

Acta Plantarum, more than a forum: a new national floristic distribution database completes the numerous online IPFI facilities

DANIELA LONGO^{1,*}, ARTURO BAGLIVO¹, CARLO CIBEI¹, GIANNI DOSE¹,
FRANCO GIORDANA¹, CRISTIANO MAGNI¹, GIULIANO SALVAI¹,
SERGIO SERVODIO¹, DAVIDE TOMASI¹, MARINELLA ZEPIGI¹,
GIANLUCA NICOLELLA¹

¹ *Acta Plantarum, www.actaplantarum.org (Italy)*

* *corresponding author, email: info@actaplantarum.org*

Keywords: botanical forum; citizen science; floristic data; Italian flora.

SUMMARY

Citizen science projects are able to collect massive amounts of data engaging thousands of motivated volunteers. Moreover web-based communities are a powerful way to promote citizen involvement. This paper describes Acta Plantarum (www.actaplantarum.org), an open source project born in 2007, aiming at the study of spontaneous Italian flora and hosting one of the most popular floristic web-based communities in Italy. Participation in the project is free and takes place, upon registration, by posting pictures and contributions in a discussion forum. This represents the heart of the website together with IPFI (Index Plantarum Florae Italicae), a complete nomenclatural database of Italian flora species created to archive all the botanical information. Over the years, thanks to the participation of amateur botanists from all Italian regions, a relevant amount of floristic records has been accumulated in Acta Plantarum. A new utility now allows the retrieval of floristic records stored in the forum through automatic and semi-automatic functions. As of 30 June 2020, Acta Plantarum had 1,793 active members and 74,188 floristic records were automatically or manually extracted, covering about 70% of the specific and subspecific taxa occurring in Italy. An appropriate validation process ensures reliability of data that can be extremely useful to the general audience, policy makers, amateur and professional botanists. Acta Plantarum results confirm the fundamental role of amateurs to develop large floristic databases and to increase floristic knowledge both at local and national level.

INTRODUCTION

“Citizen science” is the term commonly used to define scientific work undertaken by non-professional scientists, with or without the involvement of professional scientists (Pocock et al. 2017). However, the debate on the definition of “citizen science” is still ongoing (Eitzel et al. 2017). A broad division in citizen science approaches is between “contributory approaches”, where participants are primarily involved as data collectors, and collaborative/co-created approaches”, where participants are involved in additional steps of the scientific process (Pocock et al. 2018). Thus, citizens can be enrolled in citizen science projects on different levels, from the passive use of existing resources, through simple data collection, to a large-scale engagement in cognitive tasks (Haklay 2015).

The progress in communication technologies has improved and simplified the citizen science approach (Roy et al. 2012). Technological updates promoted the development of virtual communities like forums and blogs, but also the implementation of front-end methods for data collection and visualization through websites, social media, and smartphone applications (Graham et al. 2011, Joly et al. 2016, Bonnet et al. 2018, 2020, Kress et al. 2018).

Public participation in scientific projects is becoming increasingly frequent and successful worldwide (Bonney et al. 2014), thanks to the ability to collect massive amounts of data with a large territorial coverage at low costs (Martellos 2017). Indeed, it is possible to launch highly participatory initiatives engaging thousands of motivated volunteers (Domroese and Johnson 2017). Most projects are able to obtain and manage data at scales or resolutions that are unreachable by classical research groups, to address both large-scale and local challenges (Bonney et al. 2014). Data collected by citizen scientists are currently used for several purposes, such as global biodiversity monitoring (Chandler et al. 2017, McKinley et

al. 2017, Pocock et al. 2018), local biodiversity conservation (Bell et al. 2008, Schmeller et al. 2009, Barnard et al. 2017, Milanesi et al. 2020), monitoring and mapping alien species (Delaney et al. 2008, Ingwell and Preisser 2011, Burrack et al. 2012, Crall et al. 2015, Nimis et al. 2019), monitoring of protected areas or taxa (Forrester et al. 2017, Bonnet et al. 2020), and production of distribution maps (Riservato et al. 2014, Pocock et al. 2015, Croce and Nazzaro 2017).

Data quality is a major issue in citizen science (McDonough MacKenzie et al. 2017) but this concept does not always have a homogeneous and shared meaning, being it a multidimensional construct (Wang and Strong 1996). The quality of data collected by non-professional scientists is often questioned. Several studies analyzed and compared citizen science data against professionally collected data, in order to verify data reliability (Conrad and Hilchey 2011, Crall et al. 2011, Aceves-Bueno et al. 2017). Completeness, one the attribute of data quality, is often not reached by citizen science projects (Gouveia et al. 2004). On the other hand, accuracy in the identification of objects does not differ between professional and non-professional scientists in many citizen science projects, especially when non-professional scientists have expertise and are strongly motivated or when multiple criteria for data validation are introduced in the projects (Wiggins and Crowston 2011, Lewandowski and Specht 2015). After all, the use of different techniques of data acquisition also affects data quality. For example, comparing field data acquisition through mobile apps to PC-based data entry, data accuracy can change from 30% to 70%. The delay between data collection and submission can support observers in providing more confident and informative data (Wiggins and He 2016).

In Italy, Citizen science is not a widespread concept, although many projects were proposed in the last years (Eitzel et al. 2017). Some successful initiatives were funded within the LIFE Programme, e.g., CSMON-LIFE (www.csmon-life.eu) and MIPP

(www.lifemipp.eu/mipp/new/), and were designed to collect occurrence data of target species. Other national or local citizen science programs were launched to improve the distributional knowledge of many species and have accumulated a large amount of data within short timeframes (Riservato et al. 2014, Mannino & Balistreri, 2018). INaturalist (2020), one of the largest and most structured international communities of nature observers, has released its website and smartphone application also in Italian language. Furthermore, the informal group Citizen Science Italia, born in 2015, decided to create a space for managing and sharing further existing initiatives (Citizen Science Italia 2020). One of the most well-known and relevant floristic projects is WikiPlantBase, a national online platform where contributors can introduce data from published literature, herbarium specimens, and unpublished field observations (Bedini et al. 2016).

Acta Plantarum (AP - www.actaplantarum.org), is an open-source project aimed at the study of spontaneous Italian flora. It is a citizen science project not carried out by professional scientists (Mathieu 2011). Since its foundation in 2007, AP hosted amateur botanists and photographers excited to share their floristic passion. This created a free flow of information that allowed everyone to increase and develop personal knowledge, but also to contribute to the fostering and the dissemination of floristic culture in Italy. The project was officially presented to both the Italian (Baglivo et al. 2010) and the international scientific community (Baglivo et al. 2016).

Participation in AP is free. After registration, users can post their pictures and contributions in a discussion forum, divided in thematic sections. The forum is supported by a daily updated gallery of pictures that are organized by family, genera, and species. Other thematic galleries are also available, such as one dedicated to seeds and other primary dispersion units and one dedicated to basal

rosettes. Moreover, the website includes an illustrated glossary of botanical terms, an etymological dictionary, a short but complete section on plant morphology, and a series of botanical sheets written by registered users. Many tools are provided to members such as a very useful search engine for the forum and the galleries, and a utility designed to publish and share in-progress floristic checklists for a specific area, called “florule”.

Thanks to the participation of amateur botanists from all Italian regions, AP has accumulated a large amount of floristic records that are potentially extremely useful to enthusiasts and researchers. Nevertheless, looking for occurrences in a web forum is not always immediate and often requires time and effort. To make this heritage more immediately and massively accessible, a new utility was designed to allow the easy retrieval of floristic data. The aim of this paper is to illustrate the results achieved by the AP project in these years, to explore its role within the botanical community and within the Italian citizen science, and to introduce the new utility, which allows users to transform the floristic information contained in the AP forum into a database of floristic records, easily accessible to the interested audience and helpful for both amateur and professional botanists.

MATERIALS AND METHODS

Data management for the AP project is powered by the relational database management system MYSQL, installed on a stand-alone Apache web server. The used programming language is PHP, while the user interface is written with custom HTML, CSS and Javascript coding. The AP website has 72 freely accessible different pages. Thirteen additional pages are for members, to manage their own account, while 50 maintenance pages are reserved to moderators and administrators. The forum is based on a free software package named phpBB® (2001 onwards) with few customizations. All other website pages were

designed and maintained by a team of volunteer software engineers involved in the AP project. The related source code totals 315,000 slocs. Forum data is contained in a dedicated database consisting of 80 tables. The remaining website data are contained in 3 different databases for a total of 153 tables.

A nomenclatural database, called Index Plantarum Florae Italicae (IPFI), was created and used as a unique nomenclatural reference in order to archive and retrieve all the botanical information. It includes more than 11,000 documented specific and subspecific taxa, in accordance with the checklists of the Italian vascular flora (Bartolucci et al. 2018a, Galasso et al. 2018a) and their recent updates (Bartolucci et al. 2018b, 2019a,b, 2020, Galasso et al. 2018b, 2019a,b, 2020). For each accepted specific and subspecific taxon nomenclatural reference, regional distribution, synonyms, relationship with all the main Italian floristic repertoires (Fiori 1923-1929, Pignatti 1982, Aeschmann et al. 2004, Conti et al. 2005, Pignatti et al. 2017-2019, Bartolucci 2018a, Galasso 2018a), vernacular name, etymology, life form, chorological type, protection status, and other useful information is provided. IPFI includes links to AP galleries and botanical sheets, when available in the site, as well to a series of Italian and international databases accessible through dynamic or static links, such as Euro+Med (2006 onwards), Tropicos (Missouri Botanical Garden, 2020), The Plant list (2013 onwards), IPNI (2020), anArchive (Lucarini et al. 2015), Chrobace (Bedini et al. 2012), Wikiplantbase (Peruzzi et al. 2017), Portale della Flora Italiana (Martellos et al. 2020).

In AP, like in other botanical websites based on virtual communities, species identification is a participatory process to which members contribute with images, comments, and new information until the correct identification of the diagnostic traits of the species (Guarino et al. 2010). The structure of the Forum is functional to this approach and the processing of topics is an essential element of

the validation process that guarantees the quality of retrievable data (Kosmala et al. 2016).

AP members are able to post pictures of an identified taxon simply opening a topic in “Foto e notizie di specie della flora spontanea italiana” (Photos and news of the Italian spontaneous flora species) and “Esotiche naturalizzate o casuali” (Naturalized or casual exotic species), from here on referred to as “Foto e notizie...” (Photos and news...), according to the status of native or alien plant. The data and images are checked daily by the moderators. In any case, topics remain in these subforums for 3 months to be viewed by all users. If doubts about identification are raised, the topic is moved to “Che pianta è?” (What plant is it?). This subforum is normally used to ask for help in identifying plants or flowers whose names are unknown. As possible, moderators and expert members can propose an identification. When it is not possible to reach a correct identification, further pictures or information can be requested, otherwise the topic will be deleted after about a month. When there are at least 3 consistent identification proposals, the topic will be transferred to “Foto e notizie...” (Photos and news...). Finally, after 3 months, the topic will be moved to the “Archivio Floristico” (Floristic Archive) subforum, where no direct changes will be available. It is still possible to question the identification and, in this case, the topic will return to “Che pianta è?” (What plant is it?). All the topics removed by “Archivio floristico” (Floristic Archive) are tracked for statistical purposes.

Data and pictures from unreliable or unknown members receive particular attention. Moderators can move related topics to “Che pianta è?” (What plant is it?) even if the species is already identified. Also, when the topic is a first notice of a new taxon for Italy or for an Italian administrative region, additional documentation or collection of a specimen for submission to a specialist are required.

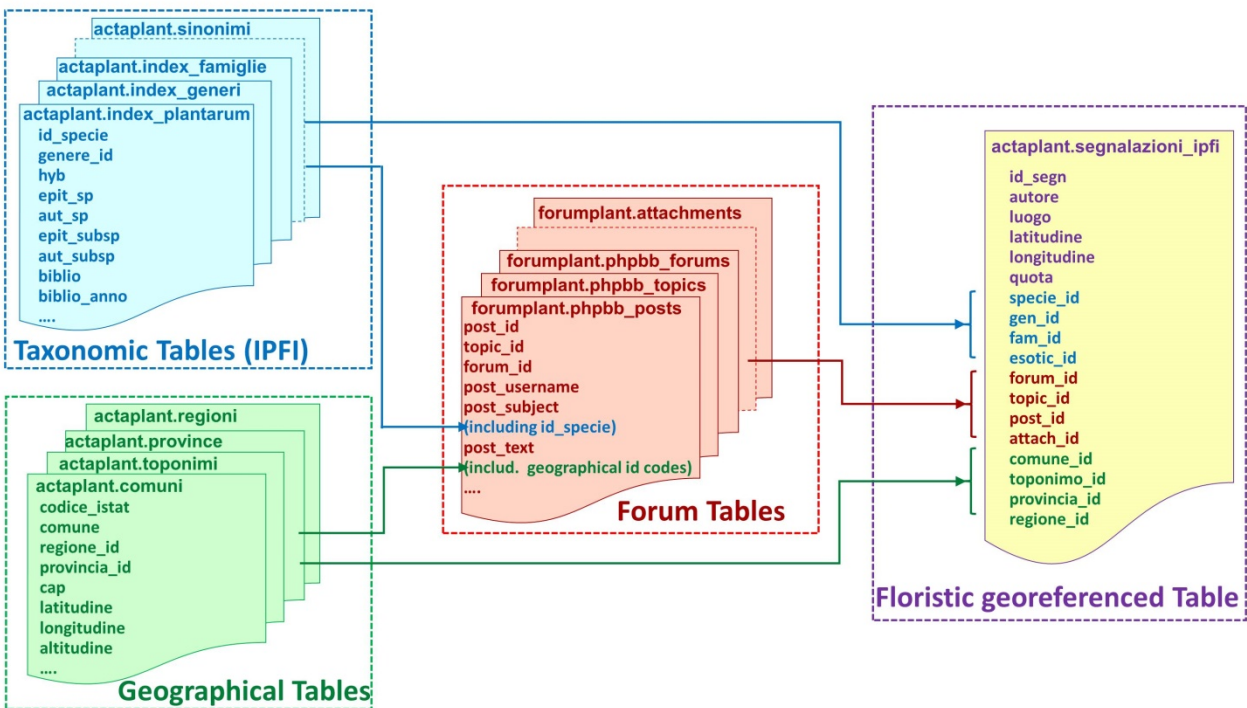


Figure 1. Forum, geographical and IPFI tables and their relationships with the floristic record.

The new utility was designed between 2018 and 2019 and aims to extract nomenclature and location data from the forum and transfer it to the floristic database. The relationships between the different database tables are shown in Figure 1.

Automatic extraction is possible due to the data formalization. Strict rules are required to upload the information to Forum. A text form is proposed and reinforced by moderators' suggestions. Each picture posted in the forum must include at least the name of the specific or subspecific taxon according to the IPFI nomenclature, location (city or toponym), administrative province, altitude, date, and author's name.

Only "validated" data, i.e., data that have been in the forum for at least 3 months and whose identification has not been questioned during this time period, are automatically extracted. Two steps are necessary. Step 1 analyzes the text associated with the pictures present in the forum, checking for complete and correct information. Using the

60,000 synonyms stored in IPFI, the correctness of the botanical nomenclature is verified and a unique IPFI identifier is associated with the record. Location data are also encoded using numeric codes related to the municipality (LAU level 2, formerly NUTS level 5), province and metropolitan city (NUTS level 3), and region (NUTS level 2) (Eurostat 2020). Administrative geographic information is downloaded from the ISTAT website (ISTAT 2020) and periodically updated. In case of missing taxon or locality name, this information is reported, too. If possible, an automatic correction is proposed, otherwise the original text can be manually changed (Fig. 2).

In Step 2, the information previously analyzed is transferred to the dedicated database table "segnalazioni_ipfi" using numeric codes to ensure relationships among the database tables (Fig. 3).

The utility has been available to forum moderators since about one year. This time period was used to test its features, fix bugs, and develop improvements.

To date, the following features are available:

- Automatic check of botanical nomenclature and location data stored in the forum database tables (Step 1 utility).

- Automatic extraction of the data checked with the Step 1 utility and subsequent import into the floristic records table (Step 2 utility).

Controllo e modifica titoli e testi di topic e posts relativi alla flora italiana

Selezione operazione: Controlla presenza sigla della provincia nel primo post [SCEGLI]

Selezione forum: Foto e notizie di spec [v]

Tipo topic:

- Solo non allineati
- Solo non esaminati
- Tutti i topic

Topic_id > di: 113177 [SEL] Primo id 113177, ultimo id 116647 dei forum selezionati.

[INVIA] [?]

Nei forum selezionati sono presenti 348 topic relativi ai parametri selezionati; esaminati 348 topic in questa pagina, contenenti 348 topic con province non allineate e 0 topic con province allineate.

[AGGIORNA PAGINA] [AGGIORNA TOPIC CORRETTI] [MODIFICA AUTO RISOLTI NON ESCLUSI]

Topic_id	Titolo topic	Testo post luogo	Provincia nuova	Stato old	N. Foto galleria	Mod manuale	Escludi auto
113177	Limonium virgatum (Willd.) Fourr. {ID 4723}	Pantelleria	Trapani	Non trovata	3	[MOD]	<input type="checkbox"/>
113699	Bupleurum odontites L. {ID 1402}	Montemurlo	Prato	Non trovata	0	[MOD]	<input type="checkbox"/>

Controllo e modifica titoli e testi di topic e posts relativi alla flora italiana

Selezione operazione: Controlla presenza sigla della provincia nel primo post [SCEGLI]

Selezione forum: Foto e notizie di spec [v]

Tipo topic:

- Solo non allineati
- Solo non esaminati
- Tutti i topic

Topic_id > di: 113177 [SEL] Primo id 113177, ultimo id 116647 dei forum selezionati.

[INVIA] [?]

Nei forum selezionati sono presenti 348 topic relativi ai parametri selezionati; esaminati 348 topic in questa pagina, contenenti 348 topic con province non allineate e 0 topic con province allineate.

[AGGIORNA PAGINA] [AGGIORNA TOPIC CORRETTI] [MODIFICA AUTO RISOLTI NON ESCLUSI]

Topic_id	Titolo topic	Testo post luogo	Provincia nuova	Stato old	N. Foto galleria	Mod manuale	Escludi auto
113177	Limonium virgatum (Willd.) Fourr. {ID 4723}	Pantelleria	Trapani	Non trovata	3	[MOD]	<input type="checkbox"/>
113699	Bupleurum odontites L. {ID 1402}	Montemurlo	Prato	Non trovata	0	[MOD]	<input type="checkbox"/>

Figure 2. Step 1 utility for the checking of complete and correct information in the forum.

Selezione categoria

- Specie IPFI in forum
- Specie di "Paese che val..."
- Esotiche in Italia e all'estero
- Tutte le specie in forum
- Segnalazioni esotiche forum
- Segnalazioni italiane forum
- Estrai automaticamente
- Estrai manualmente
- Vedi segnalazioni
- Vedi topic non estratti
- Add specie da subsp.

Selezione parametri

Estrate in totale 71205 segnalazioni di entità italiane; estratte 67827 segnalazioni dal 22-11-2007 al 08-11-2020 nei forum selezionati

Saranno estratti/aggiornati 500 topic per volta, inclusi "Itinerari..." e "Schede..."



[INVIA]

Filtri e comandi

- Solo Archivio Foto
- Solo Itinerari, Schede,...
- Solo Vediamo dov'è
- Estrai nuove
- Aggiorna segn. estratte
- Aggiorna entità provincia mancanti
- Aggiorna con mancanze
- Cancella multiple
- Cancella non in forum

[RESET] [?]

Vengono estratti solo topic (per Archivio floristico, Foto e notizie,...) e posts (per Itinerari e Schede) già "marcati" tramite nomi_forum (entità IPFI e provincia già trovati e memorizzati). Per "marcarne" altri utilizzare l'altra funzione.

Nei forum selezionati sono presenti 748 topic di segnalazioni italiane di cui 0 da estrarre; estratti altri 0 topic in questa pagina, contenenti 0 segnalazioni diverse.

[salva file csv] [salva file xls]

Figure 3. Step 2 utility for information extraction and further verification.

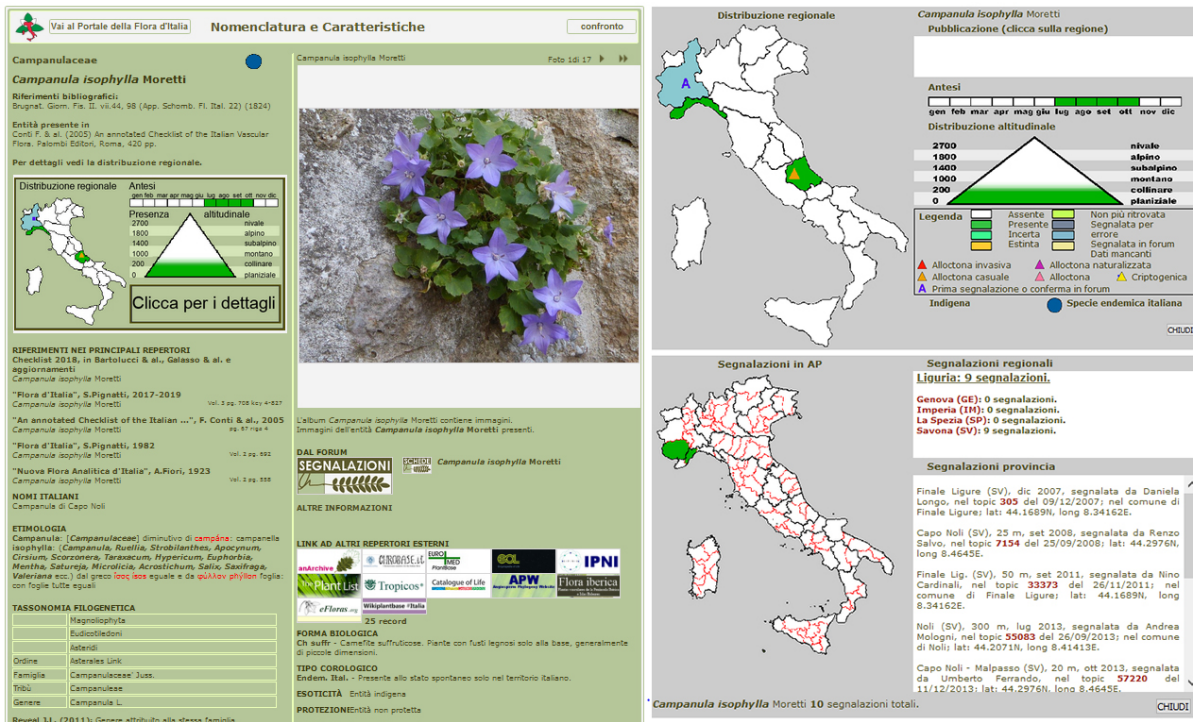
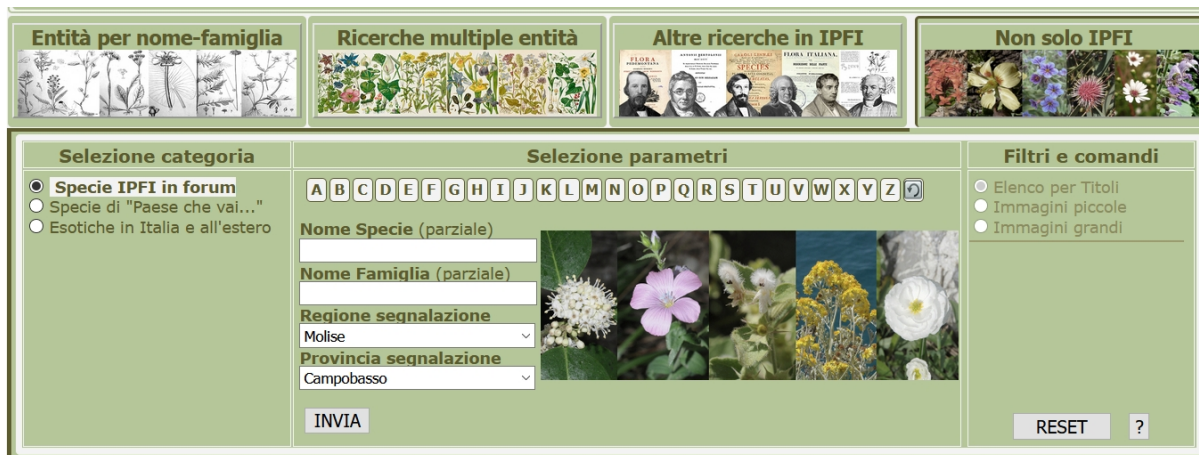


Figure 4. Left side: IPFI taxon page; Right side: distribution map generated by using the presence at the regional level (upper) and distribution map showing AP floristic records aggregated at the province level.



Nei forum selezionati sono presenti 64404 topic/segnalazioni estratte; presenti in questa pagina 5 segnalazioni di 390 topic/segnalazioni rispondenti ai criteri selezionati

Per accedere a tutte le potenzialità di IPFI è necessario essere iscritti al forum e aver effettuato il login

« Pagina 14 »

Forum	Nome entità	Data post	Nome famiglia	Provincia	Luogo foto	Data foto	Autore	Scheda
Archivio floristic...	<i>Cardamine hirsuta</i> L.	10-04-2009	Brassicaceae	Campobasso	Termoli (CB)	apr 2009	Franco ROSSI	IPFI
Archivio floristic...	<i>Cardamine enneaphylos</i> (L.) Crantz	23-12-2015	Brassicaceae	Campobasso	S. Massimo (CB), 700 m	lug 2011	Donato Palermo	IPFI
Archivio floristic...	<i>Cardamine kitaibelii</i> Bech.	26-12-2015	Brassicaceae	Campobasso	Monti del Matese (CB), 1300 m	apr 2013	Donato Palermo	IPFI
Archivio floristic...	<i>Cardopatum corymbosum</i> (L.) Pers.	02-06-2018	Asteraceae	Campobasso	Trivento (CB), 300 m	mag 2018	Donato Palermo	IPFI
Archivio floristic...	<i>Carduus corymbosus</i> Ten.	07-05-2008	Asteraceae	Campobasso	Guardiafiera (CB)	mag 2008	Franco ROSSI	IPFI

Figure 5. Query interface with the available filters in the upper side and the list of floristic records provided in the lower side.

- Computer-aided manual extraction of floristic records not automatically detectable (Step 2 utility).
- Search for incorrect or missing information with the possibility to edit, delete or add (Step 2 Utility).
- Visualization of all already extracted records.

There are two different ways to browse the floristic records collected in the Forum. The first way is through the IPFI taxon page. A graphical button "Segnalazioni" allows users to visualize on a distribution map the occurrences aggregated at the province level (Fig. 4). All provinces containing records are shown in green. Detailed information, including the link to the original topic, can be accessed by clicking on the map.

The second way is using a query interface (Fig. 5). It allows users to filter the query by taxon, family, genus, administrative region, or province. The query also works by entering only part of the taxon or family name. A list of floristic data is provided at the bottom of the same page and links to IPFI taxon pages are available.

Both pages are accessible to registered and unregistered users, although some non-essential but useful functions are reserved for forum members only.

RESULTS

Website and Forum

In the last year, AP had an average of 3,859 visits every day, with a peak of 10,575 visits, and an average number of 95,970 pages views. About 7% of the visitors were foreigners, mainly Swiss, German, and French, but also from the United States and Canada.

The forum is currently divided into 76 subforums containing 85,844 topics, 370,574

posts, and 374,884 images. Most of these, namely 66,918 topics, 252,734 posts, and 304,343 images, have a floristic character.

As of 30 June 2020, AP had 1,793 active members. The region with the highest number of members was Lombardia (Lombardy), followed by Lazio, Toscana (Tuscany), and Emilia Romagna (Fig. 6). During the 13 years of the project's life, more than 8,000 users registered to the forum. However, the AP policy states the cancellation for users who do not post messages.

Floristic records utility

As of 30 June 2020, 74,188 floristic records were automatically or manually extracted from the AP forum, transferred to the floristic database, and geo-referenced. All the records, resulting from the contribution of 1,220 members, have a correct botanical nomenclature and only 1,271 records have geographical information only at regional level. The records refer to 184 families, 1,365 genera, and 7,053 specific and subspecific taxa, covering 96%, 88%, and 70% of the list of Italian flora available in IPFI, respectively.

The most represented families are Asteraceae, Fabaceae, and Orchidaceae (Fig. 7). The richest genera are *Ophrys* L., *Saxifraga* L., and *Campanula* L. (Fig. 8). Specific and subspecific taxa with the greatest coverage are *Lilium bulbiferum* subsp. *croceum* (Chaix) Jan, *Orchis mascula* subsp. *speciosa* (Mutel) Hegi, and *Dactylorhiza maculata* subsp. *fuchsii* (Druce) Hyl. (Fig. 9).

Lombardia (Lombardy) is the region with the highest number of total floristic records, while Emilia Romagna is the region with the highest number of records referred to different specific and subspecific taxa (Fig. 10). Fig. 11 shows the 20 provinces with the highest number of floristic records and relative number of specific and subspecific taxa. Cuneo is the province hosting the highest number of floristic records, while Brescia is the province with more specific and subspecific taxa represented.

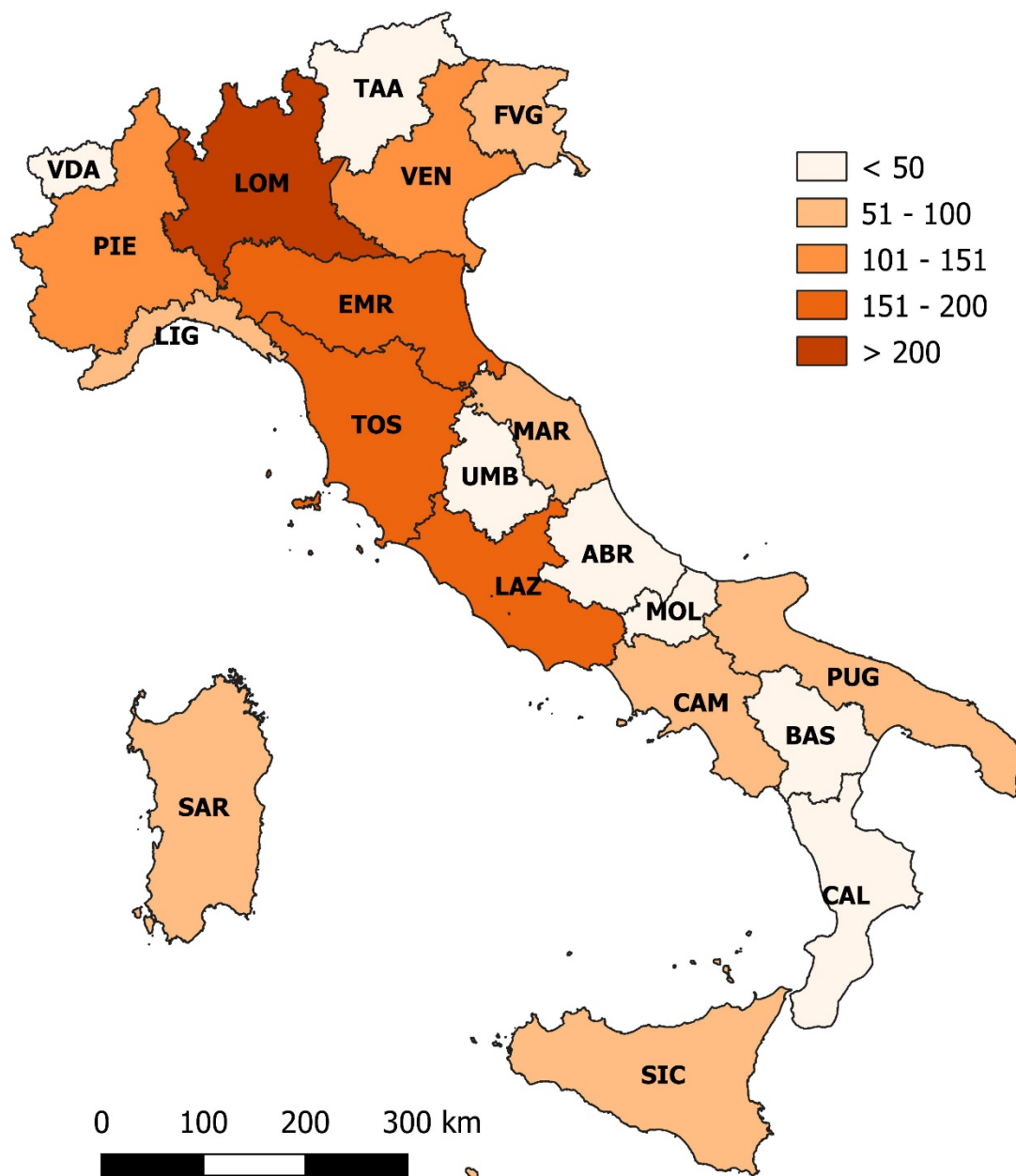


Figure 6. AP members according to the Italian administrative region of provenance. VDA: Valle d'Aosta (Aosta Valley); PIE: Piemonte (Piedmont), LOM: Lombardia (Lombardy); TAA: Trentino-Alto Adige (Trentino-South Tyrol); VEN: Veneto; FVG: Friuli Venezia Giulia; LIG: Liguria, EMR: Emilia Romagna; TOS: Toscana (Tuscany); UMB: Umbria; MAR: Marche; LAZ: Lazio; ABR: Abruzzo; MOL: Molise; CAM: Campania; PUG: Puglia (Apulia); BAS: Basilicata; CAL: Calabria; SIC: Sicilia (Sicily); SAR: Sardegna (Sardinia).

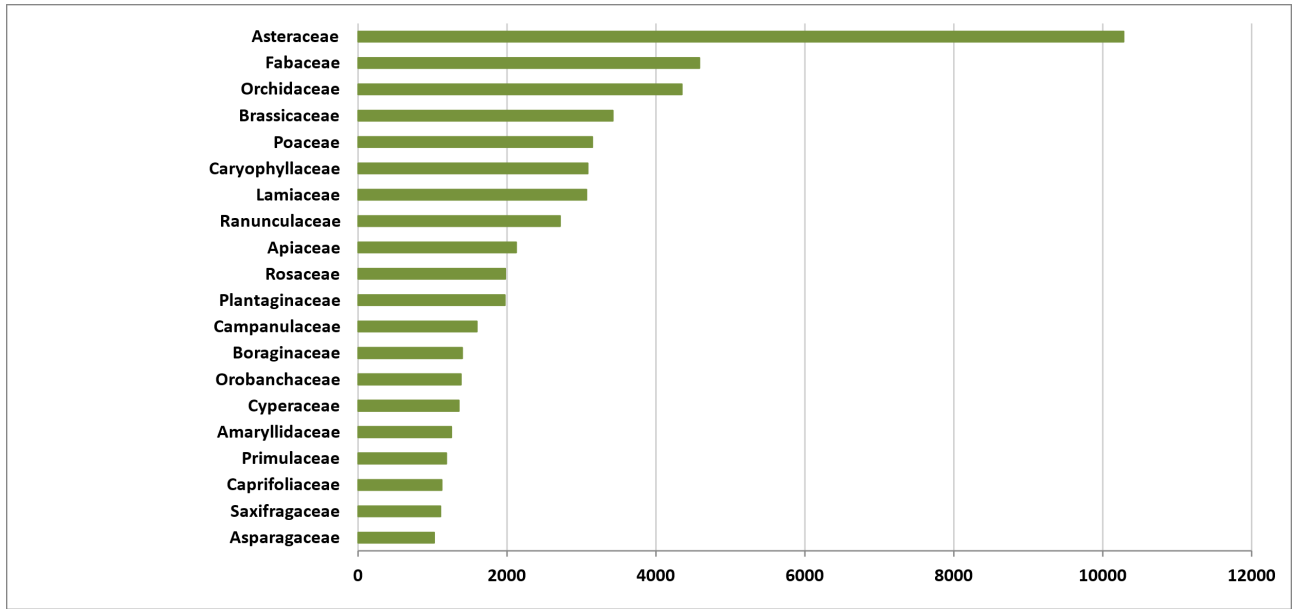


Figure 7. Top 20 families represented in AP (number of floristic records).

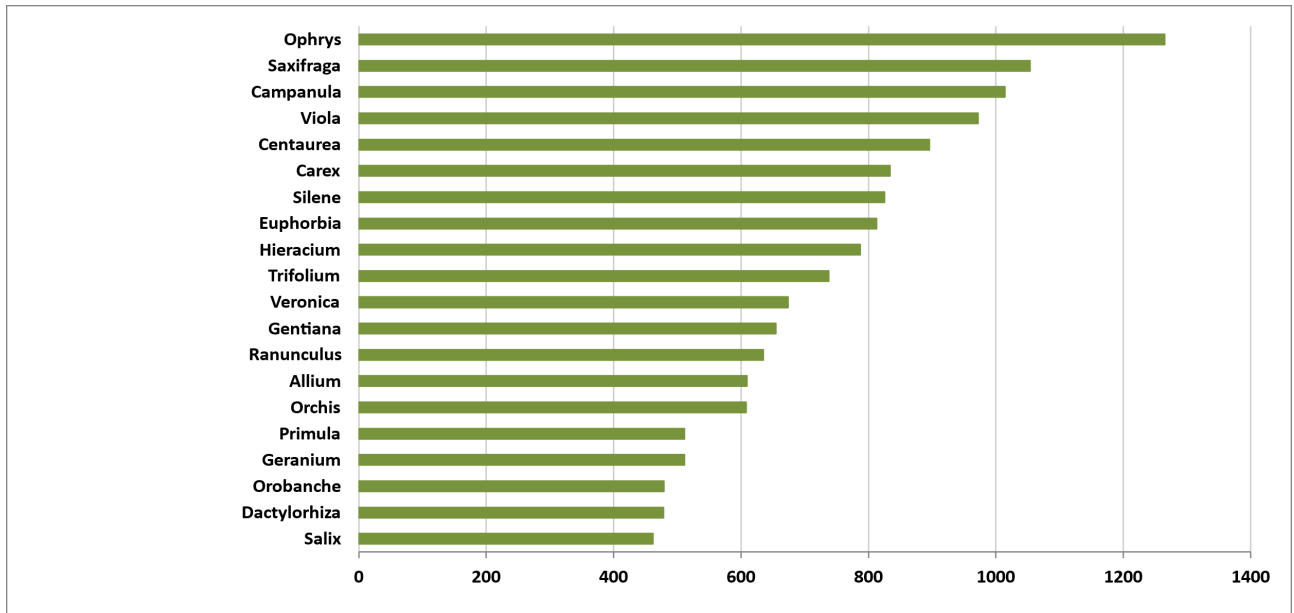


Figure 8. The 20 most frequent genera in AP (number of floristic records).

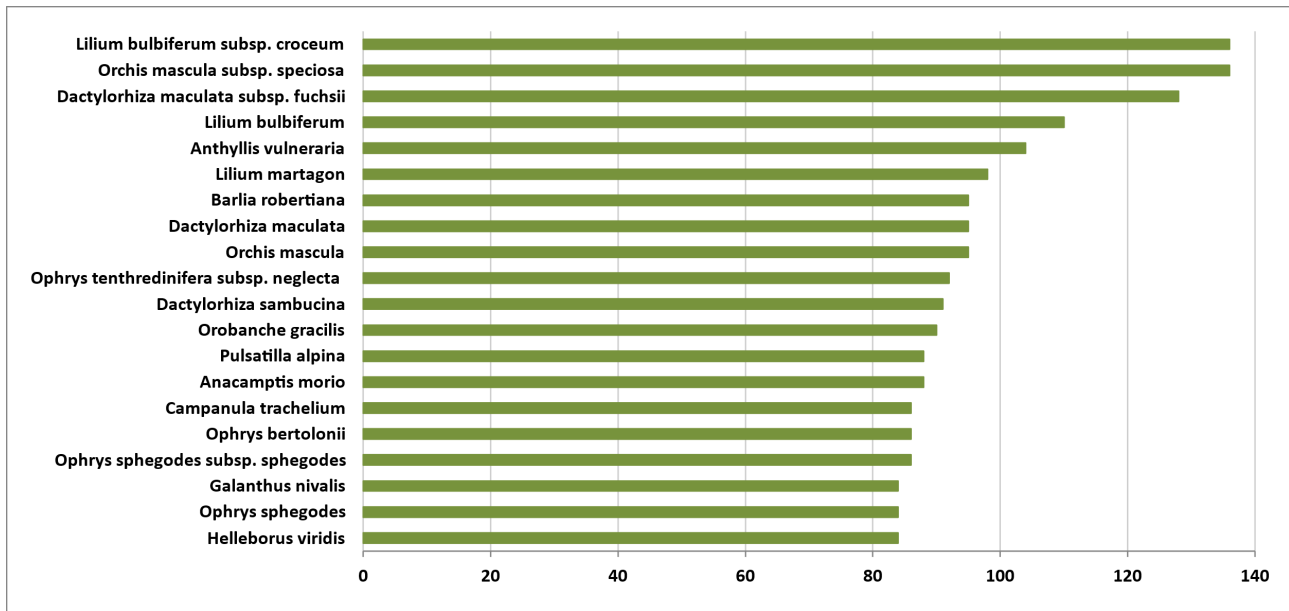


Figure 9. The 20 most frequent specific and subspecific taxa in AP (number of floristic records).

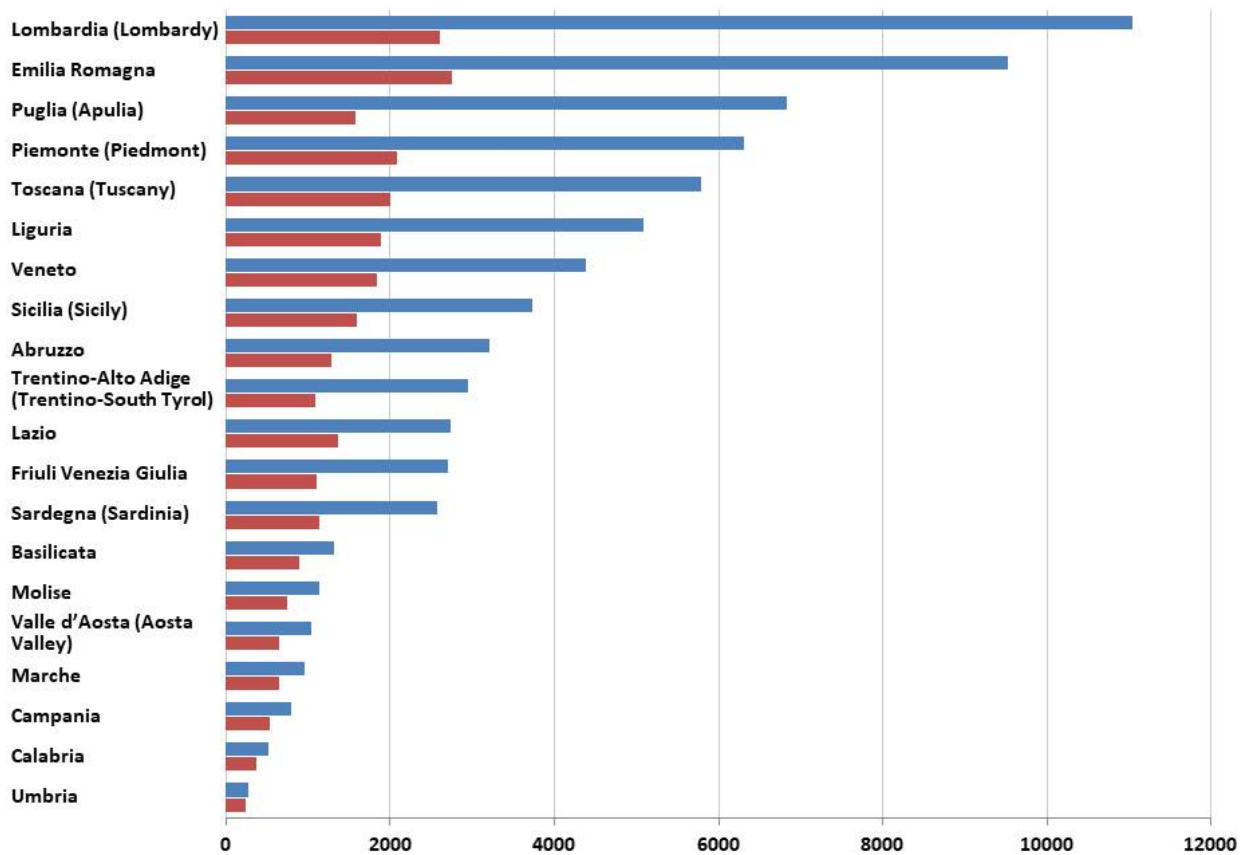


Figure 10. Number of records (blue bars) and of specific and subspecific taxa (red bars) per administrative region.

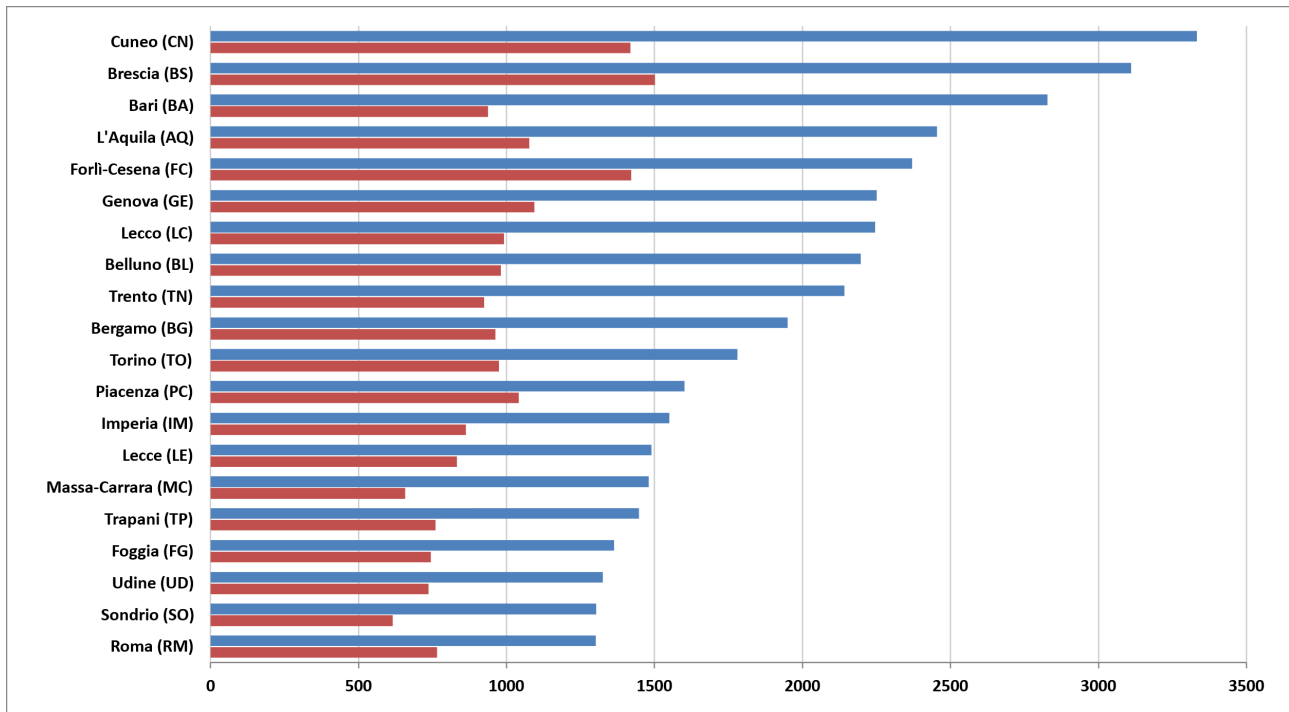


Figure 11. Top 20 administrative provinces according to the number of floristic records (blue bars) with relative number of specific and subspecific taxa (red bars).

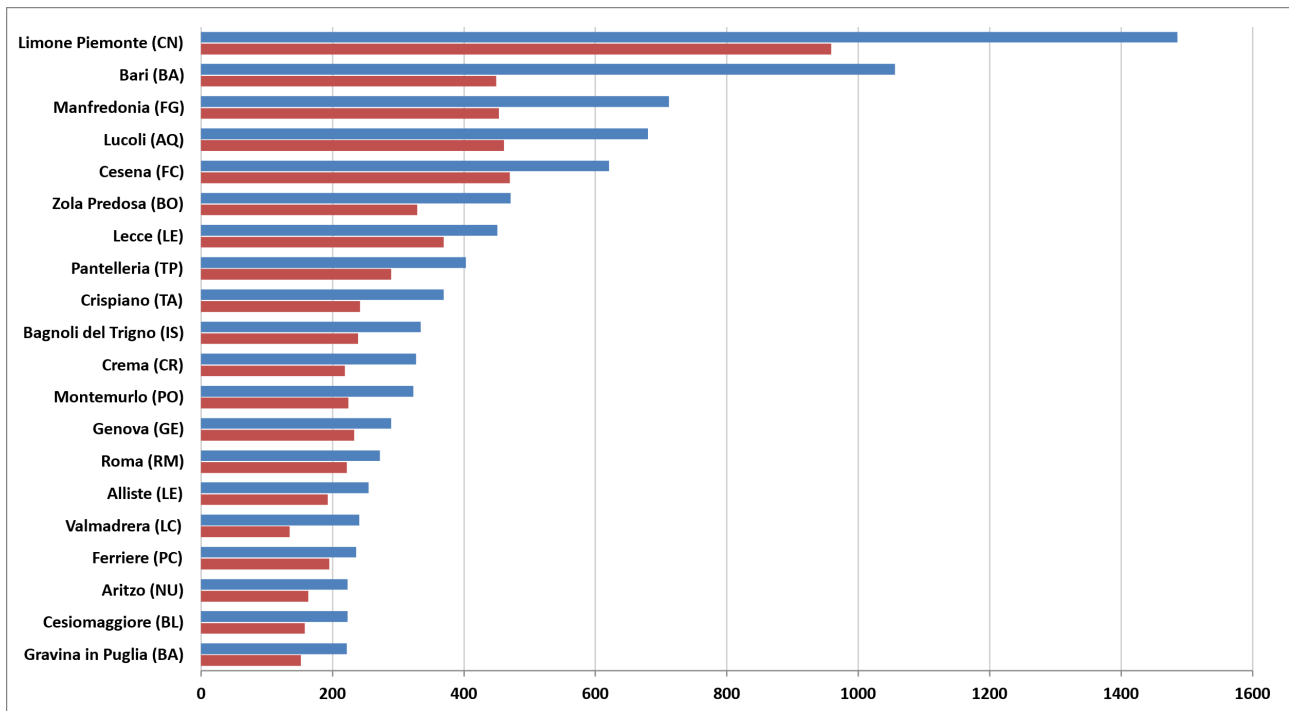


Figure 12. Top 20 Italian administrative municipalities according to the number of floristic records (blue bars) with relative number of specific and subspecific taxa (red bars).

At the municipal level, 2,272 municipalities have at least one record. Limone Piemonte is the first both for number of records and specific and subspecific taxa represented (Fig. 12).

Data quality

As a result of the validation process, less than 2% of the topics moved to "Archivio Floristico" have returned to "Che pianta è?" in the last 10 years, showing a good quality in accuracy of the stored data. Moreover, about 28,800 topics, over 30% of the total floristic topics, have been deleted over the years due to misidentification and/or impossibility to receive a correct identification.

The first release of the utility, including the automatic extraction mode only, was available since September 2019. Just over 64,000 records were extracted in the first step. After nine months and with the addition of the manual computer-aided mode, there has been an increase of about 16%. Around 4,600 of the new records concern new information published in forums, while around 5,600 have been extracted in manual computer-aided mode through the analysis of less than 18% of the candidate topics. An annual increase of about 6,000 records is expected from the automatic extraction, and the finalization of the manual extraction will produce at least additional 30,000 records.

DISCUSSION

The AP project

The involvement of citizens in floristic research is now a given. Since several years, the amateur groups help researchers in the collection of data, performing a job that nowadays professionals struggle to carry out due to economic and organizational problems. Web-based communities are currently a fast and safe

way to promote research projects engaging amateurs and common citizens.

The AP project is one of the most popular floristic web-based communities in Italy. The number of visits and accesses to the AP website suggests that it has become a reference point both for amateurs and for professionals involved in floristics. Moreover, the results in terms of number of discussions and posted pictures confirm the potential of this project in the collection of information and occurrence data on the species of the Italian flora.

The materials stored on the AP website are extremely useful for students and teachers as they are easily accessible, regularly updated, and focused on the Italian context. Already, many teachers and university professors asked for the use of AP contents and pictures for their lessons. At the same time, students visited the AP website for the botanical glossary, morphology, floristic gallery or to use IPFI, and joined the forum to get help with species identifications.

The importance of the AP contribution to floristic knowledge is highlighted by the several times that the first record of new species for Italy or for an Italian administrative region appeared in the AP forum (Iamonico et al. 2014, Sirotti et al. 2017, Bartolucci et al. 2018b, Galasso et al. 2018b, Bartolucci et al. 2019b, Rosati et al. 2020). Other times, topics and images published in AP have enabled botanical experts to point out the occurrence of species or to confirm it for some Italian region or even for Italy (Raab-Straube and Raus 2015, Nobis et al. 2020). The AP website also allowed many researchers to confirm observed or collected species identifications (Montanari 2012, Faggi et al. 2013, Galasso et al. 2016, Carta et al. 2018, Salinitro et al. 2018). Records in AP, based on photographs, have been also useful to cover underrepresented geographical areas or to confirm old data (Cecchi and Selvi 2014, Troia and Greuter 2015).

AP has become one of the main photographic databases to draw on when aiming to publish something about the Italian flora (San-Miguel-Ayanz et al. 2016, Venditti et al. 2016, Iamónico 2017, García-Trenas et al. 2018).

IPFI proved to be a particularly useful tool not only for the AP project, but also for anyone who needs to update floristic nomenclature for their studies (Latini et al. 2018, Salinitro et al. 2018) or for those who were looking for a taxonomic web source (Iamónico 2014, Croce 2015, Lucarini et al. 2015). In addition, in recent years, it has provided quick and easy access to large amounts of information such as phenology or chorology (Fascetti et al. 2014), plant uses and properties (Perrino et al. 2014), plant toxicity (Guarrera and Savo 2016), etymological notes (Lobão and Machado 2015), and many other plant traits (Russo et al. 2015, Falasca et al. 2016, Guarise et al. 2019, Byalt et al. 2020, Uhl et al. 2020).

It is not easy to find projects similar to AP. Probably, the closest one is Tela Botanica (Heaton et al. 2010). Like AP, this French project is focused on a website hosting a well-structured forum and an extensive photo gallery. It also devotes the same attention to the scientific aspects of nomenclature and distribution. Unlike AP, however, it is an association and receives public funding. In Italy, NaturaMediterraneo (2020) has a forum quite similar to AP, but it is a more generalist project, rather focused on fauna and insects than on flora. Moreover, in the Plant section it seems to be less formal about scientific nomenclature and locality indication.

Remarkable is the longevity of AP, which has been going on for over thirteen years. Instead, other CS projects such as CSMON-LIFE generally address limited time and scope surveys. Although they are important for recording invasive species or plants of Community Interest, it is difficult to compare them to projects targeting the whole national

flora. Despite sharing the same nomenclatural references and a data entry process following extremely strict and precise rules, Wikiplantbase is a quite different project. It is essentially a repository of floristic records, while AP can be considered a working tool providing many different resources. For this reason, the two projects are linked, complementing each other. AP offers a photo gallery and a discussion forum, which is missing in Wikiplantbase, while AP users can have easily access to bibliographic and herbarium records.

As a web-based community, AP is powered by the collaboration of people interested in botany, who often approach the website to learn. The structure of the project allows anyone to contribute, even those who initially have no expertise in botany. By following the project, however, they can increase their knowledge and become expert members over time. Members attending the AP forum can regularly continue their development within the community and they can be involved, after appropriate training, in critical activities for the project, such as moderating subforums or implementing utilities.

Floristic records

Since AP is a photographic forum, the attitude of species at being photogenic and the ability of identification through pictures or easily recognizable characters are important to justify relative frequencies. Comparing the largest families of the Italian flora as reported in the checklists of the Italian vascular flora (Bartolucci 2018a, Galasso 2018a) and those most represented in the AP floristic records, among the top 20 families, only Plumbaginaceae and Rubiaceae are replaced by Primulaceae and Saxifragaceae, which are certainly showier and more photogenic. The top 10 families are the same, although in different order. Floristic records for Fabaceae, Orchidaceae, and Brassicaceae are more abundant than those for Poaceae, which is the

second largest family in Italy. This is probably due to the lack of photographic appeal of the members of Poaceae, or maybe because the identification of these plants requires a lot of care and patience to photograph smallest details. On the other hand, many of the largest genera of the Italian flora are in backward positions among the floristic records. *Hieracium* L., *Taraxacum* L., *Pilosella* L., *Limonium* Mill., and *Alchemilla* L. are critical genera, for which photographic material is usually insufficient for identification. As a result, they are poorly illustrated in photographic forums. Among the critical genera, the only one that is quite well represented in AP is *Hieracium*. This is certainly due to the great advice given both in forums and privately by two of the greatest specialists of this genus, Günther Gottschlich and Jean-Marc Tison. Instead, genera with the largest floristic records are the showiest ones, with beautiful flowers, often with characters well detectable through pictures and therefore easier to identify. The same is true for specific and subspecific taxa. Among the 20 most represented specific and subspecific taxa, 11 orchids are present, showing how much these flowers are searched for and appreciated by amateurs.

An evident unbalance is present from a geographical point of view. Northern Italy provides more data to the forum and consequently to the floristic records database. Regions with the highest number of records are also those with more members, except for Abruzzo and Trentino Alto Adige (Trentino-South Tyrol). Probably, many photos from these regions are posted by tourists and not by residents, since they have a beautiful and rich alpine flora that attracts many people during vacation periods. Puglia (Apulia), Emilia Romagna, and Liguria, on the other hand, show more active users than other regions, providing a higher average number of records. Provinces and municipalities with several records are likely to be those with particularly active users who limit their research to restricted areas or

perhaps are systematically studying a given territory.

In general, the number of specific and subspecific taxa per region is consistent with the number of floristic records, with few differences. Contributors from Emilia Romagna and Lazio seem to prefer to post pictures for species always different, while for Puglia (Apulia) and Trentino Alto Adige (Trentino-South Tyrol) a large number of records do not match an extensive floristic list.

The quantity of geo-referenced species occurrences stored or potentially storable in the AP database will never reach the numbers of projects specifically born to collect occurrence data (e.g., iNaturalist, Pl@ntNet, Wikiplantbase), or containing herbarium and bibliographic data too. Most important, it is very distant from big public data aggregators, such as the Global Biodiversity Information Facility (GBIF, www.gbif.org). However, data extracted from GBIF are often incorrect and inaccurate, due to different collecting methodologies, lack of centralized curation, and data-entry errors (Zizka et al 2019). AP aims to provide a contribution focused on quality rather than quantity. Indeed, all occurrences in AP are reliable, original, and recent observations, collected within the last 13 years and geo-referenced well enough. Such sound floristic data will be extremely useful to the general audience, policy makers, amateurs, and scientists alike.

Data quality

As AP was born as a discussion forum rather than a floristic data repository, no indicators were initially provided to test the quality of the data. However, analyzing both the characteristics of the community and the validation process, it is possible to recognize the different factors that contribute to the high quality of the database.

First of all, the user community is somewhat known. Members are divided into

informal but relevant categories: newbies, common members, “botanists” (i.e., members posting regularly), botanical moderators, and global moderators. Members are not anonymous, favoring the ability to validate the posting of data (Hunter et al. 2013). To improve the quality of floristic data several techniques are applied. Multiple validation methods are used (Wiggins et al. 2011), such as the presence of images with significant content, automatic filtering of unusual reports, up to three identification confirmations with at least one confirmation from an expert member. This last point can be a limitation. If some genus or families are not well known by AP experts, they will be less common in the validated topics, causing a lack of completeness (Brandon et al. 2003). Furthermore, the validation process is repetitive (Kosmala et al. 2016) and it is possible to modify the validation along all the life of the project. Overall, while the huge number of floristic topics deleted over the years highlight the scientific rigor of the project, and the relatively low percentage of formerly stored topics that have been questioned is proves the good accuracy of AP data.

The AP validation process is quite similar to the INaturalist one. In this CS platform three confirmations are always needed for the identification, but the process seems much leaner and less controlled. Photos showing the diacritical characters, for instance, are not specifically required. The validation of a moderator or "expert user" is also missed. Moreover, differently than in AP, INaturalist community consists of people not knowing each other and therefore it is not possible to assess their reliability. The checklist is not properly updated, and taxa not included in the list cannot be posted. No control is carried out on the real status of the alien species submitted. As in AP, data validation by experts is present instead in CSMON, as well as in Wikiplantbase.

For the future

The AP purpose for the future is to go on with the same policy followed in these years. Sharing of knowledge and personal development of the members, as well as of the community, will certainly be still the cornerstones of the project. Free access to the data will be ensured and further collaborations with other floristic projects will be considered. Efforts will continue to increase the AP databases with additional information useful for the identification and characterization of species.

As regards the new utility, since the most difficult and challenging part of the project has ended, some further improvements are under discussion. A table of toponyms can be added to the database to get also a more precise and more generalized geo-referencing. Other sources from which floristic records could be extracted will be taken into account, e.g., reliable floristic lists stored in forums but not accompanied by images, "florule" (local floristic checklists) lists and articles of APNotes, the AP project non-periodic publication. Moreover, additional filters will be added in order to achieve floristic lists by toponym or municipality.

The initial aim of AP to illustrate all the Italian flora has now been joined by the possibility of providing a large number of original occurrences. Therefore, many initiatives are in development. The first one started in June 2020 to increase the collection of floristic records and was presented as a game. Every month, a small list of about fifteen species is released, and then members are asked to provide as many photos and location data as possible. Some species of certain identification were initially chosen, but more complex lists may be proposed in the coming months, as the initiative is enjoying a good success. These could address issues of specific floristic interest, such as the distribution of species of conservation concern or the spread of invasive alien species. The collection of records for

species that are not particularly rare or beautiful could be further encouraged, and contribution to the compilation of municipal or provincial lists could be stimulated. Finally, collaborations with other online data sharing initiatives both on a national and international level could be explored.

CONCLUSION

Overall, AP results suggest that web-based floristic communities can be valuable tools for field research and to increase floristic knowledge at both local and national levels. The work of skilled and highly motivated volunteers can be a very useful resource for the whole botanical community. Web discussion forums host a large amount of valuable data and the development of specific utilities allows the best use of this information for the general audience.

AP results also confirm that the role of amateurs is fundamental to the development of extensive floristic databases and that data collected by citizen scientists are extremely reliable when supported by an appropriate validation process. However, in projects where identifications are based on pictures, data collection is affected by the photographic appeal of the species and by the easiness of taxa recognition. Critical genera are therefore usually underrepresented.

The achieved results invite to continue the project and to further extend it with the imagination that has always distinguished it.

ACKNOWLEDGEMENTS

Thanks to all the Acta Plantarum members. It is only through the continuous contribution of almost 1,800 botanical enthusiasts that the project has become what it is and that it was possible to create an extremely rich and useful database.

Thanks to all the Acta Plantarum moderators. It is only through the daily and

patient work of more than 20 people that it is possible to have reliable and well-organized data suitable for the floristic database.

DATA ACCESS

The entire IPFI database including botanical records is freely accessible online through the Acta Plantarum website: <https://www.actaplantarum.org/flora/flora.php>.

REFERENCES

- Aceves-Bueno, E., Adeleye, A.S., Feraud, M., Huang, Y., Tao, M., Yang, Y. & Anderson, S.E. (2017) The Accuracy of Citizen Science Data: A Quantitative Review. *The Bulletin of the Ecological Society of America*, 98, 278–290. DOI: 10.1002/bes2.1336
- Aeschimann, D., Lauber, K., Moser, M., & Theurillat, J.P. (2004) *Flora Alpina*. Zanichelli, Bologna.
- Baglivo, A., Cibei, C., Dose, G., Giordana, F., Longo, D., Michelucci, A., Nicolella, G., Salvai, G. & Zepigi, M. (2010) Acta Plantarum - un progetto open source. In: 105° Congresso Nazionale della Società Botanica Italiana held 25-28 August 2010, Milano, Italia.
- Baglivo, A., Zepigi, M., Cibei, C., et al. (2016) ActaPlantarum, an amateur virtual community for the floristic and botanical knowledge sharing. In: XV OPTIMA Meeting held 6-11 June 2016, Montpellier, France (ed. by F. Medail and G. Domina), p. 77. JF Impression, Montpellier, France.
- Barnard, P., Altwegg, R., Ebrahim, I. & Underhill, L.G. (2017) Early warning systems for biodiversity in southern Africa – How much can citizen science mitigate imperfect data? *Biological Conservation*, 208, 183–188. DOI: 10.1016/j.biocon.2016.09.011
- Bartolucci, F., Domina, G., Alessandrini, A., et al. (2019a) Notulae to the Italian native vascular flora: 7. *Italian Botanist*, 7, 125–148. DOI: 10.3897/italianbotanist.7.36148
- Bartolucci, F., Domina, G., Andreatta, S., et al. (2020) Notulae to the Italian native vascular

- flora: 9. *Italian Botanist*, 9, 71–86. DOI: 10.3897/italianbotanist.9.53429
- Bartolucci, F., Domina, G., Ardenghi, N.M.G., et al. (2018b) Notulae to the Italian native vascular flora: 6. *Italian Botanist*, 6, 45–64. DOI: 10.3897/italianbotanist.6.30575
- Bartolucci, F., Domina, G., Ardenghi, N.M.G., et al. (2019b) Notulae to the Italian native vascular flora: 8. *Italian Botanist*, 8, 95–116. DOI: 10.3897/italianbotanist.8.48626
- Bartolucci, F., Peruzzi, L., Galasso, G., et al. (2018a) An updated checklist of the vascular flora native to Italy. *Plant Biosystems*, 152, 179–303. DOI: 10.1080/11263504.2017.1419996
- Bedini, G., Garbari, F. & Peruzzi, L. (2012) Karyological knowledge of the Italian vascular flora as inferred by the analysis of “Chrobase.it.” *Plant Biosystems*, 146, 889–899. DOI: 10.1080/11263504.2011.611182
- Bedini, G., Pierini, B., Roma-Marzio, F., Caparelli, K.F., Bonari, G., Dolci, D., Gestri, G., D’Antraccoli, M. & Peruzzi, L. (2016) Wikiplantbase #Toscana, breaking the dormancy of floristic data. *Plant Biosystems*, 150, 601–610.
- Bell, S., Marzano, M., Cent, J., Kobińska, H., Podjed, D., Vandzinskaite, D., Reinert, H., Armaitiene, A., Grodzińska-Jurczak, M. & Muršič, R. (2008) What counts? Volunteers and their organisations in the recording and monitoring of biodiversity. *Biodiversity and Conservation*, 17, 3443–3454. DOI: 10.1007/s10531-008-9357-9
- Bonnet, P., Botella, C., Munoz, F., Monestiez, P., Chouet, M., Goëau, H. & Joly, A. (2018) Automated Identification of Citizen Science Observations for Ecological Studies. *Biodiversity Information Science and Standards*, 2, e25450. DOI: 10.3897/biss.2.25450
- Bonnet, P., Joly, A., Faton, J.-M., et al. (2020) How citizen scientists contribute to monitor protected areas thanks to automatic plant identification tools. *Ecological Solutions and Evidence*, 1, e12023. DOI: 10.1002/2688-8319.12023
- Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J. & Parrish, J.K. (2014) Next Steps for Citizen Science. *Science*, 343, 1436–1437. DOI: 10.1126/science.1251554
- Brandon, A., Spyreas, G., Molano-Flores, B., Carroll, C. & Ellis, J. (2003) Can volunteers provide reliable data for forest vegetation surveys? *Natural Areas Journal*, 23, 254–261.
- Burrack, H.J., Smith, J.P., Pfeiffer, D.G., Koehler, G. & Laforest, J. (2012) Using Volunteer-Based Networks to Track *Drosophila suzukii* (Diptera: Drosophilidae) an Invasive Pest of Fruit Crops. *Journal of Integrated Pest Management*, 3, B1–B5. DOI: 10.1603/IPM12012
- Byalt, V.V., Egorov, A.A., Pismarkina, E.V. & Galanina, O.V. (2020) Additions to the flora of northern Asia: alien vascular plant records in the Yamal-Nenets Autonomous District (Russia). *Check List*, 16(1), 137–153. DOI: 10.15560/16.1.137
- Carta, A., Forbicioni, L., Frangini, G., Pierini, B. & Peruzzi, L. (2018) An updated inventory of the vascular flora of Elba island (Tuscan Archipelago, Italy). *Italian Botanist*, 6, 1–22. DOI: 10.3897/italianbotanist.6.26568
- Cecchi, L. & Selvi, F. (2014) A synopsis of Boraginaceae subfam. Hydrophylloideae and Heliotropioideae in Italy. *Plant Biosystems*, 148, 2–12. DOI: 10.1080/11263504.2013.873499
- Chandler, M., See, L., Copas, K., et al. (2017) Contribution of citizen science towards international biodiversity monitoring. *Biological Conservation*, 213, 280–294. DOI: 10.1016/j.biocon.2016.09.004
- Citizen Science Italia (2020). Citizen Science on the Website of the Museo di Storia Naturale della Maremma. Available at: <https://www.museo.naturalemaremma.it/csi/> [Last accessed 29 December 2020]
- Conrad, C.C. & Hilchey, K.G. (2011) A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment*, 176, 273–291. DOI: 10.1007/s10661-010-1582-5

- Conti, F., Abbate, G., Alessandrini, A., et al. (2005) An annotated Checklist of the Italian Vascular Flora. Palombi Editori, Roma.
- Crall, A.W., Jarnevich, C.S., Young, N.E., Panke, B.J., Renz, M. & Stohlgren, T.J. (2015) Citizen science contributes to our knowledge of invasive plant species distributions. *Biological Invasions*, 17, 2415–2427. DOI: 10.1111/j.1755-263X.2011.00196.x
- Crall, A.W., Newman, G.J., Stohlgren, T.J., Holfelder, K.A., Graham, J. & Waller, D.M. (2011) Assessing citizen science data quality: an invasive species case study. *Conservation Letters*, 4, 433–442. DOI: 10.1111/j.1755-263X.2011.00196.x
- Croce, A. (2015) Vascular flora of eight water reservoir areas in southern Italy. *Check List*, 11(2), 1–23. DOI: 10.15560/11.2.1593
- Croce, A. & Nazzaro, R. (2017) An atlas of orchids distribution in the Campania region (Italy), a citizen science project for the most charming plant family. *Italian Botanist*, 4, 15–32. DOI: 10.3897/italianbotanist.4.14916
- Delaney, D.G., Sperling, C.D., Adams, C.S. & Leung, B. (2008) Marine invasive species: validation of citizen science and implications for national monitoring networks. *Biological Invasions*, 10, 117–128. DOI: 10.1007/s10530-007-9114-0
- Domroese, M.C. & Johnson, E.A. (2017) Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. *Biological Conservation*, 208, 40–47. DOI: 10.1016/j.biocon.2016.08.020
- Eitzel, M.V., Cappadonna, J.L., Santos-Lang, C., et al. (2017) Citizen Science Terminology Matters: Exploring Key Terms. *Citizen Science: Theory and Practice*, 2, 1. DOI: 10.5334/cstp.96
- Euro+Med (2006 onwards) Euro+MedPlantBase - the information resource for Euro-Mediterranean plant diversity. Digital resource available at <http://ww2.bgbm.org/EuroPlusMed/>. Accessed 16/03/2021.
- Eurostat (2020) Nomenclature of Territorial Units for Statistics. Digital resource available at <https://ec.europa.eu/eurostat/web/main> Accessed 29/07/2021.
- Faggi, G., Montanari, S., & Alessandrini, A. (2013) Aggiornamenti floristici per la Romagna. *Quaderno di studi e notizie di storia naturale della Romagna*, 38, 7-26.
- Falasca, A., Caprari, C., De Felice, V., Fortini, P., Saviano, G., Zollo, F. & Iorizzi, M. (2016) GC-MS analysis of the essential oils of *Juniperus communis* L. berries growing wild in the Molise region: Seasonal variability and in vitro antifungal activity. *Biochemical Systematics and Ecology*, 69, 166–175. DOI: 10.1016/j.bse.2016.07.026
- Fascetti, S., Potenza, G., Castronuovo, D. & Candido, V. (2014) Wild geophytes of ornamental interest in the native flora of southern Italy. *Italian Journal of Agronomy*, 9, 99–106. DOI: 10.4081/ija.2014.595
- Fiori, A. (1923-1929) *Nuova flora analitica d'Italia, contenente la descrizione delle piante vascolari indigene inselvatiche e largamente coltivate in Italia*. Tipografia di M. Ricci, Firenze.
- Forrester, T.D., Baker, M., Costello, R., Kays, R., Parsons, A.W. & McShea, W.J. (2017) Creating advocates for mammal conservation through citizen science. *Biological Conservation*, 208, 98–105. DOI: 10.1016/j.biocon.2016.06.025
- Galasso, G., Conti, F., Peruzzi, L., et al. (2018a) An updated checklist of the vascular flora alien to Italy. *Plant Biosystems*, 152, 556–592. DOI: 10.1080/11263504.2018.1441197
- Galasso, G., Domina, G., Adorni, M., et al. (2020) Notulae to the Italian alien vascular flora: 9. *Italian Botanist*, 9, 47–70. DOI: 10.3897/italianbotanist.9.53401
- Galasso, G., Domina, G., Alessandrini, A., et al. (2018b) Notulae to the Italian alien vascular flora: 6. *Italian Botanist*, 6, 65–90. DOI: 10.3897/italianbotanist.6.30560
- Galasso, G., Domina, G., Andreatta, S., et al. (2019b) Notulae to the Italian alien vascular flora: 8. *Italian Botanist*, 8, 63–93. DOI: 10.3897/italianbotanist.8.48621
- Galasso, G., Domina, G., Ardenghi, N.M.G., et al. (2016) Notulae to the Italian alien vascular flora: 2. *Italian Botanist*, 2, 55–71. DOI: 10.3897/italianbotanist.2.11144

- Galasso, G., Domina, G., Ardenghi, N.M.G., et al. (2019a) Notulae to the Italian alien vascular flora: 7. Italian Botanist, 7, 157–182. DOI: 10.3897/italianbotanist.7.36386
- García-Trenas, T., López, J.C. & Peña-García, A. (2018) Proposal to forest Alpine tunnels surroundings to enhance energy savings from the lighting installations. Towards a standard procedure. Tunnelling and Underground Space Technology, 78, 1–7. DOI: 10.1016/j.tust.2018.04.019
- Gouveia, C., Fonseca, A., Câmara, A. & Ferreira, F. (2004) Promoting the use of environmental data collected by concerned citizens through information and communication technologies. Journal of Environmental Management, 71, 135–154. DOI: 10.1016/j.jenvman.2004.01.009
- Graham, E.A., Henderson, S. & Schloss, A. (2011) Using mobile phones to engage citizen scientists in research. Eos, Transactions American Geophysical Union, 92, 313–315. DOI: 10.1029/2011EO380002
- Guarino, R., Menegoni, P., & Pignatti, S. (2010). Educational or emotional languages? An interactive experiment with the Lucanian flora (S-Italy). In: Tools for Identifying Biodiversity: Progress and Problems (ed. by P.L. Nimis, L. VignesLebbe), pp. 405-409. EUT Edizioni Università di Trieste, Trieste.
- Guarise, M., Borgonovo, G., Bassoli, A. & Ferrante, A. (2019) Effect of Fertilization on Yield and Quality of *Sisymbrium officinale* (L.) Scop. Grown as Leafy Vegetable Crop. Agronomy, 9, 401. DOI: 10.3390/agronomy9070401
- Guarrera, P.M. & Savo, V. (2016) Wild food plants used in traditional vegetable mixtures in Italy. Journal of Ethnopharmacology, 185, 202–234. DOI: 10.1016/j.jep.2016.02.050
- Haklay, M. (2015). Citizen science and policy: a European perspective. The Wodrow Wilson Center, Commons Lab.
- Heaton, L., Millerand, F. & Proulx, S. (2010) « Tela Botanica »: une fertilisation croisée des amateurs et des experts. Hermes, La Revue, 57, 61–68.
- Hunter, J., Alabri, A. & Ingen, C. van (2013) Assessing the quality and trustworthiness of citizen science data. Concurrency and Computation: Practice and Experience, 25, 454–466. DOI: 10.1002/cpe.2923
- Iamonico, D. (2017) Alien taxa of the tribe Senecioneae (Asteraceae) in Italy: a nomenclatural synopsis. Hacquetia, 16, 281–292. DOI: 10.1515/hacq-2017-0005
- Iamonico, D. (2014) *Arenaria tenuifolia* versus *Arenaria hybrida* (Caryophyllaceae): Nomenclatural study and taxonomic implications. Phytotaxa, 173, 235–240. DOI: 10.11646/phytotaxa.173.3.6
- Iamonico, D., Iberite, M. & Nicoletta G. (2014) Aggiornamento alla flora esotica del Lazio (Italia centrale). II. Informatore Botanico Italiano, 46, 215–220.
- INaturalist (2020). INaturalist website, Available at: <https://www.inaturalist.org/> [Last accessed 29 December 2020]
- Ingwell, L.L. & Preisser, E.L. (2011) Using Citizen Science Programs to Identify Host Resistance in Pest-Invaded Forests. Conservation Biology, 25, 182–188.
- IPNI (2020) International Plant Names Index. Digital resource available at <http://www.ipni.org>. Accessed 29/12/2020.
- ISTAT (2020) Istituto nazionale di Statistica. Digital resource available at <https://www.istat.it/it/archivio/6789>. Accessed 29/12/2020.
- Joly, A., Bonnet, P., Goëau, H., et al. (2016) A look inside the Pl@ntNet experience. Multimedia Systems, 22, 751–766. DOI: 10.1007/s00530-015-0462-9
- Kosmala, M., Wiggins, A., Swanson, A. & Simmons, B. (2016) Assessing data quality in citizen science. Frontiers in Ecology and the Environment, 14, 551–560. DOI: 10.1002/fee.1436
- Kress, W.J., Garcia-Robledo, C., Soares, J.V.B., Jacobs, D., Wilson, K., Lopez, I.C. & Belhumeur, P.N. (2018) Citizen Science and Climate Change: Mapping the Range Expansions of Native and Exotic Plants with the Mobile App Leafsnap. BioScience, 68, 348–358. DOI: 10.1093/biosci/biy019
- Latini, M., Iberite, M. & Abbate, G. (2018) Using woody flora to define phytogeographic units: analysis of a west–east transect in central Italy.

- Nordic Journal of Botany, 36. DOI: 10.1111/njb.01650
- Lewandowski, E. & Specht, H. (2015) Influence of volunteer and project characteristics on data quality of biological surveys. *Conservation Biology*, 29, 713–723. DOI: 10.1111/cobi.12481
- Lobão, A.Q. & Machado, A.F.P. (2015) (28) Request for a binding decision on whether *Bonannia* Guss. (Apiaceae) and *Bonania* A. Rich. (Euphorbiaceae) are sufficiently alike to be confused. *TAXON*, 64, 1064–1064. DOI: 10.12705/645.28
- Lucarini, D., Gigante, D., Landucci, F., Panfili, E. & Venanzoni, R. (2015) The anArchive taxonomic Checklist for Italian botanical data banking and vegetation analysis: Theoretical basis and advantages. *Plant Biosystems*, 149, 958–965. DOI: 10.1080/11263504.2014.984010
- Mannino, A.M. & Balistreri, P. (2018) Citizen science: a successful tool for monitoring invasive alien species (IAS) in Marine Protected Areas. The case study of the Egadi Islands MPA (Tyrrhenian Sea, Italy). *Biodiversity*, 19, 42–48. DOI: 10.1080/14888386.2018.1468280
- Martellos, S. (2017). Il ruolo dell'informazione e della Citizen Science. *Biologia Ambientale*, 31: 147-150
- Martellos, S., Bartolucci, F., Conti, F., Galasso, G., Moro, A., Pennesi, R., Peruzzi, L., Pittao, E. & Nimis, P.L. (2020) FlorItaly – the portal to the Flora of Italy. *PhytoKeys*, 156, 55–71. DOI: 10.3897/phytokeys.156.54023
- Mathieu, D. (2011) Observer la nature, une problématique «science citoyenne» ?. *Forêt méditerranéenne*, 32, 115–118.
- McDonough MacKenzie, C., Murray, G., Primack, R. & Weihrauch, D. (2017) Lessons from citizen science: Assessing volunteer-collected plant phenology data with Mountain Watch. *Biological Conservation*, 208, 121–126. DOI: 10.1016/j.biocon.2016.07.027
- McKinley, D.C., Miller-Rushing, A.J., Ballard, H.L., et al. (2017) Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, 208, 15–28. DOI: 10.1016/j.biocon.2016.05.015
- Milanesi, P., Mori, E. & Menchetti, M. (2020) Observer-oriented approach improves species distribution models from citizen science data. *Ecology and Evolution*, 10, 12104–12114. DOI: 10.1002/ece3.6832
- Missouri Botanical Garden (2020) Tropicos. Digital resource available at <http://www.tropicos.org>. Accessed 19/12/2020.
- Montanari, S. (2012) Checklist commentata della flora vascolare del Podere Pantaleone (Bagnacavallo, Ravenna). *Quaderno di studi e notizie di storia naturale della Romagna*, 35, 1-77.
- NaturaMediterraneo (2020). NaturaMediterraneo, il portale della natura, Available at: <https://www.naturamediterraneo.com/> [Last accessed 29 December 2020]
- Nimis, P.L., Pittao, E., Altobelli, A., Pascalis, F.D., Laganis, J. & Martellos, S. (2019) Mapping invasive plants with citizen science. A case study from Trieste (NE Italy). *Plant Biosystems*, 153, 700–709. DOI: 10.1080/11263504.2018.1536085
- Nobis, M., Marciniuk, J., Marciniuk, P., et al. (2020) Contribution to the flora of Asian and European countries: new national and regional vascular plant records, 9. *Turkish Journal of Botany*, 44, 455–480.
- Perrino, E.V., Ladisa, G. & Calabrese, G. (2014) Flora and plant genetic resources of ancient olive groves of Apulia (Southern Italy). *Genetic Resources and Crop Evolution*, 61, 23–53. DOI: 10.1007/s10722-013-0013-1
- Peruzzi, L., Bagella, S., Filigheddu, S., et al. (2017) The Wikiplantbase project: the role of amateur botanists in building up large online floristic databases. *Flora Mediterranea*, 27, 117–129. DOI: 10.7320/FlMedit27.117
- phpBB® (2001 onwards) The #1 Free, Open Source Bulletin Board Software. Digital resource available at <https://www.phpbb.com/>. Accessed 29/07/2021.
- Pignatti, S. (1982) *Flora d'Italia*. Edagricole, Bologna.

- Pignatti, S., Guarino, R., & La Rosa, M. (2017-2019) *Flora d'Italia*, 2a edizione. Edagricole di New Business Media, Bologna.
- Pocock, M.J.O., Chandler, M., Bonney, R., et al. (2018) Chapter Six - A Vision for Global Biodiversity Monitoring With Citizen Science. In: D.A. Bohan, A.J. Dumbrell, G. Woodward, & M. Jackson (eds.) *Advances in Ecological Research. Next Generation Biomonitoring: Part 2*. Academic Press, pp. 169–223. DOI: 10.1016/bs.aecr.2018.06.003
- Pocock, M.J.O., Roy, H.E., Preston, C.D. & Roy, D.B. (2015) The Biological Records Centre: a pioneer of citizen science. *Biological Journal of the Linnean Society*, 115, 475–493. DOI: 10.1111/bij.12548
- Pocock, M.J.O., Tweddle, J.C., Savage, J., Robinson, L.D. & Roy, H.E. (2017) The diversity and evolution of ecological and environmental citizen science. *PLOS ONE*, 12, e0172579. DOI: 10.1371/journal.pone.0172579
- Raab-Straube, E.V. & Raus, T. (2015) Euro Med-Checklist Notulae, 5. *Willdenowia*, 45, 449–464. DOI: 10.3372/wi.45.45312
- Riservato, E., Fabbri, R., Festi, A., Grieco, C., Handersen, S., Landi, F., Utzeri, C., Rondinini, C., Battistoni, A. & Teofili, C. (2014) *Lista Rossa IUCN delle Libellule Italiane*. Comitato italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma.
- Rosati, L., Fascetti, S., Romano, V.A., et al. (2020) New Chorological Data for the Italian Vascular Flora. *Diversity*, 12, 22. DOI: 10.3390/d12010022
- Roy, H. E., Pocock, M. J., Preston, C. D., Roy, D. B., Savage, J., Tweddle, J. C., & Robinson, L. D. (2012). *Understanding citizen science and environmental monitoring: final report on behalf of UK Environmental Observation Framework*. EOF. NERC Centre for Ecology & Hydrology and Natural History Museum.
- Russo, G., Vivaldi, G.A., De Gennaro, B. & Camposeo, S. (2015) Environmental sustainability of different soil management techniques in a high-density olive orchard. *Journal of Cleaner Production*, 107, 498–508. DOI: 10.1016/j.jclepro.2014.06.064
- Salinitro, M., Alessandrini, A., Zappi, A., Melucci, D. & Tassoni, A. (2018) Floristic diversity in different urban ecological niches of a southern European city. *Scientific Reports*, 8, 15110. DOI: 10.1038/s41598-018-33346-6
- San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., & Mauri, A. (Eds.) (2016) *European Atlas of Forest Tree Species*. Publication Office of the European Union, Luxembourg.
- Schmeller, D.S., Henry, P.-Y., Julliard, R., et al. (2009) Advantages of Volunteer-Based Biodiversity Monitoring in Europe. *Conservation Biology*, 23, 307–316. DOI: 10.1111/j.1523-1739.2008.01125.x
- Sirotti, M., Bugni, E., Faggi, G., Montanari, S., Saiani, D., & Alessandrini, A. (2017) *Aggiornamenti floristici per la Romagna. Quarta serie. Quaderno di studi e notizie di storia naturale della Romagna*, 46, 27-52.
- The Plant List (2013 onwards). Version 1.1. Digital resource available at <http://www.theplantlist.org/>. Accessed 16/03/2021.
- Troia, A. & Greuter, W. (2015) *Conspectus of Italian Selaginella (Selaginellaceae), with some typifications*. *Plant Biosystems*, 149, 695–702. DOI: 10.1080/11263504.2015.1057265
- Uhl, B., Wölfling, M. & Fiedler, K. (2020) Local, forest stand and landscape-scale correlates of plant communities in isolated coastal forest reserves. *Plant Biosystems*, 0, 1–13. DOI: 10.1080/11263504.2020.1762776
- Venditti, A., Frezza, C., Sciubba, F., Foddai, S., Serafini, M., Nicoletti, M. & Bianco, A. (2016) Secoiridoids and other chemotaxonomically relevant compounds in *Pedicularis*: phytochemical analysis and comparison of *Pedicularis rostratocapitata* Crantz and *Pedicularis verticillata* L. from Dolomites. *Natural Product Research*, 30, 1698–1705. DOI: 10.1080/14786419.2015.1136307
- Wang, R.Y. & Strong D.M. (1996). Beyond accuracy: what data quality means to data consumer. *Journal of Management Information Systems*, 12, 5–33.
- Wiggins, A. & Crowston, K. (2011) From Conservation to Crowdsourcing: A Typology of Citizen Science. In: 2011 44th Hawaii

International Conference on System Sciences, pp. 1–10. DOI: 10.1109/HICSS.2011.207

Wiggins, A. & He, Y. (2016) Community-based Data Validation Practices in Citizen Science. In: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing. CSCW '16. New York, NY, USA: Association for Computing Machinery, pp. 1548–1559. DOI: 10.1145/2818048.2820063

Wiggins, A., Newman, G., Stevenson, R.D. & Crowston, K. (2011) Mechanisms for Data Quality and Validation in Citizen Science. In: 2011 IEEE Seventh International Conference on e-Science Workshops, pp. 14–19. DOI: 10.1109/eScienceW.2011.27

Zizka, A., Silvestro, D., Andermann, T., et al. (2019) CoordinateCleaner: Standardized cleaning of occurrence records from biological collection databases. *Methods in Ecology and Evolution*, 10, 744–751. DOI: 10.1111/2041-210X.13152

Submitted: 30 July 2020

First decision: 15 November 2020

Accepted: 29 July 2021

*Guest editor for the special section
Citizen Science in Biogeography:
Stefano Martellos*