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An ontological model to support citizen science in the field of invasive species research

Radoslav Milchev[1], Galin Milchev[1], Rumen Tomov[2]

[1]*Department of Computer Systems and Informatics, Faculty of Business Administration, University of Forestry, 1797 Sofia, Bulgaria*

[2]*Department of Plant Protection, Faculty of Agronomy, University of Forestry, 1797 Sofia, Bulgaria*

Abstract: *Advances in information technology developments have led to improved ways and means of sharing information and good practices in various areas of social development. Providing the necessary tools enables Citizen Sciences (CS) to play an important role in raising awareness and engaging various stakeholders in the prevention of invasive alien species (IAS). In Bulgaria, up until this point, it is poorly developed, and this is largely due to the lack of information to the general public regarding the categorization of species, pathways of introduction and their negative impact. The article examines the possibilities for introduction and use of an advanced ontological model in the area of invasive alien species research, which will aid the process of involving a wide range of stakeholders in various initiatives that will contribute to preventing the introduction and spread of IAS. The researched approach using the advantages of modern information and communication technologies includes acquaintance with the basic concepts in the area of IAS, the processes related to their introduction and spread, as well as taking into account the existing interrelationships, which would provide opportunities for early detection and the rapid eradication of IAS. The developed model will also be applied to measures and policies put in place to change the attitudes of the general public to the problem of IAS.*

Keywords: Citizen Sciences, Invasive species, Ontologies, information technology

Corresponding author: gmilchev@ltu.bg

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Introduction

Citizen science is a prerequisite for the successful implementation of initiatives related to conservation of biodiversity and prevention and control of invasive alien species (IAS), in addition its generated data are becoming an increasingly key factor for organizations involved in these issues. The technological development of information and communication technologies (ICT), the facilitated ways of sharing information, the wide choice of use of applications for the purposes of citizen sciences - commercial or open source allow more and more participants to become involved in the process. In Bulgaria, so far, the IAS citizen science is not at a high enough level, despite the provision of necessary tools. In order to increase awareness and engagement, it is necessary to inform the general public about the categorization of species, pathways of introduction and their negative impact. Becoming familiar with the basic concepts and the existing relationships between them, their generalization and summary will help individual participants to gain the necessary confidence, in terms of their proper judgment. Ontologies are an appropriate tool in this regard. The possible introduction and application of a model based on their use in the field of IAS research will support the processes of involving a wide range of stakeholders in individual initiatives.

Accurate, up-to-date, well-documented, standardized and openly available information on alien species is at the heart of science-based strategies for dealing with biological invasions [1]. In order to achieve effective collection of information on alien species, with possibilities for its combination and use in individual initiatives, biodiversity-related data need to be interoperable. At this stage, this is hindered due to their dispersion. The benefits of using an ontological model in terms of aggregating and summarizing data related to alien species can be sought in the direction of their documentation, through metadata, as well as their formatting based on existing standards. On the other hand, such an approach will allow for their easier maintenance and updating, in order to ensure their valorization. In many cases, it is necessary to include the spatial component of the data needed in order to achieve the objectives of individual activities. In order to model reliable intelligent applications, as well as to avoid misinterpretation when designing spatial data infrastructures, an ontology-based approach can be used [2]. The benefits of such a blurred approach and level-based approximation will be related to: presenting and managing the uncertainty of volunteers in describing their observations in order to avoid inaccuracies and imperfections concerning said observations; obtaining verified and reliable information to compensate for their poorly defined knowledge in the relevant field. The development of citizen sciences, as an area related to large-scale information gathering, mobilization and social action of participants and organizations developing relevant initiatives, is associated with the careful choice of terminology [3]. For this purpose, the use of ontological models will be of great benefit, and in addition to refining the terms, a detailed explanation of their use is needed after conducting a systematic study of terminological trends in citizen sciences. Most errors with serious consequences, arising

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from their use in the control and reporting of circumstances related to biological invasions, are caused due to a lack of knowledge or inaccurate detection, or as a result of contextual dependence and ambiguity related to language misunderstanding [4]. The contribution of the use of ontologies in these cases can be sought in the direction of improving the accuracy of information in the lists of IAS, and despite the fact that uncertainty will never be completely eliminated, these approaches will significantly improve the transparency, repeatability and comparability of IAS lists. Having an overall understanding and presentation of citizen science projects, the participants and their results are key to ensuring a seamless exchange of knowledge and data [5]. In this sense, the application of ontologies will be useful in the implementation of a conceptual model related to the presence of an overall understanding and presentation of initiatives pertaining to citizen sciences, participants and the information they have generated. Built on the basis of fundamental citizen science concepts describing the activities and data in a standardized way, and with a focus on the participants and what they have done, it will contribute to a good foundation in ensuring their smooth exchange. In recent years, citizen sciences have been the subject of numerous projects and technological developments aimed at their functional and effective use.

Based on the practical experience gained by the members of the research team in the field of developing ontological models for different subject areas and the established practices in the field of determining the characteristics of invasive alien and native species, the aim of the present paper is to develop an ontological model to support the development of Citizen Sciences in the area of IAS in Bulgaria. The aim of the present study is to facilitate the design and development of an ontological model, which on the one hand to facilitate the learning or self-learning processes of a wide range of potential representatives of Citizen Sciences in the area of invasive alien species, and on the other hand to support the development of appropriate desktop and mobile applications to take advantage of the opportunities to formalize the knowledge provided by ontologies.

Methods

The ontological model is built in the Protégé 5.5.0 application environment [6]. The method for building an ontological model, through the use of information technology tools, allows the integration of mechanisms and tools that facilitate the processes of formalization of knowledge. The ontological model describing IAS with the means of information technology allows the analysis and detection of relationships that are difficult to implement with standard analysis tools, while allowing the model to be integrated for other purposes, such as software application development. The main statistical parameters of the ontology are shown in Figure 1, as well as parameters such as version, project description, authors and other characteristics including 112 classes, 253 axioms, 18 object properties and etc.

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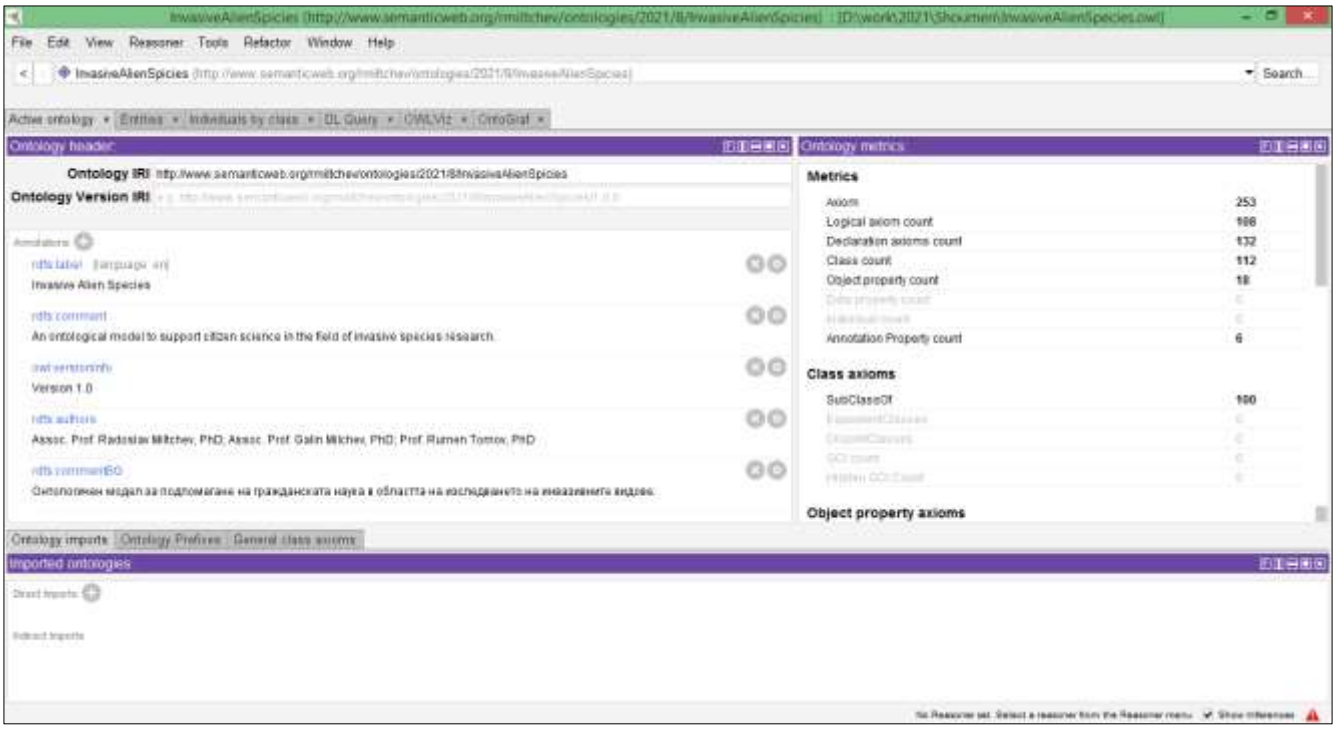


Figure 1. Basic statistical parameters of the ontology

Results

The model successfully shows the applicability of the ontologies in the given subject area and allows subsequent addition and expansion, which in turn will affect the main statistical parameters of the project, which can be seen in the figure with the ontology description.

The hierarchy of classes in the developed ontological model is shown in Figure 2. In this case the class with key terms for determining species is illustrated, which contains three subclasses with annotations in Bulgarian and English and a source of the used definitions content. The model has 12 main classes.

The model has also developed a set of object properties (Figure 3), used to describe the individual species that could be registered and identified by the representatives of citizen sciences.

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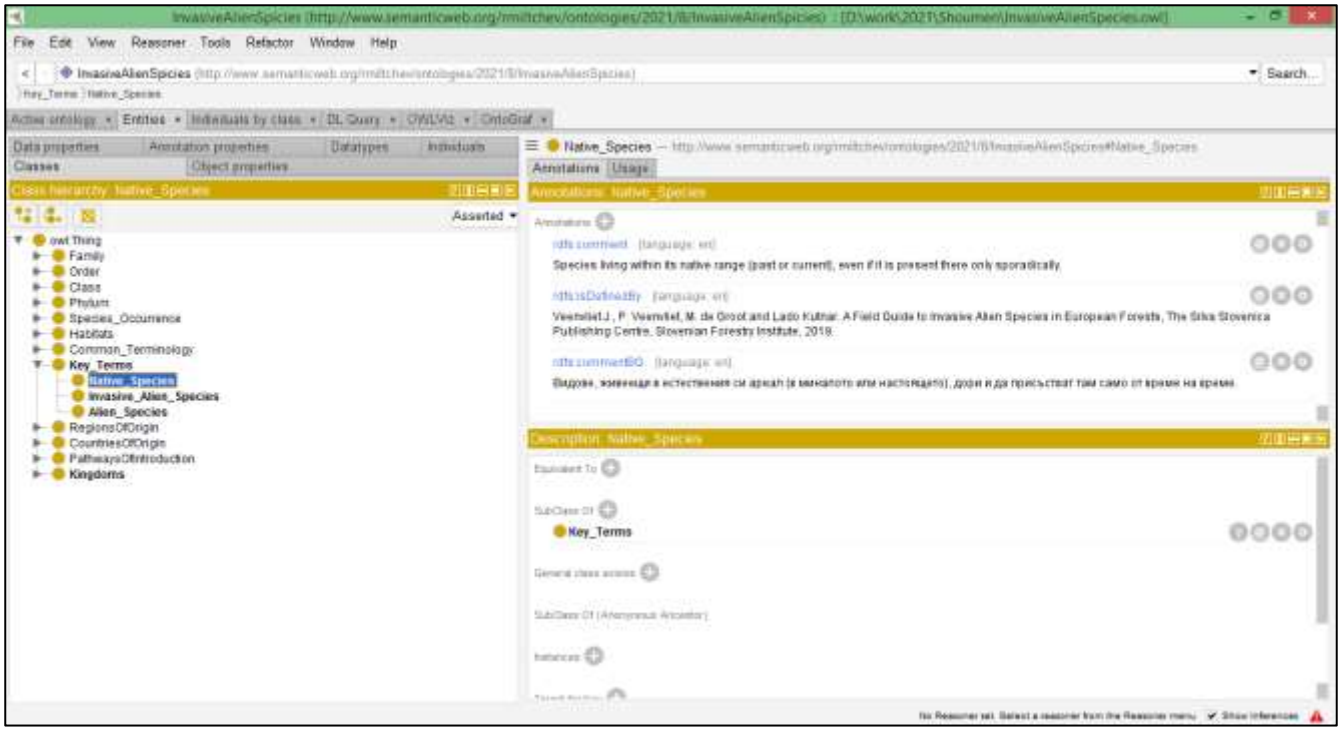


Figure 2. Hierarchy of classes in the ontological model

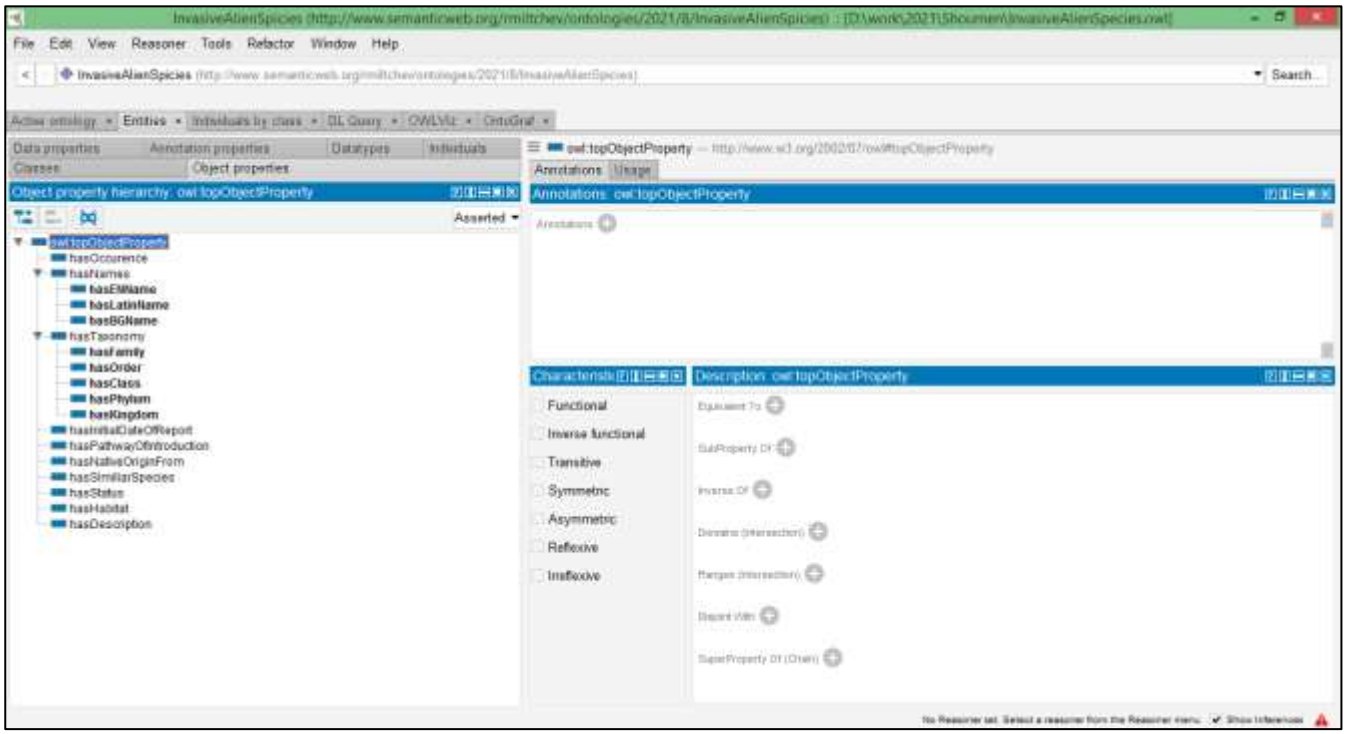


Figure 3. Object properties of the individual species

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The individual species belonging to different kingdoms for which there is information in the scientific community at the moment of the research, are in the process of specification. These species are pre-processed before being imported into the model, the data being as shown in Figure 4.



Figure 4. Processing and preparation of data before importing into the model

Ontological models offer a number of advantages in the analysis, study and presentation of the studied subject areas.

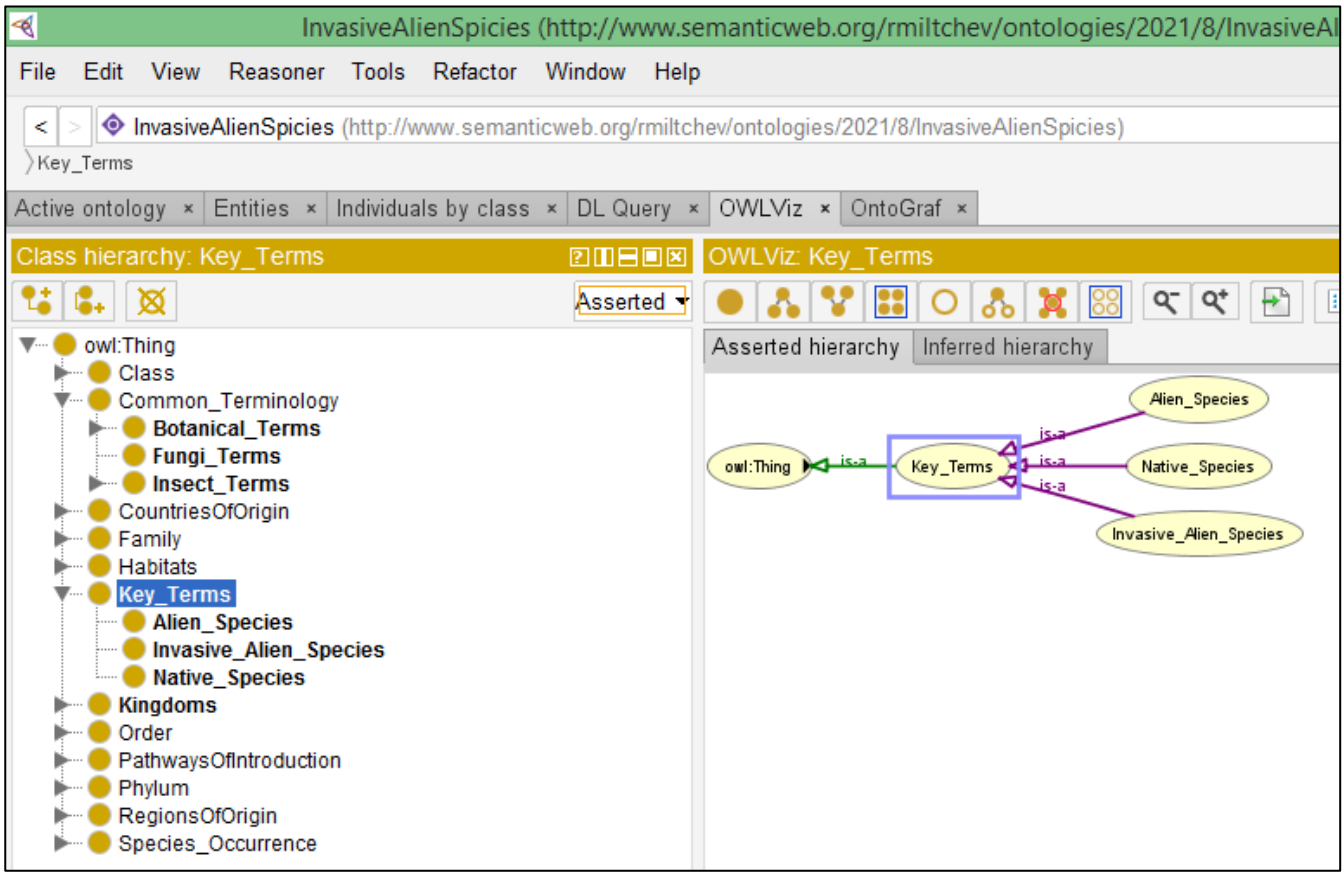


Figure 5. OWLViz visualization tool

Various visualization tools such as OWLViz or OntoGraf can be used for that purpose. The results from using these tools are shown in Figure 5 and Figure 6.

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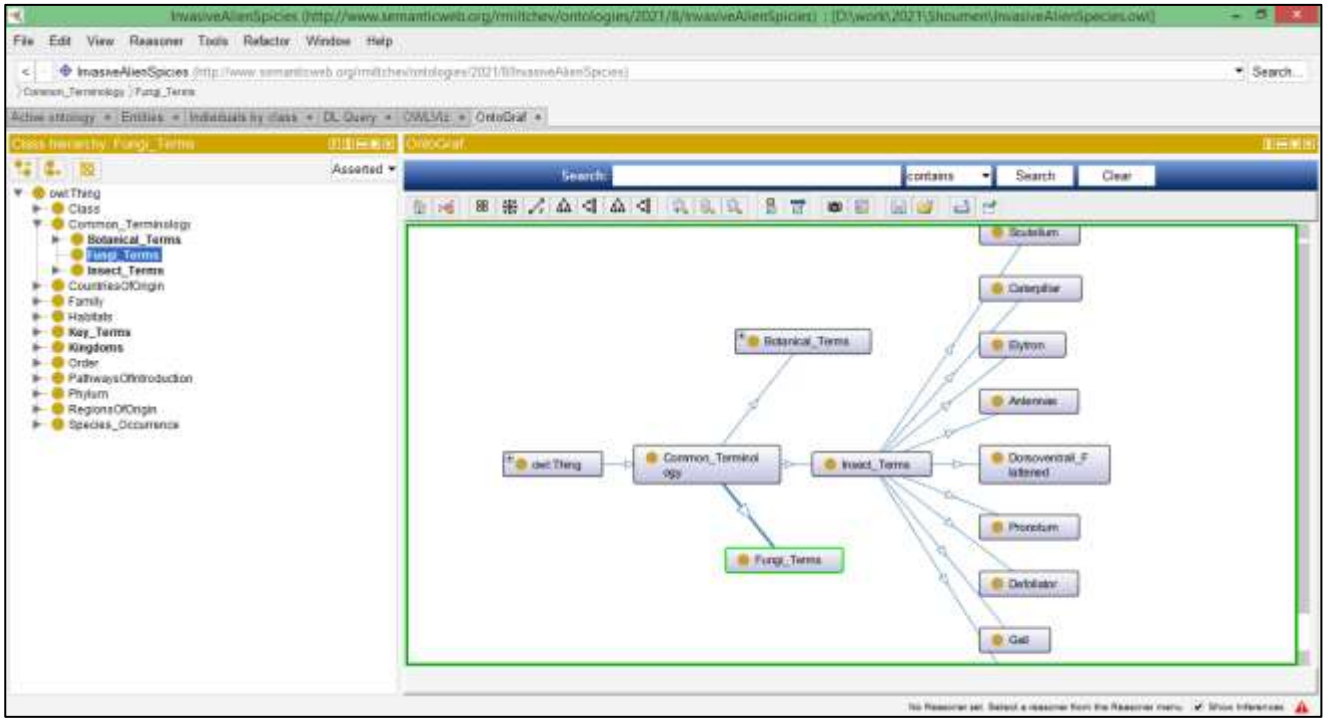


Figure 6. OntoGraf visualization tool

Discussion and conclusions

The design of related ontological models should take into account the information gained from the many platforms acting as centers for knowledge, aggregation, dissemination and popularization of experience related to citizen sciences [6] and in particular invasive species. The conceptual models developed for the operation of some of them consist of the project metadata model, the metadata model from the data set, and the observation data model, specially developed for citizen sciences initiatives. Studies related to citizen sciences initiatives show that cultivating a passion for species identification is key to both "supporting nature" and broader stakeholder education [7]. On the other hand, citizen sciences are a tool for achieving universal and equal access to scientific data and information [8]. This determines the need for an accurate and detailed description, which can be achieved by using a methodology based on ontological models. In this way, the quality of the data the participants receive from the related initiatives will be optimized and improved, which will in turn bring scientific and public benefits in accordance with existing programs, such as the "Sustainable Development Agenda 2030[1]".

[1] https://www.un.org/sustainabledevelopment/development-agenda/

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Results from previous studies [9] related to the use of ontology-based approaches show a number of possibilities they provide in describing complex dependencies in a format where the stimulation code is automatically generated by the definition of the ontology of the model. This determines the possibility for automatic connection of models and data sources, as well as for automatic detection of similarities and differences and generation of model copies of common principles. Ontologically based methods can find application in citizen sciences initiatives related to alien species by supporting activities aimed at engaging additional systematic knowledge using a multi-evidence approach [10]. In this way, the initiatives will enjoy better legitimacy, based on ethical and reciprocal relations, which will reflect on improving the results aimed at managing and maintaining biodiversity. Despite the development of ICT, many good practices, including those in the field of citizen sciences, remain poorly documented. This has a direct impact on the management of results generated by them and especially on their future integration, sharing and dissemination. To make them visible to the general public, the use of an ontological knowledge management approach will enable stakeholders to share and understand knowledge at the domain and instance level, to reduce possible ambiguities, and to integrate with other sources of knowledge compared to traditional approaches for information management [11].

In the formalized description of knowledge regarding the IAS citizen sciences, through the use of ontologies it is necessary to take into account the possibility of including an explicit evaluation procedure, as without a well-structured one it will be difficult to assess the suitability of developed models in related research and their practical application [12]. Ontologies provide the necessary basis for the proper operation of semantic network-based applications - technologies that can provide instructions and clear rules in the processes of data collection, integration and use [13] in IAS citizen sciences initiatives. By providing semantic interoperability of the descriptive models built for presenting the information, the use of ontologies will allow for the generation and analysis of different scenarios in their implementation [14], with the help of built-in visualization tools showing the connection and interaction between the individual classes, as well as the flow of information and the specific properties of the objects within the classes.

The development, use and application of ontological models in various subject areas is a powerful and effective method for the application of modern information and communication technologies in the study of said areas. The created ontological model in the field of IAS can significantly improve the participation rates of citizen sciences representatives in the field of registration and detection of invasive species, both at the territory of the Republic of Bulgaria and at regional level. The model improves the opportunities for interaction between professional researchers and civic researchers, setting a bridge to unify terminology and thus create a prerequisite for better registration of phenomena and events, even by people who do not have the necessary specialized knowledge obtained as part of the educational process they went through. The proposed

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ontological model allows continuous supplementation and updating in the context of dynamic changes which we observe in the environment we inhabit.

Conflict of interest statement

All authors have approved the manuscript with no conflict of interest.

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