

**In this research project, I utilised GenAI, specifically ChatGPT 4.0, to assist in the research proposal writing and drafting phases. The AI tool was used to structure my initial ideas, timelines points of importance for a PhD proposal, and brainstorm ideas for a title. I critically reviewed all AI-generated content, and I assure that the text is accurate and of high academic integrity. Using GenAI improved my efficiency, but I remained vigilant to validate all information to maintain the rigour and originality of the work.**

# TEMPLATE APPLICATION FORM (based on NWO Open Competition Domain Science – M)

When you apply for research funding you normally use a given template from the funding agency. For the Writing Assignment/Research proposal of the GSLS you will use an adapted version of the NWO Open Competition Domain Science – M, which is intended for a group leader who applies for a PhD student to do a four year research project.

For more information concerning the writing, please see the Master Writing Assignment Guide for students. For the assessment of the research proposal a specifically designed rubric is available. The assessment will not only be on the scientific proposal, but also on the professional attitude of the applicant and the structure and style of the writing, as is customary for other writing assignments.

## Part A – Applicant

### How to fill out this application form?

This application form consists of two parts. In Part A you fill out the basic details of the applicant and the examiners; only name and affiliation are required. Part B is devoted to the scientific proposal, including abstract, and a plain language summary. Please adhere to the provided rules when filling out this application form.

#### A.1 Applicant

Name student (initials, first name, last name, student number):	MJP, Mateo Joel Pearson, 9823522
Affiliation (university/institute + department):	Utrecht University / AMS-Institute
Name first examiner:	Jaco Appelman
Affiliation (university/institute + department):	Utrecht University / Biology
Name second examiner:	Peter Mooij
Affiliation (university/institute + department):	AMS-Institute

## Part B – Scientific proposal

#### B.1 BASIC DETAILS

Part B.1 covers the basic details of the application. It contains both an abstract suited for your scientific peers and a plain language summary.

##### B.1.1 Title

The title should be clear and concise and represent the content.

Pioneering Urban Biodiversity: Using AI-sensors, eDNA and traditional methods to create a novel biodiversity monitoring toolkit and assessment framework.

##### B.1.2 Abstract

The abstract should summarize the proposed research in a maximum of 250 words in a clear way and should be aimed at your scientific peers.

While human-made elements often overshadow urban ecosystems, they have recently shown to be able to support and harbour significant biological diversity, which is critical yet challenging to monitor effectively. Given the fact that 68% present of the world's population is expected to reside in cities by 2050, these systems are under great pressure by rapid urbanisation and understanding how these systems function becomes increasingly important. There is an urgent need for the creation of novel, more comprehensive

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monitoring techniques, that overcome the disadvantages from labour and time intensive, invasive and biased traditional methods and to enable more nuanced and faster conservation efforts. This study proposes a novel methodological framework to harmonize different data sets, reduce biases and enhance comparability across biodiversity studies, addressing gaps in standardized methods and data collection.

We propose an integrated multimethod approach that combines sensors based on Artificial Intelligence (AI), environmental DNA (eDNA), and conventional ecological methods, to enhance accuracy, efficiency and scalability of urban biodiversity monitoring. With the use of AI-based sensors, large volumes of data and species can be analysed and determined rapidly in real time, while eDNA offers a way to assess a broad taxa spectrum from environmental samples. Combining and ground truthing these methods with traditional observational methods, we aim to provide a more comprehensive understanding of urban biodiversity.

Our project will result in a biodiversity monitoring toolkit designed for use by scientists, citizen and policymakers, which will engage a broader community in conservation efforts. By leveraging the strengths of AI, eDNA and traditional methods, this toolkit will advance urban ecological research and impact sustainable urban planning and policymakers.

### B.1.3 Plain language summary

[The plain language summary explains your research proposal to the public in a maximum of 500 words. It can be written in Dutch or English and should be written at high school Biology level.](#)

Cities and population are currently growing faster than ever before. 68% of the human population is expected to live in cities by 2050. This leads to natural landscapes vanishing and being replaced by urban infrastructures such as impervious surfaces like streets and buildings. This also means that a lot of greenery is lost and thereby habitats for animals like birds, mammals, insects is reduced. These animals play an important role in the well-being of humans which is often overlooked, as they maintain functions of ecosystems such as pollination, food provisioning or pest control. However, urban ecosystems have recently shown that they can also harbour biological diversity instead of only being a sink. Despite their importance, traditional methods of monitoring urban wildlife, like trapping, are time and effort-consuming, costly, and often disturb the animals. Therefore, in times of rapid urbanization finding ways to be able to effectively monitor biodiversity and thereby create timely conservation efforts is becoming increasingly important.

In our research we want to revolutionize the way we can monitor biodiversity in cities by integrating new technologies with traditional ecological methods. We propose using Artificial Intelligence (AI)-based sensors, environmental DNA (eDNA) and conventional ecological methods to create a more comprehensive, efficient, and non-invasive approach. Current data collection often leaves out less accessible areas and less detectable species, leading to knowledge gaps. Additionally, the lack of a standardized monitoring framework complicates data collection across different studies and regions.

We propose a new standardized and scalable monitoring framework, that uses a combination of techniques and can be adapted to different urban setting worldwide. The AI-based sensors will use cameras and microphones to continuously record its surrounding. These sensors can analyse and determine the species that they encounter in real-time. Furthermore, they are non-invasive and give insight into urban wildlife's behaviour without disturbing their natural activities. Environmental DNA allows for the collection of genetic material from water, soil, or air, identifying species that are difficult to observe directly. This method provides a broader understanding of an area's biodiversity without direct observation of the wildlife.

By combining the AI-based sensors, eDNA and traditional methods we can gather more fine-grained picture of the urban wildlife and its interaction with the urban environment. This multimodal strategy enhances reliability, compensates for individual biases and limitations of each method, and improves our ability to detect lesser-known species.

With the knowledge gained during this research the goal is to develop a user-friendly biodiversity monitoring toolkit, that uses AI-sensors, eDNA sampling and guidelines for traditional methods. This toolkit will be designed for use not only by scientists but also by citizens, companies, and governments, enhancing community involvement and standardizing data collection across various regions.

This research will have great impact on urban planning and conservation efforts. By generating more accurate and timely data, governments and city planners can design more effective interventions and measures to strengthen and support urban ecosystems. Cities would not only become more sustainable but also more liveable for humans and wildlife.

This multimethod approach is big step forward to learning how to conserve urban ecosystems and monitor biodiversity in a time of rapid urban development and the need to preserve natural environments in our cities.

## B.1.4 Keywords

Use **three to five** representative keywords to describe your research proposal. This can aid to quickly understand the broad scope of your proposal.

- Urban Biodiversity
- Integrated Multimethod Approach
- Artificial Intelligence
- Environmental DNA
- Traditional Ecological Monitoring

## B.2 SCIENTIFIC PROPOSAL

While drafting your research proposal, keep the assessment criteria from the rubric for proposals of the GSLS in mind. For the assessment of proposals, the basic principle generally is that the proposals must describe in a clear and concise way **what** will be investigated and **why** the proposed research should be carried out (urgency). The GSLS asks for a more extensive introduction of the research topic than customary. A minimum of 5000 words is required for paragraphs B2.1 to B2.5, but the total amount of words should not exceed 7000. Section B2.6. is excluded from the word count.

### B.2.1 Research topic (What)

Include an extensive description of the background (a), leading to the overall aim (b) of the proposal. The aim should be subdivided into several sub-questions/objectives (c) that help answer the overall aim. This part also deals with the scientific originality and/or the innovative approach of the proposed research and investment, including its cutting-edge aspects and/or ground-breaking character.

#### *The importance of Urban Ecosystems*

At this moment 55% of the world's population lives in cities and urban areas. This rising trend is expected to reach 68% by 2050 (United Nations 2018). Urban areas, while often overlooked in conservation practices, are vital in maintaining ecological balance, offering unique ecosystems and hosting diverse species, when managed correctly (Kowarik, 2011; Pickett *et al.*, 2011; Calviño *et al.*, 2023). Urban ecosystems host diverse wildlife, including birds, mammals, amphibians, arthropods, each vital for ecological health. For example, birds help in pest control, pollination, and seed dispersal and serve as indicators of environmental quality. Arthropods play critical roles in pollination, biological pest control, and soil aeration, and their population dynamics serve as sensitive and valuable indicators of urban environmental health.

These species are essential not only for their direct ecological roles but also for maintaining the overall balance and functionality of urban ecosystems. Their health and diversity are crucial for assessing and managing the impacts of urbanization on natural habitats, making them key to sustainable urban development.

#### *Urban Ecosystems under pressure*

The rapid urbanization of the 21st century and accompanied conversion of natural areas into impervious surfaces (Fenoglio, Rossetti and Videla, 2020) has placed immense pressures on biological diversity within city environments. This leads to significant ecological disruptions and loss of biodiversity.

#### *The need for effective mitigation strategies*

To understand the wildlife's response to urban factors, evidence is required to effectively determine mitigations strategies for urban planning advice. Comprehensive biodiversity assessment is however associated with major challenges.

- In the bigger scheme there is a persistent lack of comprehensive data across diverse and critical regions like the tropical zones. These gaps are the result of often fragmented data collection practices in which certain areas are under and others are overrepresented. These geographical and temporal biases lead to incomplete data coverage which negatively impacts the reliability of biodiversity insights (Troia & McManamay, 2016; Wetzel *et al.*, 2018).
- Data Bias has shown to present another major issue. It occurs due to unequal data collection and non-uniform sampling, where certain methods prioritize easily accessible locations or species. This prevents less accessible yet crucial ecosystems to be assessed. These biases can lead to skewed biodiversity assessments which can result in incomplete or misleading conclusions about ecosystem status and species health (Geijzendorffer *et al.*, 2016; Proença *et al.*, 2017). This becomes especially problematic in large unstructured data sets in which suffer from high variability and inconsistent quality making analysis and interpretation more challenging (Bayraktarov *et al.*, 2019).
- A further obstacle is the lack of a framework for standardized methods. There is a range of methods used, which lead to variability and inconsistent data collection approaches, which complicates the comparability and integration of data across different studies and regions. As noted by Geijzendorffer *et al.* (2016) on Essential Biodiversity Variables (EBVs) and standardized metrics this makes large-scale biodiversity assessments and policy alignments more complicated. This is because without universally accepted standards it becomes challenging to harmonize data and accurately track biodiversity dynamics over time.
- On the smaller scheme of assessments, we are also posed with challenges. Traditional biodiversity monitoring methods have predominantly relied on direct observations, species trapping, and manual surveys. However, these methods face numerous challenges. Conventional ecological techniques are time-consuming, often require extensive labour and expertise, can be invasive and potentially disturb or influence the species being monitored and pose a bias towards certain species. The

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required labour for data collection and processing limits the frequency of sampling and the number of locations (Hoffmann et al., 2010; Klink et al., 2022; Kühn et al., 2020; Montgomery et al., 2021; Stephenson et al., 2020; Wearn & Glover-Kapfer, 2019). While these methods are invaluable for a detailed, species-specific studies, they are also limited to temporal and spatial boundaries. This leads to data gaps as well as a restricted scalability, particularly in dynamic and densely populated urban areas settings.

These issues highlight the need for a coordinated, structured and bias-aware biodiversity monitoring approach. By improving the standardization of data, reducing geographic and taxonomic biases, ensuring a comprehensive scalable coverage of assessments and mitigating the downsides of conventional monitoring, more robust biodiversity insights in urban environments can be achieved. These insights would aid guiding governments, policymakers and city planners in creating more liveable spaces for humans and nature and potentially be applied in all other ecological landscapes as well.

### *Combining AI, eDNA and conventional methods for biodiversity monitoring.*

To address these challenges, we want to push forward the integration of novel and advanced technologies such as AI powered sensors and environmental DNA (eDNA) with conventional ecological methods that can offer a promising solution.

Newly emerged technologies such as AI-powered sensors offer revolutionary potential in biodiversity monitoring. AI can process complex data from images and sounds to continuously detect and classify species with greater speed and accuracy than human observers on a large spatio-temporal basis. Thereby a substantial reduction in manual labour and time is suggested as well as the study of animal population dynamics during spikes in air pollution, heatwaves and other climate-change related impacts could be groundbreaking. On the other hand, AI's effectiveness is restricted to the availability of substantial training data sets to ensure accuracy and it could struggle with identifying rare or cryptic species without having been trained with prior data (Beery, 2023; Norouzzadeh et al., 2021). This where the combination with other techniques would complement each other well, creating a synergy and compensating for individual drawbacks.

Another novel technique, environmental DNA (eDNA) sampling, has emerged, which involves collecting and analysing environmental samples (such as soil, water, air) for DNA traces shed by organisms in that environment. This presents a non-invasive way to assess a wide range of taxa, including cryptic and rare species which are often not detected by conventional methods if available in reference data base. This offers the ability to explore ecosystem-level processes, next to ecological and evolutionary ones (Bohmann et al., 2014). Furthermore, the sampling methodology is simple, rapid and doable by non-specialists. However, this method is more susceptible to environmental contamination and the data can be difficult to interpret without expert knowledge (Ficetola et al., 2008; Rees et al., 2014; The Biodiversity Consultancy, Cambridge, 2021).

It is apparent that each of these methods hold their own advantages and limitations but through the combined integration, these techniques hold significant potential to enhance urban biodiversity monitoring. For instance, AI can continuously analyse data from imagery and sound recordings to track biodiversity changes in real-time, thereby reveal early indicators of insect recovery as well as signs of population tipping points. Together with the broad detection spectrum of eDNA and using traditional methods to provide ground-truthing and detailed behavioural observations that AI and eDNA might miss, this integrated approach would not only improve monitoring efficiency but also enhance our ability to manage and conserve urban biodiversity more effectively. Furthermore, this innovative approach aims to address the lack of consistent, reliable data on arthropod and other wildlife populations.

### *Possible Support from non-scientists to advance emerging technologies*

Non-scientists such as residents or companies could also facilitate the widespread adoption of these monitoring techniques on their own premises and increase data collection efforts and expand sampling regions. Currently with applications such as iNaturalist and PictureInsect for example, citizens are already helping to compile visual and audio training data for AI and contribute to expanding essential reference libraries. Some projects that are based on DNA technologies, rely on the help of citizens for the collection of samples, which are then sent to the laboratory and analysed by scientists (Svenningsen et al., 2021). Therefore, if this project opens the opportunity to the integration of the said non-scientist's groups, through which accuracy and efficiency could be reinforced in AI determination, eDNA sampling, and expand spatial and temporal sampling efforts.

### *Research Integration and Innovation:*

This research proposal aims to synthesize these diverse, conventional and novel technologies into a unified, standardized framework and thereby address the gaps such as the lack of comprehensive, reliable population data that can operate effectively across various

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ecological landscapes and conditions (Basset et al., 2023; Wagner et al., 2021). The potential of a scalable, efficient, less invasive monitoring system could be groundbreaking for ecological research and future conservation practices.

Combining AI's processing power with the broad detection spectrum of eDNA and the precision of traditional methods can create a comprehensive and standardized monitoring strategy that leverages the strengths of each approach while mitigating their individual weaknesses.

This fundament is the foundation for the development of a biodiversity monitoring toolkit that is based on a novel and integrated multi-method approach with the goal at surpassing limitations of current methodologies and make use of the strengths of new technologies.

### b) Overall Aim

The goal of this research proposal is to create a new standardized methodology in form of a practical toolkit to conduct biodiversity monitoring by integrating AI-powered sensors, environmental DNA (eDNA) and traditional ecological methods into a comprehensive and adaptive framework. Within this framework its design is based on the enhancement of accuracy, efficiency and scalability of biodiversity assessment of urban settings. These measures are crucial for sustainable urban planning and conservations efforts. Eventually this framework will be transformed into a simple-to-use toolkit that can be used by different types of organizations, scientists, citizens and companies to maximize data collection efforts across various ecological landscapes.

The proposed approach is expected to provide deeper insight into population and biodiversity dynamics, through which timely and informed conservation decision-making efforts will be enabled and the lack of consistent and reliable data will be addressed. Furthermore, through the establishment of a robust, real-time monitoring system, we aim to bridge the gap between rapid urban development and the need to preserve urban ecosystems as well as effectively test nature-based solutions. This multi-method approach aims to create a new holistic picture of what biodiversity means and how it can be measured.

### c) Sub-Questions/Objectives

To fulfil the overall aim, the research will address several focused sub-questions/objectives:

1. Comparative Effectiveness: How do AI sensors, eDNA sampling, and traditional ecological methods perform individually and in combination when applied to urban biodiversity monitoring?
  - Objective: To determine the strengths and limitations of each method in urban settings (one case study) and identify optimal strategies for their integration.
2. Technological and Methodological Integration: How can an integrated monitoring framework be developed and tested that combines novel methods to maximize data accuracy and coverage?
  - Objective: To create a seamless workflow that utilizes AI for data collection, processing and analysis, eDNA for broad species detection, and traditional methods for in-depth, species-specific insights, and find a way to standardize and harmonize different data sets
3. Real-Time Monitoring and Data Analysis: How can real-time data analysis capabilities be implemented to provide ongoing insights into urban biodiversity trends?
  - Objective: To develop algorithms and models that can analyse large datasets in real-time, facilitating immediate ecological assessments and conservational responses.
4. Determine the Best Integration of Techniques: How can the various methods be optimally combined to enhance the efficiency and efficacy of biodiversity monitoring while addressing the limitations inherent in each technique?
  - Objective: Identify the most effective ways to integrate and deploy various methods to maximize data quality and insights, minimize invasiveness, conserve resources, and reduce costs and other drawbacks associated with comprehensive monitoring.
5. Toolkit Development: How can the methods be synthesized into an easy-to-use biodiversity monitoring kit for other scientists and the broader public/citizens science?
  - Objective: Use acquired information to develop an easy-to-use biodiversity monitoring kit for scientists and broader public. Synthesize kit into a usable product that can be easily deployed, set-up, collected and used by scientists, citizens and non-scientists organisations like governments, companies etc.

### d) Scientific Originality and Innovation

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Our proposed research presents scientifically innovative and original approach in the field of urban ecology for a range of reasons.

- **Interdisciplinary Approach:** Within the AMS-Institute we follow an interdisciplinary approach to solve current (urban) biodiversity monitoring problems by blending AI (computer science from MIT and TU Delft), biotechnology (eDNA with University of Wageningen) and ecology (University of Wageningen). The fusion of these fields presents a leap forward in ecological monitoring techniques.
- **Advanced Data Integration and Analytics:** This project will aim to streamline and harmonize the different types of data sets that emerge from the different methods into comprehensive reporting structure. Furthermore, the goal is to develop models and algorithms which integrate and analyse data from diverse sources (AI sensors, eDNA, traditional surveys) in real time. This approach can provide immediate and actionable insights into the status of ecosystems and biodiversity.
- **Community Centric Science Tool Kit:** The development of the urban biodiversity monitoring toolkit, is tailored in such a way that it in the future prospect citizens and other parties, besides scientists can take part in science and conservations efforts. This will lead to non-scientists also being able to contribute meaningful data but also help educate and the public and raise greater awareness and foster more community and company involvement in urban conservation efforts. Furthermore, this can lead to data collection being done in areas, where universities don't yet have a focal point.
- **Policy-Relevant Outcomes:** The outcomes of the researched are designed in such a way that they are directly applicable to urban planning and policy making. By providing this type of data, this project can make a substantial impact on faster and more nuanced urban management.
- **Global Impact and Applicability:** The scalable nature of this system means that it could be adapted in cities and geographical regions around the world, making it a globally relevant innovation. The universal applicability through which consistent, reliable data is ensured could lead to a grant improvement of global biodiversity assessments.

All these aspects lead to this project not only advancing scientific knowledge but also providing and contributing to practical solutions to combat current environmental challenges that (urban) areas are faced with.

### B.2.2 Approach (How)

Describe the proposed research (a), i.e. which methods and techniques will be used, and discuss their applicability and accessibility. Include a detailed work plan (b) and indicate the duration of the proposed research.

#### a) Proposed Research Methods and Techniques

Our proposed research will apply a multi-method approach by integrating AI-based technologies, eDNA sampling, and conventional ecological survey techniques. Thereby, the unique advantages will be leveraged, and the limitations of each method are compensated. This approach aims to provide a nuanced and comprehensive understanding urban biodiversity. This is how each method will be utilized:

##### *AI-based sensors*

**AI-based sensors:** These sensors will both utilize image and acoustic recognition capabilities to monitor and classify species diversity and activity, next to measuring environmental conditions like humidity and temperature. The AI architecture for image detection is based on YOLO (You Only Look Once), a real-time object detection system that stands out for its accuracy and speed, offering state-of-art technology in image detection (Jiang et al., 2021; Plastiras et al., 2018). The acoustic recognition software is Kaleidoscope Pro, which has proven successfully in automated passive monitoring of birds and bats (Knight et al., 2017; Pérez-Granados & Schuchmann, 2022). The output of visual AI processing will consist of taxa lists, activity, abundance and interactions between organisms. The acoustic AI can give insight over taxa lists, activity and occurrences. AI will process visual and sound data to track abundance and richness of species during day and nighttime (Klink et al., 2022). The AI models will furthermore be trained on extensive datasets to ensure high accuracy in species identification.

##### *Environmental DNA*

**Environmental DNA (eDNA):** eDNA sampling will be used to detect biological material from environmental samples such as water, soil, and faeces. Samples will be collected and sent to the laboratory for genetic analyses. This will help uncover species that are elusive, hard to assess or only present in low numbers. With the data base from the metabarcoding project ARISE from Naturalis Biodiversity Center, a non-invasive way to assess the broad-spectrum occurrence of all living organisms in the sampling area is provided. From that, information such as taxa list, species occurrence, interactions (mutual, parasitic, symbiotic relationships,) and trophic relationships can be gathered (Klink et al., 2022; Wolfgang et al., 2022).

##### *Conventional Ecological Methods*



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Conventional Ecological Methods: These will consist of observational visual surveys, point counts, transect walks, pitfall traps, quadrat sampling and pan-traps. These traditional methods provide critical data on various aspects of biodiversity and population dynamics which is indispensable for ground truthing observations derived from the novel technologies. They are critical for validating the findings from AI and eDNA analyses and for providing data on the ecological context which the novel methods might miss. In this way, the conventional research together with AI and eDNA can achieve a more holistic and comprehensive view of urban biodiversity in which the breadth and depth of ecological assessments is enhanced.

### *Combining the best of all worlds*

By combining these methods, the spatial and temporal coverage of biodiversity assessments will be drastically increased. After initial testing each of the methods will be deployed in such a way that resources are optimized, and the overall effort and costs are reduced. Through the integration of these methods, multiple data points and validations across techniques will provide deeper ecological insights, enhanced data reliability and a more robust overview.

Therefore, this study will develop standardized protocols for the effective integration of these methods.

This research will focus on one intervention as a case study, which has the advantage of not having to take varying environmental conditions into account, as for all used methods are exposed to the same conditions.

### Applicability and Accessibility

This research will be conducted as a PhD candidate within the AMS-Institute (Institute for Advanced Metropolitan Solution, Amsterdam). Through the collaborative nature of AMS-Institute with MIT Senseable City Lab, TU Delft, University of Wageningen and the Municipality of Amsterdam, a broad access to research groups and resources is available. Therefore, collaborations with computer scientists, data scientists, biotechnologists, ecologists, urban planners are in place. Additionally, a collaboration with Naturalis Biodiversity Centre and their program of ARISE and Bioacoustics AI project will be set up. These partnerships offer applicability and accessibility.

- The AI-based sensors which MIT is developing, offers a versatile tool that can be applied in species identification through image and sound analysis, real-time data processing and predictive modelling of biodiversity trends. It is accessible through the collaboration with MIT, as their research group has paved the way for creating a well-trained open-source YOLOv8 model drastically increasing the access (Venverloo & Duarte, 2024).
- eDNA can be applied in a wide variety of environments, from terrestrial to aquatic to systems even to the atmosphere. This makes it a valuable tool for indirectly detecting species by not having to visually confirm or the need to capture individuals. The biotechnological laboratory facilities necessary for the eDNA sample processing and expertise in molecular techniques will be provided by The University of Wageningen. Sample collection can later be done by laymen as well as scientists, as it consists of taking samples from the environment and simply sending them to a laboratory.
- Conventional methods such as trapping, direct observations and manual surveys have been the norm in ecological research and are almost universally applicable. They are essential for ground-truthing data obtained by other methods and give insight into direct and detailed evidence of species behaviour, abundance and population dynamics. These methods are very accessible in terms of technology and cost, and therefore widely used in varied ecological research. However, they do require extensive human labour, niched expertise, and the scalability is thereby largely limited in time and area that can be covered.
- Access to research areas will also be granted easily through the AMS-Institute which works tightly together with the municipality of Amsterdam, which can provide a variety of interventions sights as the municipality is of great interest to test and figure out if their interventions are achieving the desired effect of biodiversity increase they are aiming for.

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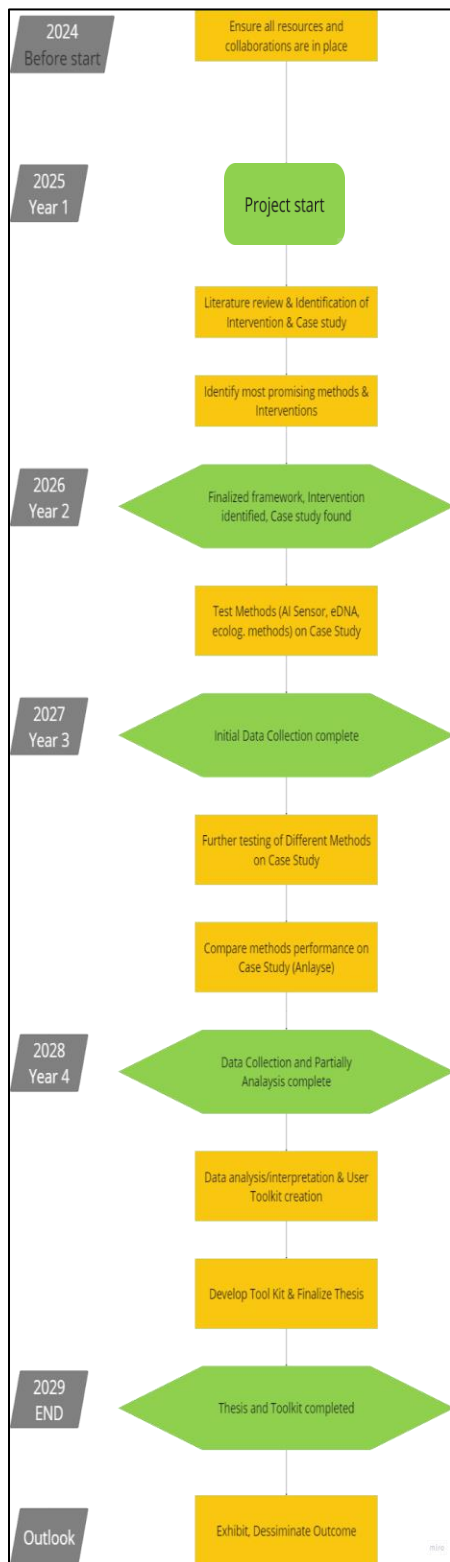


Figure 1: Timeline of workplan

## b) Detailed Work Plan and Duration

Year 1: Setup and Preliminary Studies: To ground the project in robust scientific knowledge and select a suitable urban intervention for detailed study.

- Tasks:
  - **Literature Review:** Conduct a comprehensive literature review on existing biodiversity monitoring metrics and techniques, focusing on how AI sensors can be integrated and used with eDNA and conventional ecological methods as well as data integration.
  - **AI-Sensor calibration:** Develop, calibrate and train AI models using existing datasets.
  - **Selection of Intervention:** Select and prepare one urban intervention site as focal study area.
  - **Research Framework Definition:** Develop a detailed research framework that outlines the comparative study of AI sensors, eDNA, and conventional methods.
  - **Publish Paper:** Publish the literature review and framework

• Duration: 12 months

Year 2: Implementation and Initial Data Collection: To implement and initially compare the effectiveness of AI sensors with eDNA and conventional methods in a controlled setting.

- Tasks:
  - **Implementation:** Begin Data Collection at chosen sight of intervention:
    - Deploy AI sensors at the intervention site.
    - Begin regular eDNA sampling across various points within the site.
    - Conduct monthly conventional ecological surveys.
  - **Initial Comparative Analysis:** Start preliminary data analysis to refine methods and integration protocols. Assess data quality, species identification and system integration effectiveness
  - **Method Refinement:** Address and troubleshoot data integration issues, adjusting methodologies as necessary based on findings.

○ **Performance Benchmarking:** Establish performance benchmarks based on initial data comparisons.

• Duration: 12 months

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Year 3: Intensive Data Collection and Analysis: To extensively test all methods under various urban conditions and conduct a thorough comparative analysis, insight into optimal configuration, Exhibit and Publishing.

- Tasks:
  - **Full-Scale-Testing:** Continue with systematic AI monitoring, eDNA sampling, and conventional surveys.
    - Include environmental data such as: humidity, temperature, VOC's, air pollutants, seasonal variations
  - **Data Analysis:** Conduct detailed data analysis to compare the effectiveness, comprehensiveness, reliability and cost-effectiveness of different methods.
  - **Method Refinement:** Enhance data integration protocols based on initial findings with research partners and stakeholders.
  - **Presentation and Publication:** Write paper and publish paper on early findings. Take part on exhibit to promote community engagement and awareness (Dutch Design Week, NEMO, Naturalis)
- Duration: 12 months

Year 4: Final Analysis, Development of the Toolkit, and Dissemination: To synthesize the findings into actionable insights and develop a toolkit that can be utilized by both researchers and the public.

- Tasks:
  - **Synthesis of Findings:** Finalize data collection and perform comprehensive data analysis.
  - **Toolkit Development:** Develop a user (scientist, citizen, company, government) science toolkit, which includes easy-to-use tools, educational materials, and guidelines based on the research findings
  - **Presentation and Publication:** Write and defend the PhD thesis; prepare and publish research papers; host workshops to disseminate toolkit and present findings at conferences and public forums. Finalize and defend the PhD thesis.
- Duration: 12 months

Future Prospect: **Public Engagement, Feedback Impact Assessment, Widespread Adoption** of kit by government, citizens, (ecological) companies

The proposed research is laid out to be completed in the set time frame of 4 years, with each year being dedicated to specific sequential tasks that build upon previous work. With this timeline, thoroughness and success in research execution, data analysis and dissemination are ensured.

### B.2.3 Feasibility / Risk assessment

Discuss the feasibility of the research proposal and indicate the possible risks involved with the proposed research, including risks from the methods, techniques, etc. Indicate how these risks can be mitigated and whether an alternative approach (plan B) exists.

Optional: describe how the proposed research and investment fit with the participating researcher(s) and techniques and equipment available in the lab (embedding).

#### Feasibility of the Research Proposal

The proposed integration of AI-powered sensors, environmental DNA (eDNA), and traditional ecological methods into a comprehensive urban biodiversity monitoring system stands on the cutting edge of ecological research. Several key factors ensure the feasibility of this ambitious project:

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- *Technological* *readiness:*  
Both AI and eDNA technologies have already reached a level of maturity that allows for their widespread application in ecological monitoring. Numerous wildlife studies have proven AI's capabilities to correctly identify and classify species from vast amounts of data sets automatically. Its use is already wide spread in applications like iNaturalist, PictureThis, ObsIdentify and PictureInsect (e.g., [www.iNaturalist.org](http://www.iNaturalist.org) [www.picturethisai.com](http://www.picturethisai.com) and <https://observation.org/apps/obsidentify/>) (developed by Naturalis). Similarly, eDNA has shown to be able to detect even miniscule DNA traces from the environments, providing an accurate insight into species occurrence without the need of physical sighting and is extensively being used in metabarcoding project "ARISE" (Klink et al., 2022).
- *Infrastructure* *and* *Expertise:*  
The AMS Institute has access to various laboratories that are equipped with the necessary technology for high-throughput genetic sequencing (Wageningen University), sophisticated AI computations (MIT/ TU Delft) and arthropod classification equipment (Naturalis / Wageningen) and a Makerspace (AMS-Institute) to develop the monitoring toolkit. These facilities include the hardware that is needed for the extensive data storage and analysis, which is crucial for processing the large data sets from all monitoring techniques.
- *Interdisciplinary* *Collaboration:*  
The AMS-Institute constitutes a range of experts from various fields, including machine learning (MIT/TU Delft) molecular biology (Naturalis / Wageningen), urban ecologists (Wageningen University) as well as a tight link to governmental institutions (AMS-Institute / municipality Amsterdam), which ensures a comprehensive approach. This diverse expertise is inevitable for approaching the complex challenges of the integration and interpretation of different technologies into an ecological context.
- *Institutional* *support:*  
As this project is hosted by the AMS-Institute (Institute for advanced metropolitan solutions) which has a strong focus on sustainable, future proof and urban ecological research, an encouraged environment for such pioneering studies is guaranteed. The commitment from the institution to these areas ensures ongoing support for funding, infrastructure and academic dissemination.

### Risk Assessment

Despite the strong feasibility foundations of this project, there are certain risks that could affect its success:

#### *Integration complexity / Standardization of Data and Interoperability:*

- Risk: Combing diverse data formats and scales from AI, eDNA and traditional ecological data creates a great complexity in integration. This can lead to challenges and difficulties in data aggregation, harmonization and analyses.
- Mitigation strategy:
  - Adopt standard metadata and data protocols (e.g. Darwin Core or Ecological Metadata Language) to ensure that interoperability with other biodiversity data bases is ensured.
  - Conduct early-stage pilot studies to identify and troubleshoot integration issues and adjust methodologies based on these findings
  - Develop a software tool that integrates and harmonizes input from different sensor and data sources

#### *Data Volume and Management / Data Overload and Storage:*

- Risk: Large volumes of data generated by AI and eDNA analyses may cause the storage and management systems to overload and result in data loss or mismanagement.
- Mitigation strategy:
  - Use of edge computing to pre-process data locally and only transmit essential information or reduce overload and ease transmission
  - Implement state-of-the-art data management systems which are tailored to handle high-throughput ecological data including storage backups and data compression tools

# TEMPLATE APPLICATION FORM (based on NWO Open Competition Domain Science – M)

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## *Technological reliability*

- Risk: High-tech equipment is susceptible to processing errors or malfunctions which can affect data accuracy
- Mitigation strategy:
  - Conduct regular calibration and maintenance protocols to ensure reliable operation and data quality
  - Implement quality controls protocols at each stage of data management; from collection of samples to processing, to analysing

## *Maintenance and Durability*

- Risk: Monitoring equipment exposed to harsh environments is prone to wear and degradation, impacting durability and longevity of monitoring devices.
- Mitigation strategy:
  - Use weather-resistant material in construction and establish preventive maintenance routines

## *Taxonomic Impediments*

- Risk: Limited reference data bases can hinder accurate identification which can lead to incomplete, skewed or biased biodiversity data – especially for rare and cryptic species
- Mitigation strategy:
  - Further train machine learning algorithms, with newly collected data
  - Build collective databases and share resources with institutions and researchers focused on rare species

## *Security/Vandalism*

- Risk: Monitoring stations are prone to be subject to vandalism or theft, leading to data loss or high replacement costs
- Mitigation strategy:
  - Chose case study in a safe environment, which is not accessible by public

Despite the risk analysis and mitigation strategies laying a strong foundation for feasibility, risks can remain. This Plan B offers an alternative framework to manage these challenges.

## Alternative Approach (Plan B)

If the integration of all three monitoring methods shows to be problematic, the research could switch to a more phased approach:

- Phased implementation: One could first focus on integrating two of the methods (e.g. AI and conventional observations), optimize that system and then start to incorporate eDNA. Through this stepwise approach a solid foundation of the integration of techniques and troubleshooting methods can be first established, which can then be applied later as well
- Modular development: One measure could be to develop each method independently to its fullest potential before the integration. This way each method can stand alone, still providing valuable data, if the integration seems too challenging.

## Research and Investment Fit

The proposed research aligns well with the capabilities and objectives of the participating research groups and institutions. The collective expertise complements the project's needs and the specialized knowledge and skill that each member brings and thereby contributes significantly to the innovative approach of the project. The available laboratory equipment and research facilities are suited to support the extensive genetic, computational, and fieldwork demands and requirements of this project. Therefore, high-level research without additional investments needed in further infrastructure can be conducted.

Furthermore, the institution could result as a leader in urban ecological research with the innovative nature of this project's approach to urban biodiversity monitoring. This could lead to new partnerships, funding opportunities and academic collaborations. This not only

reinforces the feasibility of the project, but moreover increases its potential to contribute significantly to scientific advancements and practical conservation strategies.

### **B.2.4 Scientific (a) and societal (b) impact**

Include a perspective on the short and long term impact the proposed research will have on its own research field. Highlight the relevance to other scientific and societal areas. If applicable, give a possible application perspective and describe how the output of the proposed research can lead to new insights and/or technologies in society or industry.

#### **a) Scientific Impact**

##### *Short-Term Impact:*

In the short term, this proposed research will significantly advance the field of urban ecology by developing an integrated framework that joins AI-powered sensors, eDNA and traditional ecological methods. Thereby, immediate improvements in efficiency, accuracy and thoroughness of biodiversity monitoring will be achieved. This will lead to rapid data collection and analysis which in turn result in faster responses to biodiversity changes and more fitted conservation strategies. The academic output from this project is expected to entail several high-impact journal publications, presentations at international conferences and workshops aimed at disseminating and spreading the adoption of the developed methodologies and tool kit.

##### *Long-Term Impact:*

In the long term, this research project's goal is to redefine the standard practices within urban ecology but also broader ecological monitoring disciplines. A novel and easily adoptable framework for how biodiversity data is collected, integrated, analysed and interpreted will be created. Consequently, this research will pave the way for future research initiatives and hopefully influence policy and planning at not only local but also global scale. The widespread adoption of a monitoring strategy that is scalable, efficient and less invasive, could contribute to global conservation efforts in different ecological and geographic contexts. Additionally, this work will be an example of how an interdisciplinary research approach can lead to success and act as the foundation for training the next generation of ecologists, with knowledge in cutting edge technologies.

Regarding other academic sectors, these research efforts could therefore also advance other scientific fields such as landscape ecology, environmental sciences, data science, computer sciences and facilitate future interdisciplinary collaboration and knowledge exchange.

#### **b) Societal Impact**

##### *Short-term Impact:*

In the short run, this project will contribute to public awareness and engagement regarding current urban biodiversity challenges, by inviting the public to workshops and dissemination events.

##### *Long-term Impact:*

In the long run this research can drastically increase public awareness and citizen engagement regarding urban biodiversity challenges. They will be integrated into data collection and determination processes and by allowing citizens and other non/scientists to set up monitoring kits in their own surroundings, a feeling of empowerment and great contribution could be achieved. Furthermore, profound impacts could be achieved in how cities and government plan and implement green infrastructure projects and how they strategize urban developments. By being able to provide city planners and governments with accurate and real-time data on urban biodiversity changes, smarter and more sustainable urban developments can take place that align with biodiversity conservation goals. This could result in a healthier and more resilient urban environments that provide ecological balance and a higher quality of life for residents.

The newly developed insights could also find application in industrial sectors. For example, real-estate developers or architects could integrate this monitoring tool to design and create more sustainable living spaces. Furthermore, governments could make use of biodiversity assessments to ensure that they comply with environmental regulations and validate if their measures and interventions are successfully working.

Additionally, this project can contribute to new technologies. For example, new sophisticated AI algorithm detection technologies, new data bases, data merging technologies and statistical methods, and finally a new user-friendly biodiversity monitoring toolkit will be created. These fields have the potential to be further developed in future stages.

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By addressing these various impacts, there is great potential for this research to deliver long reaching, practical and actionable solutions for science, society, industry and nature.

## B.2.5 Ethical considerations

Describe relevant ethical issues concerning your research proposal.

To ensure that our research that combines AI-powered sensors, eDNA and traditional ecological methods for urban biodiversity monitoring is conducted responsibly we must assess several ethical considerations.

### Data Privacy and Security of Eco surveillance

- **Concern:** Using AI-sensors and eDNA techniques large amounts of photo, acoustic and genetic data is collected. Some of this information could contain private information from individuals, especially when set up in urban areas.
- **Mitigation:** Implement data privacy protocols in which all data is anonymized and secure. Another step is to encrypt the data, ensure secure data storage and adhere to relevant data protection regulations.

### Impact on Local Communities and Their Environment

- **Concern:** Some community members could rise suspicion and distrust regarding surveillance through the deployment of the monitoring station.
- **Mitigation:** Engage with the residents with informational workshop sessions before deployment. Set up information board that clearly states the purpose, benefits and prospects of the station.

### Handling of eDNA Samples

- **Concern:** Working with eDNA samples poses a risk of other environmental contamination. Therefore, sample collection and analysis must be done carefully. Furthermore, eDNA samples, could be used for other purpose than the one intended for the research, which could raise questions of misuse and consent.
- **Mitigation:** Strict data collection, handling and storage laboratory protocols should be followed, to minimize the risk of contamination. Clear rules and guidelines should be established for the handling of eDNA samples to ensure that they are only used for the intended purpose of our research. Follow strict protocols for the collection, handling, and storage of eDNA samples to minimize contamination and errors. Emphasis on the creation understandable sampling protocols for laymen.

### Use of AI in Monitoring

- **Concern:** AI models can introduce biases based on the data sets they were trained on. With limited training data (typically for cryptic or rare species) AI models tend to perform poorly and with disproportionately large amounts of data (typically for conspicuous data) they tend to overpredict.
- **Mitigation:** Several public and validated reference libraries could be combined from iNaturalist, ImageNet, GBIF (Global Biodiversity Information Facility). These should be updated regularly as well as the evaluation of AI models for accuracy and bias should be done. The AI findings should regularly be checked by ecological experts so that reliability and comprehensiveness of the assessments are validated and ensured.

### Use of conventional ecological methods

- **Concern:** Often trapping methods are associated with invasive procedures in which organisms die or their habitats disturbed. This can have an especially negative impact on rare species or fragile ecosystems.
- **Mitigation:** Try to employ less invasive or minimally invasive methods wherever possible over intrusive or lethal ones. It is important to conduct a prior essay of the ecosystem at the sight, to adjust methods and installations to reduce harm and invasion.

### Ethical Use of Research Findings

- **Concern:** The resulting research findings could lead to certain actions being justified that have a negative effect on biodiversity for example when the removal of certain species could be seen as less important.

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- Mitigation: All the research findings should be presented in a balanced manner, where all species regardless of their perceived value are seen as ecologically important. Furthermore, the data interpretation of policymakers and urban planners should be taught coherently so that misinterpretation does not lead to actions that diminish biodiversity conservation efforts.

All these ethical considerations are key factors in the design and execution of the research proposal. By following them responsibly, the nature of the research will have positive contributions to urban biodiversity monitoring and conservation, while simultaneously aligning with values of residents and the protection of the environment.

### B.2.6 Literature/references

The list of references should be relevant to the research proposal, cited in the texts of section B.2. The list should not include internal documents (such as master theses).

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Figure 1: Timeline of workplan .....10

Supplementary:

**Use of AI:**

In my research i am writing a phd proposal for the approach of combining AI, eDNA and traditional methods to enhance urban biodiversity monitoring. can you come up with some titles?

**ChatGPT said:**

ChatGPT

Certainly! Crafting an engaging and descriptive title for your PhD proposal is crucial as it sets the tone and provides a concise preview of your research focus. Here are several title suggestions that encapsulate the essence of your project, highlighting the integration of AI, eDNA, and traditional methods for enhancing urban biodiversity monitoring:

1. **"Integrating AI and eDNA with Traditional Ecological Methods for Enhanced Urban Biodiversity Monitoring"**
2. **"Fusion of Technology and Ecology: A Novel Approach to Urban Biodiversity Monitoring"**
3. **"Revolutionizing Urban Biodiversity Assessments: A Multi-Method Approach Involving AI, eDNA, and Conventional Techniques"**
4. **"Towards a Holistic Urban Ecosystem Assessment: Integrating Artificial Intelligence and Environmental DNA with Traditional Methods"**
5. **"Synergistic Biodiversity Monitoring: Combining AI, eDNA, and Traditional Ecological Practices in Urban Landscapes"**
6. **"The Next Frontier in Urban Ecology: Multi-Technique Biodiversity Monitoring Using AI, eDNA, and Traditional Methods"**
7. **"Bridging Technology and Nature: Advanced Methodologies for Urban Biodiversity Monitoring"**
8. **"Advancing Urban Biodiversity Monitoring Through the Convergence of AI, eDNA, and Traditional Ecological Methods"**
9. **"Urban Eco-Synthesis: A Comprehensive Approach to Biodiversity Monitoring with AI and eDNA Technologies"**

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### 10. "Enhancing Urban Biodiversity Insights: An Integrated Monitoring Approach Using AI, eDNA, and Traditional Methods"

Each title is designed to reflect the innovative blend of technological and traditional methodologies that your research proposes, emphasizing the advancement of urban biodiversity monitoring and the comprehensive assessment approach you plan to explore.

- OpenAI. (2024). *ChatGPT* (Nov 24 version) [Large language model]. chat.openai.com/

Hi I am supposed to write a NWO Open Competition Domain Science – M applying for a phd position. These are my notes: Can you help me structure a concrete idea taking Amsterdam as a main focus city - Ideas for research proposal: o Urban ecology o Biodiversity o NBS solutions - - SENSING GARDEN: - AI model classification model, picture of dog = dog, system was trained on dog data model, next iteration - from classification to detection (rather than saying image of dog this is an image and HERE is the dog (pinpointing) = being able to count and pinpoint several objects in one image, make it and integrate with current code. - Second objective: what camera, thermal camera, audio, all different types of technologies add ons, what sensing tech can help to make detection - Community driven approach (diagnosis opposite, no open source, no sharing, only classification, they don't publish anything, - Titius Everything OPEN SOURCE, NOT ON CODE, TECHNOLOGY, OPEN SOURCE WITH PURPOSE - We need to invest into monitoring technology - Key aspect for scientific device: - Biobased 3D printed casing for device. - Natural looking systems - Scientifically Back up interventions - Develop case study/ prototypes - Tech ready in March USE OF sensing garden as method Think of different set up of camera Help develop biobased prototype for SEND to Titius every now and then, support letter from Marine Terrain and MIT? MIT and AMS (Biodiversity possible, agreement for next 5 years) If submit, submit with local PI and Professors, (NWO doesn't fund American institutes, only European) Figuring out indicator species for cities that indicate the health, try to link figure out (biology tool box, air quality) have sensors, biological tool box Check indicator species? Can you design a basic sensor / tool box from that Have a simple idea: biological tool box, look for certain tool boxes, What is already being measured, what indicators are out there Talk to Thijs Turel Use biology for more privacy friendly measuring system Look at what grant is asking for!! On website! Monitoring BD but also look at what other interventions (urban reef) could help improve BD, talk to urban reef How to monitor interventions, Using organisms as a measuring tool monitoring current state look at different ways to monitor: plan of what you would like to research and think of how to do it Meeting: - Discuss pages and words - Open mind proposal, - Symbiotic city, planetary health (ELS workshop), as her input Meeting: showing our materials (urban reef), me, Patricia (both a bit uncertain) Expect them to have a design, first ideas Idea is to make print this year, we can offer that we can make their 3D prints, and thereby be part of their exhibition What is feasible for this Dutch design week? Start with a framework of how it should look Take AMS as context

#### ChatGPT said:

ChatGPT

It sounds like you have a great foundation for your research proposal, which centers on urban ecology, biodiversity, and nature-based solutions (NBS), with a focus on Amsterdam as your case study city. The idea of a "Sensing Garden" is especially interesting, as it can combine cutting-edge AI and monitoring technologies with ecological research in a community-driven and open-source framework.

Here's a structured approach to help you organize your ideas into a coherent and compelling proposal:

#### Title:

"Sensing Garden: Integrating AI, Urban Biodiversity, and Community-Driven Nature-Based Solutions in Amsterdam"

#### 1. Introduction & Background

- **Context:**
  - Introduce the challenges faced by urban areas like Amsterdam due to biodiversity loss, climate change, and urbanization. Cities are hotspots for environmental issues, but they also offer opportunities for nature-based solutions (NBS) and urban ecology interventions.
  - Highlight the growing interest in monitoring biodiversity and the importance of urban ecosystems to city resilience.
- **Urban Ecology in Amsterdam:**
  - Discuss why Amsterdam is a suitable case study. Mention its efforts to become a sustainable city, its focus on biodiversity, and existing environmental initiatives (AMS Institute, Marine Terrain collaboration).
- **Research Gap:**
  - Identify the gap in existing urban monitoring technologies: while classification technologies (such as AI models detecting objects in images) exist, they lack accuracy in pinpointing biodiversity changes, integrating various sensors, and community engagement.

#### 2. Research Objectives

- **Main Objective:**

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- Develop and implement a “Sensing Garden” as an open-source tool for monitoring biodiversity and ecological health in urban environments like Amsterdam.

- **Specific Objectives:**

1. **AI & Detection:**

- Evolve AI models from basic classification (e.g., detecting a dog in an image) to pinpointing and counting multiple species, tracking their behavior over time.

2. **Sensing Technologies:**

- Integrate multiple types of sensors (e.g., thermal cameras, audio sensors, biological sensors) to enhance biodiversity detection.

3. **Community Engagement & Open Source:**

- Develop a community-driven approach where residents contribute data, and all tools and results are openly shared for greater transparency and collaboration.

4. **Biobased Prototypes:**

- Create biobased, 3D-printed casings for the sensors to minimize environmental impact and blend naturally into urban green spaces.

### 3. Theoretical Framework

- **Nature-Based Solutions (NBS):**

- Define NBS in the context of urban biodiversity. Cite the role of NBS in promoting biodiversity, urban cooling, flood control, and other ecosystem services.

- **Ecological Monitoring:**

- Discuss current methods of monitoring biodiversity (e.g., indicator species, air quality, biological toolboxes) and their limitations. Highlight how a new sensor network could improve accuracy and scalability.

- **Planetary Health & Symbiotic Cities:**

- Link your work to broader concepts like planetary health, where human and environmental well-being are interconnected. Explain how a "symbiotic city" could harmonize human development with urban ecosystems.

### 4. Methodology

- **Prototype Development:**

- Create a biobased, 3D-printed sensor housing that fits the aesthetic of natural ecosystems. Collaborate with local partners (e.g., Urban Reef) to design and test prototypes.

- **Sensing Garden Setup:**

- Deploy a network of sensors (e.g., cameras, thermal, audio, and environmental) in key green areas in Amsterdam (e.g., parks, community gardens).
- Use AI models that classify, detect, and track species, integrating data from multiple sensor types to monitor species activity and ecosystem health.

- **Community-Driven Approach:**

- Involve local residents in collecting and interpreting data through an open-source platform. Consider ways to make the data accessible and actionable for both scientists and citizens.

- **Biological Toolbox:**

- Explore the use of indicator species as a measure of urban health (air quality, pollution levels). Design a "biological toolbox" based on these species and link it to real-time sensing data.

- **Scientific Backup & Monitoring of Interventions:**

- Use data to evaluate the impact of NBS interventions, such as urban reefs or green rooftops, on biodiversity over time. Analyze which interventions work best in promoting urban biodiversity and resilience.

### 5. Expected Outcomes

- **Improved Biodiversity Monitoring:**

- The sensing garden should allow for more precise and real-time monitoring of urban biodiversity in Amsterdam.

- **Community Participation:**

- Residents become active participants in urban ecological monitoring, contributing to a greater understanding and protection of local biodiversity.

- **Open Source Impact:**

- All tools, data, and models are openly shared, fostering collaboration between cities, researchers, and citizens globally.

- **Sustainable Urban Design:**

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- The biobased sensor housing and other prototypes contribute to more sustainable urban development practices, integrating nature into the cityscape.

### 6. Timeline & Deliverables

- **Year 1:**
  - Develop AI models, design and test sensor prototypes (in collaboration with Urban Reef), set up initial sensing gardens in pilot locations in Amsterdam.
- **Year 2:**
  - Deploy sensors across more locations, begin gathering data, engage with the local community through workshops, and refine AI and sensor systems based on feedback.
- **Year 3:**
  - Analyze data, evaluate the impact of NBS on biodiversity, and scale the sensing garden concept to other cities or urban settings.
- **Ongoing:**
  - Collaboration with local partners (AMS, Marine Terrain, etc.), integration with future urban biodiversity projects, and publication of findings.

### 7. Collaborators & Support

- **Local and International Partnerships:**
  - Collaborate with AMS Institute, MIT (for biodiversity monitoring), and local professors and scientists to bring an interdisciplinary approach to the project.
- **Funding:**
  - Secure funding through the NWO Open Competition and explore co-funding from local government and private stakeholders.

### 8. Conclusion

- Summarize how the Sensing Garden will advance urban biodiversity monitoring and make Amsterdam a leader in sustainable, nature-based urban interventions. Highlight the importance of open-source tools and community engagement in addressing global biodiversity challenges.

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This structure organizes your key ideas into a focused research proposal. You can expand on each section, adjusting the level of detail to match the NWO's expectations and guidelines for the competition.

- OpenAI. (2024). *ChatGPT* (Nov 24 version) [Large language model]. [chat.openai.com/](https://chat.openai.com/)