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Community involvement in natural history: a growing opportunity for entomology and science

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Natural History in all its Branches

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ABSTRACT

Community involvement in science, driven largely by advances in digital photography and the widespread use of online databases, has experienced exponential growth over the past decade. This study focuses on potential opportunities in iNaturalist, the leading international platform for community science observations, covering all life-forms. It is essentially based on photographs, usually in the field. iNaturalist is now the largest global contributor of insect species records from community science observations; the surge in observational data offers the potential to address significant gaps in the scientific record.

We analysed entomological data from the platform to evaluate the volume, growth trends, and quality of submissions. We also surveyed iNaturalist's top insect identifiers to identify opportunities for enhancing data utility and community engagement. The survey responses explored the various reasons for many observations being unavailable to be identified to Research Grade status.

Based on our findings, we propose a development framework to enhance the research utility of community science data in entomology and to better leverage its potential. This includes the establishment of an entomology "Community of Practice", an advisory group comprising a diverse group of influential leaders within the stakeholder communities, to guide future initiatives. The objective would be to formulate actionable strategies for improving the use of iNaturalist and resolve the issues raised by the wider iNaturalist stakeholder community. While this paper focuses on iNaturalist, the findings may have applicability for other platforms.

INTRODUCTION

Community Science in Entomological Research

The rapidly expanding volume of insect observations by community scientists is having a growing impact on entomological research. A review of 2123 publications involving community science (also referred to as citizen science) data (Skvarla and Fisher 2023) showed a sharp rise in the number of entomological studies incorporating data from photograph-sharing platforms over recent years. These observations contributed to at least 28 different research areas including taxonomy, behaviour, species distribution, ecology and conservation.

Photographic images and associated metadata through community science can provide rich ecological context material for professionals and enthusiasts alike. Skvarla and Fisher (2023) concluded that while challenges such as geographic and taxonomic biases, identification accuracy, and digital data impermanence remain, the potential for both scientific discovery and public engagement is substantial. Examples include revealing plant-insect interactions (Bitonto et al. 2025), predator-prey dynamics (Roy et al. 2016), insect resilience in urban environments (Stephenson et al. 2025), shifts in species distribution due to climate change (Carreón et al. 2025), infrequently detected insect behaviours (Portman et al. 2021), and the effects of invasive species on ecosystems (Mesaglio and Callaghan 2021). The common factor in these cases is that community science allows researchers to crowd-source data that single observers could not find themselves.

Species have been rediscovered after long absences or photographed for the first time (Mesaglio et al. 2021, Molyneaux 2023, Skejo et al. 2020). For example, an unusual species of Syrphidae, *Odyneromyia iridescens*, the white-spotted red hoverfly, was photographed live for the first time in 2022 and loaded to the iNaturalist database as a community science observation. This hoverfly appears not to have been observed since 1985. The identification, with corroborations, was provided by experts on iNaturalist (Figure 1).

Documenting undescribed species lays the groundwork for further community science engagement with formal taxonomic description (Hitchings & Ridden 2022; Bolton 2023). New species have been described after experts saw observations on iNaturalist (Connors et al. 2023; Newton & Winterton 2025; Polašek et al. 2025).

For example, an undescribed species of Australian leaf-footed bug in the genus *Amorbus*, reported in an unpublished PhD thesis (Steinbauer 1996) which does not meet the formal taxonomic description requirements of the International Code of Zoological Nomenclature, has been given the working identifier of "*Amorbus* sp. number 3" by one researcher. It is probably the most frequently observed member of the *Amorbus* genus on iNaturalist (Figure 2).

The increasing regulatory difficulties in obtaining traditional destructive samples, especially in national parks and other protected areas, and increasing restrictions on export of biological materials from key areas (South Asia, Australia, South America, etc.) make it extremely hard for researchers to routinely make and share new collections. The scientific treatment of insects known only from photographs is a keenly debated subject as the number of undescribed photographic observations rise (Kasalo et al. 2021; Marshall and Evenhuis 2015). Community science data has also been used to publish updated regional species checklists and identification keys (Buck and Bennett 2025, Buck et al. 2008).

The Global Biodiversity Information Facility (GBIF) serves as a central collection point for data from sources such as specimen collections and observational databases such as iNaturalist. The Global Biodiversity Information Facility (GBIF), with over 3 billion species occurrence records, is the largest international record keeping platform for biodiversity data. These records are aggregated from various sources including natural history museums, environmental recording schemes and community science initiatives. About 1 million insect species have been formally described, but only about 160,000 have photographic records on platforms like iNaturalist, the dominant international platform for community science insect observations.

While acknowledging the significant contributions of other related community science platforms and complementary data from other sources, this international study targeted iNaturalist to analyse the volume, growth rate, and quality of its data, and surveys leading entomological identifiers to identify key areas for improvement and capacity-building within the platform. In an Australian context, other platforms include Questagame, NatureMapr and Insect Investigators.

Figure 1. ***Odyneromyia iridescens*****, the white-spotted red hoverfly, photographed at the Eurobodalla Regional Botanic Garden, South Coast, NSW, Australia in September 2022. (Photo P. Warburton)**

Figure 2. Undescribed species of *Amorbus*, a leaf-footed bug, photographed at Moruya, NSW, Australia in November 2024. (Photo: P. Warburton)

About iNaturalist

iNaturalist is a free, biodiversity community science platform and online social network that enables users to document, identify, and share natural history observations. It is distinguished by its global participation, georeferenced data, and identification records verified by a structured process. Since about 2020 iNaturalist has emerged as the largest contributor to GBIF, in terms of the number of species with records, including observations of insects (Loarie 2023a). iNaturalist records inform species distribution models (SDMs), critical for assessing current conservation status. iNaturalist is frequently used as a representative platform for observational studies and has served as a data source for numerous scientific publications (Mason et al. 2025).

Most observations are accompanied by photographs, although users can also add audio recordings. Date and location metadata are typically extracted automatically from the media files, while additional details, such as life stage, sex and evidence type, can also be annotated by both observers and identifiers.

The iNaturalist Computer Vision (CV) identification tool, an Artificial Intelligence tool, is a core feature of the platform, and uses pattern recognition and location data to generate suggested identifications of an observation. Users typically begin with an initial identification (ID), often based on the automated suggestion, which is then reviewed by the broader iNaturalist community. Other users may confirm, refine, or correct the identification, contributing to a collaborative verification process.

Each iNaturalist observation is assigned one of three quality levels:

- **Needs ID** indicates that the observation's initial identification has not yet been confirmed or sufficiently refined by the iNaturalist community to meet the requirements for Research Grade. It is considered unverified.

- **Research Grade** designation is given once the community reaches a more than two-thirds consensus on species-level identification. It can later be overturned by disagreeing identifications.

- **Casual** observations do not meet the Research Grade criteria due to missing media, inaccurate date or location, or other factors.

All observations remain accessible within the iNaturalist platform. If the observation reaches Research Grade status, and meets the creative commons license criteria, it is then exported to GBIF. Some observations quickly gather sufficient identifications that allow conversion to Research Grade, others remain at Needs ID level for longer, perhaps reaching finer levels of identification over a longer period. Such identifications may still be valuable for analysis while at coarser levels of identification, such as subgenus or species groups level (Williams 2023). The growing data provides a basis of learning for Artificial Intelligence including the CV identification tool and the iNaturalist Geotool which takes a location as input and predicts the most likely species present at that location based on an ecological niche model built using data from iNaturalist (Loarie 2023b).

METHODS

This study comprised a quantitative analysis of insect observations on iNaturalist, to identify growth trends and spatial patterns, and a qualitative email survey of iNaturalist's top insect identifiers to explore key issues related to taxonomic identification.

1. Analysis of Insect Observations

Most core attributes of iNaturalist data are accessible via its public interface. For this analysis, we examined trends in the volume and geographic distribution of insect observations, focusing on the two primary quality categories, Needs ID and Research Grade, over the period 2014 to 2024. To forecast future growth, we applied the AAA triple exponential smoothing forecasting technique (also known as the Holt-Winters method), a statistical method widely used in the social sciences for time series analysis and predictive modelling.

2. Survey of Top Insect Identifiers

In May 2023, fifty individuals were randomly selected from the top 500 insect identifiers worldwide on iNaturalist. The selected participants were asked a series of questions by email relating to their experiences, challenges, and suggestions regarding taxonomic identification on the platform. 34 people responded, including 4 of the authors of this document prior to their involvement in preparing this paper.

The questions posed were:

1. A significant number of insect observations are not identified to species and remain with the ID at a higher taxon level. What are the main reasons for this? (Please allocate percentages to each answer so that your total adds up to 100% overall. You don't need to put the percentage sign in your answer).

2. How accurate do you think the "Research Grade" identifications are on iNaturalist?
3. What do you think are the key things that need to happen to improve the accuracy of identifications?
4. What do you think are the key things that need to happen to reduce the number of observations that remain rated as "Needs ID"?
5. Any other comments?
6. Your name (optional).
7. Which taxa are your main focus?

RESULTS

1. Analysis of insect observations

Insect observations are one quarter of the total observations on iNaturalist – more than tripling in quantity between 2020 and 2024. By the end of 2024 there were nearly 60 million insect observations; The number of observers has more than doubled between 2020 and 2024. About 1.7 million insect observers have contributed to the database. As observations have increased, the percentage achieving Research Grade has declined. Of the total insect observations (34.5 million), 58 % were rated as Research Grade by the end of 2024, down from 69 % at the end of 2011. For non-insect taxa 67 % reached Research Grade in 2024. There were over 25 million insect observations rated as Needs ID, at the end of 2024 - though many were identified to genus, subgenus or species-complex, and have utility for many ecological and biogeographic analyses.

There is a potential risk to user satisfaction and engagement if the rate of conversion to Research Grade continues to decline (this is less likely to affect more experienced insect observers who appreciate the difficulties and complexities with this taxonomic class).

Geographical inequalities

Europe and North America have the highest rate of converting observations to Research Grade. Australasia, Asia, Africa and South America have lower rates (Figure 3). This geographic disparity also applies to preserved insect specimens and indicates areas for potential focus for taxonomic projects.

Taxonomic biases

The top seven insect orders (of a total of 29 orders), represent most of the Research Grade observations; record numbers in other orders fall away quickly (Figure 4). The species-rich and well-known orders Coleoptera and Hymenoptera are highly recorded; attractive taxa such as Odonata and Lepidoptera are recorded out of proportion to their species richness. Diptera, one of the most species rich taxa, is relatively neglected.

Less visible orders, cryptic orders, and those which demand photo microscopy are less often observed. Psocodea (lice) are only infrequently recorded (83,074 observations with only 29% Research Grade). Siphonaptera (fleas) are seldom reported by iNaturalist users despite their wide distribution (only 2,767 observations, with 13% Research Grade). Strepsiptera (Twisted-wing insects) are distributed around the world but are even less frequently recorded with only 1,158 observations (though there are

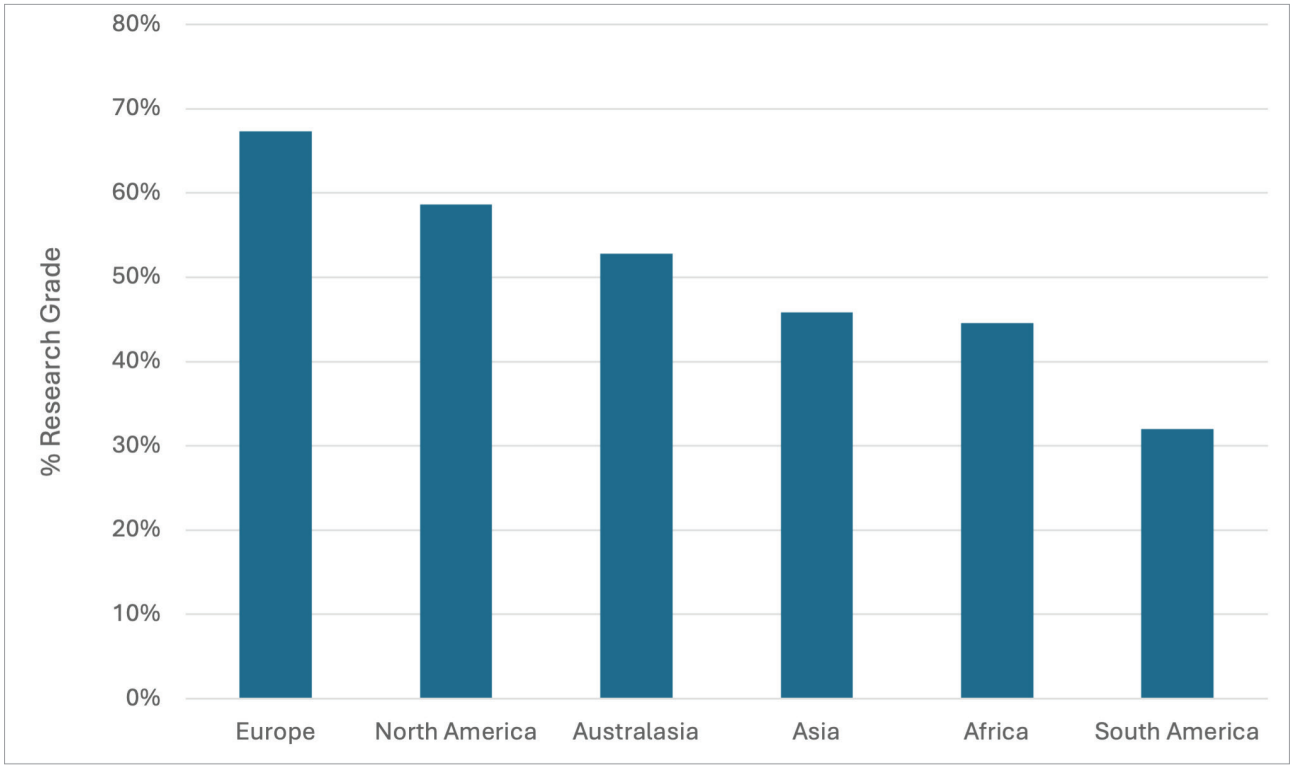

Figure 3. iNaturalist Research Grade % by region, show that insect observations in Europe and North America are more likely to be identified than in other regions

photographic records of Hymenopterans and other insects, that have been parasitised by Strepsipterans but not recorded in separate observations).

There is a significant drop in Research Grade conversion for the less commonly recorded orders relating to factors including difficulty in identifying certain taxa from photographs; difficulties in getting photographs of more cryptic taxa or taxa in inaccessible habitats; the photographic skill levels of observers; and camera limitations in photographing small insects (Mesaglio et al. 2023).

- There are over 500 super-identifiers globally who have each logged 27,000 or more identifications
- The top 100 of those super-identifiers account for about half of all identifications
- The top 10 identifiers have each logged over 400,000 identifications
- The top individual identifier has logged 1.7 million identifications
- Together the top 500 insect identifiers have made 49 million identifications.

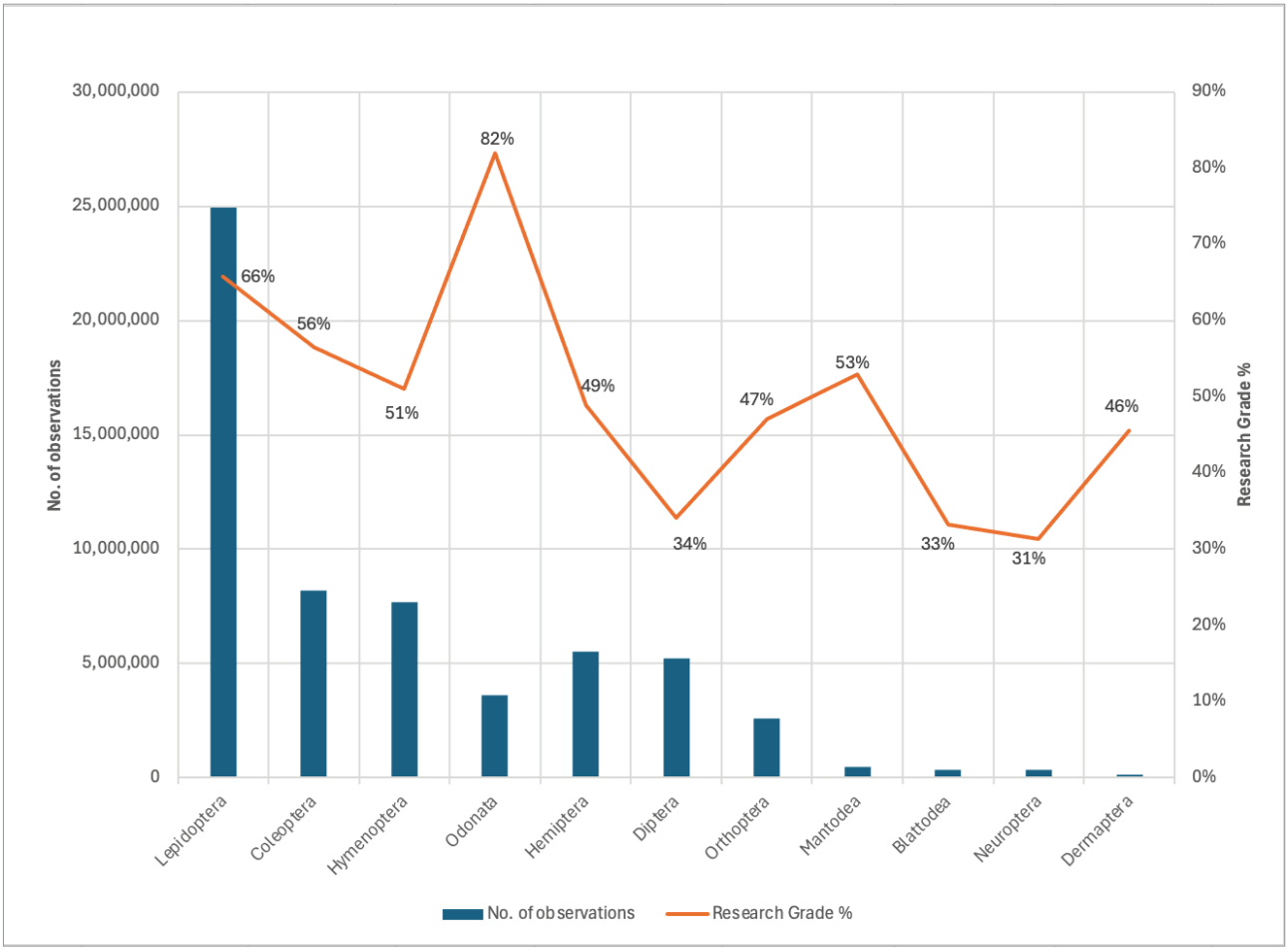

Figure 4. Observations by insect order show that most insect observations are in 7 orders out of the total of 29 orders

Identifier workload

A noticeable trend is that the workload of the identifiers is growing, as the number of observations rises. The average number of identifications per person in the identifier group has risen from 54 per person in 2014 to 322 per person in 2024, though this is not the complete picture, as a clear long-tailed, or pareto, distribution applies to the identifier group. iNaturalist is very dependent on a small number of "super-identifiers" (Campbell et al. 2023), those expert entomologists, taxonomists and highly skilled amateurs who do a disproportionate amount of the insect identification work. This group is central to the successful operation of the iNaturalist insect dataset (Figure 5).

iNaturalist Computer Vision

The iNaturalist Computer Vision (CV) is trained by Research Grade and Needs ID observations. However, it has not yet reached the point where the CV, on balance, is reducing the workload on the expert identifiers. Discussion groups suggest that it is still generating human work in correcting CV related errors which might otherwise become embedded, due to repeated incorrect suggestions. Accelerating the learning of the CV to cover more taxa will be critical for addressing the emerging identification bottleneck.

The CV is being trained to recognise a new taxon as quickly as sufficient data becomes available, but

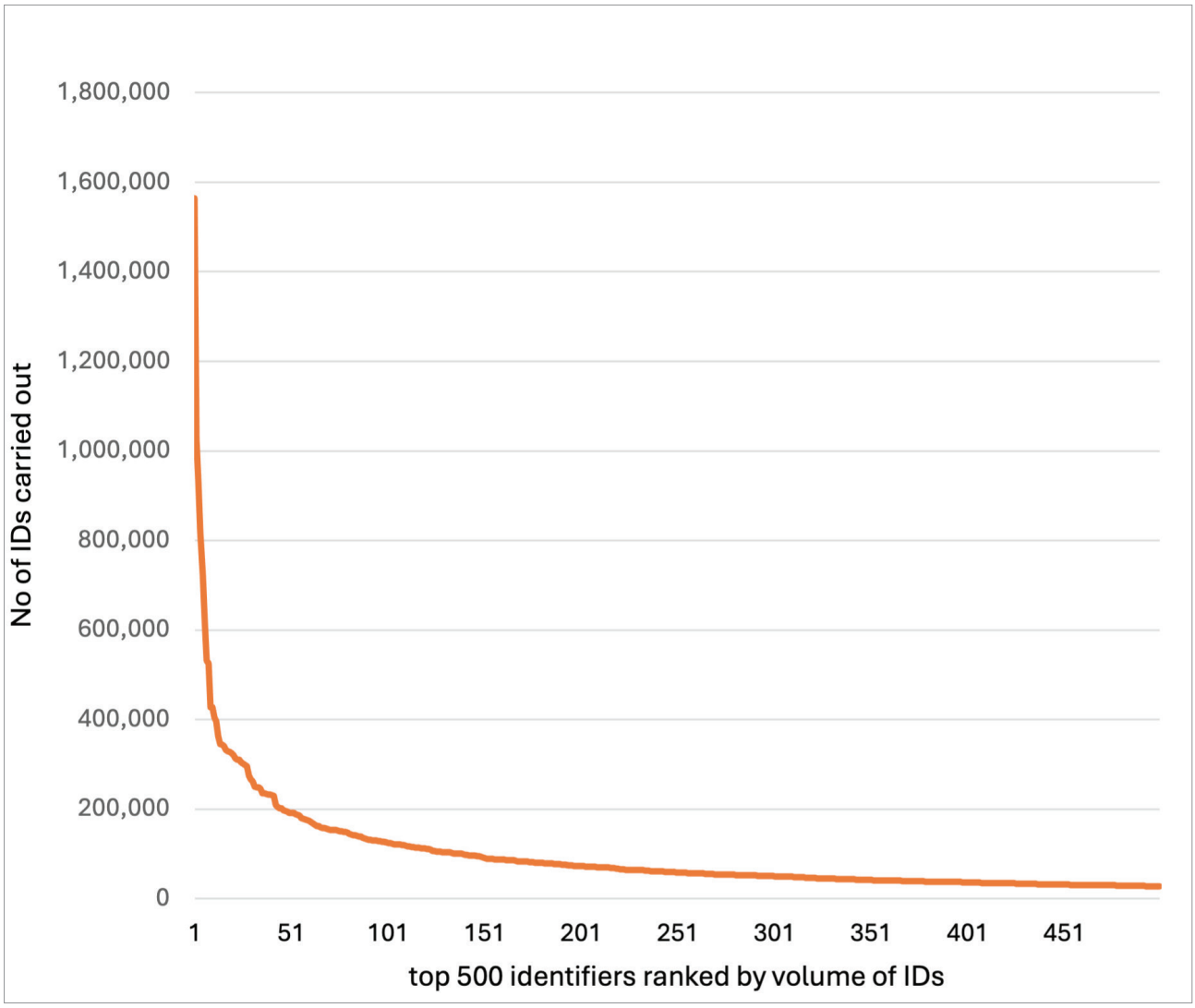

Figure 5. Ranking of the top 500 super-identifiers based on the cumulative number of identifications they have carried out

CV learning rates are constrained by the rate at which human expert identifiers can verify observations (Campbell et al. 2023). Unfortunately for the class Insecta, the rate currently seems to be insufficient to reduce the workload of the human identifiers. As noted earlier, the percentage of Insecta observations that reach Research Grade fell (from 69% to 58%) between 2011 and 2024. This is a concern, given the strong growth and likely future volumes of observations. This should not detract from one remarkable statistic, the improved pace of conversion to Research Grade. Across all taxa, including non-insect groups, the time to convert an observation to Research Grade fell precipitously, from **one year** in 2011, to just **four hours** in 2021, because of work by identifiers supported by the CV (Campbell et al., 2023).

Future growth projections

The projected future growth of iNaturalist, using the AAA triple exponential smoothing forecasting technique based on actual data from 2019-2024, indicates that another 1 million insect observers will be added in the next four years. Potentially by 2028, 2.5 million or more global insect observers may be using the platform. By 2028, the cumulative number of observations is likely to be more than double the observations made up to the end of 2024. This will greatly outstrip the current capacity for identifications (Figure 6).

Over the next five years the number of insect species recorded on iNaturalist is expected to increase by approximately 25%, equating to some 40,000 additional species. This will enhance the significance of iNaturalist data in research (Figure 7). However, identification of additional species for iNaturalist records is a more difficult task than identifying an observation of a species already on the database, as the CV can provide no assistance for species outside its training. This is an essentially human-required step and will put further workload on the already-stretched identifier group. Fortunately, as one of the identifiers reported, "*this is the part of the task that is the most fun*"!

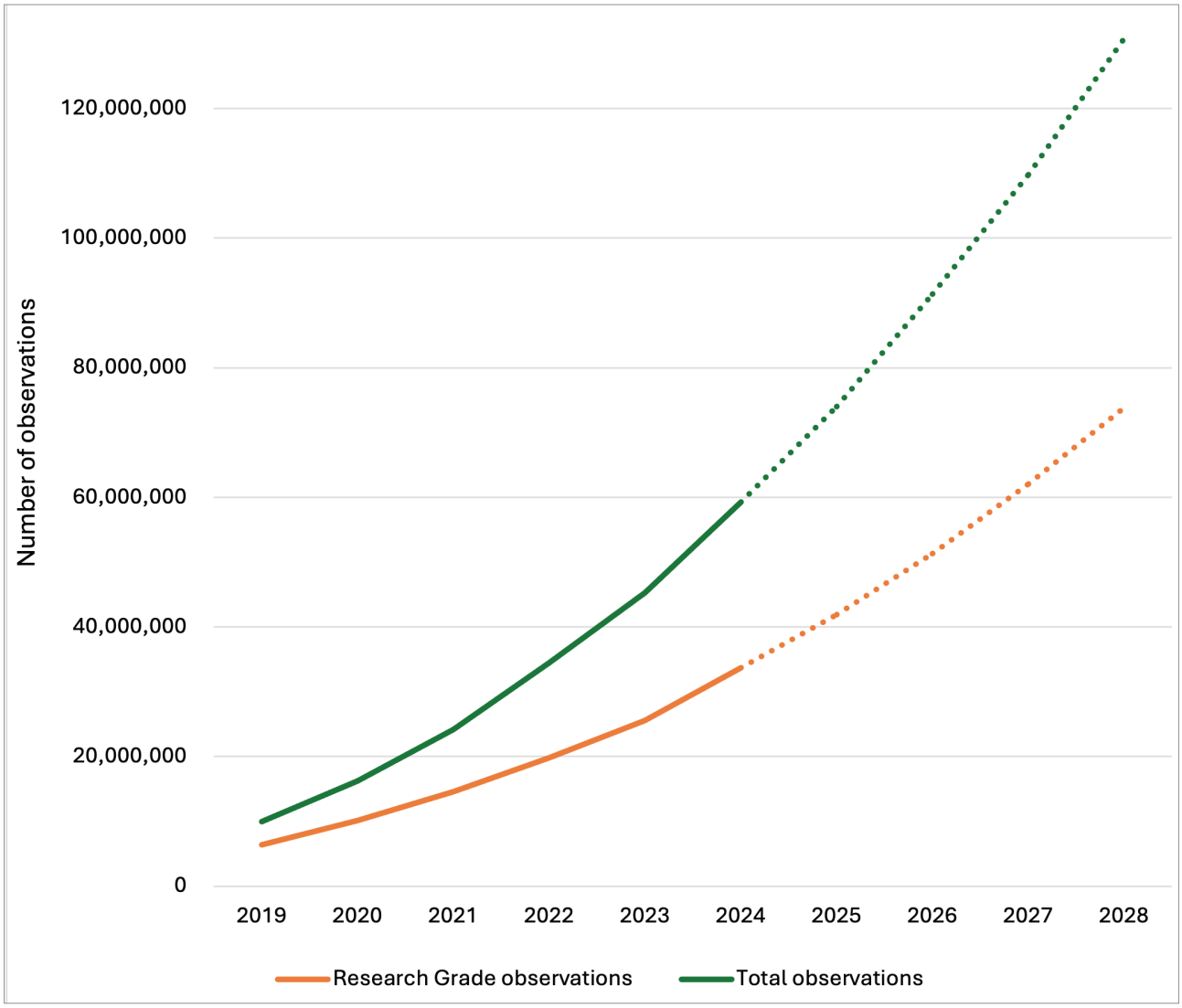

Figure 6. Growth in the number of insect observations (the dotted lines are the forecasted volumes)

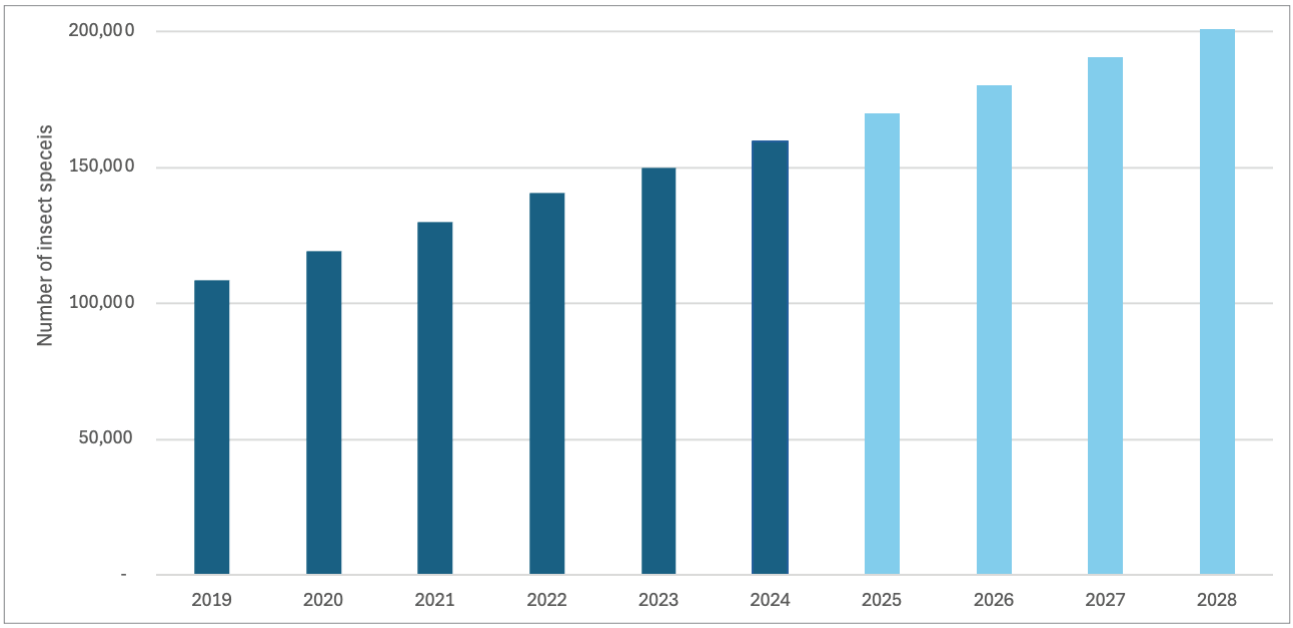

Figure 7. Number of insect species represented in insect observations on iNaturalist (light blue bars indicate forecast numbers)

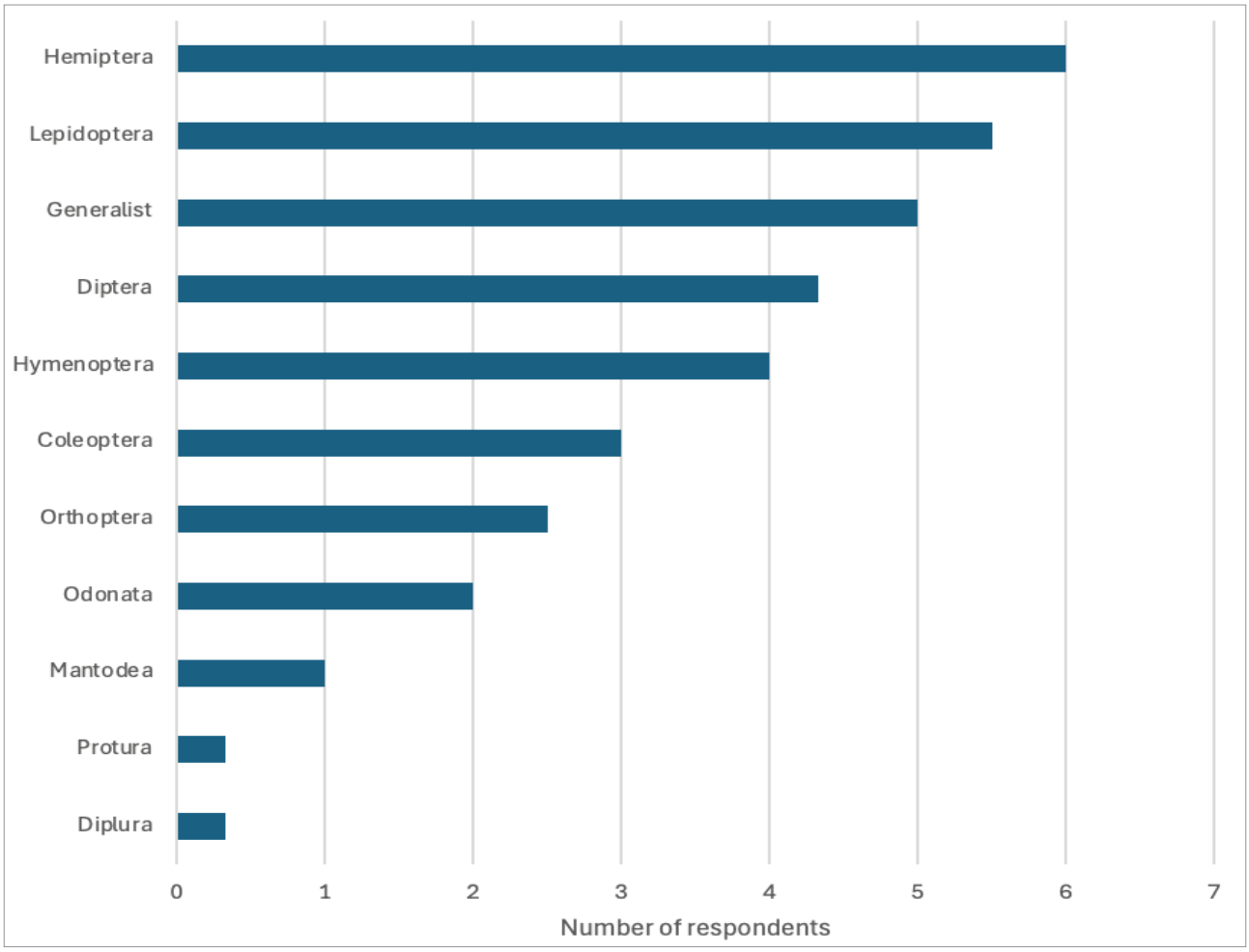

Figure 8. Specialisations of the 34 super-identifier survey respondents

2. Survey of top insect identifiers

An analysis of the 34 respondents' specialisations reveals broad expertise, but focused on the top seven insect orders, mirroring observer community trends. Five participants identified as generalists (Figure 8). (Some respondents indicated more than one taxon as their specialisation - in those cases, it has been assumed they divide their time equally amongst those taxa).

The super-identifiers described the status of Research Grade observations for insects as "mostly correct" (Figure 9) which falls short of an unequivocal endorsement of the accuracy of ID assessments. Consequently, scientific researchers have consistently emphasised the importance of conducting rigorous data-cleaning and validation procedures before leveraging iNaturalist datasets (Dorey et al. 2023, Zarillo et al. 2025). Such data cleaning exercises are absolutely required in any scientific research and are just as important for repositories of physical specimens and their digitised records, which are equally susceptible to identification errors.

The combined involvement of multiple researchers ultimately drives meaningful improvements in the accuracy and reliability of the broader database. For example, Singapore-based researcher John Ascher has now verified 1.7 million Hymenopteran identifications for 6476 species. Another small Australian team put in a massive effort to verify identifications in the Mantodea.

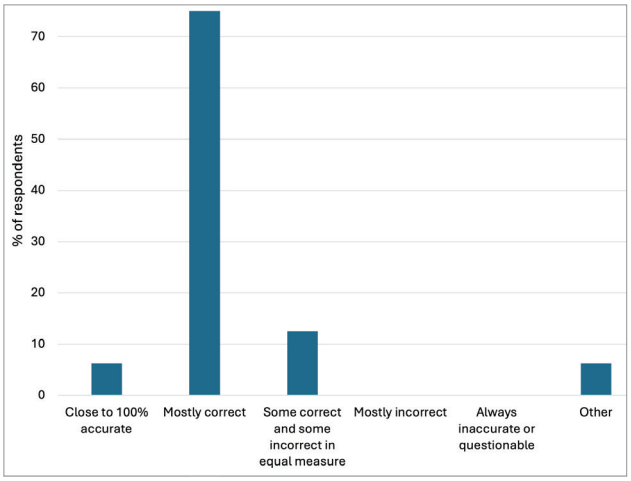

Figure 9. Accuracy of 'Research Grade' identifications based on estimates given by 34 super-identifiers in a survey in May 2023

The survey respondents gave various reasons why many observations are not identified to species and accorded Research Grade status (Figure 10). In order of importance, the reasons cited by respondents are:

"The taxon requires identification based on features that photographs are never likely to show".

This issue was said to explain about 26% of the observations that did not make it to Research Grade status and reflects the issue that microscopy or dissections of physical specimens are required to identify such species. It is possible this may change in the future as photographic techniques improve and as AI tools, such as the iNaturalist Geomodel, provide new perspectives on the likely species. (Specifically, these tools may inform initial identifications by observers and allow for filters that expose lower probability observations to experts).

"There are too few identifiers for the volume of observations being generated".

The respondents rated this as the reason for 25% of the failures to identify to Research Grade. This is clearly a major issue and was emphasised by most of the respondents.

"Quality of photographs is not adequate".

The respondents rated this as the reason for 19% of the failures of the "needs ID" observations.

"Characterising the observed species from published scientific papers is too difficult, or there is too much work involved".

About 12% of the 'Needs ID' category fall into taxonomic groups that are poorly documented making identification complicated and time demanding. Skilled identifiers often lack the time or specific funding to carry out this work.

"There are no reference photos available for the species".

Work is underway at museums around the world to digitise large insect collections, including holotypes of species that are rarely seen and have yet to be logged as a verified observation on iNaturalist (e.g. Chan 2025, Singapore Biodiversity 2025, Smithsonian 2025).

"The observation is likely an undescribed species".

Some IDs fail to make Research Grade status simply because the species is not known. It is generally accepted that the number of undescribed insect species is at least as large as the number of described species, so it is perhaps surprising then that this factor did not feature more prominently in the survey feedback. This probably reflects the taxonomic bias of observers towards conspicuous taxa such as Lepidoptera and Coleoptera, and that the most unknown faunas are in inaccessible places.

"Other".

The 4% of the "Needs ID" group that fell into the "Other" category included respondents who indicated that larval insect forms often cannot be identified to species.

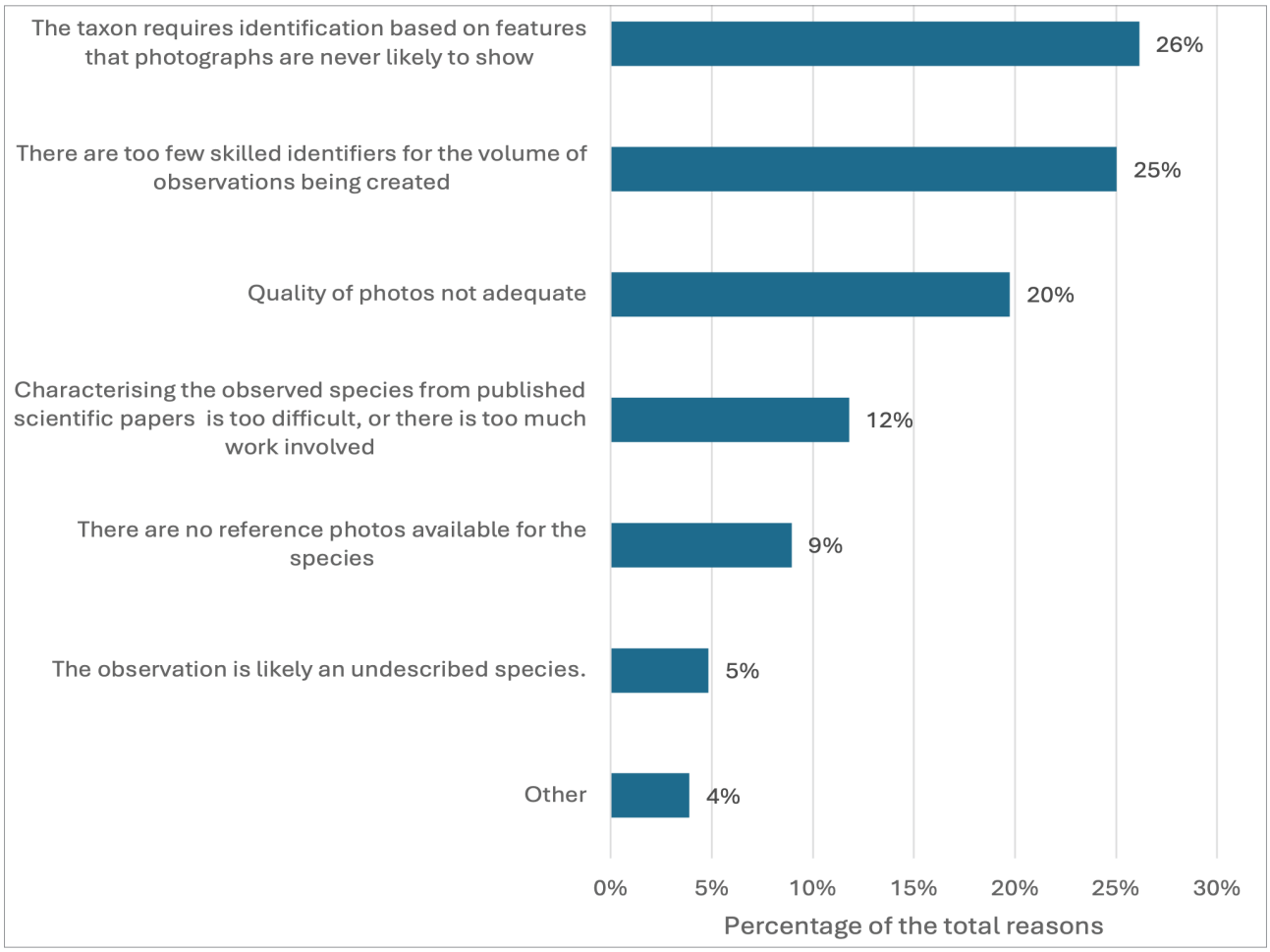

Figure 10. Reasons that some observations are not identified to species level based on a survey of 34 super-identifiers in May 2023

DISCUSSION

The surge in entomological observational data on iNaturalist offers the potential to address significant gaps in the scientific record. However, there are recent signs that the rate of growth may now be moderating. This may indicate a natural maturing of the "market", but it is also possible that user engagement is affected by the decline in the rate of identifications in some taxa. In recent years there has been a marked rise in the use of other social media groups such as Facebook to seek identifications of photographic observations. There is anecdotal evidence that some iNaturalist users widen their search, posting elsewhere when iNaturalist identifications are not forthcoming. This can be seen as a positive response, promoting synergy through discourse across multiple platforms, without losing the rigour of an enduring spatial and temporal record on iNaturalist. These concerns about user engagement are speculative at this stage, but could limit future potential, particularly with growing volumes and any further deterioration in the rate of conversion to Research Grade.

Associated with anticipated growth is the increasing importance of the identifier group. The significant role that expert identifiers and associates play in maintaining data accuracy, training the CV, and creating bridges between museums, universities, and related organizations is noted in publications by iNaturalist staff and expert identifiers, as well as the need to recognise and credit them (Campbell et al. 2023), and the need to recruit additional experts (Callaghan et al. 2022). Further recognition might include establishing mechanisms for participation in publications, university activities and training, especially for contributors without current institutional-related affiliations.

In terms of the geographic and taxonomic biases evident in the data bases, there is benefit in addressing under-represented areas - perhaps using site tools, such as filters, to focus on under-represented, neglected, or high value geographic regions and taxa. Further efforts to sponsor and support projects that focus on under-developed areas could increase the utility and robustness of the database, while bringing new expert identifiers to the platform.

Community of Practice

Considerable desire for implementing value-adding solutions has been expressed in online iNaturalist discussions but leveraging opportunities demands a coordinated effort by diverse stakeholders. For a global public platform like iNaturalist, mobilising groups or individuals to achieve coordinated efforts remains challenging. The individuals in those groups may be unknown to each other and generally have little interaction. Site tools such as iNaturalist Projects can offer solutions to bring individuals together for coordinated actions.

There is potential benefit in an over-arching structure for bringing key stakeholders together and it is proposed here that a **Community of Practice** be formed to advance initiatives for developing the iNaturalist platform in the field of entomology. A Community of Practice is a working group of a community of stakeholders, based on ideas by Lave and Wegner (1991) about community learning and development. The constituents of a Community of Practice group would be influential or senior representatives of each of the stakeholder communities with an objective to formulate actionable strategies for improving the use of iNaturalist and bringing resolution to issues discussed by users of the platform.

To focus this proposed Community of Practice, a development framework has been constructed (Figure 11) and is populated below with some examples to illustrate its use to advance initiatives (Appendix 1). The examples are not intended as a comprehensive list. The proposed Community of Practice group would decide which actions to progress and would refine the framework as it is used.

The proposed development framework includes four main stakeholder groups:

- Community science/iNaturalist users
- iNaturalist platform developers and staff
- The scientific and academic community
- The conservation community

There may also be important contributions from other stakeholder groups such as GBIF staff, other data aggregators, external project organisers and benefactors or not-for-profit organisations with interests in the way iNaturalist is used. As the role of such additional stakeholders is clarified the development framework will evolve. The inclusion of GBIF may offer benefits for both iNaturalist and GBIF objectives. These may include more complete sharing of information about identification history, improving the robustness of Research Grade identifications through sophisticated data quality checks, and a more nuanced identifier reliability metric. There may also be shared guidelines for data miners, project owners, etc., about how to address/credit/engage super-observers and/or super-identifiers who have made an objectively disproportionate contribution to compiling and/or validating data.

CONCLUSION

Entomological data from the iNaturalist's platform responses from top insect identifiers suggest opportunities for enhancing data utility and community engagement. This includes the establishment of an entomology "Community of Practice", an advisory group comprising a diverse group of influential leaders within the stakeholder communities, to guide future initiatives and to ensure the expanding influence of community science through platforms like iNaturalist.

A proposed Community of Practice, comprising influential individuals from stakeholder groups, could serve as a vital hub for leveraging expertise, prioritizing common goals, and developing science platforms in general and amplify their power to contribute to research, conservation, and public involvement in the years to come.

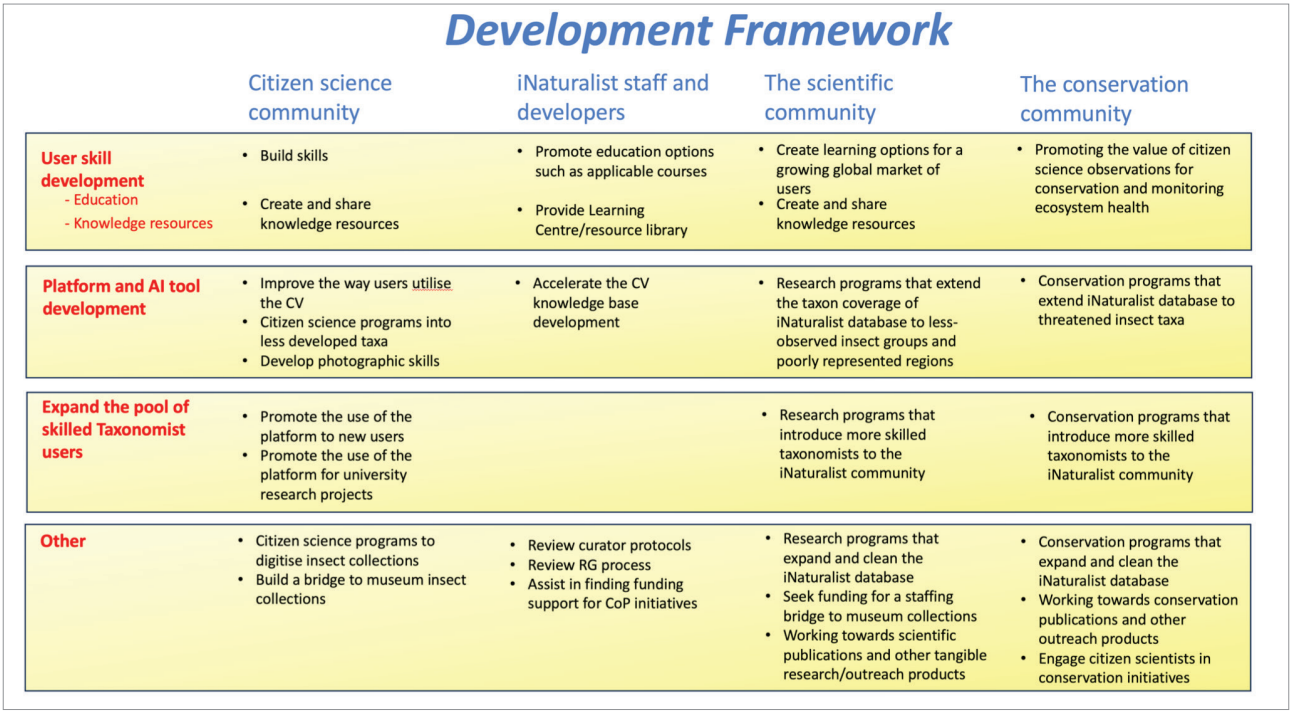

Figure 11. Development Framework with illustrative examples for consideration by a Community of Practice

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Appendix 1. Responses of surveyed iNaturalist super-identifiers highlighting issues and suggested actions relevant to a *Community of Practice*

Example 1 - User skill development

There is a global market for education in entomology, including 1.7 million photographers and amateur community scientists on iNaturalist who are often interested in enhancing their skills and knowledge. This number is predicted to increase to 2.6 million by 2028. Many of these individuals have full-time jobs and may prefer online or self-paced learning opportunities. Academic institutions should consider how to address this growing market. iNaturalist can play a role in promoting educational offerings.

When new users register on iNaturalist, there is extensive onboarding material guiding them on how to use the site. However, there is potential to emphasise better practices, especially in reducing "guessed" identifications and indiscriminately corroborating such guesses.

Suggested actions

> "I'm dreaming of (probably wiki-based) ID guides embedded in iNat directly. On each taxon page there would be an article (written by the community) pointing to key features for image-based identifications, also listing lookalikes and ways to tell those apart. Some information like that is already present, but hidden in forum posts, journal entries and the like. "
> **Survey respondent #3**

> "[We need to develop user skills] for better image quality: avoid blurry photos, always perpendicular dorsal view, good light and photos should be cropped".
> **Survey respondent #19**

> "[We need to educate] some observers to take clearer photos or crop photos (which staff/community can help educate/inform them about); etc.".
> **Survey respondent #6**

> "Encourage people to provide more pictures from different angles. More care needs to be taken to rely only on recognizable features and not on guesses".
> **Survey respondent #5**

To improve user identification skills, we might consider rebuilding the 'guides' section into a comprehensive "Education Centre" for entomology, which could include:

- On-line courses endorsed by iNaturalist in entomology, taxonomy, and photography
- Book recommendations and links to external resources and synergistic on-line portals such as BugGuide.net
- An extensive collection of in-site entomology guides with extensive annotation and referencing
- Funded programs to develop community scientist skills in neglected taxa
- Enhancing photographic skills is crucial. Techniques for photographing small insects and laboratory/ studio methods can aid in digitising museum insect collections
- A Community of Practice in cooperation with iNaturalist may support training in entomological photography, focusing on areas such as:
- Essential characters for Research Grade status
- Macro photography/ Photomicroscopy
- in the field and lab/studio/museum (Warburton 2024)
- Application of new and emerging technologies such as insect-detecting automatic cameras (Gardiner et al. 2024).

Example 2- Leveraging museum collections

Museum collections hold the key to identifying many observations for which there are no existing photographs and limited reference material. Accelerating museum collection digitisation or easier access to insect collections could help. The Smithsonian National Museum of Natural History, the British Natural History Museum, and the Paris Natural History Museum, for example, collectively house well over 100 million insect specimens, yet these are challenging for iNaturalist identifiers to access. This would have the ancillary benefit of making it significantly easier to check inaccuracies in specimen collections.

> [We need] more digitisation of specimen records in museums etc so photos can be compared more easily with keys and reference.
> **Survey respondent #1**

> "The best way to address shortfalls in identifying the most rare and obscure taxa, would be to employ an ultra-fanatic (not mere fanatic) identifier at a museum with world-class holdings (AMNH, Smithsonian) so they could cross-check with a near complete reference set".
> **Survey respondent #33**

Suggested actions

iNaturalist stakeholders to develop a program for encouraging community scientists to support the work of museums in digitizing their collections.

Funding should be sought to place taxonomists to work in museums, to provide a bridge to iNaturalist users.

Example 3
Use of the CV tool

The CV tool helps engage more active observers due to its ease of use but often leads to misidentifications. For insects, it can be overly confident, causing users to accept incorrect identifications blindly. Other users then confirm these errors based on similar CV suggestions.

To reduce this issue, iNaturalist developers should adjust the CV wording for insects and make identifications more tentative. In AI terms, this is known as "reducing the temperature" for more conservative assessments. This topic is discussed periodically in online iNaturalist discussions.

> "The best way to address shortfalls in identifying the most rare and obscure taxa, would be to employ an ultra-fanatic (not mere fanatic) identifier at a museum with world-class holdings (AMNH, Smithsonian) so they could cross-check with a near complete reference set".
> **Survey respondent #33**

Importantly, users also need to be educated to be more conservative in their acceptance of "suggestions" from the CV and to avoid blind agreement with another person's identification.

> "[We need] better education to users that push "agree" if they don't know how to identify the organism. These mistakes can be perpetuated if a non-expert chooses a species-level ID and another non-expert clicks to agree……. My biggest concern with research grade is caused by the agree button. This is caused when people click "agree" on identifications without the background knowledge to really know if they agree. …. Misuse of the agree button amplifies mistakes."
> **Survey respondent #17**

Suggested actions

Further discourage the blind confirmation of identifications. Adjust the certainty of recommendations in Insecta to make more conservative assessments for entomological observations.

Example 4 - Skilled taxonomist users

Multiple respondents to the survey remarked that there are insufficient skilled taxonomists working on the platform to keep pace with the growing demand, reflecting similar online discussions that insect taxonomy is a generally neglected area and needs more funding.

> "The main issue is simply a lack of skilled identifiers. For many taxa, a detailed understanding of the group is required before one can start making accurate identifications. Often there is nobody on iNat (or nobody in the world) sufficiently knowledgeable to ID these taxa. Another problem lies in the sheer number of observations that are now on iNaturalist. Having lots of observations is of course a good thing, but there are just not enough skilled identifiers to tackle them all. This is okay for groups where observers know that identification might be difficult, but often an incorrect or overzealous ID will be assumed by others to be correct, and the issue quickly multiplies. It takes a lot of effort to correct these, and sufficient time needs to be put in even after the corrections have been made, to ensure that users (and the AI) can learn and the problem does not begin again".
> **Survey respondent #18**

> More identifiers are needed. A lot more taxa are identifiable from photos than many people understand, but many experts don't put the time into their taxa to keep the datasets accurate and in turn train new experts from the users who in many cases are very interested in "learning by doing". If a taxon has dedicated experts, then it will in create new experts from the users. If not, then it will stagnate, and the ID's will come the computer vision suggestion.
> **Survey respondent # 25**

There is an opportunity in promoting the significant advantages of participating as an entomological identifier on the platform. Over time, this will happen naturally, as the platform expands and becomes impossible to ignore. Additionally, the iNaturalist advocates, who currently promote iNaturalist at scientific forums and through scientific publications, are carrying out a vital role in encouraging more taxonomists to enter the community (Callaghan et al. 2022).

One experienced taxonomist had a very positive perspective on the value of iNaturalist that is worth sharing more widely.

> "I have found [iNaturalist] an unparalleled source of enjoyment and intellectual stimulation. The greatest part of being a good taxonomist is just spending time immersed in your taxon of interest, and iNaturalist provides a ready way to just spend time looking at and getting to know the insects I like. I have increased my abilities SO much through it and am a much better taxonomist now than before I started. It also provides a great incentive to delve into the literature---both old and new---and many papers now hold a relevance for me that they previously did not, and I find myself engaging much more closely with them than I had before (Cool! A new paper is out! Are any of these species on iNaturalist???)".
> **Survey respondent # 23**

Suggested actions

Consider if there are further opportunities for bringing taxonomists to the platform through a program for promoting iNaturalist scientific projects, including projects targeting the more neglected taxa.