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COVER IMAGE: *Gladiolus illyricus* flower at the 'Gladiolenwiese.' © Birgit Pichorner

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LAND KÄRNTEN
Kunst und Kultur

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BOOK REVIEWS

How fast must one run to stay in the same place? On the second issue of *Carinthia Nature Tech*

Susanne Aigner, Michael Jungmeier

According to the 2024 Science Barometer of the Austrian Academy of Sciences, 77% of Austrians are “proud of the country’s natural beauty,” 73% “trust science very much” or “strongly,” and as many as 80% are convinced that “science and research improve our lives” [1]. These encouraging statistics stand in contrast to the daily experiences of many scientists. Alongside medicine and climate change, biodiversity research is increasingly becoming a target of a science-skeptical public. Against this backdrop, transparent methods and clearly explained results are essential. The first issue of the young journal *Carinthia II part 3 - Nature Tech* has already demonstrated that these methods are currently undergoing significant transformation due to digitalization.

Fig. 1

Figure 1:
Presentation of the contributions in the first issue of *Carinthia Nature Tech.*
Daniel Dalton, the head of the Editorial Office, presents the articles of the first issue in detail. This reveals the journal’s thematic focus as well as the range and quality of the individual articles. Clubrooms of the *Natural Science Association for Carinthia*, kärnten.museum Klagenfurt. (Photo: Johannes Puch)

Abbildung 1:
Präsentation der Beiträge in der ersten Ausgabe der Carinthia Nature Tech.
Der Leiter des Editorial Office, Daniel Dalton, stellt die Artikel der ersten Ausgabe im Detail vor. Dabei werden die inhaltliche Ausrichtungen der Zeitschrift sowie die Bandbreite und die Qualität der einzelnen Artikel sichtbar. Vereinsräume des Naturwissenschaftlichen Vereins für Kärnten, kärnten.museum Klagenfurt. (Foto: Johannes Puch)

On October 17, 2024, the Natural Science Association for Carinthia (NWV, Naturwissenschaftlicher Verein für Kärnten) and Carinthia University of Applied Sciences (CUAS, Fachhochschule Kärnten) jointly presented the new journal *Carinthia Nature Tech* (Figure 1). The presentation took place in the NWV’s clubrooms at the Carinthian State Museum, at the symbolically significant “Round Table” where the association’s founding is said to have occurred during the revolutionary year of 1848 (Figure 2). NWV President Helmut Zwander spoke about the long and varied history of the journal *Carinthia*, which dates back to 1811. He emphasized the need for constant innovation with a quote from Alice in Wonderland: “My dear, here we must run as fast as we can, just to stay in place. And if you wish to go anywhere, you must run twice as fast as that.”
CUAS CEO Siegfried Spanz discussed CUAS’s future strategies and the significance of the newly established collaboration for the future development in Carinthia and beyond. The digitalization of the sector, he noted, presents new opportunities (Figure 3). CUAS shall be considered as Carinthia´s major driver in applied sciences. Daniel Dalton from the *Carinthia Nature Tech* Editorial Office introduced the individual contributions, illustrating the

Fig. 2

Figure 2:
The guests at the Round Table.
On the table in the foreground are the three volumes of the *Carinthia II* family: *Popular Science Communications* (*Carinthia II/1*), *Scientific Communications* (*Carinthia II/2*), and *Carinthia Nature Tech* (*Carinthia II/3*). Clubrooms of the *Natural Science Association for Carinthia*, kärnten.museum Klagenfurt. (Photo: Johannes Puch)

At the Round Table, seated (from left to right) / um den Runden Tisch sitzend (von links nach rechts) Alice Burger, Susanne Aigner, Brigitte Winkler-Komar, Helmut Zwander, Sandra Malliga, Miriam Paul, Michael Jungmeier. At the Round Table, standing (from left to right) / um den Runden Tisch stehend (von links nach rechts): Felix Schlatti, Wilfried Elmenreich, Claudia Dojen, Wolfgang Muchitsch, Gregory Egger, Siegfried Spanz, Ilja Svetnik, Elisabeth Wiegele, Mohammad Mustafa Sadoun, Polona Zakrajšek, Daniel Dalton, Christina Pichler-Koban.

Abbildung 2:
Die Festgäste am Runden Tisch.
Am Tisch liegen im Vordergrund die drei Bände der Carinthia II Familie: Populärwissenschaftliche Mitteilungen (Carinthia II/1), Fachwissenschaftliche Mitteilungen (Carinthia II/2) sowie Carinthia Nature Tech (Carinthia II/3). Vereinsräume des Naturwissenschaftlichen Vereins für Kärnten, kärnten.museum Klagenfurt. (Foto: Johannes Puch)

mission of the new journal: to combine classical scientific and field biology methods with modern technologies to achieve new levels of quality results.
In the long term, technology-based methods will enable a more systematic, reliable, and—arguably—more transparent evidence base regarding the state of nature in general and biodiversity in particular. A continuous challenge remains: integrating these findings into political and societal discourse. The articles in the second issue of *Carinthia Nature Tech* are intended to contribute to this ongoing dialogue.
In the current issue of the journal, there are two peer-reviewed *Short Papers*, two *Short Notes*, and two *Book Reviews*. There are no *Full Papers* in this issue. The editorial team has decided that regular publication of the young journal is more important than representing all categories of contributions. However, *Full Papers* will appear again in the next issue of *Carinthia II part 3 -Nature Tech*. The reception of the first issue of the new *Carinthia II part 3 -Nature Tech* was very positive. Nevertheless, it is now important to increase awareness and outreach of the journal. Therefore, we warmly invite interested authors to submit their contributions. The Editorial Office is very happy to provide support in this regard.
We wish the contributions in this volume a positive reception in the spirit that these articles inspire and motivate the advancement of new technologies for the assessment and monitoring of biodiversity and ecosystem services.

Zur zweiten Ausgabe der Carinthia Nature Tech: Wie schnell muss man laufen, um am selben Platz zu bleiben?

ZUSAMMENFASSUNG

Im Vorwort zur zweiten Ausgabe der *Carinthia Nature Tech* wird auf die Präsentation der Zeitschrift am 17. Oktober 2024 Bezug genommen. Auch wenn die Österreicherinnen und Österreicher laut der Österreichischen Akademie der Wissenschaften hohes Vertrauen in Wissenschaft und Forschung haben, muss Wissenschaft einer zunehmend kritischen Öffentlichkeit mit transparenten Methoden und verständlichen Ergebnissen entgegentreten. Im Bereich von Biodiversität und Ökologie können Technologien, wie sie in dieser Zeitschrift adressiert sind, einen wesentlichen Beitrag leisten.

Fig. 3

Figure 3:
Tradition and Innovation.
In a symbolic act, the President of the *Natural Science Association for Carinthia*, Helmut Zwander, and the CEO of *Carinthia University of Applied Sciences*, Siegfried Spanz, integrate the digital *Carinthia II part 3 - Nature Tech* into the series of analog sister journals; exhibition room of the kärnten.museum Klagenfurt. (Photo: Johannes Puch)

Abbildung 3:
Tradition und Innovation.
In einem symbolischen Akt gliedern der Präsident des Naturwissenschaftlichen Vereins Helmut Zwander und der Geschäftsführer der Fachhochschule Kärnten Siegfried Spanz die digitale Carinthia II part 3 - Nature Tech in die Reihe der analogen Schwester-Zeitschriften ein; Ausstellungsraum des kärnten.museum Klagenfurt. (Foto: Johannes Puch)

Der *Naturwissenschaftliche Verein für Kärnten* (NWV) und die *Fachhochschule Kärnten* (FH) haben das neue Journal *Carinthia Nature Tech* gemeinsam entwickelt und die erste Ausgabe im Herbst 2024 gemeinsam präsentiert. Bei diesem Anlass illustrierte der Präsident des NWV, Helmut Zwander, die Bedeutung ständiger Innovation mit einem Zitat aus Alice im Wunderland. „Demnach müsse man so schnell laufen wie möglich, nur um an Ort und Stelle zu bleiben. Und wenn man irgendwohin gelangen wolle, müsse man sogar doppelt so schnell rennen." FH Geschäftsführer Siegfried Spanz betonte die Bedeutung der Zusammenarbeit von NWV und FH für Kärnten und darüber hinaus. Daniel Dalton aus der Redaktion stellte die Beiträge vor und illustrierte damit detailreich die inhaltliche Ausrichtung der neuen Zeitschrift. Diese will ja „klassische" wissenschaftliche Methoden und bestehende Wissensgebiete der naturwissenschaftlichen Forschung mit digitalen Technologien zusammenführen.
Zudem wird eine Übersicht über die Artikel der aktuellen Ausgabe geboten. Es folgt eine Einladung an potentielle Autorinnen und Autoren, die Publikationsmöglichkeit der neuen Zeitschrift zu nutzen. Das Team des Editorial Office steht dabei unterstützend zur Verfügung.

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Short Articles

Deep-learning based population monitoring of the endangered plant species *Gladiolus illyricus:* lessons learned for implementation of a technology-based biodiversity monitoring approach

Klaus Steinbauer, Vanessa Berger, Ulf Scherling, Michael Jungmeier

ABSTRACT

New technologies offer promising possibilities in biodiversity monitoring to increase standardization of sampling methods and improve cost efficiency. Among the former, uncrewed aerial systems (UAS) are widely used today to produce orthomosaics of a particular area. At the same time, computer-intensive methods for automated object detection within images have increased accordingly. While they are widely used in science, applied nature conservation makes little use of these methods. The current study aimed to test the applicability of UAS in combination with a deep-learning based object detection workflow in Schütt-Graschelitzen, a small-scale Natura 2000 protected area near Villach, Austria. For this purpose, we trained a YOLO_v8 algorithm with flowers of *Gladiolus illyricus* from an orthomosaic. The orthomosaic was split into about 1000 equally sized tiles with 80 tiles used for training and 20 tiles used for validation. For ground truthing, the individual inflorescences were counted manually. Our main findings indicated moderate model performance with the training and validation dataset and also with new data. Moderate – rather than strong – performance is likely a result of too little training data. While object detection worked considerably well, background revealed too high variability, making reliable classifications challenging. Comparing the different work steps (without UAS mission) suggests that creating a representative training dataset is the most time-intensive part of the workflow. For small areas and a single survey, this is likely not efficient compared to traditional field sampling methods. However, its efficiency increases with each resurvey event, as pretrained deep-learning models developed during prior monitoring cycles can be reused. This can reduce the amount of training data required in a subsequent survey. Additionally, UAS- and deep-learning based monitoring can help at sites with high sensitivity to trampling and favors large study areas, as its efficiency increases with the sample size area.

KEYWORDS

- Deep-learning
- biodiversity-monitoring
- *Gladiolus illyricus*
- flower detection
- UAS

Deep-learning basiertes Populationsmonitoring der gefährdeten Sumpfgladiole Gladiolus illyricus: Erkenntnisse zur Implementierung eines technologiebasierten Biodiversitätsmonitoring

ZUSAMMENFASSUNG

Neue Technologien bieten vielversprechende Möglichkeiten für Biodiversitätsmonitoring, um die Standardisierung von Erhebungen zu erhöhen und die Kosteneffizienz zu verbessern. Zu diesen Technologien gehören unbemannte Luftfahrtsysteme (UAS), die heute weit verbreitet sind, um Orthomosaike eines bestimmten Gebiets zu erstellen. Gleichzeitig haben rechenintensive Methoden zur automatisierten Objekterkennung in Bildern entsprechend zugenommen. Während diese Methoden in der Wissenschaft mittlerweile weit verbreitet sind, werden sie im angewandten Naturschutz wenig genutzt. Die aktuelle Studie hatte zum Ziel, die Anwendbarkeit von UAS in Kombination mit einem Deep-Learning-basierten Objekterkennungs-Workflow im Gebiet Schütt-Graschelitzen, einem kleinräumigen Natura 2000-Schutzgebiet in der Nähe von Villach, Österreich, zu testen. Zu diesem Zweck haben wir einen YOLO_v8-Algorithmus mit Blütenfotos von Gladiolus illyricus aus einem Orthomosaik trainiert. Das Orthomosaik wurde in etwa 1.000 gleich große Kacheln aufgeteilt, wobei 80 Kacheln für das Training und 20 Kacheln für die Validierung verwendet wurden. Um die Treffsicherheit des Modells zu bestimmen wurden die am Orthomosaik sichtbaren Infloreszenzen manuell gezählt. Unser Hauptergebnis zeigt eine mittelmäßige Modellleistung mit dem Trainings- und Validierungsdatensatz, sowie mit Objektdetektierungen in neuen Daten. Dies ist wahrscheinlich auf zu wenig Trainingsdaten zurückzuführen. Die Objektdetektierung lieferte dabei zufriedenstellende Ergebnisse, aber vor allem bei der Klassifikation von Hintergrund (Bilder ohne ein Vorkommen des Zielobjekts) hatte das Modell Probleme. Der Vergleich der verschiedenen Arbeitsschritte (ohne UAS-Mission) legt nahe, dass die Erstellung eines repräsentativen Trainingsdatensatzes der zeitintensivste Teil des Workflows ist. Für kleine Gebiete und eine einzelne Erhebung ist dies wahrscheinlich nicht effizient im Vergleich zu traditionellen Feldprobennahmemethoden. Allerdings steigt die Effizienz mit jeder erneuten Erhebung, da vortrainierte Deep-Learning-Modelle, die während vorheriger Überwachungszyklen entwickelt wurden, wiederverwendet werden können. Dies kann die Menge der benötigten Trainingsdaten bei einer nachfolgenden Erhebung reduzieren. Von Vorteil kann der Einsatz von UAS und automatisierter Bilderkennung insbesondere sein, wenn ein Untersuchungsgebiet empfindlich auf Betritt ist.

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INTRODUCTION

Halting global biodiversity loss is among the greatest challenges of our time. Taking directed management actions, therefore, is of utmost importance for the global nature conservation movement [1]. Evidence-based decisions are required to improve the current state of biodiversity [2]. This evidence is chiefly derived by determining the status and trends of biodiversity indicators, allowing future projections [3]. Knowledge on long-term trends is particularly important for taking directed actions [4, 5]. A lack of experts and limited financial resources are still among the main reasons for the scarcity of biodiversity time series [6]. New technologies offer promising opportunities to increase the frequency and consistency of biodiversity monitoring programs. Notably, technological approaches can help make expert knowledge more broadly available and allow its application over large spatial areas. However, application of expert knowledge in nature conservation is often a limitation because of potentially high costs, communication challenges with stakeholders, and data processing limitations [7].

In the present work, we tested two technologies in combination – aerial images by uncrewed aerial systems (UAS) and a deep-learning image detection algorithm – that offer promising opportunities to improve biodiversity monitoring programs. UAS are used today in nature conservation to assist with habitat classification [8] and to monitor mammals in open landscapes [9], among other applications. Combined with AI-based image detection algorithms, a high degree of automatization is possible. The hardware and software requirements can be accommodated today on a standard personal computer [10]. However, the use of these technologies in applied conservation by environmental agencies, regional governments, NGOs, and environmental consultancy firms remains limited. This is partly because certain official reporting requirements (e.g., Habitats Directive Article 17) do not currently consider new technological advancements. Lack of awareness about these technological opportunities, as well as uncertainty regarding the required personal and financial resources to implement them, are relevant factors [7, 11].

The primary goal of this study was to assess a workflow for applying a deep-learning algorithm on imagery of a rare plant species gathered from a UAS mission. Specifically, we aimed to determine whether reliable detection of an easily recognizable target is possible without requiring advanced technological expertise. We determined which aspects of the workflow are the most time-intensive. To address these questions, we evaluated the ability of the algorithm to automatically detect and count flowers of *Gladiolus illyricus*, wild gladiolus, in a protected area southwest of Villach, Austria, using UAS imagery.

METHODS & WORKFLOW

The study area was located in the Alpine biogeographical region, southwest of Villach, Austria in a Natura 2000 area called Schütt-Graschelitzen (site code AT2120000, https://biodiversity.europa.eu/sites/natura2000/AT2120000; Figure 1). The study object was an easily recognizable plant species, *G. illyricus*, that is known in Austria only within the wet meadows of the "Gladiolenwiese" of Dobratsch Nature Park, Carinthia. The Gladiolenwiese is owned by a conservation NGO and is specifically managed to support the habitat of *G. illyricus*. Management practices include controlled mowing to prevent the encroachment of reed (*Phragmites australis*), tall herbaceous plants, and woody species. We developed a UAS-generated RGB orthomosaic from images taken at flight altitude 30 m and horizontal speed of 5 m s^{-1} by an aerial vehicle (drone: DJI Matrice 600 RTK; camera: Sony Alpha 7R II with 50mm objective). The drone flight was performed during peak flowering of *G. illyricus* on June 8th, 2022 at noon. Weather conditions consisted of scattered clouds resulting in mixed light conditions (mix of direct and diffuse sunlight).

The forward/side overlap of images was 80/80. Post-processing of the orthomosaic was conducted using Metashape Version 1.7.4 build 13028 (Agisoft LLC, St. Petersburg, Russia) software and resulted in a ground sampling distance of 0.85 cm pixel^{-1}.

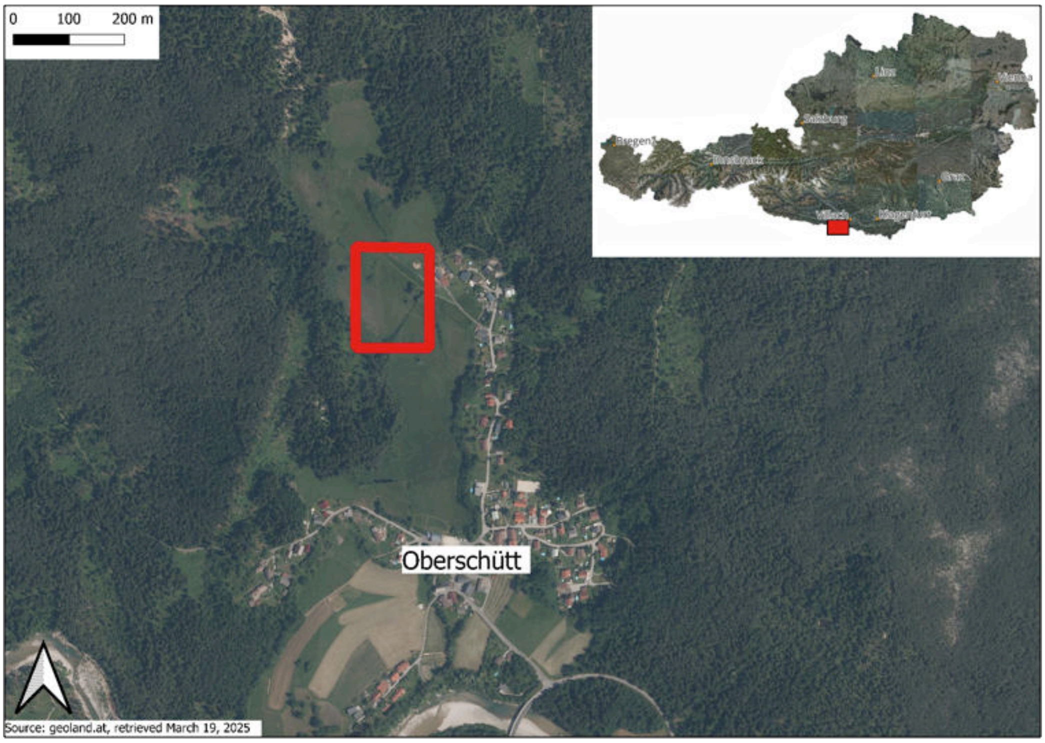

Fig. 1

Figure 1: Overview of the study area. The area of the actual UAS mission is indicated in red.

Abbildung 1: *Überblick des Untersuchungsgebiet. Der Bereich indem die UAS-Mission durchgeführt wurde ist in roter Farbe dargestellt.*

For ground truthing, flowers of *G. illyricus* were counted manually on the orthomosaic. The manual identification of *G. illyricus* from the orthomosaic was conducted using QGIS 3.30 [12]. For automated detection of inflorescences of *G. illyricus* we used a YOLO_v8 [13, 14] algorithm in a Python environment. Model performance was assessed on the object (label) level. We used the three key metrics: normalized confusion matrix, F1 score, and mean average Precision (mAP) [15]. In the normalized confusion matrix each row represents the distribution of predicted classes for a given true class. The normalized confusion matrix is further used to calculate precision (ratio of true positives to total number of predicted positives) and recall (ratio of true positives to total number of actual positives). Precision and recall are further used to calculate the F1 score at different confidence levels. The F1 score helps understand how well a model handles false positives or false negatives at different confidence levels [15]. Plotting precision against recall allows quantification of the area under the resulting precision-recall curve. This area reflects the average precision (AP). The metric mAP50 suggests that a detection is considered correct when the Intersection over Union (IoU) exceeds 0.5. IoU is calculated as the ratio of the area of overlap between the ground truth bounding box and the predicted bounding box to the area of their union [16]. For mAP50, a detection is considered correct if 50% of the predicted and true bounding boxes are overlapping. mAP50–95 reflects a more comprehensive assessment by calculating the average precision across multiple IoU thresholds, typically from 0.5 to 0.95 in steps of 0.05.

Our basic workflow is represented in Figure 2 and consisted of the following steps:

1. Generating an orthomosaic of the entire study area using orthophotos from the UAS mission (Figure 2a).

2. Cropping the orthomosaic into equally sized tiles of 448 × 448 pixels per tile (Figure 2b). This step was conducted using R [14], with the packages raster [17], terra [18], sf [19, 20], and stars [21]. As the orthomosaic was not perfectly rectangular, white parts containing no information were included in the tiles.

3. Selecting training images: A subset of 100 tiles was selected (representing around 10% of the overall tiles) reflecting a medium to high presence of *G. illyricus* flowers (different light conditions, different background), which were marked accordingly with bounding boxes (Figure 2c). This task was performed using the online software tool CVAT (Computer Vision Annotation tool, https://app.cvat.ai). This tool allows uploading of training images, marking the target objects and saving the output in the format required for YOLO algorithms (i.e., one folder containing the training image and a second folder with a .txt file including labels and coordinates of the target objects).

4. Randomly split the 100 tiles into training (80 tiles) and validation data (20 tiles).

5. Setting up the YOLO model with the training data in Python.

6. Using the trained YOLO model for detection of target objects in new images (Figure 2d).

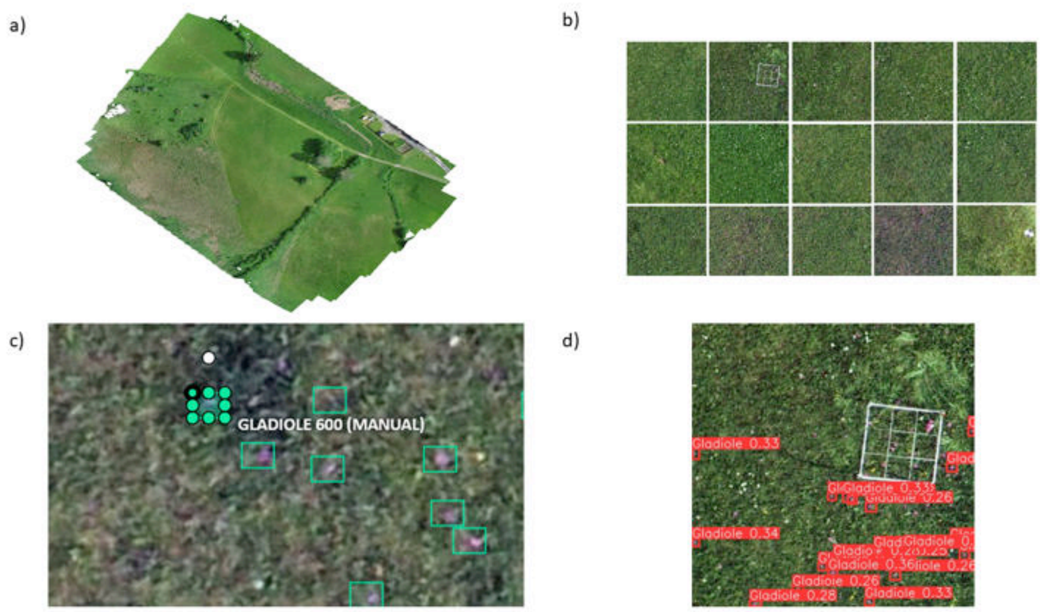

Fig. 2

Figure 2: Basic steps for deep-learning based monitoring of *Gladiolus illyricus*. Letters a-d denote work steps. a) UAS orthomosaic of the study area; b) the UAS orthomosaic cropped into equally sized tiles (e.g., 448 × 448 pixels); c) 100 tiles were used for creation of a training dataset; and d) after training, the model was used for detection of new target objects. The numbers in step d denote confidence scores of the trained model.

Abbildung 2: *Grundlegende Schritte für das Deep-learning basierte Monitoring von Gladiolus illyricus. Die Beschriftung von a-d spiegelt einzelne Arbeitsschritte wider. a) UAS-Orthofoto des Untersuchungsgebiets; b) UAS-Orthomosaik wurde in gleich große Kacheln (z. B. 448 × 448 Pixel) unterteilt; c) 100 Kacheln wurden zur Erstellung eines Trainingsdatensatzes verwendet; d) nach dem Training wurde das Modell zur Erkennung neuer Zielobjekte eingesetzt. Die Zahlen in Schritt d geben den Confidence Score des Modells wieder.*

RESULTS & DISCUSSION

In the current study, comparison between automatically detected flowers and manual counting indicated a difference of 12% more automatic detections (5,444 flowers) compared to manual verification (4,866 flowers). The normalized confusion matrix, however, showed a high ratio of correct detections for the validation data (0.84) and no false detections of *G. illyricus* flowers (Figure 3). The final model showed satisfactory prediction values

(Table 1). The model had high precision (0.88; very few false detections), moderate recall (0.80; most of the objects are detected), and good performance (mAP50 = 0.89). Model performance dropped at stricter IoU thresholds (mAP50-95 = 0.50). Although a majority of model parameters were within an acceptable range, the fact that 12% more flowers were detected by the model compared to manual counting indicated problems with overfitting and a small training dataset. In addition, the confidence scores of detections tended to be rather low (< 0.40; Figure 2.d, Figure 4). Moreover, the model lacks the ability to detect background at its current stage. Even an increase of background training data by 120 tiles couldn't solve this problem. This indicates that the background shows high variability, a factor that needs to be addressed in future work. Poor background differentiation explains the low confidence scores for the detected flowers.

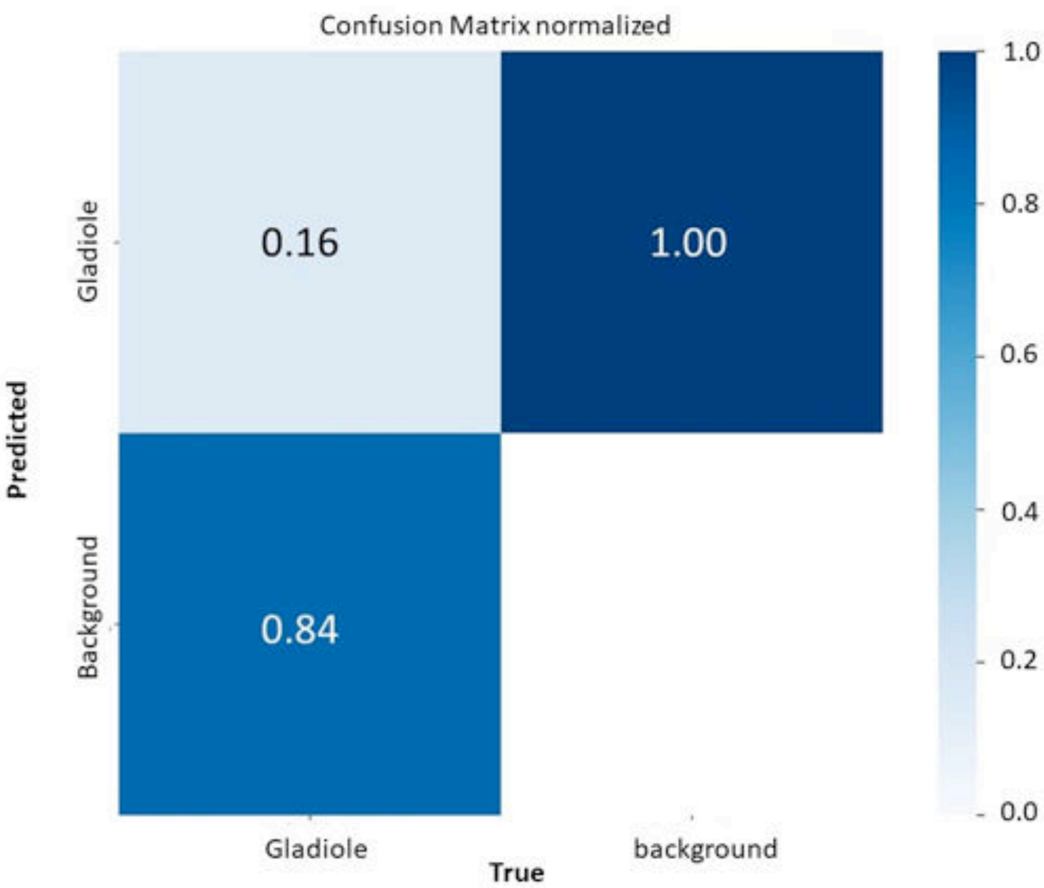

Fig. 2

Figure 3:
Normalized confusion matrix of the YOLO_v8 model for 20 tiles of the validation dataset.

Abbildung 3:
Normalisierte Konfusion Matrix des YOLO_v8 Modells für die 20 Kacheln der Validierungsdaten.

Tab. 1

Performance parameter	**Model performance**
mAP50	0.89
mAP50-95	0.50
Precision	0.88
Recall	0.80
Fitness	0.54

Table 1:
Model performance parameters of the final used YOLO_v8 model.

Tabelle 1:
Modell performance Parameter des finalen YOLO_v8 Modells

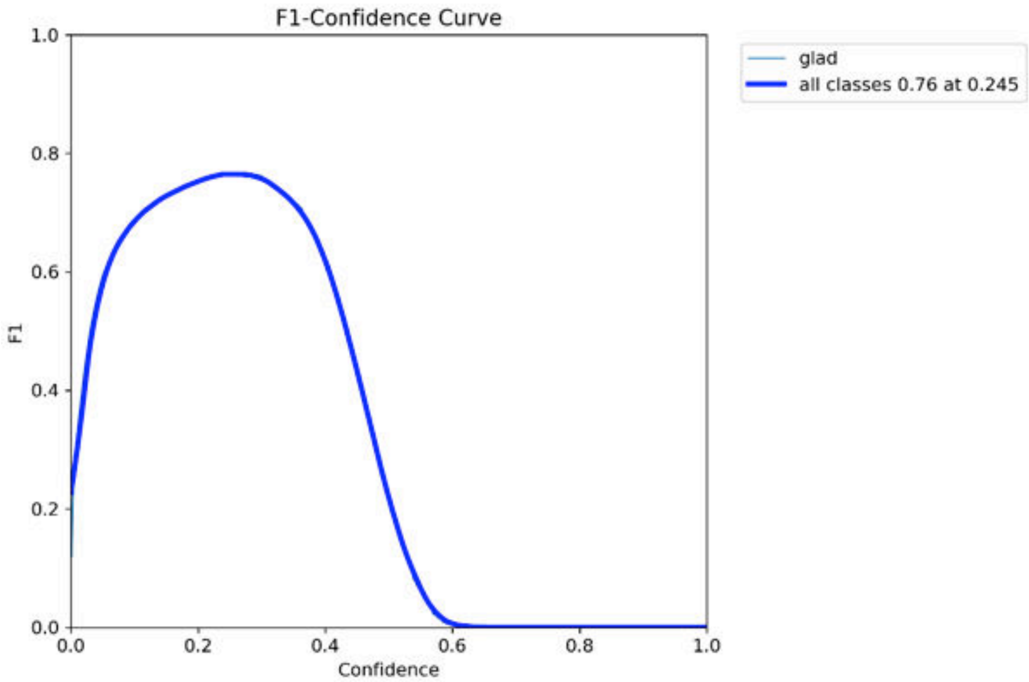

Fig. 4

Figure 4: F1 Confidence Curve of the YOLO_v8 model.

Abbildung 4: *Konfidenz-Kurve des YOLO_v8 Modells*

The selected tile size of 448 × 448 pixels produced a total of about 1,000 tiles from the area of interest. In terms of time, preparation of the training data demanded the greatest amount of resources. The process of marking and labeling the 100 training tiles took about 24 hours, or three full working days. The amount of time needed for creating training datasets is the most critical point for deep-learning-based monitoring techniques and must be evaluated carefully. Noteworthy, for monitoring a single site one time only, the time effort might be too high. On the other hand, if long-term monitoring is planned with several resurveys over an area of interest of several hectares, the approach will be more cost-effective.

One criterion that was not formally assessed in this study was conducting the UAS mission itself, including material costs and time requirements. For mission planning, a wide range of models and software is available, as well as software for post-processing of aerial images. UAS missions are a widely used earth observation approach that is often subcontracted to private companies at competitive prices. Terrain characteristics (e.g., steep or rugged terrain) and the size of the area of interest may affect the ease at which a flight campaign can be accomplished; thus, flight campaigns represent a cost factor that must be taken into account. A notable advantage of a UAS mission is its airborne nature. Traditional methods of accurately surveying plant populations in natural habitats often require physically entering the area, which can be hazardous to the field worker and potentially disruptive to the environment. These problems can be avoided by using UAS technology. However, UAS may disturb non-target species through the generation of noise or because the equipment resembles predatory species. Local flight regulations and restrictions must be carefully followed.

Using only 100 training images can be considered too few for training data (cf. [22]). Given the complexity and variation of biological data, this low volume of training data is insufficient to cover the variation expected under natural conditions. High variation in biological datasets can be considered the rule, not the exception, and should be accounted for when planning a biodiversity monitoring program. Sources of variability include changing light and weather conditions during UAS missions, variable background, potentially different sensors used in different missions, and variability in the study object itself. Given natural variability, a considerably higher volume of training data (500-1,000 training images) is recommended [23]. This implies further that for a new monitoring cycle a smaller set of supplemental training images should be considered. The amount of new training images needed for a resurvey wasn't tested in detail and will be addressed in future research. However, methods like transfer learning can help reduce the number of new required training images [24, 25]. In the current study, where only one UAS mission was conducted over a small area of interest, weather-related sources of variability were mitigated and all equipment was used according to internal standard protocols.

Marking the object of interest prior to the UAS flight is important in situations when similar species or objects of similar appearance and/or color are present at the study site. This is needed for the preparation of the training dataset to ensure that only the target object is used for training. In our case, *G. illyricus* was the only pink-colored flower present in the meadow from a bird's-eye view. Therefore, we were able to confidently mark our object of interest on the tiles of the orthomosaic. Accurate marking of flowering plants could be realized through the use of a differential GPS, but for small clustered objects such as the flowers in this study, marking could be imprecise. Labeling target objects in the field could be a major time-consuming part of the overall workflow, requiring labeling of some 500-1,000 individual points. The spatial arrangement of target objects in the field (scattered vs. clustered) affecting walking distances, and the terrain itself are additional factors that should be considered.

To address our research question, we trained the deep-learning algorithm to detect *G. illyricus* inflorescences. This allowed quantification of phenological trends but provided no direct estimation of the population, since the number of flowers varies by individual plants. This is an important consideration when preparing training data. To estimate population size, one approach could be to calculate the mean number of flowers per individual and use this value to estimate the number of plants present based on number of inflorescences detected [26]. While population size is ecologically relevant, for the purposes of producing a model, individual flower clusters can be used to train the algorithm.

Overall, we conclude that the YOLO_v8 model is a promising tool for reliable detection of inflorescences of *G. illyricus* from orthomosaics. At the current stage, however, the model shows several limitations that have to be resolved before further use in UAS-based monitoring. The most critical point is the collection of sufficient training data and testing the model on novel data sets [27]. Insufficient training hinders reliable estimation of the model performance. Nevertheless, given that a majority of *G. illyricus* inflorescences were detected while false detections were lacking, the basic utility of the model was confirmed.

Additional challenges relate to the necessary practical aspects of performing UAS missions, post-processing of the data, and training a deep-learning algorithm. From our perspective, the obstacles have decreased considerably in the past decade but still require considerable technological understanding and programming skills. Though the current challenges are undeniable, we see the growing potential for developing the workflow for future biodiversity monitoring. One major advantage arises from the reusability of pre-trained deep-learning models, decreasing the amount of training data required in a follow-up survey. Embedded in a smart biodiversity monitoring program, adequately addressing the challenges stemming from this technology can help to improve standardization and increase the spatial coverage and temporal frequency of surveys.

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BACK TO CONTENT

Comparative effectiveness of acoustic devices for monitoring bat species: a case study of *Plecotus macrobullaris* in Thomatal

Jennifer Insupp, Maria Jerabek, Vanessa Berger, Daniel T. Dalton

ABSTRACT

The current study reports on the presence and activity of bats at the St. Georg Parish Church, Thomatal, Salzburg, Austria. This site was known in previous years to host a maternity roost of the alpine long-eared bat (*Plecotus macrobullaris*). Passive acoustic monitoring (PAM) and traditional roost emergence counting techniques were used to document bat activity. The study compared the effectiveness of three ultrasonic detection devices: Song Meter Mini Bat, Echo Meter Touch 2 Pro, and batcorder. Following expert verification, the study confirmed the presence and seasonal emergence phenology of *P. macrobullaris* and documented additional bat species including *Eptesicus nilssonii* and *Myotis daubentonii*. The results highlighted variations in the accuracy and species detection capabilities of the devices. While differences in device performance were clear, the findings emphasize the applicability of PAM for monitoring bat populations. Findings underscore the importance of proper device handling and appropriate data analytical techniques to ensure reliable species identification.

KEYWORDS

- bat
- passive acoustic monitoring
- *Plecotus macrobullaris*
- Thomatal
- ARU

Vergleich der Effektivität akustischer Geräte zum Monitoring von Fledermausarten: Eine Fallstudie zu Plecotus macrobullaris in Thomatal

ZUSAMMENFASSUNG

Die vorliegende Studie berichtet über das Vorkommen und die Aktivität von Fledermäusen an der Pfarrkirche St. Georg in Thomatal, Salzburg, Österreich. Dieser Standort war in den vergangenen Jahren dafür bekannt, ein Wochenstubenquartier der Alpen-Langohrfledermaus (Plecotus macrobullaris) zu beherbergen. Passives akustisches Monitoring (PAM) und traditionelle Methoden der Zählung beim Quartierausflug wurden verwendet, um die Fledermausaktivität zu dokumentieren. Die Studie verglich die Effektivität von drei Ultraschalldetektoren: Song Meter Mini Bat, Echo Meter Touch 2 Pro und batcorder. Nach Verifizierung durch Expertinnen bestätigte die Studie die Präsenz und das saisonale Auftreten von P. macrobullaris und dokumentierte weitere Fledermausarten wie Eptesicus nilssonii und Myotis daubentonii. Die Ergebnisse zeigten Unterschiede in der Genauigkeit und Artbestimmung zwischen den Geräten. Während die Leistungsunterschiede der Geräte deutlich waren, betonen die Ergebnisse die Anwendbarkeit von PAM zur Überwachung von Fledermauspopulationen. Die Ergebnisse unterstreichen die Bedeutung einer fachgerechten Handhabung der Geräte und geeigneter Datenanalysetechniken, um eine zuverlässige Artbestimmung zu gewährleisten.

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INTRODUCTION

Passive acoustic monitoring (PAM) is an approach that utilizes autonomous recording units (ARUs) to record sounds in the environment [1]. PAM enables wildlife researchers to monitor animal species that produce sounds in the audible, ultrasonic, and infrasonic spectra without disturbing them. Recorded wavelengths of sound outside the range of human hearing are captured as electronic signals that can then be converted into forms audible to people. Despite the advantages, PAM is prone to potential sources of error including call misclassification. Misclassification may occur due to inadequate recording quality or incomplete call libraries that cannot differentiate calls among closely related species [2]. However, sound clips can be reanalyzed upon improvements to acoustic libraries or a reviewer's ability to validate them.

ARUs create original and permanent records of animal activity and offer several advantages over traditional monitoring of sound-producing animals. Their semi-permanent installation allows researchers to non-invasively document animal activities or rare species. ARUs enable long-term and continuous recording of soundscapes, including periods in which expert-based monitoring is difficult due to timing of animal activity [3]. Ultrasonic detectors are a class of ARUs configured to record frequencies that are produced by mammals such as bats and shrews, as well as certain insects [4, 5]. Most bat species use echolocation to survey their environment, for communication, and to locate prey. Most species are difficult to observe.

The alpine long-eared bat, *Plecotus macrobullaris* (syn. *P. alpinus* and *P. microdontus*), is a Eurasian species found in Southern Palearctic mountainous regions [6]. Although *P. macrobullaris* is listed on the European Red List as Near Threatened [7], in Switzerland the species is considered Endangered with unknown population trends [8]. In Europe, it is restricted to the Pyrenees, Alps, and Dinaric mountainous regions [9]. In parts of its distribution area the species is known to roost in rock crevices, and there the three main factors predicting roosting sites include close proximity to rocks (within 1 km), steep slope, and elevation above 1000 m (optimal elevation 1600 m) [10]. In flight, *P. macrobullaris* emits faint, brief, downward modulated frequency calls that feature sonic characteristics similar to the brown long-eared bat *P. auritus* and grey long-eared bat *P. austriacus* [11]. Morphologically, *P. macrobullaris* resembles an intermediate of *P. auritus* and *P. austriacus*. Physical characteristics of *P. macrobullaris* include the presence of white fur on its ventral side, its relatively large thumb, claw, and forearm [12], long ear covers, and a concave chin pad on the lower mandible [13, 14].

The St. Georg Parish Church is located at the base of Schwarzenberg Mountain in the community of Thomatal, within the Lungau region of the Salzburger Lungau and Kärntner Nockberge Biosphere Reserve. The Mires of the Schwarzenberg, a conservation area designated under the Ramsar Convention, includes 14 protected bogs near the mountain's summit [15]. In 1998 a population of *Plecotus* sp. was observed at the St. Georg Parish Church. During the early 2010s, A. Kiefer confirmed the species as *P. macrobullaris* on a morphological basis (M. Jerabek, pers. comm.).

This study served as a test of the ability of commercially available ARUs to detect bat activity at a known maternity roosting site of *P. macrobullaris*. Previous species inventories across Salzburg Province indicated that *P. macrobullaris* was restricted to the Lungau region, with only two summer roosting sites identified there [16]. The area surrounding St. Georg Parish Church in Thomatal - at an elevation of 1055 m - satisfies the main explanatory variables in species habitat models [10]: about 150m from a steep rocky slope of Mt. Schwarzenberg (summit elevation of 1779 m), indicating the suitability of the area for *P. macrobullaris* summer activity.

METHODS

Traditional methods

To compare different monitoring methods on detecting bat species at St. Georg Parish, traditional roost emergence counts were conducted in combination with ARU deployments. Voucher photographs were taken of bats roosting in the church attic as evidence of species occupancy at the maternity roost. As the composition of the diet of *P. macrobullaris* was investigated in a parallel study, clean sheets of paper were laid out along the attic floor once per month from May to September to collect bat fecal pellets directly below the roosting site. The final paper deployment was retrieved the night of October 7th. Roost emergence counts followed established protocols [17, 18] and occurred from the churchyard at twilight once per month from June to October, starting approximately at sunset and ending after a period of about 10 minutes of no flight activity following previous activity. A bat was counted using a hand-held click counter if it was observed to fly out of the bell tower into the landscape, but it was not counted if it flew immediately back into the bell tower. Additionally, bats entering the bell tower from the surrounding environment were not counted. Roost emergence counts lasted 30-45 minutes.

Passive acoustic monitoring

Three types of ultrasonic sensor were used for comparison of their utility for PAM of bats (Table 1). While monitoring occurred from the period of May 6th 2022 – October 11th 2022, all devices were used together at St. Georg Parish Church on only one date, June 6th. Two ARUs are designed to record the soundscape for long periods of time (scale of days to weeks), while the third ARU is designed to be used for short, targeted periods (scale of minutes). The purpose of simultaneous device deployment was to gain perspective on the advantages and disadvantages provided by each ARU.

Song Meter Mini Bat (SMU, Wildlife Acoustics, Inc., Maynard, MA, USA) is a commercially available full-spectrum ARU that is designed to detect ultrasonic wavelengths up to 500kHz. When an incoming signal reaches the sensor, the device is activated and the signal is recorded. Song Meter devices are managed through the Song Meter Configurator (Version 3.0) smartphone app and can be programmed to be active at particular times of the day. A SMU was installed in the flight pathway of the alpine long-eared bats at the northeast corner of the churchyard on May 6th and was removed during the day on October 11th. It was set to record incoming ultrasonic signals each day from 30 minutes before sunset until 30 minutes after sunrise [19]. The acoustic settings were: sample rate of 256kHz, a gain of 12, and a trigger window of three seconds. Data were backed up onto a computer and batteries replaced every 3-4 weeks during the season, based on when data storage capacity was expected to be met or battery life was projected to expire, according to the configuration app.

Echo Meter Touch 2 Pro (EMT2P, Wildlife Acoustics, Inc., Maynard, MA, USA) is a small device that connects directly to a smartphone and transforms bat echolocation signals into frequencies that are audible to humans. It is controlled by the Echo Meter Touch Bat Detector (Version 2.8.11) app and automatically records incoming ultrasonic signals up to 384kHz. EMT2P suggests the most likely bat species in real time based on their calls. Data and suggested species identities are saved directly onto the smartphone. In this study EMT2P was connected to a smartphone on June 6th and September 5th. On both dates, the device was stationed about 10 m to the east of the exit flight path of the bell tower and about 5 m south of the SMU.

The batcorder (EcoObs GmbH, Nuremberg, Germany) is an ARU designed to record ultrasonic signals. This full-spectrum ARU is designed to detect ultrasonic wavelengths up to 500kHz. When an incoming signal reaches the sensor, the device is activated and the signal is recorded. Data are saved onto a SDHC card and can be analyzed afterwards with the computer programs bcAdmin, bcIdent, and bcAnalyze. In this study the batcorder was installed 2-3 m above ground atop a pole for the observation periods with a sample rate of 500kHz and a gain of 16. Batcorders enable observation periods from several hours up to 10 days or more with the normal battery pack. Configured as a box-extension – in a robust plastic box, a 6V to 17V battery, solar panel and GSM module – it can work for several weeks and is limited by the SDHC card´s capacity. The aerial configuration of the batcorder reduces echoes, allowing for an expert to identify clearly recorded calls in a later step. In this study, the batcorder was stationed inside the churchyard about 2 m to the southwest of the SMU and was used on June 6th, July 3rd, August 8th, and October 7th.

Data analysis

The call analyses for SMU and EMT2P were performed in a multi-step process. First, automatic species identification was recorded as assigned by Kaleidoscope Pro 5.6.8 software (Wildlife Acoustics, Inc., Maynard, MA, USA) (Table 1). To verify the automatic classification of the calls from Kaleidoscope, all detected bat calls were subjected to manual review by an expert in a following step [20–23]. This allowed assessment of the accuracy of the automatic species identification classifications. A minimum of three calls (N calls) is required for the identification of many bat species [22, 23]. Additionally, an arbitrary threshold of 75% identification probability, called Matching Rate, was applied to the manual analysis of SMU and EMT2P devices to increase the likelihood of accurately identifying the correct species.

The calls that were recorded using the batcorder were first analyzed by the automatic species identification software bcAdmin, bcIdent, and bcAnalyze. In a second step, the bat calls were manually checked by an expert from the Coordination Centre for Protection and Research of Bats in Austria, KFFÖ.

Tab. 1

Feature	Song Meter Mini Bat	Echo Meter Touch 2 Pro Android	batcorder
Version	1.0	1.0	
Firmware version	3.0	App 2.8.11	3.1
Latitude, Longitude	47.072, 13.749	47.072, 13.750	47.072, 13.749
Make	Wildlife Acoustics, Inc.	Wildlife Acoustics, Inc.	ecoObs GmbH
Sample rate (Hz)	256000	256000	500000
Analytical software	WA|Kaleidoscope v. 5.4.6	WA|Kaleidoscope v. 5.4.6	bcAdmin4
Classifier version	Bats of Europe 5.4.0	Bats of Europe 5.4.0	bcAdmin4
Classifier settings	min freq :8000, max freq:120000, min dur:0.002000, max dur:0.500000, cf min freq:0, cf max freq:0, cf max bw:0, min calls:2, enhance: on, sensitivity: balanced	min freq :8000, max freq:120000, min dur:0.002000, max dur:0.500000, cf min freq:0, cf max freq :0, cf max bw :0, min calls:2, enhance: on, sensitivity: balanced	Min freq:16000, max frq:150000
Audio settings	Rate:256000, gain:12, trig window:3.0, trig max len :60.0, trig min freq:16000, trig max freq:128000, trig min dur:0.0000, trig max dur:0.0000	Rate:256000Hz, gain:0.00, trig level:0.00, trig max len:0.00, trig window:0.00, trig min freq:0.00, trig max freq:0.00, prefix:null	Rate: 500000, gain:16, thresh-old:-36 dB, quality/sensitivity:20, criti-cal freq:14000, post trigger:800 ms

Table 1:
Settings and configuration of Song Meter Mini Bat, Echo Meter Touch 2 Pro and batcorder devices and analytical software

Tabelle 1:
Einstellungen und Konfiguration der Geräte Song Meter Mini Bat, Echo Meter Touch 2 Pro und batcorder sowie der Analysesoftware

RESULTS

Traditional methods

Visual confirmation of the roost of *P. macrobullaris* was based on morphological features of bats observed inside the church attic [13] during the first site visit on May 6th (Figure 1). No other bat species were observed in the church attic during the study. Most guano samples found in the roost were composed of small fecal pellets; however, on each survey date a specific location always contained fecal pellets of a larger size consistent with *Myotis myotis* [24]. When evaluated against a comparative collection, the small pellets were evidence of continuous occupation by *P. macrobullaris*, while the large pellets indicated the cohabitation of small numbers of *M. myotis*.

Fig. 1

Figure 1: Alpine long-eared bats on May 6th, 2022 in the St. Georg Parish Church, Thomatal, Lungau, Salzburg, Austria (source: © Wolfgang Forstmeier)

Abbildung 1: *Alpen-Langohrfledermäuse im Wochenstubenquartier in der Pfarrkirche St. Georg, Thomatal, Lungau, Salzburg, Österreich am 6. Mai 2022 (Quelle: © Wolfgang Forstmeier)*

Roost emergence counts revealed that the seasonal flight activity at St. Georg Parish Church was dominated by a small- to medium-sized bat, with occasional sightings of larger individuals. Flight activity peaked in July and decreased each following month (Figure 2). Animals could not be visually confirmed to the species level during roost emergence

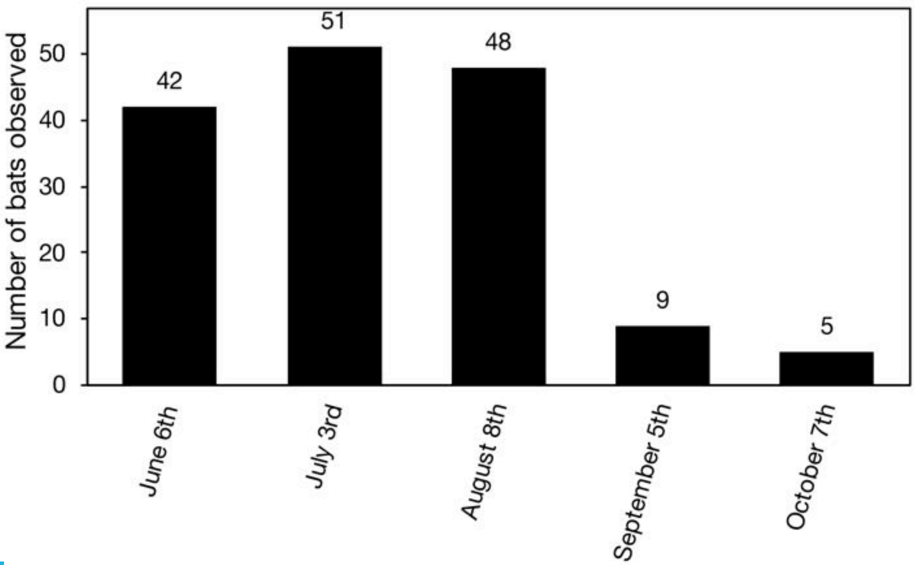

Fig. 2

Figure 2: Number of bats observed at the St. Georg Parish Church during monthly emergence counts in 2022

Abbildung 2: *Anzahl von Alpen-Langohren, die 2022 bei den monatlichen Ausflugszählungen an der Pfarrkirche St. Georg beobachtet wurden* counts, but animal sizes and habitus as well as the flight behavior were consistent with those expected of *P. macrobullaris* and *M. myotis*. Furthermore, the monthly collected guano samples were consistent with the presence of *P. macrobullaris* and *M. myotis*.

PASSIVE ACOUSTIC MONITORING

The original intention of the study was to compare the performance of the three ARUs against each other on multiple dates from spring to fall. Due to equipment error and limited availability of trained volunteer personnel, data were obtained from all devices on one date, restricting our comparisons to this single event. Data from the three ARUs deployed on June 6th are shown below. In total, 136 recordings from the SMU, 53 recordings from the EMT2P, and 66 recordings from the batcorder were analyzed. These devices produced a total data volume of 603 MB.

Song Meter Mini Bat

The SMU collected ultrasonic data from 20:48 to 23:58 CEST. After the manual reclassification of the 136 recordings, four bat species were identified: the northern bat (*Eptesicus nilssonii*), Daubenton's bat (*Myotis daubentonii*), common noctule (*Nyctalus noctula*), and common pipistrelle (*Pipistrellus pipistrellus*) (Figure 3). However, there were too few recordings of *N. noctula* to reliably confirm the presence of the species. Two non-specific genera (*Myotis* sp. and *Plecotus* sp.) and a species group (Nyctaloid [20]) were further classified. Given the historical presence of *P. macrobullaris* at the St. Georg Parish Church and the visual confirmation of the species at the beginning of the monitoring period, recordings of *Plecotus* sp. were assigned to *P. macrobullaris.* Ten recordings contained only 'noise' (artificial or natural noises but no bat calls), and for 27 recordings no further identification of the bat calls was possible.

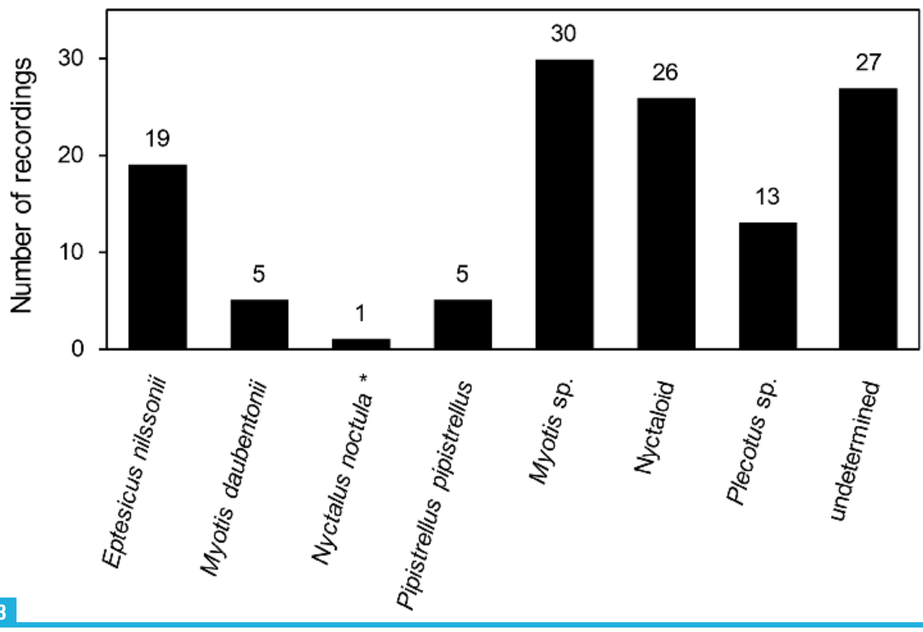

Fig. 3

Figure 3: Number of recordings with Song Meter Mini Bat on June 6th, 2022, in Thomatal, after verification (*uncertain species identification due to too few recordings)

Abbildung 3: *Anzahl von Aufnahmen mit Song Meter Mini Bat am 6. Juni 2022, in Thomatal, nach Verifizierung (*unsichere Artbestimmung wegen zu wenigen Aufnahmen)*

Of the 136 recordings, 25% were correctly classified by the automatic classifier in Kaleidoscope (Table 1, Figure 4). When only recordings with a classification probability of ≥ 0.75 and a minimum number of three calls were considered [20], the proportion of correctly classified recordings was increased to 66%, and the same four bat species as identified through expert review remained (Figure 5).

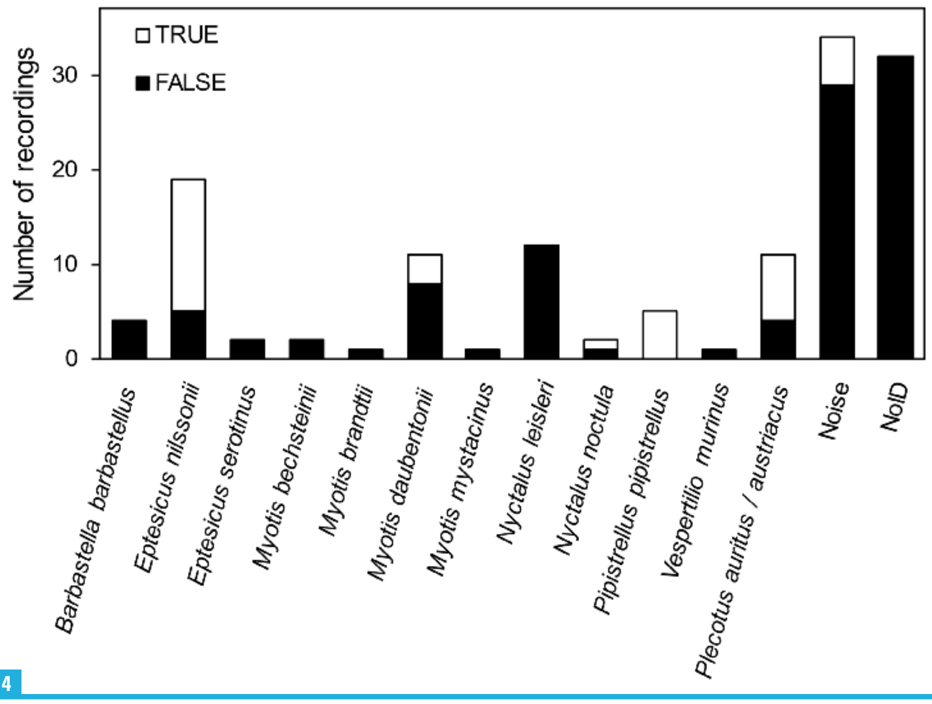

Fig. 4

Figure 4: Number of Song Meter Mini Bat recordings correctly identified by the automatic classification in Kaleidoscope

Abbildung 4: *Anzahl von Song Meter Mini Bat Aufnahmen, die durch die automatische Klassifikation von Kaleidoscope korrekt identifiziert wurden*

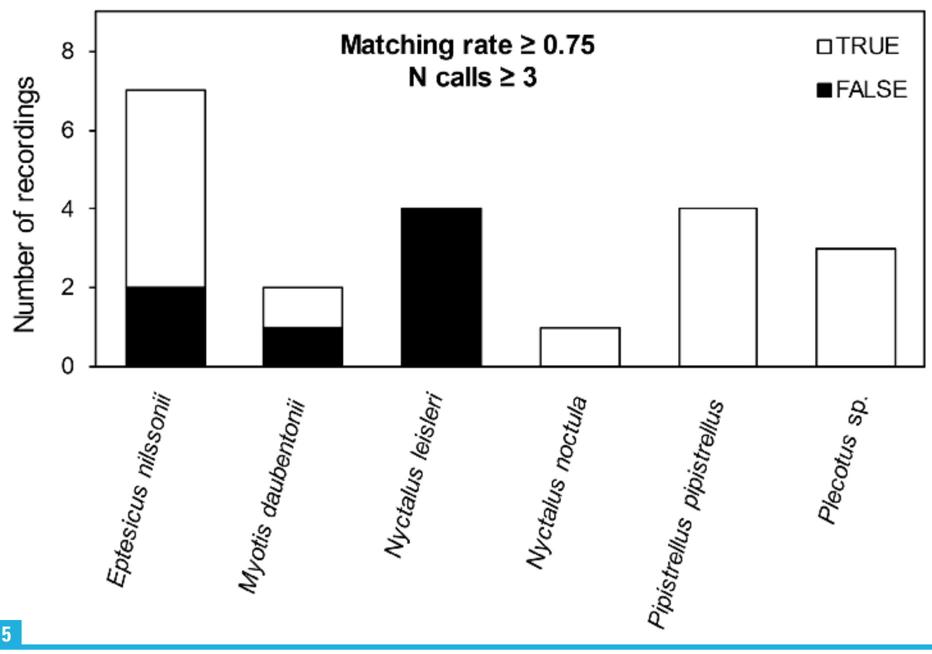

Fig. 5

Figure 5: Number of Song Meter Mini Bat recordings correctly identified by the automatic classification in Kaleidoscope, filtered by identification probability (Matching Rate) and minimum number of call sequences (N calls)

Abbildung 5: *Anzahl von Song Meter Mini Bat Aufnahmen, die durch die automatische Klassifikation von Kaleidoscope korrekt identifiziert wurden, gefiltert nach Identifikationswahrscheinlichkeit (Matching Rate) und Mindestanzahl von Rufsequenzen (N calls)*

Tab. 2

Table 2: Number of recordings per bat species and method (* uncertain species identification due to too few recordings)

Tabelle 2: *Anzahl von Aufnahmen pro Fledermausart und Methode (*unsichere Artbestimmung aufgrund zu wenigen Aufnahmen)*

Species	**Common name**	**SMU**	**EMT2P**	**batcorder**
Eptesicus nilssonii	northern bat	19	1	1
Myotis daubentonii	Daubenton's bat	5	-	-
*Nyctalus noctula**	common noctule	1	-	-
Pipistrellus pipistrellus	common pipistrelle	5	-	-
Myotis sp.	mouse-eared bat	30	1	27
Nyctaloid		26	2	5
Plecotus sp.	long-eared bat	13	8	30
undetermined		27	4	3
	Total	126	16	66

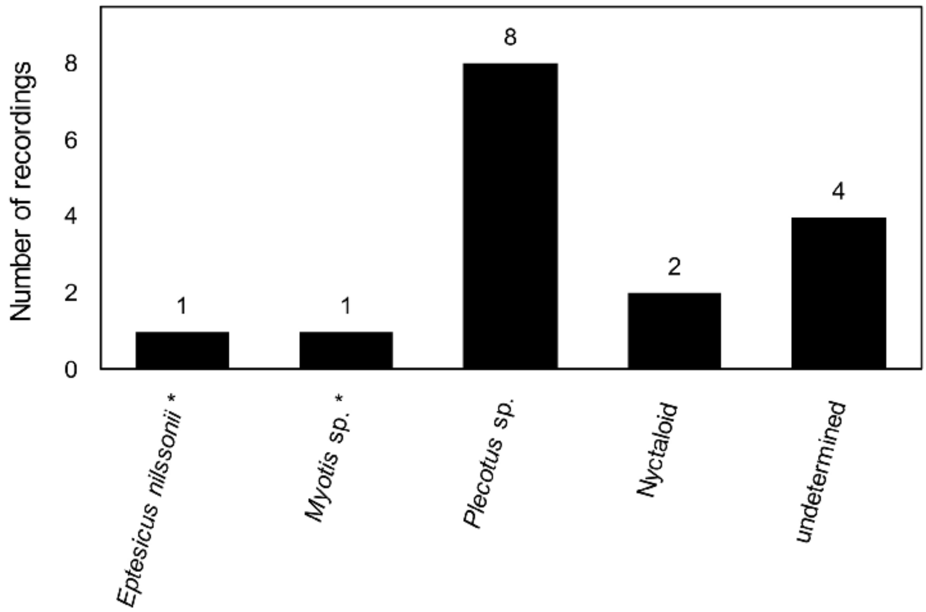

Fig. 6

Figure 6: Number of recordings with the Echo Meter Touch 2 Pro on June 6th, 2022, in Thomatal, after verification (*uncertain species identification due to too few recordings)

Abbildung 6: *Anzahl von Aufnahmen mit Echo Meter Touch 2 Pro am 6. Juni 2022 in Thomatal, nach Verifizierung (*unsichere Artbestimmung wegen zu wenigen Aufnahmen)*

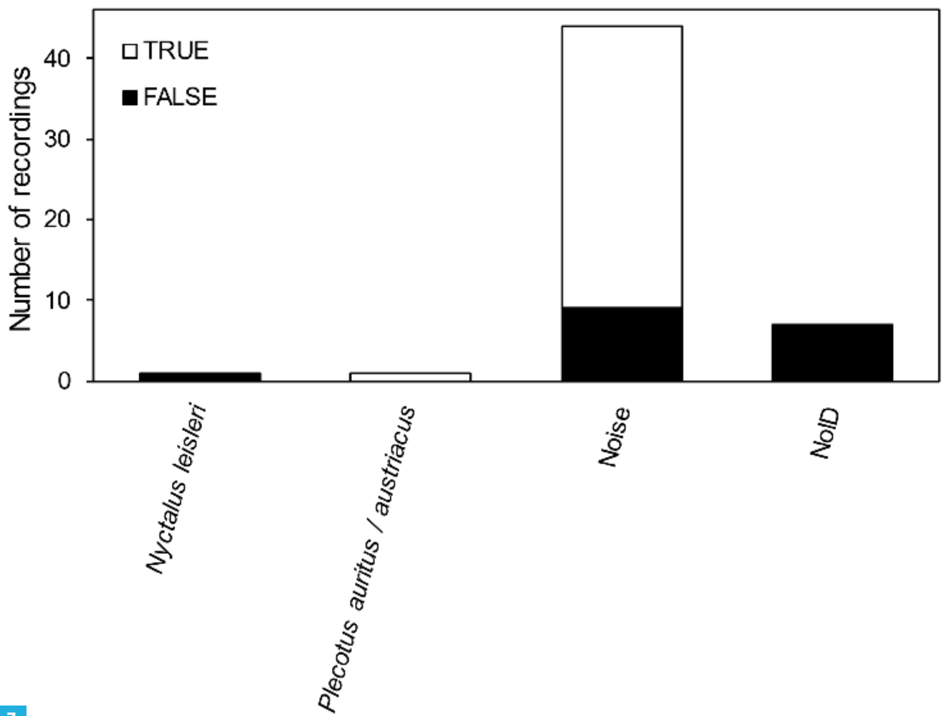

Fig. 7

Figure 7: Number of Echo Meter Touch 2 Pro recordings correctly identified by the automatic classification in Kaleidoscope

Abbildung 7: *Anzahl von Echo Meter Touch 2 Pro Aufnahmen, die in Kaleidoscope durch die automatische Klassifikation korrekt identifiziert wurden*

Echo Meter Touch 2 Pro

The EMT2P was deployed between 21:26 and 21:49 CEST on June 6th, 2022. The automatic classification of the device identified 44 noise recordings, seven recordings with unclassifiable bat calls, and one classification of each of two species. During the manual review, 16 recordings with bat calls from at least four bat species were identified. Two recordings could be assigned to the Nyctaloid species complex but were not identifiable in finer resolution. Eight recordings indicated presence of *P. auritus / P. austriacus*, and one recording showed the presence of *E. nilssonii* (Figure 6). One recording showed calls from an unclassifiable *Myotis* sp. However, a single recording is generally not sufficient for a reliable species identification [20]. Overall, 32% of the automatic classifications were correctly assigned (Figure 7), and only *Plecotus* sp. bat calls could be detected with an identification probability ≥ 0.75.

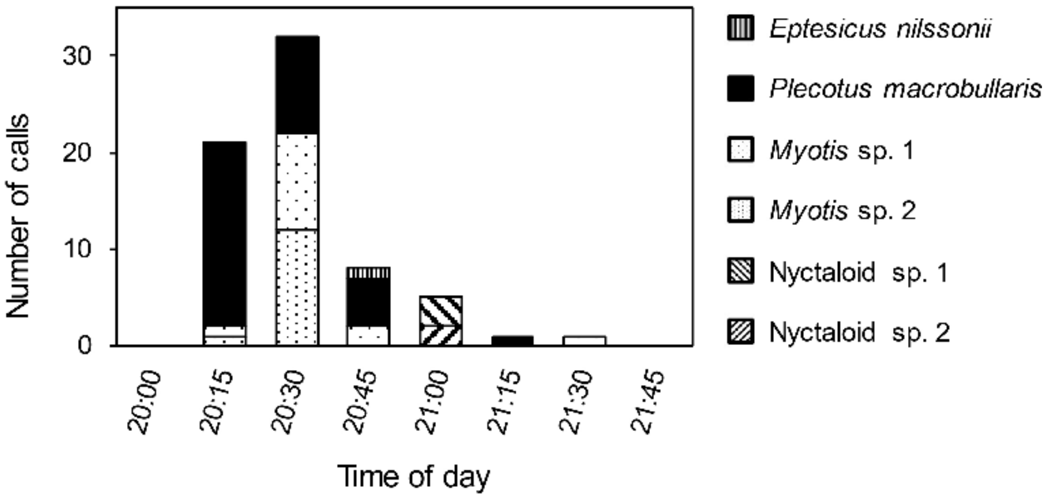

Fig. 8

Figure 8: Occurrence of bat calls at St. Georg Parish Church on June 6th 2022, as recorded by the batcorder

Abbildung 8: *Vorkommen von Fledermausrufen an der Pfarrkirche St. Georg am 6. Juni 2022, aufgezeichnet mit batcorder*

Batcorder

The batcorder was programmed to work on June 6th, 2022 from 20:00 CEST onwards. The first bat calls were registered at 20:43, the last bat calls were recorded at 21:15, and then the batcorder was deactivated manually upon leaving the churchyard. Out of 68 sequences detected by the batcorder, 66 sequences could be determined as bat calls, and the dominant species in the soundscape was recorded as *Plecotus* sp. The automated species detection of the bc suite of analytical tools identified 12 out of the 30 *Plecotus* calls, and 12 additional call sequences had an indication of *Plecotus* in the details of the call identification (without assigning them to *Plecotus*). The rest of the calls could be identified manually. Additionally, *Myotis* sp. emitted calls. Classifications for *E. nilssonii* and the Nyctaloid species complex appeared in the data from June 6th (Figure 8).

SUMMARY

Overall, at least five bat species could be detected during the study period (Table 2). After the manual reclassification and verification provided by the two experts, two species could be identified with the recordings of the batcorder, one species with EMT2P, and four species with SMU. Where fewer than 3 recordings can be assigned to a species, these classifications should be considered uncertain. However, the recordings from the Nyctaloid group clearly indicate activity of at least one more species in addition to *E. nilsonii*. The Nyctaloid species group also includes the Leisler's bat (*Nyctalus leisleri*), the parti-colored bat (*Vespertilio murinus*), and the serotine bat (*Eptesicus serotinus*).

DISCUSSION

Due to differential behaviors and call signatures of bat species, scientists have long recognized the necessity to combine multiple sampling techniques to determine the full range of community diversity [25]. The primary target species of the study, *P. macrobullaris*, was visually identified in a maternity roost by experienced chiropterists. However, it is currently missing in the Kaleidoscope automatic classification species list. With Kaleidoscope, the automatic classification software attributed calls of *Plecotus* sp. to either *P. auritus* or *P. austriacus* during the classification process (Figure 4, Figure 7). Classifications from analysis of batcorder data did not differentiate calls of *Plecotus* sp. This output is in agreement with previous findings on structural similarities of *Plecotus* sp. calls [11]. Our archived recordings were made in close proximity to the confirmed roost of *P. macrobullaris* and serve as permanent voucher records of activity of the species. This study provides guidance into further research on PAM of *P. macrobullaris*, serving as a basis of knowledge on the suitability of three different acoustic devices, their effectiveness and limitations in identifying not only *P. macrobullaris*, but also other bats of Central Europe and the Alpine region, including *M. myotis*, *M. daubentonii*, and representatives of the Nyctaloid species group. The research demonstrated advantages of ARU deployment compared to traditional methods, while also showing the importance of the correct use of devices and appropriate data storage.

In comparing the methods, differences in quality and quantity are evident and depend primarily on how the device is handled. The batcorder was used by a professional chiropterist with considerable experience on handling the device, as well as the automatic and the subsequent manual verification processes. Many *Plecotus* sp. recordings may have been missed by the automatic detection due to very quiet calls [11]. In contrast, some difficulties occurred while handling the SMU and EMT2P for the first time. The batteries of the SMU were not replaced frequently enough, resulting in interruptions to continuous data recording. SMU and batcorders save sound files directly onto SD cards, and data from the cards can be quickly uploaded onto a computer for further analysis. The EMT2P device was used only twice, as the smartphone required for its operation was damaged and some data were lost before uploading. The loss of data highlights not only the importance of timely data transfer, but also the greater convenience of SD card storage for data management. The automatic classification capabilities of SMU and EMT2P, while useful for a first assessment, had a high rate of misclassification (Figure 4, Figure 7). Kaleidoscope produced a high rate of 'NoID' and 'Noise', which if troubleshooting its sensitivity settings to 'more sensitive' should result in greater percentage of correct identifications [26]. ARUs and identification software are prone to type I error (false positives) or type II error (false negatives) because they are susceptible to interferences caused by nearby reflective surfaces such as water or vegetation. But even poor-performing classifiers may provide important information for monitoring purposes [26, 27]. Kaleidoscope and bcAdmin can process a large amount of data, but manual verification by an expert is still mandatory, particularly when dealing with species that have similar call signatures or are not represented in the underlying automatic identification algorithm [2]. This underscores the importance of expertise both in deploying acoustic devices and the subsequent analysis of recorded data. *Plecotus macrobullaris* is not yet included in the species list of the automated classification of Kaleidoscope or the bc analytical suite of tools for batcorder analysis. However, in our study, since the recordings were made in close proximity to the known roost of *P. macrobullaris*, it can be assumed that the recorded *Plecotus* sp. call sequences belong to this species.

The EMT2P was used for a shorter period than the SMU and batcorder. Its short deployment time and limited ability to accurately classify bat species highlight the role of the EMT2P as a supplementary tool rather than a primary method for comprehensive species inventories. The SMU recorded the presence of *P. pipistrellus* and *N. noctula* outside the operating period of the EMT2P and the batcorder. The multi-day to month deployment capacity of SMU and batcorder is a chief advantage because a fuller picture of the bat community can be illustrated, including migratory species. During the parallel deployment of the three devices, only *M. daubentonii* could be identified to the species level by the SMU, while the other acoustic devices identified *Myotis* sp. at the genus level, and the batcorder identified Mkm ("Myotis klein-mittel") as a *Myotis* species group.

One of the study's noteworthy findings is the confirmation that *P. macrobullaris* maintained a maternity roost at the site of St. Georg Parish Church in 2022, confirming the area's suitability for the species. Greater monitoring efforts should be invested to characterize the diversified bat community in the Thomatal region, as suggested by the potential presence of other species including *E. nilssonii* and *M. daubentonii*. Particularly given the singular identification event for *N. noctula*, additional surveys would be required to confirm the presence of this species. Considering the poor resolution of sound profiles produced by species in genus *Plecotus*, a legacy of this study is the initiation of a sound library containing examples of *P. macrobullaris*. This sound library can be resampled following future improvements to sound classification algorithms and can potentially be scanned for other species of interest, such as bush crickets [28].

In conclusion, while PAM has proven to be an effective method for studying bat populations, the choice of device, approach toward data management, and the experience level of the operator are critical factors that influence the quality of the data collected. The batcorder is a highly efficient tool designed for experts with advanced skills in device operation and bat identification. For a cost-effective alternative, the SMU is a solid choice for monitoring bats; however, it still requires substantial expertise to use effectively, particularly for validation. Meanwhile, the EMT2P is particularly well-suited for citizen scientists and enthusiasts seeking to deepen their understanding of bats, but bears risks associated with storage of the data on a hand-held device. The study also highlights the need for continued refinement of automated classification algorithms to reduce the reliance on manual verification, which is time-consuming and requires specialized expertise.

ACKNOWLEDGEMENTS

This study was supported as a pilot action funded in the Austrian Research Promotion Agency (FFG) COIN project *Biodiversity Monitoring Technologies Test, Development and Transfer of disruptive engineering technologies into conservation practice* (*BioMONITec*) and the Austrian Federal Ministry of Labour and Economy (BMAW).

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BACK TO CONTENT

Short Notes

BioDivTech Lab – conceptualizing a new research infrastructure for biodiversity monitoring

Michael Jungmeier, Astrid Paulitsch-Fuchs, Gernot Paulus, Martin Schneider

ABSTRACT

With the advent of new technological capabilities for recording and monitoring biodiversity, the requirements for research infrastructure are changing. Currently, Carinthia University of Applied Sciences (CUAS) is developing testing facilities designed to enable synchronized biodiversity assessment at various scales in the medium term. This major investment is supported by the Austrian Research Promotion Agency, FFG, and is scheduled to become fully operational in the coming years. The facilities comprise several components, including the SKS research site at Metschacher Moos, stationary measurement and observation networks, a mobile biodiversity laboratory, and laboratory and computational resources at CUAS. These infrastructure components are utilized by researchers and students at CUAS and are also intended to be made available to collaborating scientific institutions and companies.

KEYWORDS

- Biodiversity monitoring
- Infrastructure
- Test site
- Outdoor lab

BioDivTech Lab – Eine Forschungsinfrastruktur für das Monitoring von Biodiversität

ZUSAMMENFASSUNG

Mit den neuen technischen Möglichkeiten für die Erfassung und das Monitoring von Biodiversität verändern sich die Anforderungen an Forschungsinfrastrukturen. Derzeit entwickelt die FH Kärnten (FH) eine Versuchsanlage, die mittelfristig eine synchrone Erfassung von Biodiversität auf unterschiedlichen Maßstabs-Ebenen ermöglichen soll. Die Groß-Investition ist wird von der FFG unterstützt und soll in den kommenden Jahren in vollem Umfang in Betrieb genommen werden. Die Infrastruktur besteht aus mehreren Komponenten, darunter das SKS-Forschungsgelände am Metschacher Moos, stationäre Mess- und Beobachtungsnetze, ein mobiles Biodiversitätslabor sowie Labor- und Rechenkapazitäten an der FH. Die Infrastrukturen werden von den Forschenden und Studierenden der FH genutzt und sollen darüber hinaus auch anderen wissenschaftlichen Einrichtungen und Unternehmen zur Verfügung stehen.

INTRODUCTION

The decline of biodiversity necessitates immediate action to halt further losses, as emphasized in international frameworks such as the Kunming-Montreal Global Biodiversity Framework of the Convention on Biological Diversity (CBD) and European biodiversity policies. Effective conservation measures require robust evidence on biodiversity and ecosystem services, driving the need for efficient and technology-based monitoring systems [1].
Technological advances in fields like sensor technology, robotics, data science, and molecular biology are revolutionizing biodiversity research by enhancing efficiency, data quality, and reproducibility [2]. Further, artificial intelligence opens up extensive new possibilities for biodiversity assessment and monitoring [3]. This shift demands new approaches to research infrastructure, emphasizing collaboration and shared use. To address these evolving needs, Carinthia University of Applied Sciences (CUAS) is establishing the Interdisciplinary Centre for Ecosystem Services and Biodiversity (I.C.E.B.). I.C.E.B. shall operate a modular research infrastructure laboratory, the BioDivTech Lab, designed to advance biodiversity monitoring technologies.

CONSIDERATIONS FOR THE R&D INFRASTRUCTURE

The BioDivTech Lab is designed to address recent demands in research and teaching. Its modular architecture supports flexibility and collaboration while promoting open data principles. The infrastructure's primary goal is the development and testing of technologies for synchronous multiscale monitoring of biodiversity and ecosystems. It combines fixed, mobile, and computational components into a cohesive system, enabling holistic assessments of diversity across landscape, species, and genetic levels. This approach, as illustrated in Figure 1, establishes a solid basis for tackling the complexities of biodiversity monitoring.

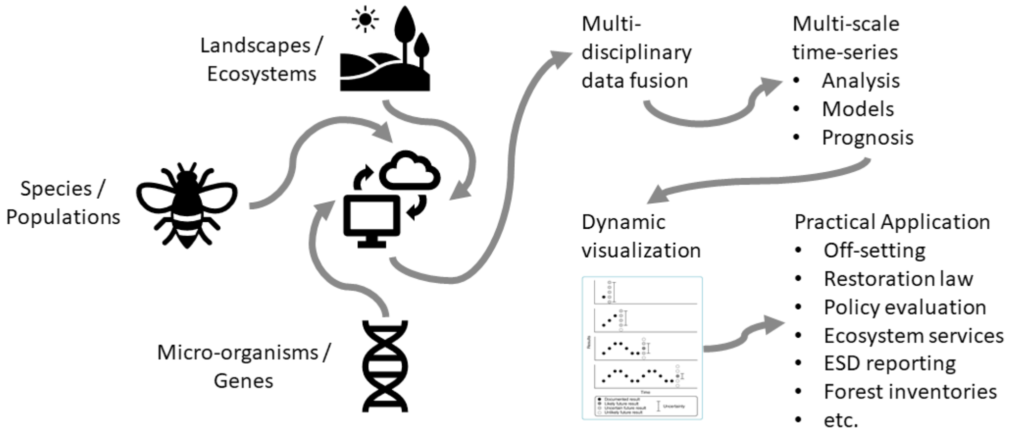

Fig. 1

Figure 1: Operation of the planned infrastructure. With the new infrastructure, the potential for synchronized detection and processing of biodiversity signals across three different scales (microorganisms/genes, species/populations, landscapes/ecosystems) will be developed and tested. The practical applications of these technologies are diverse, ranging from off-setting and restoration to policy and measure evaluation, as well as sustainability reporting. (Source: own figure, dynamic visualization: [3])

Abbildung 1: *Einsatz der geplanten Infrastruktur. Mit der neuen Infrastruktur sollen die Möglichkeiten für eine synchrone Erfassung und Verarbeitung von Biodiversitäts-Signalen auf drei unterschiedlichen Maßstabsebenen (Mikroorganismen/Gene, Arten/Populationen, Landschaften/Ökosysteme) entwickelt und getestet werden. Die praktischen Anwendungsfelder der Technologien sind weit gestreut: Sie reichen von Off-setting, Renaturierungen, Evaluierung von Maßnahmen und Politiken bis hin zu Nachhaltigkeits-Reporting. (Quelle: eigene Abbildung, dynamic visualization: [3])*

CONCEPT OF THE INFRASTRUCTURE

The infrastructure consists of four modules, each fulfilling specific functions while integrating seamlessly into the broader system. These modules are installed at different locations to optimize their utility. This requires a major investment supported by the Austrian Research Promotion Agency, FFG. Currently, the infrastructure is being configured, with operations set to begin in 2026. The infrastructure is composed of numerous elements that interact, as depicted in Figure 2.

Module M1: Long-term Field Research Lab

This module encompasses permanent infrastructure located at the Metschach Experimental and Test Site (hereafter “Metschach”), a restored 14-hectare former moorland area in Carinthia owned by the Bank of Carinthia Foundation, SKS. Metschach provides a long-term data series on vegetative succession (1990–2019), serving as a reference for research and teaching [5]. Additional fixed components are planned for sites such as those used in the BiodiverCITY Villach initiative. A three-component module is planned:

- C1.1 Biotic and abiotic measuring and sensor network. This module includes devices for automated long-term collection of field data.
- C1.2 Biotic reference data kits for calibration. The database allows for the management of all samples and digital evidence of species (e.g., a spectrogram) at the site as documentation.
- C1.3 Semi-stationary field lab (research station, container). The research container provides the basic technical infrastructure for fieldwork on-site.

Module M2: Short-term and Mid-term Multi-site Lab

This module ensures the R&D infrastructure can be deployed at various locations and in different ecosystems. A multi-purpose off-road vehicle equipped with mobile devices is the cornerstone of this module. The infrastructure supports species and population studies as well as remote and close-range sensing. The vehicle is designed for specific research sites and as transport to additional locations. The module will consist of three components:

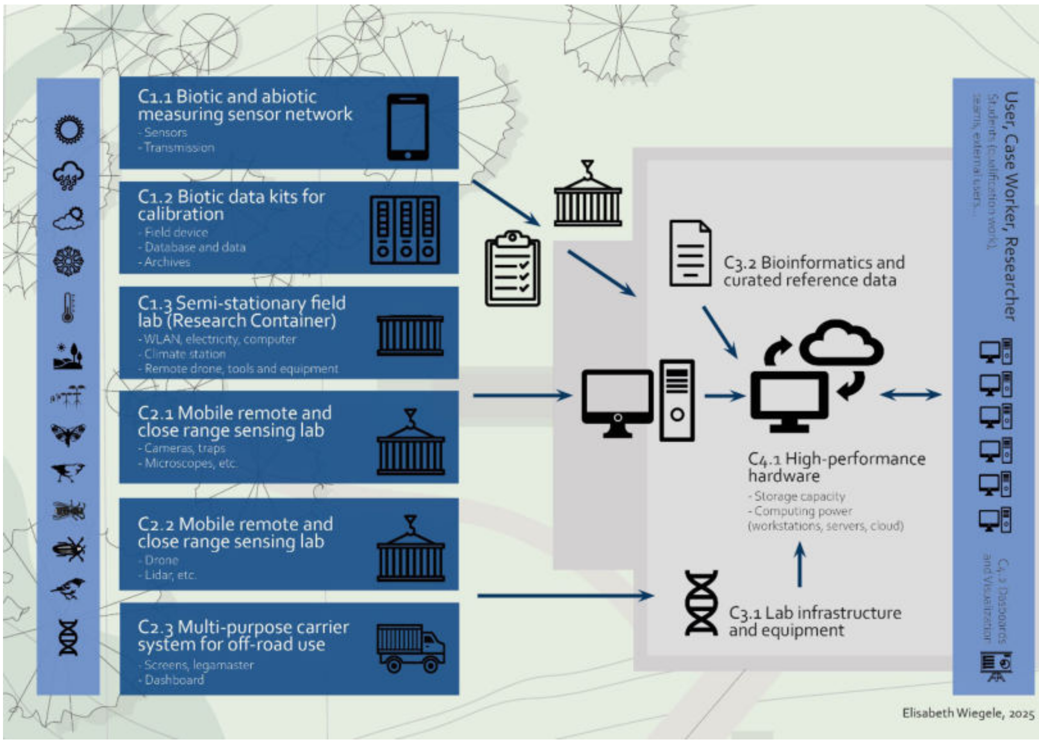

Fig. 2

Figure 2: Functional interaction of the components. The new infrastructure is designed to enable the entire workflow from field data collection through processing and analysis to visualization. Both fixed installations and mobile devices (such as the "Biodiversity Truck") are used for field data collection. (Source: own figure)

Abbildung 2: *Funktionelles Zusammenspiel der Komponenten. Die neue Infrastruktur soll den gesamten Workflow von der Erfassung im Gelände über die Prozessierung und Auswertung bis hin zur Visualisierung ermöglichen. Bei der Geländeerfassung kommen fix installierte Geräte ebenso wie mobile Geräte ("Biodiversity Truck") zum Einsatz. (Quelle: eigene Abbildung)*

- C2.1 Mobile biodiversity lab for all-purpose use. The mobile lab allows for various assessments and analyses directly in the field.
- C2.2 Mobile remote and close-range sensing lab. This is a mobile base for operations in the field of earth observation and remote sensing.
- C2.3 Multi-purpose carrier system for off-road use. The vehicle can transport equipment and gear directly to the deployment site for various missions.

Module M3: Molecular Biology Lab

The existing biomedical laboratory at the CUAS campus in Klagenfurt will be expanded to enhance molecular and microbiological analysis capabilities. This lab will facilitate the identification and detection of organisms, including from bulk sample and eDNA analysis, using cutting-edge tools such as automated nucleic acid extraction, PCR, and next-generation sequencing (NGS). It will consist of two components:

- C3.1 Lab infrastructure and equipment. The operational molecular biology lab is expanded with the latest technologies.
- C3.2 Long-term sample storage and calibration kit. This module primarily involves acquiring storage facilities for genetic samples (deep freezing) for comparison purposes.

Module M4: Data Integration and Analysis Lab

Situated at the CUAS campus in Villach, this module manages the vast volumes of data generated by technology-based biodiversity research. With advanced storage and computational capacities, the Data Integration and Analysis Lab supports data preprocessing, integration, and analysis across spatiotemporal scales. The lab enables big data analysis using a data lake and data warehouse, facilitating insights into biodiversity and ecosystem services. The module will consist of two components:

- C4.1 High-performance hardware for data integration and analysis. Existing computing and storage capacities are significantly expanded.
- C4.2 Dashboards and dynamic visualization tools. Displays and presentation options for various applications are created.

CONCLUSION AND FURTHER PERSPECTIVES

The development of the BioDivTech Lab represents an ambitious initiative to establish a comprehensive research infrastructure tailored to address the challenges of biodiversity monitoring. While this article provides a brief outline of the project, many technical specifications are still under development. The goal is to create an infrastructure capable of driving impactful research and teaching over the next decade. Collaboration with partners from academic institutions, government agencies, companies, and startups will be essential to fully realize its potential.

ACKNOWLEDGMENTS

The procurement of the infrastructure is supported by the Austrian Research Promotion Agency (FFG, F&E-Infrastrukturförderung) in the frame of the project *BioDivTech Lab: Interdisciplinary R&D infrastructure for time synchronous multiscale monitoring of biodiversity and ecosystems*. The development of the I.C.E.B. is supported by the *Privatstiftung Kärntner Sparkasse*.

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I.C.E.B.: Interdisciplinary Centre for Ecosystem Services and Biodiversity

BACK TO CONTENT

TREEgital – digital knowledge transfer about forests for schools

Irene Gianordoli

ABSTRACT

The COVID-19 pandemic has accelerated digitalization in education. The TREEgital project is taking advantage of this trend to use digital tools to impart forest knowledge in schools. It explores the forest as a living, recreational and economic space and emphasizes its role in protecting the climate and biodiversity. Key topics are biodiversity, climate change, and career guidance in green industries, all within the framework of Education for Sustainable Development (ESD). In addition, TREEgital teaches pupils digital skills.

Digital educational products for schools have been developed, such as the augmented reality app "Öswald - App in den Wald!", which improves learning by overlaying virtual elements with real environments, and YouTube career guidance videos focusing on STEM topics. In the "TreeCast" video podcast, forest experts discuss topics ranging from climate change to soil health. The social media series "Ask the Expert" provides insights into the professional world of forest research.

TREEgital - Digitaler Wissenstransfer rund um den Wald für Schulen

ZUSAMMENFASSUNG

Die Covid-Pandemie hat die Digitalisierung im Bildungswesen beschleunigt. Das Projekt TREEgital macht sich diesen Trend zunutze, um mit digitalen Tools Waldwissen in Schulen zu vermitteln. Es erforscht den Wald als Lebens-, Erholungs- und Wirtschaftsraum und betont seine Rolle beim Schutz des Klimas und der biologischen Vielfalt. Zentrale Themen sind Biodiversität, Klimawandel und Berufsorientierung in grünen Branchen, alles im Rahmen der Bildung für nachhaltige Entwicklung (BNE). Darüber hinaus vermittelt TREEgital Schüler:innen digitale Kompetenzen.
Digitale Bildungsprodukte für Schulen wurden entwickelt, wie z.B. die AR-App „Öswald – App in den Wald!", die das Lernen durch Überlagerung von virtuellen Elementen mit realen Umgebungen verbessert, und YouTube-Berufsorientierungsvideos mit Schwerpunkt auf MINT-Themen. Im Video-Podcast „TreeCast" diskutieren Wald-Expert:innen über Themen vom Klimawandel bis zur Bodengesundheit. Die Social-Media-Serie „Ask the Expert" gibt Einblicke in die Berufswelt der Waldforschung.

KEYWORDS

- environmental education
- ESD
- digital tools
- augmented reality
- biodiversity
- climate change
- forest
- vocational guidance
- inclusive education

INTRODUCTION

TREEgital aims to make learning about forests, ecosystems, and related careers engaging and accessible, addressing the increased need for digital educational resources highlighted by the COVID-19 pandemic. The project provides digital materials for various school levels, focusing on biodiversity, climate change, and STEM career orientation. Its mission includes developing an augmented reality (AR) app, career guidance videos, a video podcast, primary school materials, an online course for linguistically sensitive teaching, and a social media series to integrate forest education into the classroom effectively.

INNOVATIVE DIGITAL PRODUCTS

1. **Augmented Reality App "Öswald – App in den Wald!"** This app immerses students in Austrian forests, using AR to overlay interactive maps, 3D simulations, quizzes, and storytelling elements (Figure 1, Figure 2). Designed for secondary school students, it includes pedagogical materials to help teachers integrate the app into lessons, covering topics like forest ecosystems, conservation, and environmental science. The app brings digital information into the real world, allowing students to explore forests through their smartphones, making learning interactive and engaging. By

Fig. 1

Figure 1:
Insight into the AR app "Öswald - App in den Wald!"

Abbildung 1:
Einblick in die AR-App "Öswald - App in den Wald!"

scanning a reference image, users can activate AR features that display information blocks and quizzes related to forest ecosystems, conservation, and environmental science. This comprehensive tool includes three learning chapters with 3D simulations and storytelling elements.

- iOS version
- Android version

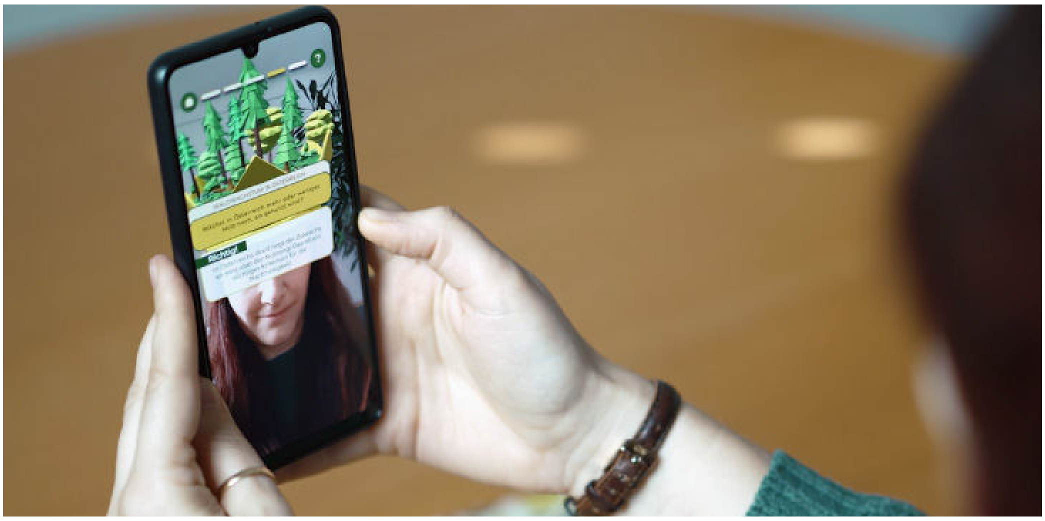

Fig. 2

Figure 2:
If you correctly answer quiz questions in selfie mode, a tree crown grows on your head!

Abbildung 2:
Beantwortet man Quiz-fragen im Selfie-Modus richtig, wächst eine Baumkrone am Kopf!

2. **Vocational Orientation Videos** showcase careers in forestry and related fields, featuring professionals like a GIS specialist, forest technician, ecological geneticist, and natural hazard expert (Figure 3). Each episode provides insights into their careers, educational backgrounds, and the societal impact of their work, aiming to inspire students to pursue STEM careers. For instance, the GIS specialist demonstrates the use of geographic information systems to map and analyze forest data for sustainable management, while the forest technician highlights the technical aspects of forestry, including operating advanced machinery. The ecological geneticist discusses research on genetic diversity in forest ecosystems, and the natural hazard expert addresses the assessment and management of natural hazards.

Fig. 3

Figure 3: Behind the scenes of the production

Abbildung 3: *Hinter den Kulissen der Dreharbeiten*

3. The **Video Podcast "TreeCast"** (Figure 4) features discussions with forestry and environmental science experts on topics like climate change, soil health, and biodiversity. Available on YouTube and Spotify, the podcast offers flexible learning for students and teachers. Each episode dives into specific environmental challenges and the latest scientific research, making it an ideal resource for both classroom and personal enrichment. The format allows listeners to access valuable information at their convenience, whether at home or in the classroom.

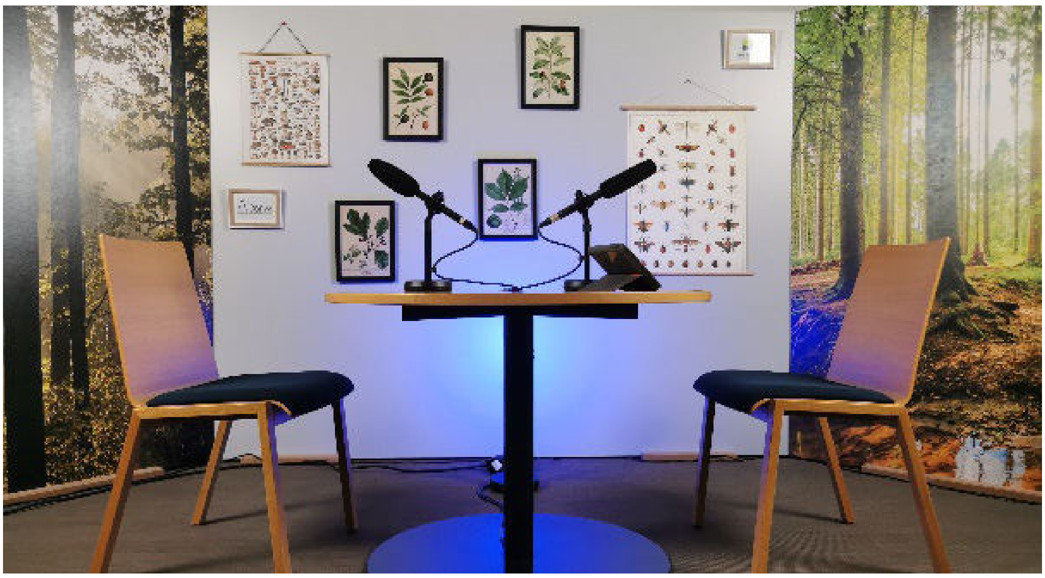

Fig. 4

Figure 4: Behind the scenes of the video podcast shooting

Abbildung 4: *Hinter den Kulissen der Dreharbeiten zum Videopodcast*

4. **Primary School Material: "Wald 3D: outDoor, inDoor, Digital"** is designed for primary school children in grades 2-4. This resource integrates outdoor experiences, classroom learning, and digital elements to teach biodiversity and environmental awareness. It includes lesson plans, worksheets, and activities that emphasize practical exercises and the use of digital tools. The material consists of three units with detailed lesson plans, incorporating observation in nature, STEM subjects, and digital tools to enhance students' understanding of biodiversity.

5. **Biodiversity Online Course for Linguistically Sensitive Subject Teaching:** This course supports teachers in delivering biodiversity and climate change content to secondary-level students who speak German as a second language. It includes strategies, resources, and activities to help all students understand scientific concepts, promoting inclusive education. Structured into four modules, the course covers different aspects of forest biodiversity and provides instructional strategies, background information, lesson plans, and classroom activities. This ensures that teachers can tailor the content to meet the diverse needs of their student populations, making science concepts more accessible and engaging for all learners.

6. The **Social Media Series #AskTheExpert** connects students with professionals in ecology and forestry through short, informative videos. Available on various social media platforms, the series simplifies complex topics and encourages engagement through likes, shares, and comments. The series features expert profiles, educational content, and interactive elements, fostering a community of environmental enthusiasts and inspiring students to pursue environmental careers by connecting them with role models.

CONCLUSION AND KEY MESSAGES

TREEgital uses digital media to promote understanding and appreciation of forests as essential ecosystems, fostering sustainable thinking and environmental stewardship among students. By combining digital innovation with hands-on learning, the project highlights the role of intact forests in combating climate change and conserving biodiversity. It makes forest ecosystems accessible through digital tools, encouraging student engagement with environmental and vocational issues. This pioneering approach equips students with the knowledge and skills necessary to take responsibility in a globalized world.

ACKNOWLEDGEMENTS

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Book Reviews

Comprehensive overview of Germany's biodiversity: *Faktencheck Artenvielfalt*

Michael Jungmeier

REVIEW

The recently published *Faktencheck Artenvielfalt. Bestandsaufnahme und Perspektiven für den Erhalt der biologischen Vielfalt in Deutschland* (translated *Biodiversity fact check. Inventory and perspectives for the conservation of biodiversity in Germany*) [1] is an exceptional compendium on the current state and future of biodiversity conservation in Germany. Edited by Christian Wirth, Helge Bruelheide, Nina Farwig, Jori Maylin Marx, and Josef Settele, this monumental work spans 1,256 pages and synthesizes contributions from over 150 authors across 75 institutions. An additional 200 experts reviewed the manuscripts, ensuring high scientific rigor. The volume also includes digital supplementary materials and builds upon an extensive literature review of over 6,000 publications and 15,000 time-series data sets on biodiversity.

The book's primary goal is to offer an exhaustive account of biodiversity within Germany, addressing essential habitats such as agricultural lands, forests, inland waters, coastlines, urban spaces, and soil biodiversity. This structure provides an in-depth analysis of the status and trends of biodiversity, the impacts on ecosystem services, direct and indirect drivers of biodiversity changes, instruments and measures for biodiversity conservation, and pathways for societal transformation towards sustainability.

Notably, the editors underscore the urgent need for evidence-based action in biodiversity policy, stating in the foreword that "science denial, the rejection of facts, and the active spread of misinformation" may pose significant challenges to biodiversity management.

The book's strengths lie in its thorough conceptual consistency, interdisciplinary breadth, and editorial precision. It provides a robust foundation for biodiversity work in Germany and beyond, as well as a substantial resource for environmental policy-making. Despite its significant physical size and price of 149 Euros, the book should find a place in every specialized library. To enhance accessibility, a summarized version for policymakers and the general public is also available as an open-access resource [2], which aligns well with the book's editorial goal of promoting evidence-based decisions.

While *Faktencheck Artenvielfalt* focuses on Germany, its findings and approaches are also highly relevant from an Austrian perspective. The effort that went into this publication is inspiring, the density of information impressive, and the call to action on biodiversity preservation substantial. It is surprising, however, that the book does not delve into the emerging technological innovations that could further enhance biodiversity research, nor does it address potential technological solutions for biodiversity-related evidence generation in its future research recommendations.

In conclusion, *Faktencheck Artenvielfalt* is an essential reference for biodiversity conservation and sustainable environmental management, offering a comprehensive compilation of information for researchers, policymakers, and practitioners. It stands as a testament to the commitment of the scientific community to halt biodiversity loss and adapt to environmental challenges.

ORIGINAL TITLE

[1] C. Wirth, H. Bruelheide, N. Farwig, J. M. Marx, J. Settele, Eds., *Faktencheck Artenvielfalt. Bestandsaufnahme und Perspektiven für den Erhalt der biologischen Vielfalt in Deutschland.* München: oekom Verlag, 2024, 1256 p., ISBN 978-3-86581-893-5.

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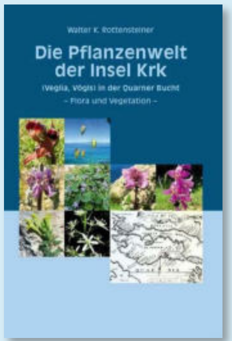
“Die Pflanzenwelt der Insel Krk”: a richly illustrated field guide for vascular plants, algae, mosses, lichens and macrofungi on the island of Krk

Felix Schlatti



REVIEW

The book “Pflanzenwelt der Insel Krk” (translated “Flora of the island of Krk”) [1] was published in May 2024 by the Natural Science Association for Carinthia. The book is written in German. The editor and author of many chapters is Walter K. Rottensteiner, an experienced author of botanical literature. For this volume he brought together 75 authors from 12 nations. The result is an attractively designed book with 1,452 pages. It fulfills the dream of many plant fans: a field guide with 3,655 illustrations for all detected wild plants and the most important cultivated species! Herbarium specimens from botanical surveys of the island are maintained at the Carinthian Botanic Center in Klagenfurt.

The book begins with a comprehensive chapter on the vegetation and natural areas of the island of Krk. It was written by Nenad Jasprica and revised by Anton Drescher and Ruth Drescher-Schneider. This chapter features a large number of memorable photos and a syntaxonomic overview.

After chapters on the landscape forms and natural reserves of the island of Krk, a special botanical treat follows. Ivana Vitasović-Kosić examines the flora from an ethnobotanical perspective, writing about local names and their uses as food and spices. Medical and cosmetic applications, especially in the form of herbal teas, are listed in separate paragraphs.

After a chapter on the special plant treasures, taxa are presented in systematically arranged chapters. In the chapters of Pteridophyta, Coniferophyta, dicotyledons, and monocotyledons, the families follow in alphabetical order. Within the families, the genera are also sorted alphabetically. This advantageous arrangement enables plant experts to quickly and easily find the correct family or genus identification key. If the family is uncertain, there is also the possibility of identifying it using an additional key. Written by Kurt Zernig, the “Schlüssel zu den Pflanzenfamilien” (translated “key to plant families”) can be found at the end of the book.

The chapters on freshwater algae, benthic macroalgae, mosses, lichens, and macrofungi give a good picture of the unexpected diversity of species in these groups. Even though there are no keys to help with species identification, a comparison with pictures and descriptions is possible. However, a determination of the Characeae down to the species level is possible. The macrofungi are summarized in a list of over 600 species based on current knowledge and are presented as typical examples.

“Die Pflanzenwelt der Insel Krk” targets a diverse readership. Experts can quickly and easily access the correct key for identification. Less experienced readers will find help, such as the family key, a chapter explaining technical terms, a scientific family, genus and species index and a German-language family and genus index. Last but not least, the book is more than just a field guide! Plant fans and Krk enthusiasts can browse through the extensive introductory chapters of the “Pflanzenwelt der Insel Krk” and learn a lot about geography, vegetation, nature conservation areas and ethnobotany.

ORIGINAL TITLE

[1] W. K. Rottensteiner (Ed.), *Die Pflanzenwelt der Insel Krk (Veglia, Vögels) in der Quarner Bucht. Flora und Vegetation*. Klagenfurt am Wörthersee, Austria: Verlag des Naturwissenschaftlichen Vereins für Kärnten, 2024. ISBN: 978-3-85328-103-1.

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Carinthia Nature Tech
Author Guidelines

Revised 2/4/2025

General Requirements

The journal Carinthia Nature Tech is organized into key sections: 1) Preface, 2) Scientific Articles: *Full Articles*, 3) Scientific Articles: *Short Articles*, 4) *Short Notes*, 5) *Book Reviews*. Two issues of Carinthia Nature Tech will be published annually. Only previously unpublished articles may be accepted. The editors may propose changes to the text based on feedback from the reviewers. Alterations will be discussed with the authors. Carinthia Nature Tech will use third party tools to check submitted texts for plagiarism. Plagiarism reports will be kept as part of the documentation process of the paper submission. Any detection of plagiarism will lead to an immediate rejection of the submission.

The articles must have a clear connection to the Alps-Adriatic Region. At least one contributing author or the study area must be directly connected to the region. The connection to the area must be clear through linking author affiliations or study locations to Carinthia. The Editorial Office will verify this connection at the time of manuscript submission.

Manuscripts submitted for publication as scientific articles undergo a double-blind peer review. This means that for *Full Articles* and *Short Articles* neither the authors nor the reviewers will be able to know each other’s identities at the time of review. Submissions must avoid self-identifying language including reference to “our previous findings” or similar wording. Author names, affiliations, contact addresses, ORCID, and short biographies (max. 500 characters including spaces) need to be provided in the title page template. For scientific articles please include a minimum of 4 keywords that define the thematic area of your article. The template can be downloaded from the homepage.

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Graphics should be submitted as .png, .jpg, or .tiff formats, or embedded in .doc, .docx formats. Images should be provided in high quality resolution (300 dpi or greater). Videos should be provided as .mp4 files. Diagrams should be submitted as .xlsx. Supplementary materials should be accessible in a commonly used file type.

References should be provided in the IEEE citation style (https://journals.ieeeauthorcenter.ieee.org/your-role-in-article-production/ieee-editorial-style-manual/) and listed at the end of the paper. Footnotes may not be used in the text. The metric system should be used for all measurements. Numerical units should conform to the International System of Units (SI).

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Full Articles: Full Articles are intended to showcase relevant and novel research findings of general scientific interest. *Full Articles* should have a strong focus on methods that advance the state-of-theart of the scientific research community. Submitted manuscripts should be 40,000 to 60,000 characters long, including spaces. Title, abstract, keywords, references, and table and figure captions count towards the character limit. *Full Articles* should be written in American English, with the title, tables, figures, and captions in both English and German. A German-language executive summary of 1,500 – 2,500 characters must be included. Exceptions to the character count restrictions will be considered by the Editorial Office on a case-by-case basis. For non-German speaking authors, the editorial office offers assistance in the German translation of the executive summary and description of tables, figures and captions.

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Format of Short Notes

The *Short Notes* section is dedicated to research reports featuring projects carried out by early career researchers, students and practitioners. The purpose of *Short Notes* is to disseminate research results or preliminary project results at a low threshold. Contributions in this section should be 10,000 to 20,000 characters long, including spaces. Title, abstract, keywords, references, and table and figure captions count towards the character limit and should follow the same formatting as for *Scientific Articles*. *Short Notes* should be written in American English, with the title, tables, figures, and captions in both English and German. A German-language executive summary of 500 – 1,500 characters must be included. Exceptions to the character count restrictions will be considered by the Editorial Office on a case-by-case basis. For non-German speaking authors, the Editorial Office offers assistance in the German translation of the executive summary and description of tables, figures and captions. *Short Notes* will not be indexed and will not receive DOIs.

Format of Book Reviews

The *Book Reviews* section is intended to evaluate new stand-alone publications in the field of technologies in nature conservation and with a connection to the Alps-Adriatic Region. Each book review should be 3,500 – 8,000 characters long, including spaces, with a German-language abstract of 200 – 500 characters, including spaces. It should include summarizing information identifying authors and editors, title of the book, year published, the name of the publisher, and a link or reference to the original source. The review should provide a brief summary of the book. Critical analysis of the strengths and weaknesses of the book, comparison to other works in its field, and its overall relevance for the intended audience should be prominent in the review. *Book Reviews* will be managed within the editorial office and evaluated by the Editorial Office. *Book Reviews* will not be indexed and will not receive DOIs.