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Towards a new flora of Liguria: the usefulness of citizen science through the Wikiplantbase floristic surveys

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SUMMARY

The current understanding of the richness and distribution of plant species on a national scale, achieved by the recent checklists of Italian flora, is largely based on the quality and thoroughness of the data provided by regional floristic studies. This knowledge benefits from regional databases, such as the Wikiplantbase #Liguria project, which offers an online platform where thousands of geo-referenced floristic records from Liguria (north-western Italy) are stored and freely accessible. In 2019, adopting a citizen science approach, a floristic survey program consisting of 11 excursions opened to the public was implemented, with the aim of deepening the floristic knowledge of some poorly investigated areas of the region. The active collaboration between scientists and volunteers led to the collection of about 4000 floristic data corresponding to more than 800 taxa, including 13 taxa unknown or no longer recorded for Liguria. These results suggest that citizen science can be a useful tool to address the knowledge gaps of regional floras. In particular, collaboration between experts and non-professional botanists allows to collect reliable data even for hardly-to-recognize taxa, contributing to fix some gaps occurring in the Wikiplantbase #Liguria project.

INTRODUCTION

The new checklists of the Italian flora provided an updated inventory of species occurrence in each Italian administrative region (Bartolucci et al. 2018, Galasso et al. 2018), largely carried out by regional experts, thus renewing the importance of regional floristic researches. Unfortunately, the inhomogeneous floristic knowledge among the Italian regions (Scoppola 2005) may compromise the understanding of national pattern of distribution and richness and hamper the actions for species conservation, thus recalling the need for regional floristic studies.

The Liguria region shows a very high floristic richness (i.e., more than 3000 species –

Bartolucci et al. 2018) despite the surface of less than 5.500 square kilometers. The unusual variety of climatic conditions caused by the crossroad of the Mediterranean, the European and the Alpine biogeographical regions (Rivas-Martinez et al. 2004) together with the high lithological heterogeneity (Capponi et al. 2008, Hartmann and Moosdorf 2012, El Ghalabzouri et al. 2013) have led to a remarkable diversification of habitats (Mariotti 2009). Moreover, the Ligurian flora is characterized by a high endemism rate (Peruzzi et al. 2014, Casazza et al. 2016, Orsenigo et al. 2018), further increased considering the sub-endemic species occurring in the Ligurian Alps, a cross-border territory of exceptional naturalistic value within the Mediterranean Basin (Martini 1984, Médail and Quézel 1997, Casazza et al. 2005, 2008, Aeschimann et al. 2011).

Nevertheless, the Ligurian floristic knowledge suffers from the scarcity of recent studies. The floristic researches published in the last two decades have concerned only small parts of the region, like the Eastern Ligurian Apennines (e.g., Vagge 2000, Bracchi et al. 2003, Peccenini et al. 2007, Montanari et al. 2013), the conglomerate of Savignone (e.g., Orsino and Dameri 2001), the Cinque Terre National Park (e.g., Peccenini 2005), the Ligurian Alps (e.g., Casazza et al. 2010, Peccenini et al. 2010, Siri et al. 2012, Marsili et al. 2013) and the Apuan Region (e.g., Marchetti 2011). Most of the other floristic studies have focused on a few target species (e.g., Cardelli et al. 2000, Arrigoni 2003, Marsili et al. 2007, 2009, Baldini et al. 2010, Barberis and Nardi 2011). Moreover, the limited access to herbaria and the scarce digitization of bibliographic data hinder the use of already existing data. All these shortcomings can explain the large number of species (nearly 300) reported for Liguria as "No longer recorded" (Bartolucci et al. 2018) and the general scarcity of georeferenced floristic data.

An opportunity to deepen the Ligurian floristic knowledge is the involvement of all florists active in the territory, both academics and amateurs, as advocated by citizen science (Mathieu 2011). Involving the public in scientific projects allow a massive data collection concerning ecology, biogeography, environments and natural heritage conservation (McKinley et al. 2017), reducing the field effort in projects on large areas or long periods (Hochachka et al. 2012), also saving public money (Schmeller et al. 2009, Harold et al. 2010, Chandler et al. 2017). For these reasons, citizen science is increasingly becoming a useful research tool employed in both basic and applied studies (Dickinson et al. 2010). Several examples exist concerning population dynamics of sensitive species (Rodriguez 2002, Sauer et al. 2003, Schultz et al. 2017), distribution of invasive species (Delaney et al. 2008, Ingwell and Preisser 2011, Burrack et al. 2012) and environmental changes (McCormick 2012, Hemmi and Graham 2014, Huddart et al. 2016).

In recent years, the Wikiplantbase project is aimed to realize a collaboration between academics and amateurs, providing a free access online platform for storing and updating geo-referenced floristic data in Italy (Bedini et al. 2016, Peruzzi et al. 2017). After the beginning in few regions with regional databases, i.e. Tuscany (Peruzzi and Bedini 2015), Sardinia (Bagella et al. 2019), Sicily (Domina et al. 2019) and Liguria (Barberis et al. 2019), this project has recently been extended to national level (Peruzzi et al. 2019). After few years from its inauguration occurred in 2016, the Wikiplantbase #Liguria dataset included about 40,000 records, thanks to the participation of 23 contributors (Barberis et al. 2019). Nevertheless, some important limitations still compromise the usefulness of the database: i) only less than a quarter of data (i.e., 23%) refers to the last ten years; ii) about a third of data (i.e., 33%) is not georeferenced; iii) species are unequally represented (except for few areas where thorough floristic research was uploaded like Pandiani 1913, Ariello 1957, Di Turi 2014); the geographical distribution of data is strongly inhomogeneous (e.g., the seven most data-rich municipalities, representing the

6.6% of the Ligurian area, cover more than 57% of the overall dataset). These issues produce a biased picture of species distribution in Liguria, highlighting the need for collecting new georeferenced data through an accurate selection of poorly surveyed areas.

In order to fill the gaps identified in the early years of the Wikiplantbase project, since 2019 a new program of floristic excursions open to both experts and citizens scientists has been implemented. This program is oriented to rapidly collect new floristic data into some poorly explored areas of the Ligurian region. Here we present the overall modalities of data collection and the results of the 11 floristic surveys carried out in the first year of this new type of collaboration between expert botanists and citizens scientists.

MATERIALS AND METHODS

Study areas

To organize monthly floristic surveys, we selected eleven floristically poorly known Ligurian municipalities (November was skipped for logistical reasons), based on the density of records in the Wikiplantbase #Liguria dataset (Barberis et al. 2019). The municipalities ranged from planitial to montane vegetation belts and included different habitats (Table 1, Supplemental Material 1).

Table 1. Main features of the floristic surveys (for a more detailed description of each floristic survey refer to the Supplemental Material 1).

Municipality (Month)	Altitudinal range (m a.s.l.)	Main vegetation belts	Main habitats
Lavagna (Jan)	15-270	Planitial, Colline	Olive groves, thermophilous forests, Mediterranean scrubs and garrigues
Loano (Feb)	20-424	Planitial, Colline	Olive groves, thermophilous forests, pine forests, Mediterranean scrubs and garrigues
Avegno (Mar)	285-637	Planitial, Colline	Thermophilous forests, Mediterranean scrubs and garrigues, rock vegetation, meadows
Chiusanico (Apr)	370-980	Colline, Montane	Olive groves, thermophilous forests, pine forests, Mediterranean scrubs and garrigues, meadows
Urbe (May)	892-1023	Montane	Mesophilous forests, rock vegetation, meadows
Rossiglione (Jun)	318-460	Colline	Mesophilous forests, pine forests, rock vegetation, meadows
Montebruno (Jul)	670-1079	Colline, Montane	Mesophilous forests, meadows
Savignone (Aug)	585-791	Colline	Mesophilous forests, rock vegetation, meadows
Crocefieschi (Sep)	742-956	Colline, Montane	Mesophilous forests, rock vegetation, meadows
Serra Riccò (Oct)	225-476	Colline	Thermo-mesophilous forests, meadows, ruderal vegetation
Magliolo (Dec)	200- 315	Colline	Olive groves, Mediterranean scrubs and garrigues, rock vegetation, ruderal vegetation

Organization of the floristic surveys and data collection

For each municipality, a map-based itinerary was advertised by email among the sympathizers of the Ligurian section of the Società Botanica Italiana, e.g. about 300 people including experts, amateurs and students. The surveys were open to everyone. In the field, data collection took place in groups, through the compilation of georeferenced floristic lists. The coordinates were collected through the

GPS systems of the participants' cell phone, thus avoiding the need for specialized equipment. The lists were repeated if the distance of 1 km was exceeded (i.e., the maximum resolution of the Wikiplantbase #Liguria dataset) or if significant environmental changes occurred. All the observed species were listed, even those already included in the previous lists, except for the cultivated plants. The collection of data about species occurrences was made through the compilation of a simple paper field card, provided to the participants (Fig.1). All species that were non-identifiable in the field were collected for the laboratory analysis, that occurred in the Herbarium of the University of Genoa (GE). The herbarium activity was open to all participants of the surveys and all the samples were deposited in GE.

Località:			Data:	
Coordinate:			Quota:	
Ambiente:				

Taxon	racc.		Taxon	racc.
1.			21.	
2.			22.	
3.			23.	
4.			24.	
5.			25.	
6.			26.	
7.			27.	
8.			28.	
9.			29.	
10.			30.	
11.			31.	
12.			32.	
13.			33.	
14.			34.	
15.			35.	
16.			36.	
17.			37.	
18.			38.	
19.			39.	
20.			40.	

Figure 1. The format of the field card used for data collection during the program of floristic surveys.

Training of participants and validation of data

We assured the participation of at least one expert botanist to each activity of the program, both on land and in herbarium. Before starting each floristic survey, the expert scientists provided all the participants with a short explanation of the activity. During the activity, the experts confirmed or corrected the determinations of the observed species performed by the citizen scientists, providing explanations on the traits useful for the plant's identification; moreover, they described the main ecological characteristics of the sampled environments and provided advice for a better collection of floristic data. During the herbarium activity, the citizen scientists have been instructed on the use of the necessary tools (e.g., microscopes, identification keys, etc.) and the herbarium collections used as a reference.

The validation of the data collected during each activity (i.e., each floristic list and each herbarium sample) was carried out with the critical review by our group of botanical experts. The data were considered correct when all experts agreed on the identification.

Floristic checklist

The nomenclature of the floristic list followed Bartolucci et al. (2018) and Galasso et al. (2018) and later updates (Portal to the Flora of Italy). Autochthonous, allochthonous (i.e., casual, naturalized and invasive) and cryptogenic taxa were identified according to the Index Plantarum Flora Italicae. We selected taxa having a phytogeographical importance (i.e., endemicity, restricted chorotypes, fragmented distribution, occurrence at distributional edges, regional rarity) or subjected to regional or international low protection.

RESULTS

Floristic surveys

The overall number of participants of the floristic surveys was 25, including 6 experts, 14 amateurs and 5 students (Table 2). The ratio between non-professional participants (i.e., amateurs and students) and experts was mainly higher than 1, except for three surveys. We collected 3974 floristic data, ranging from 132 to 483 per survey (Table 2, Supplemental Material 2). Overall, 829 taxa (ranging from 89 to 241 per survey), 416 genera (ranging from 85 to 190 per survey) and 96 families (ranging from 40 to 70 per survey) were observed. We

collected 313 herbarium specimens (referring to 238 species). Several taxa showed none (i.e., 9.4%) or less than 10 records (i.e., 33.5%) in the Wikiplantbase #Liguria dataset at the end of 2018 (13.8% and 50.7%, respectively, if only post-2000 data are considered).

Floristic checklist

The majority (i.e., 91.1%) of observed taxa was autochthonous, while the 8.1% and 0.8% of taxa were allochthonous to Liguria or cryptogenic, respectively (Supplemental Material 3). Among the allochthonous taxa, the majority were naturalized, followed by casual and invasive (i.e., 4.5%, 2% and 1.6% of the overall observed taxa, respectively). The percentages of observed taxa endemic and subendemic to Italy were 1.45 and 1.33, respectively. We found 4.7% of taxa showing phytogeographical importance, 4.3% of taxa subjected to law protection and 0.9% of taxa having both features. During the floristic surveys, 13 taxa not previously known or no longer recorded for Liguria were found (Supplemental Material 4).

Table 2. Number of participants and floristic data collected in each floristic survey. Acronyms: Participants: P tot, total number of participants; E, number of experts; A, number of amateurs; S, number of students; R, ratio between A+S and E. Floristic data: Fam, number of families; Gen, number of genera; Sp, number of species; D tot, total number of floristic data.

Municipality (month)	Participants					Floristic data			
	P tot	E	A	S	R	Fam	Gen	Sp	D tot
Lavagna (Jan)	2	2	0	0	0	45	85	89	132
Loano (Feb)	7	3	3	1	1.3	40	104	126	308
Avegno (Mar)	8	2	5	1	3	55	133	166	386
Chiusanico (Apr)	12	5	4	3	1.4	50	149	200	392
Urbe (May)	9	2	4	3	3.5	52	129	170	323
Rossiglione (Jun)	4	2	1	1	1	53	170	240	377
Montebruno (Jul)	5	2	3	0	1.5	56	171	241	409
Savignone (Aug)	5	2	1	2	1.5	57	172	223	483
Crocefieschi (Sep)	5	1	4	0	4	55	155	189	358
Serra Riccò (Oct)	4	3	1	0	0.3	70	190	231	376
Magliolo (Dec)	13	2	8	3	5.5	69	181	226	430
Total	**25**	**6**	**14**	**5**	**3.2**	**96**	**416**	**829**	**3974**

DISCUSSION

Collaboration between experts and citizen scientists

The involvement of volunteers within our program of floristic surveys was successful, as showed by the ratio of non-professional participants to experts. Most surveys have been carried out along the Ligurian hiking network within protected areas, places often visited by hikers especially in spring and winter. It has been suggested that selecting places of tourist interest may stimulate the participation of more amateurs (McKinley et al. 2017). Although the total number of volunteers who have participated in this program is quite low, it can still be considered a success. In fact, it is difficult to involve volunteers in floristic activities that require many hours of work in the field and in the herbarium for data collection, rather than in simple trips to natural places. Furthermore, the regular return of some of the participants to many of the excursions in the program gives hope that they have reached a sufficient level of interest and preparation to continue the work on their own in the future.

The main obstacles to the scientific use of data collected through citizen science have been effectively overcome in this program of floristic surveys, both in terms of training volunteers and data validation. Inadequate training of citizen scientists can lead to poor taxonomic accuracy of collected data, which has been identified as a main limitation of citizen science (Mumby et al. 1995, Genet and Sargent 2003, Conrad and Hilchey 2011, Crall et al. 2011). This is particularly true for less recognizable or highly localized species (Bloniarz and Ryan 1996, Brandon et al. 2003, Yu et al. 2010), increasing the risk to collect a high number of false positive data (i.e., data on the presence of species where the species is absent - Mumby et al. 1995, MacKenzie et al. 2006, Swanson et al. 2016). Some of the solutions commonly proposed to overcome these problems are inapplicable to our case: for example, the identification by citizen scientists of higher taxonomic categories or of a limited number of easily recognizable species, that usually assure a better performance of volunteers (Bloniarz and Ryan 1996). The former is made impossible by the settings of the Wikiplantbase #Liguria dataset, which allows data entry at species rank only (Barberis et al. 2019); the latter would not allow to overcome some of the main gaps recognized in the Wikiplantbase database, in particular the strong imbalance in the data relating to the different categories of species, thus preventing a complete picture of the distribution of plants in Liguria. In addition, it is not even possible to provide volunteers with specialized training on taxonomic identification, as this would require years of study and preparation (Mumby et al. 1995, Crall et al. 2011). To overcome these taxonomical issues, we assured the constant presence of some expert botanists during all phases of data collection and processing. The experts can thus teach the citizen scientists the diagnostic characteristics of the various groups of plants they meet and confirm or deny their determination, triggering an interactive and iterative hanging process of the volunteers. The time and energy dedicated to the training of volunteers are rewarded by the progressive experience and autonomy they acquire during the activity, allowing a better-quality data collection (Sauer et al. 1994, Dickinson et al. 2010, Bonney et al. 2014). This is particularly important for many taxa difficult to recognize, whose data are often lacking in the Wikiplantbase #Liguria dataset, leading to an underestimation of their presence in Liguria (Barberis et al. 2019). In addition, continuous expert supervision ensures that all species are taken into account and limits the tendency of volunteers to focus only on the rarest species (Lepczyk 2005, Lewandowski and Specht 2015, MacKenzie et al. 2017), thus avoiding the risk of increasing data imbalance in the Wikiplantbase #Liguria dataset. Similarly to the use of photographs as a tool for recognition and confirmation of identifications, widely used to limit identification errors in several projects (e.g., Puky 2006, Swanson et al. 2015, Smith and Davis 2019), apps (e.g., Goëau et al. 2013, Kress et al. 2018, Nugent 2018) and communities (e.g., Forum Acta Plantarum), during the floristic surveys hundreds of herbarium specimens have been collected (i.e., near the 30% of observed taxa). Despite the use of voucher specimens for the verification of data would require expert time to process (Crall et al. 2011), the herbarium samples offer advantages that make them more suitable for our type of data collection than the photographs; for example, some key morphological characters are difficult to be observed in the photos, unless the operator has professional equipment and is adequately instructed on the details necessary for identification (which vary from species to species). Moreover, the herbarium activity carried out with the assistance of botanical experts provides further training to citizen scientists and allows to collect abundant data on taxa that are scarcely identifiable on land. In the checklist performed through this program of floristic surveys, the high number of species belonging to taxonomically complex genera (e.g., *Carex, Centaurea, Rosa*) and the high proportion of taxa having few or none data in

the Wikiplantbase #Liguria dataset at the end of 2018 suggest that the collaboration with experts ensures data collection even for those taxa that non-professional observers tend to ignore or confuse (Mumby et al. 1995, Brandon et al. 2003, Swanson et al. 2016). Lastly, the inclusion of the collected samples in the public collections of the Herbarium of Genoa (GE) conveys to volunteers a greater sense of satisfaction for having personally contributed to a work that benefits the whole community, thus becoming an important source of motivation (Bell et al. 2008, Rotman et al. 2012). It should be noted that, while our approach can be effective in preventing misidentification and false positive data, it is not very effective against false negative data (in this case as the failure to detect species occurring in an area, rather than an erroneous collection of species absence data), which represent a recurrent bias in several citizen science projects (Cruickshank et al. 2019) and monitoring data (Preston 1979, Kéry and Schmidt 2008, Kellner and Swihart 2014). In fact, each of our study areas has been surveyed only once, introducing a strong seasonal bias in the floristic lists performed, as different groups of plants are manifest and identifiable only at certain times of the year. For this reason, the traditional floristic researches are conducted through repeated sampling of the area under investigation, being aimed to produce a complete floristic list of such area. Despite the settings of the Wikiplantbase #Liguria dataset allow absence data entry (Barberis et al. 2019), we avoided to take note of this type of observations to reduce the risk of collecting false negative data.

A main issue concerning data validation is the usually long time required to validate a large amount of data (Bonter and Cooper 2012). The high number of possible species, considering the whole Italian flora (more than 6000 - Bartolucci et al. 2018, Galasso et al. 2018 and their later updates) makes it impossible to use lists of possible values to accelerate data validation, a method that has been suggested to make easier the data collection from citizen scientists (Bonter and Cooper 2012). On the other hand, the use of a subset of Italian flora (e.g., the Ligurian floristic checklist) as a list of possible values could be misleading due to the known inhomogeneity and lack of floristic knowledge in some Italian regions, including Liguria (Scoppola 2005); this is confirmed by the discovery of several non-known taxa in the Liguria region occurred during our excursion program (Supplemental Material 4). A great advantage of our approach is that much of the gathered data does not require post-collection validation, because botanical experts actively participate in the data collection, validating most of the species identifications on site and in real time. Thanks to this, it was possible to carry out a critical control of the other data collected in a short time, obtaining the complete lists for inclusion in the database immediately after the end of the excursion program.

Floristic checklist

Our checklist included about the 23% of plant taxa, the 68% of families and the 47% of genera known for Liguria (Index Plantarum Flora Italicae). As expected, the largest families and some common species showed the highest number of collected data (Supplemental Material 2). The proportions of observed autochthonous, allochthonous and cryptogenic taxa were in line with those referring to the overall Ligurian flora (Index Plantarum Flora Italicae). The proportion of observed endemic plus subendemic taxa was quite lower than the Regional one (i.e., 2.8% versus 4.4%), mainly because some areas showing high endemism rate were not surveyed in this excursion program (e.g., South-Western Alps). During the surveys several taxa not known for the Liguria region were found (Supplemental Material 4). Most of these new floristic data have been published (Bartolucci et al. 2020, Galasso et al. 2020) or included in forthcoming publications (F. Bartolucci et al. unpublished, G. Galasso et al. unpublished), while for the others we report here their first discovery in Liguria

(Supplemental Material 4). Overall, these results show that all categories of species are represented in our data proportionally to their geographic abundance, contributing to fix a main bias of the Wikiplantbase #Liguria dataset. This also suggests that the reliability of the data collected by citizen scientists is comparable to that of traditional floristic researches.

Heritage taxa

All plants of particular interest for a territory, both for their naturalistic and biogeographical value, are heritage species (Gamisans and Jeanmonod 1995, Quézel 1998, Barthelat and Viscardi 2012). As they represent a heritage worthy of special conservation measures and to be monitored over time, the threat affecting these taxa has been explored (Gentili 2008) and some of them are currently protected by laws (Alonzi et al. 2006). Consequently, the collection of data on the distribution of these species is very important for conservation purposes and can benefit greatly from the employment of citizen scientists, as showed in other groups of taxa (Losey et al. 2012, Barnard et al. 2017, Edgar et al. 2017). For example, we found several entities with restricted range belonging to Apennine, Alpine or Mediterranean regions, many of which are endemic or sub-endemic to Italy (Supplemental Material 3). The distribution of some of these taxa is well known as they are repeatedly interested by traditional floristic researches (e.g., some exclusive serpentinophytes like *Viola bertolonii* Pio and *Cerastium utriense* Barberis occurring within an area less than 600 sq.km in the ophiolitic massif called "Voltri Group" - Barberis et al. 2004a,b). Nevertheless, for others the knowledge is still to be completed, as demonstrated by the recent discovery of a disjointed population of *Scabiosa mollissima* Viv. on the border between Piemonte and Lombardia (Ardenghi and Polani 2016). It is therefore evident the potential usefulness of increasing the number of well-prepared citizen scientists able to explore

those areas that have been little considered in traditional floristic research. In some cases, a taxonomical issue worsens the gap on distribution knowledge, requiring further attention in the training of citizen scientists and in the validation of collected data. For example, the Italian endemic *Centaurea aplolepa* Moretti is fragmented into ten narrow-range and morphologically similar subspecies (Bartolucci et al. 2018), which in recent years have undergone different taxonomic interpretations (Arrigoni 2003, Greuter 2006-2009, Bartolucci et al. 2018), leading to an incomplete knowledge of their distribution. This type of gap is not limited to endemics, but usually concerns any recently described or taxonomically revalued taxon, e.g. *Colchicum longifolium* Castagne (Persson 2007, Selvi 2009) and *Crocus neglectus* Peruzzi & Carta (Harpke et al. 2015).

Similar to range-restricted taxa, species with a fragmented distribution can also benefit greatly from the activities of citizen scientists. On the one hand, their discontinuous occurrence over large territories significantly increase the probability of discovering new populations in poorly explored areas. For example, *Leontodon anomalus* Ball occurs in disjunct populations within Apuan Alps, Emilian Apennines, "Voltri Group" massif and western Ligurian Riviera (Barberis et al. 2004b, Marchetti 2010 and references therein) and its distribution is probably still little known (Zidorn 2012). On the other hand, for the conservation of range-fragmented species it is essential to monitor the persistence over time and the current status of known populations, a classic application of citizen science projects (e.g., Embling et al. 2015, Martin et al. 2019, Hofmeyr et al. 2014). A similar situation concerns the taxa that reach the limit of their range in Liguria, many of which have been observed during our excursions (Supplemental Material 3). Since peripheral populations might be genetically or morphologically divergent from the central ones or locally adapted to particular environments (Lesica and Allendorf

1995), collecting data and monitoring their occurrence can be useful for conservation purposes.

Allochthonous taxa

Overall, we observed about 12.5% of the allochthonous taxa known to occur in Liguria (i.e., 67 out of 532 taxa – Index Plantarum Flora Italicae), reporting the first Ligurian locality for some exotic species.

Considering the regional status of the allochthonous taxa (i.e., casual, naturalized, invasive), we observed a lower number of casual taxa and a higher number of invasive taxa than the Ligurian checklist (i.e., our data: 2% and 1.6%, respectively; Ligurian checklist: 8.7% and 0.5%, respectively). This result could be explained by the main features of casual and invasive plant behavior (Pyšek et al. 2004). Since casual taxa sporadically occur in a few scattered sites while invasive ones usually colonize large territories (Richardson et al. 2000), these taxa might be underrepresented and overrepresented in the floristic data, respectively. Most of the observed casual taxa derived from cultivations or floricultural activities and are confined to disturbed and anthropogenic environments. In some cases, the national status suggests a higher invasive potential respect than the one shown in Liguria. These discrepancies between national and regional alien checklists often occur due to lack of accurate data or differences in terminology and interpretation of invasion phenomena (Pyšek et al. 2004, McGeoch et al. 2012). Conversely to casual taxa, some observed invasive species often occur in natural environments, affecting several habitats of Community interest with large size populations. Recent analysis carried out on the Ligurian populations of some of these invasive species (e.g., *Acacia dealbata* Link subsp. *dealbata*, *Senecio inaequidens* DC. and *S. angulatus* L.f.) have revealed that they are currently absent (or perhaps their presence is still unknown) in several climatically suitable areas in this region

(Gaspich 2016-17). This pattern could be caused by the forced introduction for ornamental purposes in less favorable areas (Donaldson et al. 2014) and, at least for some taxa, by a reproduction mainly based on asexual strategies in most of populations (Minuto et al. 2020). All these issues suggest that the knowledge of the distribution of alien species both casual and invasive could be greatly improved through a greater involvement of citizen scientists, both to rapidly discover new naturalization sites and to better monitoring invasion phenomena, aligning the information between the local and national scales.

Among the observed allochthonous taxa, particular attention should be paid to *Senecio pterophorus* DC because within the Italian territory it is exclusive to Liguria (Galasso et al. 2018), where the species is known since the 70s (Barberis et al. 1998). Initially, the species was located in San Bartolomeo del Cervo (Province of Imperia), but already in the '90s had expanded its range from Ventimiglia to Pietra Ligure. Now it is widespread eastward to Genoa and westward to France (Tison et al. 2014). Unlike other congeneric species (like *S. inaequidens*), *S. pterophorus* found in Liguria climatic conditions similar to those of its native range (i.e., southern Africa – Vilatersana et al. 2016), thus enabling its own invasive potential (Gaspich 2016-17). The species currently occur in both synanthropic and natural environments under Mediterranean climatic conditions, representing in some cases a serious threat to some habitats of Community interest. Because of its range expansion and the abundant populations, in the Italian checklist the status of this species should be changed from naturalized to invasive. Moreover, being a flashy and easy-to-recognize plant, *Senecio pterophorus* could be a valid candidate for future citizen science projects, aimed to monitoring and/or preventing the expansion of an invasive species both in Liguria and in the surrounding regions.

CONCLUSIONS

Overall, our program of floristic surveys suggests that citizen science can be a valid tool to deepen and update regional floristic knowledge, also discovering species that previously had never been observed in the study area. Our results confirmed the reliability of data collected by citizen scientists in the floristic field, if the volunteers are adequately trained and assisted by experts during the activity. Our study shows that several groups of taxa that are often subjected to traditional floristic or phytogeographic researches can benefit from the data collection by citizen scientists, in particular: i) taxa of phytogeographical interest (including endemic and subendemic taxa), because an high resolution and updated map of distribution is essential to develop further scientific researches; ii) taxa subjected to law protection, because current occurrence data are required to assess their conservation status; iii) allochthonous taxa, because a detailed occurrence dataset is useful in monitoring their spread through time. Moreover, the collaboration between professionals and non-professionals botanists allow the collection of numerous and accurate floristic data, including several hard-to-recognize taxa, thus promoting the growth of the Wikiplantbase project. These researches contribute to fill several gaps affecting the floristic knowledge of Liguria, supporting the development of an effective management and conservation of plant biodiversity. Further investigations in areas of the region not yet adequately explored are desirable in the future, also including citizen scientists.

AUTHOR CONTRIBUTIONS

All the authors participated to the data collection activity. In addition, IB wrote the manuscript; GB, DL and SP analyzed the dataset and revised the manuscript; CC revised the manuscript; DD wrote and revised the manuscript and analyzed the dataset.

DATA ACCESS

The full version of the data collected during the floristic excursions is freely accessible on the Wikiplantbase #Liguria website (http://bot.biologia.unipi.it/wpb/liguria/index.html)

SUPPLEMENTAL MATERIAL

The following Supplemental Materials are provided: 1) Detailed description of each floristic survey; 2) Summary of collected data for each family and genus; 3) Floristic checklist; 4) List of new taxa for the Liguria region.

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