save the blue heart of europe

Vjosa Wild River National Park

– Research Plan –

A Research Plan (2025 – 2034) for the Vjosa Wild River National Park

***Authors*:**

Mara Francesca Senatore,

Dr. Gabriel Singer, Department of Ecology, University of Innsbruck, Austria

With contributions from other experts.

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Acknowledged should be those people and organizations who take action to protect our natural resources, especially rivers, and who contribute to ensure that they are used equitably. Particularly, I would like to thank the scientists who are studying the Vjosa system, and who provided valuable input and feedback for the development of this research plan.

***Image credit*:**

Front page: Albanian and international scientists standing united for the protection of the Vjosa river. © Nick St. Oegger

Contents page: Vjosa river, from the "Save the Blue Heart of Europe" campaign, © Gregor Subic.

Impressum:

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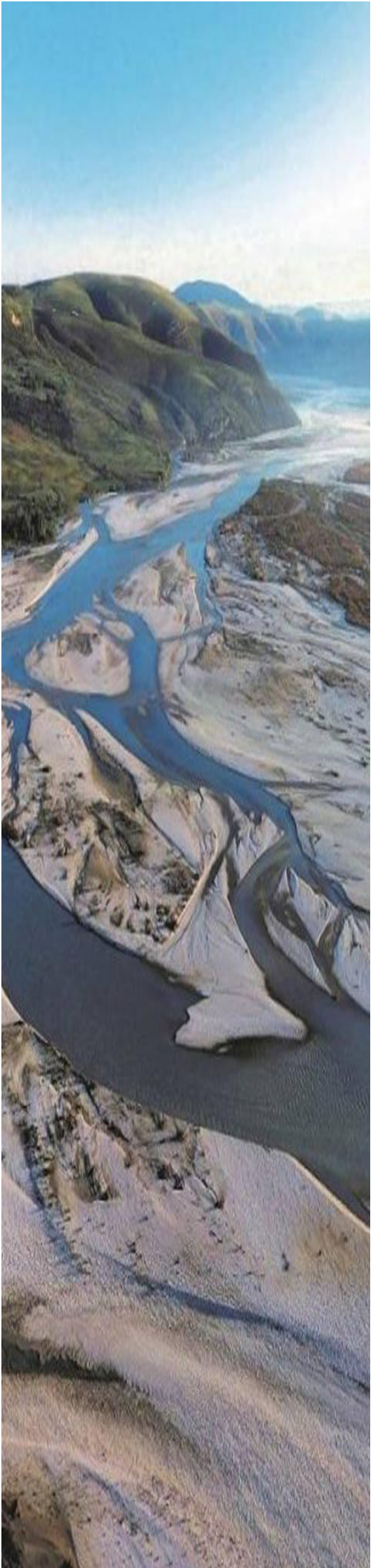

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– PREFACE –

Vjosa – A natural river laboratory with unique chances

The Vjosa is one of the last large free-flowing rivers in Europe, hosting a spectacular abundance and diversity of species, habitats and ecological processes. These unique ecological and aesthetical values depend on the widely undisturbed and well-preserved fluvial dynamics, from the headwaters in Greece (Aoos) to the delta in southern Albania (Vjosa), and including almost all its tributaries. As such, the Vjosa represents one of the last opportunities in Europe to understand what a natural river is and how it functions.

Therefore, the VWRNP needs a well-structured research plan to:

Coordinate and align research *towards the achievement of the overall objective of* ***understanding what a natural river is and how it functions****, as a basis to* ***support and adapt the management of the national park***.

Indeed, if well-coordinated, research in the VWRNP has the potential to give a picture of large-scale natural river dynamics, to assess the influence of anthropogenic and natural processes on such dynamics, and to describe the imprints of rivers on the broader landscape and how these vary through time. Moreover, understanding the large-scale river processes that sustain the unique values of the Vjosa basin is the essential underpinning for a sustainable management of the national park, and local development.

The Vjosa could provide benchmarks for European environmental policy and reference points for the fragmented, dammed and dried rivers dominating human landscapes, therefore **acting as a blueprint for the protection and restoration of other similar rivers.**

Last, given the fast pace at which climate change is affecting the Albanian territory, with evident effects in the Vjosa River Basin, continued research in the VWRNP has the potential to help **translate eventually detected patterns of change into development of adaptation strategies**, which could be applied to other similar river networks.

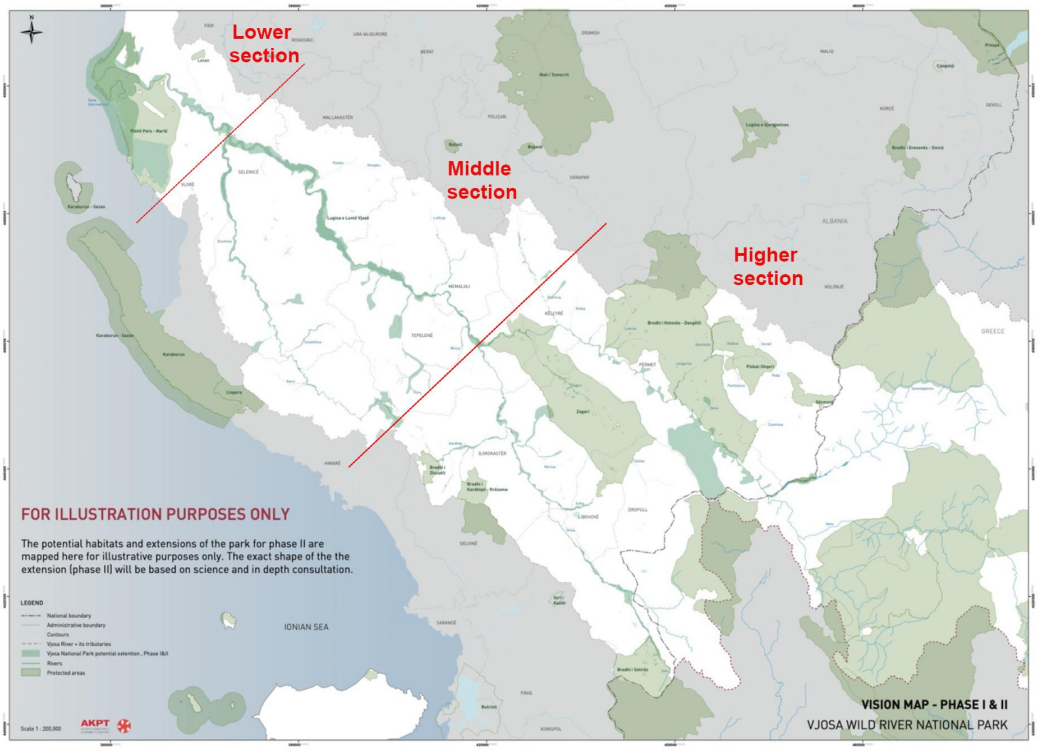


Figure 1: Vjosa basin with upper, middle and lower sections marked, and VWRNP boundaries. (map by NTPA)

1 Status quo of research and purpose of the research plan

Being one of the last free flowing rivers in Europe, the Vjosa river network has experienced growing scientific interest in recent years. Currently, there are three major ongoing projects:

- **EU4Rivers**:
  Co-funded by the EU and implemented by the Austrian Development Agency (ADA), this project is the follow-up of the EUSIWM project for an integrated water management in Albania. The overall objective is to support the Agency for Water Resources Management (AMBU) with technical assistance for the implementation of the Water Framework Directive, through the development of river basin management plans (RBMP) and of a national water monitoring system. (End: 30.09.2028)

- **ESPID 4 Vjosa** – Enhancing a Science-Policy Interface Development for the Vjosa:
  Financed by the ADA, this project aims at strengthening the management efforts for sustainable development of the Vjosa River catchment by bridging the science-policy-society interfaces. (End: 30.11.2024)

- **APPEAR–VjoSusDev** – Environmental assessment of the Vjosa riverscape as the basis for an integrated water management and sustainable catchment development:
  The project seeks to establish a long-term research cooperation of Albanian and Austrian scientists in the field of water governance. The project funds a cooperative and interdisciplinary study of the Vjosa river system, as the basis for its sustainable development. (End: 30.04.2026)

These projects are coordinated through a collaboration of universities, Non-Governmental Organisations (NGOs), and the Albanian Government. Moreover, other activities, such as the organisation of two “Science Weeks” and the creation of the “Fritz Schiemer Research Centre”, supported by the “Save the Blue Heart of Europe" campaign, catalysed research along the Vjosa.

Through all these projects and activities, evidence was collected, supporting the recognition of the Vjosa river network as an ecosystem of European importance, and setting the basis for the establishment of the VWRNP. However, according to the scientists who worked at the Vjosa, the so far achieved knowledge only represents the tip of the iceberg and there are much more values, but also threats, to be discovered.

This research plan illustrates which goals and purposes may be in the foreground, from a scientific and from a management perspective, and is based on interviews with scientists already active in the area. To integrate ongoing and future research projects, any achieved knowledge about the Vjosa system should be gathered, centralised and made publicly available. In this way the national park will provide the best conditions to enhance research of the long-term natural processes forming the Vjosa. Furthermore, such knowledge must be translated into management actions and the management plan of the national park must be updated and adapted accordingly. The research directions devised in this plan apply to the VWRNP as well as the surrounding landscape, broadly defined as the catchment area of the Vjosa valley. Indeed, as the ecological values of rivers strongly depend on the catchment they drain, looking beyond the actual boundaries of the VWRNP (which is limited only to the river channel and banks) is essential. Also, in this way research could provide valuable data for the final expansion of the national park, to be achieved in a second phase as envisaged in the Vision, Road Map and Feasibility study. This research plan is designed for a time horizon of **10 years**, and should be updated as necessary. The research priorities in this concept should be understood as suggestions – in fact, research is open to all disciplines and questions that are compatible with the protection requirements of the national park.

2 Research directions

The Vjosa represents one of the last opportunities to understand the natural large-scale processes that sustain the ecological values of natural rivers. Therefore, research in the VWRNP should be framed around the overall objective of understanding what a natural river is and how it functions. By pursuing this objective, research should always keep supporting and advising the management of the national park, translating scientific outcomes in management practices. This objective also ensures the fulfilment of the requirements that the IUCN sets for a category II national park: to protect the natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to develop appropriate conservation and sustainable development strategies.

To coordinate research towards the achievement of this objective, the VWRNP needs a concept for research that (i) implements a monitoring network, and (ii) includes priority research projects.

2.1 Monitoring and real-time data broadcasting

The overall goal of monitoring in the VWRNP should be to create continuous data-series regarding the present biodiversity, habitats, and environmental regimes; in order to support research of long-term natural processes. Indeed, data collection through monitoring is the first essential underpinning on which the development of future research projects will depend, representing the basis for knowledge generation. Partly, this was already started within the framework of some of the mentioned projects. Moreover, the Agency for Water Resources is working on the development of basin management plans to implement the WFD. In this context the VWRNP should organically gather the already available data and make it publicly available to support ongoing and future projects. Also, monitoring in the VWRNP should enhance the development of a more detailed and continuous monitoring, along both temporal and spatial scales, with respect to what is required by the WFD.

Thus, the VWRNP should enhance monitoring to:

- *diversify the monitored variables*;
- *increase the frequency of monitoring*;
- *enlarge the monitored area* towards headwaters and into the delta region;

Monitoring in the VWRNP should include: (i) a monitoring network for all those variables which can be measured through automatic monitoring devices, such as environmental variables; and (ii) periodic baseline surveys for the monitoring of plant and animal communities and habitats, which require experts working in the field.

To achieve the most appropriate monitoring resolution with an efficient allocation of resources, a strict collaboration between the VWRNP, the Agency for Water Resources, and the National Environment Agency (NEA), is essential. Furthermore, based on results from the APPEAR–VjoSusDev project, locations of monitoring sites for both biotic and abiotic assessments should be adapted to major pressures identified within the catchment. Additional sites should be established according to the occurrence/distriution of indicative umbrella/flagship or endemic organisms.

The output data of the monitoring network, as well as the outcomes of the baseline surveys, should be collected, and broadcasted through a web-based platform. Best would be to have a section dedicated to research on the official web page of the VWRNP. Such a publicly available database would enhance data employment (i.e., in other studies or in decision making) and empower the interactions among researchers, managers, stakeholders, and authorities.

2.1.1 Monitoring network for environmental variables

The monitoring of environmental variables allows to describe the different environmental regimes occurring along the Vjosa, and to assess their influence on the present habitats and biodiversity.

The number and placement of the monitoring stations should be carefully planned in order to be representative of the basin's features (e.g., elevation ranges, river confluences, land use, etc.). Furthermore, for both weather and water monitoring stations, the presence of already existing stations (which are often difficult to identify because maintained by different agencies or NGO's) must be accounted for and the number of new stations must be modulated accordingly. In the eventuality that the number of new stations can be reduced because of the presence of already existing stations, then the representation of smaller tributaries/sub-basins could be considered. Finally, to choose the exact location, a land suitability analysis should be performed (e.g., no steep slopes nearby for weather stations, or stable river bed for water gauging stations, etc.).

Furthermore, the choice of the monitoring devices should be carefully considered:

- The employment of devices designed to communicate through open-sourced protocols, requires the employment of IT personnel and of at least one data analyst to collect the data, to ensure data integrity, to set-up and maintain a centralised server, owned by the VWRNP, and to publish the data on the VWRNP's official web-site. Stations with open-sourced protocols allow for higher flexibility, as new types of sensors can be easily added, or replaced, in case of fault.

- The employment of stations with proprietary protocols for data exchange requires less work but would imply monthly costs to be sustained in the long term, and would still require the employment of personnel to export the data from the private servers and to publish it on the VWRNP's official web-site.

Moreover, with personnel onsite it would be possible to control the functioning of the monitoring devices, allowing for timely maintenance (e.g., checking reference conditions for discharge measurements). Also, it would be possible to install monitoring devices which require more frequent maintenance, such as optical sensors for suspended sediment monitoring.

Thus, the best option would be to monitor all variables employing automatic open-sourced monitoring devices provided with sensors connected to a centralised database (i.e., creating an Internet of Things (IoT) network).

Variables to monitor:

- **Weather monitoring**

  - Precipitation;
  - Air temperature;
  - Atmospheric pressure;
  - Atmospheric humidity;
  - Wind speed and direction;
  - Solar radiation;
  - Evaporation;
  - Soil moisture.

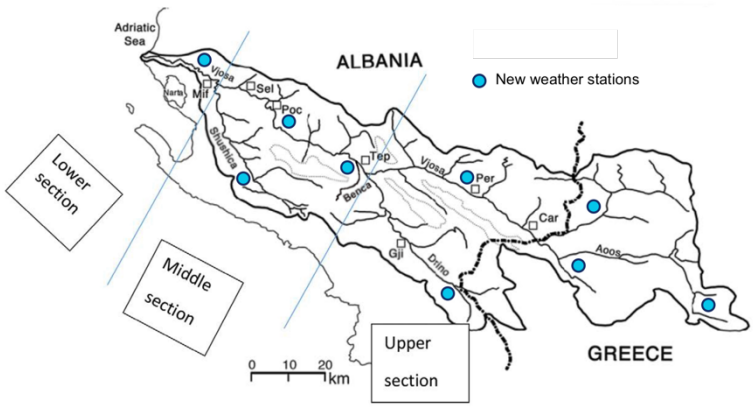


Figure 2: Sketch of the Vjosa catchment (by Dr. Andrej Sovinc, Protection study of the Vjosa River Valley based on IUCN protected area standards, 2021) and hypothetical placement of the weather monitoring stations.

Weather monitoring stations (Figure 2) should be placed along the Vjosa in order to be representative of the changing elevation. Moreover, the main tributaries (Drino, Bença, and Shushica) should also be provided with at least one weather station, in order to represent the main sub-basins. Thus, at least nine weather monitoring stations are needed: two along the Aoos, one along the Sarantaporos, three along the Vjosa (i.e., one per river section), and another three for the main tributaries. Additionally, a weather monitoring station could be installed in the area of the forest nursery.

- **Surface and groundwater monitoring**

Physico-chemical elements:
- Discharge;
- Temperature;
- Oxygen concentration;
- Electric conductivity;
- pH;
- Nutrient (Nitrogen, Phosphorus);
- Pollutants (Heavy metals, Bio-accumulable organic toxic substances, Biocides and plant protection products, etc.);
- Turbidity / suspended sediments.

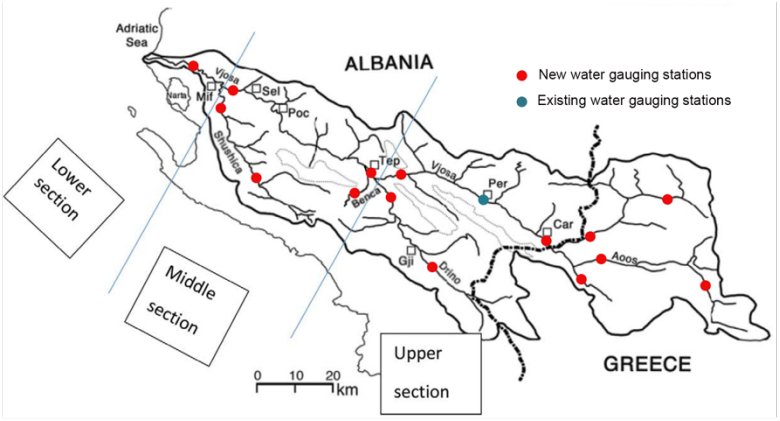


Figure 3: Sketch of the Vjosa catchment (by Dr. Andrej Sovinc, Protection study of the Vjosa River Valley based on IUCN protected area standards, 2021) and hypothetical placement of the water monitoring stations.

Water monitoring stations (Figure 3) should be placed after major confluences, and the headwaters should not be underrepresented as they can affect downstream. Thus, Aoos and Sarantaporos, in Greece, should be monitored as well. Therefore, fifteen water gauging stations are required: three along the Aoos, two along the Sarantaporos, five along the Vjosa (two in the upper section, two in the middle section, and one in the lower section), two along the Drino, one along the Bença, and two along the Shushica.

Once data about water quality is collected, it is essential to compare sites with good and bad water quality, and to acknowledge how such water conditions are reflected in aquatic and terrestrial organisms. Therefore, aquatic and terrestrial invertebrates should be investigated along transects, from each water station to up to the terrestrial area. This would allow to understand how aquatic/terrestrial invertebrates respond to nutrients/pollutants in water bodies and on land, and how the distance from the water body influences such responses.

2.1.2 Biodiversity and habitats – Baseline surveys

To conserve natural values is the first duty of protected areas. To this aim, it is fundamental to monitor and to assess the conservation status of the biodiversity and of the habitats which are present in the VWRNP, and to use such knowledge to update and adapt the management plan of the national park. This knowledge could be achieved through the establishment of Long-Term Ecosystem Research (LTER) sites where specific taxa and habitats are studied in the long term. Furthermore, the results of monitoring activities which are being implemented within ongoing projects, such as the APPEAR–VjoSusDev project, should serve as a base for setting the targets and for choosing the locations of future surveys. Indeed, the placement of LTER sites should take into account the location of sites already investigated in such other projects. At present, the study sites are too concentrated in the middle section of the Vjosa, while the headwaters (i.e., interlink with Aoos) and the delta region are underrepresented.

Baseline surveys are needed for:

- ***Fishes***:

  As the whole river channel of the Vjosa and of the main tributaries will be the core area of the national park, fishing should be regulated. To define limits, it is essential to monitor the fish communities in terms of present species and age structure. Also, data about abundances of endangered and endemic species are largely missing (Graf et al., 2017). Moreover, in some tributaries of the Vjosa, as in the Bença, there is evidence about the presence of trout (mainly in the headwaters), but the abundance and share of trout compared to other species is still unknown.

- ***Birds****:*

  A total of 157 bird species have been documented in the Vjosa river basin, but many of them are listed in the Birds Directive or in the Albanian National Red List, and are therefore considered priority species of very high conservation importance at the EU level. Thus, it is important to constantly monitor (on an annual basis) the breeding population of key bird species in the national park as well as the migratory species. Also, it is essential to assess the impacts that recreational and touristic activities can have on bird populations. Furthermore, information about populations of key bird species as well as the locations of their breeding sites must be handled carefully to avoid the risk of illegal poaching. Last but not least, the Vjosa Delta, shelters up to 18 Natura 2000 habitats and is the second most important site for bird biodiversity in Albania, acting as a wintering site for water birds such as the Greater Flamingo, Audouini's Gull, and the Dalmatian Pelican. Also, the Narta lagoon and Gjirokastra are designated as Important Bird Areas. Therefore, the species present in these areas should also be documented. Specifically, for the Narta lagoon there is data (for the last 20-25 years) regarding wintering birds and water birds, while for breeding and migratory birds a complete survey is needed.

- ***Invertebrates****:*

  The deficiency in knowledge about the diversity of aquatic, benthic and terrestrial invertebrates in Albania has been confirmed by recent descriptions of many new species, hitherto, exclusively found at the Vjosa. However, so far only timely restricted sampling campaigns were conducted within the APPEAR–VjoSusDev project. To densify data collection, continuous sampling throughout the year should be performed, and specific and group-appropriate methods should be applied. Also, as taxonomic literature is lacking, a network of international experts, of aquatic and terrestrial invertebrates, has to be established to complement the Albanian expertise in identification processes and completion of species lists. Metabarcoding of DNA released into the preservative ethanol has been proposed as a non-destructive alternative to speed up biodiversity data generation. However, this method relies on DNA barcoding reference libraries which for Albania, and the Balkans in general, are still largely missing. The VWRNP should help fill this knowledge gap. Priority should be given to:

(1.) mapping of endemic and endangered invertebrates along the Vjosa and its main tributaries, but also along smaller tributaries, especially in headwater and intermittent streams, and (2.) mapping of arthropods in areas which are not flooded often, such as recent terraces consisting of agricultural land. In such areas, a comparison between traditional and conventional agriculture should be done in terms of plant, arthropod and bird diversity (e.g., in terms of species numbers, community assemblages, threatened species, functional diversity/traits, etc.). Such a comparison could help to find facts why to keep traditional farming practice as a cultural and natural heritage.

- ***Floodplain forests**:*

By supplying food and by forming habitat, riparian plant communities constitute the major organisers of riparian ecosystems, and regulate the ecological functions a riparian area can provide. As natural alluvial forest stands are disappearing also along the Vjosa (only 22% of the area of the Vjosa basin is covered by forests), existing alluvial forests, as well as natural forest adjacent to slopes, have to be identified and their protection must be ensured. Furthermore, the Potential Natural Vegetation (PNV) and the role of the main tree species (*Populus alba, P. nigra, Platanus orientalis*) in the plant communities of the floodplain, must be acknowledged. This information is essential for the sustainable afforestation/reforestation of degraded and exposed floodplains, slopes and areas of the watershed outside and inside the VWRNP boundaries. Last but not least, the effects of slash-and-burn practices and overgrazing on PNV should be untangled. A key step to protect natural vegetation is to investigate the potential risk of neophytes spreading (i.e., *Ailanthus altissima, Robinia pseudoacacia, Paulownia tomentosa, Acer negundo*), in connection with increased tourism and land use change.

- ***Land use:***

The Vjosa catchment is populated since thousands of years, and its landscape reflects the deep-rooted cultural heritage of its inhabitants, including agricultural practices and a long tradition of nomadic livestock keeping. Therefore, any monitoring and management must be understood and implemented considering a historic context (i.e., land use history). Furthermore, human activities such as mass tourism and intensive agriculture are increasing rapidly, determining high rates of land use change. The mapping and monitoring of land use at the catchment scale would allow to assess such changes, to compare ecosystem functions and biodiversity across different land uses, and to study the effects of land use along gradients of use on a large scale. Priority shall be given to the mapping of forests, agricultural/traditional land use types (herding sheep, pastures), to be coupled with baseline surveys of terrestrial invertebrates, pollinators, and flowering plants.

- ***Pressures on biodiversity and habitats:***

Monitoring at the VWRNP should also address the pressures, including threats which origin outside of the boundaries of the VWRNP, which determine changes in environmental patterns thus affecting biodiversity and habitats. Particularly, such pressures should be recorded and mapped/monitored, in order to develop management actions and regulations aimed at reducing and mitigating the impairment of natural resources. Priority should be given to:

- Mining;
- Source point pollution (especially around urban areas);
- Diffuse pollution (extensive agriculture and monocultures such as strawberries);
- Water abstraction;
- Natural and anthropogenic siltation (e.g., erosion from agriculture);
- Oil drilling;
- Fishing (especially over-fishing of migratory species)
- Tourism-related activities (e.g., rafting, bird watching, etc.)

2.2 Priority research projects

Priority research projects, in the VWRNP, should be framed around the overall objective of understanding what a natural river is and how it functions. Also, specific research projects should address questions related to conservation and sustainable local development.
Furthermore, there are two research projects already included in the management plan, which consist in a Species and Habitats Mapping Project (see action 2.1.1 and 2.2.1 of the Integrated Management Plan), and in a Hydrological study (see action 6.2.3 of the Integrated Management Plan) aimed at mapping irrigation and drainage systems. These projects should have the overall priority, as they are a prerequisite for many other studies.

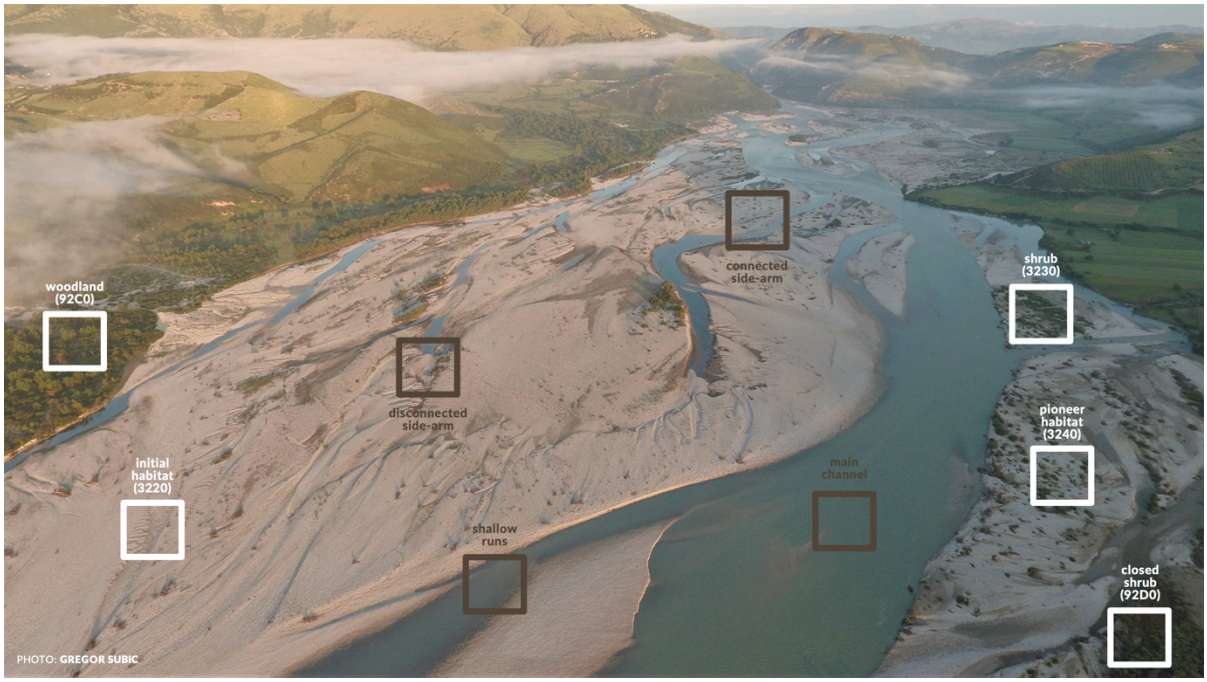


Figure 6: Overview of selected aquatic (brown boxes) and (semi)terrestrial (white boxes) habitats along the lateral expansion of the Vjosa River, numbers in brackets indicate Habitat-Directive types. The natural flow and sediment regimes of the Vjosa (and their interaction with vegetation) generates high spatio- temporal heterogeneity, continuous habitat rejuvenation, and biotic succession of well-adapted species associations. (by Meulenbroek, P., Egger, G., Trautner, J., Drescher, A., Randl, M., Hammerschmied, U., Wilfling O., Schabuss, M., Zornig, H., Graf, W., 2020)

2.2.1 Understanding a natural river network:

As rivers carve major topographic features into the land surface, their influence penetrates well beyond their channels into the atmosphere, across the land surface, and into the subsurface, and undergoes spatio-temporal variations. The formation of such topographic features depends mainly on the river's spatial structure and on the surrounding terrestrial matrix, and this combination largely influences the uniqueness of natural river networks (Figure 4 and 5). Indeed, it is the spatial structure of rivers and the connectivity of habitats along them which determine the highly dynamic mosaic of ecosystems, the great biodiversity and the diverse ecological functions, typical of natural river networks (Figure 6). However, the very same structure also determines their high vulnerability to anthropogenic perturbations, both of the river or of the catchment.

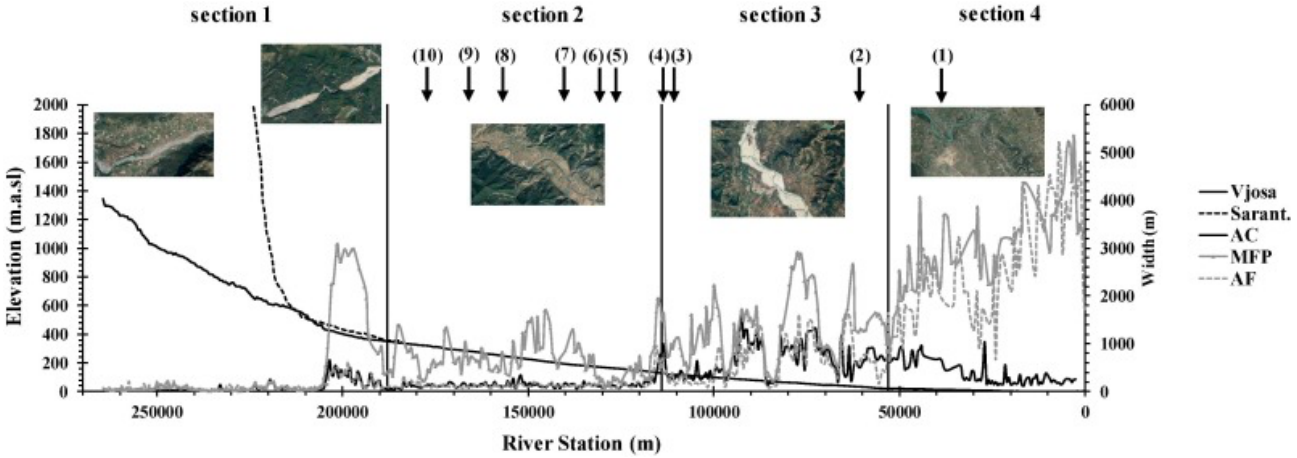


Figure 4: Landscape profiles of the Vjosa and of the Sarantaporos (river km vs. elevation), and width of their active channel, morphological floodplain and active floodplain; (by C. Hauer and K. Skrame and M. Fuhrmann, 2021)

Figure 5: Satellite series showing the evolution of the riverine landscape in the braiding middle river course of the Vjosa downstream of Kalivac; (by Schiemer F., Drescher A., Hauer C. & Schwarz U., 2018)

- ***Hydrology and disturbance regimes along a free-flowing river***

  The Vjosa represents one of the last opportunities, Europe-wide, to study the hydrology of a large, free-flowing, gravel-bed river. Therefore, understanding how the natural hydrology of the Vjosa and its natural disturbance regime, shape its rich biodiversity could provide strong reference points for the fragmented, dammed and dried rivers dominating human landscapes, and could act as a blueprint for the protection and restoration of other similar rivers.

  Open research questions:

  - How do hydrology and disturbance regimes vary longitudinally, from headwaters to estuary, and laterally across the floodplains?
  - How do hydrological exchange processes between the river channel and the hyporheic compartment vary along the Vjosa?
  - How do hydrology and disturbance regimes respond to anthropogenic water abstraction and climate change?

  Priority projects:

  - Hydrological modelling from headwaters to estuary.
  - Modelling of hyporheic hydrological exchanges.
  - Modelling the responses of hydrology and disturbance regimes to anthropogenic water abstraction and climate change.

- ***Interaction of hydrology, sediment transport and riparian vegetation***

  The unique values of the Vjosa are the result of its widely undisturbed and well-preserved hydromorphic dynamics. Such dynamics are heavily influenced by hydrology, sediment transport and riparian vegetation, and research should therefore address their interaction and their effect on biodiversity and habitat diversity.

  Open research questions:

  - How do interactions between flow, sediment, vegetation and transported materials (i.e., wood, waste, etc.) drive the physical (i.e., hydraulic and morphological) habitats that are present, the degree to which they turn over and are rejuvenated, and the biogeochemical processes they support?
  - How does disturbance (floods and droughts) drive such interactions between flow, sediment, vegetation and transported materials?
  - How does disturbance (floods and droughts) drive seasonal patterns and life cycles of aquatic/terrestrial invertebrates?

  Priority projects:

  - Modelling the interaction of riparian vegetation growth, flooding and sediment transport and describing their relative contribution to habitat-turnover (both in-stream and floodplain habitats).
  - Identifying and mapping erosion hotspots, source activation processes, and various local point sources/sinks, for both sediments and wood logs.
  - Describing lateral floodplain vegetation succession patterns.
  - Identifying life-cycles, habitat preferences and specific adaptations of selected invertebrate communities based on seasonal monitoring.
  - Test the sensitivity/resistance of indicators regarding habitat turnover.

- ***Food webs and stream metabolism***

  Streams and rivers are important contributors to the global carbon (C) cycle, and the processing of particulate organic matter (POM) by riverine biota, encompassing macro- and microorganisms, is a fundamental component of metabolic activity in fluvial networks. In other words, the biological processes of production, respiration, and excretion can drive biogeochemical cycles, and vice-versa. Thus, it is critical to understand how biological diversity and biogeochemical diversity are interlinked and how they drive stream metabolism. Furthermore, studying how food webs and stream ecosystem metabolism respond to flow dynamics is critical to explain changes in productivity and the responses of animals at the top of food webs, such as birds and fishes.

  Open research questions:

  - How does biological diversity affect biogeochemical diversity and thus stream metabolism?
  - How do food webs and stream ecosystem metabolism vary with different flow dynamics?

  Priority projects:

  - Drawing the metabolic fingerprint of the last large free-flowing river.
  - Modelling and comparing the metabolic responses to flow variations due to water abstraction and/or climate change.

- ***Nutrient dynamics***

  Large rivers and their floodplains represent hot spots of natural purification processes and support groundwater aquifers for drinking water supply. The physical and biological components responsible for the provisioning of such ecosystem service should be studied, with a special focus on the role of the hyporheic dimension.

  Open research questions:

  - How does stream-bed heterogeneity affect the physical and microbiological processes governing in-stream nutrient cycles?
  - Which taxa/species are indicators of high/low nutrient/pollution level?

  Priority projects:

  - Developing hydraulic models to quantify the effect of complex topography on hyporheic exchange and subsurface flow paths, the resultant changes in aerobic/anaerobic zones in the subsurface, and the microbial communities which can develop.
  - Mapping the distribution of diatom communities across riverine habitats, and developing an index of biological integrity (IBI) for diatoms.
  - Assessing the potential of different phyto-depuration techniques (i.e., water purification technique based on the use of aquatic plants) along the Vjosa.

- ***Metacommunity patterns***

  Rivers represent conveyor belts connecting distant communities and habitats throughout landscapes. The Vjosa gives the opportunity to study the environmental and spatial interactions determining how communities are assembled along natural river networks. The study of natural metacommunity patterns, especially with regard to zoobenthos, algae and microbes, represents a research frontier that can hardly be followed elsewhere. Furthermore, studying how environmental and spatial interactions drive community assembly, can have implications for bioassessment programs.

  Open research questions:

  - How does the interaction between spatial structuring and environmental filtering drive the structure of in-stream and terrestrial metacommunities (e.g., zoobenthos, algae, microbe, riparian vegetation metacommunities)?
  - How does this interaction vary in time? How do disturbance regimes influence this interaction?

  Priority projects:

  - Assessing the role of dispersal-linked and niche-based mechanisms in determining metacommunity assembly of in-stream and terrestrial metacommunities.
  - Assessing how the interaction of environmental and spatial processes varies in time and along disturbance gradients.
  - Acknowledging the cyclic variation of spatially dynamic refugia for mobile organisms along the Vjosa.
  - Analysing genetic exchange between habitat specific organisms with different dispersal strategies (hololimnic vs. hemilimnic).

- ***Migratory fishes***

  The functional connectivity of the Vjosa, from headwaters to sea, allows to find high numbers of anadromous, catadromous, and diadromous fish species. However, as their habitat/niche requirements change, all species migrate within their lifecycle to a certain extent. Still, knowledge about the requirements of characteristic migratory and non-migratory species is limited and further research in this direction is required to allow a sustainable protection of such species.

  Open research questions:

  - How does habitat use change in relation to population age-structure?
  - Which are the main pressures on migratory and non-migratory fish species and which mitigation measures could be employed?

  Priority projects:

  - Mapping the habitat use of different fish species and of populations with different age-structure.
  - Creating a Linkage Framework (LF). The LF is a valuable tool for decision makers that can depict interrelations in a system, and is a recommended ecosystem-based management method. It can be used to link stakeholders to their related activities in the Vjosa, which then are linked to the different pressures they induce (physical, chemical, biological), and lastly to the migratory fish species (or to any other migratory organism) affected by these pressures.
  - Quantify the pressure of fish-netting in the lower part of the Vjosa on migratory fish species, and set limits.

- ***River network – catchment links***

  In order to advance a scientific understanding of the links between catchment and river properties, research needs to explore the interactions between river systems and land surface, atmosphere and sub-surface. Such interactions extend beyond physical processes to the full array of biological, biogeochemical and ecological processes, and present strong implications for a sustainable river management. The ability of riverine corridors to mitigate floods depends on the dynamic interaction between rivers and the catchment they drain. Due to its large variability of annual flows, its large gravel body, and its wide riverbed, the Vjosa provides an important function for flood control moderating larger floods to a certain extent. However, due to several causes such as the intensive exploitation of river gravel, the high deforestation rates with resulting degradation and erosion, as well as the destruction of embankments, major floods increasingly occur, particularly at the lower section of Vjosa. The Vjosa Delta (as naturally flooded area) already partly provides a natural retention area for floods despite its intensive agricultural use. However, the full potential for natural flood control can only unfold if riparian forests are established and degraded slopes are afforested to absorb precipitations. As major flood events are becoming more frequent at the global scale, mainly due to climate change and anthropogenic perturbations of natural environments, the natural state of the Vjosa represents a great opportunity to assess floods and natural mitigation strategies.

  Open research questions:

  - Which are the most effective, conventional and nature-based, flood prevention and mitigation strategies? Which is the best option for the Vjosa basin?
  - How does deforestation at the catchment level affect local climate and the flooding regime of the Vjosa?
  - How does catchment geology affect the composition and properties of alluvial sediments?

- How do magnitude, duration and frequency of floods affect soil moisture and alluvial aquifer recharge?
- How do composition and properties of alluvial sediment influence the pathways of water exchanges between the surface and subsurface, the related biogeochemical processes and ecosystem functioning and health?
- How does large-scale river-controlled topography influence near-surface atmospheric circulation patterns and local climate properties? How do such atmospheric circulation patterns affect aeolian dispersal of fine mineral sediment particles, organic particles, seeds, and insects?

Priority projects:

- Comparing conventional and nature-based flood prevention and mitigation strategies and developing a flood prevention/protection scheme for the region.
- Hazard modelling and risk assessment for different basin/flood scenarios (e.g., assessing the impact of land-use change and deforestation, at the basin scale, on flood frequency and magnitude).
- Acknowledging/modelling the link between floods, alluvial aquifer recharge and endangered floodplain forest hotspots (e.g., employing remote sensing indices).

2.2.2 Conservation of species and habitats

Research in the VWRNP should focus on identifying threats and on developing measures to ensure that a favourable conservation status is achieved, for all species and habitats (Figure 7 and Table 1). Furthermore, to ensure the protection of species in the long term, it is essential to study the effects of climate change and of land-use change, and to shed light on possible adaptation strategies.

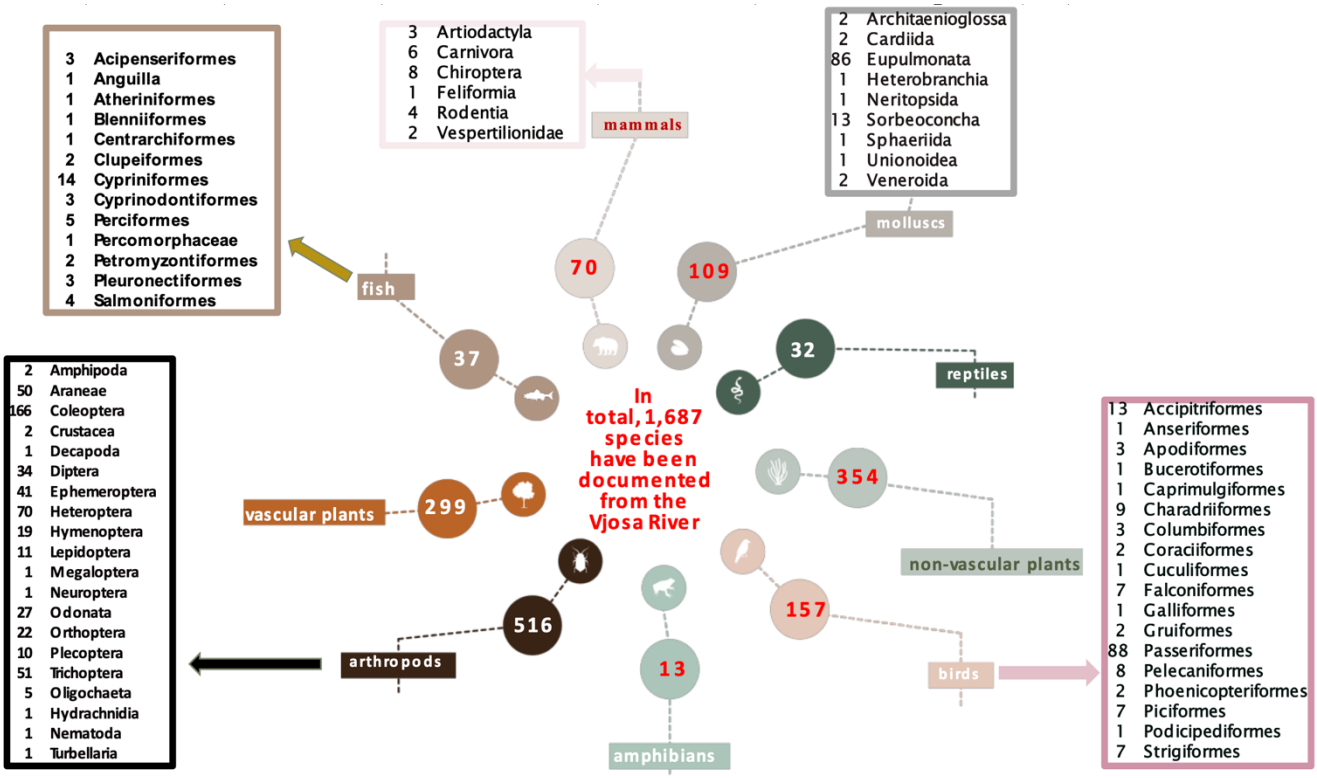


Figure 7: Biodiversity in the Vjosa WRNP (by Kovarovics Anna & Huber Michael, (with contributions from other experts). (2024). Vjosa Wild River National Park, Integrated Management Plan 2024-2033 (V 1.0 of the Draft)).

*Table 1: Most important habitat types of VWRNP (*by Kovarovics Anna & Huber Michael, (with contributions from other experts). (2024). Vjosa Wild River National Park, Integrated Management Plan 2024-2033 (V 1.0 of the Draft)).

Habitat type	Code	Priority
Alpine rivers and herbaceous vegetation along their banks	*3220*	
Mediterranean rivers with the constant flow with Glaucum flavum (yellow poppy)	***3250***	***1.8 % of European coverage***
Alpine rivers and woody vegetation with Myricaria germanica (German tamarisk)	***3230***	***1.2 % of European coverage***
Alpine rivers with woody vegetation with Salix eleagans	*3240*	
Southern coastal corridors and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)	*9200*	
Semi-natural dry grasslands and scrubland areas on calcareous substrates	*6210*	
Alder forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)	*9130*	
Platanus orientalis and Liquidambar orientalis (Platanion orientalis) forests	*92C0*	

- ***Species and Habitat Action Plans***

  To ensure the effective protection of habitats and species, specific Action Plans must be developed. Priority shall be given to species and habitats listed in the Habitat and Bird Directives, as well as rare, sensitive or endemic organisms. Furthermore, as some groups of organisms, such as specific arthropod groups, are not sufficiently addressed in the Red Lists of Albania, and would thus not be considered as priority species, it is necessary to acknowledge the presence/absence of such groups and their conservation status. For some species and habitat types action plans already exist, mostly at the European level (as for many bird species, for sturgeons, etc.) and sometimes at the Albanian state level (as for the Albanian Frog *Pelophylax shqipericus*). In these cases, the Action Plans should simply be adjusted and implemented according to the peculiarities of the VWRNP. On the other hand, for most species, the Action Plans need to be designed from scratch. In such cases they should be developed according to the guidelines provided within the Habitat and Bird Directives, and should include the following elements:

  - *Current status*: brief definition of the habitat or species and description of its status in the VWRNP, and also providing a national picture;
  - *Pressures*: list of the main factors threatening and/or causing the decline of the habitat or species;
  - *Gaps*: identification of gaps in protection, where local, national and international policies may have missed protection (e.g., endemic species).
  - *Targets*: identification of conservation targets to be met, and timescales over which the targets are to be achieved;
  - *Proposed action*: identification of actions needed to achieve the targets;
  - *Species list*: examples of priority species which will benefit from the action plan;
  * *"What you can do"*: A section which can be added to make action plans more relevant to individuals living in the VWRNP, as well as organisations;

  The range of measures, set out in such species conservation/management plans, should then be implemented and monitored in order to ensure that the favourable conservation status of the concerned population or habitat is achieved and maintained.

  Priority projects:

  - Development of action plans (including status assessment) for habitats, and species of fishes (e.g.: Anguilla anguilla, Acipenser sturio), birds (e.g.: kingfisher, bee-eaters, peregrine falcon, snake eagle or black stork), plants, macro-zoobenthos, amphibians, reptiles and selected insect groups. Priority shall be given to species and habitats listed in the Habitat and Bird Directives.

    Example: Development of a species action plan for bats.

    Out of 32 bat species recorded from Albania, 29 are known to inhabit the Vjosa watershed, and many of them are protected at various levels. A key action for the protection of bats would be to map and protect roosting and hunting sites (i.e., caves, abandoned buildings, military tunnels, etc.). Also, actions to raise awareness about the key ecological functions bats fulfil, must be undertaken. Within this topic, collaboration could take place with the Prespa national park, which already possesses an action plan for the management and conservation of bats.

  - Acknowledging the presence/absence and conservation status of groups of organisms not sufficiently addressed in the Red Lists of Albania, such as specific arthropod groups.

- ***Untangling the effects of climate change***

  As the effects of climate change on rainfall, temperature, and runoff patterns are getting undeniable world-wide, understanding their impact on biological communities and on ecological processes is key for the securing of future resources. Furthermore, the study of near natural systems, such as the Vjosa network, can provide strong references on which to develop restoration and adaptation strategies for other similar rivers.

  Open research questions:

  - How will climate-driven changes of hydrological regimes impact river morphology (e.g., bar morphology) and habitat distribution?
  - How will sea level rise impact the sandy dunes habitats of the Narta lagoon?
  - How will species shift their distribution in response to climate change?
  - How will ecosystems and species respond to increases in frequency of extreme events?

  Priority projects:

  - Modelling hydrological scenarios and river morphology responses based on different climate change projections.
  - Modelling species distribution shifts along the Vjosa, from headwaters to estuary.
  - Modelling dune retreat and implementing in-situ surveys to describe future dune evolution (also considering the impact of the planned airport).
  - Assessing the risk of neophytes and neozoa (or generally neobiota) spread, and describing their interactions with existing species.
  - Measuring the resistance and resilience of riverine communities to extreme events with varying frequencies, and describing their recovery patterns.

- ***Land use change***

  Land use has major effects on biodiversity, and habitat fragmentation and habitat loss are among the major causes of biodiversity loss. It is therefore essential to assess the effects of land-use change and to predict future trends of change.

  Open research questions:

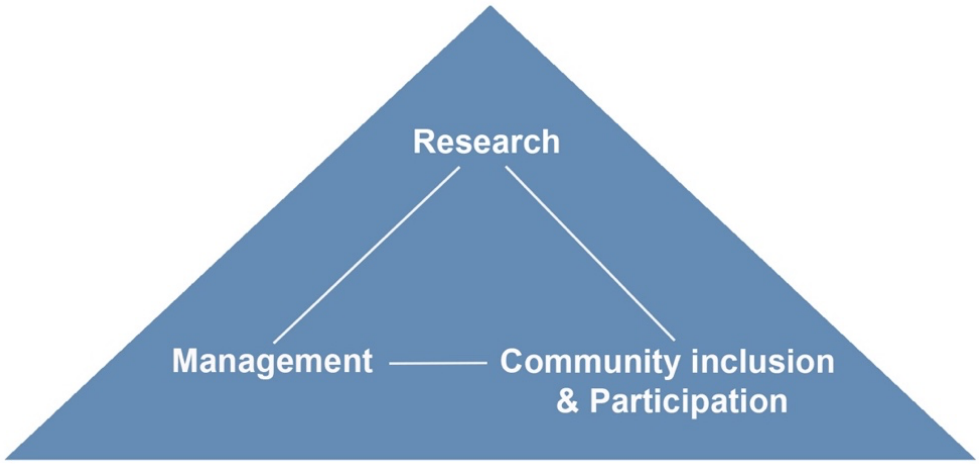
  - How does land use history affect the present biodiversity?
  - How can local habitat change or fragmentation affect biodiversity at larger scales?
  - How do climate change and land use change interact in their effects on biodiversity?

  Priority projects:

  - Assessing the historical development of land use across the basin.
  - Creating biodiversity scenarios for future land use development.
  - Linking land use change on large scales to changes in the migratory habits of species.
  - Modelling and projection of interactions of global change drivers.

2.2.3 Sustainable development

A national park should not only protect nature, but it should also sustain local development. This aspect is particularly critical for the VWRNP, since it is laying in a basin which in the next years will witness a huge expansion in the touristic and agricultural sectors. Therefore, it is fundamental to identify strategies which can valorise sustainable local development, especially regarding waste disposal and agricultural practices, to translate strategies in management practices and to involve in this process the local community. Furthermore, it is essential to provide a framework for tourism development and management within the Vjosa River valley. However, this aspect is extensively examined in the Tourism Master Plan, and will therefore not be addressed in this research plan. Jet, for the implementation and evaluation of the Tourism Master Plan a strict collaboration between the management team and the research team will be essential because it will allow to use baseline data and monitoring programs to assess negative/positive impacts.



- ***Enhancing the sustainable use of resources***

  There is a general consensus that biodiversity enables natural and agricultural systems to overcome environmental shocks, changing climates and pandemics. It allows the production of food with a minimal impact on non-renewable resources (water and soil above all) and with less need for external inputs that are costly and harmful to the environment, like fertilizers and pesticides for plants, and antibiotics for livestock. Further, it provides ecosystem services that are essential to life, like pollination and non-timber forest products. As Albanian agriculture is in a growing phase, research in the VWRNP should provide evidence to orient this sector towards qualitative changes of production practices, in terms of environmental sustainability. For that, a comparison between traditional and conventional farming is urgently needed.

  Open research questions:

  - Which is the impact of different traditional agricultural practices on wild pollinator biodiversity? And how is crop productivity influenced by the high/low levels of pollinator biodiversity?
  - Which agricultural practices can reduce the pollution impacts of agriculture on freshwaters?
  - Which are the impacts of grazing on floodplains, terraces and their vegetation? How does grazing affect the carbon cycle in such ecosystems?
  - Which perception do tourists have about local products and traditional production practices?
  - Which determinants influence local producers and tourists to assume a pro-environmental behaviour?

Priority projects:

- Comparing traditional and conventional farming in terms of biodiversity and environmental sustainability.
- Describing pollinator communities and the factors which drive pollinator diversity.
- Assessing which pollutants, especially the contaminants of emerging concern (CEC), are present in the agricultural lands within the VWRNP, and assessing the effectiveness of agronomical practices to reduce the impacts on freshwaters.
- Describing the impacts of grazing on floodplains, terraces and their vegetation, and determining the carrying capacity of such ecosystems.
- Creating a quality mark for the VWRNP to enhance and valorise sustainable production practices, from the agronomical, environmental and economic perspective. (i.e., a certification scheme, as suggested for tourism in the Tourism Master Plan, but for local products)

- ***Pollution and waste disposal***

  As tourism is expected to increase in the next few years, the impacts of pollution and waste disposal will most probably increase as well. Hence, research in the VWRNP should provide evidence about such impacts, and devise best management practices.

  Open research questions:

  - Which are the sources, fluxes, and fates of inert waste, especially plastics, in the Vjosa watershed?
  - Which are the rates of retention, transport, mineralization, atmospheric interactions, and export to oceans?
  - When (i.e., flow regimes, influence of floods) and where (i.e., geomorphic units, hydraulic units, river/floodplain elements) do such processes occur?
  - Which determinants influence local stakeholders to assume responsible and pro-environmental behaviour?

  Priority projects:

  - Watershed-scale modelling of plastic budget/transport along the Vjosa.
  - Developing a litter prevention strategy (identify key actions to drive litter behaviour).

- ***Public outreach and engagement***

  One of the main priorities of the VWRNP should be public education, outreach and engagement, especially with regard to the local community. This aspect is of prominent importance for national parks as it can strongly influence the success, visibility and acceptance of management, research and conservation strategies. As it is embedded in a landscape where commercial and private activities will increase and intensify in the next future, especially for the WVRNP these aspects are critical and the efforts and achievements of the VWRNP should be disclosed not only to the scientific community but also to local stakeholders and general public. To this purpose, as already mentioned, it is essential to create a dedicated section on the VWRNP web-page where all available data are broadcasted in real time. Additionally, the research team and the management team should also participate as speakers at civic organizations in the region and at national and international conferences. Essentially, research should get in contact with the interested society

and tourists. The VWRNP needs to attract people to stay by guiding them to attractive places and explaining natural processes which generate such places. Scientific research has to transform the perception of the public regarding nature and ecosystem services, which includes fishery, clean water for drinking and food production (including small scale cattle watering etc.), biodiversity as well as pressures which deteriorate and threaten the whole system. Rangers should be trained to give explanations on how long-term sustainability can be reached.

Priority projects:

- Engaging local community and stakeholders in setting management goals and objectives for the WVRNP, as well as in performance assessment.
- Creating educational citizen-science programs such as bio-blitzes (events during which citizens, with the help of researchers and rangers, can identify certain species), participatory mapping of ecosystem services, and deep-mapping workshops. The data obtained should be published on the web-page of the VWRNP.
- Hosting periodic scientific conferences, and creating video documentaries capturing the beauty of the Vjosa ecosystem, both the terrestrial and the aquatic compartments, and showing the work of researchers and their discoveries. Such documentaries should be published on the web-page of the VWRNP and preliminary screenings could be held at the research centre.
- Providing formation programs for rangers in which they are trained to give explanations on how long-term sustainability can be reached.
- Providing formation programs about monitoring techniques for rangers and laboratory assistants.
- Identify a suitable Money Generation Model, or create one, (i.e., economic model that can be used to estimate economic benefits of nature or national parks) and use it to evaluate the contribution of the VWRNP to local economies and job markets.

3 Catalysing research

To enhance the acknowledgement of the long-term natural processes which characterize the Vjosa catchment it is necessary to create the best conditions for research, designating the VWRNP as an attractive research area. Therefore, two key elements are: the availability of basic research facilities and the creation and publication of continuous data-series. To coordinate research and to support the management of the national park a research core team is essential. Furthermore, the creation of events, such as workshops or an annual symposium, would increase the visibility of research at the VWRNP, and would create opportunities for collaborations with other institutions and for stakeholder engagement.

3.1 Research centre and core team

The VWRNP should be provided with a modern research centre, furnished with all necessary basic laboratory equipment and big enough to allow the collaboration of different research teams (15-20 researchers) in interdisciplinary and transdisciplinary projects. Also, such facilities could enhance the involvement of schools and universities in research projects. Such a research centre could be included in the Vjosa Multifunctional Centre that the Albanian Government is planning to establish in Tepelena. Furthermore, given the extent and shape of the national park, the creation of at least one other basic research unit should be considered. Best, however, would be to have two further research stations, one in the estuary and one in the headwaters towards the border with Greece.

A core team of 3-4 researchers with technical expertise is needed. A data analyst expert and/or a spatial analyst is needed to check and broadcast the data deriving from the monitoring network, and integrate it with the data collected through previous and current projects (mainly collected in reports). Also, the correct functioning of the monitoring devices, as well as the reference values, should be controlled periodically. Furthermore, another two researchers are needed to provide onsite support to ongoing and future research projects. To cover these positions, it would be best to have researchers with an interdisciplinary background, with expertise about river ecology, protected areas, environmental management and agronomy. One option could be to have two permanent positions, one for an expert data analyst and one for a lead scientist, and then to apply for fundings to cover the costs of other two junior scientists. Finally, a research core team in the VWRNP is essential to (i) develop and maintain the monitoring network of the national park, (ii) to coordinate and align research projects and baseline surveys and (iii) to support and adapt the management of the national park, serving as a scientific advisory board for the management team.

3.2 Collaborations

The institution of a research centre at the VWRNP would allow the national park to collaborate with other institutions, such as universities, governmental and non-governmental institutions and other protected areas. Also, as a research institution, the VWRNP could independently apply for further financing programmes and schemes in the field of research. In collaboration with Greece the VWRNP could apply for financing schemes targeting transboundary rivers and protected areas. Furthermore, in addition to the priority topics and questions mentioned above and oriented towards the understanding and management of the VWRNP, questions from the topic catalogue of the Albanian research and from the action plan of the UNESCO biosphere reserves, should also be addressed. For example, it would be possible to compare usage gradients between different protection categories and countries, to compare habitat turnover determined by flooding processes, or to evaluate the development of fish populations and other organisms. Such projects could be developed together with other parks or reserves, and/or through international cooperation. In order to improve the supra-regional visibility of research, international journals and conferences should be taken into account for the dissemination of research results and research collaborations should be undertaken with renowned research institutions and other protected areas.

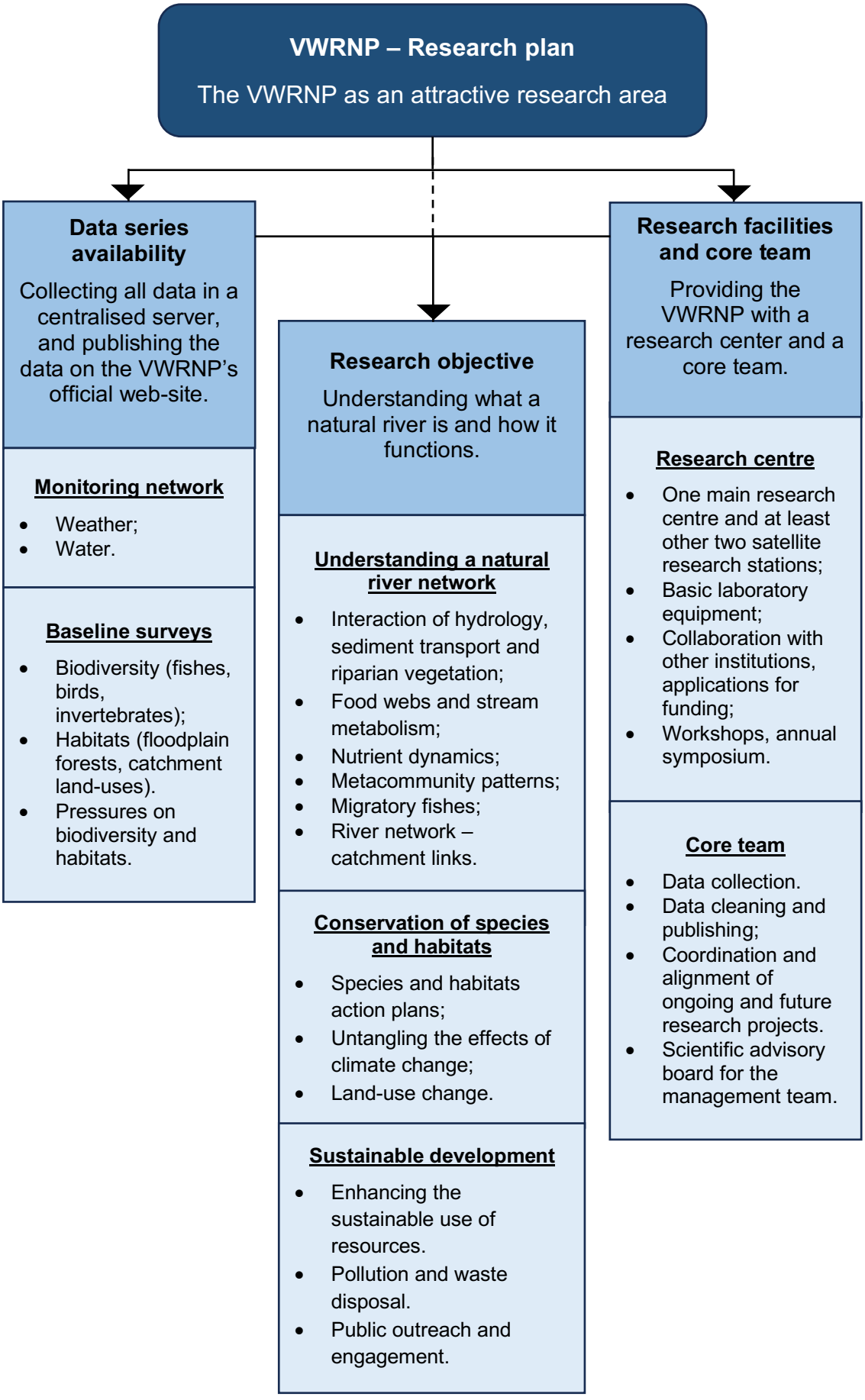


Figure 4: Flow chart describing the objectives of research at the VWRNP. This research plan provides the research core team with guidelines for the implementation of a monitoring network of the VWRNP, and for the coordination of ongoing and future research towards the achievement of the overall objective as basis for a sustainable management of the VWRNP.

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