Breeding Endangered Beetles – An EPS@ISEP 2024 Project

Cedric Florus[1], Jennifer Lattunen[1], Julius Knäuper[1], Krzysztof Jugiel[1], Marion Silva[1], Thomas Dekkers[1], Abel J. Duarte[1,2,3], Benedita Malheiro[1,4], Cristina Ribeiro[1,5], Jorge Justo[1], Manuel F. Silva[1,4], Paulo Ferreira[1], and Pedro Guedes[1,4]

[1] ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, 4249-015 Porto, Portugal
[2] REQUIMTE/LAQV, ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[3] CIETI, ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
[4] INESC TEC, Campus of Faculdade de Engenharia da Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[5] INEB, Rua Alfredo Allen, 208, 4200-135 Porto, Portugal
epsatisep@gmail.com
https://www.eps2024-wiki4.dee.isep.ipp.pt/

Abstract. Habitat loss, climate change, and pesticide use are key threats affecting beetle populations. This paper describes Scarabreed, a project that contributes to mitigate the beetle decline crisis. It was carried out by a team of six European students from different engineering fields and nationalities within the European Project Semester (EPS) at the Instituto Superior de Engenharia do Porto (ISEP), a project-based and teamwork learning framework. The designed solution – the Beetle Breeder Version 2 (BBV2) – consists of a smart modular vivarium created especially for beetle breeding. It monitors and controls relevant habitat parameters and offers two user-friendly interfaces (on-device and a Web application). The innovative modular structure of the vivarium allows easy scaling, customisation, and transportation. As a whole, the project offers significant environmental benefits: (*i*) facilitates the captive breeding of endangered beetle species, promoting population restoration efforts; (*ii*) fosters, as an educational tool, youth and general public awareness about the crucial role beetles play in ecosystems; and (*iii*) adopts eco-efficient and responsible business practices by following ethics and sustainability driven design and marketing.

Keywords: Engineering Education · European Project Semester · Beetle Modular Vivarium · Smart Monitoring · Sustainability.

1 Introduction

Once the most abundant animal species on Earth, representing 28 % of all known species, beetle populations are experiencing a worrying decline [3]. This decline

disrupts the intricate web of life within ecosystems, jeopardising global biodiversity. Research indicates that up to 40 % of all insect species, including beetles, may disappear within the next few decades as a result [11]. Such a loss of biodiversity would produce a cascading effect, affecting entire ecosystems and, ultimately, human well-being. Scarabreed addresses this challenge by offering a smart modular vivarium specifically designed for beetle breeding.

This document reports on the learning experience of Team Scarabreed, a team of international students who took part in the European Project Semester (EPS) [4] at the Instituto Superior de Engenharia do Porto (ISEP). The EPS programme fosters a unique environment where students from various countries and academic backgrounds can work together to tackle real-world challenges [6]. This project exemplifies this collaborative spirit, focusing on the design and development of a smart, market-relevant, sustainable and ethically sound solution. The following sections cover the decline of beetle populations and related projects, unveil the innovative features of the proposed solution, outline the development process from concept to prototype, supported by market, ethics and sustainability analyses, and conclude with the achievements.

2 Preliminary Studies

The initial studies included research into beetle conservation, existing solutions and the ethical and sustainability concerns relating to beetle breeding.

2.1 Related Work

Beetle populations are declining due to various threats affecting their life cycle and habitat. The International Union for Conservation of Nature (IUCN) Red List, published every two to five years, assesses the extinction risk of various species, including animals, insects, plants, and fungi. Specifically, it provides comprehensive data on endangered beetle species, such as their conservation status and the necessary protection efforts, underscoring the significance of the current project. As such, Scarabreed focuses on creating optimal conditions for breeding beetles, contributing to their conservation.

Breeding beetles involves understanding their life cycle, habitat requirements, dietary needs, and optimal environmental conditions. Figure 1 illustrates the beetle life cycle. Beetles undergo complete metamorphosis through egg, larva, pupa, and adult stages, with specific needs at each stage [2].

Different beetle species require unique habitats, including appropriate enclosures, substrates, temperature, humidity, and lighting conditions. Typically they require a diverse diet, including fresh fruits, vegetables, grains, but, depending on being herbivores, predators, scavengers, fungivores, or omnivores, may have additional dietary needs [1].

The team wishes also to explore the educational side of a beetle nursery to raise public awareness to beetle biodiversity. By observing insect behaviour and life cycles firsthand, people gain a deeper understanding of ecological concepts and

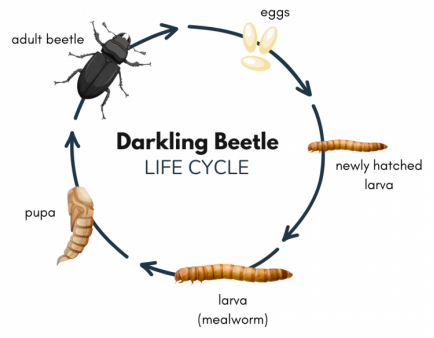


Fig. 1. Beetle life cycle

develop empathy towards endangered insects. These breeders also facilitate citizen science initiatives, allowing students to contribute to local insect population monitoring. Table 1 summarises the competing brands.

Table 1. Terraria overview

Brand	**Price** (€)	**Features**	**Target**	**Species**
ExoTerra [8]	100 - 400	Versatile Adaptable	Semi-professional Professional	Reptiles Amphibians
Josh's Frogs [9]	150 - 400	Different sizes Different shapes	Beginners Enthusiasts Semi-professional Professional	Reptiles Amphibians Arachnids Other insects
ZooMed [13]	50 - 150	Starter kit	Beginners Enthusiasts	Reptiles Amphibians Aquatic species Insects

2.2 Ethics

The BBV2 project integrates ethics and deontology in all aspects. Scarabreed translates this into concrete actions through corporate social responsibility:

- Engineering with integrity: Safe design for users and environment as recommended by the National Society of Professional Engineers [12].
- Transparent marketing: Communicate not only the benefits but also limitations, including relevant production (sustainability) and educational (beetles and biodiversity) contents.

- Sustainability first: Focus on the welfare of the beetles from breeding (BBV2 reproduces habitat conditions and provides adequate food and care) to responsible reintroduction.
- Liability taken seriously: Scarabreed is aware of its legal and moral liability and, as such, is committed to comply with relevant laws and regulations on product safety, animal welfare, and protection of endangered species.

To sum up, ethics play a crucial role in various aspects of the breeding and reintroduction of beetles, particularly when aiming to aid in ecosystem restoration and biodiversity conservation. This is why Scarabreed prioritises responsible breeding practices and transparent communication on motivations, methods, and potential risks. Furthermore, legal and moral liability ensures that breeding and reintroduction efforts comply with ethical standards and minimise harm to the environment and living organisms. Overall, ethical decision-making is crucial in guiding restoration initiatives and creating trust with stakeholders, ultimately contributing to the long-term success of biodiversity conservation efforts.

2.3 Marketing

Being a smart modular vivarium, BBV2 is positioned in the so-called blue ocean [10]. These extra functionalities make it a unique product for a more professional market in an already saturated market. The target audience includes biologists who want to help nature by breeding and reintroducing native beetle species, nature conservation organisations dedicated to preserving and propagating endangered insect species, and schools that want to inspire and make young people aware of the need to preserve insect biodiversity.

One of the main strengths is the alignment with the goals presented by the Convention on Biological Diversity for the restoration of biodiversity worldwide by 2030 [5]. There is also the opportunity to explore the European Green Deal [7]. This favourable macroeconomic situation will lead to a strong market positioning, the establishment of partnerships with nature organisations and to potential sales. When considering the level of smartness and modularity, BBV2 is extremely well positioned in respect to its competitors, indicating that is an innovative solution.

2.4 Sustainability

The eco-efficiency measures for sustainability provide a foundation for understanding environmental responsibility and resource efficiency. The overuse of georesources has compromised their availability and disrupted the ecosystems where endangered beetles live. Scarabreed aims to use resources effectively, minimise waste, and promote ecosystem conservation. Inspired by the Happy Planet Index, which measures prosperity by well-being, life expectancy, and ecological footprint, Scarabreed focuses on sustainable breeding practices to minimise its environmental footprint while maximising the well-being of beetles. Transparency

and accountability are key to any sustainability efforts. The structure uses sustainable materials, and the lighting energy-efficient light-emitting diode (LED) lamps to reduce energy consumption and operating costs while minimising the carbon footprint. In addition, regular sustainability reporting makes it possible to communicate environmental performance, social initiatives and progress towards sustainability goals to stakeholders, promoting trust and involvement.

The proposed solution offers clear environmental benefits like habitat restoration and improved ecosystem functioning. Reintroduction programs can boost endangered beetle populations, enhancing biodiversity and ecosystem services such as seed dispersal, pollination, and decomposition. As such, it contributes to Sustainable Development Goal 15 – "Life on Land" – of the United Nations[1]. Economically, Scarabreed aims to provide cost-effective beetle breeding solutions without compromising quality or sustainability. The manufacturer must foster partnerships with suppliers and distributors to create a sustainable supply chain, support local businesses, and promote fair labour practices. BBV2 has the potential to attract ecotourism, generating revenue and benefiting local businesses.

Socially, the project impacts positively the community by enhancing environmental education, customer satisfaction, employee welfare, and community engagement. Healthy ecosystems with diverse beetle populations can improve the quality of life for surrounding communities by purifying water, aerating soil, and promoting plant growth, increasing mental and physical well-being.

3 Proposed Solution

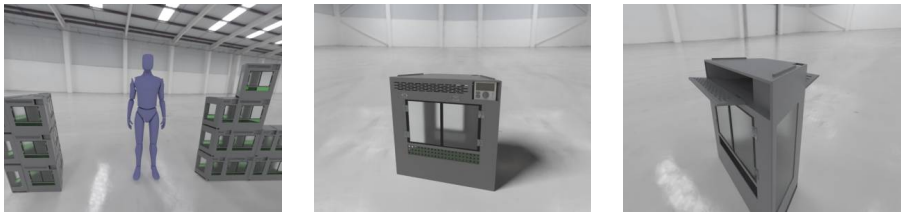
The problem of endangered beetle species is addressed by Scarabreed through a creative vivarium design. The product – Beetle Breeder Version 2 (BBV2) – emphasises smartification to ensure a habitat for beetles as close to nature as possible and modularity to facilitate upscaling, customisation and transport.

3.1 Concept

BBV2 is a modular vivarium with integrated technology for breeding endangered beetle species. Both the front and back of the device allow users to view the organisms and access the technology chamber. The smart system: (*i*) monitors the humidity, temperature and door state of the breeding chamber: (*ii*) controls the light and ventilation inside the breeding chamber; and (*iii*) communicates with a remote database. The user interacts via on-device and website interfaces.

3.2 Design

Modularity was set as a design priority. Due to its lightweight construction, the vivarium is easily scaled by connecting multiple units (Figure 2a). Additionally, the design allows for flexible configuration to suit user needs. The user control display in Figure 2b provides a user-friendly interface for effortlessly monitoring



(a) Module stacking (b) BBV2 module (c) Technical chamber

Fig. 2. Scarabreed design

essential parameters like humidity, and temperature within the vivarium. Figure 2c showcases a clear separation between the breeding area and the technological chamber. This strategic design approach minimises the risk of interference between the sensitive breeding environment and the electronic components. The selected construction material is stainless steel for its robustness and reusability.

The designed smart control system comprises a microcontroller with Wi-Fi interface and a liquid crystal display, a power supply, door contact, humidity, temperature and water level sensors, a buzzer alarm, a water tank and valve for humidification, a LED stripe for lighting, a fan for ventilation, a spiral heater and infrared light for heating, and a user interface for setup. BBV2 has a power consumption of less than 5 W and a selling price range between 200 € and 400 €.

4 Prototype Development

The proof-of-concept prototype is a simpler version of the designed product intended to test, refine and, ultimately, illustrate the proposed concept. The assigned budget is 100 €.

4.1 Assembly

The assembly of the prototype involves the building of the structure, the implementation of the smart control system and the development of the Web app.

Structure The prototype's structure prioritises functionality. Constructed entirely of wood, a cheaper yet thicker material than the initially planned thin stainless steel, is a true-to-scale replica (1:1) of the designed structure. This allows for a complete aesthetic representation, despite only having one functional door. This door has a tight seal, ensuring no gaps and allowing for beetle habitation and full functionality testing within the prototype.

[1] https://sdgs.un.org/goals/goal15

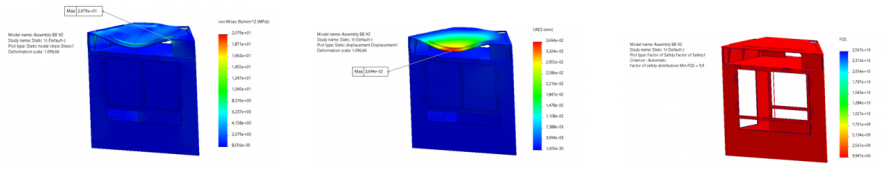
Smart Control The implemented control system excludes the humidification and heating subsystems. The menu-based user interface uses two buttons and a display. The user is able to set the temperature, light and humidity, control the ventilation and lighting, and obtain the current sensor data (humidity, temperature and door state values). The sensor data are also automatically sent to a remote database via Wi-Fi, using the Message Queuing Telemetry Transport (MQTT) communication protocol and a Mosquitto broker client library.

Web Application The Web application was simulated using Node-RED for the front-end and back-end. The back-end exposes the Application Programming Interface (API) that interfaces with the default Node-RED database. The Mosquitto broker receives and retrieves the sensor data from the MQTT messages and stores them in the database. The back-end API implements the following operations: list all sensors, add a new sensor, update the settings of a sensor, remove a sensor, get last sensor data and get past sensor data.

4.2 Tests & Results

The testing of the prototype involved characterising the strength of the structure as well as the operation of the smart system and website.

Structure The structural tests were performed with SolidWorks Software, using the finite element method. The aim of the structural tests was to determine whether the BBV2 withstands a force of 588.6 N, considering a safety factor of 1.5. Figure 3 displays the results of the stress analysis (Figure 3a), maximum deformation (Figure 3b) and minimum factor of safety (Figure 3c).



(a) Von Mises Stress (b) Deformation (c) Factor of Safety

Fig. 3. Structural tests.

The obtained results are promising: the maximum Von Mises stress value of 20.79 N/mm^2 is low, the maximum deformation of 0.037 mm acceptable, and the minimum factor of safety of 9.9 is well above the predefined minimum value. With the exception of the top of the technological compartment, the entire model is still capable of supporting larger weights.

Smart Control The tests of the control system consisted of checking the power, monitoring, control, interface and communication functions. Table 2 displays the results.

Table 2: BBV2 device: functional results.

Function	**Result**
Power supply supplies 5 V	Pass
Temperature and humidity monitoring	Pass
Door contact monitoring	Pass
Fan ventilation control	Pass
On-device menu-based user interaction	Pass
LED lighting control	Pass
Data uploading to database	Untested
Web app user interaction	Untested

Web Application Table 3 holds the functional and performance results of the implemented back-end Application Programming Interface (API). The data exchanged plus the average μ and standard deviation σ latency values were obtained by repeating each request ten times.

Table 3: BBV2 back-end API: functional and performance results.

Operation	**Method**	**Result**	**Size** (B)	**Latency** (ms)	
				μ	σ
List all sensors	GET	OK	320	18.75	0.85
Add a sensor	POST	OK	275	15.23	2.75
Update a sensor settings	PATCH	OK	234	112.13	53.21
Remove a sensor	DELETE	OK	227	126.31	61.42
Get last sensor data	GET	OK	301	221.32	15.30
Get past sensor data	GET	OK	369	200.30	17.24

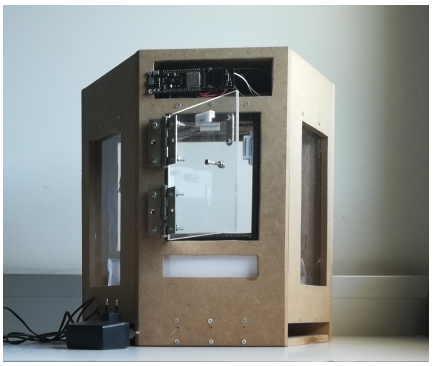
Table 4 displays the load results for the longest API request. These results show that, when in production, the Web app must be hosted by an elastic server solution to reduce the latency to values compatible to an acceptable user experience. As expected, the exchanged data per request remains unchanged.

Table 4: API load results

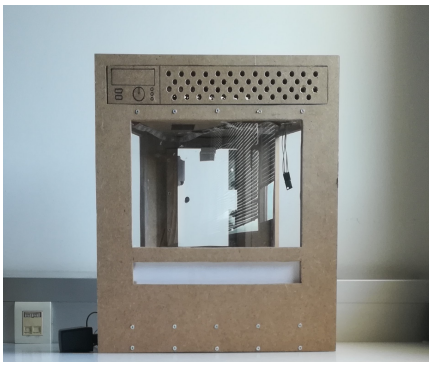
Requests/ Results	**Operation**	**Method**	**Size** (B)	**Latency** (ms)	
				μ	σ
10/10	Get past sensor data	GET	320	412.75	30.26
100/100	Get past sensor data	GET	320	1329.17	215.43

1000/1000	Get past sensor data	GET	320	10	125.27	3923.75

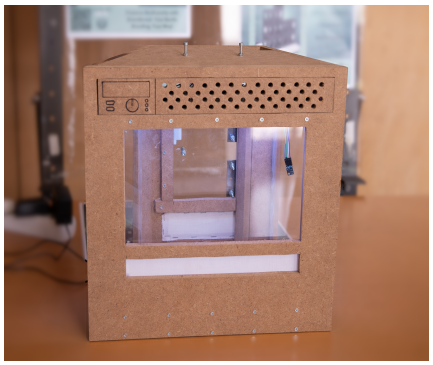
Figure 4 displays the rear view (Figure 4a) and front view (Figure 4b) of the prototype, as well as the prototype during the final demonstration (Figure 4c).



(a) Rear view



(b) Front view



(c) Final demo

Fig. 4. Scarabreed prototype

5 Conclusion

The BBV2 solution has a modular design and smart control to promote the efficient reproduction of endangered beetle species. The vivarium user interface allows the user to set the temperature, light and humidity, and get the last sensor readings and device status. With BBV2, Scarabreed enters into a secluded market segment with few, if any, direct competitors. The modular design is unbeatable among competitors, allowing the assembly of several units, an ideal

feature for larger projects. By differentiating in terms of functionality, the company can respond in a so-called blue ocean. By also working with conservation organisations, Scarabreed can actively participate in the restoration of ecosystems, repopulation and ethical rearing of endangered beetle species. It also aims to explore the educational segment, so that pupils can learn from an early age about the importance of preserving nature. All in all, Team Scarabreed believes BBV2 will contribute to the conservation of beetle species and their ecosystems.

Finally, not only is Team Scarabreed proud of BBV2, but its members also identify positive aspects in terms of learning and personal development in the context of EPS@ISEP:

Improved communication and collaboration
- Significant improvement in English fluency and communication skills – Jennifer, Marion, Cedric, Julius, Thomas and Krzysztof.
- Broadening intercultural perspective and understanding through working in an international team – Jennifer, Marion, Cedric, Julius, Thomas and Krzysztof.
- Collaboration through navigating different working styles and academic backgrounds was a valuable learning experience – Thomas and Krzysztof.

Enhanced academic skills
- Academic writing skills – Jennifer.
- Contribution to multiple subjects and extensive reading – Marion.
- Project management – Julius.

Personal and professional development
- Working on a real-world project as a member of an international team provided practical experience and helped to apply knowledge – Marion, Julius and Krzysztof.
- Working outside one's comfort zone lead to personal growth – Cedric.
- Building lasting friendships and exploring the host country created a memorable experience – Julius.

Turning obstacles into opportunities
- Combining different approaches from various educational contexts – Thomas.
- Managing the time and the work of a team with diverse individual perspectives – Jennifer, Thomas and Krzysztof.

Overall, the EPS program provided students with the opportunity to develop essential skills for the professional world while fostering personal growth and international connections. Considering future work, the plan is to focus on:

Enhanced Automation by implementing more advanced sensors and automated systems to improve the control and monitoring of the vivarium's environment.

Customisation by developing versions to accommodate different species with specific needs.

Public Engagement by increasing public awareness and educational initiatives through the integration of insect breeding devices into schools and community programs.

Sustainability by investigating new eco-friendly materials and energy-efficient technologies to minimise environmental impact.

Acknowledgements

This work was partially funded by National Funds through the Portuguese funding agency, FCT – Fundação para a Ciência e a Tecnologia, within project UIDP/50014/2020 (DOI: 10.54499/UIDP/50014/2020 | https://doi.org/10.54499/UIDP/50014/2020.

References

1. Abney, C.J.: Vivariums, everything you need to know. Available at https://bantam.earth/vivarium/ (2023), [Accessed in July 2024]
2. Anderson, G.: Beetle lifecycle and lifespan. Available at https://www.ecoguardpestmanagement.com/pest-resources/beetle-life-cycle (2023), [Accessed in July 2024]
3. Britton, D.: Beetles: Order coleoptera. Available at https://australian.museum/learn/animals/insects/beetles-order-coleoptera/ (2022), [Accessed in July 2024]
4. Budzinska, G., Hansen, J., Malheiro, B., Fuentes-Durá, P.: European Project Semester. In: Malheiro, B., Fuentes-Durá, P. (eds.) Handbook of Research on Improving Engineering Education With the European Project Semester, pp. 1–22. IGI Global, Hershey, Pennsylvania, USA (2022). https://doi.org/10.4018/978-1-6684-2309-7.ch001
5. Convention on Biological Diversity: 2030 targets (with guidance notes). Available at https://www.cbd.int/gbf/targets (2024), [Accessed in July 2024]
6. Duarte, A.J., Malheiro, B., Arnó, E., Perat, I., Silva, M.F., Fuentes-Durá, P., Guedes, P., Ferreira, P.: Engineering education for sustainable development: The european project semester approach. IEEE Transactions on Education **63**(2), 108–117 (2020). https://doi.org/10.1109/TE.2019.2926944
7. European Commission: Causes of climate change. Available at https://climate.ec.europa.eu/climate-change/causes-climate-change_en (2024), [Accessed in July 2024]
8. Exo Terra: Terrariums made by exo terra. https://exo-terra.com/products/terrariums/ (2024), [Accessed in July 2024]
9. Josh's Frogs: Terrariums made by josh's frogs. Available at https://joshsfrogs.com/search?query=Terrarium (2024), [Accessed in July 2024]
10. Kim, C., Mauborgne, R.: What is blue ocean strategy? Available at https://www.blueoceanstrategy.com/what-is-blue-ocean-strategy/ (2024), [Accessed in July 2024]
11. Lohan, T.: Climate change threatens insects — and us. Available at https://therevelator.org/insects-climate-change/ (2023), [Accessed in July 2024]
12. StudySmarter: Ethics in marketing. Available at https://www.studysmarter.co.uk/explanations/marketing/marketing-information-management/ethics-in-marketing/ (2024), [Accessed in July 2024]
13. Zoo Med: Terrariums made by zoo med for the blue death feigning beetles. Available at https://zoomed.com/beetles/ (2024), [Accessed in July 2024]