Building the Molecular Biodiversity Greece Community

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Abstract

In the face of the biodiversity crisis, concerted efforts towards understanding the effects of climate change and habitat loss and fragmentation, both locally and globally, are urgently needed. These are often attempted by leveraging the advances of modern genomics and bioinformatics methodologies. Especially in biodiversity hotspots, the need to understand, monitor and mitigate the loss of biodiversity is pivotal. Greece is a country

with especially high endemism. A large percentage of its endemic species is threatened by climate change and human activities. To this end, the national academic community in biodiversity genomics has established a corresponding network of scientists from various Greek research institutes and universities covering different disciplines of biodiversity research. The network aims to support and combine individual actions to establish a Task Force that will channel the flow of information amongst researchers, policy makers, stakeholders and the local society. Our overarching goal is to build a sustainable community and infrastructure for the efficient management of the entire molecular biodiversity data cycle (i.e., from production and storage to the analysis and modelling of data, development of computational tools, and knowledge extraction). Using national and European infrastructures, such as ELIXIR and LifeWatch, we envision to set the ground for studying biodiversity through the lens of biodiversity genomics and offer evidence-based knowledge to guide management of the habitats and the biodiversity they host, as well as the implementation of appropriate policies.

Overview

The importance of biological diversity (biodiversity) for the potential of adaptation or biological response of populations and species to environmental changes and the resilience of communities and ecosystems, as well as the persistence of ecosystem functions that are indispensable for human well-being and a healthy planet, have been long recognised (IPBES 2019). Despite the reaction by governments and international organisations through policies and decisions in accordance with the 1992 UN Convention on Biological Diversity (CBD), global biodiversity is declining at an unprecedented rate due to human induced pressures, such as climate change (Trisos *et al*., 2020, IPCC 2022), invasive species, habitat loss and degradation and the depletion of natural resources (IPBES 2019). The rapid rate of this decline can lead to hard-to-predict catastrophic shifts (Solé and Levin, 2022), such as the increased risk of new human diseases (e.g. Frumkin and Haines, 2019), the collapse of ecosystem functions (Cardinale *et al*., 2012, IPBES 2019), the degradation of natural resources and the increased possibility of a global food crisis (FAO 2019, Wezel *et al*., 2020). At the same time, a large part of species and population level biodiversity remains undescribed and underrepresented in inventories and databases (e.g. Chimeno *et al*., 2022, Bispo *et al*., 2022), thus creating a certain bias in reporting that has clear repercussions to the decision-making process on biodiversity conservation efforts (Gadelha *et al*., 2021), as shown in **Figure 1** (see data in *Appendix #1*). Humanity may miss important solutions to key problems for its survival, such as the loss of important genetic variants among wild plants and animals for agriculture (Nic Lughadha *et al*., 2020) and for dealing with health issues (Marselle *et al*., 2021). In this context, an additional emerging challenge concerns shifting perspectives from narrower, low-throughput efforts towards more holistic and high-throughput initiatives.

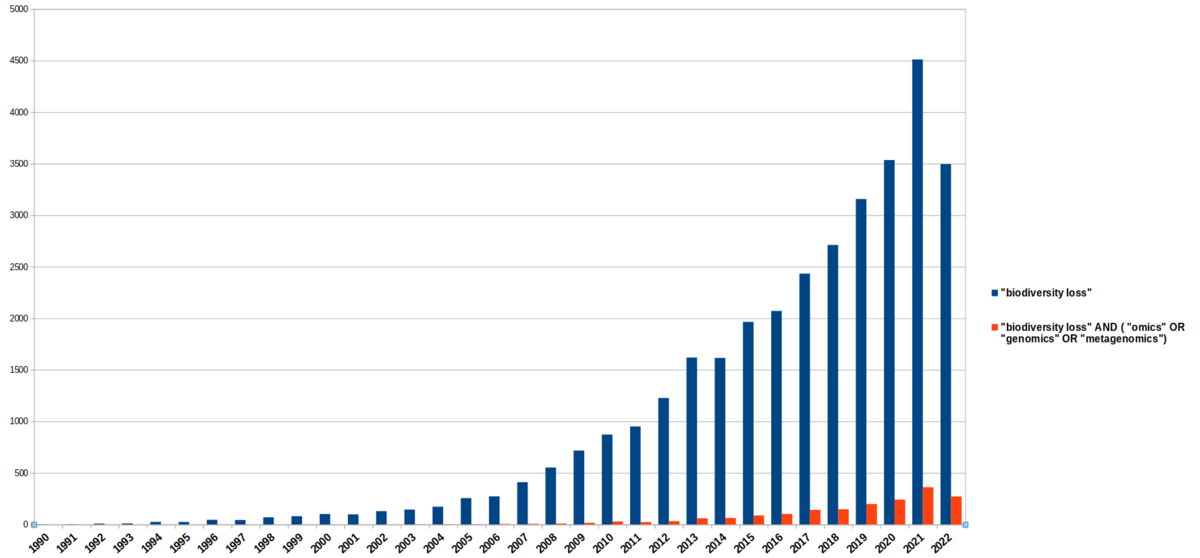

***Figure 1**: A Scopus query (against all fields) on "biodiversity loss" relates to 33,324 documents, while a query on "biodiversity loss" AND ("omics" OR "genomics" OR "metagenomics") returns only 1,795 documents. The trend analysis per year of these two queries is shown above, and the detailed data are listed in Appendix #1.*

Integrative and multiscale approaches are required to mitigate biodiversity loss. Techniques involving various molecular markers, combined with the rapid development of biodiversity informatics, have allowed an impressive progress in the accumulation, harmonisation, management, use and dissemination of data and information on the world's biota, especially during the last two decades (Gadelha *et al*., 2021, Smith *et al*., 2022, Waterhouse *et al*., 2022). Molecular biodiversity can be further considered as the "connecting tissue" of the wider biodiversity structure, ensuring that the common aspects are linked across the various levels of complexity and granularity.

When planning biodiversity conservation efforts and setting the research landscape in broader regions, such as in Europe, research in areas that are characterised as "biodiversity hotspots" should be prioritised (Myers *et al*., 2000). Such hotspots, that may include several countries or be part of a single country, often face various anthropogenic threats and at the same time demonstrate exceptionally high species richness, high genetic diversity in populations of rare and abundant species, high endemism levels and a spatially complex mosaic of ecosystems and landscapes (Myers *et al*., 2000). **Greece** is such a biodiversity hotspot, since it harbours the highest values of biodiversity at all levels in Europe (Georghiou and Delipetrou 2010, Hewitt 2011), due to its great ecological and cultural complexity with very high geographic and climatic heterogeneity and complex geomorphological and climatological history (Legakis *et al*., 2018). According to recent studies, almost 32% of all known European species are present in Greece. Greek flora includes 6,600 taxa, 1,461 (more than one fifth!) of which are endemic, while Greece's fauna is no less rich, with 23,130 animal species, of which 3,956 (close to one fifth) are endemic (NCESD/EKPAA 2018). It is also worth mentioning that insect biodiversity is substantially understudied at present, and is a key component in biodiversity. At the same time, Greece is heavily exposed to climate change and its subsequent effects (mean annual temperature in Mediterranean has risen +0.4oC above global average; Cramer *et al*., 2018), having the second highest number of threatened species in Europe as well as in the Mediterranean biodiversity hotspot, after Spain (BirdLife International 2021; IUCN 2022).

Climate change will cause rigorous changes to community structure and it is anticipated to increase the estimated extinction rates (Urban 2015). Islands and mountains are expected to be severely influenced by these shifts and the challenge is higher for the endemic species as they are more vulnerable to environmental alterations.

Several stakeholders are involved with biodiversity conservation in Greece, regulated by an extensive and often inadequate policy framework, where communication and coordination among various players should be improved (OECD 2020). In research, a multitude of groups and researchers are active in universities, research institutions and stations, organised within networks, projects and initiatives that cover all aspects of the broader scientific field of biodiversity, from applied conservation biology, to economics, bioinformatics, policy and legislation. However, despite the efforts of individual institutions or groups, the overall biodiversity research landscape is highly fragmented, with classic conservation stakeholders often not appreciating genomics and bioinformatics as a key component in studying biodiversity.

For the new targets set by the post-2020 global biodiversity framework (GBF) to succeed, research is considered to be key, especially the interaction among science, society and policy makers (Blicharska *et al*., 2019, Hermoso *et al*., 2022) with net improvements so that by 2050 we may approximate the CBD's vision of "*living in harmony with nature by 2050*". Today, scientists recognise the important role that genetic and genomic data can play in biodiversity discovery, assessment, monitoring, conservation, and restoration, to ensure the long-term provision of ecosystem services (Hoban *et al*., 2020, Gadelha *et al*., 2021, Segelbacher *et al.,* 2022). The contribution of genomics and biodiversity informatics towards these targets and the associated technical and scientific challenges are described in Waterhouse *et al*., (2022) together with the possible contribution of the ELIXIR ESFRI to meet them.

Vision

The goal of this strategy document is to define the critical components necessary to establish a vibrant community in molecular biodiversity research in Greece (see a SWOT analysis of the current status in *Appendix #2*). This dynamic and functional Molecular Biodiversity Community will be fully aligned to all relevant Initiatives and Infrastructures both within Greece (such as ERGA-EL, ELIXIR-GR and LifeWatch Greece) and between European and global counterparts (such as ERGA, ELIXIR and the ELIXIR Biodiversity Focus Group, LifeWatch ERIC, BIOSCAN Europe and others). This connection will allow for a bi-directional exchange of knowledge, synchronised actions, experience and standards between a biodiversity hotspot community (such as Greece), and the challenges encountered across the world.

The community will have a dual form. First, a diverse, inclusive **network** of **people**, with complementarity expertise and a vested interest in the study of molecular biodiversity, and second a **network of networks**, i.e. major initiatives that can support and promote the efforts around biodiversity. Ultimately, the community will be able to attract national and international funding to build and sustain the effort required for efficient management of the entire data cycle (i.e. from the production, storage to the analysis and modelling of data). The direct outcome of this collaborative network will be to support decision making by regulators and policy makers, leading to more efficient and appropriate responses to the ever-changing biodiversity landscape in Greece.

Table 1*: Overview of the connections between the Molecular Biodiversity Greece Community and the relevant Networks (active in Biodiversity and Bioinformatics)*

Research Infrastructure (ESFRIs)	**Independent presence of effort within Greece**	**Representation of the MBG Community in the networks**
ELIXIR	ELIXIR Greece (ELIXIR-GR)	☑ + ELIXIR Biodiversity Community
LifeWatch	LifeWatch Greece	☑
DiSSCo	DiSSCo-GR	☑
EMBRC	EMBRC Greece (CMBR)	☑
Projects		
BGE		☑
gBike		☑
BiCiKL		☑
Initiatives		
ERGA	ERGA-EL	☑
Bioscan		☑

As shown in ***Table 1***, the Molecular Biodiversity Greece Community has already established a number of connections to relevant initiatives, both at the national and the European level. Moreover, the Community itself already comprises a number of researchers active in the field of biodiversity and bioinformatics (see author list and corresponding affiliations, capturing over 20 organisations across Greece), representing the vast majority of organisations and initiatives in Greece.

Goals

The overarching goal of this effort is to build a sustainable infrastructure for the efficient management of the entire data cycle (i.e. from the production, storage to the analysis, software development, and modelling of data) for molecular biodiversity.

This will be achieved through the following steps:

1. Assist the local community to embrace modern genomics technologies as basic tool for assessing and monitoring biodiversity
2. Promote the Molecular Biodiversity Greece Community as a reference point for the study, research, and conservation of biodiversity, both in relevant initiatives within Greece as well as at the European level, and fully aligned to complementary efforts

(such as the ELIXIR Biodiversity Community), aiming at supporting large scale projects transcending initiatives to result in high quality outputs.

3. Develop appropriate connections with key external biodiversity partners in the field (as identified in the network of networks), and facilitate its growth while ensuring minimal overlap of the respective activities.
4. Develop core Bioinformatics open-source tools for analysing Biodiversity data
5. Develop and maintain a portfolio of tools, services, outreach and training, tailored to biodiversity researchers and conservationists, exposing the appropriate services that can be utilised to promote research in the field, while always maintaining an open channel of communication with the community for feedback and growth.
6. Promotion of the importance of bioinformatics and molecular technologies for biodiversity conservation among conservation agencies (public and private), by directly assisting policy decision making through a high level alignment of strategy and policy at the national and european level.

Objectives

The specified goals can be further defined across a number of short- and mid-term objectives:

1. Define high quality training resources (courses and materials) that can empower all relevant stakeholders to make full use of the portfolio of services of the Molecular Biodiversity Greece Community.
2. Produce a comprehensive catalogue of computational tools that can be effectively used in the study, research and conservation of Biodiversity, while facilitating the development of new tools that address emerging challenges.
3. Expand the Community by continuously engaging with partner groups, connecting to affiliated topics as well (such as environment, marine, food supply, forestry) - being inclusive for academia and industry alike.
4. Provide the computational context by leveraging existing infrastructures (such as the one offered through ELIXIR, e.g. via ELIXIR Greece's *Hypatia* cloud infrastructure, the IMBBC HPC Zorbas, the LifeWatch ERIC Tesseract workflow enactment engine, etc.)
5. Enable interoperability of the existing services, by selecting the appropriate metadata standards, adopting best practices and defining exemplar use cases.
6. Support data interoperability by promoting community standards and uptake FAIRification strategies.
7. Explicitly develop new models, algorithms, and open-source software
8. Tools developed within the «Network of networks» initiatives tailored to address Greek Biodiversity studies, will be disseminated and shared within the community members.

Roadmap

Looking forward, to make this collaborative a reality, we can identify short- and mid-term actions around three main pillars; (a) Community Building, (b) Technical Implementations and (c) Outreach.

A. Community Building

- Understand and catalogue the capabilities, interests, major players and ongoing projects in this area across the key external partners in Greece
- Contact and interview major biodiversity research players in Greece, that have interest in bioinformatics, to establish a broader contact list for regular communication
- A contact/mailing list with the major biodiversity research players interviewed
- Support the operation of the Community, in addition to the existing support that is provided to the individuals comprising the network (either through their Institutions or via the respective Initiatives).
- Establish an annual meeting of the Greek Biodiversity Community. Sharing the outcome of individual efforts to the rest of the network will maximise community uptake and add-on value.

B. Technical aspects / Development / Implementation

- Work on defining community-backed metadata standards, to facilitate interoperability. These standards will be showcased through demonstration projects.
- Support the adoption of best practices that implement FAIRification strategies.
- Promote sequencing of local species, thus leading to an increased representation of Greek species and populations in sequence databases (and the metadata accompanying them), and therefore allow for monitoring the overall progress.
- Increase visibility of the existing computational infrastructures (such as ELIXIR-GR Ypatia, LifeWatch's Tesseract, HCMR/IMBBC HPC Zorbas) and provide practical guidelines, examples and support in using them. Priority will be given to interoperable workflows that are compatible across the various computational infrastructures. Demonstration projects reusing partner developed components/datasets will be pursued.
- Develop new core software tools.
- Construct a comprehensive catalogue of computational tools that can be effectively used in the study, research and conservation of Biodiversity
- Address emerging challenges by building on the existing capacity of the community in developing new tools and methods.

C. Outreach

- Organise a kick-off workshop involving all contacted parties of the broader group, in order to coordinate efforts towards this goal - to be organised together with the annual meeting of the Community.
- Organise support for biodiversity researchers in Greece, through a web portal, similar to "ELIXIR support for biodiversity research" (at the very least we can setup a dedicated GitHub-pages site)
- Organise training workshops (either as volunteer or as funded efforts), for upskilling the members of the Community, while establishing connections to new members. This high quality training resources (courses and materials) will aim to empower all relevant stakeholders to make full use of the ecosystem of services of the Molecular Biodiversity Greece Community.

- Establish an outreach profile through selected social media channels (such as twitter, etc), as well as open communication channels (such as slack, etc).
- At mid-/long-term organise “science and society” activities. These can refer to the broad public, to citizen scientists, and to focused organisations like WWF or others.
- Prepare a regular newsletter, focused towards conservationists

Timeframe

Year 1

- Setup the structure of the Molecular Biodiversity Greece Community, including:
  - Channels of communication (incl. mailing list)
  - Regular Community meetings (frequency and type)
- Organise and hold a hybrid kickoff meeting of the Community
  - Invite talks and webinars by key ELIXIR Europe Biodiversity, ERGA and BIOSCAN partners
- Establish the groundwork for the next steps by setting up dedicated Task Forces, i.e.:
  - Mapping challenges that need to be addressed, reflecting on taxonomic clades or environment types of key importance to the Greek Biodiversity (flora, fauna, microbiome)
  - Initialise the collections of tools and services
  - Initialise the compendium of data

Year 2

- Work on community standards and best practices documents
- Initiate pilot cases that showcase the use of selected tools and services across relevant data
- Identify critical paths in skills, in order to start the collection / creation of relevant training material
- Review potential mechanisms for further support of the Community (as a network)

Year 3

- First versions of the:
  - Curated list of computational tools that can be effectively used in the study, research and conservation of Biodiversity, as a community-maintained reference registry (similar to bio.tools).
  - Collection of data entries that represent Greek species and populations in sequence databases (and the metadata accompanying them).
  - Initial list of the metadata standards, endorsed by the Community
  - Registry of mature workflows that have successfully been deployed within the selected compute infrastructures.
  - Pilot case demonstrations within and outside the community: what has been offered via bioinformatics/computational procedures
- Define roadmap for the next three years - based on Community consultation and in full alignment to the relevant initiatives/projects/networks.

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Web Resources:

1. BiCiKL
2. Biodiversity Genomics Europe (BGE)
3. Bioscan
4. CMBR
5. DiSSCo
6. ELIXIR: A distributed infrastructure for life-science information
7. ELIXIR Biodiversity Focus Group
8. ELIXIR bio.tools
9. ELIXIR Greece
10. ELIXIR Greece's *Hypatia* cloud infrastructure
11. EMBRC ERIC
12. EMBRC Greece
13. ERGA: European Reference Genome Atlas
14. gBike
15. IMBBC HPC Zorbas
16. LifeWatch ERIC
17. LifeWatch ERIC Tesseract workflow enactment engine
18. LifeWatch Greece

Appendix #1: *Biodiversity loss* trend analysis in the scientific literature

https://www.scopus.com/; 13.9.2022; query: all fields; query: "biodiversity loss"; number of matching documents per year

2024	1	not in graph
2023	5	not in graph
2022	3,496	
2021	4,510	
2020	3,535	
2019	3,157	
2018	2,711	
2017	2,433	
2016	2,071	
2015	1,965	
2014	1,615	
2013	1,619	
2012	1,227	
2011	950	
2010	872	
2009	717	
2008	552	
2007	410	
2006	272	
2005	255	
2004	172	
2003	144	
2002	129	
2001	98	
2000	101	
1999	80	
1998	69	
1997	43	
1996	45	
1995	24	
1994	25	
1993	10	
1992	8	
1991	2	
1990	1	

https://www.scopus.com/; 13.9.2022; query: all fields; "biodiversity loss" AND ("omics" OR "genomics" OR "metagenomics")); number of matching documents per year

2022	271
2021	361
2020	241
2019	198
2018	147
2017	141
2016	102
2015	87
2014	63
2013	60
2012	31
2011	23
2010	28
2009	16
2008	9
2007	6
2006	5
2005	3
2003	2
2000	1

Appendix #2: MBGC SWOT Analysis

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Strengths (internal)

- Internal meetings have so far created a good communication basis
- Interest and positive attitude so far received from first contacts with biodiversity researchers in Greece
- Good link and information flow with ERGA Greece and other initiatives
- Evident multidisciplinarity within the group, with clear complementary roles
- Broad spectrum complementarity from highly IT-specific tasks (remote access to biodiversity data, machine learning) to genetics/genomics analysis to ecology analysis & conservation planning
- Hypatia, Zorbas (IMBBC), HPC facilities: adequate compute power

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Weaknesses (internal)

- Insufficient funding
- Group members operate on a voluntary basis
- The computing capacity will be an “empty cell” to the community without tools/outreach/training tailored to biodiversity users
- Current networking and linkage between groups can be improved

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Opportunities (external)

- Rich BD in Greece with international interest
- A multitude of dynamic research groups, researchers and initiatives in Greece working on biodiversity research
- An active and dynamic ELIXIR Greece network
- ELIXIR Biodiversity Europe, an emerging community, is very active and is currently finalising a white paper (already existing white paper as a Focus Group)
- Bioinformatic tools available and good expertise within ELIXIR Greece (among other groups)
- Strong alignment to equivalent exploratory/preparatory activities ELIXIR Europe, see below
- Biodiversity Genomics Europe, a major Horizon Europe project that includes partners from MBG community, can assist in driving community efforts forward
- Strong connections to Biodiversity Research Infrastructures (LifeWatch ERIC)
- Able both to explore and to bridge the gap between classic- conservation-driven and genomics-bioinformatics-driven biodiversity research

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Threats (external)

- Limited performance of conservation efforts so far
- Climate change and human activities increasingly contributing to biodiversity loss
- Subjects in biodiversity research are very broad, with several diverse challenges associated to them
- Classic conservation stakeholders often do not appreciate DNA barcoding, metabarcoding, genomics / bioinformatics as a necessity
- Poor representation of sequences from species or populations from Greece in databases
- Poor metadata collection

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