Acústica 2020
XI Congreso Ibérico de Acústica
51º Congreso Español de Acústica
TECNIACÚSTICA 2020

UNDERWATER NOISE LEVELS AND SHIPPING OFF THE FAIAL-PICO CHANNEL, AZORES, IN RELATION TO THE ACOUSTIC PRESENCE OF BALEEN WHALES

Miriam Romagosa*[1], Irma Cascão[1] & Mónica A. Silva[1,2]

1 IMAR & Okeanos-University of the Azores, 9901-862 Horta
2 Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

Resumo

O ruído de barco sobrepõe-se às frequências de vocalização das baleias de barbas e, em altos níveis, pode perturbar o seu comportamento e afetar o alcance dos sons usados na comunicação através do processo de mascaramento. Neste estudo, medimos os níveis de ruído subaquático e quantificámos o tempo com ruído de barcos numa zona a sudeste do canal das ilhas Faial-Pico, no Arquipélago dos Açores, ao longo de um ano. De seguida, comparámos os resultados com a presença acústica de baleias azuis, comuns e sardinheiras gravadas na mesma área. Os níveis médios de ruído por mês variaram desde um mínimo de 94.3±7 dB re µPa em fevereiro até um máximo de 98.3±18 dB re µPa em agosto. O tempo médio com ruído de barcos por mês aumentou desde abril até setembro (máximo de 29% em agosto), coincidindo com a presença acústica de baleias de barbas durante 3 meses (abril até junho). Esta sobreposição aumenta os riscos de mascaramento acústico, potencialmente afectando a capacidade dos animais comunicarem com conspecíficos. A gravidade deste efeito dependerá da duração da exposição individual ao ruído. Futuros estudos irão quantificar o mascaramento das vocalizações destas espécies para avaliar os potenciais impactos do tráfico de barcos na área.

Palavras-chave: ruído subaquático, ruído de barcos, baleias de barba, Açores, mascaramento

Abstract

Shipping noise overlaps with baleen whales' vocalizing frequencies and in high levels, may disrupt their behaviour and affect their communication ranges via masking. In this study, we measured underwater noise levels and quantified time with shipping noise at a single location southeast of the Faial-Pico Islands channel, in the Azores Archipelago, during one year. Then, we compared these results with the acoustic presence of blue, fin and sei whales in this same area. Monthly averaged noise levels ranged from a minimum of 94.3±7 dB re µPa in February to a maximum of 98.3±18 dB re µPa in August. Monthly time with shipping noise increased from April through September (maximum of 29% in August) and coincided with the acoustic presence of baleen whales for 3 months (April through June). This overlap increases the risks of acoustic masking, potentially affecting an individual's ability to communicate, the severity of which will depend on the duration of noise exposure. Future studies will quantify masking of calling whales to assess the potential impacts of vessel traffic in this area.

Keywords: Underwater noise, ship noise, baleen whales, Azores, masking

PACS 43.10.Ce**,** 43.30.+m

1 Introduction

Global energy budgets clearly indicate that shipping is the main contributor to anthropogenic underwater noise[1]. Although vessel noise can cover a wide range of frequencies (from a few Hz to more than 20 kHz)[2], their maximum energies are below 1kHz[3] and overlap with baleen whale call frequencies. Some documented effects of shipping on baleen whales include interruption of behaviours (e.g. foraging, socializing and playing)[4], changes in the acoustic properties of calls (call rates, frequencies, duration and source levels)[5]–[8], disruption of singing[9] and increased levels of stress[10]. Shipping noise can also mask baleen whale calls when frequencies of both sources overlap[11] hence decreasing the animals communication space[12]. However, reported responses to ship noise can vary greatly depending on species, context and vessels with a clear bias for more accessible species[13]. More research effort is needed to cover pelagic and solitary species in different geographic areas with different vessel types and impacts[13].

In the Azores archipelago, fin (*Balaenoptera physalus*), blue (*Balaenoptera musculus*) and sei (*Balaenoptera borealis*) whales can be detected acoustically from September through June[14] but are mainly seen close to the islands from February through June[15]. During this period, blue and fin whales stop their northward migrations to feed in the archipelago [16] while sei whales pass the islands with only occasional feeding[17]. Several recreational and commercial maritime activities such as whale watching, scuba diving, sports and professional fishing and ship transportation of passengers and goods intensify from March through October, which partially overlaps with the presence of baleen whales

As a first step in the assessment of potential negative impacts that shipping noise could have on baleen whales, this study analyses one year of recordings form a passive acoustic autonomous recorder deployed southeast of Faial-Pico channel, in the Azores. Measurements of underwater noise levels and time with shipping noise are then compared to the acoustic detection of blue, fin and sei whale calls.

2 Methods

Acoustic data was collected by using an autonomous bottom-mounted Ecological Acoustic Recorder (EAR)[18] deployed at a depth of 420 m southeast of Faial-Pico Islands channel, in the Azores Archipelago (Fig. 1). Recordings were set with a sampling rate of 2 kHz and a duty cycle of 6 hours on and 18 hours off, recording every day from 0900h to 1400h UTC. The EAR consists of a sensor Technology SQ26-01 hydrophone with a response sensitivity of −193.44 dB re 1 V/µPa and a flat frequency response (±1.5 dB) from 18 Hz to 28 kHz. A Burr-Brown AD S8344 A/D converter was used with a zero-to-peak voltage of 1.25 V. A total system gain of 47.5 dB re 1 µPa was used resulting in a noise floor of 89 dB re 1 µPa (18–1,000Hz). Dynamic range of the instrument was of 57 dB re 1 µPa reaching saturation at 146 dB re 1 µPa.

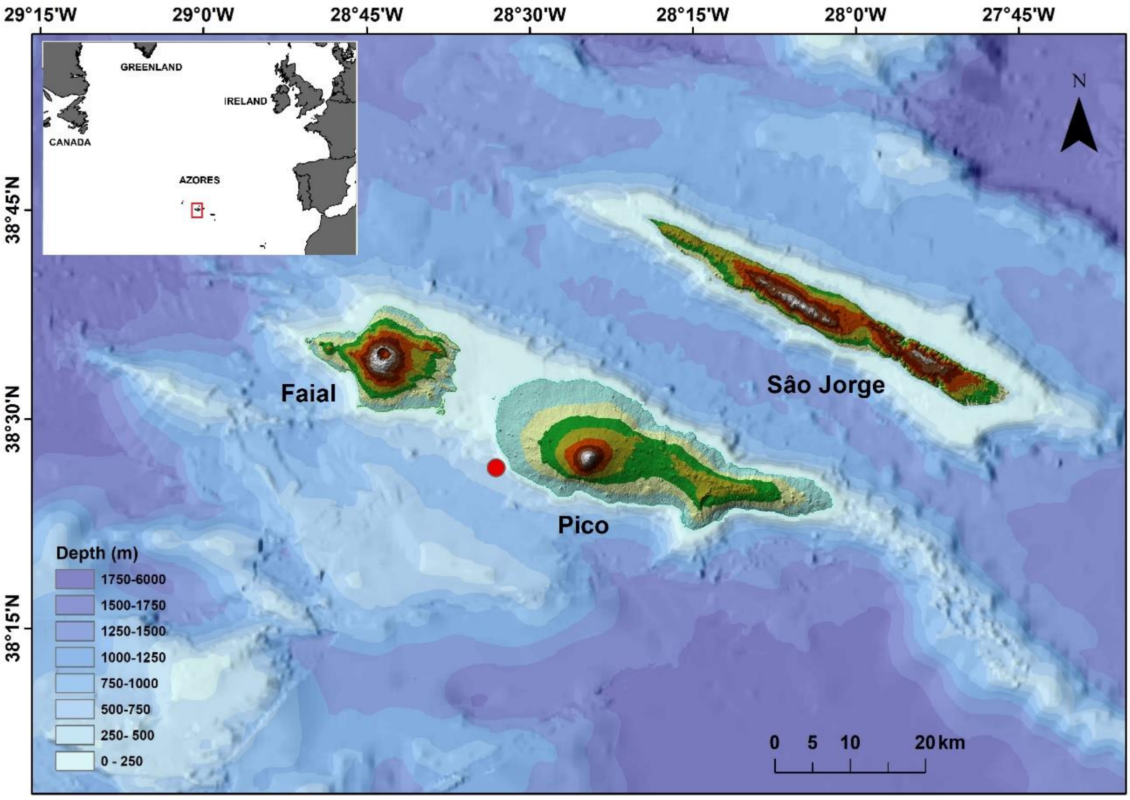

Figure 1 – EAR deployment location (red dot) southeast of the Faial-Pico Islands channel in the Azores Archipelago.

Each month of recordings was grouped and concatenated to form a single file to be analysed with the PAMGuide Matlab code [19]. The time-series of every signal was divided into m 1-s segments of consecutive samples overlapping in time (50% overlap). Each segment was then multiplied by a Hann window and transformed to the frequency domain via the Discrete Fourier Transform (DFT). Spectra were then averaged to a 60-s resolution via the standard Welch method[20] and the arithmetic mean of broadband sound pressure levels (SPLs) were calculated by day and month for the frequency band of 18-1000 Hz. Calibration data from the EAR, including the hydrophone sensitivity, system gain and the zero- to-peak voltage of the analog-to-digital converter were used to calculate calibrated noise measures.

To calculate the percentage of time with ship noise, the broadband (18–1000 Hz) noise background levels were used to apply an Adaptive Threshold Level (ATL [21,22]). The ATL allows the identification of intermittent ship noise by computing the minimum sound pressure level in a certain period of time (30 min) and summing a tolerance above this minimum, a threshold ceiling (1 dB) (see [22] for details and efficiency of this methodology). Time with levels above the threshold was summed and divided by the total recording time to obtain the Percentage of Time with noise levels Above the Threshold Level (PT-ATL) per day and month. Daily averaged wind speeds (kt) were obtained from Weather Underground historical data (www.wunderground.com) for a location 20 km away from the deployment.

To identify blue, fin and sei whale calls, a manual inspection of spectrograms was made by using Adobe Audition 3.0 software (Adobe Systems Incorporated, CA, USA). Identification of call types was made by following the same methodology described in [14]. Days with detections of each species were then summed and divided by the total days in each month to calculate a percentage of days with detections.

3 RESULTS

3.1 Underwater background noise levels, shipping noise and wind speed

SPLs showed a great variability between days but, overall, days with higher values were found from March through August, a pattern also followed by the monthly 95th percentile. Monthly median and 75th percentile values had a different pattern, slightly increasing from March through May, decreasing in the summer and increasing again in winter (Fig. 2A). As seen for the underwater background noise levels, the PT-ATL also showed considerable daily variability but days with higher PT-ATL were also found from March through August, which is well represented by monthly PT-ATL (Fig. 2B). Monthly averaged wind speeds were minimum in summer months (June-August) and showed higher levels in autumn and winter, the same pattern found for the monthly median and 75Th percentile noise levels (Fig. 2C). Monthly median and 75th percentile SPLs were highly and positively correlated with wind speed (median, $r=0.9$, $n=12$, $p<0.001$; 75th, $r= 0.8$, $n=12$, $p>0.001$) while the 95th percentile was highly and positively correlated with monthly PT-ATL ($r=0.8$, $n=12$, $p>0.001$).

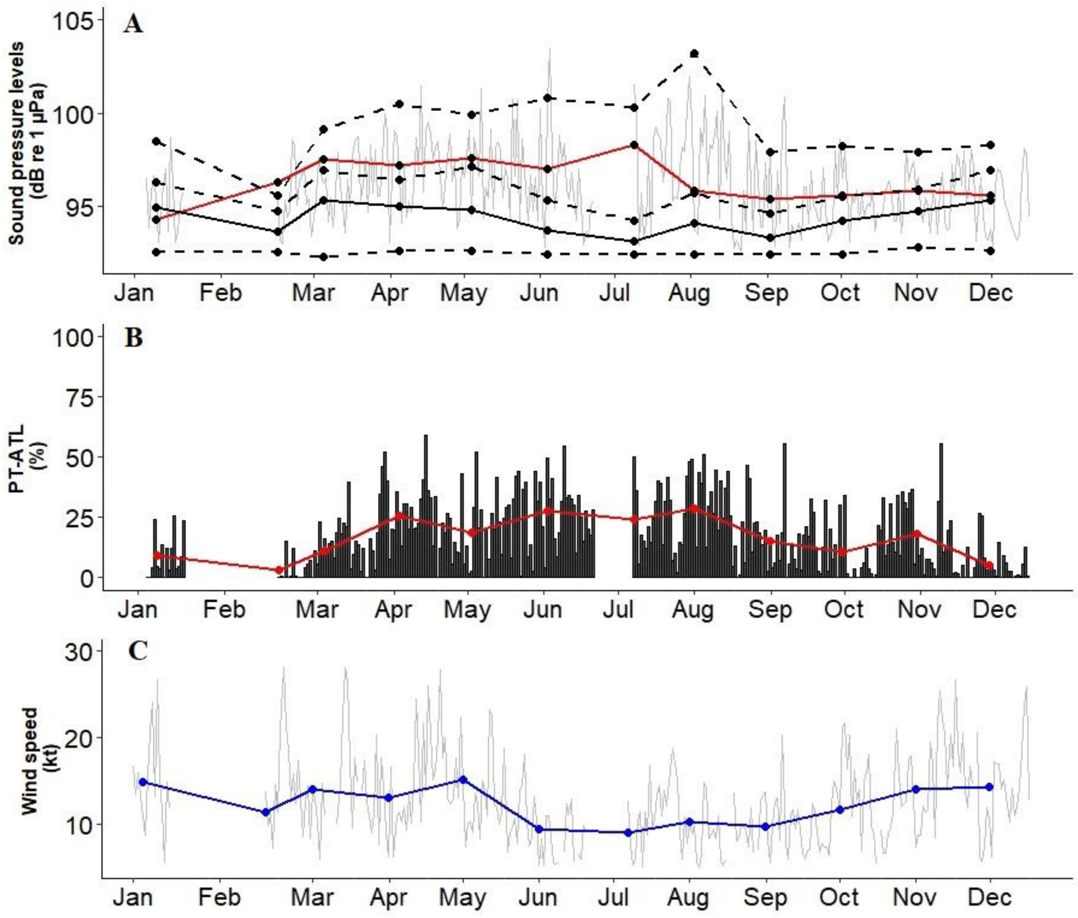

Figure 2. (A)Daily (grey line) and monthly averages (red line), medians (black line) and 5th, 75th, and 95th percentiles (dashed black lines from bottom to top) SPLs in the 18–1000Hz frequency band. (B) daily (black bars) and monthly (red line) PT-ATL (C) daily (grey line) and monthly (blue line) averaged wind speed.

3.2 Baleen whale acoustic detections and ship noise

Fin whale calls were detected from October through June with more days with detections in late winter and spring and no detections in summer. Blue whales showed a similar pattern but with less days with detections than fin whales and no detections from May through October. Sei whales were detected from March through June and then again from October through December with some detections in August. An overlap with higher PT-ATL exist for fin and sei whales from April through June and in April and May for blue whales (Fig. 3).

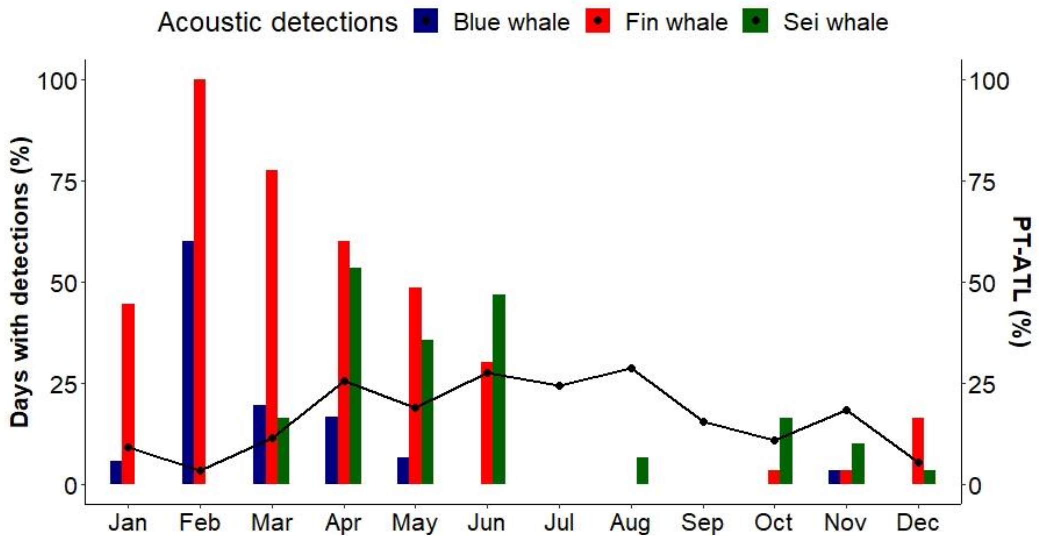

Figure 3 – Days with blue, fin and sei whale detections per month (coloured bars) and monthly PT-ATL (black line).

4 DISCUSSION

Variations in monthly median and 75th percentile noise levels were highly affected by wind-driven noise while monthly 95th percentiles were affected by shipping noise, a pattern also found in offshore seamounts of the Azores [22]. Considering this, we can assume that the increase in SPLs from June through September is mainly attributed to shipping noise while the increase from March through May is the result of the combined effect of shipping and wind-driven noise. The monthly variability in PT-ATL values found here reflect well the area's main recreational (scuba-diving, sports fishing, whale watching and recreational boating) and commercial (passenger ships and professional fishing) activities that increase from March through October [23]. In their majority, these activities use small vessels and do not carry an Automatic Identification System (AIS) that allow the tracking of ships and that can be successfully used to model ship noise[24]. In this scenario, the PT-ATL methodology applied here is a useful tool to assess the presence of ships and can increase the accuracy of AIS-based shipping noise models.

The increase in shipping noise from March through August clearly overlapped with the presence of blue, fin and sei whales (March – June). The maximum daily PT-ATL found in April was of approximately 60% and some days from March through June showed values of about 50%, which implies 3 hours with ship noise out of a total of 6 hours. Although we cannot quantify the impact it may have on baleen whales, we expect a certain degree of disturbance at least on days with higher number of boats. Baleen whales may use different strategies to compensate for high levels of noise by moving away from the source and shifting behaviour [4], changing the acoustic characteristics of their calls[6], [8] or ceasing vocalizing[9]. In any case, responses to these non-natural increased levels of noise can certainly cause a negative impact, the severity of which will depend on the intensity and exposure to the noise and the whales' behavioural context[13]. Blue and fin whales use this area in late winter and spring to feed and can stay for some weeks before resuming their migration to higher latitudes[16]. Shipping noise can disrupt foraging activities in bowhead (*Balaena mysticetus*)[4] and humpback whales (*Megaptera novaeangliae*)[25]. If blue and fin whales in the Azores show the same response, then numerous interruptions in feeding may result in less food intake which in turn would affect their nutritional state and ultimately their migrations. However, blue and fin whales preferred feeding areas are further offshore[16] where shipping noise is much lower[22] and a disruption of foraging behaviour is more unlikely. It is true though, that whale watching boats follow these species to feeding areas and could in theory, disrupt their behaviours. In contrast, sei whales seem to migrate through the archipelago with only occasional feeding[17] and expected impacts of shipping noise may be lower than those on the other two species.

Although a disruption of behaviour caused by shipping noise seems unlikely for these three species of baleen whales, the masking of their vocalisations can be of real concern. Recordings in the Azores (including the area of the study) revealed that blue and fin whales use songs in late autumn, winter and early spring[14], believed to act as reproductive displays [26], [27]. In late spring, singing stops and other calls types associated to foraging and close range communication [28], [29] are more abundant (unpublished data). Sei whales also use calls during their migration through the Azores in spring[14], believed to act as contact calls [30]. The increase in shipping noise from March through June overlaps with songs and calls of the three species thus increasing the risk of masking[11]. Masking can reduce the communication space of whales, which hinders the transmission of information between individuals [11]. A reduction in the efficiency of communication in reproductive, feeding and group cohesion contexts can surely have negative effects on the life cycles of these species. The extent of these impacts are extremely difficult to quantify but future work on masking and communication spaces for these three species will help to further predict the potential consequences of the increase of shipping noise in this area.

Acknowledgements

This work was supported by Fundação para a Ciência e Tecnologia (FCT), Azores 2020 Operational Programme and Fundo Regional da Ciência e Tecnologia (FRCT) through research projects TRACE (PTDC/ MAR/74071/2006), MAPCET (M2.1.2/F/012/2011) and AWARENESS (PTDC/BIA-BMA/30514/2017), co- funded by FEDER, COMPETE, QREN, POPH, ERDF, ESF, the Lisbon Regional Operational Programme, and the Portuguese Ministry for Science and Education. The work is also an output of project RAGES (grant agreement 110661/2018/794607/SUB/ENV.C.2). Okeanos R&D Centre is supported by FCT, through the strategic fund (UIDB/05634/2020). MR was supported by a DRCT doctoral grant (M3.1.a/F/028/2015), IR by an individual grant from FCT project AWARENESS (PTDC/BIA-BMA/30514/2017), and MAS by an FCT-Investigator contract (IF/00943/2013) and by EC funds (H2020 project SUMMER, grant agreement 817806). We are grateful to Rui Prieto, Sérgio Gómez, Gonçalo Graça, skilled skippers and crew that participated in the preparation and deployment of the EAR at DOP/IMAR.

References

[1] J. A. Hildebrand, Anthropogenic and natural sources of ambient noise in the ocean, *Mar. Ecol. Prog. Ser.*, vol. 395, pp. 5–20, 2009.

[2] C. Erbe, Underwater noise of whale-watching boats and potential effects on killer whales (Orcinus orca), based on an acoustic impact model, *Mar. Mammal Sci.*, vol. 18, no. 2, pp. 394–418, 2002.

[3] G. M. Wenz, Acoustic Ambient Noise in the Ocean: Spectra and Sources, *J. Acoust. Soc. Am.*, vol. 34, no. 12, p. 1936, 1962.

[4] W. John Richardson, M. A. Fraker, B. Würsig, and R. S. Wells, Behaviour of Bowhead

Whales Balaena mysticetus summering in the Beaufort Sea: Reactions to industrial activities, *Biol. Conserv.*, vol. 32, no. 3, pp. 195–230, 1985.

[5] S. E. Parks, M. Johnson, D. Nowacek, and P. L. Tyack, Individual right whales call louder in increased environmental noise Subject collect, *Biol. Lett.*, no. July, 2010.

[6] M. Dahlheim and M. Castellote, Changes in the acoustic behavior of gray whales Eschrichtius robustus in response to noise, *Endanger. Species Res.*, vol. 31, pp. 227–242, 2016.

[7] M. E. H. Fournet, L. P. Matthews, C. M. Gabriele, D. K. Mellinger, and H. Klinck, Source levels of foraging humpback whale calls, *J. Acoust. Soc. Am.*, vol. 143, no. 2, pp. EL105–EL111, 2018.

[8] M. Castellote, C. W. Clark, and M. O. Lammers, Acoustic and behavioural changes by fin whales (Balaenoptera physalus) in response to shipping and airgun noise, *Biol. Conserv.*, vol. 147, no. 1, pp. 115–122, Mar. 2012.

[9] K. Tsujii, T. Akamatsu, R. Okamoto, K. Mori, Y. Mitani, and N. Umeda, Change in singing behavior of humpback whales caused by shipping noise, *PLoS One*, vol. 13, no. 10, pp. 1–16, 2018.

[10] R. M. Rolland *et al.*, Evidence that ship noise increases stress in right whales, *Proc. R. Soc. B Biol. Sci.*, vol. 279, no. 1737, pp. 2363–2368, 2012.

[11] C. Erbe, C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling, Communication masking in marine mammals: A review and research strategy, *Mar. Pollut. Bull.*, vol. 103, no. 1–2, pp. 15–38, 2015.

[12] D. Cholewiak *et al.*, Communicating amidst the noise: Modeling the aggregate influence of ambient and vessel noise on baleen whale communication space in a national marine sanctuary, *Endanger. Species Res.*, vol. 36, no. May, pp. 59–75, 2018.

[13] C. Erbe, S. A. Marley, R. P. Schoeman, J. N. Smith, L. E. Trigg, and C. B. Embling, The Effects of Ship Noise on Marine Mammals—A Review, *Front. Mar. Sci.*, vol. 6, no. October, 2019.

[14] M. Romagosa *et al.*, Baleen whale acoustic presence and behaviour at a Mid-Atlantic migratory habitat, the Azores Archipelago, *Sci. Rep.*, vol. 10, no. 1, pp. 1–11, 2020.

[15] M. A. Silva *et al.*, Spatial and temporal distribution of cetaceans in the mid-Atlantic waters around the Azores, *Mar. Biol. Res.*, vol. 10, no. 2, pp. 123–137, 2014.

[16] M. a Silva, R. Prieto, I. Jonsen, M. F. Baumgartner, and R. S. Santos, North Atlantic blue and fin whales suspend their spring migration to forage in middle latitudes: building up energy reserves for the journey?, *PLoS One*, vol. 8, no. 10, p. e76507, Jan. 2013.

[17] R. Prieto, M. A. Silva, G. T. Waring, and J. M. A. Gonçalves, Sei whale movements and behaviour in the North Atlantic inferred from satellite telemetry, vol. 26, pp. 103–113, 2014.

[18] M. O. Lammers, R. E. Brainard, W. W. L. Au, T. A. Mooney, and K. B. Wong, An ecological acoustic recorder (EAR) for long-term monitoring of biological and anthropogenic sounds on coral reefs and other marine habitats., *J. Acoust. Soc. Am.*, vol. 123, no. 3, pp. 1720–1728, Mar. 2008.

[19] N. D. Merchant *et al.*, Measuring acoustic habitats, *Methods Ecol. Evol.*, 2015.

[20] P. D. Welch, The use of Fast Fourier Transform for the Estimation of Power Spectra: A method based on Time Averaging Over shoert, modified periodograms. .

[21] N. D. Merchant, M. J. Witt, P. Blondel, B. J. Godley, and G. H. Smith, Assessing sound exposure from shipping in coastal waters using a single hydrophone and Automatic

Identification System (AIS) data., *Mar. Pollut. Bull.*, vol. 64, no. 7, pp. 1320–1329, Jul. 2012.

[22] M. Romagosa *et al.*, Underwater Ambient Noise in a Baleen Whale Migratory Habitat Off the Azores, *Front. Mar. Sci.*, vol. 4, no. 109, pp. 1–14, 2017.

[23] A. Ressurreição and E. Giacomello, Quantifying the direct use value of Condor seamount, *Deep. Res. Part II Top. Stud. Oceanogr.*, vol. 98, pp. 209–217, 2013.

[24] D. Cholewiak *et al.*, Communicating amidst the noise: modeling the aggregate influence of ambient and vessel noise on baleen whale communication space in a national marine sanctuary, *Endanger. Species Res.*, vol. 36, pp. 59–75, 2018.

[25] H. B. Blair, N. D. Merchant, A. S. Friedlaender, D. N. Wiley, and S. E. Parks, Evidence for ship noise impacts on humpback whale foraging behaviour.

[26] W. A. Watkins, P. Tyack, K. E. Moore, and J. E. Bird, The 20-Hz signals of finback whales (Balaenoptera physalus), *J. Acoust. Soc. Am.*, vol. 82, no. 6, pp. 1901–1912, 1987.

[27] D. K. Mellinger and C. W. Clark, Blue whale (Balaenoptera musculus) sounds from the North Atlantic, *J. Acoust. Soc. Am.*, vol. 114, no. 2, p. 1108, 2003.

[28] W. A. Watkins, Activities and underwater sounds of fin whales, *Sci. Rep. Whale Res. Institure*, no. 33, pp. 83–117, 1981.

[29] E. M. Oleson, S. M. Wiggins, and J. A. Hildebrand, Temporal separation of blue whale call types on a southern California feeding ground, *Anim. Behav.*, vol. 74, no. 4, pp. 881–894, 2007.

[30] M. F. Baumgartner, S. M. Van Parijs, F. W. Wenzel, C. J. Tremblay, H. Carter Esch, and A. M. Warde, Low frequency vocalizations attributed to sei whales (Balaenoptera borealis)., *J. Acoust. Soc. Am.*, vol. 124, no. 2, pp. 1339–1349, Aug. 2008.