FIRST STEPS TOWARDS A METHODOLOGY TO ASSESS THE INFLUENCE OF NOISE ON A NATURAL AREA

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Résumé

Les sons naturels font partie intégrante de l'environnement naturel et sont fréquemment associés aux parcs naturels et aux zones similaires. Ils sont incontestablement des composantes inhérentes aux paysages et à leur contenu de caractéristiques naturelles et historiques, et en particulier de leur faune. Les sons naturels constituent un indicateur de la santé de l'habitat faunique et des divers écosystèmes qui composent ces zones. La génération actuelle a une obligation reconnue de conserver ces ressources naturelles au profit de celles à venir. Dans le processus de planification permettant d'atteindre les objectifs en terme de qualité acoustique du paysage sonore naturel, la principale méthode est la préservation du paysage sonore à des niveaux compatibles avec les caractéristiques du parc. Lorsque des lacunes sont identifiées, des mesures d'atténuation doivent être prises pour restaurer le paysage sonore à son état naturel. L'objectif de ce projet est d'analyser l'existence de bruits «non naturels» étrangers au milieu naturel et de protéger le paysage sonore naturel des impacts acoustiques intrusifs. L'étude a été réalisée sur la "zone naturelle" d'Anceu, située dans la municipalité de Pontecaldelas dans la province de Pontevedra, Galice (Espagne).

Mots clefs : bruit environnemental, paysage sonore, sons naturels, bruit anthropique, zones calmes, pollution sonore

Abstract

Natural sounds are integral elements of the natural environment that are frequently associated with natural parks and similar areas. They are, indisputably, inherent components of landscapes and their contents of natural and historical features, and particularly of their wildlife. Natural sounds constitute an indicator of the health of the wildlife habitat and the diverse ecosystems that comprise such areas. The present generation has an acknowledged obligation to conserve these natural resources for the benefit of those to come. In the planning process to achieve the objectives of the acoustic quality of the natural soundscape, the primary principle is the preservation of the soundscape at levels compatible with the characteristics of the park. When deficiencies are identified, mitigation measures must be taken to restore the soundscape to its natural condition. The objective of this project is to analyze the existence of "non-natural" noises foreign to the natural environment and protect the Natural Soundscape from intrusive acoustic impacts. The study was carried out on the "natural area" of Anceu, located in the municipality of Pontecaldelas in the province of Pontevedra, Galicia (Spain).

Keywords: environmental noise, natural soundscape, quiet areas

1 Introduction

Since the late 1960's various types of sound maps have been produced, initially for the largest cities of Europe and the USA. Noises due to transport and industry are the main sources of pollution generated by human activity. The coexistence of these types of sounds has lasted for years, but it is evident that at present the anthropic activities caused by noise and traffic must be considered noise and estimate that it damages the rest.

According to the report released by Environmental European Agency (EEA) in 2006 [1], a great extension of European protected areas (20%) are potentially adversely affected by noise pollution. Concerning what is meant by quiet areas, there is no exact definition. Most of the interpretations are due to state regulations and based on professional experiences [2]. Some factors, such as noise limit values, steric values or extension, allow defining potentially quiet areas [2].

A key aspect of quiet areas is their soundscape [3]. According to ISO 12913-1: 2014 [4] soundscape is the acoustic environment as perceived or experienced and / or understood by a person or people, in context. The soundscape must be understood as a complex system that boats multiple variables of different nature that interact in a site and at a certain time [5, 6]. The perception of the different sound sources is fundamental in the soundscapes [7]. This causes that before the great variety of possible sources that exist in a soundscape (biological, environmental, etc.), the soundscapes must be investigated in an interdisciplinary way [8].

The natural soundscape is constituted by the sum of all the natural sounds present in a particular natural environment, whether it is a designated park, a protected natural space, or a natural area; this concept encompasses the physical

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capacity for transmitting those sounds. Therefore, the soundscape can be defined as the "total" acoustic environment associated with a particular area such for example, a natural park. In a natural environment, the soundscape may be constituted by natural sounds alone – a natural soundscape – or else by these plus those sounds generated by certain human activities. However, although there is unanimity on the value and importance of natural sounds, these are often found to be degraded by the noises originating from the human activity of diverse origins such as industry, agriculture, forestry, mining, transport, construction, tourism, sport, and urban life in general.

Natural sounds often transcend the auditory range of human beings and can be transmitted through various media: the air, water, and solid matter. Natural sounds are integral elements of the natural environment that are frequently associated with the natural habitat. They are, indisputably, inherent components of the landscape and its natural features, and particularly of its wildlife. In reality, they constitute an indicator of the health of the diverse ecosystems present in a natural area and should be recognized as one more resource of the natural environment [9].

Human beings with normal hearing ability can perceive sounds between 20 Hz and 20 kHz, although the distribution of the amplitude of sounds varies in function of the frequency. In fact, it is known that the greatest auditory sensitivity is found at the frequency of 1/4 kHz, whereas at low and high frequencies, sensitivity is much lower. This ability is shared with other species.

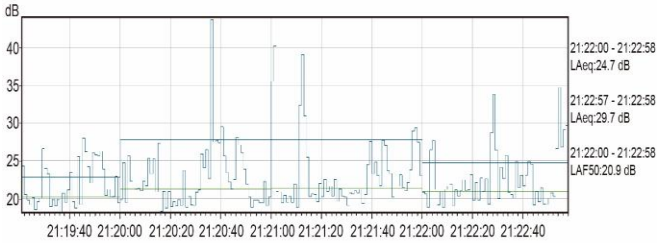

Figure 1: The behavior of the noise $L_{Aeq,\ T=1s}$ during the time interval shown.

Figure 1 shows an anthropogenic noise interval obtained in a natural area in the district of Anceu (Pontevedra), in a rural environment, during the evening [10]. The sharpest peaks correspond to the barking of dogs (Could this be considered a natural sound?) while the rest correspond to the noises made by various insects, the movement of the leaves of the trees, and the presence of sheep nearby.

Given the importance that the natural sounds have for the ecosystem and visitors to a natural area, it should be noted that, in many instances, these sounds are being masked by a wide variety of anthropogenic activities. This is due to that these soundscapes can positively influence society [11–13]. In some cases, the influence of these activities is so great that the natural sounds have disappeared or cannot be discerned. Intrusive sounds are indeed a cause for concern for visitors to a park; in a survey conducted by the National Parks Service of the United States, it was found that 91% of the visitors reported that experiencing the "soundscape" was the motive for their visit, as against 93% who said their visit aimed to enjoy the views [14]. However, it is no less true that preservation of the soundscape in natural parks has implications beyond the current enjoyment of all the resources of a park; it influences the habitat and the entire ecosystem. Its preservation is an important part of the obligation to ensure that these resources can continue to be enjoyed by future generations.

In effect, this means measuring the influence that the sounds of anthropogenic origin have on these environments. The ultimate aims of this analysis are to restore to their natural conditions, provided this is feasible, the soundscapes in the natural areas that may have been degraded by the effect of "non-natural" sounds, foreign to the natural environment; and to protect it from any unacceptable acoustic impacts that might occur.

This said certain specific questions must be answered: Which sounds can be considered appropriate, and which not? When the objectives of the park conflict with the preservation of the natural soundscape, is it necessary to develop standardized methods or protocols to enable reliable data to be obtained? And if so, what acoustic data should be considered?

An important consideration in this context is that the objectives and uses made of any particular natural area can be very varied. A wide variety of activities may take place in the park or area - recreational activities, cultural events, visitor centers, transport infrastructures, and many others. These activities can generate high levels of noise in particular zones within the park. It is thus important to be aware that, when human activities, whether within or close to the park, generate excessive noise levels, these can present a threat to the natural soundscape of the park, and can have adverse effects on the resources of the park and the purposes for which it exists or was created.

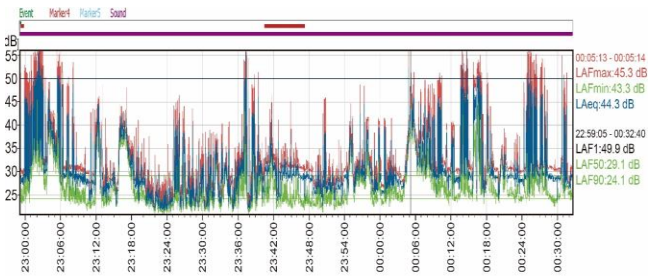

Figure 2: The behavior of the noise $L_{Aeq,\ T=1s}$ during a 1 hour of the night.

Figure 2 shows the values of the equivalent noise measurements carried out second by second, for one hour. The graph contains the sounds generated by the natural area itself (intervals free of non-natural noise) and those anthropogenic sounds that affect the natural environment.

The definition that`s used as a basis for determining the "healthy natural environment", for purposes of planning of the natural parks in other countries, and for defining the actions of environmental compliance derived from human activity, and that can give rise to inadequate or intrusive impacts on the soundscape of a park, is that of the "natural soundscape". In the majority of cases, this's considered as

synonymous with the term "natural quiet" or the silence of Nature.

A study published in the journal “Trends in Ecology and Evolution” [15] states that the noise produced by vehicular traffic, industrial plants, construction machinery, electricity transformers, etc., causes harmful interference in communication for many animals. The authors maintain that auditory contamination has become so intense that it is threatening biodiversity.

Most of the natural sounds that contribute to the soundscape of an ecosystem form part of the biological and physical resources of the park; these include sounds produced by deer, birds, bats, frogs, insects, and other wildlife and those generated by physical phenomena like the wind in the trees, rainfall, and thunder [16].

Studies of the quiet zones and soundscapes in natural parks are relatively recent multidisciplinary initiatives. Nevertheless, during the last ten years, some very interesting studies have been carried out, some of them orientated to conurbations, as is the case of the Project: “Quiet areas definition and management in action plans” [17] and others orientated to the study of the sound levels in particular natural parks. An example of the latter is the study undertaken by the Local Authority of Vizcaya, together with the company Labein, on the Urquiola Park [18] involving sound recordings in the natural parks of Vizcaya. Apart from these very recent initiatives in 2010, the authors of the present study do not know about similar activities in Europe. However, in the United States and Japan, very important steps have been taken towards recovering and protecting natural soundscapes. One notable project is titled: “100 Soundscapes of Japan”, endorsed by the Japanese Ministry of the Environment and carried out by the Japan Soundscape Study Group over several years.

1.1 Planning

Several important considerations arise in the process of planning how to analyze the acoustic quality of the natural soundscape. One of these is the objectives that should be set for defining the future conditions of the soundscape. These objectives should be compatible with the objectives and plans of the park as such and should be sufficient for restoring the natural conditions of the soundscape as far as is possible, and at the same time should allow visitors to enjoy the benefits of being physically integrated into the natural environment Figure 3.

Figure 3: Two views of Anceu, the conserved natural surroundings of the Eiras reservoir (Pontevedra, Galicia region, Spain).

In practical terms, planning how to obtain the acoustic data means deciding what acoustic data should be recorded, and selecting the most suitable places and periods in which to make measurements. On the one hand, it is necessary to evaluate the noise generated by the activities routinely taking place in the park, and that generated by other authorized activities taking place both inside the park and in nearby zones; on the other, the activities occurring external to the park that has a negative influence on the natural soundscape also need to be assessed and measured.

In all cases, those conducting the study must collaborate constructively with those responsible for the noise-generating activities, so as to be able to implement corrective actions designed to mitigate the undesirable acoustic influences identified in the study. It will also be necessary to define in qualitative and quantitative terms the “natural” reference level that represents the acoustics of a healthy natural environment. The sources of the sounds, the sound levels, and their effects must be identified. The origins of the internal and external noise sources must be identified, and finally, the conditions of the soundscape for the future need to be established.

All this should provide basic information for defining the acoustic objectives in each area of the park, and for determining the nature and the level of impact that the noise has on the environment. It should also indicate where intervention by the park management can contribute most effectively to the protection of the resources of the park. The frequency, magnitude, and duration of the “non-natural sounds” present variations over the total area of the park; the values of these parameters are generally higher in those sectors that are more developed [19]. In those sectors, and areas adjacent to the park, those responsible must take noise measures to prevent or reduce the negative effect on the soundscape of the park. To this end it is necessary to obtain measurements of noise and, if possible, to monitor the sound levels in the various ecosystems that constitute the natural area, to establish the levels that are acceptable, and which require corrective actions for their control.

1.2 The aim of this paper

The objective of this work is to improve the diagnosis of the health of soundscapes in natural areas in Spain. The interest of this work is because a good diagnosis of the problem is the best guarantee to protect this kind of soundscape from any degradation caused by non-natural noise. For doing so, in this paper, the sound quality of a case study is analyzed applying the concept of "Sound Level of the Natural Environment" as defined by the U.S. National Parks Service.

2 Method

2.1 The flow of the methodology for the evaluation of environmental noise on a natural area

Based on the current procedures for the evaluation of environmental noise, the methodology proposed must consider three distinct phases (see Figure 4).

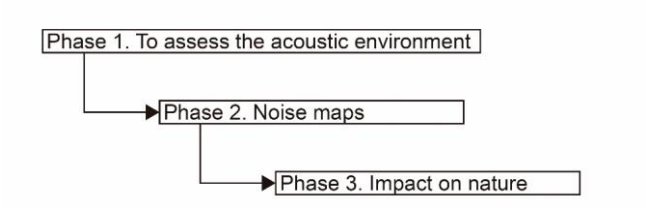

Figure 4: Flowchart of the methodology.

In the first phase, it is necessary to apply the specific methodology for establishing the most suitable parameters for assessing the acoustic environment of the natural area studied, and its influence on the habitat.

In the second phase, noise maps must be drawn, to provide a global evaluation of exposure to noise over the total area of the study zone. In this phase, it is necessary to define clearly the time interval for measurements. It is recommended that the interval should be as long as possible, in order to obtain data that are as representative as possible of the degree of exposure. Another important consideration is determining the ranges that the isophone lines are going to represent. These should span levels of sound pressure corresponding to the natural sounds characteristic of the natural area studied.

These maps should include enough information on the location of the towns and the most relevant infrastructures present in the area. Thus, sound maps should be obtained for each type of source that affects the study area. This step is very important since it establishes the degree to which this influence is perceived, and the time periods in which it is most serious.

In the third phase, from the data previously obtained, an analysis must be made of the extent to which the sound levels existing in the study area have an influence on the species that inhabit the area. This last phase requires the expert knowledge of biologists to determine as the non-natural sounds may affect species in their habitual behavior and reproductive activities.

2.2 Acoustic parameters

The acoustic studies in a natural park should measure the percentage of the time that anthropogenic noise is audible, the intervals free of noise have to be determined, and the sources that generate the sounds have to be identified.

The substantial restoration of the natural soundscape requires that "Natural Quiet" should be predominant during 75% of the time, in at least 50% of the area of the park [10]. In order to reach this objective, it is necessary to identify the natural sounds that are specific to each ecosystem and determine their characteristics. Natural sounds are understood to be those autochthonous sounds of the ecosystem independent and separate from any sound due to human action.

The sound level of the natural setting of a park is determined by the natural soundscape of that park. Under these conditions, the sounds are very varied but are often perceived in unison, as one single type of sound. In an acoustic environment subjected to high levels of noise caused by human activities, the sound of the natural environment can be masked by noise from other sources. For this reason, as a first step, it is necessary to determine the characteristic sounds emitted by all the sources that can be perceived in a specific area. For this, a parameter that is known as the 'existing environmental sound level' is employed. Generally, the existing level of environmental sound in an area is identified by reference to the L_{50} percentile. However, it is necessary to determine whether this parameter is the most appropriate or not. The calculation of the existing levels of sound is a simple procedure, by which the 50 percentile (L_{50}) value is taken, from all the data obtained for a given period (including the natural and non-natural sounds).

If those periods when the noises caused by the human activity are audible are excluded from the measurements made of total noise during a specified interval of time, the sound level corresponding to all the natural sounds present in that area during that time is obtained [11]. This concept is designated as the “Sound Level of the Natural Environment" (L_{nat}). This is often considered synonymous with the term “natural silence”. However, since nature is not usually completely silent, the term “sound level of the natural environment” is more appropriate when the object is to determine the noise derived from the interference of human activity in nature, or the "affected natural environment", and in other environmental evaluations related to the human actions that produce adverse or intrusive impacts on the soundscape of the park.

The calculation of the L_{nat} for each hour is not simple. In any natural park the two types of sound, the natural and the anthropogenic, will be audible; thus, to obtain the L_{nat} implies being able to exclude the influence of the sounds caused by man. The most appropriate method would be to obtain the L_{50} of all the data recorded at times when there is no influence from the noises generated by human activities. In this case, the problem presented is one of cost: it would be a costly exercise to make long-term measurements to eliminate the set of acoustic data that includes sounds of human origin.

For this reason, the usual procedure is to employ the statistical concept L_x (dB), which indicates the level of sound pressure that is exceeded for x% of the time of observation. If the data corresponding to that continuous period when only natural sounds are audible, or when there is actual silence, are removed from the total data obtained in the measurement made during a specified interval of time, what remains will be an interval free from noise. This parameter is known as the “Noise Free Interval” (NFI); it should not be calculated during brief periods of time. The NFI provides valuable information when the intervals of time are sufficiently long [12].

The environmental sounds attributable to human activities in natural parks are all those sounds that have their origin in anthropogenic activities. In the setting of a natural area, these sounds can be caused by the activities integral to the daily functioning of the park or they can be independent of park operations and originate outside the park. These are the sounds and noise levels that should be measured and evaluated in the processes of planning the natural area, to determine if are they compatible with or harmful to the management objectives of the soundscape. These sounds are known as "Man-made Sound Levels" (i.e., sounds of anthropogenic origin).

In all cases, the technicians making the measurements must be able to separate the natural sounds from the man-made sounds and be able to determine the percentage of time that these latter sounds are audible. It is also necessary to set the time periods during which to assess the soundscape. In this type of study two periods are considered, one diurnal between 07:00 and 23:00 hours, and the other nocturnal, between 23:00 and 07:00 hours, for one day, one month, one season of the year or one year.

It is important to keep a record, in situ, of the time when a non-natural sound is audible (e.g., when a vehicle passes, a note should be made of the time when the sound is first perceived and the time when it ceases to be perceived); the interval between the two times corresponds to the period of time in which that sound is present in the natural medium. When the recordings are carried out for measurements over a continuous period of long duration, it will be necessary to identify the source of the non-natural sound and the corresponding interval of time that it is audible. From the relationship between the total time of the recording and the time when the sound level is influenced by these sources of unwanted sounds, the percentage of time in which the noises caused by human activity are audible, and hence the L_{nat}, can be established. If the set of data only contains natural noise, the L_{50} is used to determine the L_{nat}. However, when the influence of sounds generated by human activities is detected, this can lead to an over-estimation of the sound values of the natural environment.

The L_{90} value represents the value of the sound that has been present during 90% of the total time of measurement. In these situations, the L_{90} can lead to an under-estimation of the sound values of the natural environment. Therefore, the calculation of the L_x of the set of data based on the audition of human sounds in each place of measurement, and the application of the L_x to the set of data, leads to a more accurate estimation of the sounds of the natural environment.

For the analysis described, the L_x method is employed [10]. This method consists of obtaining samples of the period of measurement to determine the percentage of audible noise of human origin present in the recordings. Because these sounds caused by human activities are usually, but not always, audible above the natural noises, they generally have higher values.

To obtain a set of acoustic data without sounds of human origin, the data are ranked from the lowest to the highest (in dB), and the percentage of the highest sounds determined by sampling the ranked data are discounted. The median value of the rest of the data set, and its corresponding L_x, is an approximation of the noise level of the natural environment, of the sub-sample. To calculate the natural level of the environmental sound for the period of measurement, this L_x is applied to the set of data (dBA and 1/3 octave band). x is obtained from the Eq. (1):

$$x = \frac{100 - P}{2} + P \qquad (1)$$

where P is the percentage of the time in which the human sounds are audible.

For example, if the non-natural sounds are audible during 40% of the time, the values from L_{max} to L_{40} would correspond to the highest sounds (usually the non-natural), and the values from L_{40} to L_{min} would correspond to the lower sounds. The mean between L_{40} and L_{min} is L_{70}. Therefore, the sound level that is exceeded during 70% of the time will be used as the base level for characterizing the sound level of the natural environment.

One worrying aspect of this method is that some loud natural sounds, like thunder, could be removed from the data before calculating the sound levels of the natural environment, and the results may thus be an under-estimation of the actual true sound levels of that natural environment. These events, however, are relatively infrequent; therefore, the elimination of these data should not have a significant impact on the calculated sound levels of the natural environment. On the other hand, some non-natural sounds that are relatively low may remain present in the sample, and the results may be an over-estimation of the sound levels of the natural environment. However, these events could be identified and dealt with, thus reducing the impact on the calculations of the natural sound levels.

2.3 Meteorological data

These data are especially relevant in the modeling of the noise maps of the areas exposed. For the wind, in general, the levels of environmental noise tend to increase the higher the wind velocity; the characteristics of the tree foliage also have an influence, since denser vegetation produces higher noise values. Jakobsen and Andersen [13] regard the natural sound of the wind (sounds generated by air turbulence), and that generated by the movement of the vegetation with the wind, as natural sounds. However, sounds caused by air turbulence on the recording microphone or the windscreen shielding of the microphone are considered non-natural sounds.

2.4 Sampling

The spatial and temporal sampling in the various areas of the park is done employing seasonal acoustic monitoring campaigns, sound recording, and records of environmental conditions. This includes the frequency, distribution, and sound pressure level of the sounds of natural origin and those generated by human activities. A priority task in this phase is identifying the most sensitive areas of natural sounds

2.5 Audio recordings

It is necessary to obtain audio recordings that allow the identification of the sounds specific to each ecosystem of the park, and that enables an acoustic profile representative of each zone to be developed. These recordings can be reproduced later for visitors to enhance their general knowledge and enjoyment of the park.

2.6 Presentation of results

The results are presented in the following order:

- **Noise maps**: Area in km² of the total natural area studied exposed to noise in the ranges:
    - <39 dBA.

- 40-44 dBA.
- 45-49 dBA.
- 50-54 dBA.
- 55-59 dBA.
- 60-64 dBA.
- 65-69 dBA.
- >70 dBA.

- In-situ, noise measurement campaigns
- **Audio recordings and Observations**:
  - Spatial and time identification and distribution of sound sources.
  - Time and date annexed to the audio recordings.
  - Number/duration of events, by each source.
- **Acoustic Indices**: For each interval and period of measurement (time history, day, month, a season of the year):
  - L_{Aeq}.
  - L_{max}.
  - L_{min}.
  - L_{eq} Spectra in 1/3 octave band between 20-20,000Hz.
- **Time of integration**: 1 second.
- **New Parameters**:
  - Percentage of time in which the noises caused by human activity are audible.
  - The sound level of the natural environment (L_{nat}).
  - The continuous period during which only the natural sounds are audible.
  - Noise-free interval (NFI).

3 Results and discussion

To aid in understanding the procedures described in this article, the results of the measurement campaign carried out in a particular natural area are reported. The study area comprises the parish district of Anceu, constituted by three localities: Anceu and Os Ramís. This district has a population of approximately 300 inhabitants; 85 dwellings are covering a total area of 17.4 Ha. As can be observed in Figure 5, the principal infrastructures that affect the study area are:

- The stretch of local highway between Esfarrapada and Barbudo;
- The local highway between Anceu and Barbudo;
- The road PO-255 between Puentecaldelas and Forzans;
- The road V-103 between the PO-250 and S. Adrian Calvos;
- The road EP-0208 between Barbudo and S. Adrian Calvos;
- and the stretch of Forest Track between Anceu and the Eiras reservoir.

However, for this example, the only road taken into account is the stretch of PO-0203 between the PO-255 and the village of Os Ramís, since that is the highway that runs through the village of Anceu where this study was carried out.

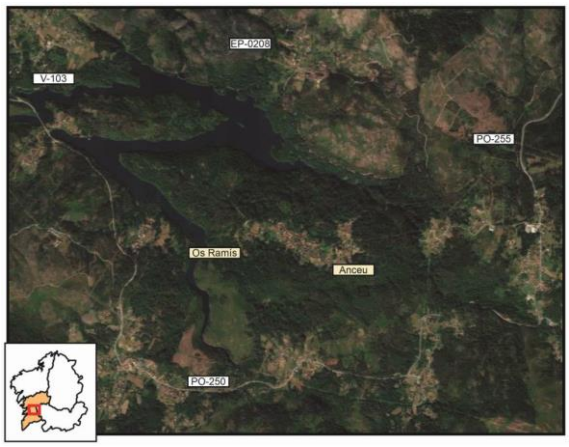

Figure 5: Case study of this research.

The test was carried out during the night period, at a point situated outside the village of Anceu (see Figure 6), where it was possible to perceive the sounds originating from the village and the PO-0203 highway. The duration of the test was slightly more than 93 minutes (1:33:35), continuously.

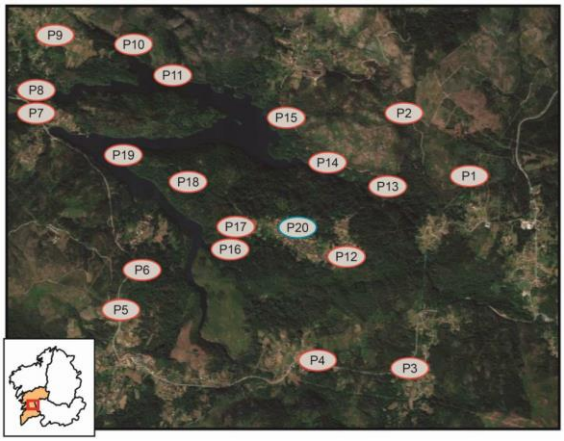

Figure 6: The natural area of the Eiras reservoir [3].

The instruments employed in the test were a model 2270 analyzer with a UA1650 windscreen, and a type 4189 microphone, polarized, of ½'' free field. For the analysis of the data, a BZ550 3 and an Evaluator type 7820 V4.16.2 of Brüel & Kjaer, were employed. The measurements were made on the night of August 12-13, 2012, between 22:59:05 and 00:32:40 hours, with a total duration of 1:33:35 hours. The recordings were taken every second in the 1/3 octave band, and the time of measurement was recorded simultaneously with the sound recording. In Figure 7 the temporal recording with the events recorded marked above the graph, can be observed.

Different soundscape recordings were rated on the characteristics given in Table 1. The procedure for determining the L_{nat} is as follows: The period of evaluation (anthropogenic sound plus natural sound) is 1 hour and 33 minutes, approximately. During the 93 minutes, the time in which sounds of anthropogenic origin are perceived is approximately 45 minutes.

The Percentage of anthropogenic noise is: 100x 45/93 = 48.4%. Therefore, x = (100+48.4)/2=74.2%.

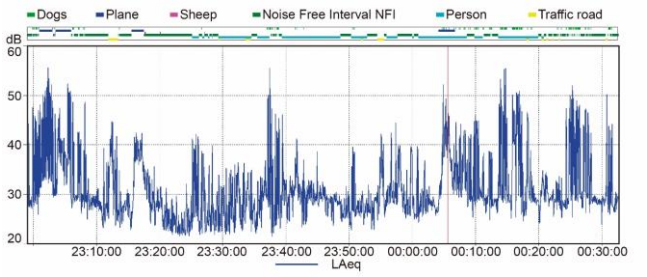

Figure 7: Time series of $L_{Aeq,\ T=1s}$ in P20.

The Evaluator software gives the value of the L_{74} =27.3 dBA. Therefore, L_{74} will be used as the base level for characterizing the sound level of the natural environment.

The L_{nat} corresponds to (100-48.4)% ≅ 52% of the time; the level corresponding to L_{52} = 27.3 dBA.

Table 1: Acoustic data - Anceu, Point 20, Village, Night

Name / duration (h:m:s)	L_{Aeq} (dBA)	$L_{AFmáx}$ dBA)	$L_{AFmín}$ (dBA)	L_{AF10} (dBA)	L_{AF50} dBA)	L_{AF90} (dBA)
Existing noise (1:33:35)	37	62.4	20.8	39.3	29.1	25
Aircraft passing (0:09:14)	42.5	59.3	23.2	47.2	37.6	31.2
Vehicles passing (0:05:43)	35.6	56.6	22.2	38.8	30.9	26.3
People (0:29:50)	37.1	62.4	21.2	39.6	29.6	26
Anthropogenic noise (0:44:47)	36.8	59.3	21.2	39	29.9	26.1
Dogs (0:08:59)	43.9	62.4	21.4	47.7	40.7	33
Sheep (0:00:35)	32.3	42.8	21.7	35.8	31.2	24.3
Noise Free Interval NFI (0:39:33)	*28.7*	*48.1*	*20.8*	*30.3*	*28*	*23.7*
Natural noise (0:48:48)	37.1	62.4	20.8	39.7	28.5	24.2

In the light of these results, the conclusion is that, although the values are low (in general), in percentage terms, for 48.4% of the time, the sounds generated by human activities are audible. Accepting that the noise produced by the tinkling of the sheep bells and the barking of the dogs in the nearby dwellings counts as natural sound, the percentage rises to 57% of the total time of the measurement. This means that only 43% of the time of measurement is free from any sound of the anthropogenic character. Figure 8 will let to understand more easily the dates given in Table 1.

Finally, the noise maps showed the most affected areas in the case study (see Figure 9). As can be seen, the isophones show how there is a wide surface of the case study with levels above 40 dB (A). This aspect is of great importance since the noise conditions are not consistent with Quiet Area conditions. This means the potential impact generated by infrastructure on the living conditions of the fauna of the area.

4 Conclusion

With respect to the planning process, when the soundscape is

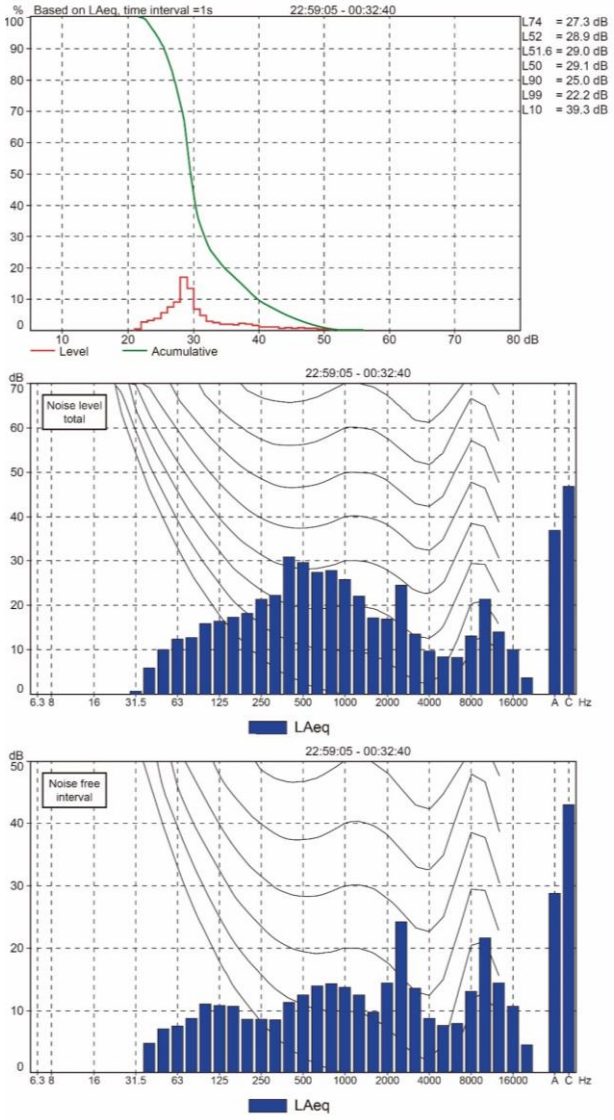

Figure 8: Example of noise measurement values representing the noise equivalent levels during the period comprised between 22:59:05 and 00:32:40 of the day after.

not affected by inappropriate sources of noise, the objective will be the maintenance of those conditions. However, when the soundscape is found to be degraded by the influence of noises foreign to the natural environment, the objective must be to devise and implement corrective actions aimed at restoring the natural soundscape.

Effective soundscape management requires the determination of, first, those specific sounds that must be preserved, with the object of the protection of biodiversity; and second, the nature of those unwanted sounds that have a negative impact on the fauna and flora in the various ecosystems of the park. It then requires the identification and specification of the actions the actions that could be taken to mitigate adverse effects, with the object of making it possible for visitors to experience directly the authentic sounds of the natural area visited.

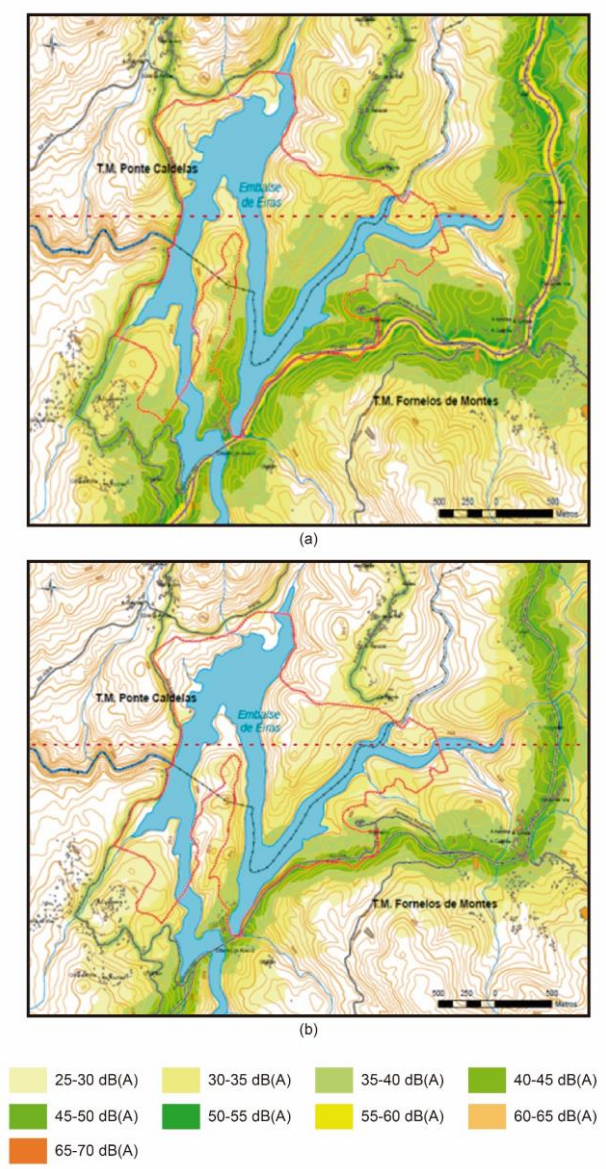

Figure 9: Influence of road traffic. Sound Maps for the day (a) and night (b) periods.

The calculation of the parameters described represents an approach for the establishment of base indices in the interests of the restoration and preservation of the natural soundscape. The determination of the most objective parameters for this task requires profound knowledge of the particular natural environment under study, in order to be able to establish what acoustic elements are harmful for the autochthonous life of that area. The results of this study suggest that, in certain zones, such as rural areas, it is relatively difficult to achieve a state of "Natural Quiet".

It will be necessary to carry out further studies to gain a better understanding of the scope and the nature of the acoustic impacts on the resources of natural parks and protected areas. On this topic, it is in the interest of the relevant authorities to support and promote studies for the cataloguing and conservation of the Soundscape in natural habitats of ecological value.

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