COST
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Brussels, 12 May 2023

COST 039/23

DECISION

Subject: Memorandum of Understanding for the implementation of the COST Action "InsectAI - Using Image-based AI for Insect Monitoring & Conservation" (InsectAI) CA22129

The COST Member Countries will find attached the Memorandum of Understanding for the COST Action InsectAI - Using Image-based AI for Insect Monitoring & Conservation approved by the Committee of Senior Officials through written procedure on 12 May 2023.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA22129
INSECTAI - USING IMAGE-BASED AI FOR INSECT MONITORING & CONSERVATION (InsectAI)

The COST Members through the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action, referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any document amending or replacing them.

The main aim and objective of the Action is to elucidate how should image-based and AI-assisted tools be developed and applied to support insect monitoring and conservation at the national and continental scale to understand and counteract widespread insect declines. This will be achieved through the specific objectives detailed in the Technical Annex.

The present MoU enters into force on the date of the approval of the COST Action by the CSO.

OVERVIEW

Summary

The **InsectAI COST action** will support insect monitoring and conservation at the national and continental scale in order to understand and counteract widespread insect declines. The Action will bring together a critical mass of researchers and stakeholders in image-based insect AI technologies to direct and drive the research agenda, build research capacity across Europe, and support innovation and application.

There is mounting evidence that populations of insects around the world are in sharp decline. Understanding trends in species and their drivers are key to knowing the size of the challenge, its causes, and how to address it. To identify solutions that lead to sustainable biodiversity alongside economic prosperity, insect monitoring should be efficient and provide standardised and frequently updated status indicators to guide conservation actions.

The EU Biodiversity Strategy 2030 identifies the critical challenge of delivering standardised information about the state of nature, and image-based insect AI can contribute to this. Specifically, the EU Nature Restoration Law will likely set binding targets for the high resolution data that cameras can provide. Thus, outputs of the Action will contribute directly to EU policies implementation, where biodiversity monitoring is considered a key component.

The **InsectAI COST Action** will organise workshops, conferences, short-term scientific missions, hackathons, design-sprints and much more, across four Working Groups. These groups will address how image-based insect AI technologies can best address **Societal Needs**, support innovation in **Image Collection** hardware, create standardised approaches for **Image Processing**, and develop novel **Data Analysis and Integration** methods for turning data into actionable insights.

Areas of Expertise Relevant for the Action	Keywords
● Biological sciences: Ecology ● Computer and Information Sciences: Machine learning algorithms	● camera ● computer vision ● statistics ● autonomous ● standards

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

<u>Research Coordination</u>

- The Action will identify pressing challenges for image-based insect AI early on and shape the research agenda over its 4 years to address existing bottlenecks (WG1-4).
- The Action will create opportunities for the side-by-side assessment of image collection technologies, AI models, and training datasets (WG1 & 2).
- The Action, by bringing together the key stakeholders in the image-based insect AI community, will build agreed data standards for image-based insect AI technologies (WG1-4) as legacy by the end of the Action.
- The Action will deliver a toolbox of analytical methods updated throughout the action (WG4) including combined analysis of image-based data and traditionally collected data, and integration with other

technologies, such as acoustics, radar, and molecular methods.
● The Action will produce good practice guides to support the sustainable uptake of image-based insect AI technologies by the key stakeholders and the scientific community to understand and counteract widespread insect declines (WG1- 4) and which will be widely disseminated by the end of the Action.

Capacity Building
● The Action will bring together stakeholders (from national government to local community groups) and technologists to ensure societies' needs are at the centre of the research agenda (WG1), in a co-creation practice to be promoted throughout the entire Action.
● The Action will build a programme of knowledge exchange which will support innovation and capacity building around image-based insect AI technologies (WG1-4) to be implemented early on and promoted during the whole Action.
● The Action will ensure inclusiveness to its activities and within the Core Group, with a target of 50:50 gender balance, 50% young researchers and innovators (YRIs), and >50% participation from ITC countries, promoting collaborative activities and mentoring support where needed during its entire duration.

TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. SOUNDNESS OF THE CHALLENGE

1.1.1. DESCRIPTION OF THE STATE OF THE ART

There is mounting evidence that populations of insects around the world are in sharp decline (Hallmann *et al* 2017, Seibold *et al,* 2019) and the drivers of these declines are variable (Wagner et al. 2021). To identify solutions that lead to sustainable biodiversity alongside economic prosperity, insect monitoring should be efficient and provide standardised and frequently updated status indicators to guide conservation actions.

Understanding trends in species and their drivers are key to knowing the size of the challenge, its causes, and how these factors vary in both space and time. In order to know this, we need robust methods for monitoring species that minimise bias and maximise the quantity and quality of data collected. Due to the recent success of artificial intelligence (AI) algorithms in other domains and applications, new image-based and AI-assisted tools, alongside traditional methods, are likely to be critical for meeting this information need.

Insect observations are traditionally collected in the field by trained entomologists using one of a suite of established methods such as malaise traps to catch flying insects, or moth traps that lure in individuals using bright or UV lights. Many of these systems are lethal, killing the insects they seek to study, and all require significant investment in time and expertise. Once captured, the insects are usually taken to the laboratory for identification by taxonomic experts and then conserved and stored in collections. In parallel to such 'professional' survey methods, there has been a rise in digitally enabled citizen science. Using mobile applications, members of the public collect images of insects and submit these to online biodiversity-recording platforms where other users aid in identification. In this way, the role of the citizen scientists in collecting observations of insects has increased dramatically.

Rapid advances are being made by researchers in Europe and across the world in the application of machine learning methods (a subset of AI) to the challenge of understanding insect ecology (Høye et al. 2021). This work includes the development of algorithms (typically deep-learning methods, hereafter referred to as 'AI'), for automatically detecting and identifying individuals, as well as imaging hardware to collect images in the laboratory or the field. Much of this work has been undertaken in the past 5 years and is mostly at the proof-of-concept phase. This work crosses multiple disciplines including engineering, computer sciences, entomology, and statistics, and has the potential to revolutionise the way we monitor insect biodiversity (van Klink et al. 2022).

Bulk image collection by cameras is set to lead to an explosion in image data for insects. The state- of-the-art systems fall into two designs. The first are systems deployed in the field that use digital cameras and attractants to take images of insects, which are then stored locally, or transmitted to the cloud. These systems are often solar powered allowing long duration, and hands-off deployment. Examples of these systems include the AMMOD system (Wägele et al., 2022), Aarhus moth trap (Bjerge et al 2021), PICT (Droissart et al 2021), Sticky Pi (Geissmann et al 2022), NEWTRAP (Didry et al 2019), and Diopsis insect camera (www.diopsis.eu), all of which are in the pilot phase. The second type of design are bench-top systems that aspire to semi-automate the classification of collected insects in a laboratory setting. These systems use macro cameras to take large numbers of images of insects, and employ AI algorithms to assist in identification. The only two projects known to have produced proof-of- concept units - BIODISCOVER (Ärje et al 2020) and Biodiversity scanner (Wührl et al 2022) - are in their infancy, but they show great promise.

AI algorithms are having a seismic impact across industries, and are already beginning to re-define the landscape of insect identification. Combined with bulk image collection systems, these algorithms lead to rapid species identification with uncertainty estimations. When built into citizen science applications these algorithms perform two roles. 1) They undertake the classification of species that are easier to identify, freeing up the time of experts to focus harder identification tasks, and 2) they provide rapid feedback to the citizen scientist, helping to guide them to the correct identification and providing instant gratification. Applications of insect AI in citizen science platforms are being led in Europe by projects such as Observation.org, and Artsdatabanken.

Given the novelty of these image collection and AI technologies, downstream infrastructure, training data repositories, and methods for analysing outputs are mostly just ideas, or even completely absent. Data storage solutions for these vast datasets are currently one-off systems, with no unified long-term solution. Metadata is not standardised, limiting the ability to combine image datasets or outputs from AI algorithms. Statistical approaches for analysing these data to assess spatial and temporal patterns are practically absent. Methods are absent for integrating data from these novel technologies with traditional monitoring data or data generated by other new technologies (e.g., acoustic, RADAR and molecular methods). European projects such as ARISE (van Ommen Kloeke et al. 2022), MAMBO (http://mambo-project.eu/), and Easy-RIDER (https://gtr.ukri.org/projects?ref=NE%2FW004216%2F1) are looking to develop workflows and standards, while global assessments of biodiversity trends such as GLiTERS (https://glitrs.ceh.ac.uk/) are developing standards of data integration which would be relevant to this area.

The state-of-the-art in insect monitoring using AI is rapidly moving, on multiple fronts. Given these challenges, and the potential game-changing impacts of these methods, the **InsectAI COST Action** is needed to foster innovation targeted at societal benefit, to build capacity, and to promote international collaboration to support this swiftly developing domain.

1.1.2. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

How should image-based and AI-assisted tools be developed and applied to support insect monitoring and conservation at the national and continental scale to understand and counteract widespread insect declines?"

This is the key challenge that the **InsectAI COST Action** will address. Insect AI technologies have emerged at a time of heightened awareness of global declines in insect populations, as well as specific examples of rapid losses of insects in Europe (Pilotto, *et al* 2020). The **EU Biodiversity Strategy 2030** identifies the critical challenge of delivering standardised information about the state of nature, and image-based insect AI can contribute to this. Specifically, the **EU Nature Restoration Law** will likely set binding targets for the high resolution data that can be provided by cameras. Outputs of the Action will contribute directly to **EU policies implementation**, where biodiversity monitoring is considered a key component. These methods are not only relevant for monitoring on-going declines, but are also fundamental to identifying ways to reverse these negative trends, shaping policy- and decision-making. To achieve this, the standardised data coming from sensors should be exploited at the international scale where e.g., EU policy instruments operate and legislation relevant to insect conservation exists. Furthermore, the use of citizen science apps to monitor community led conservation efforts allows greater insight into the impact of land management on insect populations.

New image-based insect AI technologies need to work with, and not against, traditional taxonomic expertise. AI may help to automate trivial tasks creating space for experts to take on more complex tasks. At the same time, incorporating expert knowledge in the design of AI algorithms may increase their performance and will help to build trust in the results delivered by AI.

When considering an approach to address this key challenge, further sub-challenges appear that need to be considered by the Action's working groups (WG). 1) What are the specific societal challenges where insect AI technologies can have the greatest impact for understanding and counteracting widespread insect declines (WG1)? 2) How can the community work together to drive innovation, as well as support exploitation and good practice (WG1-4)? 3) How do we build scientific capacity in the European research community needed to take advantage of these new technologies (WG1-4)?

The **InsectAI COST Action** will address the key challenge, and sub-challenges through a program of activities engaging researchers and stakeholders from across disciplines and geographies.

1.2. PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1. APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE OF THE ART

The Action will address the key challenge in three ways. 1) The Action will **engage stakeholders** to ensure that developments in image-based insect AI technologies are driven by societies' needs, and are disseminated effectively to support exploitation (WG1). 2) The Action will instigate and **nurture innovation and knowledge exchange** in image-based insect AI technologies, and develop standards and best practices to support impactful exploitation (WG1-4). 3) The Action will run an ambitious and inclusive programme of **training** to **build capacity** amongst researchers across Europe (WG1-4).

The widespread declines in insect populations globally have multiple drivers and impacts. The Action will **engage stakeholders** around key issues which are relevant and timely in the European policy context. These issues will be identified through a series of engagement activities (WG1) and are likely to include pollinator monitoring, invasive alien species, and impact assessment of farming practices. The Action's stakeholder engagement activities will bring together participants across disciplines to design innovative applications of image-based insect AI technologies that will address these key issues (WG1-3). Bringing together engineers, computer scientists, entomologists, and stakeholders (from national government to local managers), the Action will support rapid design iteration, and testing of available technologies, jump starting innovation, which is often held back by collaborations siloed within disciplines (WG2-4).

Across Europe, multiple teams are developing field and laboratory camera systems for insects, AI- assisted citizen science apps, and AI algorithms for insect detection and classification. There have been recent efforts in some of these areas to facilitate collaboration, notably the Easy-RIDER project, however these have been limited to virtual events. These efforts have demonstrated a willingness for international coordination and collaboration. This Action will provide the support to capitalise on the community's appetite, and support **innovation** and **knowledge sharing** in the following ways: 1) Activities aimed at bringing together the current leaders in the field will support the exchange of ideas, comparing hardware, and demonstration of hardware to invited stakeholders (WG1 & 2). 2) Computer scientists and entomologists will be brought together to identify bottlenecks in the development of AI algorithms and develop collaborations to address these issues (WG1 & 3). 3) The Action will support a programme of activities to bring together hardware and software developers with key stakeholders in the global biodiversity standards community (including both GBIF and TDWG). Participants will develop global metadata standards for FAIR data (data which are findable, accessible, interoperable and reusable) generated by insect AI technologies (WG2 & 3). 4) The Action will create opportunities to work directly with citizen science and maker communities, to co-design hardware and to trial the integration of image-based insect AI technologies with existing citizen science activities (WG2). 5) The action will bring together statisticians, data scientists and ecologists to generate a toolbox for analysing AI output, as well as integration with data from traditional sources and other emerging monitoring technologies (WG4) 6) Stakeholders will be engaged throughout the action to ensure the societal relevance (WG1) of the outcomes from across the WGs.

In order to realise the potential of these technologies **training** is needed to **build capacity** among European researchers. Adoption of these technologies will require researchers to move from a paradigm of 'interdisciplinary collaboration' to 'trans-disciplinary individuals'. The next generation of ecologists will not only need to develop collaborations with computer scientists, as they do now, but will need to develop the skills to use computer science techniques. This transition requires that image-based insect AI technologies are developed to be used by ecologists and that ecologists are trained in the key concepts of these technologies. The Action will contain an ambitious training programme for future leaders of image-based insect AI technologies (WG2-4), including a minimum of three Training Schools. Trainees will have access to the knowledge and experience of the current pioneers across Europe through curated training activities, and will become the first generation of researchers to realise the potential of image-based insect AI technologies beyond proof-of-concept studies.

1.2.2. OBJECTIVES

1.2.2.1. Research Coordination Objectives

The Action's research coordination objectives aim to develop a common understanding of the opportunities and challenges for image-based insect AI technologies and build a coordinated approach to our research, to the benefit of all involved (SMART elements are indicated in brackets). 1) The Action will **identify pressing challenges** for image-based insect AI (S,M) early on and shape the research agenda (A) over its 4 years (T) to address existing bottlenecks (R) (WG1-4). 2) The Action will create opportunities (A) for the **side-by-side assessment** of image collection technologies, AI models, and training datasets (WG1 & 2) (S, M, R). 3) The Action, by bringing together the key stakeholders in the image-based insect AI community (A, R), will **build agreed data standards** for image-based insect AI technologies (S, M) (WG1-4) as legacy by the end of the action (T). 4) The Action will deliver a **toolbox of analytical methods** updated throughout the action (A, R, T) (WG4) including combined analysis of image-based data and traditionally collected data (S, M), and integration with other technologies (S), such as acoustics, radar, and molecular methods (M). 5) The Action will produce **good practice guides** (S) to support the sustainable uptake of image-based insect AI technologies by the key stakeholders and the scientific community (M, A) to understand and counteract widespread insect declines (R) (WG1- 4) and which will be widely disseminated by the end of the action (T).

1.2.2.2. Capacity-building Objectives

The Action's capacity-building objectives will create a critical mass of researchers that will be able to drive forward innovations and applications of image-based insect AI technologies. 1) The Action will bring together stakeholders (from national government to local community groups) and technologists (S, M) to **ensure societies' needs are at the centre of the research agenda** (R) (WG1), in a co- reaction practice (A) to be promoted throughout the entire action (T). 2) The Action will build a programme of knowledge exchange (S, M) which will support **innovation and capacity building** around image-based insect AI technologies (A, R) (WG1-4) to be implemented early on and promoted during the whole Action (T). 3) The Action will ensure **inclusiveness** (S, R) at its activities and within the Core Group (comprising Chair, Vice-Chair, Working Group leaders, STSM coordinator, Communications manager, and YRI coordinator), with a target of 50:50 gender balance, 50% young researchers and innovators (YRIs), and >50% participation from ITC countries (M), promoting collaborative activities and mentoring support where needed (A) during its entire duration (T).

2. NETWORKING EXCELLENCE

2.1. ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1. ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

The Action will bring together leading figures in the development of state-of-the-art insect monitoring technologies. The expertise and knowledge that these leaders represent have been established through a range of recent projects and other networking activities at national, European and international scale.

A number of projects have focussed on the development of hardware systems for image collection in the field and the laboratory, such as the Diopsis, AMMOD, and Aarhus traps, and the Biodiscover and DiversityScanner laboratory systems. The Action will add value to these previous efforts by bringing together experts to **develop best practice**, deliver **capacity building** training, and run **networking activities** to connect these innovators to the **stakeholder communities** that can use these to address **societal challenges**.

Existing European funded projects such as MAMBO, STING, ARISE, and SPRING include activities to explore the application of new technologies to monitor insects. The Action will add value to these projects by creating a forum for cross-project dialogue. Through this forum will facilitate the exchange of knowledge and experience of the state-of-the-art, and provide a mechanism to widen and deepen project' impact, shaping training and knowledge creation activities planned by the Action.

Efforts to engage citizen scientists in the monitoring of insects will benefit significantly from the work of this Action. EUPoMs and the SPRING project are funded to develop pollinator monitoring across Europe, in part to meet the aspirations of the EU Biodiversity Strategy 2030 and the EU Nature Restoration Law. These projects are exploring citizen science as a data source, and stand to gain significantly from the capacity building and innovation opportunities that the Action will provide.

The Royal Entomological Society will shortly publish its Grand Challenges in Entomology (https://www.royensoc.co.uk/grand-challenges-in-entomology-project/). The advances in technology that the Action will support, as well as the communication and capacity building activities, will directly address these challenges (see 2.2.1), and in so doing support entomological community across Europe.

International efforts to monitor the state of the world's nature, and the drivers of change, such as the GLiTERS project will benefit from the new stream of monitoring data that will be provided by image- based insect AI technologies in the future. Furthermore, the Action will develop the analytical toolbox needed to integrate these data with existing datasets, setting the stage for these data to form a part of future national, and international assessments of the state of insect populations.

Efforts to standardise biodiversity data are led by a consortium of organisations around the world (such as GBIF and TDWG). This Action will bring together the key researchers in the field and this consortium to develop and agree a FAIR data standard for image-based insect AI technologies.

2.2. ADDED VALUE OF NETWORKING IN IMPACT

2.2.1. SECURING THE CRITICAL MASS, EXPERTISE AND GEOGRAPHICAL BALANCE WITHIN THE COST MEMBERS AND BEYOND

This Action is interdisciplinary, calling on the participation of engineers, computer scientists, ecologists, taxonomists, museum curators, statisticians and citizen scientists in order to achieve its objectives and meet the key challenge. Our proposed network contains the critical mass and expertise needed for all of these domains.

The Action will draw on hardware expertise from projects across Europe which are developing hardware for the bulk collection of imagery, including AMMOD, MAMBO, Easy-RIDER, and ARISE. These projects have experience in designing and deploying image collection systems.

Developments in AI at a number of national centres for biodiversity monitoring as well as within research groups in computer science institutes will be leveraged by the Action. National and international centres of biodiversity monitoring also have expertise in curation of FAIR data, and developing robust standards. The Action will seek to draw on this expertise (including at GBIF and TDWG) and work to develop FAIR data standards, for our community. The Proposer Network includes members from the USA and Canada who link the Action to relevant activities in North America.

It is key for the success of these technologies that the entomology, including taxonomy, communities are engaged with, and supportive of the Action. The Action will reach out to entomological societies across Europe ensuring the activities are informed by priorities identified by stakeholders within the entomological community (WG1). Understanding and acknowledging the motivation of entomologists to engage with image-based insect AI will be critical to the adoption of these approaches. The forthcoming publication on Grand Challenges for Entomology (https://www.royensoc.co.uk/grand-challenges-in- entomology-project/) outlines a set of key global challenges agreed by entomologists as priorities including themes relevant to the Action (taxonomy, methods and techniques, anthropogenic impacts, conservation options, ecosystem benefits, technology and resources, knowledge access, training and collaboration, and society engagement).

The Action will reach the wider community of conservation technologists by developing partnerships with existing projects and organisations that have built communities around this topic. The Action will draw on the expertise of the WILDLABS platform, which hosts webinars and forums for conservation technologists, and the Easy-RIDER project which hosts a WILDLABS group for automated camera traps for insects, and which runs webinars on this topic.

Geographic inclusivity is fundamental for this action. Existing research in this field is centred in north-western Europe. Yet, the technologies are likely to have their greatest impact, and face their greatest challenges, in other parts of Europe where insect biodiversity is much higher and image reference libraries are less well-developed. It is therefore crucial that we have engagement from ITC countries. The Action already has significant involvement from ITC countries amongst its proposers (>53%), and this will be further built during the Action by seeking contact with ITC researchers through existing EU projects and infrastructures such as SPRING, EuropaBON, BiodivERsA+, European Environment Agency, Joint Research Centre, and the Knowledge Centre for Biodiversity.

Commercial organisations have a role to play as developers of hardware and generators of data. The network of proposers has some membership from industry already, however the Action will identify and engage with industry members from hardware development (e.g., AI-enhanced cameras), mobile development (e.g., wildlife app developers) and agri-, silvi-, and horticulture.

The Action will undertake an innovative co-design event with maker communities. Maker communities consist of hobbyists who have a shared interest in crafts, electronics, technologies, etc., and come together to work on projects and socialise. These communities are motivated to work on projects that support the public good, and the environment. Some members of the proposer network are members of makerspaces; however, the Action will widen its connection with this community through successful initiatives such as the fabfoundation, the EU funded European Maker Week, and the EC Joint Research Centre in Ispra, Italy, which has its own makerspace and could host maker events.

2.2.2. INVOLVEMENT OF STAKEHOLDERS

The Action will identify stakeholders with interests in the deliverables of this Action in three key domains:

1) Research organisations and initiatives which are developing, working with, or could have an interest in the technologies. 2) Commercial organisations who are, or could be, involved in the development of hardware. 3) Governments and government agencies with a responsibility for monitoring insect biodiversity who could be interested in deploying these hardware to meet their monitoring obligations.

The Action will perform a two-step stakeholder survey. First, the Action will identify key stakeholders across professions and localities for interviews to identify additional stakeholders. Second, the Action will undertake an elicitation exercise that will be run with partners in organisations with existing connections across European industry, academia, and government to map their knowledge and expected future use of image-based insect AI technologies (task 1.1).

Once identified, the Action will involve stakeholders in both online and in-person events such as demonstration events of existing tools, making them aware of possibilities and limitations (tasks 2.1 and 2.3), hackathons (task 3.3), and 'BionicBlitzes' where the image collection and processing will be demonstrated alongside traditional methods to highlight the current state-of-the-art (task 2.4). In addition, articles will be targeted at publications most relevant to the audience for each piece, to include in popular science magazines and online fora (e.g., The Royal Entomological Society's magazine, 'The Antenna', and 'The Conversation').

Communication campaigns (through social media and including short animations) will be developed for specific audiences identified during our stakeholder mapping (task 4.1, and section 3.2.2) including amateur entomologists, researchers, and decision-makers. Specifically for the general public, the Action will devise campaigns that build on existing materials available through entomological societies to highlight the importance of insects to ecosystem functioning (Dangles *et al* 2019), and the role that image-based insect AI technologies can play in helping us to understand insects.

The action is proposed at a critical time for policy development and implementation at the EU level, specifically the EU Biodiversity Strategy and the EU Nature Restoration Law. The Action will liaise with the Joint Research Centre and the Knowledge Centre for Biodiversity to ensure the Action's Core Group is kept informed of discussions about a Biodiversity Monitoring Coordination Centre for Europe. At the project level, the Action will coordinate with EuropaBON, BiodivERsA+, SPRING and relevant Horizon Europe projects. Our consortium members will stay in close contact with national biodiversity platforms (e.g., the national nodes of LifeWatch ERIC e-Infrastructure on Biodiversity and Ecosystem Research) to facilitate uptake and implementation of the Action technological developments at national level.

3. IMPACT

3.1. IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1. SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

In the **short-term** (within the timeframe of the COST Action), the Action will:

1) Work with stakeholders to identify the critical societal needs that can benefit from image-based insect AI technologies, and develop a roadmap to realising these opportunities. This will have a direct societal impact by shaping the direction of the entire Action.

2) Initiate and foster collaboration in development of, requirements for, and best practice of, large-scale deployable cameras (both in field and laboratory) coupled with AI through workshops, reports, and scientific publications. This work will accelerate the rate at which these technologies can be deployed across Europe.

3) Establish pipelines for image collection, processing and output analysis through the development of standards, open-source toolboxes, and training activities. This will ensure that future research will follow best practices, and provide the best chance of effectively addressing societies' needs for accurate and reliable data.

4) Pave the way for integration of image based-AI with traditional data sources and other insect monitoring technologies through workshops and published reports.

5) Ensure image-based insect AI technologies benefit professionals and lay experts by bringing them together with researchers and training the next generation of insect and technology literate scientists through Training Schools. This work will support science and technology innovation, creating the future leaders in this field.

In the **medium-term** (in the years after the Action is completed), the Action will:

1) Lead to the development of affordable, scalable and reliable systems for bulk image collection, and automated identification, of insects in the field and the laboratory with the potential for innovation and breakthroughs in the scale and accuracy of these systems.

2) Build a self-sustaining and growing community of users/practitioners skilled in using, improving and teaching the next generation of trans-disciplinary individuals.

3) Increase the knowledge of these new technologies among stakeholders. This will lead to impacts through the application of these technologies by stakeholders to address societies' key challenges.

4) Expand the network of researchers beyond Europe to accelerate innovation, increase inclusivity, and see the application of the technologies in parts of the world where knowledge is most needed.

5) Increase the cost-efficiency of data collection by integrating novel methodologies with traditional approaches. This will lead to better spatial and temporal resolution of insect trends.

In the **long-term** this Action will:

1) Improve the management and protection of global insect populations by helping us to better understand and counteract widespread insect declines.

2) Further develop and integrate the technologies of automated insect monitoring and its application in nationwide and global insect monitoring schemes.

3) Improve geographical, age, and gender balance in the research community developing and using novel technology for biodiversity monitoring.

3.2. MEASURES TO MAXIMISE IMPACT

3.2.1. KNOWLEDGECREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

The Action's activities will lead to **knowledge creation** across societal needs, hardware design, AI algorithms, and data analysis and integration. The impact of this work will be ensured by publishing in open access reports and papers, sharing tools openly (e.g., via GitHub), and making all materials available on the Action's website (section 3.2.2). The Action's inclusivity strategy (see 'COST Mission and Policies') and approach to stakeholder engagement (section 2.2.2) will ensure that access to knowledge is inclusive, and that key stakeholders are engaged throughout.

Transfer of knowledge will be critical to the success of the Action and exploitation of these technologies. Three Training Schools are planned throughout the Action: 1 & 2) Introduction to image- collection systems and AI-assisted tools including practical sessions (one on laboratory systems and one on field systems); 3) Introduction to an analytical toolbox for working with AI output. Summaries of the Training Schools will be delivered by the participants as on-line webinars available through the Action website and materials from the Training Schools, including recordings, code and presentations will also be shared. We will align with other training activities in Europe, for example the EU pollinator academy in development as part of the EU pollinator initiative.

To facilitate the transfer of knowledge among researchers and practitioners, the Action Communication Manager will develop a detailed engagement plan. This will be informed by an on-line survey to identify the needs and motivations of the insect science community within the context of EU biodiversity policies (e.g., EU Biodiversity Strategy 2030, EU Nature Restoration Law, and EU Pollinator Initiative) and considering which image-based insect AI technologies will be most impactful for society (see WG1). The plan will be further refined (alongside the communication strategy 3.2.2) through the Action following consultation with end-users of the data to ensure outputs are in an accessible format.

Career development is an important ambition of the Action. For image-based insect AI to realise its potential we need to grow the research capacity in Europe. This includes a need for career development amongst these researchers. The Action will address career development at three levels, 1) supporting YRIs to build their research skills and independence, 2) giving YRIs leadership experience and, 3) providing established researchers the opportunity to support the careers of others. The Action proposer network is rich in YRIs who will be represented in the leadership of all WGs within the Action. The training activities planned will offer chances for YRIs to learn the skills needed to use image-based insect AI technologies. This unique skill set will make these researchers more employable. By putting YRIs into leadership positions within the Action we will develop transferable skills for future leadership roles. Where activities target YRIs we will additionally aim for a 50:50 gender representation.

Short-term Scientific Missions (STSMs) will provide opportunities for collaboration across the entire network and at all career stages, however, will take steps to ensure inclusivity. The Action will prioritise applications from YRIs, and work to a 50:50 gender representation across STSMs. Additionally, the action will favour applications from researchers in ITC countries seeking to spend their mission at centres of expertise elsewhere in Europe. Outputs, including blogs and posters, from the STSM will be available from the Action website. The Action will provide support to STSM applicants through feedback on proposals and reports. At each of the Action's annual conferences the Action will run an 'STSM marketplace' where potential hosts of STSMs will give lightning talks about what they can offer, and potential STSM applicants will be free to ask questions and develop ideas with hosts. Summaries of each host's lightning talk will also be placed on the Action's website for others to access.

3.2.2. PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

The Action has many stakeholders, from researchers and innovators, policymakers and non- governmental organisations, to industry and the general public. We will develop an adaptive dissemination plan and communication strategy in the first quarter of the Action. The Action will put in place a Communication Task-force, and appoint a Communication Manager. The dissemination plan will ensure effective engagement with partners, and opportunities for re-use of knowledge.

While some insects are considered to be popular with the **general public**, many are reviled despite the important ecosystem functions they perform and associated benefits to society (Losey et al 2006). The need to increase appreciation and understanding of the vital roles provided by insects has been widely recognised. Image-based insect AI technologies provide opportunities to engage the general public with insects. The Action will develop dissemination materials (postcards, posters, online infographics) in multiple languages to communicate the exciting technologies the Action is supporting, alongside engaging species accounts, focusing on their contributions to nature and people. Social media platforms will be used to share developments and outputs from the network including knowledge created through STSMs. The Action will also provide opportunities for face-to-face discussions at science festivals, citizen science activities, and other events across Europe including BioBlitzes (events aimed at engaging the public in intense wildlife recording in a specific place over a short period of time, such as City Nature Challenge), and European Researcher's Nights.

Peer-reviewed scientific journals will be used to communicate outcomes relevant to **researchers, innovators, and funding bodies**. The Action will mobilise resources to publish open-access methods papers to share knowledge created across the WGs. The Action will select journals to ensure global accessibility and high impact, including the journals published through entomological societies to increase visibility of the Action to entomologists. Peer-reviewed publications will be summarised through popular articles, blogs, webinars, and multilingual press releases as appropriate throughout the Action. All outputs will be promoted through the social media platforms and the Action website.

The Action will run activities that are innovative and impactful including design sprints with engineers and community groups, hackathons with computer scientists and entomologists, and a 'BionicBlitz' bringing image collection and analysis technologies to the traditional 'BioBlitz'. **Guidance documents** for each of these activities will be published to aid others to replicate such events across Europe

The Action will engage with relevant **local, national and global organisations -** including **policy makers** and **NGOs** - who have a responsibility to monitoring insect biodiversity, or whose activities impact on insect populations. This will include international organisations such as IUCN and IPBES, as well as national bodies with responsibilities for forestry or farming. The Action will develop policy briefs in multiple languages to introduce image-based insect AI technologies and highlight advances including creation of knowledge through the Action's diverse activities. The Action will encourage knowledge exchange with this community through quarterly on-line webinars including opportunities for discussion, and suggestions for future topics of interest within the scope of the Action.

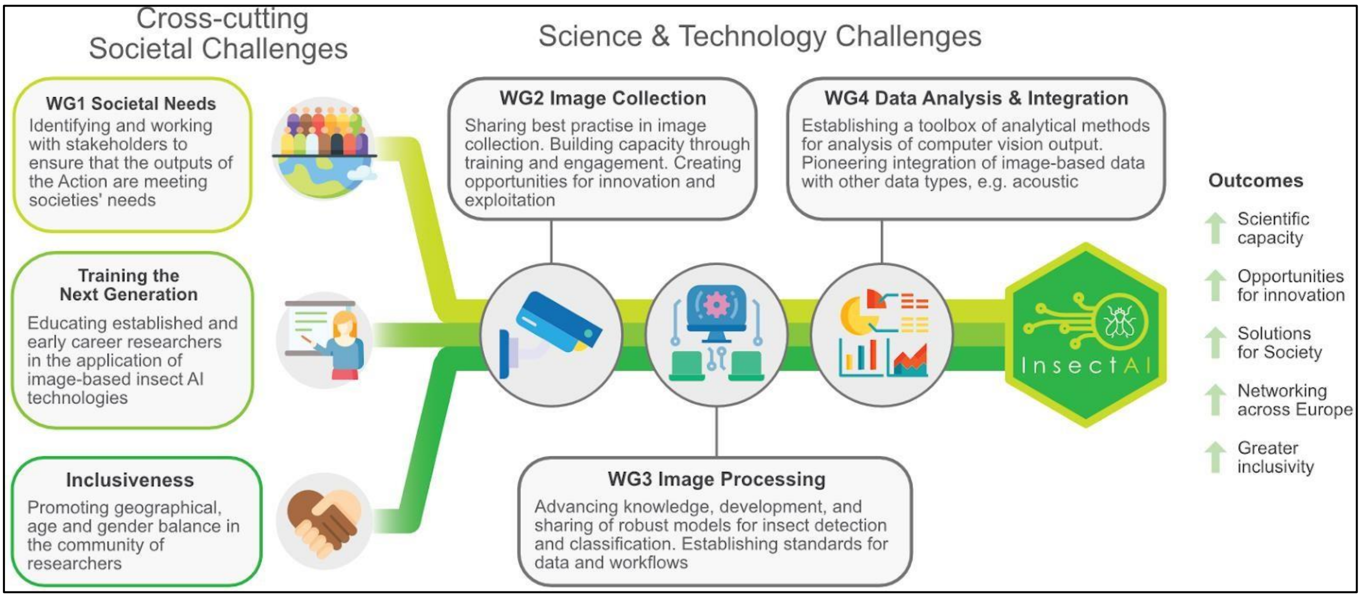
Exploitation of the Action's knowledge creation will be ensured through a programme of engagement with **industry**. The network of proposers has representation from Small and Mid-sized Enterprises (SMEs) that undertake environmental assessment, integrate AI into mobile apps, and build in situ camera systems. Through these partners the Action will identify trade shows and events where materials will be shared and research will be presented. In particular, the Action will promote the FAIR metadata standards developed with industry partners to aid data access and re-use.

All materials produced within the Action will be made available through a dedicated **website, and social media platforms**. Content will include reports from workshops, conferences and STSMs, multilingual communication materials for stakeholders, training materials from Training Schools, recording of webinars, amongst other outputs. The Communication Task-force will coordinate this activity and ensure that content is up to date and inclusive at 6-monthly reviews of the communication strategy.

4. IMPLEMENTATION

4.1. COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1. DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES



<u>Working Group 1: Societal Needs</u>

WG 1 will focus on the needs of all stakeholders, using participatory approaches to ensure that the outputs of the technological advances (WGs 2-4) are relevant and benefit as many end-users as possible. The WG will collaboratively prioritise societal needs that will benefit from image-based insect AI technologies (WG2-4). The WG will guide the development of dissemination resources to ensure effective transfer of knowledge between the Action and stakeholders.

Objectives

1. **Engage with diverse stakeholders** to collaboratively document the key questions in insect research and monitoring, with specific focus on policy-needs, and systematically prioritise those that could be addressed by imaged-based insect AI technologies in addressing the priority

questions.

2. Increase understanding of the **needs of researchers and citizen scientists** for new tools and technologies within the context of the key questions derived in (1).
3. **Assess the benefits** of implementing tools and technologies to address the key questions derived in (1), while supporting increased engagement and uptake.
4. Ensure exploitation of technologies through **dissemination and communication** activities.

Task 1.1 - Identification of stakeholders. As detailed in section 2.2.2 the Action will perform a two-step stakeholder survey. First the WG will identify key stakeholders and second undertake an elicitation exercise to map their knowledge and expected future use of image-based insect AI technologies while also considering challenges to adoption of technologies and approaches to overcome these. This stakeholder mapping will be used to ensure other tasks engage with the wider stakeholder community.

Task 1.2 - Collaboratively prioritise research themes according to societal need. The Action will develop a questionnaire to distribute to key stakeholder groups including entomologists and decision-makers to understand the societal needs for insect monitoring. Stakeholders will be invited to consider immediate and medium-term future needs.

Task 1.3 - Map priority research themes (task 1.2) against the capabilities of image-based insect AI technologies. The WG will organise a workshop at which the priority societal needs will be presented to experts in the development and application of image-based insect AI technologies. Using expert-elicitation and consensus approaches, the Action will map image-based insect AI technologies to those priorities that they can help address and will score these technology-priority relationships by timeliness, feasibility and impact. Deeper case studies will be formed around those that show the greatest promise. This work will be written up as a peer-reviewed publication.

Task 1.4 - Document gaps and innovations required to meet future societal needs. Building on the case studies from task 1.3 that have the greatest potential, the Action will work with the stakeholder network and the network of proposers to detail the barriers that may be preventing the realisation of these applications, and develop a road map of actions and actors needed to overcome these barriers.

Task 1.5 - Showcase outputs from the Action network to relevant end-users. Working across all WGs and all tasks, the WG, Communication Task-force and Communication Manager will review all deliverables (delivered and pending) at quarterly Core Group meetings. Using the dissemination plan (section 3.2.2) the WG will develop and deliver the communication strategy for each deliverable by the means best suited to each case.

Working Group 2: Image Collection

WG 2 will focus on the collection of images of insects for processing using AI workflows. The WG will consider a range of methods and contexts in which insect images are collected, including field deployments of autonomous camera traps for insects, laboratory systems for bulk sample processing, and mobile apps for aiding identification in the field. The WG will collaborate with other WGs to co-create metadata standards (WG3), survey designs (WG4), integrated approaches (e.g., combination with acoustics, WG4), and to identify priority research areas (WG1).

Objectives

1. Develop and share **best practices** for the application of hardware solutions, co-designed with stakeholders.
2. Build **research capacity**, through training and engagement, creating a community of practitioners with the skills and knowledge to use these technologies for research of national importance.
3. Create opportunities for **innovation and exploitation** of hardware for collecting images of insects in the field and in the laboratory.

Task 2.1 - Bring together hardware developers to share knowledge and build best practice. Expertise and hardware systems are currently being developed in isolation with minimal collaboration, principally because projects have a national focus and many groups have not yet published in journals. The Action will bring together these researchers, to forge collaborations, raise awareness of each other's work, and create opportunities for innovation. The Action will run conferences that will bring together all the existing hardware and their developers to facilitate the development of **best practice**, and foster collaborations. The conferences will be an opportunity for the researcher community to present the state-of-the-art to the stakeholder community. Workshops at the conferences will focus on the development of standards (WG3&4), identification of the key societal needs that can be addressed with these technologies (WG1), and developing a roadmap to achieving this development (WG1).

Task 2.2 - Develop and run Training Schools that build the capacity of European researchers to apply image-based insect AI technologies A critical barrier to the wider uptake of these technologies, especially in ICT countries, is the lack of knowledge of these systems and what they can do, and the skills and experience required to deploy them. The WG will build **research capacity** through a series of training events, mostly hosted in ITC countries, that will train the future leaders of image-based insect AI technologies. The WG will arrange two, one-week training schools, which can be repeated if they prove impactful. The Training Schools will combine lectures on theory, with practical sessions and group work to train participants on the design and use of image-based insect AI technologies. The first Training School will focus on field systems, while the second will focus on laboratory systems. Each Training School will include the application of at least two different designs of hardware and will also cover the analysis of the images using existing algorithms (WG3), and introduction to downstream analyses (WG4). Materials from the workshops will be shared on the Action website (see section 3.2.2), and they will be designed to align with the EU pollinator academy in development under the SPRING project.

Task 2.3 - Create opportunities for innovation and exploitation by running activities that focus on specific societal needs. The WG will run activities that engage stakeholders who might seek to **exploit the technology** for specific research or applied purposes. The topics of these workshops will be defined collaboratively following stakeholder engagement (WG1), however the Action envisages workshops on pollinator monitoring, early detection of invasive alien species, and impact assessment of farming practices. Each two-day workshop will consist of presentations of the state-of-the-art, and interactive sessions between systems developers (e.g., engineers, computer scientists) and domain experts (e.g., pollination or invasive species experts), to identify opportunities of exploitation, and bottlenecks in need of future development.

*Task 2.4 - **Engage with society** directly through citizen science and maker events*. Hardware systems will be deployed as a part of traditional citizen science 'BioBlitz' activities, where communities seek to identify as many species as possible in a given area over a short period of time. This new form of activity, which we term a 'BionicBlitz', will allow for direct, two-way, engagement with citizen scientists, and community organisers, as well as a comparison of the different methodologies (WG1). The WG will additionally co-develop a design sprint with the maker community and existing hardware developers. This event will seek to exploit existing knowledge to develop low-cost image collection hardware that could be built in makerspaces around the world. The activity will focus on low-cost electronics and 3D printed housings since most makerspaces have access to these technologies. Follow-on activities will be arranged in order to realise innovations and breakthroughs arising from this event.

<u>Working Group 3: Image Processing</u>

This WG will concentrate on topics relevant to the processing of images, in particular: 1) collecting and curating annotated training data for AI algorithms, 2) advancing algorithm development regarding robustness across technologies and dealing with rare species, 3) develop metadata standards for AI model outputs, and 4) specifying infrastructure for running and sharing models, as well as storing reference images.

Objectives

1. **Establish standards** for storing and sharing data, for metadata of insect images and AI model outputs including standardised annotation formats and support for experts in the annotation process.

2. Alignment of **workflows and pipelines** across projects that use AI for insect recognition to allow easier exchange and exploitation of data and algorithms.
3. Advance knowledge, development, and **sharing of robust models** for insect detection and classification that can be reused across projects and camera setups.

Task 3.1 - Develop metadata standards for annotated images of species and the outputs of AI algorithms for species detection and classification. For an easy exchange of different AI models, **standardisation of metadata** for image annotation, and species detection and classification are required to obtain comparable input and output formats for the algorithms. Several standards already exist for biodiversity data (e.g., Darwin Core (Wieczorek et al. 2012), Ecological Metadata Language (Jones et al. 2019)) and camera trapping (e.g., Camera Trap Metadata Standard (Forrester et al. 2016)), yet we still lack an integrated metadata standard for AI for species identification. The Action will run a workshop that brings together experts from various backgrounds (ecology, entomology, AI), to identify best-practices as well as key differences in current data and metadata management, and to agree on a standardised way for image data processing. The Action aims to provide this standardisation in a format that can be used by the global community. By defining standardised metadata and protocols, this WG will facilitate consistency of species identification outputs that can easily be used for further data analysis and integration with other technologies (see WG4).

Task 3.2 - Develop efficient workflows for creating annotated image datasets to support the training of AI algorithms. High-quality labelled data provided by taxonomic experts are essential for effectively training species recognition models (Wäldchen and Mäder 2018). In collaboration with WG2, this WG will bring together computer scientists, museum curators, and ecologists to identify shortcomings that currently prevent experts from fast and easy labelling of images. During a workshop series that the Action will organise, solutions will be investigated that incorporate automated suggestions from AI systems both in terms of specimen positions in the image for localisation and species labels for classification in order to **reduce the efforts for tedious labelling sessions**. A particular challenge in using AI algorithms for biodiversity monitoring is dealing with class imbalance as many species are present in relatively low numbers (Spiesman et al. 2021). This requires a focus on annotating images of rare species and algorithm design that can be adapted to deal with the large number of species which are represented by few images. Furthermore, this workshop series will train ecologists to apply AI- assisted tools for annotating data and running AI algorithms, which will be closely linked to the Training Schools described in Task 2.2.

Task 3.3 - Design a framework to enable easy sharing and reuse of AI models and algorithms. With an increasing amount of annotated images it will be possible to exploit tailored training datasets to develop AI algorithms for particular species groups, regions, or use cases such as species interactions. The WG will organise a workshop to collate state-of-the-art insect AI methods and **design a unified framework for existing and future algorithms**. By aligning workflows and pipelines in a unifying framework the Action will enable comparison, evaluation and reuse of algorithms through infrastructure for sharing image data and AI models as well as for running algorithms to train and apply AI models. The workshop will also foster discussions about limitations and possible extensions of these systems between algorithm developers, ecologists, and other stakeholders, which are relevant for the following Task 3.4.

Task 3.4 - Support algorithm development through interdisciplinary hackathons. The WG will organise hackathons to bring ecologists, engineers and computer scientists together to develop new and improved algorithms particularly focusing on the previously identified limitations of available methodologies. The WG will especially encourage investigations towards the robustness of those algorithms with respect to changing camera setups and varying species populations across different regions, which are already very important aspects. New developments will be integrated into the framework of Task 3.3.

Working Group 4: Data Analysis and Integration

WG4 will address the downstream analysis of AI output. This will ensure that the Action can meet its key challenge to "understand … widespread insect declines" using these new technologies. The WG will focus on developing our understanding of the statistical methods needed to analyse these data as well as how these data can be integrated with data on insects collected by traditional means and by other technologies, such as acoustics and radar. The WG will develop a range of workflows that will also give the unexperienced end-user ('trans-disciplinary individuals') the capability to interpret uncertainties in AI outputs, to apply rigorous statistical methods based on the available data, and to identify the best approach to integrate additional insect biodiversity data.

Objectives

1. Establishing a **toolbox of analytical methods** for analysis of AI output and for integrating traditional biodiversity data.
2. **Connecting researchers across technologies** (e.g., automated acoustic monitoring or radar), to develop methods for parallel deployment, data integration, and to identify synergies and common challenges.
3. **Train ecologists** in the interpretation and analysis of AI output.

Task 4.1 - Develop statistical workflows for the analysis of data produced by image-based insect AI technologies and their potential integration with traditional biodiversity data. AI technology is a cutting-edge tool for insect monitoring. Due to its novelty we are missing methods for performing statistical tests, time series analysis, or species distribution models which utilise the uncertainties created by AI model output. Firstly, as the initial event in a hackathon series the Action will develop an open access web application (R Shiny) to visualise biases in the AI data that comes out of the algorithms explored in WG3. This will make the vulnerabilities and gaps in these data clear particularly to those less familiar with AI tools. In collaboration with WG2 and WG3, a workshop is planned to draw on the expertise of statisticians in the field of ecology to **develop hands-on solutions on how to work with AI output** and integrate models built from different data sources. During the following second hackathon event, the Action will develop and test a possible workflow that takes in and cleans the outputs data from AI algorithms, and runs temporal or spatial analyses. To ensure transparency and documentation, the WG will create and continuously update a GitHub repository where the WG will make available code for various statistical applications, e.g., single or multispecies spatial distribution or occupancy trend model, building a **toolbox of statistical methods**.

Task 4.2. - Create opportunities for parallel development and deployment of automated insect monitoring technologies. In addition to image-based AI, other technologies for automated insect monitoring such as machine listening (computers interpreting sounds) and radar are only just emerging. Combining technologies holds great potential for insect monitoring. Joint deployment could exploit the respective strengths and compensate for weaknesses of the different technologies, or lead to more accurate interpretation (Klink et al., 2022). So far, integration of technologies rarely happens (but see the DiversityScanner integrating robotics, AI and molecular methods and the AMMOD project using multi-sensory stations). This WG will bring together researchers using image and non-image technologies as well as scientists from the fields of entomology, data science, statistics and ecology. In a workshop the Action will identify **cross-technology synergies and challenges** as well as the needs of all potential stakeholders that will deploy large scale, multi-sensory, automated insect monitoring in the future. This workshop will cover topics from all WGs, in the context of integrating technologies.

Task 4.3 - Develop and run Training Schools. The aim of this WG is develop a reproducible and robust analytical workflow that is widely accessible and endorsed. To ensure that such a complex and multi-step process can be used by many, it is important to avoid creating a black box. In addition to the public repository, the WG is therefore also planning a Training School. The Training School will provide an introduction to and guidance on the analytical toolbox and give room for feedback from end-users on suitability of the workflow and additional tools that might be desired. The two-day Training School will be run in an ITC country and will be rerun if found to be impactful.

4.1.2. DESCRIPTION OF DELIVERABLES AND TIMEFRAME

Across all WGs, the Action aims at three different control mechanisms at varying frequencies to ensure progress against the Actions deliverables and objectives. These three sets of milestones will be coordinated by the Chair.

MS1.X - The Core Group will meet every three months in an online meeting to collect and discuss reports from the different WGs, measure progress and identify risks, which may lead to necessary adaptations of risk management. (M3, M6, M9, M12, M15, M18, M21, M24, M27, M30, M33, M36). **MS2.X** - The Management Committee will meet annually in-person (in additional to a kick-off meeting) to reflect on the actions that took place in the previous year and to schedule and approve the activities for the next year. The Action aims at in person MC meetings co-located with the annual conference, and preference will be given to locations in ITC countries. Interim virtual updates will occur between in person meetings (M1, M8, M20, M32, M44). **MS3** - A midterm review meeting will take place after two years and the activities that happened in the first half of the Action will be summarised in a report along with any updated plans for the second half of the Action. (M24)

Deliverables

D1.1 - Communication plan, updated throughout the Action, including timeline for implementation of a diverse range of outreach activities for knowledge exchange including peer-reviewed publications, popular science articles, blogs, social media, webinars, public lectures given by members from across the Action (M2+). **D1.2** - An infographic and short report mapping the Action's stakeholder community and highlighting existing and potential interactions with image-based insect AI technologies (M8). **D1.3** - Report summarising the responses to the societal needs' questionnaire including a ranked list of identified societal needs. In parallel a further infographic and short animation will be developed to enable effective knowledge transfer to stakeholders including end users (M12). **D1.4** - Future outlook publication highlighting the potential of automated insect monitoring technologies to advance understanding within the context of societal needs with case studies of innovations that go beyond the current state-of-the- art (M24). **D1.5** - Peer-reviewed publication and policy brief summarising the current state-of-the-art alongside potential future developments in automated insect monitoring technologies including case studies highlighting successes in implementation of AI technologies for insect monitoring (M36).

D2.1 - A report on the best practice for the development of image collection hardware (M12). **D2.2** - A paper on the opportunities and challenges facing automated methods for meeting key information needs (M24). **D2.3** - Content for two Training Schools on the application of image collection methods. Each one week long and engaging a minimum of 15 trainees (M24). **D2.4** - A paper on the potential for image-based insect AI to support a specific research area of societal importance (e.g., pollinator monitoring, or early detection of invasive alien species) (M18). **D2.5** - Run a 'BionicBlitz' in a major city in an ITC country, alongside traditional 'BioBlitz' activities (M30). **D2.6** - Publish open designs, and an accompanying blog, on a co-design sprint with the maker community, such that the designs can be replicated by other makerspaces around the world (M42).

D3.1 - A report of the workshop from Task 3.1 with guidelines for standardising metadata for insect images and machine learning output made available on the website of the Action (M12). **D3.2** - Overview of existing insect image classification models in a shared repository for easy reuse by other projects together with a survey paper of available algorithms, repository and paper will be accessible through the website of the Action (M24). **D3.3** - Annotated datasets for five different species groups, regions or use cases, together with reports from the workshop series about established workflows for fast and easy image labelling, datasets and reports made available via the website of the Action (M36). **D3.4** - Development of three new insect identification algorithms for specific species groups, regions or use cases through multiple hackathons, summarising the results in a report or paper shared on the webpage of the Action with links to public code repositories for the new algorithms, e.g., GitHub (M48). **D3.5** - Deliver framework, with guidelines and recommended workflows, to align data and algorithms for AI insect recognition as a blog on the webpage of the Action with assigned public repositories for code and data (M48).

D4.1 Shiny app that visually presents summaries of the AI data going into the workflow to clearly show biases and gaps to less confident users (M16). **D4.2** Setting up a GitHub repository (M12) and continuously updating it with WG advances towards an analytical toolbox (M48). **D4.3** Publication (review, perspective or methods paper) on data analysis and integration methods with AI output (M36). **D4.4** A report and work plan for integration of image based-AI and other insect monitoring technologies, focusing first on AI-based acoustic monitoring (M36). **D4.5** Content for a two-day Training School on an analytical toolbox for working with data from AI systems for monitoring biodiversity (M42).

4.1.3. RISK ANALYSIS AND CONTINGENCY PLANS

The Core Group alongside the Management Committee will be responsible for identifying potential risks, impacts and appropriate mitigating actions. The risks will be documented in a risk register that will include a contingency plan. The risk register will be reviewed by the Core Group every 3 months, or more frequently if deemed necessary, and updated. The Management Committee and COST will be notified of any major risks identified and the contingency in place to manage the risk. The following risks will be included in the risk register:

1) *Disruption to schedule of in person meetings* (e.g., COVID-19). Contingency: Use a diverse range of on-

line tools to deliver the activities with commencement of in person activities as soon as possible. The work plan will include in person and on-line activities from the outset to maximise accessibility and participation. 2) *The objectives outlined in the work plan are delayed*. Contingency: Regular review of the work plan with the Core Group to assess progress and implement corrective actions if needed. 3) *Core Group member leaves the Action*. Contingency: All Core Group roles will be assigned to more than one member to ensure succession if required. 4) *Lack of communication amongst members*. Contingency: Regular on-line meetings of the Core Group to include discussion of challenges to communication ensuring corrective actions are implemented. All meetings managed to ensure inclusivity of all participants. 5) *Resources are insufficient to deliver the work plan*: Contingency: Work plan has been developed to ensure delivery through on-line and in person activities. The network has critical mass of participants to ensure sufficient capacity for delivery. The Core Group and Management Committee, led by the Chair, will review the budget every three months and implement corrective actions if there is an underspend or overspend for any of the activities. The Action will ensure the Budget Holder and Grant Administrator have the necessary training, including attending the training provided by COST, to oversee the day-to-day management of resources. 6) *Low participation in activities including STSMs and Training Schools*. Contingency: Participants will be involved in co-developing activities to ensure relevance. STSM and Training School Coordinators will be appointed to manage the process of delivering these activities including supporting applicants. 7) *Failure to engage stakeholders*. Contingency: Stakeholders have been involved in the development of this Action. At the start of the Action a questionnaire will be developed to assess the needs and motivations of stakeholders within the context of AI tools (WG4); the results will be used to refine the overarching work plan including delivery of a series of online webinars and dissemination resources. Dissemination activities will focus on retaining stakeholders within the Action.

4.1.4. GANTT DIAGRAM

Lead Working Group	Tasks and Deliverables	Year 1				Year 2				Year 3				Year 4				Partner Working Groups
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
WG1 Societal needs	Task 1.1 - Identification of stakeholders																	All
	Task 1.2 - Prioritise research themes according to societal need																	-
	Task 1.3 - Map priority research themes against InsectAI technologies																	2&3
	Task 1.4 - Document gaps and innovations required to meet future societal needs																	All
	Task 1.5 - Showcase outputs from the Action network																	All
	D1.1 - Communication plan, updated throughout the action	x		x		x		x		x		x		x		x		
	D1.2 - Infographic and report mapping the Action's stakeholder community			x														
	D1.3 - Ranked list of societal needs and communication materials				x													
	D1.4 - Paper on potential of InsectAI technologies to address societal needs								x									
	D1.5 - Paper on the state-of-the-art and future developments												x					
WG2 Image collection	Task 2.1 - Bring together hardware developers																	All
	Task 2.2 - Develop and run Training Schools																	3&4
	Task 2.3 - Activities that focus on specific societal needs																	1
	Task 2.4 - Engage with society directly through citizen science and maker events																	1
	D2.1 - A report on the best practice for hardware				x													
	D2.2 - A paper on the opportunities and challenges								x									
	D2.3 - Content for two Training Schools								x									
	D2.4 - A paper on image-based insect AI to support a specific research area						x											
	D2.5 - Run a 'BionicBlitz', alongside traditional 'BioBlitz' activities										x							
	D2.6 - Publish results from co-design sprint with the maker community														x			
WG3 Image processing	Task 3.1 - Develop metadata standards																	4
	Task 3.2 - Develop workflows for creating annotated image datasets																	2
	Task 3.3 - Develop a framework for sharing algorithms																	-
	Task 3.4 - Support algorithm development through interdisciplinary hackathons																	1
	D3.1 - A report on standards				x													
	D3.2 - Repository and paper describing existing models								x									
	D3.3 - Five annotated datasets and paper on annotation workflows												x					
	D3.4 - Development of three new insect identification algorithms																x	
	D3.5 - Blog post and code repository for data and algorithm framework																x	
WG4 Data analysis and integration	Task 4.1 - Develop statistical workflows																	2&3
	Task 4.2 - Create opportunities for integrating technologies																	2
	Task 4.3 - Develop and run Training Schools																	1
	D4.1 Shiny app that shows biases and gaps in data						x											
	D4.2 A GitHub repository containing analytical tools				x												x	
	D4.3 Paper on data analysis and integration methods												x					
	D4.4 A report and work plan for integration of other monitoring technologies												x					
	D4.5 Content for a two day Training School on an analytical toolbox														x			
Cross-group	Core group meetings																	
	Management Committee meetings		V			V				V				V				
	Mid-term Review																	
	Conference																	

V* = Zoom (virtual); x = Deliverable date

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