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ORIGINAL ARTICLE

Citizen science contribution to national wolf population monitoring: what have we learned?

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Abstract

Evidence-based management of large carnivores is a crucial step towards their effective conservation. However, monitoring of these populations is demanding and generally requires substantial fieldwork effort. Lately, citizen science has become an increasingly important part of wildlife monitoring, but can that endanger studied species? In this paper, we describe our experiences with recruiting and involving volunteers in annual howling surveys of grey wolf (*Canis lupus*) population in Slovenia and present the framework about the use of citizens for collecting data. Huge effort of participants in a 7-year-long monitoring at a national scale has yielded a total of 116 wolf vocal responses, including 53 confirmed litters. Annually, between 5 and 12 reproductive packs were detected and an increasing trend in wolf population throughout the study period was observed. Volunteer-based howling surveys proved to be a cost-effective method for detection of reproductive packs on a large spatial scale, offering an insight into wolf population trends across a longer time period and we provide some recommendations for organisation and coordination of surveys. We also discuss ethical issues raised from our experience in using citizen science for this purpose.

Keywords Monitoring · Acoustic survey · Grey wolf · *Canis lupus* · Large carnivore · Citizen science

Introduction

Monitoring large carnivores, such as grey wolf (*Canis lupus*), can be an arduous task, mostly due to the species' secretive lifestyle, relatively low population densities and large home ranges. Moreover, their presence in some areas may lead to conflict situations with humans, which makes overseeing the distribution and size of wolf population a necessity. Reliable monitoring is particularly important when a population is subjected to lethal control, in order to prevent non-sustainable culling and reduce negative side effects. Despite the wide range of available methods to survey grey wolves (e.g. non-invasive genetic monitoring, camera trapping, snow tracking, acoustic surveys), employing efficient methods over large spatial scales is often resource demanding (Llaneza et al. 2014). Therefore, monitoring of large carnivores often relies on a network of both professional and non-professional participants (Louvrier et al. 2018; Molinari-Jobin et al. 2017).

Wolf howling survey (Pimlott 1960) (hereafter howling) is one of the few fast, reliable and cost-effective survey methods available for monitoring of territorial grey wolves and reproductive events. It involves stimulation of howling from the resident wolves using a playback recording or vocal imitation by trained humans. Wolf pack members (adults and pups) respond to the imitated howls, particularly during summer and early autumn, when they stay closer to dens and homesites (Joslin 1967) and during the breeding season in winter (Harrington and Mech 1982). The method was successfully employed in wolf pack censuses in Europe (Llaneza et al. 2005; Potočnik et al. 2010; Blanco and Yolanda 2012; Llaneza et al. 2014; Bartol et al. 2016, 2017, 2018; Papin

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et al. 2019) and North America (Harrington and Mech 1982; Fuller and Sampson 1988) for studying reproduction, territorial maintenance, resource defence and activity rhythms of the species (Harrington and Mech 1979; Gazzola et al. 2002; Nowak et al. 2006; Passilongo 2013). Locating homesites with the help of howling is also an effective method complementary to non-invasive genetic sampling, as wolf homesites often contain wolf scats, wolf hair and prey remains (Joslin 1967; Stansbury et al. 2014; Majić-Skrbinšek 2014).

To our knowledge, volunteer-based howling survey has not yet been used under a national monitoring scheme framework, but rather to assess specific research questions (e.g. as a complementary method to test the intensity of territorial marking during reproduction (Llaneza et al. 2014)) or to monitor changes in population under certain anthropogenic disturbances (e.g. impact of wind farms on wolves (Da Costa 2018)). Moreover, it is rarely applied as a large-scale monitoring method, being usually limited to a smaller area of interest (Ausband et al. 2011). While the surveys are often performed by researchers and managers or rangers (Gable et al. 2018; Da Costa 2018), howling in Slovenia has been performed using the so-called "citizen-science approach", i.e. with the cooperation of trained volunteers. Citizen science has been recently demonstrated beneficial for monitoring rare large carnivores in areas of difficult access (e.g. Farhadinia et al. 2018) and is traditionally used to supplement or substitute other more expensive or labour-intensive techniques (Dickinson et al. 2012). Consequently, there is a scarcity of how-to information on organisation and coordination of large-scale howling surveys using citizen science in the scientific literature. Ethical questions, including possible exploitation of the method, are also rarely addressed, despite being a legitimate threat in surveys involving a large amount of volunteers.

In this paper, we present some guidelines and recommendations for the organisation and coordination of volunteer-based wolf howling surveys. We consider ethical issues and possible threats to the studied wildlife when including volunteers. Furthermore, we discuss if howling surveying with volunteers can be a valid and cost-effective method for confirming wolf pack presence and reproduction and to monitor population dynamics under a continuous, large-scale long-term monitoring scheme.

Methods

Study area

The study area spans from the Eastern Alps to the North-Western part of Dinaric Mountains in Slovenia (Fig. 1), through the entire known wolf range, covering 3924 km^2. It is characterized by a mosaic of various landscape structures, including mixed forests dominated by silver fir (*Abies alba*) and common beech (*Fagus sylvatica*) associations, agricultural land, larger cities, smaller settlements and rugged high mountains. The climate is alpine in the Eastern Alps and a mix of influences from the Alps, the Mediterranean Sea and the Pannonian basin in the Dinarics. The study area covers the core area of all three large carnivores present in Slovenia, i.e. grey wolf (*Canis lupus*), Eurasian lynx *(Lynx lynx)* and Brown bear *(Ursus arctos)* (Potočnik et al. 2018a, b, c). Golden jackals *(Canis aureus)* have expanded its range to Slovenia only recently (in the 1950s) and are still spreading throughout the country (Krofel et al. 2017). The area is also rich in other vertebrate species, including the main prey species for grey wolf, red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) (Potočnik et al. 2019).

We divided the study area into a grid of 3 × 3 km square cells (Fig. 1) to ensure detectability of wolf responses (Harrington and Mech 1982; Gazzola et al. 2002; Llaneza et al. 2005). Only cells containing at least 65% of the forest cover and other natural habitats (e.g. encroachment areas and natural grasslands) were considered for the howling survey. The grid consisted of 400 cells during the LIFE SloWolf (2010–2013) project (Potočnik et al. 2014). Grid was later (2015–2017) expanded to 436 grid cells (Bartol et al. 2016, 2018). The survey area was organised into sub-areas (see different colours in Fig. 1) that overlapped with potential wolf pack territories and facilitated the coordination of volunteers.

Survey protocol

The howling surveys were performed following modified Harrington and Mech (1982) protocol. The surveys were preferably conducted in three consecutive nights (Potočnik et al. 2010) in August (see Table 1 for details) in favourable weather conditions, i.e. no precipitation and minimal or no wind (Harrington and Mech 1982; Fuller and Sampson 1988; Gable et al. 2018). The survey procedure at the site is depicted in Fig. 2, and the details of the survey activities are given in Table 1.

The survey started 1 hour after sunset and lasted until 1 hour before sunrise, at the latest. Within each grid cell, one howling site was chosen by the surveyors. The criteria for choosing a howling site were accessibility (surveyors were limited to vicinity of forest roads), topography (howling from a higher elevation, choosing spots with good audibility) and distance from potential disturbances (main roads, pastures, settlements and other anthropogenic structures were avoided). In this way, the highest possible audibility of the surveyor and detectability of a response was ensured.

In the case of a wolf response, surveyors determined the bearing of the response, the number of adult wolves howling (one or more) and the response of pups (see a sample survey form in supplemental material). Data about howling site

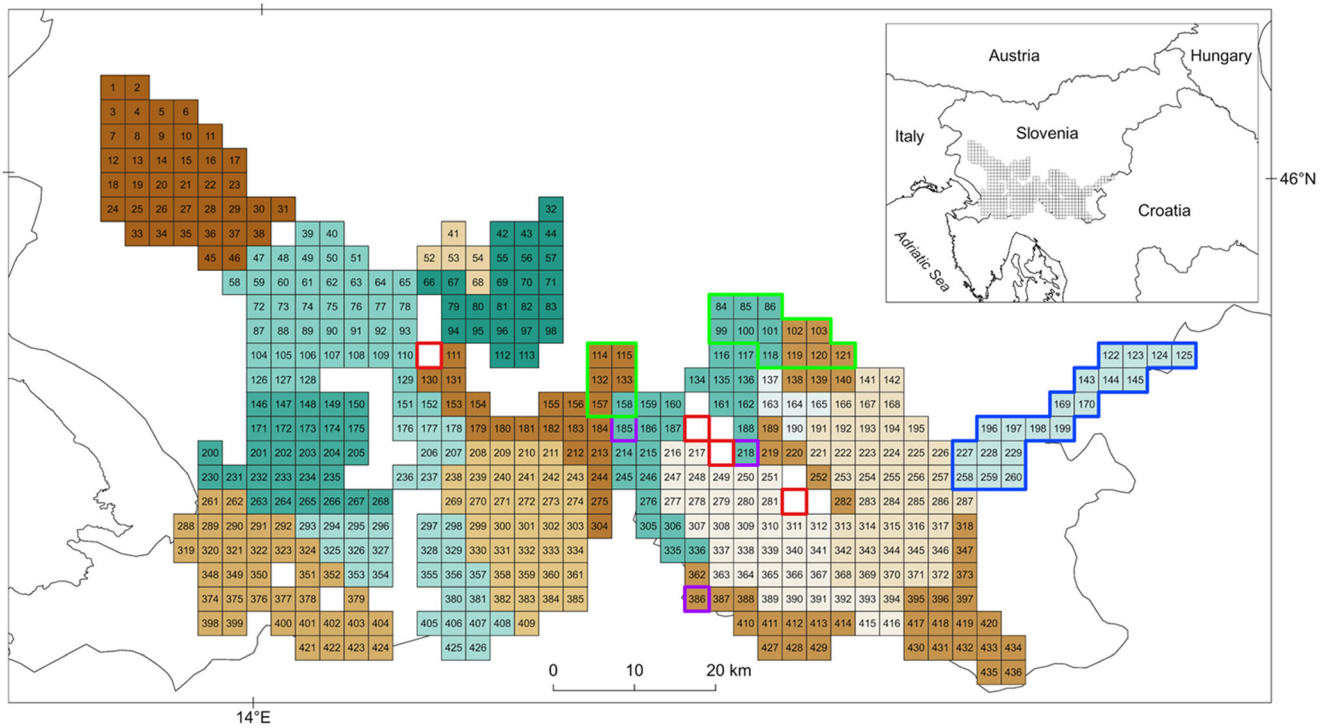

Fig. 1 A 3 × 3 km survey grid in southern Slovenia (Europe) with cell additions (2015, 2016 and 2017 with green, purple and blue outline, respectfully) and omissions (2016 in red outline), due to the proximity to anthropogenic disturbances (settlements and highway). Area was divided into sub-areas (each shaded in different colour) that enabled a more efficient coordination of volunteers

location, time of call and response details were filled in a paper form. When pups were detected, howling was terminated in the cell of response and in all adjacent cells in order to minimise disturbance to wolves. In the case of a response solely by an adult wolf (or wolves), howling was terminated in that cell and continued in the adjacent cells. In three following nights, the survey was repeated in the entire area (except the cells where reproductive packs were detected) to ensure the highest possible probability of detecting a wolf response. If reproductive pack (pups or pups with adults) responded, the grid cell was examined by researchers for non-invasive genetic samples in the following days and the presence of pups thereafter confirmed with genetic analysis (Bartol et al. 2016, 2017, 2018).

Survey coordination

Prior to the survey, volunteers attended a training session, where experts presented the most important theoretical and practical aspects of the survey, e.g. basic wolf biology, monitoring results from previous year(s), navigation skills, howling imitation, howling survey protocol and practical examples of possible wolf and other animal responses. Participants were required to demonstrate howling to be eligible to participate or, due to stage fright, instructed to practise until re-evaluated in the field prior to the survey. Volunteers that did not pass the assessment were still allowed to join the field teams as drivers or navigators, but not for simulating vocalisations. The survey was coordinated at a local scale, where each sub-area was coordinated by a pair of local coordinators. The local coordinators were constantly available for volunteers in case of technical or logistical issues (e.g. vehicle breakdowns), while the main coordinator had a general overview of the activities and was in position to effectively direct and adjust the implementation of the survey.

Volunteers within each area communicated constantly with their local coordinators in the field, who reported data about responses to the main coordinator. Any changes (such as excluding cells in case of pups' response, transmission of volunteers and others) were immediately reported to neighbouring local coordinators and to volunteers. Novice and experienced volunteers formed combined teams covering 4–5 cells per team per night. Every team was given an overview of the terrain and detailed topographic maps for navigation. Local coordinators assisted volunteers' selection of the most suitable howling sites within the grid cells. In the case of wolf pups' response, teams were reassigned to other cells the following day(s). Volunteers needed to be equipped with navigational tools and printed maps, as some locations in the survey area were not well covered with mobile networks that enabled access to online maps. Volunteers were encouraged to draw the location and direction of wolf response on the map so the information could be used in the assessment.

Table 1 Summary of howling survey activities from 2010 to 2018. Due to funding constraints, howling survey was not performed in 2013 and 2014

	2010	2011	2012	2015	2016	2017	2018
Project	LIFE + SloWolf project			National monitoring 2015/16	National monitoring 2016/17	National monitoring 2017–2020	
Date of the survey	30. 8–7. 9.	17–25. 8	16–19. 8	25–27. 8	23–25. 8	22–24. 8.	20–22. 8
Duration of howling survey [no. of nights]	9	6	3				
No. of grid cells	272	400	372	418	417	436	
No. of local coordination areas	9	8		14		15	
No. of volunteers	25	83	86	90	109	156	153
No. of professional hunters	22	26	23	20	21	22	19
No. of surveyors	47	109		110	130	178	172
Detected pups + adults responses	6	7	5	7		12	9
Detected adult-only responses	5		4	10	11	14	
Cost for professional hunters	/			€7665.00		€7760.00	
Cost for volunteers	€704.00*	€1591.00*	€2224.00*	€4889.00	€6200.00		

*The costs summarise only travel costs and snacks for volunteers; the gifts were funded by the SloWolf project

Volunteers were acknowledged for their work with practical gifts or an organised event, and later provided with the final survey reports. The drivers' travel expenses were refunded according to the reported mileage, and snacks were provided for all participants.

Results

Survey coordination activities and volunteer participation

The main howling coordination and organisation activities are reported in Table 1. Due to shortage of surveyors in years 2010 (48) and 2011 (109), the surveys were carried out in parts and lasted for 9 and 6 days, respectively. In 2013, LIFE SloWolf project ended and funding for howling surveys shifted to national in 2015. Increase in total annual amount of funds allowed the organisers to increase both the number of grid cells surveyed and the number of participating volunteers. Important improvements were made in coordination of volunteers in terms of signup (e.g. adoption of online system instead of an email application), communication (e.g. use of social platforms) and training (e.g. training events at more locations around Slovenia) (see Table 1). Volunteers were coordinated by a local NGO.

In total, 483 different participants joined the howling surveys. The number of participants increased substantially over the years, but the transience generally decreased with time (Table 1, Fig. 3). Cumulative transience (participants from all previous years) increased, and since 2012, about half of the participants had already participated in at least one of the previous surveys.

Wolf responses

From 2010 to 2018, we recorded 53 wolf reproductive pack responses and an additional 63 adult-only wolf responses (see Table 2). The responses were recorded in 96 different grid cells, confirming the presence of reproductive territorial packs all across the survey area (Fig. 4). The number of responses gradually increased over the survey period for adult-only and for reproductive packs.

Discussion

Studying large carnivores requires significant time, effort and funds. With this study, we show that involving volunteers can be an affordable and effective way of obtaining basic information about wolf populations on an annual level. Using citizen science for howling surveys, however, requires balancing the number of participants needed with the size of the survey area and the available funding. These activities have substantially progressed in Slovenia over the past 9 years, with important improvements in survey coordination in terms of cost optimisation, communication technology and critical assessment of the survey results.

Due to a high turnover of participating volunteers between years, attracting enough new participants that would provide sufficient manpower to cover the entire study area was the main challenge for the coordinating NGO each year of the survey. Staying updated with new means of communication and promotion of activities was necessary to attract an appropriate number of participating volunteers.

Importantly, however, by organising local volunteer training events in different areas with regular wolf presence (SW

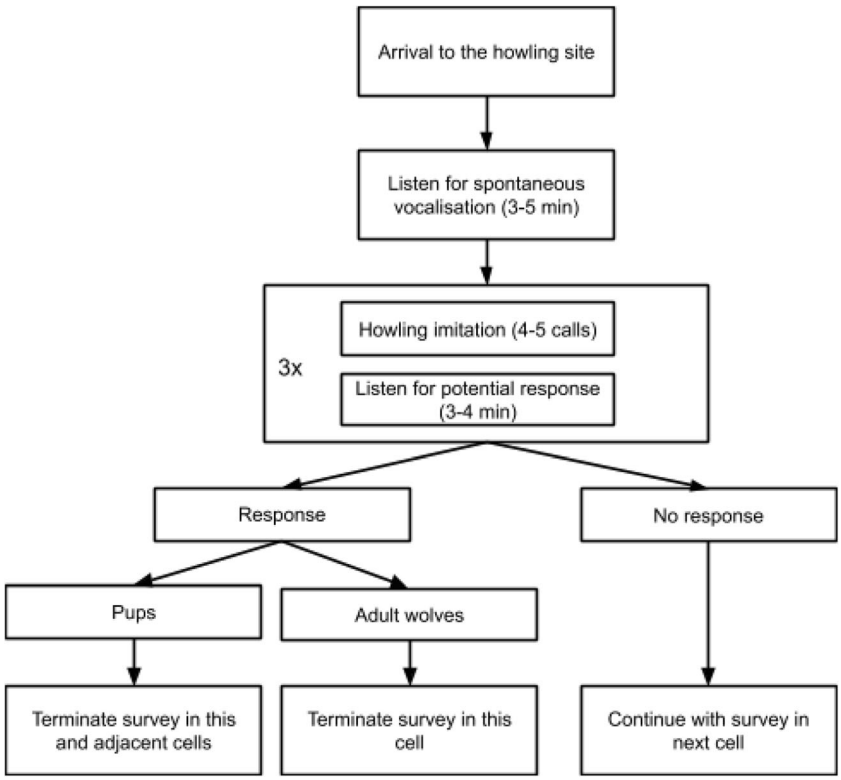

Fig. 2 A scheme depicting survey procedure at howling site. In the case of wolf response after howling imitation, survey was terminated in particular cell (adult response) or in particular and adjacent cells (pups response)

and SE Slovenia), we were successful in involving a significant proportion of locals, including hunters, in wolf monitoring. Majić-Skrbinšek (2014) has shown that active involvement of stakeholders and the general public in wolf monitoring activities improved the level of knowledge and attitudes towards wolves (at least in Slovenia). Indeed, the inclusion of interested members of the public in field research activities proved beneficial, volunteers not only gained field experience through participation but also became more aware of the general ecological issues and more susceptible to scientific research (Bonney et al. 2009; Jordan et al. 2012). Besides verbal communication, they shared their improved knowledge and experiences with others through local media, social media and presentations in their environment (e.g. in schools). As the number of participants gradually increased between the years, but transience dropped, we believe that reaching new

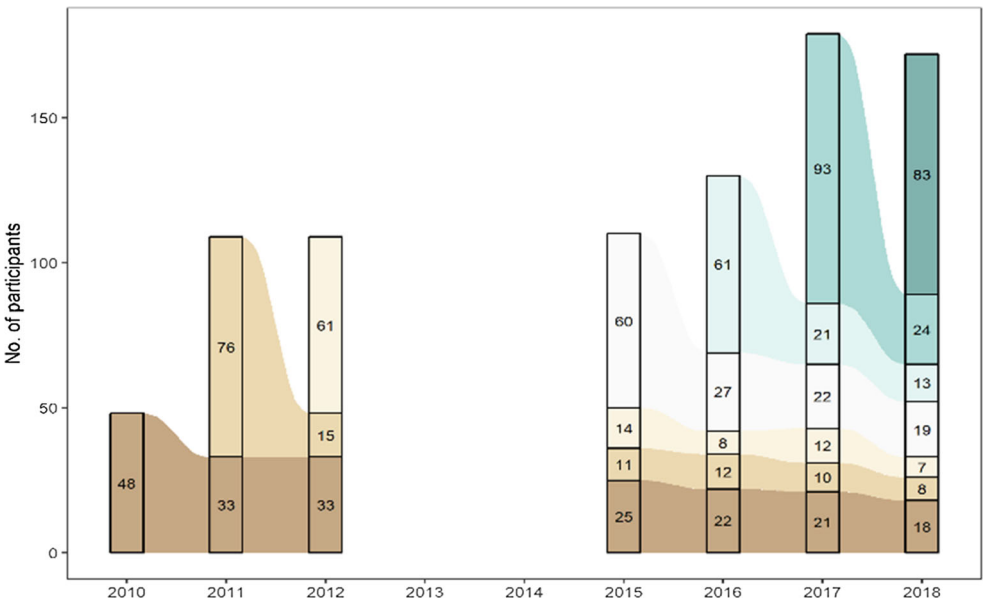

Fig. 3 Transience of participants between survey years. Colours denote a group of first-time participants in each year and their transience to successive surveys. Notice the decline of participants from their first year to the next

Table 2 Wolf responses during the howling surveys. Responses of adult wolves only indicated presence of a territorial pack, while responses from wolf pups with or without adult wolves indicated their successful reproduction

Year of survey	Detected responses	
	Pups + adults	adult-only
2010	6	5
2011	7	5
2012	5	4
2013	/	
2014	/	
2015	7	10
2016	7	11
2017	12	14
2018	9	14

people each year continued to contribute to a positive attitude towards wolves in Slovenia. The regular volunteer inflow is also necessary to cover steadily larger areas, following the expansion of wolf population in the country. A combination of main and local coordinators proved to be crucial for effective communication during the survey. The logistical optimisation, i.e. grouping volunteers by residence area and allocation of groups of volunteers to their closest local sub-areas, minimised the travel costs. Since 2017, prepaid stamped envelopes were enclosed to the howling forms for immediate posting of results to the coordinating NGO which simplified the retrieval of the forms.

A 1.7% response rate is comparable with other studies, where wolf response rates ranged from 0.1 to 56.8% (Crête and Messier 1987; Fuller and Sampson 1988; Harrington and Mech 1979; Gazzola et al. 2002; Passilongo 2013; Passilongo et al. 2015; Leblond et al. 2017). Comparing responses, pups responded in 39.1–58.3% (on average in 47.7%) of all responses.

The imitations of wolf howling induced vocalisation of non-target species, the most frequent being tawny owl (*Strix aluco*), ural owl (*Strix uralensis*), domestic dog and in recent years also golden jackal (*Canis aureus*). Results obtained by howling survey were evaluated by a group of experts (researchers and managers) after the survey. In the last 2 years, the after-survey communication was especially important due to golden jackal vocalisations being mistakenly recognised as wolves by volunteers. To mitigate this, volunteers were provided with example recordings of typical wolf and jackal responses. Volunteers were also encouraged to record the elicited howling responses which proved beneficial in critical review of detected responses. Assessment of the detected responses was another crucial step for filtering out potential golden jackal responses. Based on all the available data collected in the field by volunteers, data on golden jackal distribution (Potočnik et al. 2018a, b, c) and all known information about residential wolf packs (Bartol et al. 2017, 2018), experts were able to critically assess and discard erroneous records.

This study shows that howling enabled the assessment of real-time information about the presence of residential wolf

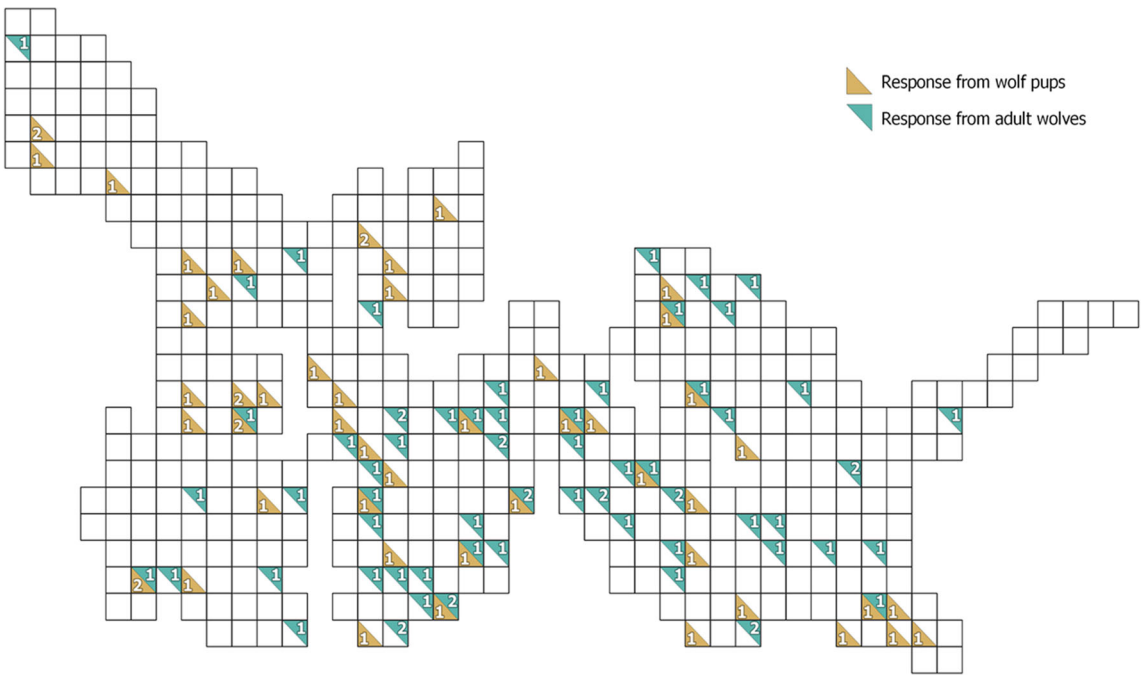

Fig. 4 Joint results from howling surveys in period from 2010 to 2012 and 2015–2018. Responses of adult wolves (green) and reproductive packs (brown). Numbers indicate the count of recorded responses in each grid cell

packs and their reproduction in Slovenia. Interestingly, wolf pups were heard each year in different cells, except for five cells, where their response was heard twice. Responses from adults were also mostly heard in different cells (except for eight cells). This gives additional information about the use of different rendezvous sites and thus denning sites of a wolf pack as well as on the dynamic use of the entire territory throughout different years.

Although the acoustic method cannot provide the same resolution of the data as genetic method, it gives an immediate result and is a good orientation for field work and targeted inspection of the area (systematic walks and drives on close roads and paths) to collect genetic biological samples (scat, hair urine samples, and prey remains) (Skrbinšek et al. 2014). Even though wolf howling was elicited from August–September when the pack activity is focused around rendezvous site and the rate of response is higher compared with other seasons (Harrington and Mech 1979, 1982; Gazzola et al. 2002; Nowak et al. 2006; Passilongo et al. 2010), there is no guarantee for a response (Harrington and Mech 1982). Moreover, there may be pack-specific differences in the likelihood of response (Gable et al. 2018) as well as limitations of human auditory abilities of hearing wolf responses in combination with topographical features (Harrington and Mech 1982; Fuller and Sampson 1988; Nowak et al. 2006). Variation in responses could happen due to stochastic chance of responding, population growth and pack movement. Even during the same year, wolves often move pups between different den and randezvous sites. It is also important to be aware that some transboundary wolf packs may stay undetected if they had their rendezvous sites in a neighbouring country while it is possible to detect a transboundary pack by genetic monitoring later in the season. This might be one of the main reasons for yearly variation of acoustically detected territorial packs (Table 2). A possible solution would be an expansion of the howling grid across the border with Croatia or even a collaborative approach to wolf monitoring between countries.

After almost a decade of howling in the entire wolf range in Slovenia, howling results indicate an increasing trend of Slovenian wolf population. The method is not recommended for estimating wolf population size in a specific country and specific year, but rather to be used over a longer time period to follow population trends or as a complementary method to facilitate collection of non-invasive genetic samples, as already demonstrated in other studies (e.g. Harrington and Mech 1982; Llaneza et al. 2005; Stansbury et al. 2014).

Howling can be an especially useful approach in areas with expanding wolf populations and in areas with an unknown wolf distribution (Papin et al. 2019). Moreover, real-time data obtained with howling could be used in short-term management decisions and actions considering further monitoring by other methods, prevention of damages and raising awareness. An additional benefit of the method is its potential to create a positive attitude towards the returning species, if conducted with the help of local volunteers.

Despite the outlined benefits, there are some drawbacks of involving volunteers in wolf surveys which have to be considered. Citizen science is defined as the involvement of volunteers in science, so it has the dual benefits of making a contribution to science while also engaging with the general population (Pocock et al. 2014). However, there are many different types of citizen science (Roy et al. 2012) including projects strongly shaped by the volunteer participants, so-called 'collaborative' and 'co-created projects' (Bonney et al. 2009). This sometimes brings volunteers into natural environments that they otherwise would not visit, bringing additional disturbance into the area. Organising once-a-year events lowers such pressure, but possible disturbances of wildlife must be considered when organising such surveys. In our experience, giving the volunteers explicit instructions and detailed protocols can help lower negative impact. As the howling method is easy to perform, volunteers must be clearly informed not to use it in any other occasion except during surveys, although this is almost impossible to control. We need to trust involved participants, as we bring them to areas with possible dens and rendezvous sites, which are most intimate and vulnerable wolf refuges year round, not to exploit given opportunities. Although chances of getting a response from wolf pups in our study area were low (0.79% response rate), there is always a possibility of the divulgation of the den and rendezvous sites locations. So far, the attitude towards wolves in Slovenia is positive (Skrbinšek et al. 2014), and we are not aware of negative examples, although situations in other countries could be the opposite.

Not only engaging people with science and their environment, cost effective data collection, but also straightforward data collection due to technological advances (Pocock et al. 2014) are some positive reasons for citizen science projects. But we need to bear in mind the ethical issues. Organisation should be regularly adjusted to the current situation, areas and species background, specifics of the people, their knowledge, trustworthiness and attitude. Researchers should decide whether involving citizen science is suitable for the proposed project, or could it bring more harm to the wildlife, than positive consequences. As with any other scientific tool, citizen science activities will not always be the most appropriate approach for specific research or monitoring tasks, but can be a useful support when properly conducted.

Below, we provide the following main recommendations for organisation and coordination of a vocal survey using citizen science:

I. Consider ethical issues about suitability of citizen science for the proposed project
II. Collecting suitable and available data on species presence, survey area and its accessibility.
III. Constructing coordination plan and estimating required funds prior to organisation of survey.
IV. Outlining a detailed financial plan covering all resources, with collection and implementation of information and its transformation into organisation of survey.
V. Ensuring volunteers are well trained and clearly coordinated. Training and lectures performed by researchers should be efficient, practical and detailed, providing volunteers with protocols, knowledge, confidence and skills.
VI. Shared coordination and planning. A good plan with specified tasks, a priori arrangements, shared transportation suggestions and good knowledge of local areas (choosing the best howling points in advance, considering terrain, possible sound travel, distance from roads, settlements, natural hides) can save significant time and money.
VII. Good collaboration within the coordination team and volunteers can make the organisation much easier. Volunteers should be competent and confident in what they do, able to cooperate, enjoy the fieldwork and feel appreciated. Taking part in a survey should not be money consuming for volunteers. Small gestures of attention and expressed gratitude are appreciated.
VIII. Analysis of collected data and feedback information should be immediate and shared with volunteers, participating bodies and to some extent, media.
IX. Using online platforms for constant and immediate communication between the organisers and the volunteers is very time efficient but requires good responsiveness.
X. Using howling results to complement other data for monitoring (e.g. genetic) is highly recommended and a combination of different methods for monitoring can yield optimal results.

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Compliance with ethical standards

Conflict of interests The authors declare that they have no financial or other conflict of interest.

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