Tracking the long-term dynamics of plant diversity in Northeast Spain with a network of volunteers and rangers

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Abstract

Scientific projects can greatly benefit from the participation of non-professionals in identifying environmental changes at a variety of spatial and temporal scales. In 2010 we launched a long-term project in Northeast Spain (MONITO) that has recruited more than 200 volunteers and rangers. Participants monitor regional-species distribution and local-population abundance for a wide variety of plant species: threatened, rare, and indicators of climatic change or habitats of interest. At the local abundance level (the novel "*Adopt-a-plant*" program), they carry out annual censuses of population abundance for 10 years at least, to eventually estimate standard trends and future vulnerability. In order to show the functional structure of the network and facilitate implementation elsewhere, we evaluate the key aspects of MONITO, which currently involves 183 single-species or multi-species monitoring sites. We use the participant database, an anonymous survey, and the analyses of time invested in fieldwork training, participant turnover, and scientific assessment of monitoring quality. No significant differences were found between volunteers and rangers regarding time invested per monitoring site, quality of data collected or primary motivation ("participating in a real scientific experience"). Volunteers fit better the local abundance level, and reach higher satisfaction and learning. Rangers contribute more to the distribution level, and present a higher turnover throughout the monitoring period. MONITO represents a successful way of tracking real biodiversity changes, and connecting scientific research to public outreach. Mentoring is a key element of this project, together with a socially integrative (participants with and without experience) and methodologically complementary approach.

Keywords

Citizen Science; population trends; data quality; LTER; vulnerable plant species; Species and Habitats of Community Interest

Length of the manuscript: 6050 words + 1 Table + 5 Figures

1. Introduction

Ecological systems naturally vary through time, but overwhelming evidence demonstrates that the current rate of species extinctions far exceeds anything in the fossil record (Barnosky et al. 2011). Projections of future biodiversity based on macroecological models indicate a further loss due to the effects of climate and habitat change (Engler et al. 2011; Newbold et al. 2015). This alarming situation has prompted scientists, Environmental Agencies and citizens to join forces in order to track on-going biodiversity changes and evaluate to what extent environmental drivers are responsible for them, before reaching a non-return point (Chapin et al. 2000).

The complexity and the magnitude of current biodiversity changes make it difficult to use simple variables and indicators to get a real overview of what is going on in ecological systems (but see Tittensor et al. 2014). Important biodiversity changes can often be estimated by analyzing changes through time in habitat cover and structure with remote sensing. A major challenge, however, is assessing the extent of local short-term changes in the abundance of particular species in communities characterized by high biodiversity. The rigorous assessment of changes in species distributions and population abundances was recently nominated as one of the Essential Biodiversity Variables (EBV; Pereira et al. 2013), but collecting this kind of information in a standardized form at different scales becomes a major challenge (Kissling et al. 2017). We urgently need to track biodiversity changes from massive data collection in order to determine the current rate of biodiversity loss and future vulnerability (Magurran et al. 2010). This is, however, very much dependent on long-term programs (LTER; Long Term Ecological Research) not easy to be implemented and supported through time. The main reason is that they depend on a stable crew of well-trained people able to record and process data year after year (Schmeller et al. 2015), a nearly impossible task for professional scientists and resource managers alone. Fortunately, the long-term monitoring of EBV can be covered by programs involving volunteers (Chandler et al. 2017), demonstrating the high value of public participation in ecological monitoring.

Citizen Science (CS) programs are increasingly helping with environmental, evolutionary, biogeographic, and conservation issues at broad scales, and have yielded important scientific results (Bonney et al. 2015; Devictor et al. 2010; Dickinson et al. 2010; Silvertown et al. 2011). Volunteers not only supply a large quantity of data at relatively low cost (see for example Schmeller et al. 2009; Levrel et al. 2010; Bonney et al. 2015), but they also experience a personal increase of their understanding of science (Pocock et al. 2015). Public data collection projects are, for such reasons, becoming an essential part of environmental monitoring and adaptive management (Aceves-Bueno et al. 2015). Nevertheless, these projects may entail an important risk for subsequent data analysis if non-professionals tasks go beyond using digital devices recording environmental variables. Moreover, data collection might be challenging when dealing with living organisms because some are difficult to be spotted or present difficulties for taxonomical identification; as a result, variations in sampling effort might end up in serious bias and compromise the scientific use of the data. Therefore, volunteer mentoring and data validation are key elements in programs involving the participation of non-professionals (Crall et al. 2011; Isaac and Pocock 2015).

Well-designed and supervised CS projects not only improve cost effectiveness compared to traditional monitoring involving professional experts, but they also reduce the cost of achieving community engagement in environmental issues. Since volunteer characteristics such as education, motivation, prior experience or training can affect the quality of data (Ahrends et al. 2011; Crall et al. 2011; Jordan et al. 2012), an important question in CS programs is to explore weather their previous experience or academic background can influence their personal satisfaction, effort invested, or quality of data gathered.

In this paper we describe the structure, functionality and effectiveness of the network behind a participatory monitoring project carried out in a very diverse region of the Northeast of Spain: MONITO (see details at http://www.liferesecom.ipe.csic.es/en.php, webpage of a LIFE project included). The overall objective of MONITO is to arrange a long-term system able to assess the conservation status of the most singular, vulnerable and/or interesting flora, as well as some key species of habitats of interest to the European Union for which remote sensing does not work. To accomplish this objective, we promote and arrange widespread data collection at two complementary levels entailing different degrees of commitment and skill: regional-distribution species and local-population abundance. The first level (distribution) is a classical approach based on species distribution with the aid of photo vouchers, GPS records or herbarium specimens, plus additional information on the population size and actual threats. In this case participants need a minimum botanical knowledge and they conduct the surveys on their own. The second level (local abundance) focuses on demographic changes at local scale through the collection of abundance data over one decade, following a population-specific protocol. This is the "*Adopt-a-plant*" program, which has a strong scientific component and will produce standard indexes like the population growth rate (see for example García et al. 2010). This second level is expected to provide earlier warnings of negative trends than the distribution one. To the best of our knowledge, the *Adopt-a-plant* program is a unique case in the world because, contrary to most traditional CS projects where volunteers contribute to better map plant diversity (see for example Pescott et al. 2015), it deals with long-term trends of plant populations, and sampling designs are carefully set for each monitored population (see below).

An important point of the philosophy of MONITO is that anyone should be able to participate, either at the distribution or local abundance level, or both. Although the overall project has an important CS component, rangers working for the Administration also do participate. Rangers and volunteers get the same kind of training and carry out similar tasks under the supervision of a team of scientists. Neither rangers nor volunteers are "professionals", but the former participate as part of their job, have easier movement within their working range (four wheel cars available and no permits needed to drive through protected areas), and they have experience or background on environmental issues (censuses of birds or mammals are part of their job).

In order to examine the effectiveness of the fast growing MONITO network, and find out key points for the implementation of the novel *Adopt-a-plant* program elsewhere, we analyzed its current structure, some characteristics of people involved, the effort investment (days for training and hours of fieldwork), and the data quality. We compared those variables between volunteers and rangers to test if our methods are good enough to make results independent on collective background and professional situation. On the other hand, evaluating what can encourage participation of citizen scientists is critical, and which incentives keep their enthusiasm need to be an integral part of a long-term project. Consequently, we also report the learning growth and overall satisfaction of the participants, an information not commonly reported in CS programs (Bela et al. 2016). In particular, we aimed to answer the following questions: 1) do volunteers and rangers perform similarly at the distribution and population levels, and what are the main differences between them?; 2) what is the main reward volunteers get when they are involved in the *Adopt-a-plant* program?; and 3) what is the cost and rate of success of the *Adopt-a-plant* program in terms of time invested by trainers and participants?. Identifying the strength and weaknesses perceived by participants and scientists will help to increase the success of similar projects in the future.

2. Material and Methods

2.1 The MONITO project

MONITO was launched as a pilot project for the Natura 2000 network of NE of Spain in 2010 by the Pyrenean Institute of Ecology (IPE-CSIC), under request of the Regional Government of Aragón. Later it was supported by national research projects and mainly the European Union through a LIFE project carried out by both institutions. The Natura 2000 network is the largest network of protected areas in the world, and consists of a set of selected European areas for the conservation of species and habitats. Many of the studied species so far in MONITO are catalogued of Community Interest and listed in Anexes II, IV and V of the Habitats Directive, whereas others are cataloged as threatened at the regional or national level. Another important monitored group of plants are narrow endemics, or classified as rare, alpine, or indicator of climatic change (e.g. typical of wetlands). A last group of plants are characteristic of Habitats of Community Interest, and their dynamics will be used to evaluate habitat changes. The area where MONITO is carried out covers an extension of 50000 km^2 across an altitudinal range of

40 - 3355 m a.s.l. (the whole Aragón Autonomous Community), and includes about 3500 vascular plants, which represents one fourth of the European flora according to the collective work *Flora Europaea* (Tutin et al. 1964-1980). Populations of monitored species are located in contrasted environments, from semi-deserts of the Ebro Valley to Pyrenean alpine summits.

The MONITO people network is made of two different collectives: volunteers (VOL) and rangers working for the Regional Government of Aragón (RAN). VOL pay their own expenses, and carry out censuses during free-time (vacation or weekends). RAN are selected by their coordinators at the Regional Government according to time availability, background knowledge on botany, and previous experience in other ecological monitorings. Participants are offered a choice of species and populations among a list of plants of interest. They can decide according to their physical condition and preference to visit a site over the next decade. Often volunteers just want to be of any help to the project, and let scientists to choose the monitored plant or habitat for them. The number and kind of plants or habitats adopted by rangers, on the contrary, is usually limited to threatened plants and habitats of community interest occurring in the area they conduct their work. Monitored sites are annually visited by individuals or teams of up to six people. When there is more than one person involved in the same monitoring site, one is designated in charge of communication (responsible) and the others as assistants. The turnover of responsible participants was calculated for VOL and RAN since the beginning of the program.

Sampling design, fieldwork protocols and training, and overall coordination of the network are carried out by the research team. This team is also responsible for subsequent data validation and analyses to produce conclusions on the dynamics of biodiversity in the working area (Fig. 1).

< Figure 1 >

Besides accurate geolocalization of the populations, fieldwork protocols for the distribution level request information on the total occupancy area and population size, as well as current threats or disturbances. Protocols for the population level request information on the abundance of the target plant such as presence, plant cover or number of individuals in permanent, replicated areas across the population. Sampling design is customized for each site (variable number and size of permanent plots or transects) to fit the physical conditions of the responsible person or team, and to reduce sampling error by taking into account density, population size, and biological features such as plant size. The ultimate goal is to produce reliable population time series from single-species or multi-species monitoring schemes. The first monitoring year the scientists spend one day with each team in the field, explain the reasons to set up the design in a particular way, and train them to overcome difficulties by carrying out the census together. If necessary, scientists assist volunteers and rangers over a second or third year to make sure that errors in species detection and individual counting across multiple sampling units are minimized, and the sampling method holds through time. Personal communication with participants is frequent later on, in order to assist or provide them with the necessary information, materials, or to validate data. That interaction usually takes place individually, although general meetings also take place in towns or cities (Fig. 1).

2.2 Assessment of MONITO's network: structure, functionality and effectiveness

We used four different sources of information to describe the MONITO network and its functionality (see Table 1):

1) The volunteers network database in December 2017, containing information of variables such as age, academic background and current job.

2) The total number of monitored sites and the onset year.

3) An anonymous survey requesting information to VOL and RAN such as degree of satisfaction with the program, and evaluating the scientists mentoring them. The survey was answered by 102 people (72 volunteers and 30 rangers), representing about 70% of participants at the time it was conducted (December 2016).

4) The total number of training hours in the field, and a scientific evaluation of the quality of the monitoring carried out by the participants ("quality assessment"). Both summarize the effort made by the research team, and the data accuracy in each monitored population.

2.3 Data analysis

Chi-square tests were used to compare differences between VOL and RAN for variables listed in Table 1. In the anonymous survey, if one of the levels of the variable under analysis got extremely low frequencies, "(very)low" and "intermediate" frequencies were added up to be compared with "high" (df=1 instead of df=2). Exact Fisher tests were used instead when cell proportions of the 2x2 contingence table did not meet Chi-square test requirements.

< Table 1 >

3. Results

MONITO consists of 205 active participants by December 2017, 65% volunteers (133) and 35% rangers (72). About one fourth of VOL (35 persons), and half of RAN (35 persons) have participated in the distribution level, providing information on the presence and population extension or size of catalogued or rare species across the region. The higher participation of RAN in this level reflects their facility to move around, higher time availability in the area where plants occur, and experience with maps and GPS devices. This level seems therefore more suitable for rangers than volunteers.

A much higher proportion of participants (93%) are engaged in the *Adopt-a-plant* program (local-abundance level), i.e. monitoring one or several plant populations or habitats. This program was launched in 2010, and it has grown at an average of 31 new monitoring sites per year since 2014. Before launching MONITO, only a handful of populations of endangered plants had been monitored in the region, whereas 183 population time series from single-species or multi-species monitoring schemes are being produced now (Fig. 2). RAN and VOL contribute similarly to this program in terms of number of plants or habitats monitored, although volunteer participation has been growing faster in the last years (Fig. 2).

< Figure 2 >

VOL ages range between 23 – 77 years old, although more than half (57%) are between 46-65 yrs old (n=122; Fig. 3A). Gender ratio is balanced (1.2:1 for males:females respectively; X^2=0.538; d.f.=1, p=0.463), although females outnumber males at younger stages (26-45 yrs old). Gender ratio for the RAN collective, in contrast, is very much biased, with 65 males and only 6 females involved (X^2=29.629, df=1, $p<0.001$), which is in accordance with a rather unbalanced gender ratio in this collective.

The typical profile of a volunteer is a College graduated (64%), with no previous background in Biology or expertise in monitoring (65%) and working as a state employee for the public Administration (45%; Fig. 3B). There are some expert amateurs very skillful for plant identification, but many VOL engaged in the *Adopt-a-plant* program carry out fieldwork in small groups and do not know the scientific names of the plants. After a short fieldwork training, however, they are able to distinguish a juvenile and adult plant of the species they have adopted. There is a high variability in their academic and professional status, from elementary studies to University professors, and from students to owners of small companies. Their jobs represent a cross-section of the Aragon community, including nurses, teachers, salesmen, businessmen and women, massage therapists, policeman or Director of a public Research Institute (Fig. 3C). Only 14% of VOL are retired, and, consequently, most volunteers collaborate in the project during weekends or vacations. Despite such variety of academic backgrounds, professions and expertise, the quality of data gathered by both collectives was similar, slightly but not significantly higher for RAN than VOL (94% and 85% got the category of “high or very high” respectively; X^2=2.847, df=1, p=0.092).

< Fig. 3>

Since the pilot project was launched virtually all participants have monitored their population every year. Three volunteers dropped the program due to job requirements or health problems.

Meanwhile, some people from other Spanish regions have requested to participate when they knew about the *Adopt-a-plant* program, which means it is attractive enough to people that has to travel hours and stay longer than a single day in the region. The main difference between RAN and VOL is the higher turnover for RAN (25%) than VOL teams (6%; X^2=13.23, df = 1, p <0.001), caused by the high job mobility of the formers. In these cases, we have to find replacements, and sometimes repeat the training to make sure that the newcomers will follow exactly the same protocol.

Most VOL invest less than one hour travelling and hiking to the population or habitat they monitor, and less than half a day carrying out the annual census (Fig. 4). Between 11% and 14% (VOL and RAN respectively) invest more than three hours before they start monitoring. A few (8% and 10%) declared that it takes them more than a full day to finish the census. Overall, both collectives show a similar pattern of time invested per site monitored, slightly lower for RAN than VOL (Fig. 4). The total time invested by scientists training or assisting them in the field was very similar for VOL and RAN: 1.3 and 1.4 working days per monitored site respectively. Actually, the range of such assistance goes from just using the phone to instruct them how to proceed (in very simple cases of populations consisting of a few individuals it was not necessary to do training in the field) to up to five days in five years (when there was a high turnover of people through time, or it was necessary to change the method or to set up new permanent areas due to disturbances or loss of signs).

<Fig. 4>

According to responses of the survey (Fig. 5), both collectives ranked similarly as “low or very low” the effort they invested for fieldwork (X^2 = 0.691, df = 1, p = 0.406), although it seems to be less costly for RAN (60%) than VOL (49%). The degree of learning or participating in science did not differ between collectives either (X^2 = 1.0512, df = 2, p = 0.591), but 43% of VOL considered it “high or very high” whereas the same percentage scored it as “intermediate” among RAN (Fig. 5). VOL declared a higher satisfaction of being enrolled in MONITO than RAN (83% versus 67% respectively; X^2 = 3.477, df = 1, p= 0.0622), and scientists got higher marks from VOL than RAN too (93% and 80% of VOL and RAN scored the work of scientists with them as “good or very good”; Fisher exact test p-value = 0.077). Interestingly, RAN were more prone to “adopt a new plant” (63%) than VOL (43%), suggesting that either rangers really enjoy the program or prefer this activity to other regular tasks included in their jobs.

Almost half of the people (47% of both collectives) have suggested colleagues or friends to join the program, and 60% of VOL knew the program through a colleague or friend. Only 12% was aware of the program through the media. Thus, participant recruitment is not a problem, since newcomers usually join the project through friends and relatives, not publicity campaigns. VOL and RAN seem to get a similar enjoyment from their involvement in the project, ranking first their “participation in a scientific project” (61%-67% respectively), and second, third and fourth “improving their botanical knowledge”, “learning about the dynamics of a threatened plant”, and “being part of a network” (53% - 67%). Whereas VOL rank fifth “to go out to the field” (36%), RAN have no interest on that, which makes sense because they spend most of the time outdoors; they placed “training courses” in fifth position (10%).

<Fig. 5>

4. Discussion

MONITO can be considered a “targeted monitoring” (*sensu* Nichols and Williams 2006) and “adaptative monitoring” project (Lindenmayer and Likens 2009), conceived as a tool to track the tendencies of many singular, vulnerable, or key plant species of habitats through time. It involves two different collectives of participants (volunteers and rangers), and two complementary operational levels of data gathering (regional-species distribution and local-population abundance). The complexity and integrative nature of MONITO confers the project with the capacity of addressing broad environmental questions related to biodiversity changes.

The Group of Earth Observations Biodiversity Observation Network (GEO BON) recently proposed monitoring species distribution and population abundance and structure as one of the Essential Biodiversity Variables related to biodiversity changes (Pereira et al. 2013), and citizen science as a feasible method for that (Chandler et al. 2017). At the same time, determining trends in abundance has become a standard indicator adopted by EU members to implement the Convention on Biological Diversity (European Environmental Agency 2009; Levrel et al. 2010), but only for selected species of birds and butterflies. In this paper we have demonstrated that collaborative projects such as MONITO, based on personalized research experiences of non-scientists, can accurately contribute to track changes of plant population abundance besides species distributions, and produce reliable and standard indicators similar to the ones used for animals.

As most CS programs, a scientific institution is behind MONITO data collection on plant distribution, i.e. CREW in South Africa (https://www.sanbi.org/biodiversity-science/state-biodiversity/biodiversity-monitoring-assessment/custodians-rare-and-endan), POC in Chicago (Havens et al. 2012), etc. The Pyrenean Institute of Ecology, home base for the project, has welcomed public participation in its herbarium for decades since its foundation in the 1960s. The citizen involvement has increased after launching two digital platforms that describe the flora or the NE of Spain and offer extensive information about the distribution and biology of plants in the region: FLORAGON (http://floragon.ipe.csic.es/alfabetica.php) and FLORAPYR (http://atlasflorapyrenaea.org/florapyrenaea/index.jsp). With these tools, visual self-learning about plant identification has become easier for amateur volunteers and rangers, and their contribution to species distribution has increased in the last decade (García et al. unpublished). It is crucial to keep their enthusiasm through collaborative and coordinated projects because these expert amateurs, together with ecological consultants, will have to sustain the inventory and surveillance of biodiversity in the near future after the loss of professional taxonomists in academic institutions (Drew, 2011). Therefore, the contribution of non-professionals to biodiversity is not just an opportunistic option but a need if we want to acquire reliable inventories of biodiversity to implement effective conservation management practices.

The main concern of CS programs is the quality of the data from a scientific point of view, as low-quality data would lead to inappropriate conclusions. Some studies have explored unavoidable shortcomings and statistical solutions for error and bias (Bird et al. 2014; Isaac et al. 2014), but most analyses rule out concerns about low quality of data gathered through CS projects, as many examples show that volunteer-collected data in well-designed studies are as good as those collected by professional scientists (Comber et al. 2016; Lewandowski and Specht, 2015). Prior knowledge has been suggested to improve data quality, and professionals are also thought to produce data of higher quality than volunteers because they are likely to have more training and experience (e.g. Ahrends et al. 2011). However, a recent review failed to conclude that (Lewandowski and Specht, 2015). Moreover, much assessment on data quality has concentrated on surveillance monitoring of species over broad geographic regions (Dickinson et al 2010), and CS methods are so diverse that it is difficult to make generalizations. The potential effect of prior experience or any other social variable or demographic trait of participants on their skill for the collection of high quality data seems to be very much task dependent (Crall et al. 2011).

Concerning MONITO, we found that the regional-species distribution level seems to be more suitable for rangers because of their stronger background or experience in environmental monitoring, besides easier movement in areas of high diversity. Only a few expert volunteers can make a valuable contribution in an independent way, as most of them restricted their contribution to filling up the protocol of their monitored plant population. Giving the high turnover of rangers, this “opportunistic monitoring” (*sensu* Lewandowski and Specht, 2015) seems more suitable for them because it is not as dependent on repeated visits or censuses as the local-abundance level. They spend much time in the field, know well remote places, and have higher chances to find out rare local plants compared to volunteers. Data gathered through this level serve to qualitatively assess the overall conservation status of target plant species (i.e. number of populations, overall population sizes, threat and pressures), but they might be less useful to produce indexes describing the current performance of populations.

Participants of the *Adopt-a-plant program*, on the other hand, follow a strict protocol set up by scientists in the field at each monitored site. Since this program fits a systematic monitoring scheme based on repeated annual censuses over a decade, special care is taken to guarantee that neither the participant nor the method for data collection change through time. To ensure data accuracy, data are validated by the scientific team after collection: if suspicious data come up, participants are contacted to avoid mistakes (Fig. 1). Maintaining the same methods for both volunteers and rangers allowed us to test the general validity of the protocols and procedures, and, as we discussed in previous sections, we could not find significant differences in the quality of their contribution. Actually, we think that the difficulties for carrying out an accurate census have little to do with the collective and come up from the local conditions of the monitored plant or population. For example, to estimate abundance data for a small plant with clonal reproduction, occurring at high density, or under high interspecific competition usually entails a higher sampling error than counting large individuals clearly separated.

Personal interaction is a crucial variable in MONITO, and that needs a strong implication and commitment of the scientists. Our approach greatly differs from most successful web-based portals where volunteers collect and send information on their own. In our case, the success of the project among volunteers with high academic level might have to do with their enjoyment of the rigorous scientific methodologies, and among volunteers with no botanical experience with the security provided by scientists. Real-time communications and face-to-face interactions make rangers and citizen scientists feel that their participation is a personal and unique research experience, and they become more confident and motivated about the utility of their contribution to science.

Rangers often work in protected areas of high biodiversity value, sometimes located in remote or more isolated mountain places difficult to reach, and monitor threatened plants. They play an important role for policy-makers, responsible for the assessment of the conservation status of listed plants or habitats in official catalogues. However, rangers have many other tasks, and their contribution to the future growth of the network will be probably limited by the size of the collective and high turnover. Volunteers, on the other hand, need to be often mentored and helped during weekends and they need special permits to monitor protected species or move across protected areas, but we notice how quickly they learn plant names and natural history, and try to enroll friends and relatives in MONITO. Since their recruitment is faster and less than 3% of them abandoned the program, they will probably make a larger contribution to the expansion of the network in the future.

It is well known that volunteers are more likely to stay with projects in which scientists regularly offer feedback, provide progress reports, thank them for participation, and arrange field trips and local meetings to increase the likelihood of easier communication (Bell et al. 2008; Havens et al. 2012; Kühn et al. 2013). This is also what we found in our program, and that is why we pay attention to social aspects of the project beyond data quality. MONITO volunteers constitute a community of participants sharing common features (they do not enjoy any economic incentive, hardly use technological tools, the majority have no previous botanical knowledge), and interests (enrollment in a scientific program and potential for increasing knowledge are common motivations). That is why besides personal communication about annual data collection, every year we arrange an "*Adopt-a-plant* celebration day" in a protected area. We show the results collected over the year, introduce new volunteers, hike to enjoy the area and learn local plants, promote exchange of information among people, and give them the annual certificate of engagement with a particular plant or group of them in a habitat. Such event is our way of saying thank you and paying back for their work. As demonstrated in other projects, including human and social components since the beginning is a guarantee of success in volunteer-based long-term monitoring schemes (Dickinson et al. 2012).

Citizen Science projects are often focused on environmental data collection across an array of locations, sometimes at continental scale. MONITO is geographically more restricted. It was born to expand the reduced capacity of scientists and managers in a region of high biodiversity with very few professionals, and solve the dependence of data collection from annual budgets approved by politicians. The project, therefore, aims at resolving some of the shortcomings of environmental monitoring and public engagement, by providing a way of involving amateur botanists and plant ecologists in a scientific project. CS programs have a great potential for *in situ* long-term monitoring given their relative independence of external funding. Actually, well-organized CS projects are several years longer than the mean length of US National Science Foundation grants (Theobald et al. 2015). Recent studies demonstrated that some CS projects monitoring forests, birds and butterflies resulted in large net savings as compared to the expected costs of monitoring by government employees (see review in Aceves-Bueno et al. 2015). The impact of biodiversity-based CS projects is enormous all over the world: more than two millions of volunteers collect data, which translates into billions of US$ or € and hundreds of scientific publications (see reviews in Bonney et al. 2015, Theobald et al. 2015). But developing and implementing public-data collection projects that yield both scientific and educational outcomes requires significant effort (Bonney et al. 2009). CS programs cannot be regarded neither a panacea nor a cheap way of collecting biodiversity information (Levrel et al. 2010). They require coordination and assistance, and have very important educational and social emergent properties that go beyond pure academic or management subjects. In the case of MONITO it has been necessary to set up easy and robust designs in the first fieldwork visit, train participants in a very effective way, simplify protocols to become straightforward and easy to be filled, and launch new social activities every year to keep the motivation of veteran participants. This also means to maintain the availability of the facilities (the Herbarium and biodiversity database), and the salaries of the trainers. The scientific team has to find and check the suitability of new populations to monitor in the field, assure data quality control through interactive communication with participants, and assist with general meetings and activities. But obviously the cost-benefit of a CS coordinated system is very efficient.

5. Conclusions

MONITO represents a clear improvement in the first step of plant conservation management: the integrative and extensive collection of rigorous data on distribution, occupancy, threats, and trends of plant species over a diverse territory. Besides, the project constitutes an example of partnership between participants with and without experience, managers and scientists, and also serves to connecting scientific research to public outreach and education. Volunteers are always there, but their enthusiasm and energy need to be coordinated and hold through time. Managers need information from monitoring programs for resource management, and have employees enrolled in them. Scientists should be either responsible or involved in “adaptive monitoring” (*sensu* Lindenmayer and Likens 2009) for designing adequate and efficient monitoring systems, to establish quality controls and apply rigorous statistical analysis. The success of a project with more than 180 monitoring sites and the regional recruitment of 200 rangers and volunteers in less than a decade in a small European region is an evidence of its potential, and make us confident that it can be replicated in other regions.

In the near future, standardized population trends will be associated to global change drivers such as extreme climatic events or habitat modification, because other data are being gathered in parallel with plant abundance: temperatures are recorded by miniaturized instrumentation, and land use changes by remote sensing. This design turns our cluster of monitoring sites into a “long-term monitoring mini-sites network” (Haase et al. 2018), where both biotic and abiotic variables are integrated to provide more powerful conclusions. Well-organized networks involving volunteers, even operating at regional scales such as MONITO, constitute promising and feasible observatories of biodiversity changes: they increase our scientific knowledge, facilitate public awareness of environmental problems, and provide information to policy-makers responsible for adaptive managements.

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Fig. 1 MONITO organizational structure including stakeholders and actions involved in each step of the process, from sampling design to final reports for administration, agencies, and general public.

Fig. 2 Cumulative number of monitored plant populations or habitats started with volunteers (VOL) and rangers (RAN) since MONITO was launched as a pilot study in 2010. The map shows the European area where MONITO is implemented (Northeast of Spain: Aragón region).

Fig. 3 Demographic and social characteristics of MONITO volunteers: gender and age structure (A), academic background (B), and current job (C). See Table 1 for further details.

Fig. 4 Percentage of participants (VOL: volunteers, RAN: rangers) of the program *Adopt-a-plant,* according to the total time invested for travelling (driving + hiking) to get to the monitoring site plus carrying out fieldwork once arrived to the site (results come from the answers of n=100 participants).

Fig. 5 Percentage of participants according to their perception of general effort, learning or approaching to science through the project, overall satisfaction, and assessment of his/her scientific mentor (results come from the answers of n=102 participants).

Figure_1

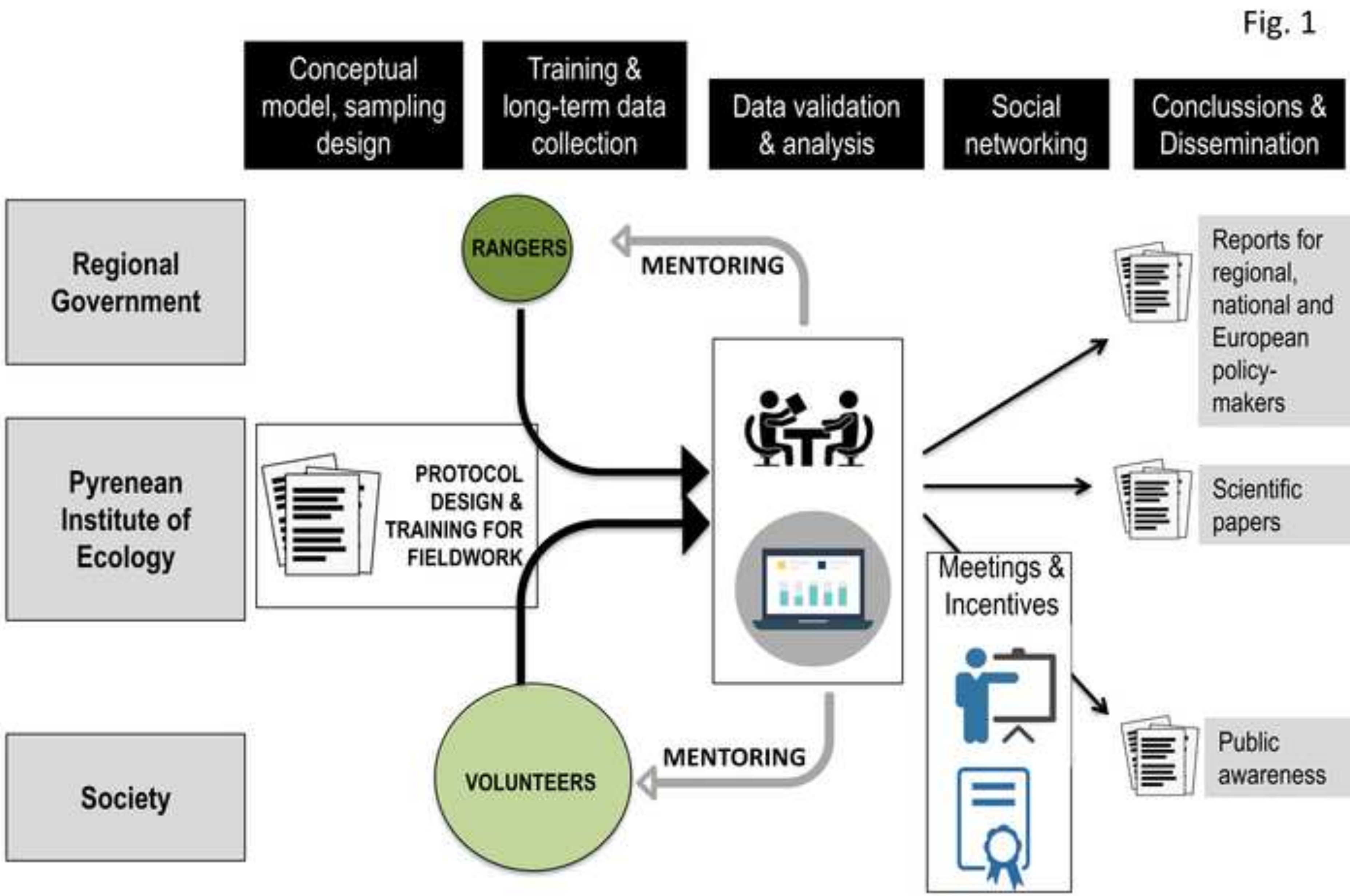


Fig. 1
Conceptual model, sampling design
Training & long-term data collection
Data validation & analysis
Social networking
Conclussions & Dissemination
Regional Government
Pyrenean Institute of Ecology
Society
RANGERS
MENTORING
PROTOCOL DESIGN & TRAINING FOR FIELDWORK
VOLUNTEERS
MENTORING
Meetings & Incentives
Reports for regional, national and European policy-makers
Scientific papers
Public awareness

Figure_2

Fig. 2

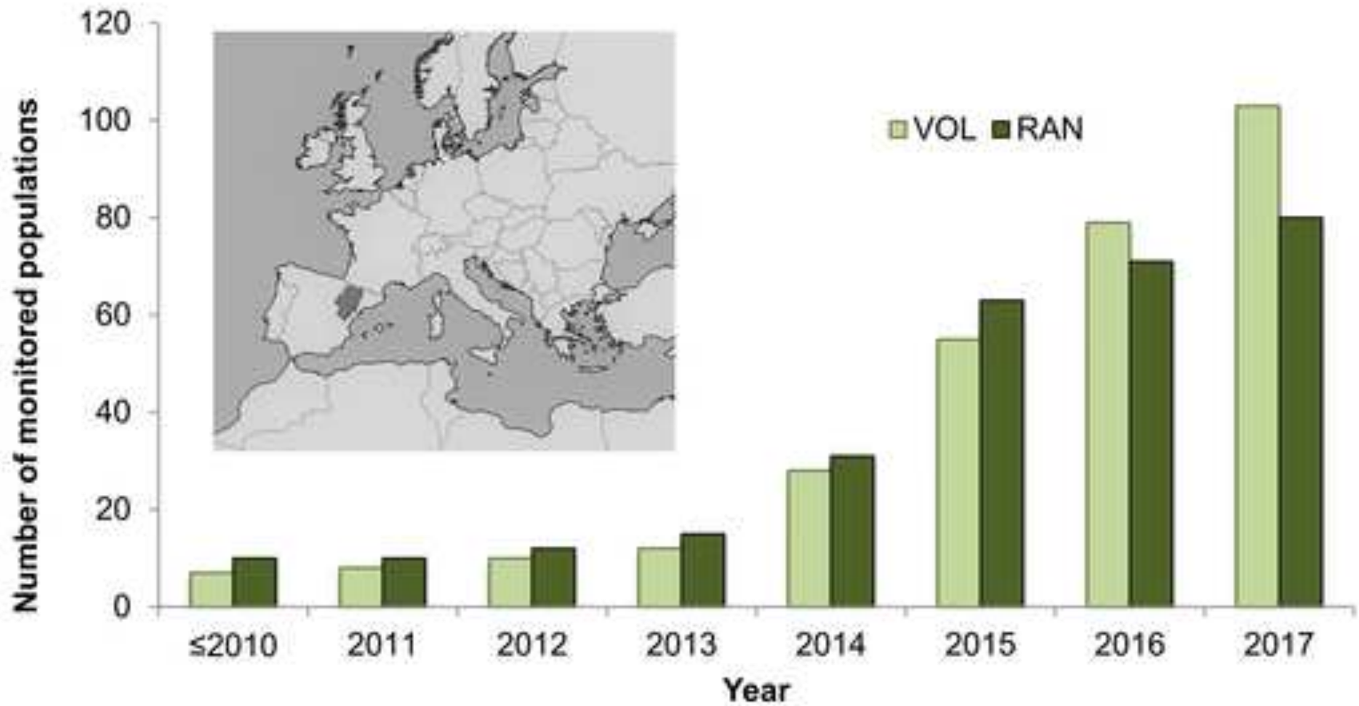


Figure_3

Fig. 3

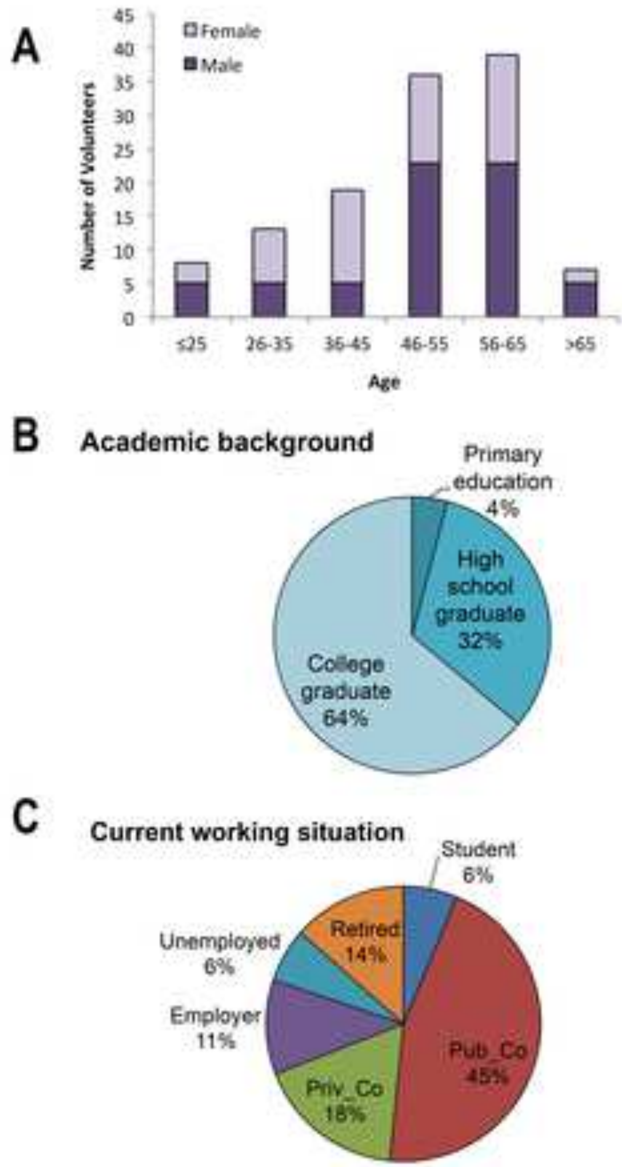


Figure_4

Fig. 4

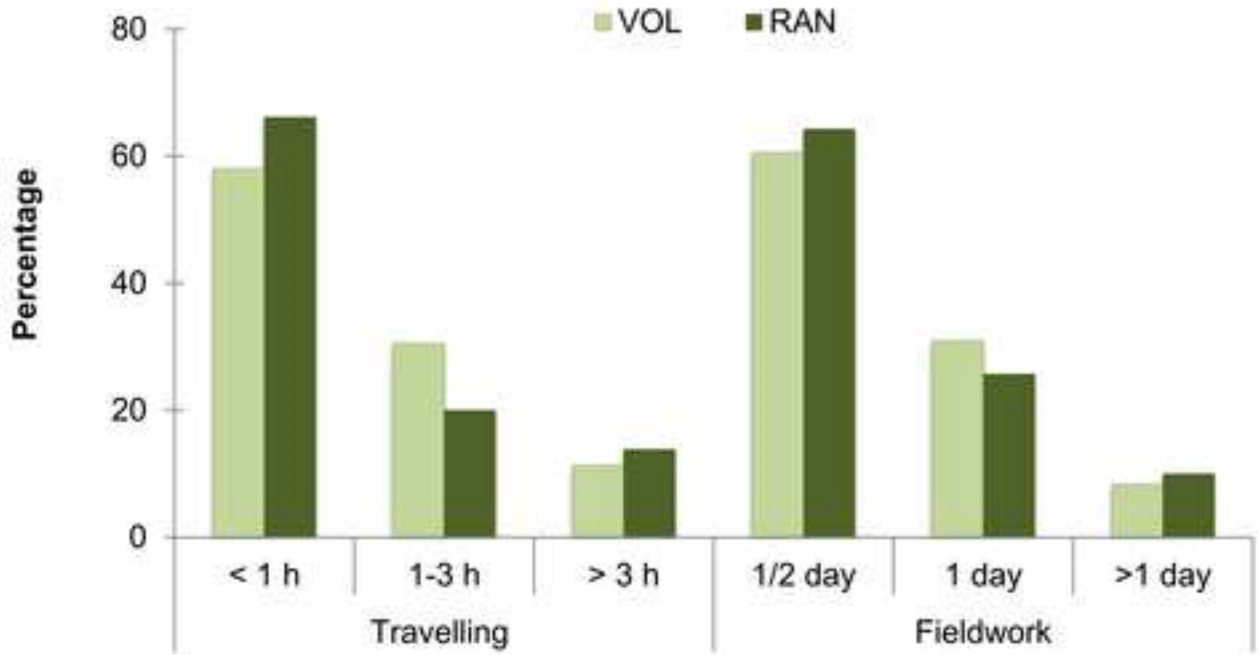
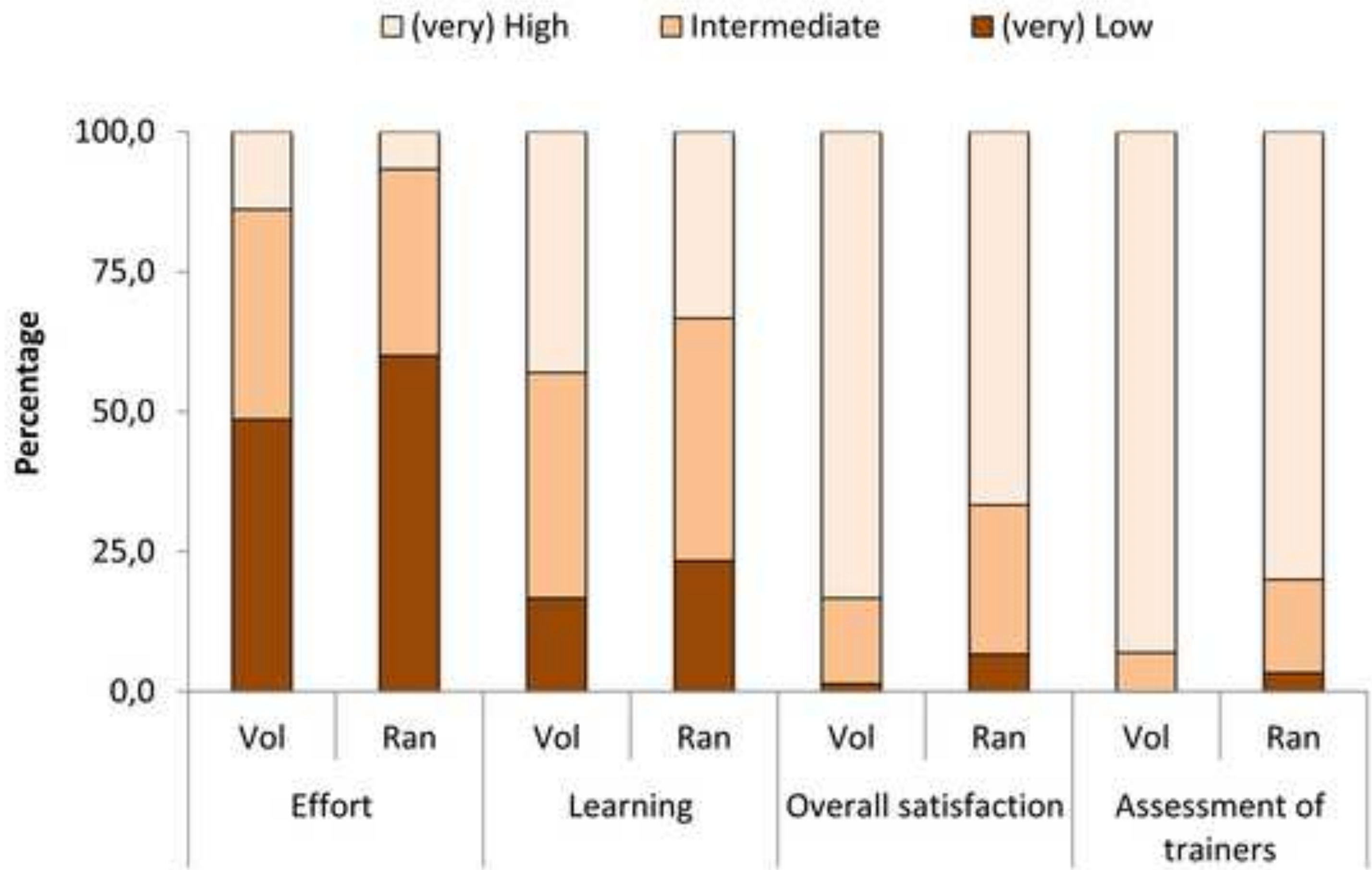


Figure_5

Fig. 5



Table

Table 1 Variables obtained from three different information sources to describe and assess MONITO, and possible values or responses

Information source	Variable	Score or answer
Monitored sites		
	Collective responsible	VOL (volunteer) / RAN (ranger)
	Starting year of the monitoring site	≤2010 / 2011 / 2012 / 2013 / 2014 / 2015 / 2016 / 2017
Volunteers network database		
	Collective	VOL (volunteer) / RAN (ranger)
	Age (years)	≤25 / 26-35 / 36-45 / 46-55 / ≥65
	Academic background	Primary education / High school graduate / College graduate
	Current working situation	Student / Pub_Co (Employed in a public company) / Priv_Co (Employed in a private company) / Employer / Unemployed / Retired
	Biological background or experience in monitoring	Yes / No
	Participation in distribution and/or local abundance level	Distribution/Local abundance/Both
Anonymous survey (VOL + RAN)		
	Collective	VOL (volunteer) / RAN (ranger or equivalent)
	Days per year invested in the "Adopt-a-plant" program	1 / 2-3 / 4-10 / More than 10
	Hours invested in travelling to the monitoring place	1 / 1-3 / >3
	Time invested in fieldwork once in the monitoring place	Half day / One day / More than one day
	Perception of time invested in the project	(very)Low / Intermediate / (very)High
	Perception of scientific learning or approach to science in the project	(very)Low / Intermediate / (very)High
	Degree of overall satisfaction as participant in the project	(very)Low / Intermediate / (very)High
	Evaluation of the responsible scientist	(very)Low / Intermediate / (very)High
	Would you adopt another plant?	Yes /Maybe / No
	How did you know about the network?	By friends or colleagues / Naturalist associations / Media / Others
	Have you recommended other people to participate?	Yes / No

	What do you like most of participating?	Be part of a scientific project / Learning botany / Determine the success of an endangered or rare plant / Share experiences with other people doing the same / Going out for fieldwork / Attending trainining courses / Others (free description)
	What would you like to get from the project and do you miss?	(Free description)
Scientist assessment		
	Total number of days of fieldwork assistance per MU to train participants	1 / 2 / 3 / 4 / 5
	Degree of accuracy after participants independency	Low / Intermediate / High