Applied Acoustics 127 (2017) 207–214

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

The distribution and importance of Quiet Areas in the EU

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ARTICLE INFO

Article history:
Received 27 December 2016
Received in revised form 8 May 2017
Accepted 12 June 2017

Keywords:
Quiet Areas
Ecosystem services
Noise pollution
Landscape ecology

ABSTRACT

The delineation of Quiet Areas (QAs) forms nowadays a national obligation of EU countries. Nevertheless the variable applications of QAs among Member-States have highlighted the need for an international common approach for the preservation of Quietness. The objective of this paper is to identify and thus protect QAs of EU. Our methodological design consisted of the implementation of a coarse scale distance-based methodology regarding the identification of QAs among different countries, environmental and altitudinal zones with a view to investigating the spatial pattern of QAs as well as their spatial relation to other protected areas. QAs cover 56.09% of EU territory with most of the sites comprising an area larger than 100 km^2 indicating that Quietness provides a valuable ecosystem service for human well-being. Central Europe demonstrates lower percentages of Quietness whereas Mediterranean and Scandinavian areas contain higher percentages of Quietness. Also our findings regarding the spatial overlap of QAs with Natura 2000 network suggest that QAs actually indicate sites of environmental quality, and could thus be incorporated into environmental policy initiatives.

1. Introduction

Quietness has been recently recognized as a factor affecting health [28,57,1], biodiversity [48], economy [14], aesthetics ([53]) and education ([17]), thus introducing a novel cultural ecosystem service, which citizens could easily access [40]. Recognizing the importance of Quietness, there have been several attempts of defining the spatial pattern of Quiet Areas (QAs) ranging from local (e.g. [33]), to regional (e.g. [13]; QUADMAP) and national scale ([63,60] utilizing questionnaires, noise and land use mapping, experts' opinion or combination of these methods. Nonetheless a unified, common international approach is missing.

The Environmental Noise Directive (END 2002/49/EC) was the first EU policy that explicitly addressed QAs. The implementation of END required, as one of the first strategic steps towards reducing exposure to environmental noise, the delineation of QAs. This is a national obligation and it has been performed across all EU Member States. Several Member States adopted methodologies of actual sound-pressure level measurements, underlying the need for further development of relevant approaches taking other parameters which influence the perception of the soundscape into account [10,23]). Another successful approach to map QAs was noise mapping by measuring environmental noise exposure [65]. The approach of surveys based on the evaluation of visitors' experience resolves many of the limitations of the above-mentioned approaches [37], but it is a weather-dependent, time-consuming and cost-demanding process ([42]).

While END does not dictate a unique approach of preserving Quietness, a noise policy which will guarantee the avoidance of harmful effects from all noise sources and the preservation of QAs by the year 2020 is required by all Member States [64,32]. As a result there is a high degree of variation and extent of methodological applications regarding how this task is performed among EU countries. Thus, the findings about QAs are difficult to compare [29].

The global concern about nature degradation has highlighted the importance and urgency of environmental management that aims to conserve biodiversity conservation but also mitigate effects of the global climate change and contribute to poverty alleviation. The main EU policy for biodiversity conservation is the designation of the Natura 2000 network of protected areas. But these protected areas are also linked with cultural values and socioeconomic activities [59,55]. Therefore there is a need for an integrated ecosystem management, established on a multidisciplinary framework of environmental policies and strategies at academic and management level ([41]), as this is underscored by the recent EU biodiversity strategy — Our life insurance, our natural capital [18]. Thus the integrated management of nature conservation and quietness is beneficial for both policies [61]. QAs have been used as green corridors ([53]), and are suitable to protect a range of endangered species [46]. Under this concept, not only the preservation of Quiet

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http://dx.doi.org/10.1016/j.apacoust.2017.06.007
0003-682X/

protected areas has been proposed ([22]), but also the creation of quiet buffer zones around protected areas to safeguard the survival of threatened species [3].

In the present study, we apply the QAs modeling methodology proposed by Votsi et al. [60], to the extent of the EU. This methodological approach could constitute a first estimation of QAs at the EU level. Though there is a wide variance in QAs definition [10,51], we chose to adopt END terminology regarding QAs in open country, according to which QA is *an area that is undisturbed by noise from traffic, industry or recreational activities*. Our application of the techniques aims to define the spatial pattern of QAs in the EU with view to protecting them as END requires. Our results include the comparison of the Quietness status per Member State, and the investigation of the environmental and topographic profile of QAs. Last but not least we examined the spatial overlap of QAs with the established Natura 2000 protected areas in the EU to assess the interaction between biodiversity and Quietness. The relationship between QAs and protected areas could result in the establishment of an alternative environmental policy integrating the two different policy objectives so as to simultaneously protect nature as well as human health and well-being [61].

2. Materials and methods

2.1. Study area

The analyses were applied to the 27 member states of the EU, before Croatia entered the EU, in 2013.

2.2. Modeling Quietness

Here we apply, at continental scale, the distance-based methodology that has been proposed by Votsi et al. [60] and applied at national scale. This approach was also presented in EEA [15,16], and has been verified at specific sites by Votsi & Kallimanis [62]. This is a first attempt to identify QAs across the entire extent of the EU, overcoming many of the methodological limitations for this continental scale analysis, ([63,23,60]. The method is based on the identification of human-induced noise sources, using spatial data that are reliable and available for all the EU Member States such as Corine Land Cover dataset and Open Street Map. The identified noise sources are then buffered to determine the noise propagation until the sound level drops to the Quietness threshold ([19]), which according to EEA and the majority of relevant studies is 50 dB [4]; [58]). Last but not least the specific method takes into consideration the effect of multiple noise sources, by increasing the buffer zone around locations that two or more noise sources overlap (for more detailed information see [60]).

The noise sources that were taken into account are:

- *Primary roads* (www.openstreetmap.org), with identified sound level at the source 85 dB (i.e. [39,23]). A buffer zone of 1000 m was implemented on primary roads in order to calculate their noise propagation.
- *Secondary roads* (www.openstreetmap.org), with 68 dB recorded on average (i.e. [23]). Noisy areas of secondary roads were spatially designated by applying a 650 m buffer zone around them.
- *Tertiary roads* (www.openstreetmap.org), usually emit 60 dB (i.e. [23]), thus a buffer zone of 400 m was implemented.
- *Railway* (www.openstreetmap.org), based on literature review demonstrate a sound level of 75 dB ([31]). In order to calculate railway's noise propagation, 750 m around them was considered noisy area.
- *Agglomerations* (http://www.eea.europa.eu/dataand-maps/-data/urban-atlas), with recorded sound level of 87 dB [49] and a standardization of 5 dB were buffered at 1200 m.
- *Industrial centers* [6], on average demonstrate sound levels of 100 dB [43,2]. With view to designating their noise propagation a buffer zone of 1500 m was applied.
- *Local industries* [6], emit on average 66 dB ([23,9]). A buffer zone of 500 m was implemented around them.
- *Airports* [6], with 110 dB [45]; http://www.pbcgov.com/airport/terminology.htm) were buffered by a zone of 2000 m and standardized by 6 dB.
- *Ports* [6], usually demonstrate 85 dB of noise levels [8]. They were then buffered with a 1000 m zone and standardized by 4 more dB.
- *Construction sites* [6], according to literature emit 90 dB [50]. The buffer zone around them was set to 1250 m while the standardization included 12 dB.
- *Recreational activities* [6], are recognized as noise sources of 80 dB [7,24]). The noise propagation is calculated if a buffer zone of 850 m is implemented along with a standardization of 5 more dB.

When all the noisy areas were mapped, surfaces that did not fall within the range of any noise source were identified as QAs. Nevertheless, a minimum required size of each QA was set. The lower limit serves two purposes: (i) given the coarse scale of our analysis small areas are hard to delineate accurately, therefore there is a degree of uncertainty in small areas, and (ii) the management and protection of larger areas is a more efficient policy both for nature conservation and for quietness. A small area has a low probability to be successfully protected and thus to ensure species preservation [52]. Furthermore, as it is also verified at the national level, small surfaces of QAs between large noisy areas, cannot ensure a status of Quietness [60]. Therefore we adopted the criteria that for an area to be considered Quiet its surface should be greater than 10 km^2 (Fig. 1a). This lower limit of Quietness is supported to serve decision making processes [21] and it has been adopted at a national [60] but also European level ([15]).

Recently European Environment Agency (EEA) ([15]) proposed a multidimensional methodology introducing the Quietness suitability index outside urban areas, which is actually based on the noise-mapping data reported by each Member State to the EEA in response to END. This approach defines areas of naturalness and ruralness but it demands noise data that are not available for all Member States. Our methodological approach follows this concept, and focuses on the in-depth study of QAs ([15]). The distance-based methodology applied here, has the advantage that it could determine QAs at continental scales without demanding noise data and maps, especially for Member States where no such data are available ([58]). Our results could provide insights for environmental policy initiatives at international level.

2.3. Analyzing quietness

Adopting the distance-based methodology the spatial pattern of QAs in the EU was computed, as well as the mean size and the percentage of QAs per Member-State with view to comparing the distributional pattern of Quietness among Member-States.

The next step included the investigation of some abiotic factors of QAs. More precisely, we overlaid the European environmental zones, which are derived from a range of environmental variables [36] and interpreted the spatial distribution of QAs in accordance to the environmental stratification of the EU. We also explored the altitudinal distribution of QAs using the five relief topologies (low coasts, high coasts, inlands, uplands and mountains) proposed