racecourses B and C were located; see Fig. 1), indicating the potential for auditory masking effects on these species. Consequently, increases in underwater noise from motorized vessels present during on-water events, such as AC36, may result in behavioral or physiological impacts with potential fitness consequences for marine fauna which could extend over considerable distances.

Nevertheless, it is not necessarily the increase in ambient sound levels alone that could lead to negative effects on marine wildlife, but also the duration of exposure, and size and location of spectator flotillas at events. The AC36 took place between the 10th and 17th March 2021, but two qualifying events occurred shortly beforehand. These were the America's Cup World Series (17th to 19th December 2020) and the Prada Cup (15th January to 2nd February 2021). Therefore, this event spanned multiple months and resulted in several weeks of racing, which based on the results of this study, will have considerably increased underwater noise levels in this region several times over the three months. Furthermore, the variation in flotilla size, configuration and relative proximity to the racecourses could also influence underwater noise levels and should be further explored to allow for more informed management decisions. The potential effects of sustained increases in underwater noise as a result of the variable sizes and spatial extents of spectator flotillas on marine wildlife were not investigated in this study but are warranted. In particular, the exploration of potential impacts from exposure to large numbers of motorized vessels and the repeated increases in ambient sound levels on cetacean behavior during racing events should be considered, given that several species have been shown to respond to vessel noise (see review by: Erbe et al., 2019). Cetaceans have also been sighted near or within regatta racecourses (e.g., SailGP, 2023).

Mitigating increases to ambient sound associated with spectator flotillas attending large sailing regattas should be considered during event planning stages, as part of the impact assessment, particularly for those events located in areas of high ecological significance. The environmental impact assessment for AC36, for example, considered impacts on the marine environment, such as water quality, marine litter, biosecurity, and marine mammal protection (America's Cup Event Ltd., 2021), but did not specifically consider or address underwater noise pollution. Notwithstanding, some of the protection measures afforded to marine mammals during AC36 would have concurrently reduced underwater noise pollution, such as restricting spectator vessel speeds to 5 knots to reduce strike risk (America's Cup Event Ltd., 2021), as increasing evidence indicates that slowing down motorized vessels reduces underwater radiated noise (Findlay et al., 2023; MacGillivray et al., 2019). Race organizers could also consider introducing designated areas where spectator vessels are encouraged to congregate. Additional benefits may also be gained from visual and/or real-time acoustic marine mammal detection platforms to encourage adoption of best practices during periods when animals are near spectators. Limiting the number of vessels viewing these events could be challenging as many racecourses can be accessed via multiple routes and therefore constraining flotillas (and their associated noise) to specific areas may be a more viable solution for event organizers. Managers may also consider implementing more than one measure that targets specific times during regattas to maximize their effectiveness. For example, slowdowns will likely only prove effective at reducing noise while boats are transiting to and from the race, while designating viewing areas during racing may prove more effective at localizing noise while the race is underway. Furthermore, measures such as staggering the exit of vessels to break up spectator flotillas into smaller groups; promotion of land-based spectating; providing spectators with guidance on measures they can take/ behavioral changes they can adopt to reduce the amount of noise their vessel emits (e.g., turning off echosounders whilst idling and avoiding sudden speed changes (Lagrois et al., 2022)); and educating spectators on underwater noise effects to marine species could also be considered, where appropriate. Consequently, early consideration of how elevated noise levels from spectator vessels may alter acoustic habitats, and for how long, would help to identify potential threats to marine animals and ensure the adoption of appropriate mitigation measures and solutions. Promisingly, proactive decisions to limit environmental impacts are increasingly being adopted during race events by some organizations and individuals (e.g. AC37 and The Ocean Race[1]). Nonetheless, greater efforts are required to limit the potential impacts of motorized vessel underwater radiated noise during these large, internationally renowned events.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2024.116309.

CRediT authorship contribution statement

Matthew K. Pine: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Emily Hague:** Writing – review & editing, Visualization, Conceptualization. **Anna Kebke:** Writing – review & editing, Visualization, Conceptualization. **Lauren McWhinnie:** Writing – review & editing, Visualization, Funding acquisition, Conceptualization. **Charlotte R. Findlay:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Lauren McWhinnie reports financial support was provided by Horizon Europe. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This work was funded by several sources. The authors would like to

[1] (e.g., AC37 Event Limited, 2023; The Ocean Race, 2023).

thank the MASTS-SFC Saltire Emerging Researcher Scheme, whose funding to support network building facilitated the initial in-person meeting of MKP, EH, CRF and LM. CRF was funded by the European Union's Horizon Europe Framework Program under the Marie Skłodowska-Curie Actions grant agreement No. 101063364. EH was funded by a James-Watt postgraduate research scholarship, administered via Heriot-Watt University. AK was funded by an IAPETUS2 postgraduate research scholarship (NERC grant NE/S007431/1) administered via the University of Glasgow.

References

AC37 Event Limited, 2023. Sustainability and Investment in Barcelona's Blue Economy at the Heart of 27th America's Cup and World Sailing Sanctioning Agreement [WWW Document]. URL https://www.americascup.com/news/2157_SUSTAINABILITY-AND-INVESTMENT-IN-BARCELONAS-BLUE-ECONOMY-AT-THE-HEART-OF-37TH-AMERICAS-CUP-AND-WORLD-SAILING-SANCTIONING-AGREEMENT (accessed 11.1.23).

America''s Cup Event Ltd, 2021. America's Cup Event Limited Final Event Report. Auckland, New Zealand.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., Krützen, M., 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conserv. Biol. 20, 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x.

Chou, E., Southall, B.L., Robards, M., Rosenbaum, H.C., 2021. International policy, recommendations, actions and mitigation efforts of anthropogenic underwater noise. Ocean Coast. Manag. 202, 105427 https://doi.org/10.1016/j.ocecoaman.2020.105427.

Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E., Embling, C.B., 2019. The effects of ship noise on marine mammals—a review. Front. Mar. Sci. 6, 1–21. https://doi.org/10.3389/fmars.2019.00606.

European Commission, 2008. Marine Strategy Framework Directive (MSFD).

Findlay, C.R., Rojano-Doñate, L., Tougaard, J., Johnson, M.P., Madsen, P.T., 2023. Small reductions in cargo vessel speed substantially reduce noise impacts to marine mammals. Sci. Adv. 9, 1–11. https://doi.org/10.1126/sciadv.adf2987.

Frankel, A.S., Zeddies, D., Simard, P., Mann, D., 2014. Whistle source levels of free-ranging bottlenose dolphins and Atlantic spotted dolphins in the Gulf of Mexico. J. Acoust. Soc. Am. 135 (3), 1624–1631. https://doi.org/10.1121/1.4863304.

Frankish, C.K., von Benda-Beckmann, A.M., Teilmann, J., Tougaard, J., Dietz, R., Sveegaard, S., Binnerts, B., de Jong, C.A.F., Nabe-Nielsen, J., 2023. Ship noise causes tagged harbour porpoises to change direction or dive deeper. Mar. Pollut. Bull. 197, 1–10. https://doi.org/10.1016/j.marpolbul.2023.115755.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., 2008. A global map of human impact on marine ecosystems. Science (80-.) 319, 948–952. https://doi.org/10.1126/science.1149345.

HELCOM, 2021. HELCOM Recommendation 42–43/1: Regional Action Plan on Underwater Noise. RAP Noise.

Hermannsen, L., Mikkelsen, L., Tougaard, J., Beedholm, K., Johnson, M., Madsen, P.T., 2019. Recreational vessels without automatic identification system (AIS) dominate anthropogenic noise contributions to a shallow water soundscape. Sci. Rep. 9, 1–10. https://doi.org/10.1038/s41598-019-51222-9.

IMO, 2023. Revised Guidelines for the Reduction Of Underwater Radiated Noise From Shipping to Address Adverse Impacts on Marine Life.

Kight, C.R., Swaddle, J.P., 2011. How and why environmental noise impacts animals: an integrative, mechanistic review. Ecol. Lett. 14, 1052–1061. https://doi.org/10.1111/j.1461-0248.2011.01664.x.

Lagrois, D., Chion, C., Sénécal, J.F., Kowalski, C., Michaud, R., Vergara, V., 2022. Avoiding sharp accelerations can mitigate the impacts of a Ferry's radiated noise on the St. Lawrence whales. Sci. Rep. 12, 1–21. https://doi.org/10.1038/s41598-022-16060-2.

Li, S., Wu, H., Xu, Y., Peng, C., Fang, L., Lin, M., Xing, L., Zhang, P., 2015. Mid- to high-frequency noise from high-speed boats and its potential impacts on humpback dolphins. J. Acoust. Soc. Am. 138, 942–952. https://doi.org/10.1121/1.4927416.

MacGillivray, A.O., Li, Z., Hannay, D.E., Trounce, K.B., Robinson, O.M., 2019. Slowing deep-sea commercial vessels reduces underwater radiated noise. J. Acoust. Soc. Am. 146, 340–351. https://doi.org/10.1121/1.5116140.

Maritime New Zealand, 2020. 2020 regional recreational boating summary [WWW document]. https://www.maritimenz.govt.nz/public/researchers/recreational-research/.

Marley, S.A., Salgado Kent, C.P., Erbe, C., Parnum, I.M., 2017. Effects of vessel traffic and underwater noise on the movement, behaviour and vocalisations of bottlenose dolphins in an urbanised estuary. Sci. Rep. 7, 1–14. https://doi.org/10.1038/s41598-017-13252-z.

McWhinnie, L.H., O'Hara, P.D., Hilliard, C., le Baron, N., Smallshaw, L., Pelot, R., Canessa, R., 2021. Assessing vessel traffic in the Salish Sea using satellite AIS: an important contribution for planning, management and conservation in southern resident killer whale critical habitat. Ocean Coast. Manag. 200 (105479), 1–17. https://doi.org/10.1016/j.ocecoaman.2020.105479.

Merchant, N.D., Pirotta, E., Barton, T.R., Thompson, P.M., 2014. Monitoring ship noise to assess the impact of coastal developments on marine mammals. Mar. Pollut. Bull. 78, 85–95. https://doi.org/10.1016/j.marpolbul.2013.10.058.

Merchant, N.D., Fristrup, K.M., Johnson, M.P., Tyack, P.L., Witt, M.J., Blondel, P., Parks, S.E., 2015. Measuring acoustic habitats. Methods Ecol. Evol. 6, 257–265. https://doi.org/10.1111/2041-210X.12330.

Nedelec, S.L., Radford, A.N., Gatenby, P., Davidson, I.K., Velasquez Jimenez, L., Travis, M., Chapman, K.E., McCloskey, K.P., Lamont, T.A.C., Illing, B., McCormick, M.I., Simpson, S.D., 2022. Limiting motorboat noise on coral reefs boosts fish reproductive success. Nat. Commun. 13, 1–9. https://doi.org/10.1038/s41467-022-30332-5.

OSPAR, 2022. Summary Record of the Meeting of the Environmental Impacts of Human Activities Committee (EIHA). EIHA 122/11/01-E.

Pine, M.K., Jeffs, A.G., Wang, D., Radford, C.A., 2016. The potential for vessel noise to mask biologically important sounds within ecologically significant embayments. Ocean Coast. Manag. 127, 63–73. https://doi.org/10.1016/j.ocecoaman.2016.04.007.

Pine, M.K., Wilson, L., Jeffs, A.G., McWhinnie, L., Juanes, F., Sceuderi, A., Radford, C.A., 2021. A gulf in lockdown: how an enforced ban on recreational vessels increased dolphin and fish communication ranges. Glob. Chang. Biol. 1–10 https://doi.org/10.1111/gcb.15798.

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., Halvorsen, M.B., Løkkeborg, S., Rogers, P.H., Southall, B. L., Zeddies, D.G., Tavolga, W.N., 2014. Sound Exposure Guidelines for Fishes and Sea Turtles, Springer Briefs in Oceanography. Springer Cham Heidelberg New York Dordrecht London. https://doi.org/10.1007/978-3-319-06659-2.

Putland, R.L., Merchant, N.D., Farcas, A., Radford, C.A., 2017. Vessel noise cuts down communication space for vocalizing fish and marine mammals. Glob. Chang. Biol. 24, 1–14. https://doi.org/10.1111/gcb.13996.

Richardson, W.J., Greene Jr., C.R., Malme, C.I., Thomson, D.H., 1995. Marine Mammals and Noise. Academic Press, London, UK.

Rolland, R.M., Parks, S.E., Hunt, K.E., Castellote, M., Corkeron, P.J., Nowacek, D.P., Wasser, S.K., Kraus, S.D., 2012. Evidence that ship noise increases stress in right whales. Proc. R. Soc. B Biol. Sci. 279, 2363–2368. https://doi.org/10.1098/rspb.2011.2429.

SailGP, 2023. Better Planet [WWW Document]. URL. https://sailgp.com/general/purpose/better-planet/ (accessed 11.1.23).

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C., Popper, A.N., 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Trends Ecol. Evol. 25, 419–427. https://doi.org/10.1016/j.tree.2010.04.005.

Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., Tyack, P.L., 2019. Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects. Aquat. Mamm. 45, 125–232. https://doi.org/10.1578/AM.45.2.2019.125.

The Ocean Race, 2023. Sustainable Sports & Innovation [WWW Document]. URL. https://www.theoceanrace.com/en/racing-with-purpose/sustainable-sports-and-innovation (accessed 11.1.23).

Weilgart, L.S., 2017. The Impact of Ocean Noise Pollution on Fish and Invertebrates. Report for OceanCare, Switzerland, p. 34.

Wilson, L., Constantine, R., Van Der Boon, T., Radford, C.A., 2022. Using timelapse cameras and machine learning to enhance acoustic monitoring of small boat sound. Ecol. Indic. 142, 109182 https://doi.org/10.1016/j.ecolind.2022.109182.

Wilson, L., Constantine, R., Pine, M.K., Farcas, A., Radford, C.A., 2023. Impact of small boat sound on the listening space of *Pempheris adspersa*, *Forsterygion lapillum*, *Alpheus richardsoni* and *Ovalipes catharus*. Sci. Rep. 13, 1–12. https://doi.org/10.1038/s41598-023-33684-0.

Wisniewska, D.M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., Madsen, P.T., 2018. High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). Proc. R. Soc. B Biol. Sci. 285, 1–10. https://doi.org/10.1098/rspb.2017.2314.