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BIODIVERSITY CITIZEN SCIENCE DEVELOPMENT IN CROATIA: INSIGHTS FROM OVER HALF A MILLION INATURALIST RECORDS

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Polašek, O.: Biodiversity citizen science development in Croatia: Insights from over half a million iNaturalist records. Nat. Croat., Vol. 35, No. 2, _____, 2026, Zagreb.

Citizen science platforms are rapidly expanding biodiversity data availability, yet their national trajectories and policy implications remain under-documented in Southeast Europe. iNaturalist observations from Croatia were analysed for 2016-2025, to describe temporal growth, spatial coverage, taxonomic composition, and engagement with taxa flagged as threatened. The dataset comprised 506,816 verifiable observations contributed by 14,950 observers and identified by 10,437 identifiers to 14,138 species. Activity surged during the COVID-19 period (2020-2022) across observations and species, with sustained but slower growth thereafter. Records concentrated along the Adriatic coast, major cities, and protected areas, while inland regions showed persistent under-representation. Platform-flagged threatened taxa accumulated 23,585 observations spanning 525 species from 3,378 observers, indicating strong potential for conservation monitoring if expert review capacity keeps pace. A relative stagnation in the number of active identifiers versus the growth in observations suggests a validation bottleneck. Proposed tasks include a practical programme to (i) micro-target inland gaps, (ii) invest in identifier capacity, and (iii) integrate citizen-science streams with institutional monitoring and data governance. These steps would convert high volunteer effort into verified, policy-relevant biodiversity information for Croatia.

Key words: citizen science; biodiversity monitoring; iNaturalist; spatial bias; threatened taxa; Croatia; validation bottleneck

Polašek, O.: Razvoj građanske znanosti o bioraznolikosti u Hrvatskoj: uvid u preko pola milijuna opažanja na platformi *iNaturalist*. Nat. Croat., Vol. 35, No. 2, _____, 2026, Zagreb.

Platforme građanske znanosti ubrzano povećavaju dostupnost podataka o bioraznolikosti, no njihov nacionalni razvoj i implikacije za politike nisu dovoljno dokumentirani u jugoistočnoj Europi. Analizirana su *iNaturalist* opažanja iz Hrvatske (2016.-2025.), uključujući promjene kroz vrijeme, prostornu pokrivenost, taksonomsku strukturu i zapise koji sadržavaju podatak o ugroženim vrstama. Analizirano je više od pola milijuna zapažanja, s 14 950 promatrača i 14 138 vrsta. Tijekom razdoblja COVIDa-19 (2020.-2022.) zabilježen je nagli porast aktivnosti, nakon čega je uslijedio stabilan, ali sporiji rast. Opažanja su koncentrirana uz jadransku obalu, veće gradove i zaštićena područja, dok su kontinentalni dijelovi nedovoljno pokriveni. Za taksone koje je platforma označila ugroženima zabilježeno je preko 23 000 opažanja (za 525 vrsta), uz 3378 promatrača, što ukazuje na velik potencijal za praćenje zaštite prirode uz uvjet adekvatnog stručnog pregleda. Zapaženo zaostajanje broja aktivnih determinatora u odnosu na rast opažanja upućuje na usko grlo validacije. Predložene aktivnosti za dalji razvoj uključuju (i) ciljane aktivacije u kontinentalnim „hladnim zonama“, (ii) ulaganja u kapacitete determinatora i (iii) povezivanje građanske znanosti s institucionalnim monitoringom i upravljanjem podacima, kako bi se volonterski doprinos pretvorio u provjerljive i primjenjive informacije za politike očuvanja prirode u Hrvatskoj.

Ključne riječi: građanska znanost; praćenje bioraznolikosti; iNaturalist; prostorna pristranost; ugroženi taksoni; Hrvatska; usko grlo validacije

INTRODUCTION

Citizen science has become a practical way to collect large biodiversity datasets that would be too expensive or slow for professionals to assemble on their own (MILLER-RUSHING *et al*., 2012). Platforms such as iNaturalist and eBird gather fine-scale observations across broad areas and longer time spans, which helps address questions about ecological change under rapid climate and biodiversity pressures (ESTIEN *et al*., 2024; RODE & TORKAR, 2023). They also enable fast detection and tracking of invasive species (GONZÁLEZ-MORENO *et al*., 2025).

Beyond a simple data acquisition, citizen science also enhances public understanding and engagement with the environmental issues, thus providing indirect benefits as well (PHILLIPS *et al*., 2019). Simple mobile tools, on-device suggestions, and community review lower the barrier for newcomers and still yield records that are useful to science (SHEARD *et al*., 2024). This participatory approach, accompanied by photographic evidence and expert validation, contributes significantly to ecological modelling, species distribution mapping, and the identification of new or rediscovered populations (ARISTEIDOU *et al*., 2021). Such outputs are vital in supporting proactive conservation strategies, including early warning programs for invasive species (KATSANEVAKIS *et al*., 2023; POCOCK *et al*., 2023). Concentrated effort in well-visited places can still produce cost- and time-efficient documentation of under-recorded, high-priority taxa (Díaz-Calafat *et al*., 2024). This collective effort not only enriches scientific understanding but also empowers communities to participate in the stewardship of their local environments, bridging the gap between scientific research and public action (RUCK *et al*., 2024). In some cases, these platforms even contribute to species discoveries and rediscoveries (POLAŠEK *et al*., 2022; POLAŠEK, 2022), thus providing an additional, fundamental supplement to institutional research. In extreme cases, species may even be known only from iNaturalist photographs, without any voucher specimens deposited in museum collections, which complicates their formal description (KASALO *et al*., 2021). Notably, this process can also operate in the opposite direction. *Eumenes massarum*, Polašek 2025 a species recently described from Croatia (POLAŠEK, 2025), gained its first national record when a 2024 observation (PFZ, 2024), was re-determined following the species description. This suggests that the accumulated photographic records gain additional value as the taxonomy advances. A similar process was observed for two African species, *Ropalidia amabala* and *R. jemmae*, which were first recorded on iNaturalist, and later found in the collections and formally described (POLAŠEK *et al*., 2022, POLAŠEK & DE BEER, 2023), or an entire layer of *Ropalidia* nesting architecture information that originated from iNaturalist observations (POLAŠEK, 2026).

While citizen science has seen rapid growth globally, its trajectory in Croatia presents unique characteristics shaped by the country's specific socio-economic conditions, historical contexts, and technological adoption rates. Early citizen-science activity in Croatia was organised largely through social media, most notably Facebook identification groups such as "Koji je ovo pauk/kukac?" ("Which spider/insect is this?") and "Koja je ovo ptica?" ("Which bird is this?"), alongside numerous botanical and mycological groups. With the arrival of iNaturalist, much of this community has gradually migrated to a single platform offering structured data organisation and community validation, a process that is still ongoing. The research uptake of these data is already substantial; a Google Scholar search combining "Croatia" and "iNaturalist" returns more than 1,400 records (search performed in September 2026), attributing approximately 5% of all Google Scholar records mentioning the platform to Croatia. Local projects such as Biologer show energy but also fragmentation (VIRIĆ GAŠPARIĆ

et al., 2022), in the absence of a general national citizen science policy. This paper utilizes the iNaturalist observation base to examine the development of biodiversity-focused citizen science in Croatia. The aims of the paper were to (i) describe temporal growth, (ii) assess spatial coverage and gaps, and (iii) discuss implications for systematic policy design, with particular relevance to the Croatian Science Foundation as the principal national research-funding agency.

MATERIALS AND METHODS

Data source and scope

iNaturalist platform was used as the data source (http://www.inaturalist.org) for observations assigned to Croatia (iNaturalist place_id = 8196). Notably, the Croatia polygon used by the platform does not include the islet of Jabuka, where several endemic and threatened taxa are registered. Data were accessed on 2025-11-02 (and restricted to all entries that were made by 2025-11-01). Analyses covered observations with observation dates from 2016-01-01 to 2025-11-01 (ISO 8601).

Inclusion and filtering

Unless stated otherwise, summaries used iNaturalist's "verifiable" observations (quality grade: Research Grade or Needs ID), excluding records marked as captive/cultivated. All observations were based on observation date (`observed_on`) as the temporal reference (not upload date). Duplicate records were removed based on `observation_id`. Obscured/Private coordinates were retained and counted but are mapped only to their publicly available accuracy. All query strings and filters used for individual summaries are reported in the Results to facilitate crosschecks and replication.

Threatened taxa note

"Threatened" status followed iNaturalist's metadata (`conservation_status`), as displayed for each taxon within Croatia at the time of access. No additional checks or validations were made to reconcile these assignments against national red lists or other sources; the platform flags are not completely aligned with the Croatian national red list or EU annexes. For some taxonomic groups, national red-list statuses have been curated by local users (e.g., vascular plants), while others rely on global IUCN assessments (e.g., Orthoptera) or on sources that are not clearly documented.

Variables and aggregation

Annual numbers of selected estimates were computed by calendar year of observation. When relevant, taxon information was also extracted, using iNaturalist's taxonomy at access time. Spatial summaries used the polygon for Croatia associated with place_id 8196; density maps rely on iNaturalist's public map tiles and therefore reflect any coordinate obfuscation.

Visualisation

Geographic maps were produced with the iNaturalist user interface; non-map figures (e.g., annual trends) were prepared using standard plotting routines from exported summary tables.

Statistical analysis

Temporal trends were quantified two ways. **Absolute change per year**, δ/yr, where each annual series y_t (for observations, species, observers, and identifiers) was fitted to an ordinary

least square model, where $y_t=\alpha+\beta t+\varepsilon_t$, and report β as δ/yr with 95% confidence intervals. **Multiplicative change**, %/yr was based on a log model, where $\log_{10}(y_t+1)=\alpha'+\beta t+\varepsilon'_t$, and report %/yr as 100 (10^b-1) with 95% CI obtained by transforming the CI of b. To reflect pandemic dynamics, a segmented log-linear regression was fitted, assuming three periods; pre-COVID (2016-2019), COVID (2020-2022), and post-COVID (2023-2025). Next, an interaction model was built, as $\log_{10}(y_t+1)$~t × period. Reported period slopes were considered as time coefficient within each segment; differences between segments were tested with Wald tests on interaction terms. A chi-square test was used to analyse the seasonal patterns, assuming equal month durations and an equal number of monthly events as the expected distribution. All tests were two-sided with $\alpha = 0.05$. Analyses were conducted in R (https://www.r-project.org), using base functions (`*lm*`, `*aov*`) and standard plotting and export routines.

Reproducibility

The exact queries (place filter, date bounds, quality grade, captive/cultivated flag, and any taxon filters) and the derived summary tables used for figures are provided alongside the Results to enable validation and re-use. For exact validation, an additional filter should be used, restricting the entries that were uploaded to exact date of the search (2025-11-02).

RESULTS

Within the search period spanning from 01/01/2016 to 01/11/2025 there were 506,816 observations recorded by 14,950 observers in Croatia, yielding 14,138 species that were assigned by 10,437 identifiers. The corresponding search term was (notably, *Verifiable* level observations were included):
https://www.inaturalist.org/observations?created_d1=2016-01-01&created_d2=2025-11-01&d1=2016%2F01%2F01&d2=2025%2F11%2F01&place_id=8196&subview=map.

The breakdown by year of observation suggested a substantial increase in all four measures (number of observations, species, identifiers and observers), with a notable decline in number of observers in 2020 (Fig. 1). The temporal trends analysis for the whole period 2016-2025 had shown that the annual observations increased by +14,855/yr or +47.8%/yr. Number of verified species rose by +906/yr, observers +484/yr and identifiers at +302/yr (Tab. 1). Using segmented log-linear regression indicated a significant decline in the number of identifiers in the post-COVID period (Tab. 1).

Tab. 1. Temporal trend analyses, with ordinary least squared model (δ/yr) and segmented log-linear regression model for pre-COVID, COVID and post-COVID periods (%/yr).

Metric	δ/yr (95% CI)	%/yr (95% CI)	Pre-COVID %/yr (P*)	COVID %/yr	Post-COVID %/yr (P*)
Observations	14,855 (11,033-18,677)	47.8 (40.9-55.0)	48.5 (0.435)	66.0	31.8 (0.207)
Species	906 (801-1,011)	21.9 (17.7-26.3)	26.6 (0.992)	26.5	11.4 (0.215)
Identifiers	302 (252-351)	13.5 (10.1-17.0)	23.9 (0.237)	15.7	1.5 (0.020)
Observers	484 (390-579)	36.1 (27.9-44.9)	74.3 (0.061)	61.4	15.4 (0.178)

*significance for comparisons with COVID period

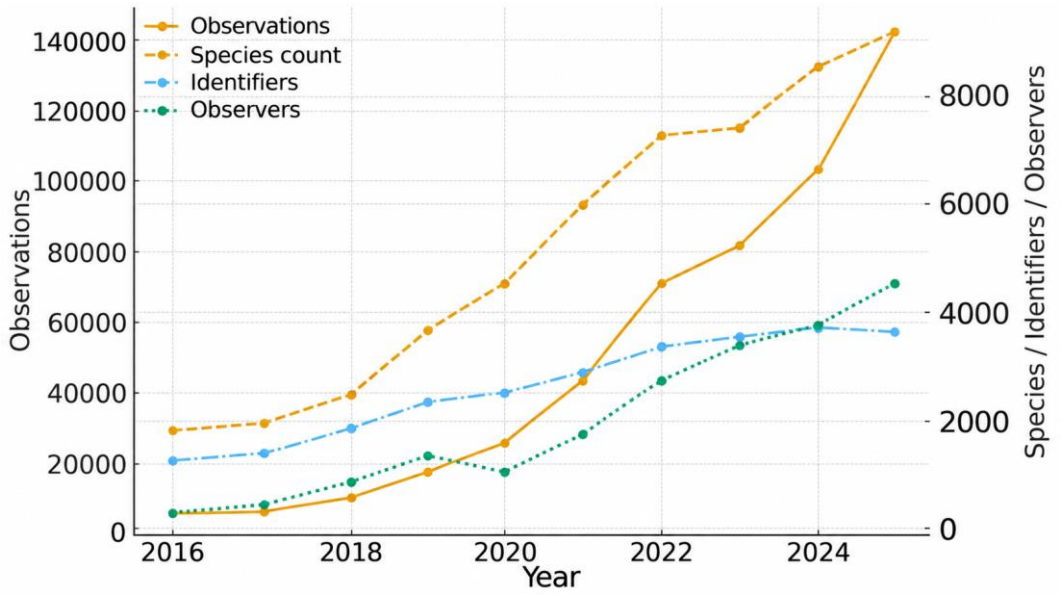


Fig. 1. Line graph showing the number of observations (left axis) and number of observed species, identifiers and observers (right side), over the 2016-2025 period.

Seasonal patterns were strong; 6,232 observations were made in December, as opposed to 89,566 in July (P<0.001). The analysis of the top 10 commonest taxa suggested a blend of insects (5), reptiles (3), plants (1) and birds (1; Tab. 2). Notably, top 10 taxa share in total number of observations has declined steadily, suggesting increasing taxonomic diversity of analysed observations in more recent years (Tab. 2). Breakdown by observation year suggested substantial difference across the investigated period. Other than top 10 taxa shown in Tab. 2, the remaining taxa for 2016 included tessellated snake, *Natrix tessellata* (25), gold sponge, *Aplysina aerophoba* (40), Mediterranean damselfish, *Chromis chromis* (27), warty crab, *Eriphia verrucosa* (27), Saint Piran's crab, *Clibanarius erythropus* (23) and marbled crab, *Pachygrapsus marmoratus* (32). Remaining top 10 taxa for 2017 included marbled crab (29), common seabream, *Diplodus vulgaris* (32), painted comber, *Serranus scriba* (31), Stone goby, *Buenia affinis* (28), warty crab (28) and saddled seabream, *Oblada melanurus* (27). Additional top 10 taxa for 2018 included marbled crab (46), Aleppo pine, *Pinus halepensis* (62), broad-leaved anemone, *Anemone hortensis* (50) and hen-and-chicks, *Sempervivum marmoreum* (41). In 2019, the list was supplemented by mallard, *Anas platyrhynchos* (62) and painted lady, *Vanessa cardui* (56). 2020 additions to the top 10 taxa included mallard (66), European stag beetle, *Lucanus cervus* (83), Asian lady beetle, *Harmonia axyridis* (73), European rose chafer, *Cetonia aurata* (69), and red admiral, *Vanessa atalanta* (66). 2021 list is supplemented by ash cicada, *Cicada orni* (140), rough bindweed, *Smilax aspera* (130) and tree-of-heaven, *Ailanthus altissima* (115). In 2022, additional top 10 taxa included wild boar, *Sus scrofa* (249), Eurasian otter, *Lutra lutra* (453), roe deer, *Capreolus capreolus* (271) and red deer, *Cervus elaphus* (212). 2023 included painted comber (347), wild boar (421), red deer (291), East Atlantic wrasse, *Symphodus tinca* (377), red fox (313), salema porgy, *Sarpa salpa* (286) and European shag, *Gulosus aristotelis* (281). Two additional taxa were added to the 2024 list, namely three-toothed orchid, *Neotinea tridentata* (273) and common snowdrop, *Galanthus nivalis* (493), while the 2025 list is only supplemented with white stork, *Ciconia ciconia* (427).

Tab. 2. Top 10 most common observation by year; italicized numbers are provided for each taxon when it was not included in the top ten annual count.

Species	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Italian Wall Lizard *Podarcis siculus*	47	58	84	165	118	177	307	384	455	577	2,372
Yellow-legged Gull *Larus michahellis*	32	35	47	99	80	118	261	297	359	427	1,744
European Mantis *Mantis religiosa*	*20*	*19*	50	73	91	218	249	308	258	437	1,722
Egyptian Grasshopper *Anacridium aegyptium*	*12*	*22*	38	52	*58*	*111*	*144*	*229*	358	454	1,477
Dalmatian Wall Lizard *Podarcis melisellensis*	51	40	38	108	*62*	158	*162*	*202*	283	364	1,449
Rock Samphire *Crithmum maritimum*	*16*	27	*37*	*40*	*50*	136	198	*230*	265	338	1,337
Scarce Swallowtail *Iphiclides podalirius*	*21*	*26*	55	72	69	143	224	*160*	*229*	315	1,314
Italian Locust *Calliptamus italicus*	*7*	*15*	*29*	*27*	*52*	147	236	*253*	269	*236*	1,271
Schmidt's Cricket *Eupholidoptera schmidti*	*14*	*12*	*30*	63	*27*	*61*	*147*	*269*	278	357	1,258
Common Wall Lizard *Podarcis muralis*	22	*14*	*25*	70	72	*88*	*162*	*214*	*250*	315	1,232
Top 10 species annual share (%)	5.75	5.81	5.20	4.62	3.04	3.39	3.73	4.04	3.19	2.82	2.99

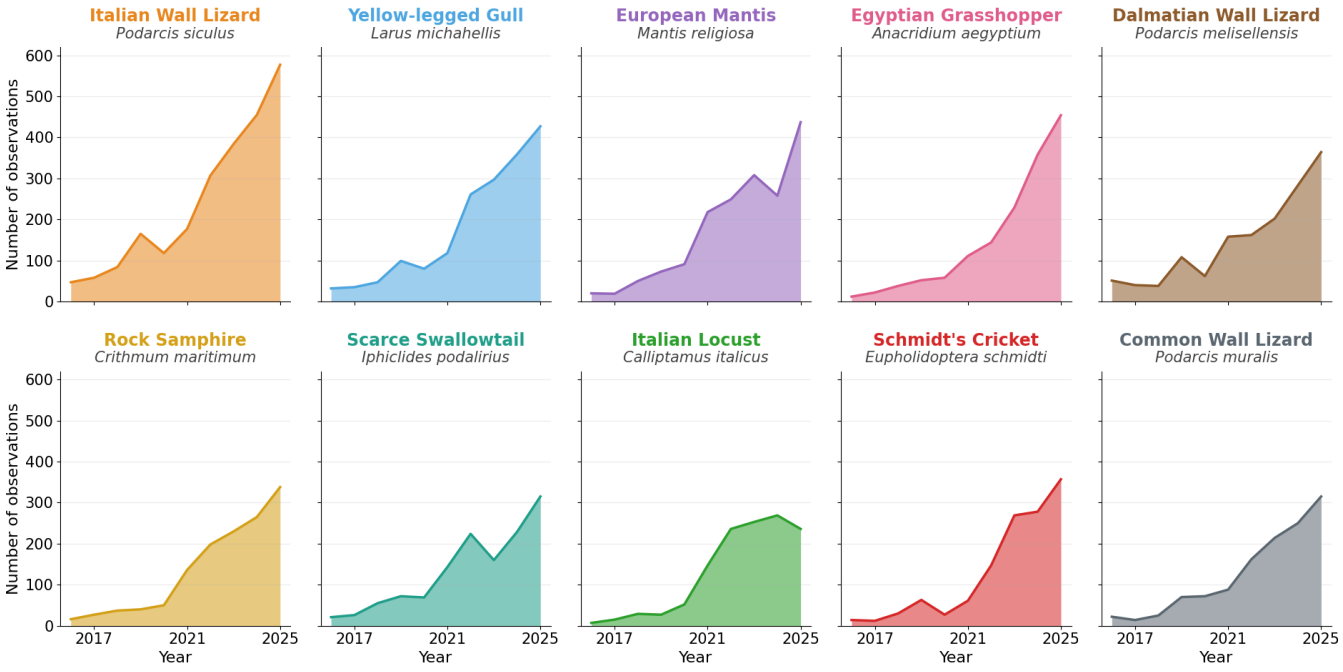


Fig. 2. Annual occurrence of the top 10 most observed taxa in Croatia, total observation for 2016-2025.

A selection of iNaturalist observations from Croatia, illustrating the taxonomic breadth of the platform records, is shown in Fig. 3.



Fig. 3. Examples of iNaturalist observations from Croatia: (a) *Podarcis siculus*; (b) *Leptochilus quintus*; (c) *Fossombronia caespitiformis*; (d) *Periclimenes aegylios*; (e) *Gnathophyllum elegans*; (f) *Oroniscus dalmaticus*; (g) *Bilobella* sp.; (h) *Echinarmadillidium fruxgalii*. Photographs reproduced from iNaturalist, cropped from the originals; credits: (a) © Michael Taylor , iNaturalist obs. 360901425; (b) © Ozren Polašek, obs. 138807982; (c) © Marko Doboš, obs. 198517195; (d) © Jessica Toms, obs. 244268756; (e) © le0p0ld_d, obs. 394412557; (f) © Anton Gjeldum, obs. 69211265; (g) © Manuel Raab, obs. 292565268; (h) © Anton Gjeldum, obs. 177318206.

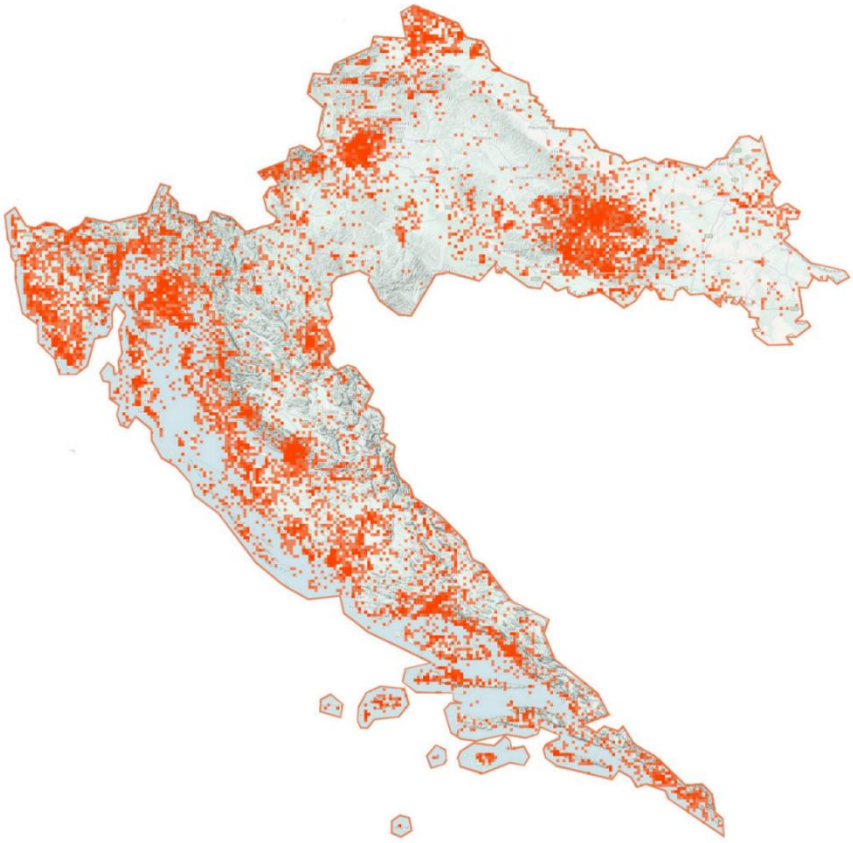


Fig. 4. Occurrence of the iNaturalist observations for Croatia, 2016-2025. The map was taken directly from the platform output and trimmed to show only Croatia, with publicly available coordinate for geotagged data.

The geographic representation of the iNaturalist observations for Croatia reveals an additional diversity. The majority of observations originates from the coastal areas, with notable hotspots around major cities, national parks (notably Plitvice Lakes and Paklenica), and a very large number of observations from Papuk and Psunj regions (Fig. 4). Notably, there are also large areas of low interest, including the inland parts of continental Croatia, such as the wider Osijek region, Bjelovar region, Banija and Kordun, and parts of Bilogora (Fig. 4).

On average, there were 1.24±0.95 identifications per observation, with as many as 15 identifications provided for a single observation. The top 10 observers contributed 122,905 observations during the study period (24.24%), with a search term that reflected their predominantly local activity (Tab. 3, map not shown):

https://www.inaturalist.org/observations?created_d1=2016%2F01%2F01&created_d2=2025%2F11%2F01&d1=2016%2F01%2F01&d2=2025%2F11%2F01&place_id=8196&subview=map&user_id=2396439,1417603,1008197,4565033,992441,393102,3949919,1050572,6240360,3434666.

Tab. 3. Top 10 users with their number of observations and species, alongside number of threatened species observation and species count.

Rank	User	User ID	Top ten species group	All species		Threatened	
				Obs.*	Spec.*	Obs.*	Spec.*
1	*markod*	2396439	Mammals (6)	35,863	3,822	2,214	188
2	*sebcato*	1417603	Plants (9)	17,990	3,366	1,065	179
3	*antonjo*	1008197	Insects (7)	16,155	3,143	351	88
4	*stefadrian*	4565033	Maritime (10)	11,516	709	180	110
5	*pzf*	992441	Insects (5)	9,486	1,796	252	69
6	*lucaboscain*	393102	Insects (7)	7,615	1,860	269	69
7	*mani_raab*	3949919	Maritime (9)	7,145	1,244	162	35
8	*marija_kovacevic*	1050572	Plants (5)	6,978	1,193	895	62
9	*vesna15*	6240360	Plants (8)	5,154	964	437	49
10	*irinazupan*	3434666	Plants (10)	5,003	1,094	355	51

*Obs. - observations, Spec. - species.

The identifier analysis is shown in Tab. 4. The top 10 identifiers provided 197,253 identifications, with an even stronger concentration than among the observers; the leading identifier alone accounted for 45.1% of the top ten total. Only three of the top 10 identifiers were also present among the top 10 observers (Tab. 3), suggesting that the observing and identifying communities only partially overlap. Most of the top identifiers had clearly specialised profiles, dominated by botany and entomology, corresponding to the taxonomic composition of the most commonly observed taxa. Interestingly, two of the top identifiers displayed a distinct, dedicated-identifier activity pattern; one has accumulated 1.5 million identifications globally, without a single observation of their own, while another provided over half a million identifications, with only 16 observations.

There were 23,585 observations of the threatened taxa, with 525 species reported from Croatia; the search term was:

https://www.inaturalist.org/observations?created_d1=2016%2F01%2F01&created_d2=2025%2F11%2F01&d1=2016%2F01%2F01&d2=2025%2F11%2F01&place_id=8196&subview=map&threatened.

These observations were made by 3,378 observers, displaying a wide base of observers that can be mobilized in threatened taxa monitoring. Collectively, top 10 observers contributed with 6,180 observation of the threatened taxa, with the search term:

https://www.inaturalist.org/observations?created_d1=2016%2F01%2F01&created_d2=2025%2F11%2F01&d1=2016%2F01%2F01&d2=2025%2F11%2F01&place_id=8196&subview=map&threatened&user_id=2396439,1417603,1008197,4565033,992441,393102,3949919,1050572,6240360,3434666.

Tab. 4. Top 10 identifiers with their number of identifications and principal taxonomic groups*.

Rank	User	Identifications	Principal taxa groups	Background
1	*sebcato*	89,019	Botany (88.4%), entomology (9.7%)	Biology student
2	*stefadrian*	21,313	Marine invertebrates (43.9%), fishes (32.4%), molluscs (17.9%)	Biologist
3	*esant*	19,588	Ichthyology (90.1%), arachnology (7.4%)	Citizen scientist
4	*ubovich*	16,416	Botany (99.0%)	Not stated
5	*skejo*	13,217	Entomology (88.9%)	Biologist
6	*fregje*	7,852	Entomology (100%)	Not stated
7	*antonjo*	7,848	Entomology (43.4%), botany (38.4%)	Citizen scientist
8	*dubec*	7,682	Entomology (76.5%), ornithology (15.5%)	Biologist
9	*karmela_adzic*	7,186	Entomology (97.1%)	Biologist
10	*ducco*	7,132	Botany (99.8%)	Not stated

*Identifier totals as reported by the platform include both leading and supporting (concurring) identifications, and therefore reflect the overall engagement, rather than independent expert determination. Principal taxa were derived from each identifier's overall identification profile at the time of extraction. Background is given as self-described in public platform profiles at the time of access; "not stated" denotes profiles without background information.

DISCUSSION

iNaturalist hosts more than half a million observations from Croatia between 2016 and 2025, generated by a rapidly expanding volunteer base that now contributes at national scale. Contributions are highly skewed—the top 10 observers supplied 122,905 records (24.2%), yet their activity is spatially narrow, while the wider community improves national coverage. Spatially, records cluster along the Adriatic coast, major cities, and protected areas (e.g., Plitvice Lakes, Paklenica, Papuk-Psunj), with inland gaps around Osijek, Bjelovar, Banija/Kordun, and Bilogora. Conservation-relevant engagement is evident: 23,585 observations of threatened taxa spanning 525 species. Taxonomic focus shifted over time from an early marine dominance to later peaks in insects and plants; in 2025 orchids, snowdrop, and white stork became especially prominent, reflecting changing access, interests, and phenology.

These patterns align with known properties of large citizen-science datasets: deep taxonomic reach that supports research uptake; spatial and temporal biases inherent to opportunistic data and validation bottlenecks that require expert management (Mason *et al*., 2025). Segmenting trends into pre-COVID (2016-2019), COVID (2020-2022), and post-COVID (2023-2025) periods shows a pandemic-era surge followed by slower but sustained growth, consistent with evidence that external shocks can lift near-home nature engagement and leave a higher baseline.

A notable tension is the imbalance between the growth in observations and the relatively stagnant number of active identifiers. Without a corresponding rise in expert or experienced community reviewers, backlogs grow and the value of the data is under-utilized. At the same time, the identifier data also provide encouraging information, since half of the leading identifiers publicly declare a biology background. This suggests that the national taxonomic expertise is already present on the platform, and that the main challenge remains in capacity building and recognition, rather than in recruitment. This echoes wider guidance that citizen science is most impactful when embedded in institutional workflows with sustained investment in training, tooling, and data governance (CHANDLER *et al*., 2017). The prominence of threatened-taxa observations suggests immediate opportunities for red-list tracking and targeted monitoring, provided geoprivacy and curator review are maintained.

Despite the growing recognition of citizen science's potential, several barriers persist in fully integrating these initiatives into mainstream biodiversity monitoring and conservation efforts. These include concerns regarding data accuracy, standardization across diverse projects, and the capacity for long-term data curation (POCOCK *et al*., 2023). One primary concern revolves around the quality of data collected by non-experts, as inconsistencies in observation and identification can introduce biases compared to expert-collected data (KALLIMANIS *et al*., 2017; BACKSTROM *et al*., 2025; HABEL *et al*., 2025). This is well illustrated by the wall lizards, where as many as three species (*Podarcis siculus*, *P. melisellensis*, and *P. muralis*) are among the ten most observed taxa in Croatia. These species are highly variable in colouration and difficult to separate morphologically, occasionally even for the experts, while reliable discrimination often requires molecular methods (PODNAR *et al*., 2005). Therefore, even the Research Grade records of these taxa should be interpreted with caution.

Based on these findings, several possible implications can be made, tailoring a wider programme design. One of the initial ones is to close the inland gaps with micro-targeted activation. Instead of broad national campaigns, a development path can include county-level bioblitzes, school partnerships, and short, place-based challenges in under-sampled inland regions. This plays to the observed geography of participation and can be evaluated with coverage metrics. Secondly, a flattened trend of identifiers needs to be addressed in a different way. These include the recruitment of taxonomic experts from museums, universities and NGOs into structured "ID-hours," seasonal "ID-a-thons," or mentorships for new identifiers. Such efforts could further be institutionalized with recognition of contributions with formal credit, badges, or micro-grants, or even incorporated into the national researcher career advancement stage. The greatest benefit in this line of work could be achieved if the priority was placed on the taxa with the largest backlogs to reduce time-to-validation.

A very interesting source of information revolves around monitoring of the threatened taxa. National experts should be included more in such monitoring records, via designed alerts or a regular platform queues, allowing for rapid review. A tighter connection between the citizen science groups and individuals to the national databases and biomonitoring schemes would enable even better knowledge base, particularly for species and habitats that are under-represented in traditional monitoring schemes (VAN DER PLAS *et al*., 2025; MOERSBERGER *et al*., 2024). Local initiatives (e.g., Biologer) remain vital. A developed national policy should set standards and provide resources, while counties and national parks can lead engagement and adaptation on the ground. This tiered approach enables a responsive feedback loop between policy development and on-the-ground implementation, fostering adaptive management within biodiversity conservation (RUCK *et al*., 2024). National funding

bodies can significantly bolster citizen science development by establishing dedicated grant programs that prioritize projects focused on biodiversity monitoring, data infrastructure development, and community engagement, while also facilitating long-term sustainability through recurring funding cycles. This includes supporting the development of open-source tools and platforms that enhance data interoperability and accessibility, crucial for integrating citizen science contributions into national biodiversity information facilities, as exemplified by the Finnish Biodiversity Information Facility model (SCHULMAN *et al.*, 2021).

For the Croatian Science Foundation (CSF), the results suggest a dedicated, mid-length funding line that (i) supports "identifier fellowships" and seasonal ID-a-thons to clear backlogs; (ii) provides county-level microgrants for gap-filling bioblitzes in inland under-sampled areas; and (iii) builds shared data infrastructure that translates into policy. Projects should include clear indicators, that could include verifiable metrics, for example >70% of new observations reaching Research Grade within 90 days, >20% increase in verified inland records, median review time for threatened taxa under 14 days, and require data-management and geoprivacy plans. Management agencies can act on these streams by targeting routine surveys to cold spots identified here, linking threatened-taxa observations to rapid curator review, and embedding citizen-science outputs into park and county monitoring calendars. Teacher training and school challenges can stabilize participation, while small equipment budgets and recognition for top identifiers sustain expertise. Together, these steps tie public effort to policy, where CSF ensures continuity and standards, while the local authorities deliver place-based engagement and swift use of the data in conservation decisions.

This study suffers from inherent single-platform biases: coastal tourism and protected-area draw, uneven observer effort, and seasonality. Identification lags can understate recent trends; threatened-taxa status was taken directly from platform metadata without external reconciliation. These constraints do not negate the value of the data but argue for careful interpretation and ongoing expert involvement (DÍAZ-CALAFAT *et al.*, 2024). Ethical considerations around location privacy for sensitive species remain central (GROOT & ABMA, 2022).

Citizen science in Croatia has scaled quickly on iNaturalist, producing broad coverage with clear spatial gaps and an identification bottleneck. Targeted inland activation, deliberate investment in the identifier community, and closer ties to institutional monitoring can convert volume into verified, policy-relevant information (GUERRINI *et al.*, 2018). National frameworks and funding can set standards and ensure continuity, while local projects can deliver participation and context, providing a functional blend.

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Data availability

All data used in the study is publicly available.

Author contributions

OP is the sole contributor.

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Conflicts of interest

OP is the Director of the Croatian Science Foundation. OP is an ambassador for the iNaturalist platform. Neither institution provided privileged access to either data or protocols; all analysed data is freely available in the public domain.

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