EMSO TIME SERIES CONFERENCE
OBSERVING OCEAN SOUND
20-22 OCTOBER 2021
CANARY ISLANDS SPAIN

Shipping and noise levels 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]

[1] Okeanos R&D centre, University of the Azores & Institute of Marine Research (IMAR), Horta, Portugal

Shipping, the main contributor to anthropogenic underwater noise, has maximum energies below 1 kHz[1] that overlap with baleen whale call frequencies. Effects of shipping noise on baleen whales include interruption of behaviours, changes in the acoustic properties of calls, increased levels of stress and a reduction in communication space due to masking[2]. Fin (*Balaenoptera physalus*) and blue (*B. musculus*) whales stop their northward spring migration to feed in the Azores archipelago[3] while sei whales (*B. borealis*) transit through the islands with only occasional feeding[4]. Several recreational and commercial maritime activities intensify from March through October, partially overlapping with the presence of baleen whales. As a first step to assess the potential negative impacts of shipping noise on baleen whales, this study analyses one year of underwater recordings from the Azores to measure levels of shipping noise in relation to the acoustic presence of blue, fin and sei whale calls.

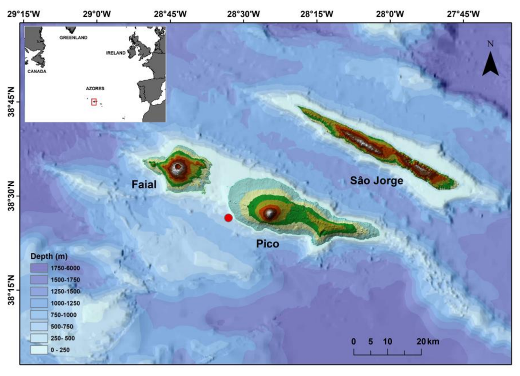

Figure 1. EAR deployment location (red dot) in the Azores Archipelago.

METHODS & RESULTS

Underwater background noise levels, shipping noise and wind speed

- One year of data was collected by an autonomous bottom-mounted Ecological Acoustic Recorder (EAR)[5] at a depth of 420 m (Fig. 1) recording everyday from 0900h to 1500h UTC.
- Averaged calibrated broadband sound pressure levels (SPLs) were calculated using PAMGuide Matlab code[6] for the frequency band of 18-1000 Hz.
- Percentage of time with ship noise (PT-ATL) was calculated by applying an Adaptive Threshold Level (ATL)[7] (Fig. 2).
- Daily averaged wind speed was obtained from Weather Underground historical data (www.wunderground.com).

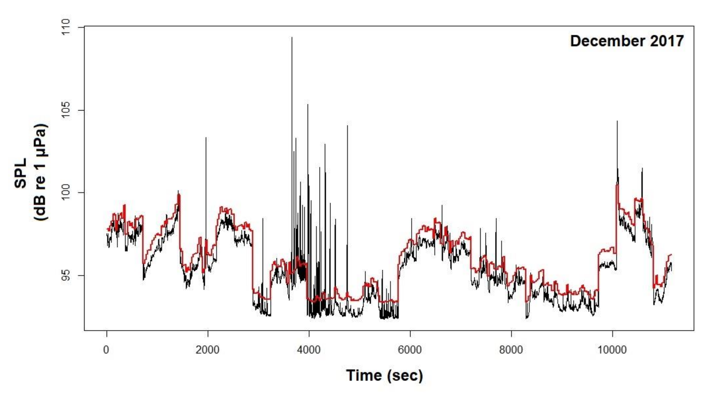

Figure 2. Example of SPLs measurements (black line) and ATL (red line). ATL computed the minimum SPL over a 30-min time period and summed a tolerance of 1 dB above this minimum threshold.

- Days with higher SPL and PT-ATL values were found in spring and summer (Mar-Aug) (Fig. 3A & B). Maximum daily PT-ATL ranged from 50-60%, corresponding to ~3 hours with ship noise out of a total of 6 recording hours.
- Monthly median and 75th percentile SPLs were positively correlated with wind speed (Fig. 3A & C) (median: r=0.9, n=12, p<0.001; 75th: r=0.8, n=12, p<0.001) while the 95th percentile was positively correlated with monthly PT-ATL (Fig. 3A & B) (r=0.8, n=12, p<0.001).

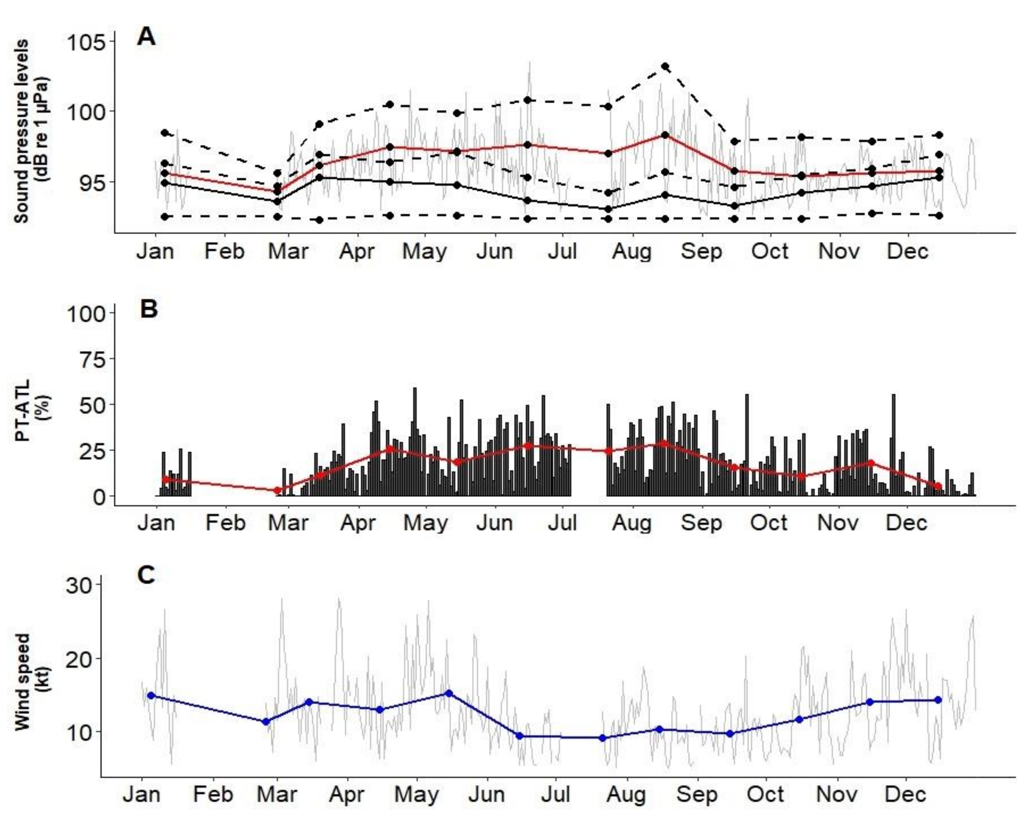

Figure 3. (A) Daily (grey line) and monthly average (red line), median (black line) and 5th, 75th, and 95th percentiles (dashed black lines from bottom to top) SPLs in the 18–1000 Hz frequency band. (B) daily (black bars) and monthly (red line) PT-ATL. (C) daily (grey line) and monthly (blue line) averaged wind speed.

Baleen whale acoustic detections and ship noise

- Blue, fine and sei whale calls were detected by visually inspecting spectrograms with Adobe Audition 3.0 software. Call types (Fig. 4) were identified from comparison with calls available in the literature.
- Days with detections of each species were summed and divided by the total days in each month to calculate a percentage of days with detections.

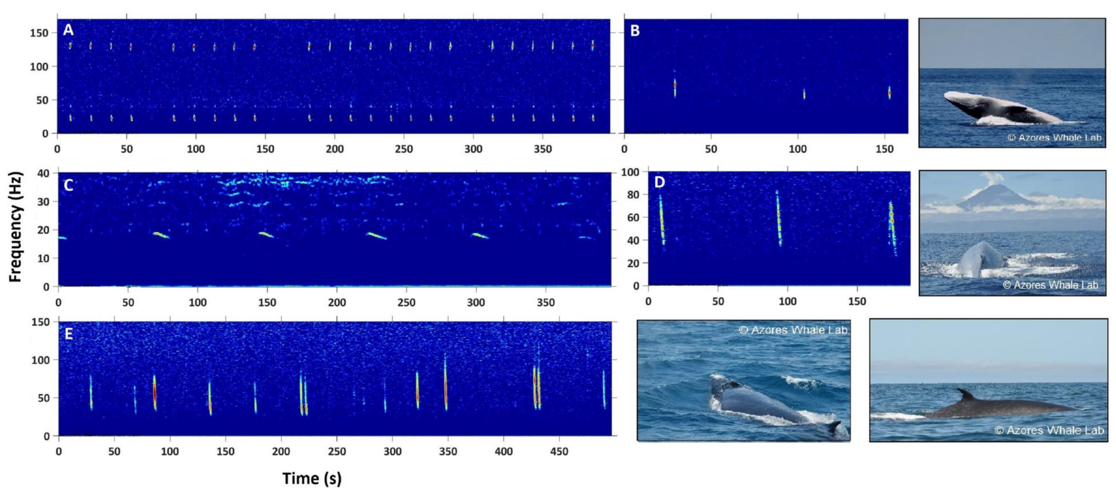

Figure 4. Spectrograms of vocalisations of fin whales: (A) 20-Hz song and (B) 40-Hz call; blue whales: (C) A song and (D) D calls; and sei whales: (E) downsweep calls.

- Fin whale calls were detected every month except from July, August and September, with more days with detections in late winter and spring.
- Blue whales showed a similar pattern but had fewer detections relative to fin whales and no detections in June - October and in December.
- Sei whales were mostly detected in spring and early summer (Mar–Jun) and in autumn and early winter (Oct-Dec) with some detections in August.
- An overlap with higher PT-ATL existed for fin and sei whales in April-June and in April and May for blue whales (Fig. 5).

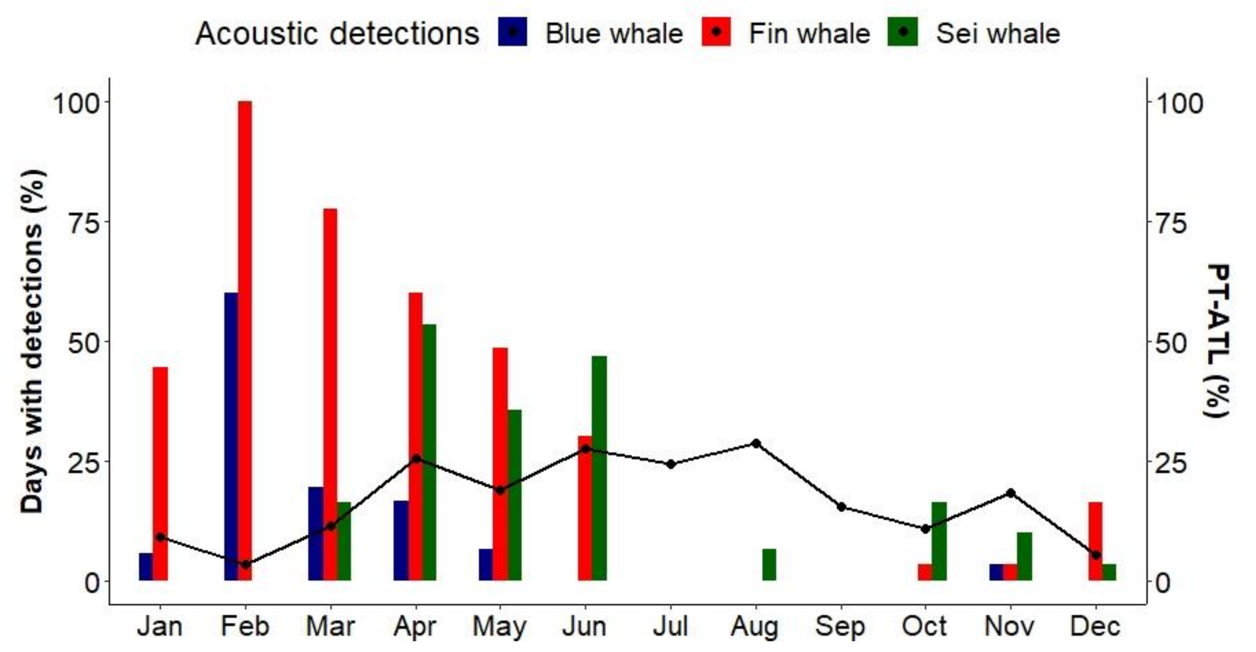

Figure 5. Days with blue, fin and sei whale detections per month (coloured bars) and monthly PT-ATL (black line). Winter: Dec-Feb, Spring: Mar-May, Summer: Jun-Aug, Autumn: Sep-Nov.

DISCUSSION

- Higher SPLs levels found in summer and early autumn (Jun – Sep) were mainly attributed to shipping noise while wind-driven noise had a greater contribution to background SPLs levels in the remaining months of the year.
- The monthly variability in PT-ATL values reflect the seasonality of the main recreational (scuba-diving, sports fishing, whale watching and recreational boating) and commercial (passenger ships and professional fishing) activities that peak in March - October. These activities mostly use small vessels with no Automatic Identification System (AIS), which means they remain unaccounted for in underwater noise models using AIS data. In this scenario, the PT-ATL methodology applied here is a useful tool to assess the presence and noise levels of these vessels and complement predictions from AIS-based shipping noise models.
- Higher shipping noise in spring and early summer clearly overlapped with the presence of fin, blue and sei whales. Responses to these increased levels of anthropogenic noise could have negative impacts on individual whales, the severity of which will depend on the noise intensity, exposure duration and the whales' behavioural context[2]. More research is needed to quantify the impact this may have on these species.

[1]Hildebrand, J. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Mar. Ecol. Prog. Ser.*, 395, 5–20.
[2]Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E. and Embling, C.B. (2019). The Effects of Ship Noise on Marine Mammals—A Review. *Front. Mar. Sci.* 6, 606.
[3]Silva, M.A., Prieto, R., Jonsen, I., Baumgartner, M.F. and Santos, R.S. (2013) North Atlantic blue and fin whales suspend their spring migration to forage in middle latitudes: building up energy reserves for the journey? *PLoS One*, 8, e76507.
[4]Prieto, R., Silva, M.A., Waring, G.T. and Gonçalves, J.M.A. (2014). Sei whale movements and behaviour in the North Atlantic inferred from satellite telemetry. *Endanger. Species Res.* 26, 103–113.
[5]Lammers, M.O., Brainard, R.E., Au, W.W.L., Mooney, T.A. and Wong, K.B. (2008). 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*. 123, 1720–1728.
[6]Merchant, N.D., Fristrup, K.M., Johnson, M.P., Tyack, P.L., Matthew, J., Blondel, P. and Parks, S.E. (2015). Measuring acoustic habitats. *Methods Ecol. Evol.* 6, 257–265.
[7]Merchant, N.D., Witt, M.J., Blondel, P., Godley, B.J., and Smith, G.H. (2012). Assessing sound exposure from shipping in coastal waters using a single hydrophone and Automatic Identification System (AIS) data. *Mar. Pollut. Bull.* 64, 1320–1329.

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), IC 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 Marc Lammers, Rui Prieto, Sérgio Gomes, Gonçalo Graça, skilled skippers and crew that participated in the preparation and deployment of the EAR at DOP/IMAR.