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It Is Not Just a Matter of Noise: *Sciaena umbra* Vocalizes More in the Busiest Areas of the Venice Tidal Inlets

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Abstract: Boat noise is known to have a detrimental effect on a vulnerable Mediterranean sciaenid, the brown meagre *Sciaena umbra*. During summer 2019, two acoustic surveys were conducted at 40 listening points distributed within the inlet areas of Venice (northern Adriatic Sea). Two five-minute recordings were collected per each point during both the boat traffic hours and the peak of the species' vocal activity with the aims of (1) characterizing the local noise levels and (2) evaluating the fish spatial distribution by means of its sounds. High underwater broadband noise levels were found (sound pressure levels (SPLs)$_{50\text{–}20\text{kHz}}$ 107–137 dB re 1 µPa). Interestingly, a significantly higher background noise within the species' hearing sensibility (100–3150 Hz) was highlighted in the afternoon (113 $\pm$ 5 dB re 1 µPa) compared to the night (103 $\pm$ 7 dB re 1 µPa) recordings due to a high vessel traffic. A cluster analysis based on *Sciaena umbra* vocalizations separated the listening points in three groups: highly vocal groups experienced higher vessel presence and higher afternoon noise levels compared to the lower ones. Since the species' sounds are a proxy of spawning events, this suggests that the reproductive activity was placed in the noisier part of the inlets.

Keywords: coastal areas; fish; anthropogenic noise; passive acoustic monitoring; protected species; reproduction

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1. Introduction

Many human activities generate sounds in the aquatic environment that are very different from those arising from natural sources both at the intensity and frequency levels; as a result, man-made noise has changed the acoustic underwater landscape of many areas, and it has become a pollutant of international concern, given its potential to harm marine fish [1].

Living in a very noisy environmental condition represents a constraint for aquatic species. It has been widely recognized that anthropogenic noise can threaten animals at both the physiological and behavioral levels, increasing the hearing thresholds and stress hormones and impacting their foraging and anti-predatory ability and reproductive success, with potential consequences in terms of survival and fitness (reviewed in [2–4]). In marine ecosystems, commercial shipping and recreational boating are common sources of anthropogenic noise, and noise from vessel traffic along coastal areas is a widespread stressor [5] to which animals have to cope. Vessel noise was demonstrated to affect fish [6] by inducing changes in fish swimming, brooding, and anti-predator behaviors in both laboratory and field environments, as well as impacting fish social communication interfering with the receiver's ability to hear the signal's original content.

Continuous and chronic disturbance from boat noise is typically associated with marinas, boat channels, and harbor entrances. This is also expected to be the case of the inlets that allow for shipping traffic in and out of the Venice Lagoon; Venice is one of the principal ports of the northern Adriatic Sea, with a number of about 3500 port calls for commercial vessels and cruise ships. The large number of fishing boats and motor- and speed-boats operating along the inlets also gives a large contribution to the local anthropogenic noise levels, particularly during the summer period [7].

On the other side, the Venice inlets, which are constituted by piers made by artificial 3-D structures, represent a standardized homogeneous habitat that has the potential to attract and aggregate the local pelagic and benthic fauna in accordance with other artificial structures in coastal areas [8]. In more detail, since they are constituted by rocky reefs with holes and shelters close to the soft substrates that act as feeding grounds, the inlets resemble the typical reproductive habitat of a small-sized sciaenid occurring along most of the Mediterranean coast, the brown meagre *Sciaena umbra* [9,10]. A preliminary survey confirmed the local presence of this species, with a variable number of heterogeneously distributed individuals [11].

The brown meagre is a slow-growing species that can live for up to approximately 30 years and exceed 60 cm in total length [12,13]. In the Mediterranean, it is frequently targeted by spear-fishers and caught by the coastal commercial fleet, leading to a change in the abundance and composition of its populations [14,15]. As a result, it is listed in the Annex III (Protected Fauna Species) of the Barcelona Conventions and classified as a vulnerable species by the International Union for Conservation of Nature (IUCN), although a slow recovery has been recently reported [16].

Sciaena umbra is sedentary with a limited capability for adult dispersal, particularly during the autumn and winter months [14,17]. During the summer season, daytime site fidelity is corroborated by underwater observations [18,19], whereas there is a general lack of data on its nocturnal behavior; it is known that *S. umbra* feeds actively on crustaceans during the night [10,14], but the spatial extent of its nocturnal movements is unknown. Feeding has been proved to be mainly focused during the spring gonad maturation [17,20].

Sciaena umbra reproduces from late spring to autumn [20,21]. It emits drumming sounds as part of its reproductive process [22–24], whose acoustic features are consistent in space and time [25]. As a consequence, the species can be acoustically identified at sea by mean of its vocalizations. *S. umbra* vocalizations consist of low-frequency pulsed sounds with main energy below 1 kHz (mean dominant frequency of 200–300 Hz); they are made of 4–7 pulses, with a pulse period of approximately 70–145 ms and a pulse duration of approximately 16–27 ms [9,11,21,23,25,26]. Recently, a two-year continuous acoustic monitoring at a study site inside the no-take Réserve de Couronne (near Marseille, France) highlighted a strong consistency in the sound production along the reproduction period [21], thus further confirming the site-fidelity for breeding, vocalizing individuals.

Being sedentary, *S. umbra* benefits from protection measures inside marine protected areas (MPAs), where it is usually present at high densities [18,19,27,28]. Chorusing activity produced by spawning aggregations has been recorded within fully protected zones of old MPAs in the northwestern Mediterranean Sea, where *S. umbra* was present in approximately 70–80% of the monitored stations, though a generally lower probability of detecting *S. umbra* calls was found in younger MPAs (approximately 30% of the stations; [21]). Sound production has also been reported in anthropized coastal areas [9,11,21], where the species could be nevertheless affected by the underwater noise produced by vessel traffic. Thus far, *S. umbra* behavior and vocal activity have been proved to be influenced by boat passages by two different studies run inside MPAs [19,29]. MPAs represent an ideal situation to evaluate the impact of potential stressors on relatively pristine animal populations. However, it remains unclear whether fish avoid high-noise areas. To explore this question, the distribution of the protected fish species *Sciaena umbra* was analyzed here in a potentially highly noisy area: the Venice inlets. This research aimed at (i) evaluating the vessel traffic and the received sound pressure level of noise along the three Venice inlets while considering the hearing thresholds of the target species; (ii) monitoring the spatial distribution of *S. umbra* in the inlets by recording its acoustical activity, following a previous established methodology [9,11,21,24]; and (iii) observing and interpreting the fish distribution in relation to the local underwater anthropogenic noise pressure.

2. Materials and Methods

2.1. Data Collection

During summer 2019, two acoustic surveys were conducted at 40 listening points distributed along the three inlets that connect the Venice lagoon to the sea (Figure 1). The total number of listening points (n = 40) were allocated into the three different sea inlets (n = 13 Lido, north-eastern inlet; n = 15 Malamocco, the central inlet; and n = 12 Chioggia south-western inlet; see Figure 1). They were distributed along both the internal and external sides of the inlets, with each at about 300 m apart; this distance was based on the sound source levels reported by [22], assuming a cylindrical spreading loss.

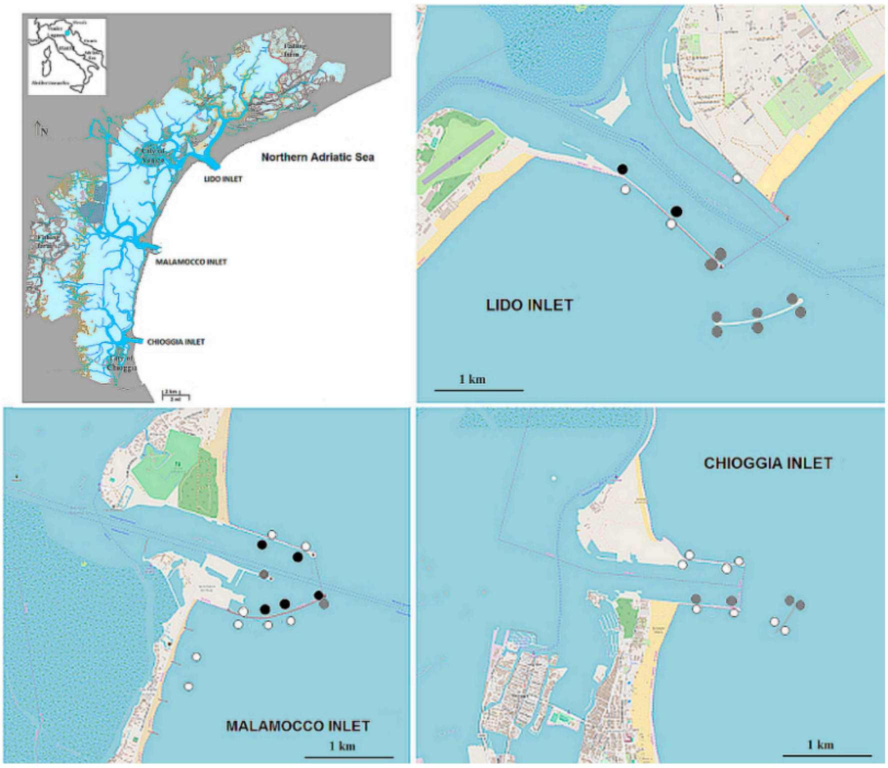

Figure 1. Map showing the 40 listening points in the three inlets (Lido, Malamocco, and Chioggia) explored during the acoustic monitoring. The map also visualizes the stations characterized by higher *Sciaena umbra* vocalization rates with different colors (black dots for group 1 and dark grey dots for group 2), whereas white dots indicate stations characterized by lower vocalization rates (group 3), in accordance with the results presented in this study.

Each listening point was replicated twice, one at the end of July and the other at the end of August (5 and 29 August for the Lido inlet; 29 July and 28 August for the Malamocco inlet; and 1 August and 27 August 2019 for the Chioggia inlet). Within the above-indicated monitoring days, each listening point was also replicated twice per station: one 5-min acoustic sample was collected in the late afternoon, corresponding to one of the local peaks of boat traffic in the summer period (17–19); a second 5-min acoustic sample was collected a few hours later, corresponding to the peak of the species' vocal activity (19.30–23) [23,25]. The earlier acoustic samples were mainly meant to instantaneously evaluate the man-made noise pressure per listening point, whereas the sunset-nocturnal ones locally monitored the presence of the target species by means of its reproductive sounds. *Sciaena umbra* vocalizations consist of pulsed sounds with main energy below 1 kHz and a mean dominant frequency of 200–300 Hz; they are made of 4–7 pulses, with a pulse period of approximately 70–145 ms and a pulse duration of approximately 16–27 ms [23,25].

Recordings were obtained using a pre-amplified Colmar GP1280 hydrophone (sensitivity of −170 dB re 1V/μPa and frequency range of 5–90 kHz) connected to a Tascam Handy Recorder (Tascam Corporation, Santa Fe Springs CA, USA; sampling rate 44.1 kHz, 16 bit) generating Waveform Audio File Format (WAV). Prior to each survey, the signal was calibrated using a generator of pure waves of known voltage. The hydrophone was lowered from a 7.5 m open boat to an average depth of 4 m (range of 2–6 m in depth). Sampling was carried out only in a sea state of less than two on the Douglas scale and a wind speed of less than 10 km/h. Surface water temperature was measured prior to each recording by using a digital thermometer (HANNA Checktemp® 1 HI98509 ± 0.1 °C), resulting in an average of 27.4 °C (range: 26.6–28.5 °C) for the acoustic samples containing *S. umbra* sounds.

A quantification of the traffic in the area was obtained by keeping a log of the vessels visible by eye per each acoustic recording; this was further confirmed by scoring the number of vessel signals that were visually and aurally identifiable for their unique signature in the acoustic files. The same vessel was never included in two different acoustic files because of a minimum of 10 min needing to pass from the end of one recording and the start of the next one.

2.2. Data Analysis

A total of 160 5-min recordings were collected and analyzed minute by minute using the Adobe Audition software by the aural and visual assessment of the spectrograms (sampling rate—FS 44.1 kHz, 16 bit, resampled at 6 kHz, Fast Fourier Transform—FFT = 512, and 50% overlap). This allowed us (i) to discriminate geophony (waves and currents), biophony (i.e., *S. umbra* sounds), and anthropophony (vessels and cargo), as well as (ii) to score their presence/absence per acoustic sample. The Adobe Audition software was also used to quantify both the vessel passages and the *S. umbra* calls.

S. umbra produces low-frequency pulsed sounds with a main energy below 1 kHz that are clearly detectable even in the presence of vessel noise (Figure 2). The pulses were identified and scored by an aural and visual assessment of the recorded file, following [11,26]; the number of pulses present per minute was defined as the pulse rate (PR). The PR was further scaled on a quantitative scale (pulse code: PC) ranging from 0 (no sound) to 5 (maximum pulse rate): 0 = no sound production, 1 = very few sounds (less than 50 pulses min^{-1}), 2 = some sounds (30–50 pulses min^{-1}), 3 = semi-continuous sound production (>50 pulses min^{-1}), 4 = continuous sound production (>100 pulses min^{-1}), and 5 = 'chorus'.

The acoustic samples were analyzed as instantaneous sound pressure level (SPL) by using the software SpectraPlus 5.0 (Pioneer Hill Software, Sequim, WA, USA; Hanning windows, 32768-pt FFT size, 75%FFT overlap, and averaging fast) previously calibrated with a signal of 100 mV RMS at 1 kHz and the hydrophone sensitivity value. This software utilizes the discrete fast Fourier transform algorithm to compute the frequency spectrum among 1/3 octave bands (center frequencies of 50–20,000 Hz) and the broadband SPL per each second. Per each sampling station, a single SPL value was further obtained (i) for the 1/3 octave bands and (ii) along the whole broadband by log-averaging in the dB domain the obtained values over the sample (300 s). Energy levels (hereafter called "ELs") were also calculated for the frequency range of 100–3150 Hz ($EL_{100–3150}$; range: 89–3548 Hz), which was consistent with the species' audiogram, and 200–630 Hz ($EL_{200–630}$; range: 178–708 Hz), which corresponded to the species' best hearing range [30]. Energy levels were calculated by summing the energy of the corresponding 1/3 octave bands by a log-sum in the dB domain.

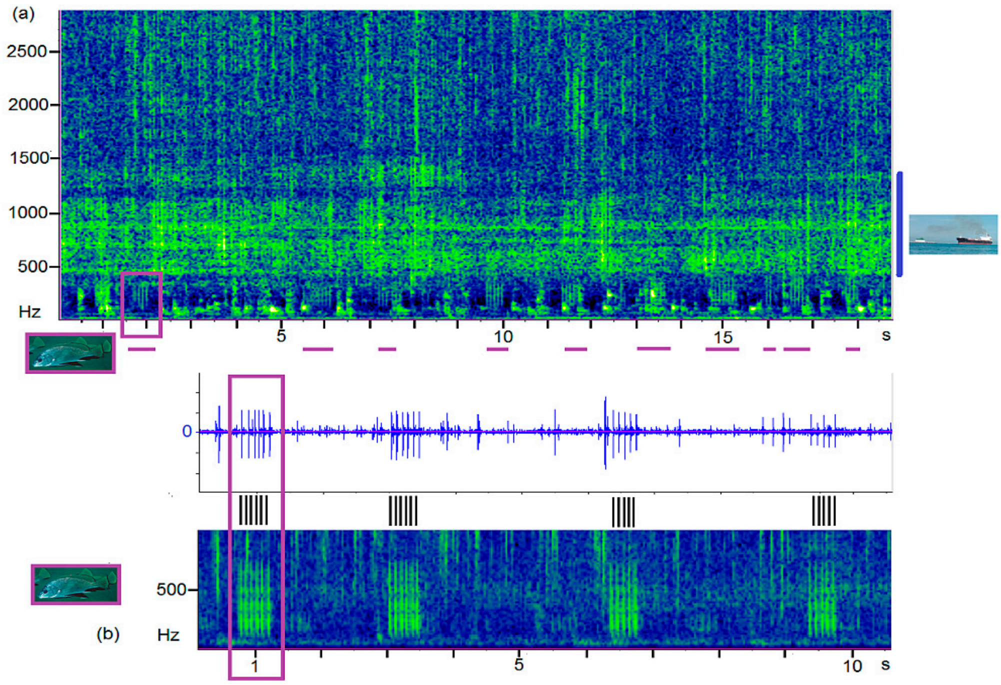

Figure 2. (**a**) Spectrogram (FS = 44.1 kHz, resampled at 6 kH, FFT = 512, and 50% overlap) of an acoustic sample containing both the noise of a distant cargo passing through the Venice inlet (most of the energy was located in the frequency range of 400–1100 Hz; blue line) and the sounds of the target species, *Sciaena umbra*, visible below 400 Hz (indicated by the purple square and lines). (**b**) Spectrogram (FS = 44.1 kHz, resampled at 6 kH, FFT = 512, and 50% overlap) and waveform of four *Sciaena umbra* sounds made by a series of low frequency pulses; the black bars indicate the number of pulses per sound, as scored in accordance with [11,26].

Median one-third octave band levels generated from all the 5-min SPL averages were compared to the *S. umbra* audiogram [30] to estimate which parts of underwater noise spectra might be audible to the species. For a quantitative evaluation, the average difference between the *S. umbra* audiogram and the median values in the sensitive frequency band ($EL_{200–630}$) was calculated for (i) the afternoon (n = 80) and (ii) night (n = 80) recordings, (iii) the night recordings characterized by the *S. umbra* chorus (n= 11) and (iv) the recordings containing more than three boat passages (n = 31); almost all the files containing more than three boat passages were recorded in the afternoon in the absence of fish sounds (see results). As a consequence, their ELs were representative of the anthropic contribution to the local background noise in case of high boating traffic.

In order to group the recording stations of the three inlets according to the local vocal activity of the target species, a hierarchical cluster analysis based on Ward's algorithm was applied to the listening points by using the *S. umbra* PC as a variable; for this analysis, the PC values were standardized as (x − min)/(max − min), with x being the average PC value over the 5-min-file recorded per single station and the min and max being the minimum and maximum average PC recorded along all the monitored stations, respectively. The cluster groups were calculated by using the Ward's minimum variance method using Euclidean distances. Groups were based on an *a priori* level of 70% of similarity.

To compare the collected data, statistical analyses were performed with non-parametric tests, with an alpha level of 0.05: (1) the Kruskal–Wallis Test was used for spatial comparisons between the three inlets or for comparisons of the *S. umbra* vocalization rate or noise levels between the groups of recording point, (2) the Mann–Whitney U Test was used for temporal comparisons between the two surveys (end of July/beginning of August vs. end of August), and (3) the Wilcoxon pair test was used for temporal comparisons between afternoon vs. night collected data per each recording point.

3. Results

3.1. Acoustic Characterisation of the Data Collected in the Venice Inlets

The acoustic data collected in the Venice inlets were characterized by the sounds produced by the waves and the water current (present in 53% of the collected acoustic samples), the irregular transit of different type of vessels (70%) or cargo (5%) contributing to both the high and low frequency bands, and the sounds produced by biological sources such as the snapping shrimps (100%) and Sciaenid fish vocalizations (50% of the collected nocturnal acoustic samples).

From a quantitative point of view, the background noise (broadband) varied from 107 to 137 dB re 1 μPa in the afternoon recordings and between 109 and 133 dB re 1 μPa in the night recordings. The broadband SPLs calculated per each listening point did not differ between these two periods (Wilcoxon signed rank test, $p = 0.38$), suggesting a temporal consistency of the noise levels within this broadband frequency spectrum. Furthermore, no difference was found in the broadband SPLs of samples collected during the first (end of July/beginning of August) vs. the second (end of August) surveys (Mann–Whitney U test: $p = 0.84$ for the afternoon samples and $p = 0.53$ for the nocturnal samples) nor when comparing the average SPLs recorded at the three inlets (Kruskal–Wallis Test: $p = 0.49$ for the afternoon samples and $p = 0.38$ for the nocturnal samples).

The local SPLs were highly influenced by the vessel passages, as clearly shown by Figure 3. A significantly higher presence of vessel passing along the inlets was detectable in the afternoon (2.4 ± 2.2 vessel passages per five-minute sample, corresponding to about 30 vessel passages per hour along the 17–19 period) compared to the night (0.8 ± 0.8 vessel passages per 5-min sample, corresponding to about 10 vessel passages per hour along the 19.30–23; Wilcoxon signed rank test, $p < 0.001$). As a result, 30 out of 31 acoustic files containing more than three boat passages were recorded in the afternoon in the absence of fish sounds.

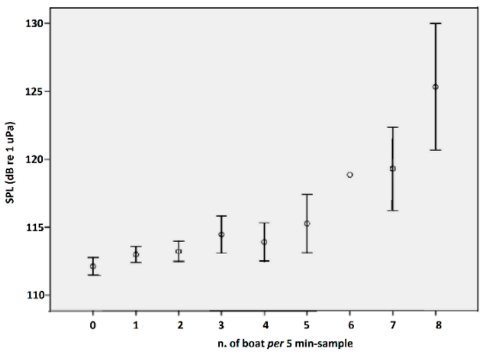

Figure 3. Variation of the mean (±standard error) sound pressure levels (SPLs) of recordings containing a variable number of boat passages.

The background noise, as described by the 1/3 octave band spectrum (Figure 4), showed consistently high SPLs at low frequency, which increased above 2 kHz with a peak around 4 kHz, which was mainly attributable to the activity of snapping shrimps (the *Alpheus* and *Synalpheus* genera). After comparing the recorded levels with the *Sciaena umbra* audiogram (Figure 4), an overlap of the background noise with the species hearing thresholds was evident.

An average $EL_{100–3150}$ value of 113 (±5 SD) dB re 1 μPa and an $EL_{200–630}$ value of 103 (±7 SD) dB re 1 μPa were found along the *S. umbra* hearing frequencies (100–3150 Hz) and the restricted range of 200–630 Hz, respectively. The average difference between the *S. umbra* audiogram and the median $EL_{200–630}$ in the sensitive frequency band (200–630 Hz) was equal to approximately 10 dB re 1 μPa for both the afternoon (10.7 dB re 1 μPa; n = 80) and night (10.3 dB re 1 μPa; n = 80) recordings. This increased to 16.6 dB re 1 μPa for the afternoon recordings containing more than three boat passages (n = 31) and to 14 dB re 1 μPa for the night recordings characterized by the *S. umbra* chorus (n = 11). It has to be noticed that out of eleven files with chorusing activity, only two contained the signals produced by one passing recreational boat.

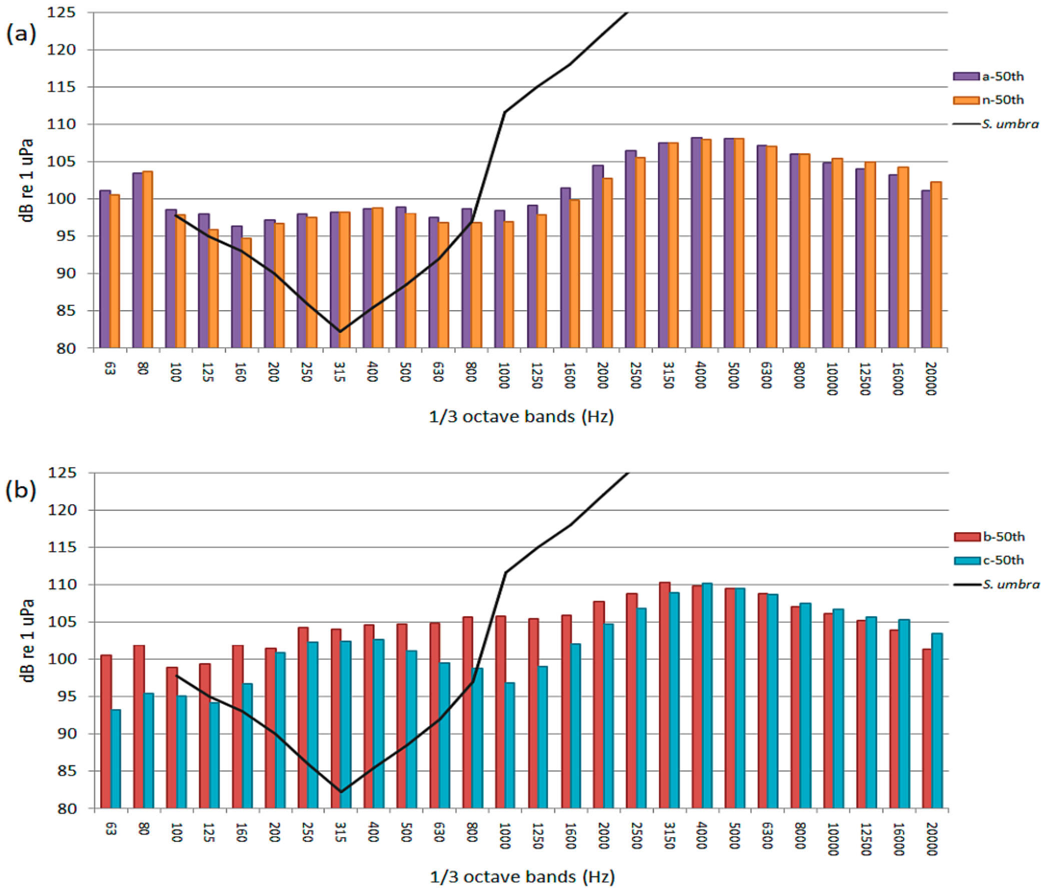

Figure 4. One-third octave band levels (median) related to (**a**) the afternoon (a-50th; 17–19, sample size of n = 80) and night (n-50th; 19.30–23, sample size of N = 80) recordings; (**b**) the afternoon recordings containing three or more boat (b-50th; sample size of N = 31) passages and the nocturnal *Sciaena umbra* chorus (c-50th; sample size of n = 11). The levels are compared to the *Sciaena umbra* audiogram; noise above the audiogram lines is expected to be audible.

The background noise for each recording point was slightly higher in the afternoon than in the night recordings when considering the 100–3150 Hz ($EL_{100–3150}$ = 114 ± 5 dB re 1 µPa vs. $EL_{100–3150}$ = 112 ± 4 dB re 1 µPa; Wilcoxon signed rank test, $p = 0.027$) but not the 200–630 Hz frequency ranges ($EL_{200–630}$ = 104 ± 7 vs. $EL_{200–630}$ = 103 ± 7 dB re 1 µPa, respectively; Wilcoxon signed rank test, $p = 0.131$). In the 200–630 Hz range, however, the *S. umbra* nocturnal chorus was responsible for increased values, like the ones resulting from the boat noise contributions observed in the afternoon (Figure 4) [31].

The afternoon SPL levels were similar across the three inlets for both the 100–3150 and 200–630 Hz frequency ranges (Kruskal–Wallis test: $EL_{100–3150}$, $p = 0.07$ and $EL_{200–630}$, $p = 0.25$, respectively), indicating a spatial homogeneity in accord with the case of the broadband SPLs.

3.2. Sciaena umbra Vocalizations

Sciaena umbra vocalizations were recorded at sea only after the sunset. About half of the collected nocturnal samples included these sounds (39 out of a total of 80). During the first and second surveys, *S. umbra* sounds were found in 21 and 18 out of 40 listening points (i.e., in 52% and 42% of points), respectively. The species' PR (i.e., the number of pulses per minute) ranged between 0 and 350 pulse min^{-1} (mean: 68 pulse min^{-1} ± 125 SD), not being consistent along the monitored area. In detail, the mean PR varied across the three tested inlets (Kruskal–Wallis test, $p = 0.04$), with a mean of 100 pulse min^{-1} (±21 SD) and 113 pulse min^{-1} (±23 SD) at the Lido and Malamocco inlets, respectively, whereas a mean of only 11 pulse min^{-1} (±4 SD) was recorded at the Chioggia inlet. Boat noises were present in about half of the samples containing *S. umbra* vocalizations (19 out of a total of 39; in six cases, one of the noise sources was a cargo ship).

A cluster analysis based on the *S. umbra* pulse code (PC) created a total of 14 possible groupings, one for each node at descending Euclidean distances (Figure 5). The grouping produced at a distance of 0.3 have three distinct assemblages that clearly differed for the species vocalizations activity: group "1" included seven points characterized by a higher vocalization rate (PC = 4.3 ± 0.3, i.e., characterized by a continuous sound production of >100 pulses min^{-1} and/or the chorus, following [11]) distributed mainly in the internal side of the Lido and Malamocco inlets (see also Figure 1) whereas group "3" contained nineteen points with a very low vocalization rate (PC = 0.1 ± 0.08, i.e., characterized by less than 30 pulses min^{-1}, following [11]), mostly facing the external sea side of the inlets and/or located in the Chioggia inlet. Group "2" consisted of an intermediate vocal activity of the target species (PC = 1.5 ± 0.3, i.e., characterized by 30–50 pulses min^{-1}, following [11]).

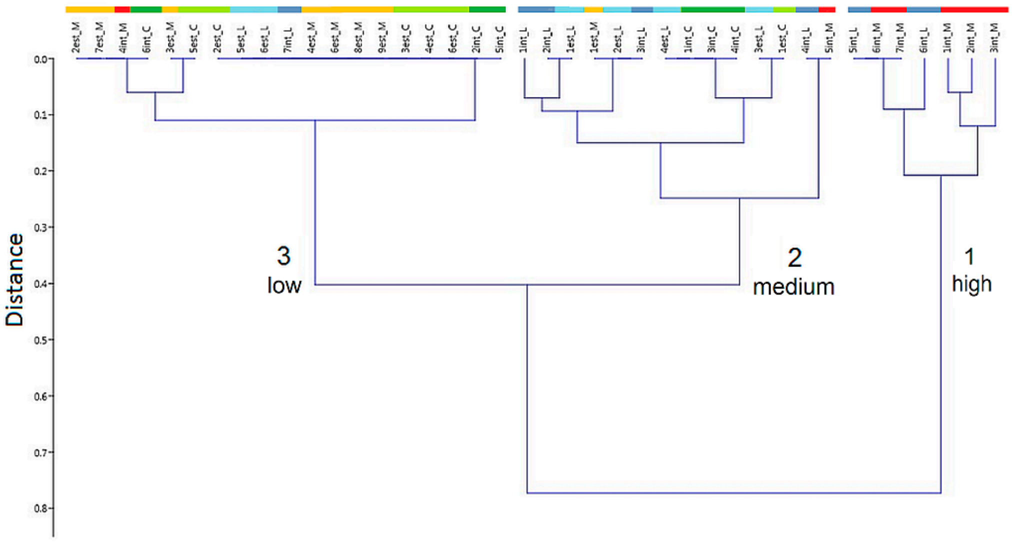

Figure 5. Tree diagram provided by cluster analysis using the pulse code to visualize which listening points were more similar in the Venice inlets; colored lines refer to points located at Malamocco internal side (red), Malamocco external sea side (orange), Lido internal side (blue), Lido external sea side (light blue), Chioggia internal side (green), and Chioggia external sea side (light green). The positions of the points in the inlets are highlighted in Figure 1 (black dots are used for group coded "1," dark grey dots are used for group coded "2," and white dots are used for group coded "3").

The three groups of locations produced by the cluster analysis were characterized by a slightly but significantly different background noise levels along the afternoon recordings (Kruskal–Wallis test, broadband $p = 0.001$; $EL_{100–3150}$ $p = 0.018$, $EL_{200–630}$ $p = 0.017$), with group 1 and 2 having higher values compared to group 3 for all considered frequency ranges. Figure 6a shows the case of $EL_{200–630}$. Consistently, groups 1 and 2 were characterized by a higher number of vessel passages compared to group 3 (Kruskal–Wallis test, $p = 0.021$; Figure 6b).

On the contrary, neither the SPLs and ELs (Kruskal–Wallis test, p = 0.1, 0.4, and 0.5 for the broadband, $EL_{100–3150}$, and $EL_{200–630}$, respectively) nor the number of vessel passages (Kruskal–Wallis test, $p = 0.602$) varied between the three groups of locations during the night recordings. Though not significant, a slightly higher value was evident while comparing the average $EL_{200–630}$ of group 1 vs. group 3 (Figure 7a). This was likely due to the contribution of the *S. umbra* vocalizations, given the overall low number of vessel passages after sunset (Figure 7b).

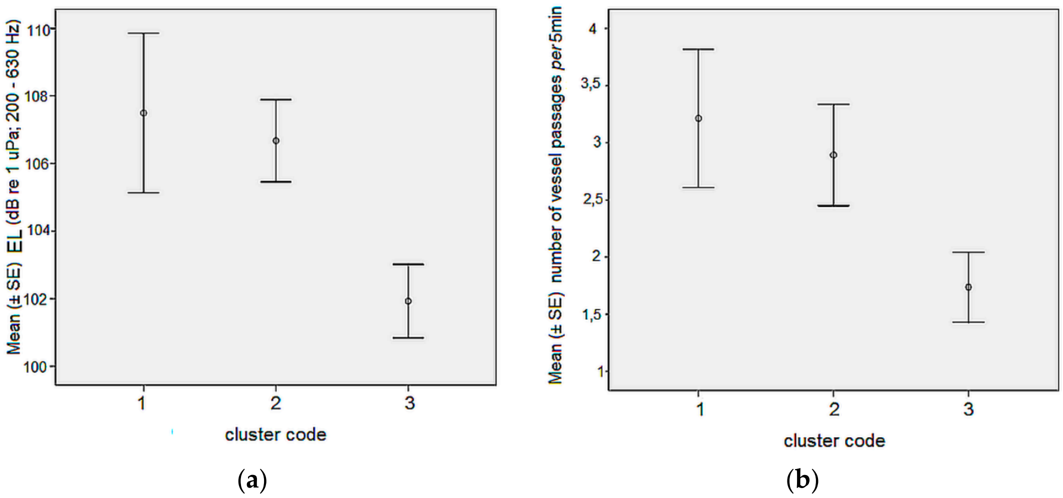

Figure 6. Mean (±standard error) (**a**) noise levels (energy level (EL)$_{200–630}$, dB re 1 μPa) and (**b**) number of vessel passages at the listening points belonging to the three groups highlighted by cluster analysis for the afternoon recordings.

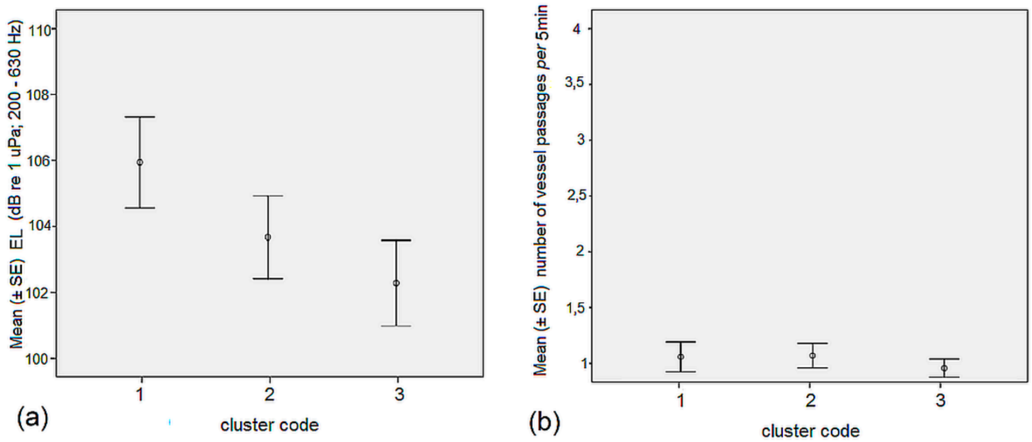

Figure 7. Mean (±standard error) (**a**) noise levels (EL$_{200–630}$, dB re 1 μPa) and (**b**) number of vessel passages at the listening points belonging to the three groups highlighted by cluster analysis for the night recordings.

4. Discussion

The Venice lagoon, located in the northern part of the Adriatic Sea, is one of the largest lagoons in Europe. Its port is characterized by a double function: a passenger port in the lagoon city (hosting two million passengers and providing services to 200 mega-yachts) and a commercial port on the mainland. It is therefore not surprising that such vessel traffic influences the underwater acoustics in the inlet areas, resulting in high underwater noise levels (overall recorded SPLs$_{50Hz–20kHz}$ ranging from 107 to 137 dB re 1 μ), with maximum values similar to those reported in other Italian and Portuguese areas (i.e., Gulf of Trieste: SPLs$_{50Hz–20kHz}$ 76–141 dB re 1 μPa; Gulf of Naples: SPLs$_{16Hz–40kHzH}$ 108–140 dB re 1 μPa; and Port of Civitavecchia: SPLs$_{12.5–16\ kHz}$ 45–158 dB re 1 μPa) [32–34]. Noise levels at the low-frequencies are mainly produced by vessel engines, electrical machinery, and propeller cavitation (<3 kHz [35,36]). They were found to be slightly, but significantly, higher during the afternoon than night-recordings, mirroring the number of operating vessels in the inlets. A similar pattern was recently found by the authors of [37] in a large Portuguese coastal lagoon: during summer, the underwater noise tended to remain sustained from 7 to 17 at levels that approached or exceeded 120 dB re 1 μPa, with a smooth and progressive variation at dawn and evening as a result of the reduced boat traffic nearby.

The present study could not fully define a continuous and extremely variable phenomenon such as marine background noise by using a non-continuous monitoring approach; nevertheless, the acquired data are indicative of an environment saturated by the anthropic presence at the lower frequencies (<2–3 kHz) during the afternoon period, whereas the vessel presence was found to be reduced at night. Vessels generated acoustic signals that were unpredictable in intensity, in a context of a persistent low intensity background. According to the present paper, the background noises were at similar levels to the *Sciaena umbra* audiogram. Further, if vessel activity expanded into evening hours, then the associated acoustic input associated to boating had the potential to exceed the *S. umbra* vocalizations even during chorusing activity. This likely led to a reduction in the detectability of signals of interest. This effect was supported by a laboratory study, where the playback of one single recreational boat noise (mean ambient noise—$LLeq_{,1\ min}$ 132 dB, with a maximum instantaneous SPL of 138 dB re 1 μPa) induced an upward shift in the *S. umbra* auditory threshold by about 25 dB and a reduction of the species acoustic communication from 500 m under ambient noise to only about 1 m under the boat noise conditions [22].

Boat noise is known to affect the efficiency of fitness-related fish behaviors such as foraging and antipredator behaviors, risk assessment, nest-defense, and parental care [38–44]. Fish responses, however, depend on many variables, including boat and engine types, boat speed, distance from noise source, motivational and physiological fish state, and the social context [41,43,45]. Therefore, there can be a continuum of responses to disturbance in in situ conditions ranging from mild to more severe forms.

In the context of conservation, the critical factor is whether a disturbance results in lower population sizes, especially in case of an already vulnerable species, such as the brown meagre. Usually, these assessments rely on proximate measures as the behavioral responses to a stimulus. In this context, the in situ exposition to boat noises (the mean SPL ranged from 134 to 146 dB re 1 μPa) did not cause displacement or elicit any significant activity changes in *S. umbra* groups (for a total of 65 tested brown meagres) living in an Italian MPA besides a reduction in the duration of active swimming [19]. An individual variability in response was found by the authors: on average, one third of exposed fish in a group reacted to noise by flighting and hiding. They resumed behavior quickly after exposures.

Conversely, visual-based methods could not be applied to the Venice inlets due to the risks connected with high boating and cargo traffic. As a consequence, it was not possible to investigate the *S. umbra* behaviors in relation to the local traffic. Since *S. umbra* is a vocal fish, the passive acoustic method (PAM) was the best option for the species-specific recognition of its presence and distribution in the inlets.

Noise effects could also be evaluated by relating the presence of animals to varying rates of disturbance across a number of sites [46]. Along the Venice inlets, brown meagre vocalizations were found in about 50% of the investigated points; this was an intermediate value compared to the case of the old and younger MPAs investigated in the northwestern Mediterranean Sea, where *S. umbra* was found to be present in approximately 70–80% and 30% of the monitored stations, respectively [21]. Such a result is somehow surprising: since animals select a location based upon its perceived quality, areas degraded by anthropogenic (noise) disturbance are expected to be poorly occupied.

Following [19], brown meagre groups were reported to remain on site year by year despite high boat traffic (18.7 boat passages h^{-1} during the tourist season), showing a higher abundance than other surrounded less anthropized sites. The present study also indicated that the brown meagre did not avoid the Venice inlets despite a vessel traffic corresponding to an estimation of 10–30 boat passages h^{-1} on average due to motorboats, cargos, or cruises. Interestingly, most of the listening points characterized by a high *S. umbra* pulse rate (groups 1 and 2) were located in the internal side of the inlets. These areas represent the only water connections between the inner lagoon and the sea and are therefore characterized by a high boating traffic. Given the sedentary and site-related *S. umbra* attitude [14,18,19], the nocturnal distribution is expected to mirror the diurnal distribution.

Furthermore, only the busiest locations in the internal side of the inlets were characterized by chorusing (group 1). Since the latter is a reliable natural indicator of the *S. umbra* breeding sites [24], we conclude that the brown meagre does reproduce in these sites, despite the relatively high anthropogenic noise levels experienced mostly but not exclusively during the diurnal hours. This result was also unexpected if we consider that a reduction in the ability to detect conspecific signals due to boat noise [22,47] could potentially affect the courtship efficacy. It has to be stressed, however, that in the inlets, the vessel traffic was reduced during the sunset-nocturnal hours, when the brown meagre vocalized. In its turn, this could result in a lower masking effect on the species calls, thus diminishing the costs expected for the animals living in the area.

The animals could be following the best-of-a-bad-job strategy: if the resources found in the Venice inlets are unique in the local coastal area, the fish will not leave them. Exposed fish could increase tolerance by a declining response from learning that the stimulus does not have any detrimental consequences or through shifts in hearing sensitivity thresholds. Behavioral and physiological attenuation have been found in fish after the repeated playback of the same motorboat-noise [48]; accordingly, the responses to motorboat noise in wild endemic cichlids in Lake Malawi were lower in areas with higher levels of motorboat disturbance [49]. One way to potentially assess this effect would be to generate and compare audiograms of the fish living in the three groups of locations in the inlets.

The decision of whether or not to stay in disturbed areas is determined not only by the quality of the site but also by the distance to and quality of other suitable sites and/or their relative risk of predation, the availability of prey, the density of competitors, and the investment that an individual has made for establishing a territory, gaining dominance status, and so on [46]. The Venice inlets are a structurally homogeneous area made by artificial standard blocks that are matched by distance to the shore. Theoretically, there are plenty of suitable sites for *S. umbra* along the inlets where noise disturbance is minimal, such as the locations facing the open sea. Therefore, these sites were expected to be more exploited by the species. As this was not the case, other factors (current, water depth, salinity, bottom composition, and so on) seem to be crucial for the species, "forcing" it to remain in some areas regardless of whether or not noise represents a disturbance. A deep assessment of the habitat characteristics of those areas, where the vocal production and likely the reproductive activity was more intense, should be carried out in future studies. In other words, we need to address the structure of the reproductive habitat of the brown meagre in this highly anthropic ecological context. Such information could help to evaluate the suitability of surrounding locations for the reproduction of the target species. It could also be used to evaluate the real extent of disturbance on the local fish population: if there are relevant, less disturbed, but not exploited areas in the surroundings, we can conclude that *S. umbra* is not strongly affected by boat noise. On the contrary, the species is likely to be impacted by the anthropic pressure because it is constrained to stay and to tolerate the costs of disturbance [46]. Data are currently being acquired to confirm the observed spatial distribution of *S. umbra* in the Venice inlets and to evaluate the role of environmental factors leading the habitat selection of this species.

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achieved by means of underwater records of sounds that are naturally produced. Human presence for investigation purpose was comparable with the usual anthropogenic pressure in the areas.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available because the funding project is not ended. Data will be available at project end, in 2022.

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