

Relationship between recorded noise from WP3 and recreational boat Losinj case study area

Final Version of 15/10/2021
Deliverable Number D.4.4.2.



Project Acronym	SOUNDSCAPE
Project ID Number	10043643
Project Title	Soundscapes in the north Adriatic Sea and their impact on marine biological resources
Priority Axis	3
Specific Objective	3.2
Work Package Number	4
Work Package Title	Data collection about target species
Activity Number	4.4
Activity Title	Habitat suitability modelling for specific target species
Partner in Charge	CNR
Partners Involved	CNR, BWI
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Status	Final
Distribution	Public
Citation	Ghezso M., Petrizzo A., Picciulin M., Radulović M., Falkner R., Rako-Gospic N., Madricardo F. Relationship between recorded noise from WP3 and recreational boat Losinj case study area .SOUNDSCAPE project, WP4, 22 pp, 2021

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Abstract

This deliverable analyses the relationship between the recorded underwater noise and the recreational boat traffic in the Losinj study area (Croatia). A first exploration of recreational boat data distribution in terms of typologies, spatial and temporal distribution was performed in the Cres and Losinj archipelago. The present analysis indicates that the recreational boat is mainly distributed during the summer (from July to September) and the most represented boat category is the motor boat. The boat distribution was compared with the underwater noise maps produced by the model QUONOPS. The soundscape of the offshore Susak recording station resulted to be more noisy and influenced by the AIS vessel traffic, whereas the Losinj one showed lower SPL levels and it was more related to the recreational boat activity.

Further, the underwater noise recorded by the two hydrophones located in the Cres-Losinj archipelago was also extracted and analysed at the frequencies of 63, 125, 250, 4000 Hz 1/3 octave bands. In order to find the possible relationship between recreational boat presence and the recorded underwater noise data, the boat abundance was calculated in a square of 4 km from the hydrophone for each station. Then, the underwater noise trend was analyzed for the time interval corresponding to the

boat's presence, depicted from the Deliverable 4.1.3. No clear correlation between levels and boat presence was found, with the exception of a few special cases.

Overall, the actual state of data and analysis method does not permit to fully evaluate the contribute given by the recreational boat noises to the local natural soundscape.

1. Introduction

Close to the shallow coastal areas, mid-to-high frequency noise arising from small recreational vessels significantly contribute to the local soundscapes (Hermansenn et al. 2019), with potential negative effects on marine species that depend on these habitats to forage, breed and/or rest; these effects include alterations of the hearing threshold and masking of communication in fishes, stress-related physiological responses and behavioural modification (Slabbekoorn et al. 2010). In fish boat noise exposure has been proved to cause alteration of the schooling behaviour, reduction in the defence of the own territory and decrease in feeding frequency (corresponding to changes of physiological conditions), in the anti-predator response and in the spawning probability in fish species (reviewed by Di Franco et al 2020). On the other hand, seasonal influence of nautical tourism on resident bottlenose dolphins through changes in their home range sizes has been reported (Rako-Gospic et al. 2017), confirming that recreational boating has adverse effects on dolphin communication and habitat use in coastal areas, such as the Cres and Lošinj archipelago (Rako et al. 2013a; Rako-Gospić and Picciulin 2016). In this area, data on recreational boat presence, typology and distribution was recorded during the SOUNDSCAPE their order to quantify the leisure traffic and, if possible, to include this source in the underwater noise modelling. In the present report, the relationship between recreational boats spatio-temporal distribution and the recorded underwater noise is explored.

2. Recreational boat data

The recreational boat database was collected by BWI on the west and east side of the Losinj island starting from June 2020 until April 2021. Details on the methods related to this data collection are available in the deliverable D 4.1.3. It has to be noticed that all the information on the monthly analysis are referred to the periods June-December 2020 and January to April 2021. The month of May is missing.

The distribution of the recreational boat is reported in Figure 1. The area covers the region between 44° and 45° N and 14° to 16° E. The figure also shows the position of the hydrophones of Susak and Losinj and the area used to perform the analysis close to the stations.

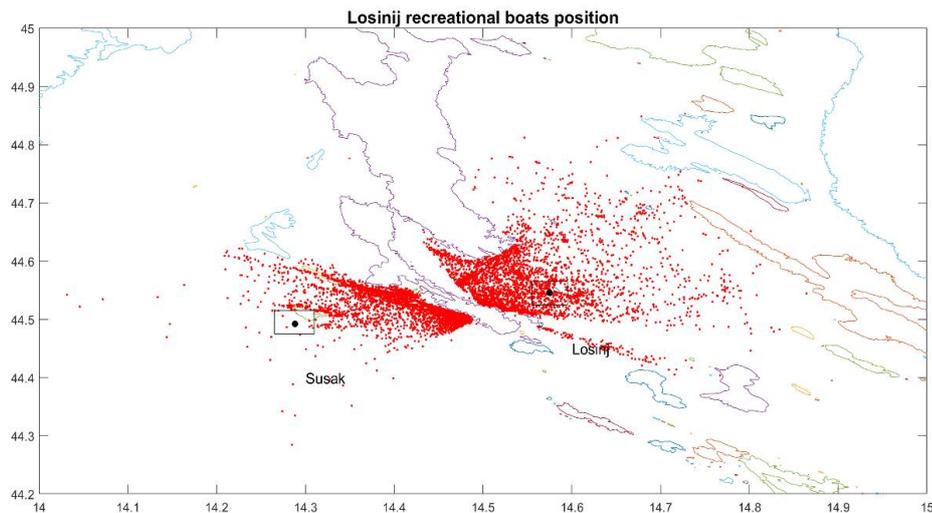


Figure 1 Distribution of the recreational boat database (red points), position of the two hydrophones (black points) and polygons considered as buffer areas of boats having influence in the hydrophones recordings

2.1 Boat distribution in the whole studied area

The abundance of each boat category scored from June 2020 until April 2021 in the Losinj archipelago is reported in Table 1 and visualized as histogram in Figure 2. The top 3 observed categories are 'sailing boat', 'motor boat' and 'speed boat', representing 37%, 27.5% and 23.6 % of the total registered numbers, respectively.

Table 1 Recreational boat categories: numeric label for the considered categories, category names and total abundance for each category

Gillnet	Motor boat	Motor yacht	Purse	Sailing	Speed boat	Tour boat	Trawler	TOTAL
119	1712	264	76	2680	1992	77	330	7250

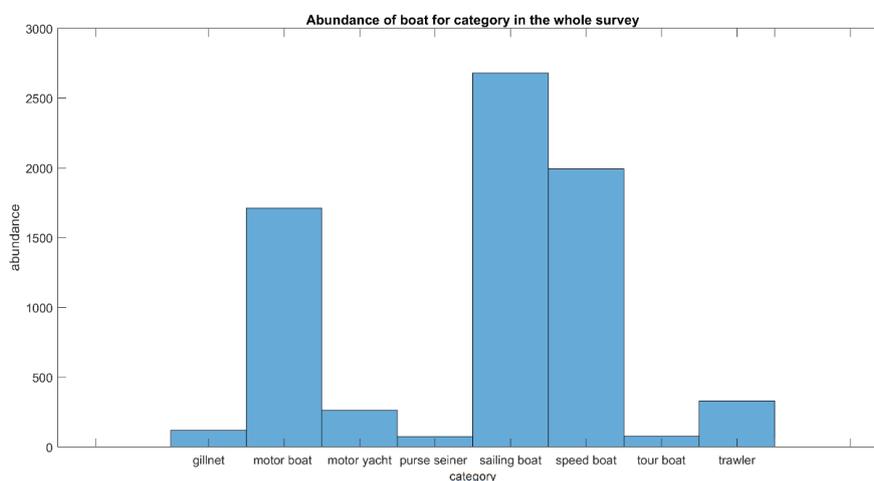


Figure 2 Abundance of each boat category calculated on the whole database

Boat categories, which were scored more than 100 times along the study period, are respectively ‘trawler’, ‘motor yacht’ and ‘gillnet’, representing the 4.5%, the 3.6% and 1.6% of the total number of observed boats in the Cres-Losinj area. The spatial distribution for each different boat category for the whole period is shown in Figure 3. Boats are spread all around the study area, with the exceptions of the *pure seiners*, that are mainly located on the west side of the Losinj island and the *tour boats*, that are distributed on a more restricted area.

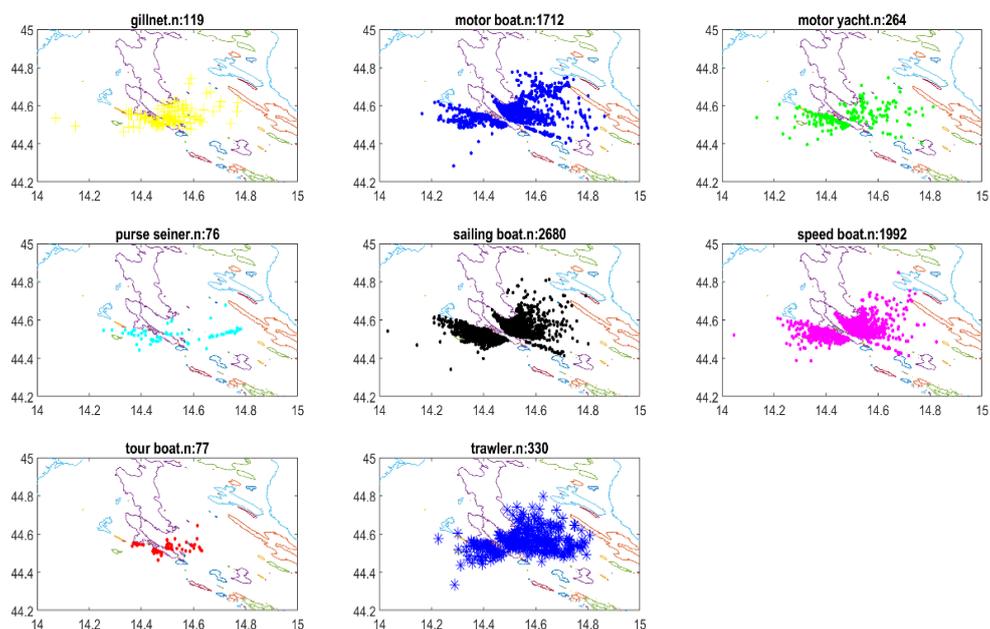


Figure 3 Spatial distribution of each boat category for the whole period and total number of items.

The analysis of the monthly abundance of the different boat categories (Figure 4) indicates that *sailing boat* (5) and *speedboat* (6) are the most represented overall in July and August 2020, while their number is decreasing in September 2020. During the 2021 winter season, the boat presence was scarce in respect to the summer. Only the category ‘motor boat’ is represented every month passing from a low abundance from January to April to a more intense and almost constant presence from June to November.

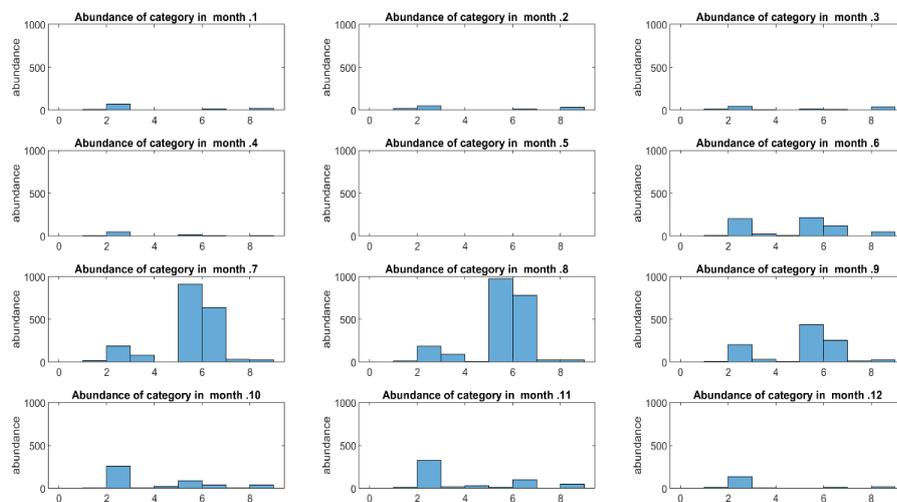


Figure 4 Distribution of categories for month. Note: records from June to December are referred to the year 2020, instead records from January to April are referred to the year 2021. May is missing. Boat category are the same as in Table 1

The temporal variation of the boat abundance during the target period and considered *per* each boat category is reported in Table 2 and in Figure 5.

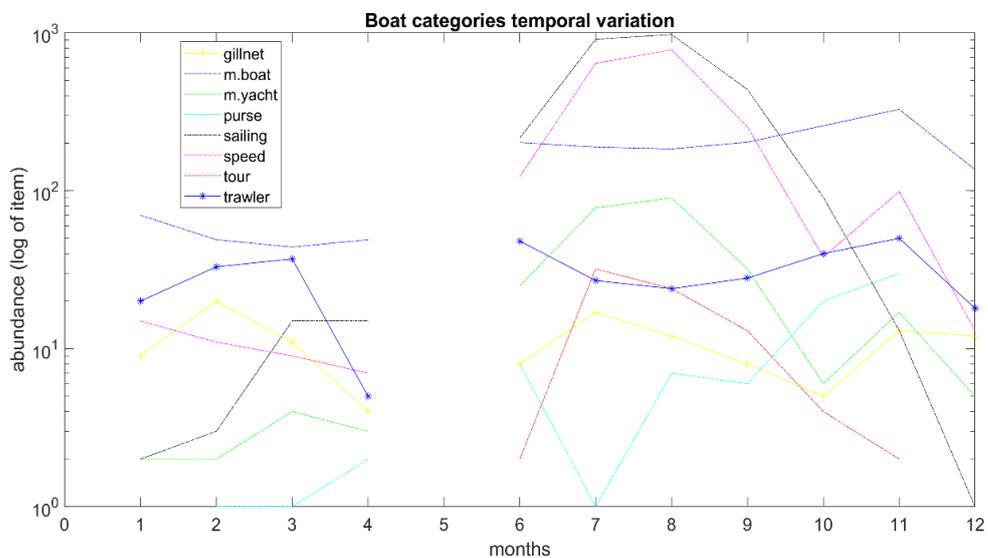


Figure 5 Monthly variation of each category of recreational boat (log scale). June-December 2020, January – April 2021, May is missing.

The summer months are the most relevant for the recreational boats, with a trend of presence that is similar for all the categories, peaking in July and August, except for two categories, ie. *purse seiner* and *trawler*: *purse seiner* has the minimum abundance in July and *trawlers* are almost constantly present from July to November.

Table 2 Monthly presence of each category of recreational boat

	Gillnet	Motor boat	Motor yacht	Purse seiner	Sailing boat	Speed boat	Tour boat	Trawler	TOTAL
Jan 2021	9	70	2	0	2	15	0	20	118
Feb 2021	20	49	2	1	3	11	0	33	119
Mar 2021	11	44	4	1	15	9	0	37	121
Apr 2021	4	49	3	2	15	7	0	5	85
May	-	-	-	-	-	-	-	-	nd
Jun 2020	8	202	25	8	216	123	2	48	632
Jul 2020	17	189	78	1	910	641	32	27	1895
Aug 2020	12	184	90	7	977	782	24	24	2100
Sep 2020	8	203	32	6	437	254	13	28	981
Oct 2020	5	258	6	20	91	38	4	40	462
Nov 2020	13	328	17	30	13	99	2	50	552
Dec 2020	12	136	5	0	1	13	0	18	185
TOTAL	119	1712	264	76	2680	1992	77	330	7250

2.2 Boat distribution in the restricted areas surrounding the hydrophone positions

To verify the influence of the recreational boat noises on the acoustic recordings, we calculated the number and the typology of boats located inside a square of 4000 m around the position of the hydrophones. The position and dimension of the squares related to the two hydrophones are shown in Figure 1. The total number of boats in the whole considered period equals to 9 in the Susak square and to 239 in the Losinj square. The monthly abundance of the boats is reported in Table 3 for the Susak and Losinj squares, respectively.

Table 3 monthly distribution of recreational boat categories inside the square in the Susak recording station

SUSAK	Gillnet	Motor boat	Motor yacht	Purse seiner	Sailing boat	Speed boat	Tour boat	Trawler	TOTAL
Jan 2021	0	0	0	0	0	0	0	0	0
Feb 2021	0	0	0	0	0	1	0	0	1
Mar 2021	0	0	0	0	0	0	0	0	0
Apr 2021	0	0	0	0	0	0	0	0	0
May	-	-	-	-	-	-	-	-	nd
Jun 2020	0	2	0	0	0	0	0	0	2
Jul 2020	0	1	1	0	0	0	0	0	2
Aug 2020	0	0	0	0	0	0	0	0	0
Sep 2020	0	1	0	0	0	1	0	0	2
Oct 2020	0	1	0	0	0	0	0	0	1
Nov 2020	0	0	0	0	0	1	0	0	1
Dec 2020	0	0	0	0	0	0	0	0	0

TOTAL	0	5	1	0	0	3	0	0	9
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Table 4 monthly distribution of recreational boat categories inside the square in the Losinj recording station

LOSINJ	Gillnet	Motor boat	Motor yacht	Purse seiner	Sailing boat	Speed boat	Tour boat	Trawler	TOTAL
Jan 2021	0	1	0	0	0	0	0	0	1
Feb 2021	0	4	0	0	0	0	0	0	4
Mar 2021	0	1	0	0	0	0	0	2	3
Apr 2021	0	0	0	0	0	0	0	0	0
May	-	-	-	-	-	-	-	-	nd
Jun 2020	1	4	1	1	3	5	0	1	16
Jul 2020	0	6	3	0	17	21	3	4	54
Aug 2020	0	8	0	0	24	21	0	3	56
Sep 2020	1	16	0	0	13	11	2	1	44
Oct 2020	1	10	0	0	3	3	0	3	20
Nov 2020	1	18	1	0	0	5	0	1	26
Dec 2020	0	10	1	0	0	2	0	2	15
TOTAL	4	78	6	1	60	68	5	17	239

In the Susak square the most represented category is *motor boats* and the most busy months are June, July and September. Similarly, in the Losinj square the most represented category is *motor boat*, followed by *speed boat* and *sailing boat*; the latter is mostly present in July, August and September, although the most abundant category (ie. *motor boat*) is active mainly from September to December. The months having higher recreational boat presence as July and August are more characterized by categories as *sailing boat* and *speed boat*. September represents a transition month with a well distributed presence in *motor boats*, *sailing boats* and *speed boats*.

Figure 6 shows the distribution of the boats observed in the Susak square along the whole considered period. The single boat that went closer to the Susak hydrophone during the sampling sessions is a *motor yacht*, scored in July (see green color in figure 6). All the details on the observed boats are reported in Table 5

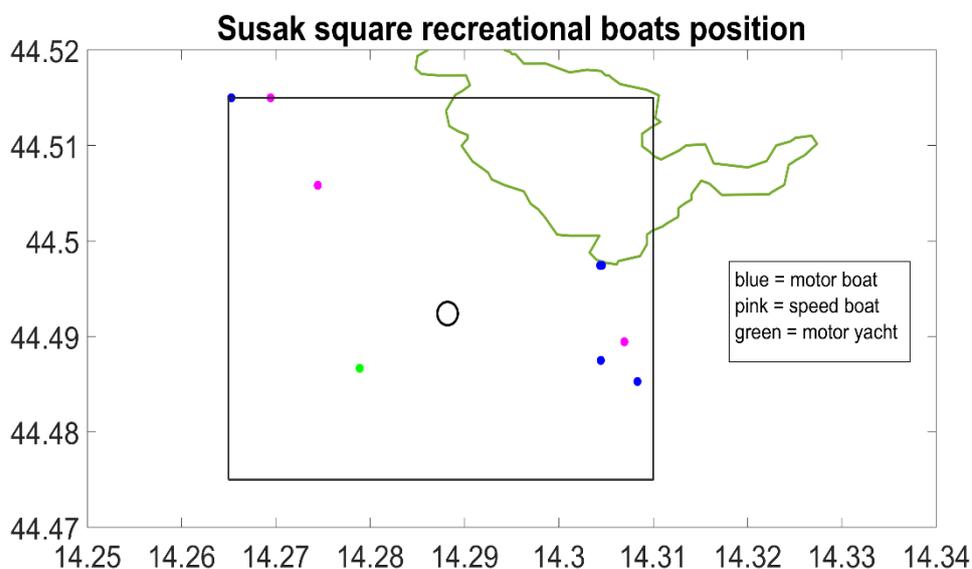


Figure 6 Distribution of the recreational boat recorded close to the Susak hydrophone (4km square).

Table 5 Position, category and distance from the hydrophone of each boat recorded in the Susak square

ID number	Lat	Long	Type	Typology	Month	Day	Time	Distance from the hydrophone
1	44,50	14,30	2	motor boat	6	10	1656	1403
2	44,50	14,30	2	motor boat	6	12	1814	1417
3	44,52	14,27	2	motor boat	7	10	959	3103
4	44,49	14,28	3	motor yacht	7	15	1655	977
5	44,49	14,31	6	speed boat	9	21	1247	1527
6	44,49	14,31	2	motor boat	9	30	940	1786
7	44,49	14,30	2	motor boat	10	20	940	1402
8	44,52	14,27	6	speed boat	11	7	1041	2921
9	44,51	14,27	6	speed boat	2	28	1406	1851

When considering the Losinj square, a total of 239 boats were scored. A restricted square of 1 km around the hydrophone position is here considered in order to produce a visualization of the data (Figure 7); in this case a subsample of 20 close boats was obtained.

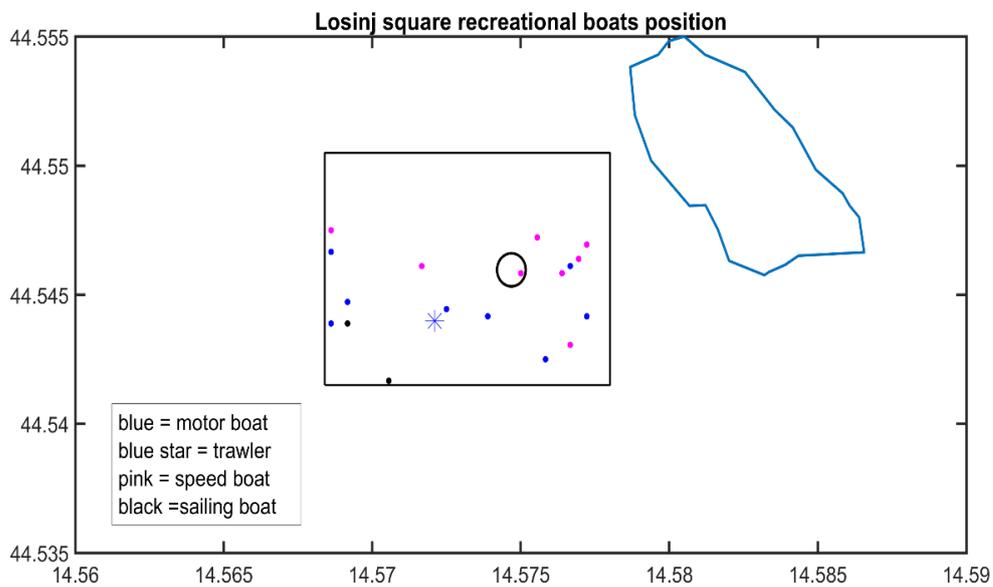


Figure 7 Distribution of the recreational boat observed close to the Losinj hydrophone (1 km square).

The Table 6 reports position, distance from the hydrophone and typology of the boat for each of the spotted boat in the square during the monitoring sessions. The closest boats are (i) a speed boat in August and (ii) a motor boat in December. The passages are distributed for almost 60% in summer, when the most trafficked month is July and 40% in winter, mostly in November. The only category found in winter is *motor boat*, in summer there are more variable as *speed boat*, *sailing boat* and *trawler*.

Table 6 position, category and distance from the hydrophone of each boat recorded in the area of Losinj

ID number	Lat	Long	Type	Typology	Month	Day	Time	Distance from the hydrophone
1	44,54	14,57	8	trawler	6	13	1154	301
2	44,54	14,58	6	speed boat	7	10	1740	360
3	44,54	14,57	5	sailing	7	14	1639	495
4	44,55	14,57	6	speed boat	7	19	1635	512
5	44,55	14,58	6	speed boat	7	20	1635	186
6	44,55	14,57	6	speed boat	7	21	1739	240
7	44,54	14,57	5	sailing	7	27	1231	580
8	44,55	14,58	6	speed boat	7	28	1733	136
9	44,55	14,58	6	speed boat	8	12	1740	229
10	44,55	14,58	6	speed boat	8	17	1730	29
11	44,54	14,58	2	motor boat	10	18	935	284
12	44,54	14,57	2	motor boat	10	18	1331	535
13	44,55	14,58	2	motor boat	11	3	1331	158
14	44,54	14,58	2	motor boat	11	22	1340	396
15	44,55	14,57	2	motor boat	11	25	1331	489
16	44,54	14,57	2	motor boat	11	25	1331	242
17	44,55	14,58	2	motor boat	12	7	831	29
18	44,55	14,58	6	speed boat	12	12	1334	156
19	44,54	14,57	2	motor boat	2	18	828	460
20	44,54	14,57	2	motor boat	2	24	1337	210

Summing up, the data analysis on the whole database indicates:

1. Recreational boat traffic peaks in summer months, especially in July and August, when it is mainly represented by *sailing* and *speed boats*;

2. October and November are characterized by an intermediate presence of recreational boats, with a predominance of the *motor boat* category;
3. September is a month of well distributed presence of different categories, *asmotor boats*, *sailing boats* and *speed boats*.

For what concern the area close to the hydrophones, the data analysis indicates:

1. In the Losinj area the presence of recreational boats is definitely higher than in Susak. If the recreational boats would be the only source of man-made noise, higher SPLs levels could be expected in Losinj than in Susak. However other source of noises as the cargo or other AIS vessels were present in the Susak area facing the open sea, introducing in their turn man-made noises (see below).
2. July is expected to be the most impacted month by recreational boat presence in the Losinj small scale area.

3. Underwater noise data

The available data on underwater noise in the study area are (i) the acoustic samples recorded by the hydrophones in Susak and Losinj and (ii) the modelled data by Quonops noise model. The modelled data are available with high temporal resolution during the period from September 2020 to February 2021, and with monthly frequency for the whole North Adriatic during the period from January to December 2020.

3.1 Analysis of recorded acoustic data - SPLs

The noise recorded by the two hydrophones was elaborated and the Sound Pressure Levels are shown in violin plot graphs: for each station; the violin plots are plotted for the 4 investigated frequencies to better synthesize the monthly characteristics of the underwater soundscape. Violin plots are used to

visualize summary statistics of the data, displaying the range, median, and they can show the full distribution of the data. Statistics are represented like Exceedance Level (EL): a XX EL is the SPL value that is exceeded the XX% of the time (e.g. median is the 50 EL)

In the graphs, the circle indicates the 50 EL, the box the 25 and 75 ELs, the whiskers the 10 and 90 ELs, and the shape of the violin indicates the kernel density plot. The presence of the density plot allows to visualise the distribution of data over a continuous interval or time period and to highlight the presence of different peaks (if multimodal), their position and relative amplitude.

Figure 8 and Figure 9 show the violin graphs for the Susak station, named as MS5, and for the Losinj station, named MS6, respectively. The analysis starts from March 2020 to March 2021 for the 4 frequency : 63, 125, 250, 4000 Hz 1/3 octave bands.

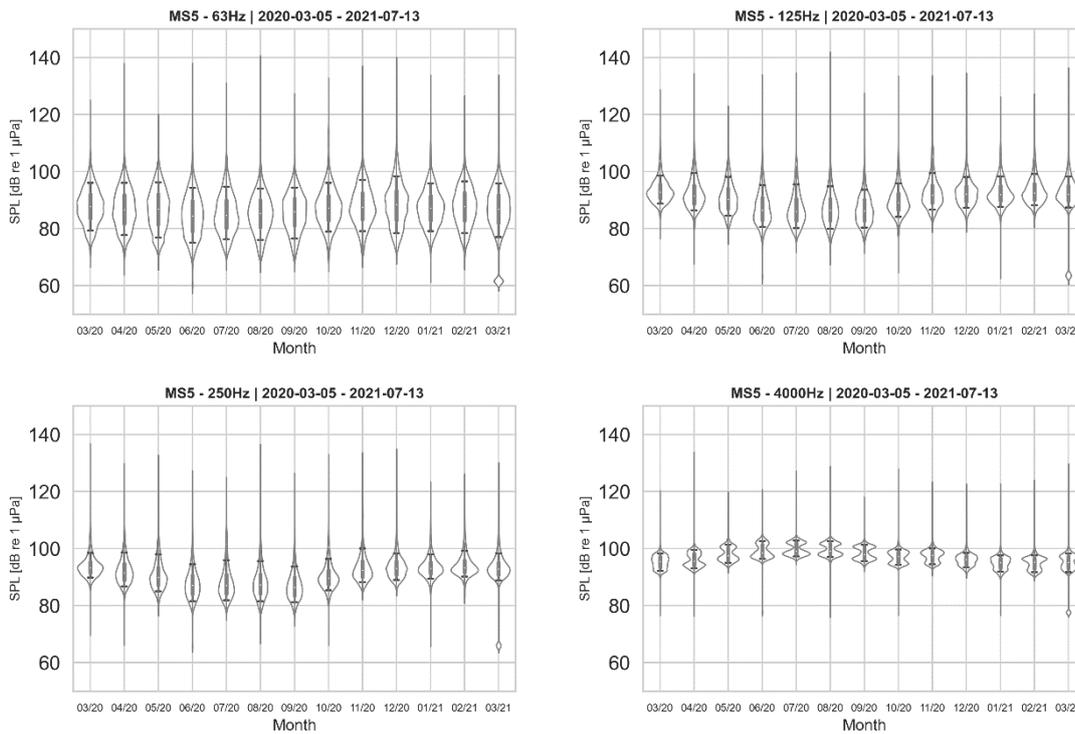


Figure 8 Susak station- SPLs monthly elaboration

In Susak station the monthly 50EL for 63 Hz 1/3 octave band is almost constant around 86 dB re 1 μ Pa. The 125 Hz and the 250 Hz 1/3 octave bands have a similar behaviour, showing higher values in the winter/spring months (50EL around 91 dB re 1 μ Pa) with a decrease (50EL around 87 dB re 1 μ Pa) in summer months. The 4000 Hz 1/3 octave band exhibits a different trend, increasing in summer months to 100 dB re 1 μ Pa in respect to an 50EL of 97 dB re 1 μ Pa.

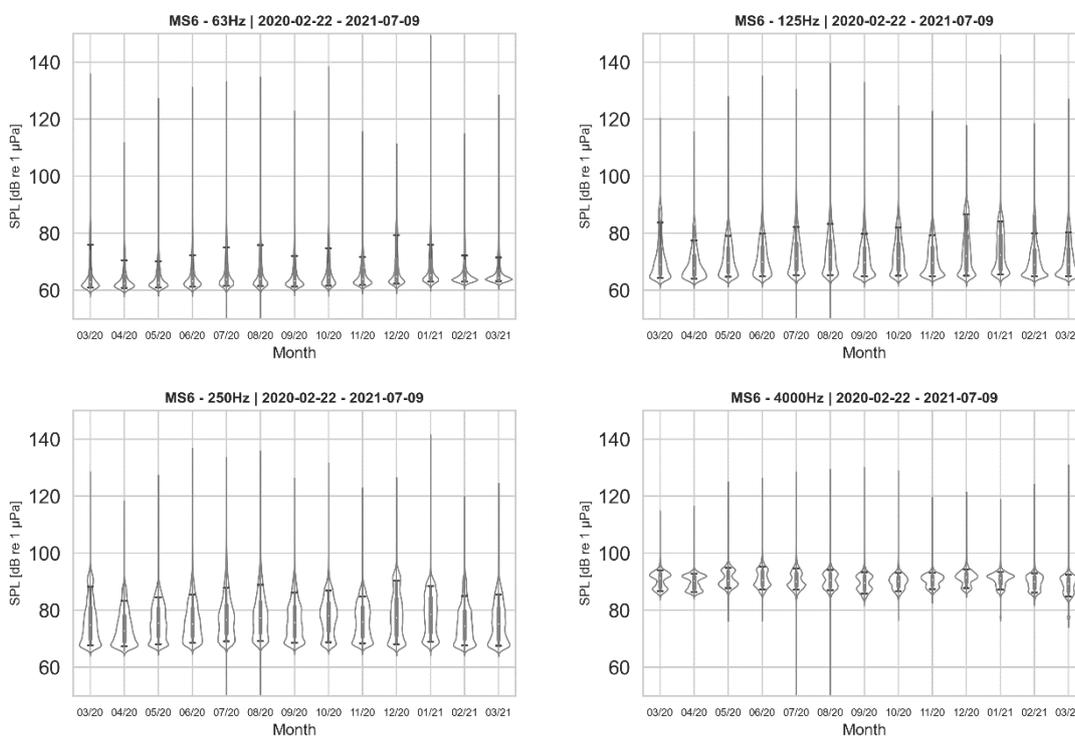


Figure 9 Losinj station – SPLs monthly elaboration

In Losinj station the monthly 50EL for 63 Hz 1/3 octave band is almost constant around 64 dB re 1 μ Pa. The 4000 Hz 1/3 octave band exhibits a constant trend each month, but it reaches higher values arriving close to 90 dB re 1 μ Pa. Also the 125 Hz and the 250 Hz 1/3 octave bands show a constant trend (50EL around 70 and 76 dB re 1 μ Pa respectively) but with a higher variability.

The comparison between the two stations highlights that the Susak station is more noisy than Losinj in all the frequencies considered (see table 7).

Table 7 Comparison between yearly value of 50th percentile of SPL [dB re 1 μ Pa] for each frequency in Susak and Losinj station and relative difference

1/3 octave bandcentred at a given frequency [Hz]	Susak [dB re 1 μ Pa]	Losinj [dB re 1 μ Pa]
63	85	64
125	90	70
250	91	76
4000	97	90

It can be noticed, however, that during summer the difference between the monthly 50* percentile (SPLs) calculated for the 125 and 250 1/3 octave bands at each of the two recording stations becomes smaller compared to the winter period (Figure 10), possibly due to the acoustic input given by the recreational boats in the Losinj area, assuming AIS vessel remain constant in time in Susak.

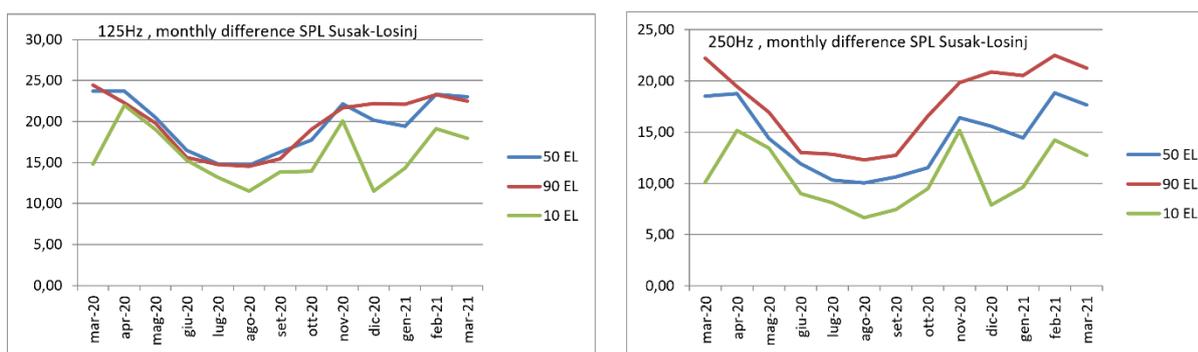


Figure 10 Difference in monthly SPL between Susak and Losinj station for the 1/3 octave bands centred at 125 and 250 Hz

3.2 Boat noise identification in the recorded acoustic files

In order to evaluate the presence of spotted boat in the acoustic recordings, we considered the passages of the closest boats to the Susak and Losinj hydrophones and we analyzed the concomitant recorded noise level in the $4 \frac{1}{3}$ octave bands, in order to highlight a potential relationship.

In Susak, a motor boat passed at a distance of 977 m from the hydrophone at 16th July hour 16:55. Unfortunately it is not a clear correspondence in the hydrophone record for all the considered frequency.

In Losinj, a speed boat passed at a distance of 29 m from the hydrophone at 17th August at time 17:30 (id 10) and a motor boat passed at a distance of 30 m from the hydrophone at 7th December at time 8:30 (id 17). Figure 10 shows for the first selected boat the only frequency having a shift at the time indicated by the recreational boat passage. The SPL increase from 75 to 95 dB in the 63 Hz frequency, suggesting a potential noise input due to the boat.

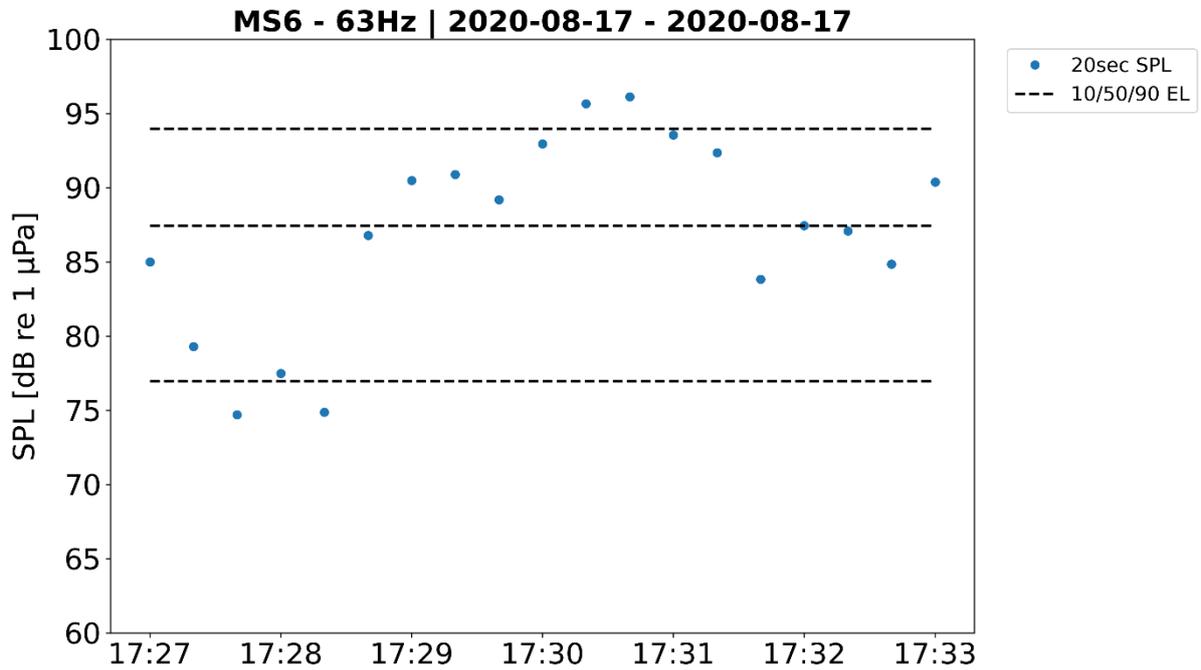


Figure 11 Losinj area, Sound Level Pressure in 63 Hz for boat presence in August (id. 10)

Figure 11 shows for the second selected boat the two frequencies having a shift at the time indicated by the recorded recreational boat passage. The SPLs increase exactly at 8:30 at 63 Hz 1/3 octave band from 63 to 74 dB re 1 µPa and a few minutes later also the frequency of 250 Hz increases from 70 to 80 dB re 1 µPa, suggesting potentially a starting boat.

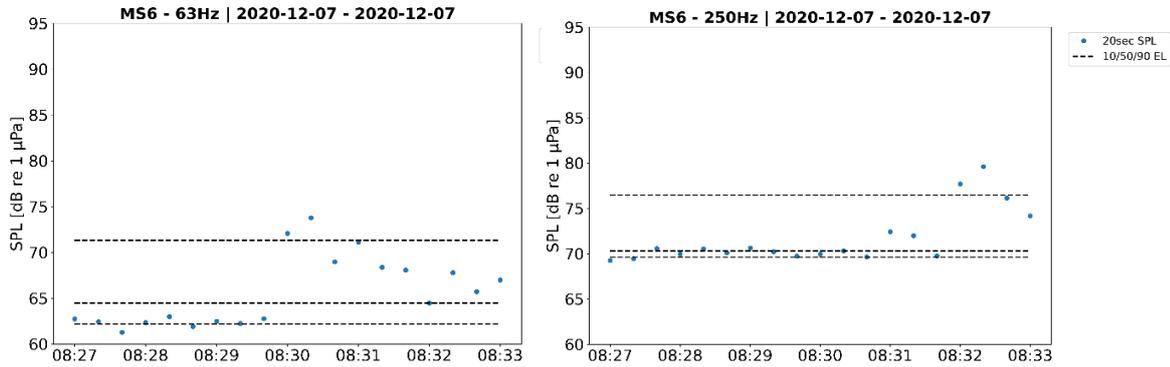


Figure 12 Losinj area, Sound Level Pressure in 63 Hz and 250 Hz for boat presence in December (id. 17)

The last relevant case is the passage of a boat at 20th July at hour 16:35 (id 5), causing a decrease of around 20dB in the frequency of 125 and 250 Hz as shown in Figure 12. This could be a boat stopping.

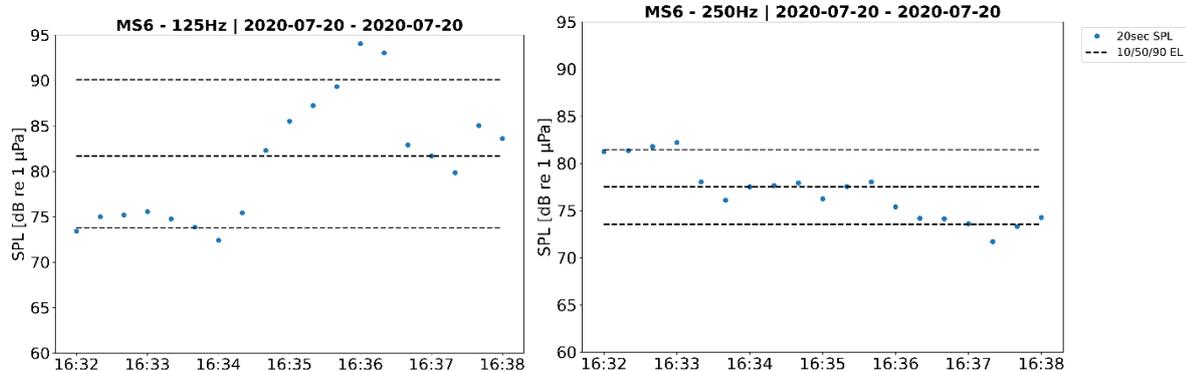


Figure 13 Losinj area, Sound Level Pressure in 125 Hz and 250 Hz for boat presence in July (id. 5)

Since such an effect cannot be highlighted for other cases, it is very difficult to define a robust and detailed relationship between the recorded noise and this fragmentary information on recreational boat positions.

3.3 Analysis of QUONOPS modelled data

The QUONOPS model assesses the monthly noise distribution in the whole North Adriatic area for the main 4 frequencies during one year from January 2020 to December 2020. In addition, a focus in the Losinj area is available for the period from 9th September 2020 to 18th January 2021. It uses the same spatial resolution as in the whole North Adriatic, but considers the more frequencies than the previous 4 1/3 octave bands centred at 63 Hz, 125 Hz, 250 Hz and 4000 Hz, including also 16, 31.5, 500, 1000 and 2000 Hz 1/3 octave bands, and it offers the results with instantaneous (at the same time of AIS acquisition) temporal resolution. The model result includes the noise due to natural sources (rain, wind) and to marine traffic represented by vessels equipped with AIS. Starting from AIS data the model propagates the noise in a tridimensional domain considering sea water density, bathymetry and sediment grain sizes. More details are available in the dedicated deliverables. An example of maps in the August month for each frequency calculated on the whole water column and corresponding to the 50 percentile of the noise in the month is shown in Figure 13 .

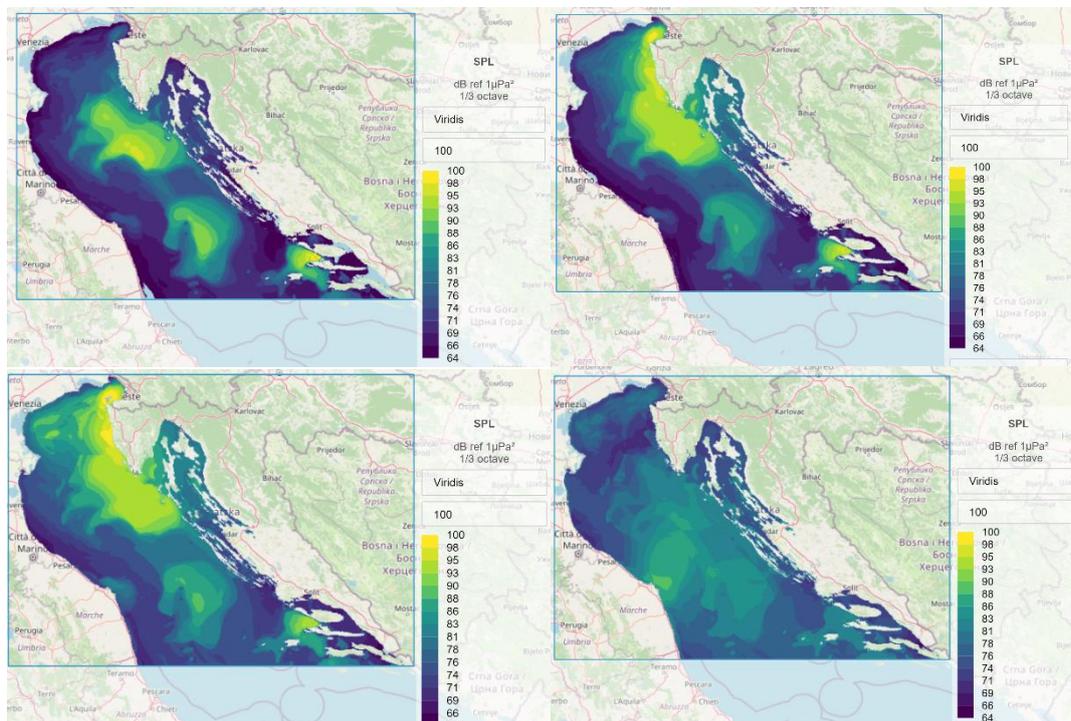


Figure 14 QUONOPS model, August map. Sound Level Pressure elaborated as 50 percentile in August on the whole column for the frequency 63 and 125 Hz (top left and top right panels), and 250 Hz and 4000 Hz (bottom left and bottom right panel)

The comparison between the 50% percentile of the Susak and Losinj stations and the monthly maps produced by the QUONOPS model indicates that the Susak station is more noisy than the Losinj station for all the seasons.

Similar results are obtained analysing the instantaneous maps of the detailed model done for the Losinj area. The Susak station is the most frequented by the AIS vessels and results the most noisy whereas only occasionally some AIS vessels pass by Losinj station.

When interpreting these data, it has to be considered that these maps are based on a model which considers only the AIS vessel traffic as anthropogenic source of noise; as a consequence this implies that the recreational boat input cannot be evaluated. On the other hand, it should be stressed that the

monthly values of the 50° percentile in the areas of the hydrophones are similar to the corresponding values obtained elaborating the hydrophones records.

4. Conclusion

The present analysis indicates that the recreational boat is mainly distributed during the summer, from July to September, and the most represented boat categories are the motor boats. The offshore Susak station is more noisy and influenced by the AIS vessel traffic, the Losinj station is more quiet but more involved in the recreational boat activity.

The actual state of data and analysis method does not permit to fully evaluate the contribute given by the recreational boat noises to the local natural soundscape.

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