© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Acta ZooBot Austria **155**, 2018, 1–40

The Vjosa River corridor: a riverine ecosystem of European significance

Fritz Schiemer, Anton Drescher, Christoph Hauer & Ulrich Schwarz

The paper provides an overview on the ecology of the Vjosa-Aoos river system in the Balkan. Its unique value is due to the widely undisturbed and maintained fluvial dynamics throughout its course, from the headwaters in Greece (Aoos) to the delta in southern Albania (Vjosa). The ecological functions and specific biodiversity of river-floodplain ecosystems are highly dependent on their intact geomorphic dynamics. The construction of two commissioned hydropower plants would destroy the Vjosa's present high value as a natural heritage and constrict options for alternative socio-economic uses of the catchment. The apparent hazards of a dam construction in the central part of the river course have not been seriously addressed by the environmental impact assessment presented for the hydropower plans. In order to strengthen a scientific approach for management, a collaborative study of Albanian and international scientists was initiated at the floodplains of Poçemi and Kalivaçi, which are representative of the middle reach of the river. A first combined study took place in April and September 2017. It included an assessment of the geomorphology of the river and its floodplains, its habitat turnover rates, vegetation ecology and the biodiversity of major aquatic and terrestrial faunal groups. Despite the short field work period, our assessment demonstrates an excellent conservation status of highest value. The Vjosa deserves international attention as a natural laboratory for river ecology and a benchmark for European environmental policy. Before major management plans are implemented, a detailed scientific analysis of its social and environmental characteristics should be carried out as a basis for an evaluation of long-term management effects.

Schiemer F., Drescher A., Hauer C. & Schwarz U., 2018: Die Vjosa in Südalbanien: eine Flusslandschaft von europäischer Bedeutung.
Der Artikel gibt eine Einführung zu einer Serie von Aufsätzen, in der die Ökologie der Flusslandschaft der Vjosa in Südalbanien und ihre Fauna und Flora behandelt werden. Der einmalige Wert des Gebietes ist auf seiner weitgehend ungestörten flussmorphologischen Dynamik begründet. Der Bau von zwei kommissionierten Staudämmen im Mittellauf des Flusses würde den einmaligen Wert des Fluss-Systemes schwer beeinträchtigen und eine ökologische Verschlechterung im Sinne der EU-Wasserrahmenrichtlinie darstellen. Die offenkundigen Bedrohungen durch eine Staudamm-Errichtung im Mittellauf der Vjosa bei Poçemi und Kalivaçi werden in den vorgelegten Umweltverträglichkeitsprüfungen völlig unzureichend behandelt. Modernes Fluss-Management erfordert eine wissenschaftliche Basis. Um die Schutzwürdigkeit des Gebietes zu illustrieren und die Notwendigkeit einer vertieften interdisziplinären Erforschung klarzustellen, fanden im April und September 2017 erste gemeinsame Untersuchungen von albanischen und internationalen Experten statt. Sie umfassten eine Analyse der Landschafts- und Habitatstruktur und ihrer Dynamik, erste vegetationsökologische Untersuchungen sowie Erhebungen der Biodiversität wichtiger aquatischer und terrestrischer Faunengruppen. Unsere Befunde bestätigen die naturschutzfachlich herausragende Bedeutung des Gebietes auf europäischer Ebene und zeigen, dass die Vjosa als weitgehend ungestörtes Fluss-System internationale Aufmerksamkeit verdient. Im Sinne einer europäischen Umweltpolitik sind vertiefende Untersuchungen über die Schutzwürdigkeit des Gebietes sowie der zu erwartenden negativen Folgen von Staudammerrichtungen unverzichtbar.

Keywords: Balkan river, river-floodplain ecosystem, fluvial dynamics, habitat turnover, succession, biodiversity, conservation, river management, hydropower.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Introduction

Large rivers and their floodplains offer manifold services for human well-being. They represent hot spots in natural purification processes and support groundwater aquifers for drinking water supply and agriculture. They provide flood mitigation, maintenance of natural biodiversity, and offer unique opportunities for development of tourism and recreation (Junk et al. 1989, Petts & Amoros 1996, Schiemer 1999, Naiman et al. 2005, Arthington et al. 2010). The key for understanding the processes responsible for ecological services and the high biodiversity of riverine landscapes is their hydromorphologic dynamics: especially flooding and high sediment transport lead to a continued turnover of the landscape (Tockner & Stanford 2002, Thorp et al. 2006), creating "hot spots and hot moments" in the recycling of matter and the specific routing of nutrients and carbon (McClain et al. 2003, Décamps et al. 2004, Pinay et al. 2007). Like other landscapes controlled by frequent disturbances, floodplain rivers are characterized by a dynamic equilibrium of characteristic habitats despite their continued change and biological successions from pioneer stages to riverine woodlands (Pickett & White 1985, Décamps 1996, Townsend et al. 1997, Winemiller et al. 2010). The mosaic structure in context with the dynamic water level fluctuations provide the habitat conditions for a highly specific and diverse biota (Ward et al. 1999a).

River engineering in the past has resulted in a strong reduction of the original fluvial dynamics in most parts of Europe (Petts et al. 1989, Dynesius & Nilsson 1994). In turn this has had profound and long-term environmental consequences and trends, e.g. increased frequency of catastrophic floods, reduced water quality, uncontrollable incision of river beds, dwindling groundwater resources in alluvial floodplains, and loss of biodiversity (Buijse et al. 2005, Naiman et al. 2005, Tockner et al. 2008).

Over the past 20 years, operational rules for river management have been developed. EU regulations, e.g. the Water Framework Directive, stipulate the maintenance of a good ecological status. It became apparent that management must be based on a good scientific understanding of the environmental conditions and trends, which requires interdisciplinary research.

Our scientific knowledge about ecology and management of rivers refers primarily to strongly impacted and deteriorated conditions. Today, this historic over-regulation of rivers necessitates costly restoration measures for compensation. Wise river management requires improved scientific understanding. Studies of natural reference sites are highly significant in this respect (Buijse et al. 2005, Nilsson et al. 2007, Poff et al. 2003, Schiemer 2015, Surridge & Harris 2007, Vaughan et al. 2009). This makes the Vjosa so attractive for an international river science: with its widely unobstructed fluvial morphology over the entire river corridor, its longitudinal continuity in water flow and sediment transport processes from its headwaters to the Adriatic Sea, the Vjosa represents an important reference system for dynamic floodplains that have already been lost all across Central Europe.

The area is also highly interesting from a biogeographical point of view. With its high degree of endemic biota (Griffith et al. 2004, Shumka et al. 2018b this vol.) it provides excellent conditions to study ecological processes and the specific biodiversity under near-natural conditions. For these reasons, it should be conserved as a large-scale natural laboratory for river ecology and a benchmark for environmental policy of pan-European significance.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

All this is endangered by the currently planned hydropower projects in the central parts of the river at Poçemi and Kalivaçi. These projects would destroy environmental services for people in its valley and lead to a major loss of its specific biodiversity. The expected hazards and threats of a dam construction are not properly addressed by the Environmental Impact Assessment (EIA) presented for the Poçemi project plan.

In order to strengthen a scientific approach in the evaluation of management options we organized an international Vjosa science conference held in June 2016 at the University Tirana, together with Albanian colleagues. A memorandum was formulated, requesting a 3-year-moratorium on construction plans of the hydropower dams to allow for a detailed assessment of the environmental, cultural and economic value of the Vjosa river system.

A research project was started in April 2017 and continued in September 2017 as a joint venture of scientists from Albania, Austria and Germany.

The expertise represented in the team of over 20 colleagues included hydrology and geomorphology, geology, limnology, vegetation ecology, and taxonomy and biogeography of major aquatic and terrestrial bio-indicator groups of invertebrates and fish.

Our program applied an integrated approach in order to create a solid background for management decisions and to help build up scientific know-how at the local institutions. Combining those interests with the expertise available at Albanian universities and institutions of higher learning provides the chance of jointly gaining insight and building up an increased local capacity for assessing riverine landscapes and the expertise to communicate scientific know-how to the public and decision makers.

The main goals of our efforts are:

– an assessment of geomorphological dynamics
– an assessment of major habitat types and their turnover rates in the light of their conservation status in an European context
– a survey of biodiversity and its distribution pattern, as well as an assessment of habitat relationships and population and meta-population dynamics in a near-natural riverine landscape.

With the presentation of first results and an outline of the general characteristics of the Vjosa catchment, we provide a starting point for further studies, a strategy for further integrated research and a baseline for a continued environmental monitoring with regard to the requirements of an Environmental Impact Assessment.

A short overview of the Vjosa catchment: geography, geology, climate & hydrology

The Aoos-Vjosa river extends over 272 km from its sources in the Pindos mountains, east of Ioannina at the foot of Mavrovouni (2159 m a.s.l.) in Greece through the south of Albania to the Adriatic Sea. During its course, it follows a SE-NW direction. The first 80 km are situated in Greece, where the river is named Aoos. The total catchment size is 6 704 km^2 of which 4 365 km^2 are on Albanian territory. Figure 1 provides an overview of the Vjosa catchment and its main tributaries and major cities.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

In Greece the river flows through the Vikos-Aoos National Park characterized by deep gorges. At the border to Albania a major tributary – the Sarandoporo – combines with the Aoos to form the Vjosa. Because of the border situation, the alluvial floodplains of the Sarandoporo near the confluence are particularly undisturbed with well-maintained floodplain forests (Fig. 2). The channel pattern changes over its course in Albania (see Daja et al. 2018 this vol.). In the upper section the Vjosa follows a sequence of steep canyons between Permet, Kelcyra and Dragot, entrenched in steep gorges intersected by areas with large alluvial fans and islands (Fig. 2). After Dragot the river valley widens except for the gorges of Kalivaçi and Poçemi. At the city of Tepelena – before and after the confluence with the river Drino – large gravel and sand bars formed by the braiding river dominate the fluvial landscape. After Selenica the watershed slope of the river decreases, the valley becomes wide, and the river starts meandering (Fig. 3d). The Vjosa discharges into the Adriatic Sea north of the Narta lagoon, a managed "Nature Reserve".

Important tributaries are the Sarandoporo, Lengarica, Drino (catchment size 1 302 km^2), Bënça and Shushica (catchment size 715 km^2).

Figure 4 illustrates the elevation profile along the river course in Albania with a steeper watershed slope in the upper reach. For the last 40 km before entering the Adriatic Sea, the slope of the river is low. Here the river changes from a braided to a meandering course. This interphase in river pattern occurs over a narrow stretch of about 15 km in length. The following delta spans over 15 km river course and almost 30 km coastline including the Narta lagoon in the south (20,000 ha; see Fig. 2). Further information on the river course and its accompanying landscapes is provided by Durmishi et al. 2018 this vol., Pano & Avdyli

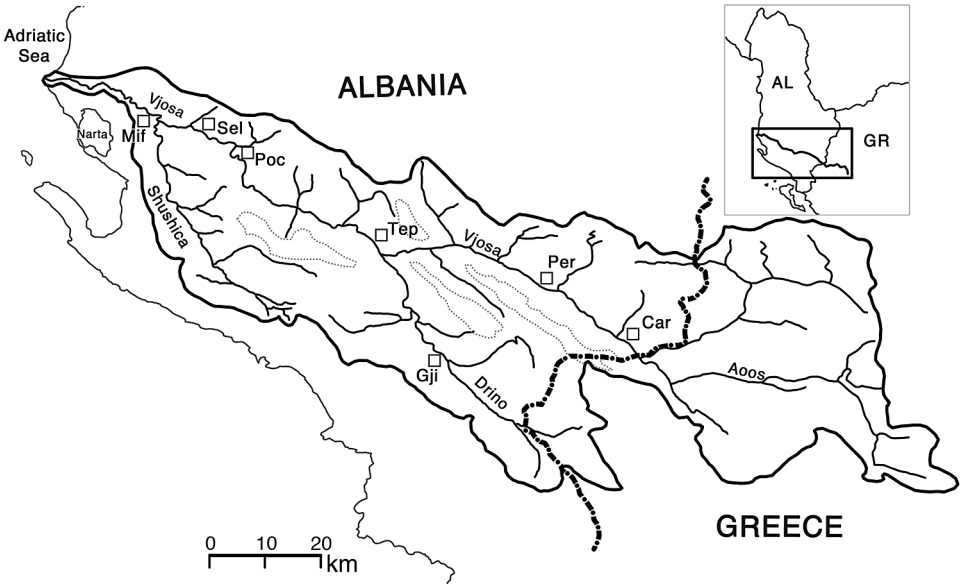


Fig. 1: Map of the Vjosa-Aoos catchment. Indicated are major mountain ranges in the Albanian part (dottet line) and the position of major cities: Mif (Mifoli), Sel (Selenica), Poc (Poçem), Tep(Tepelena), Per (Permet), Car (Çarshova), Gji (Gjirokastro). – Abb. 1: Karte des Einzugsgebietes Vjosa-Aoos. Die punktierte Linie zeigt größere Gebirgszüge im albanischen Teil, die Quadrate markieren wesentliche Städte im Einzugsgebiet.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at



Fig. 2: Satellite overviews of the lower Vjosa valley with the delta into the Adriatic Sea and the Narta lagoon. The image shows the short meander reach upstream of Mifoli and the intersection between the meandering and the braided river course. – Abb. 2: Satellitenaufnahmen vom Unterlauf der Vjosa mit dem Delta und der Übergangszone zwischen der Mäanderzone und der Furkationszone.

1984, Pano et al. 2008, Lazaridou-Dimitriadou et al. 2002, Apostolakis & Simixhiu 2008, Chatzinikolaou et al. 2008, Seferlis et al. 2008, Kesh-report 2009.

Geologically, the Vjosa catchment is embedded within five tectonic zones, the largest of which is the Ionian zone. They are part of the Albanides-Hellenides chain, which together with the Dinarides composes the dominant mountain range in the Western Balkans, representing the southern zone of the orogenic Alpine belt. Tectonic movements during the Permian-Triassic, the Jurassic, Cretaceous and the Neogene period led to a "fault and thrust" system in Albania and NW Greece (Durmishi et al. 2014, Durmishi et al. 2018 this vol.). The complex tectonic structure consists of two domains, the eastern or Internal and the western or External Albanides (Aliaj 2006).

The Ionian zone developed as a deep pelagial trough from the Triassic period onward. The oldest Permo-Triassic layers are covered by dolomitic limestone sedimented during the Upper Triassic to the Lower Jurassic period. The hard and consistent carbonate formations made of pelagic limestone of Upper Jurassic to Paleogene origin is covered by Oligocene to Lower Miocene flysch. The succession is completed by pre-molasse to molasse formations from the Middle Miocene onwards, consisting of various sediments like marl, sandstone and organogenic limestone (for details see Durmishi et al. 2018 this vol.). The south-eastern part of the catchment is characterized by Ophiolite, which is represented in the fine-grained sediments of the Vjosa river and its eastern tributaries.

© Zool.-Bot. Ges. Österreich, Austria, download unter www.zobodat.at

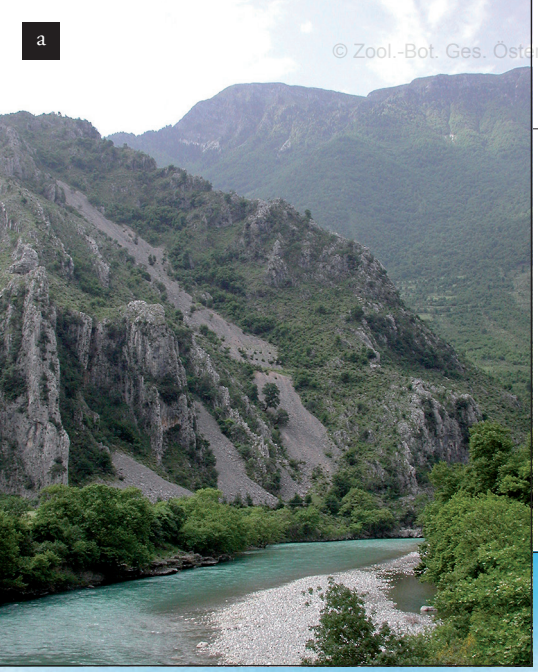








Fig. 3: Landscape scenarios along the Vjosa, a) constrained section upstream Permeti (Photo: Schiemer), b) gorges at Permeti (Photo: Schiemer), c) the river floodplain system at Poçemi (Photo: Subic), d) downstream section (near Mifoli), where the river changes from a braided to a meandering form (Photo: Drescher). – Abb. 3: Landschaftsfotos a) eingeengten Flußlauf oberhalb von Permeti, b) Flußeinschneidungen bei Permeti c) Furkationsbereich des Flusses bei Kalivaçi und Poçemi, d) Unterlauf in Richtung Mifoli.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

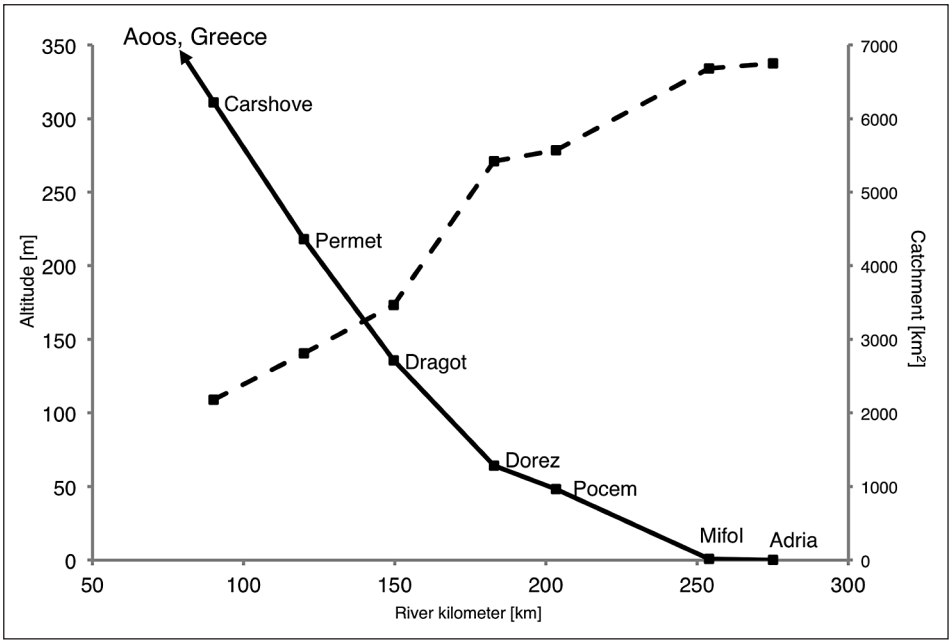


Fig. 4: Landscape profile of the Vjosa in Albania (river km vs. altitude). – Abb. 4: Höhenprofil der Vjosa (Fluss-km vs. Höhenlage).

The overall geomorphology of the Vjosa basin is characterized by a NW-SE orientation of the folded structures and tectonic planes. The valleys of the Vjosa and their tributaries follow predetermined tectonic lines of the Alpine thrust system. The middle part of the valley is surrounded by mountain ranges with an elevation between 300 metres in the north to almost 2000 m. a.s.l. in the south. The Gribe mountain range with its highest peak Mt. Kudhësit (1907 m) separates the Vjosa in the north and northeast from the Shushica valley in the southwest. At Poçemi, the river is situated between two parallel mountain ranges composed of limestone and flysch. The groundwater resource of the Vjosa basin is discussed by Durmishi et al. (2018 this vol.).

The climate of the Vjosa catchment is subject to a variety of weather patterns during the winter and summer seasons (Fig. 5). It is governed by its geographic position at the coastline facing the Adriatic and Ionian Sea and its highlands backed upon the elevated Balkan landmass. The coastal lowlands are characterized by typical Mediterranean-, while the highlands have a Mediterranean continental climate. In higher altitudes the climate resembles alpine conditions, but without glaciation (Seferlis et al. 2008). The average annual temperature oscillates around 16–17 °C in the coastal area and around 7 °C in the northern mountainous region.

The hydrological regime is classified as pluvio-nival with heavy precipitation and resulting peak-flows in spring (Pano 2015). On average, the flow of the Vjosa exhibits a distinct seasonal pattern with high water from December to April, intermediate flow in May and October and low flow from June to September (Fig. 6). Referring to published information (e.g. Pano & Avdyli 1984, Pano 2015, Kolaneci 2014 in Rössler 2017), monthly

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

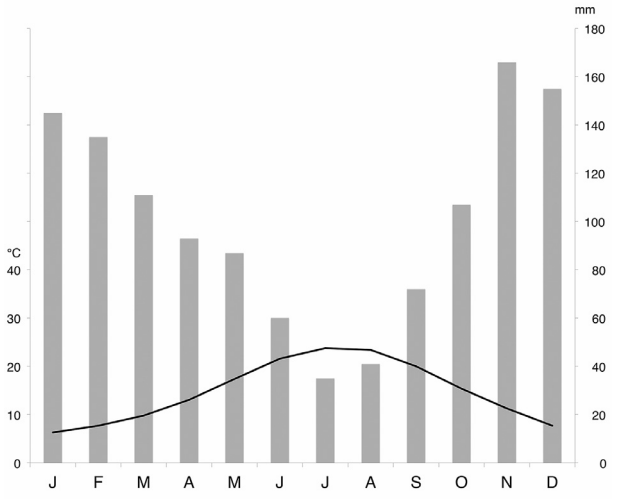


Fig. 5: Monthly mean temperature and rainfall, at Selenice, lower Vjosa. Data from Kesh-report (2009). – Abb. 5: Klimadiagramm (Monatsmittel der Temperatur und des Niederschlages) vom Unterlauf der Vjosa bei Selenice.

mean flow values in the period 1967 to 1990 fluctuated considerably from year to year, especially in the high water period from November to May (see vertical bars in Fig. 6). The annual mean flow for the whole period at Poçemi is 141.5 m^3/s.

The mean annual value in Poçemi matches the annual flow measured at the gauge Dorez (a few kilometres above Poçemi) for the period 1958–1990: 148,4 (range 66.4–324.1 m^3/s) (in Pano 2015). The time series shows higher flow rates in the period 1958–1967 (180.7 m^3/s) compared to 1978–1988 (140.1 m^3/s). The average flow was particularly low in the year 1990 (66.4 m^3/s).

From the time series 1967–1990 at Poçem the following high flood events are recorded:
1970: 2760 m^3/s (Dec.)
1971: 4160 m^3/s (Jan.)
1976: 2464 m^3/s (Dec.)
1981: 2806 m^3/s (Oct.), 2293 m^3/s (Dec.)
1982: 2670 m^3/s (Dec.)
1985: 2619 m^3/s (Jan.)
1987: 2456 m^3/s (Feb.)
1990: 2300 m^3/s (Dec.)

Characteristic flood flow levels at Poçemi are: HQ_1: 1820, HQ_5: 2620, HQ_{10}: 3130, HQ_{20}: 3630, HQ_{50}: 4420, HQ_{100}: 4860 m^3/s.

One of the shortcomings for the interpretation of our ecological data is the lack of detailed data on hydrology and the rating curve connecting water surface elevation to discharge. Long-term time series on magnitude, duration, timing and predictability of floods pulses and flow pulses below bankfull, both in terms of river stage and discharge need to be known for a detailed assessment. Information on flow is relevant for the understanding of the geomorphic dynamics, whereas the fluctuation of the river stage is the master factor for the riverine and riparian biotic communities. A detailed monitoring of such data is urgently required for an environmental impact assessment on the effects of engineering measures.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

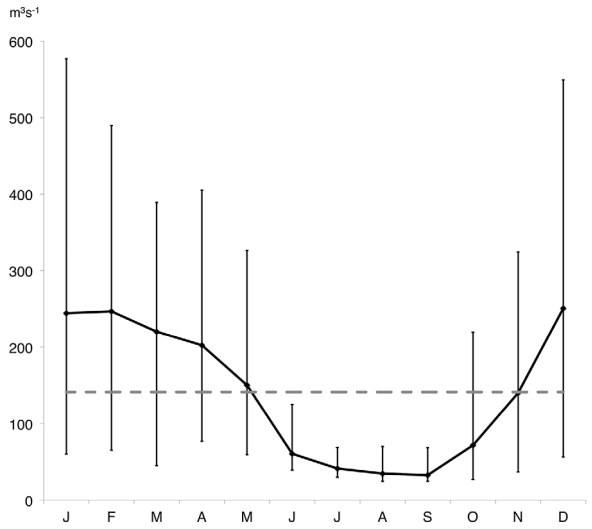


Fig. 6: Hydrology. Mean monthly flow rates at the Poçemi hydrometer station for the period 1967 to 1990 (gauge closed). The vertical bars indicate the range of monthly flow rates over these 24 years of observations. Data from Kolaneci in Rössler (2017). – Abb. 6: Saisonale Abflusswerte der Vjosa bei Poçemi. Durchschnittliche Monatsmittel und deren Streuung in der Zeitserie von 1967–1990. Die strichlierte Linie gibt das langjährige Jahresmittel an.

In the course of the excursion water- samples were taken in the Vjosa and major tributaries for reference of the geochemical conditions. All samples show medium conductivity values and medium concentrations of major macro-ions (Tab. 1).

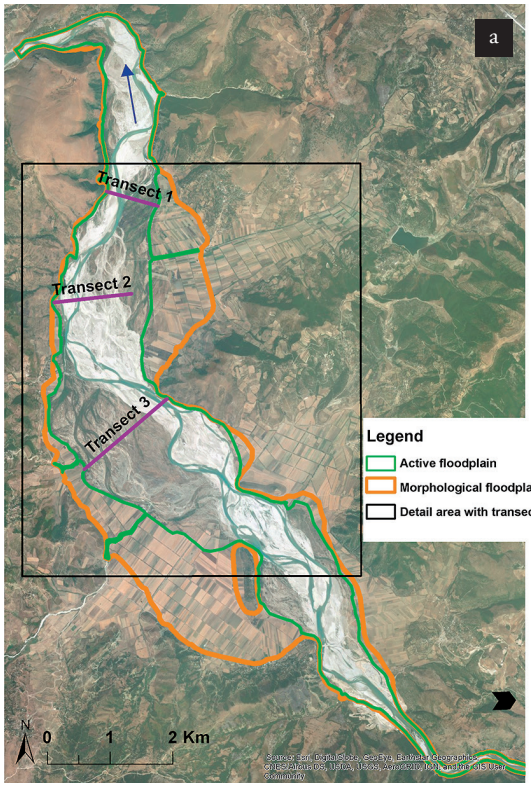
Tab. 1: Geochemical parameters of the Vjosa and major tributaries, Samples were taken during the field excursions in April (4/17) and September (9/17) 2017. – Tab. 1: Geochemische Daten über die Vjosa und einige wesentliche Zuflüsse. Die Wasserproben wurden im Rahmen der Exkursionen im April (4/17) bzw. September (9/17) 2017 entnommen und an der Univ. Wien analysiert.

	Cond. µS/cm	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^{+} mg/l	K^{+} mg/l	Cl^{-} mg/l	SO_4^{3-} mg/l
Sarandoporo (9/17)	505	44.8	8.7	32.8	2.6	47.9	44.0
Drino below Gjirokastro (4/17)	452	78.7	6.6	11.7	0.7	16.8	52.1
Bënça (4/17)	323	57.0	7.5	3.8	0.6	5.8	26.8
Vjosa at Poçemi (4/17)	432	49.9	22.4	13.8	0.8	15.5	26.8
Vjosa at Poçemi (9/17)	259	38.5	6.4	8.1	0.5	11.8	31.1
Shushcica (9/17)	431	57.9	9.0	20.3	1.2	33.4	33.1

Geomorphology of the Poçemi–Kalivaçi floodplains, landscape structure and habitat types

The geomorphology of a riverine landscape in context with hydrology provides the framework for habitat composition and ecology. The river-floodplain section upstream of Poçem, studied in April and September 2017, is representative for the middle part of the river between Selenice and Tepelena (see Fig. 1). This stretch of about 70 km length represents a bar-braided and island braided river type (see below). Our research program was based on the analysis of satellite images. In a detailed review of about 30 available satellite scenes, those from 1968, 2006, 2012 and 2016 were analyzed in full detail (Google Earth 2018, USGS, 2018). Scenes were selected according to their temporal distribution, water level and spatial resolution for interpretation (see Carbonneau & Piegay 2012,

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at



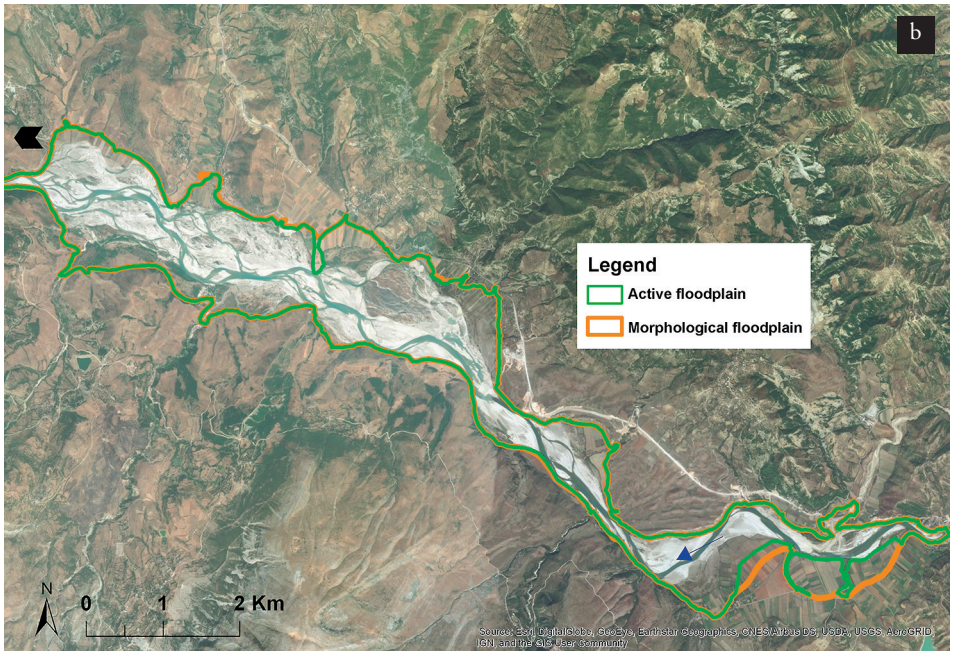


Fig. 7: Satellite overviews (2012) of the Poçemi (a) and Kalivaçi (b) river sections with the borders of morphological floodplain, active floodplain and active channel. Fig. 7a shows the 3 transects along which the bathymetry of the terrain was assessed. Habitat composition and habitat turnover in Tables 3 and 4 refer to the delineated area. – Abb. 7: Satellitenbilder des Gebietes von Poçemi (a) und – im Anschluss – von Kalivaçi (b) Eingetragen sind die Außengrenzen des Überflutungsgebietes („morphological floodplain"), der häufig überflutenden Au („active floodplain") und dem „active channel". In 7a sind die Transekte 1–3 markiert, an denen im April 2017 die Untersuchungen durchgeführt wurden. Weiters ist der Gebietsabschnitt abgegrenzt, auf den sich die Abschätzung der Flächen der verschiedenen Habitattypen und deren zeitliche Dynamik beziehen (Tab. 3 und 4).

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Metivier & Barrier 2012 on methodology). In combination with the results of our field surveys, the structural properties and dynamics of this river-floodplain type can be illustrated.

The overall landscape structure between Poçemi and Memaliaj bridge (about 35 km river length) is illustrated by satellite images (Fig. 7a and 7b) which show the extensive floodplains. In the graph the outer borders of 3 major zones the "morphological floodplain" (MF), the "active floodplain" (AF) and the "active channel" (AC) are delineated. In the following discussion we have included also the higher elevated islands situated within the white band of the very active fluvial zone as part of the "active channel". The "morphological floodplain" is defined by the valley margins. The area outside the "active floodplain" (green line) is only flooded sporadically at very high floods (HQ over 100 years). This area is largely used as arable land. The "active floodplain" is regularly flooded, e.g. to a large extent at a HQ of 5–10 years flood recurrence.

The figures illustrate the clear distinction between the active channel and the floodplain (see also Figs. 9–11). The two river segments upstream of Poçemi (Fig. 7a) and upstream of Kalivaçi (Fig. 7b) are constrained by two gorges, and by bedrock structures leading to a high variability in the lateral extent of the riverine landscape. Within the "active channel" large bars are deposited and more perennial islands with woody vegetation, mainly shrubs (see Fig. 8), are formed by channel avulsion and cutoff.



Fig. 8: Overview-photo of the study area at Kute, April 2017, with the positions of transekt 1 & 2, see text (Photo: Subic). – Abb. 8: Überblicksfoto des Untersuchungsgebietes bei Kute mit der Position von Transekt 1 und 2.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

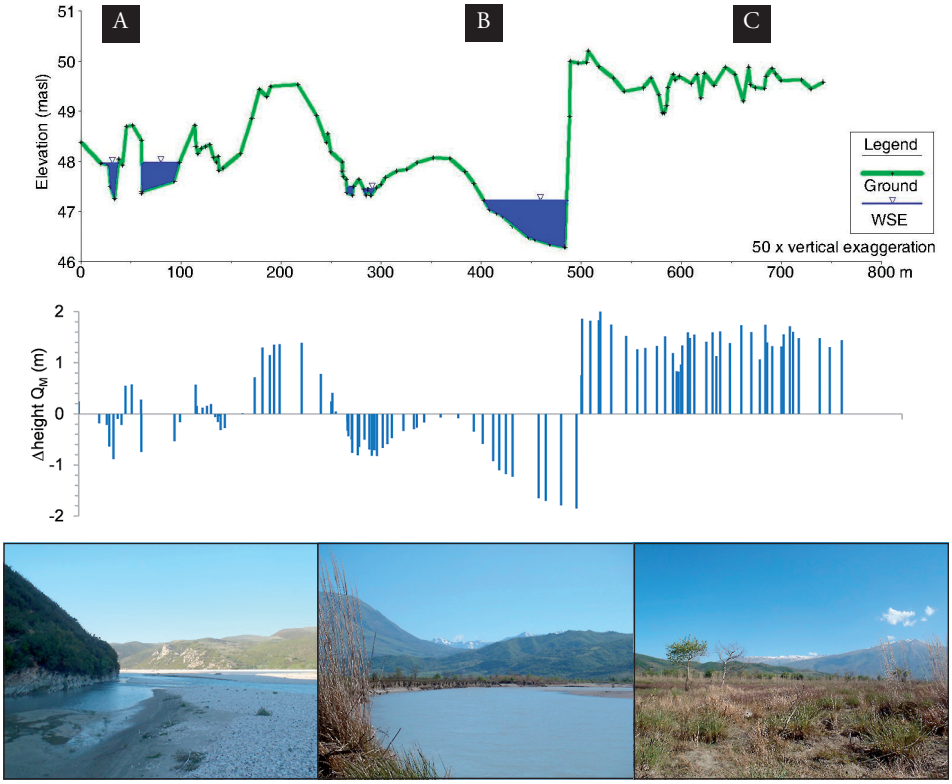


Fig. 9: Bathymetry of the Vjosa at Transect 1 including a differential plot of terrain height and mean discharge (QM) water level; Photo A – gravel deposits secondary channel (downstream view), Photo B – main channel (upstream view), Photo C – floodplains (upstream view). (Photos: Hauer). – Abb. 9: Landschaftsrelief Transekt 1 mit einem Differential-Plot des Terrains bezogen auf die Mittelwasserhöhe. Fotos A–C zeigen den Landschaftstypus entlang des Transektes.

The two gorges constitute bottlenecks in sediment transport resulting not only in lateral but also longitudinal sediment sorting processes. Besides the high load of gravel, a significant feature is the high content of finer sediments transported by the river, leading to large areas of silt depositions but also to a high compaction and reduced porosity of the river bed.

The low areal extent of softwood forests in the elevated floodplains (see Fig. 8) is caused by the intensive human use of these areas as pastures, by regular burning and extraction of timber. This explains the comparatively small role of large woody debris in the active channel, compared, for example, with the situation in the Tagliamento, where large woody debris constitutes an essential hydromorphological structuring element (Gurnell et al. 2001).

A detailed topographic, bathymetric assessment of the landscape relief along three transects perpendicular to the active channel (Fig. 9–11) shows the extreme heterogeneity in the landscape terrain at various scales. The graphs include differential plots of terrain height at mean discharge water level (Q_M 141,5 m^3/s), an important aspect for understanding the vegetation development. The width of the active channel (AC) varies between 400–

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

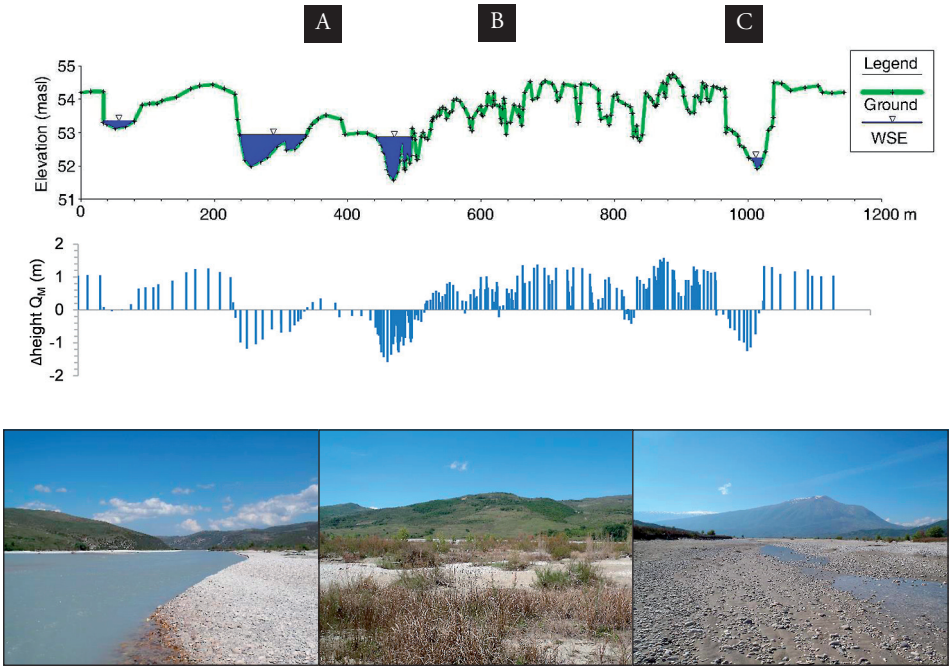


Fig. 10: Bathymetry of the Vjosa at Transect 2 including differential plot of terrain height and mean discharge (QM) water level; Photo A – main channel (downstream view), Photo B – accumulation of gravel, fines and initial stages of vegetation (transect view), Photo C – secondary channel (upstream view) (Photos: Hauer). – Abb. 10. Landschaftsrelief Transekt 2 mit einem Differential-Plot des Terrains bezogen auf die Mittelwasserhöhe. Fotos A–C zeigen den Landschaftstypus entlang des Transektes).

1000 meters due to the morphology of the valley. Larger islands and gravel bars within the AC are strongly structured by erosion channels and show the cumulative effects of changing water levels and flow pulses. An interesting feature, apparent in all three transects, is that the water levels of the main arm, in disconnected arms and erosion pools differ by more than one meter. This confirms that the lateral groundwater exchange is low, due to the high clogging and compaction of the riverine sediments.

The scarp at the border of the AC and the elevated floodplain is on average 2–3 meters high, measured from the mean water level of the main river arm. Transect 3 shows a continuous decline at the orographic left hand side through the former island (see below) and towards the former main arm. Even at such areas at the outer zones of the floodplains the occurrence of wetlands is low, indicating the restricted groundwater percolation.

The following classification of habitat types provides a common reference for integrating the various ecological, faunistic and floristic findings:

Aquatic habitat types

Different types of aquatic habitats can be distinguished within the active channel, ranging from fast current to stagnant conditions. Their ecological characteristics change continuously with the expansion and contraction of the river, i.e. in water table height. Even

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

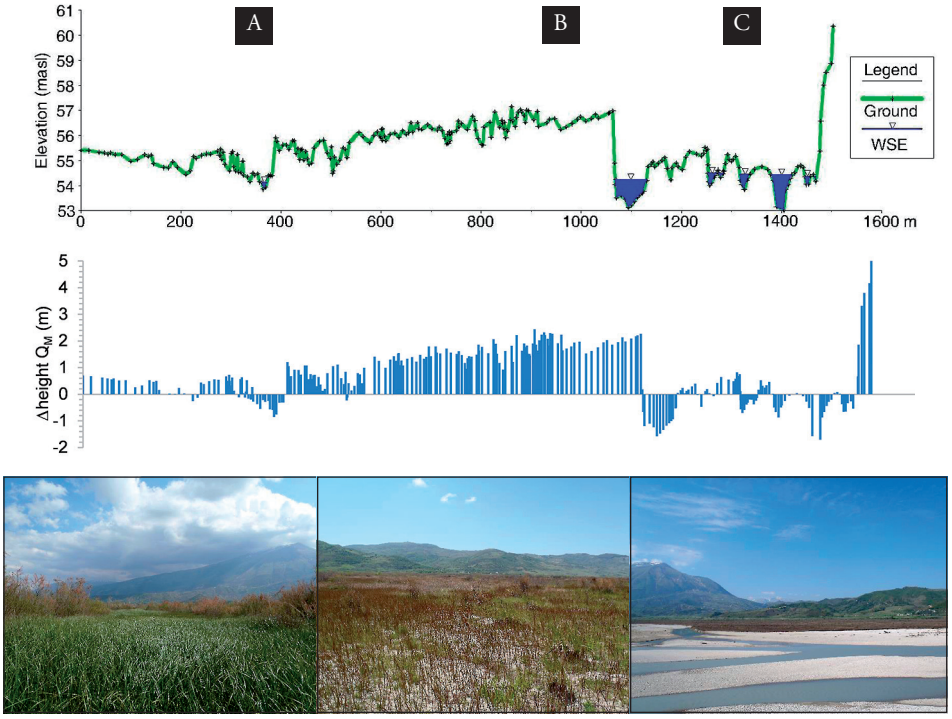


Fig. 11: Bathymetry of the Vjosa at Transect 3 including differential plot of terrain height and mean discharge (QM) water level; Photo A – semi-aquatic habitats (upstream view), Photo B – overbank fine sediment deposits (transect view), Photo C – braided main channel (transect view) (Photos: HAUER). – Abb. 11: Landschaftsrelief Transekt 3 mit einem Differential-Plot des Terrains bezogen auf die Mittelwasserhöhe. Fotos A–C zeigen den Landschaftstypus entlang des Transektes.

small water level fluctuations and "flow pulses" lead to continuous changes in the flow-age line and habitat conditions, especially for the aquatic biota and the riparian fauna (see below). Moreover, the geographic position of the main arm shifts with each major flood pulse (see below). Under such hydrologically dynamic conditions the application of the Amoros-Roux classification of water body types for floodplain rivers (e.g. eupotamal, par-apotamal, plesiopotamal) (AMOROS et al. 1987) is not easily applicable.

The following list defines the principal aquatic habitat elements encountered:

A1: main branches of the river, fast current in the thalweg.

> The beds are generally shallow, with a maximal depths of approximately 3–4 meters in erosion zones (see Figs. 9–11). In the central runs, the compaction of sediments is generally high, however the variability in the relief causes local runs with loose gravel. Thus, micro-habitat conditions show a high variability, which is of significance for the colonisation of macrozoobenthos and fish (see below).

A2: inshore zone of the main branch and shallow side branches, low current.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

A3: downstream connected side-branches, partially with percolating flow.

However, hyporheic flow appears to be generally low due to the compaction of the gravel bottom with fine sediment.

A4: disconnected side-branches.

An intensive algal growth can develop; however, for the growth of macrophytes, the "life time" of such side branches is too short: these areas fall dry at receding water levels.

A5: erosion and evorsion pools within the active channel.

A characteristic aquatic habitat type within the active channel are erosion pools, especially along the borders of the elevated floodplains or behind obstacles such as eroded trees and eroded parts of the higher floodplains (Fig. 12d, scouring holes). Their areal extent is low (Tab. 3). These small to medium sized (a few m^2 to 1000 m^2) pools partially retain water during low water phases and allow for intensive growth of algae. Water temperatures are distinctly higher during the vegetation period compared to the main branch. Such thermal heterogeneities have been analysed for the Tagliamento riverscape (Arscott et al. 2001).

Deeper stagnant pools with higher water residence time and fine sediment deposition can develop behind bedrock structures or artificial groynes. Such longer-term stagnant water-bodies within the active channel can be densely covered with semiaquatic and aquatic vegetation (e.g. *Chara* sp., *Potamogeton nodosus*).

A6: backwaters and riparian wetlands within the floodplains.

In former river arms within the elevated floodplains wetlands can be developed. A characteristic example was found in transect 3 (see Fig. 11) on the orographic left hand side. During our field visits at low (September, 2017) and mean water level (in April 2017) very few such aquatic backwaters were found in the whole floodplain section between Poçemi and Memaliaj.

A7: wetlands along hillslope streams entering the floodplains.

Such habitats characterized by low flow and fine-grained deposits were found along the outer floodplain borders at Kute and Tepelena. Along the course of such small streams, different successional stages can be identified:

a) slowly flowing water with *Typha* spp., *Veronica anagallis-aquatica, Bolboschoenus maritimus, Scirpoides holoschoenus, Alisma plantago-aquatica* and others,

b) early succession stages with characteristic shrub vegetation *Salix alba, S. triandra, Populus alba* and others and

c) succession stages with small trees in ditches that are filled with water only during flooding events.

In April 2017, in Kute, these wetlands comprised of small shallow pools and low current running water with a rich invertebrate and fish community (e.g. *Pelasgus*) and *Emys orbicularis*. In September 2017, these wetlands had fallen dry.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at



Fig. 12: Photo-gallery of aquatic habitat types: a) overview of aquatic habitats within the active channel (A1-A4, Photo: Subic), b) main arm at the scarp of the elevated floodplain (A1, Photo: Schiemer), c) disconnected side arms falling dry (A4), unvegetated fine sediment depositions (C1, Photo: Schiemer), d) erosion pools (scouring holes) within the active channel (A5, Photo Schiemer), e) larger erosion pools (A5, Photo: Schiemer), f) wetlands along streams entering from the side slopes (A7, Photo: Schiemer). Initial vegetation along slow flowing disconnected side arms or tributaries with silty sediments and scattered vegetation of *Cyperus fuscus, C. michelianus, Sparganium erectum.* Pioneer scrub of *Salix triandra* and *Salix amplexicaulis* and scattered herb vegetation (*Typha minima, Mentha longifolia, Equisetum palustre* a.o.). – Abb. 12: Fotos aquatischer Habitattypen: a) Überblicksbild des Flusslaufes, Habitattypen A1–4, b) Hauptarm (A1), c) abgetrennter, trockenfallender Nebenarm (A4) und vegetationsfreie Sandablagerungen (C1), d) kleiner Erosionstümpel (A5), e) größere Erosionstümpel mit Makrophytenentwicklung (A5), f) Feuchtgebiete entlang kleiner zufließender Bäche mit Sumpfvegetation (A7).

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Between these major types of aquatic habitats, ecological gradients provide the multitude of microhabitat conditions required to support the diverse communities of fish, macrozoobenthos and riparian fauna e.g. carabid beetles (see below).

Semiterrestrial and terrestrial habitat types

Terrestrial habitats on elevated bars within the active channel and the floodplains exhibit an even higher complexity, dependent on sediment sorting processes, elevation above mean water table, frequency of flooding, distance from the thalweg, etc. (see Drescher 2018 this vol., Rössler et al. 2018 this vol.).

The main factors for differentiation within the floodplain are:

- Sediment composition (grain size diameter) as a main factor for the germination of plants (water capacity),
- Intervals and dimension of flow pulses resulting in a time span for vegetation development,
- The situation of the groundwater table and its connection with the fine grained sediment cover, i.e. water retention capacity,
- Transformation by human impact (gravel mining, logging, burning, grazing).

Along the transects through the river-floodplain complex, an enormous range of transition zones occurs at small scale. In the following classification, this complexity is reduced to a few easily identifiable types in order to provide a common framework for a presentation of the various biota. A more detailed account will be provided in the chapter on vegetation ecology (Drescher 2018 this vol.).

Within the active channel we can distinguish between vegetation successions on gravel/coarse sand (series B) and on fine-grained sediments (fine-grained sand and silt, series C). Loam and clay deposits play a subordinate role in the Vjosa floodplain. The series B1 to B3, and C1 to C3, represent succession phases of increasing age of a more or less undisturbed vegetation development (Fig. 13a-f, see also Figs. 9–11 and Fig. 20: succession scheme).

B1: Initial phase on coarse-grained sediment bars without vegetation (Fig. 13a).

B2: Pioneer phase on coarse-grained sediment bars with seedlings of annual and perennial herbs (dominant) and woody species (less than one year old; 1–30 cm high).

B3: Pioneer phase on coarse-grained sediment bars and islands with dominating woody **species** like *Tamarix*, *Salix eleagnos, S. purpurea*, *Populus nigra* and others (1–2 years old; 30–120 cm high).

B4: Shrub phase, on coarse-grained sediment bars and islands partly with fine-grained cover with perennial herbs and scattered (dominating) woody species like *Tamarix*, *Salix* spp., *Populus nigra* and others (2–5 (8?) years old; 1–4 m high) (Fig. 13b).

C1: Initial phase on fine-grained sediment, bars without vegetation.

C2: Pioneer phase on fine-grained sediment, bars and islands (with seedlings of annual and perennial herbs and woody species, less than one year old; 1–30 cm high) (Fig. 13c).

C3: Early succession stage on fine-grained sediment, bars and islands with perennial herbs (*Imperata cylindrica*) and dominating woody species like *Salix alba, S. purpu-*

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

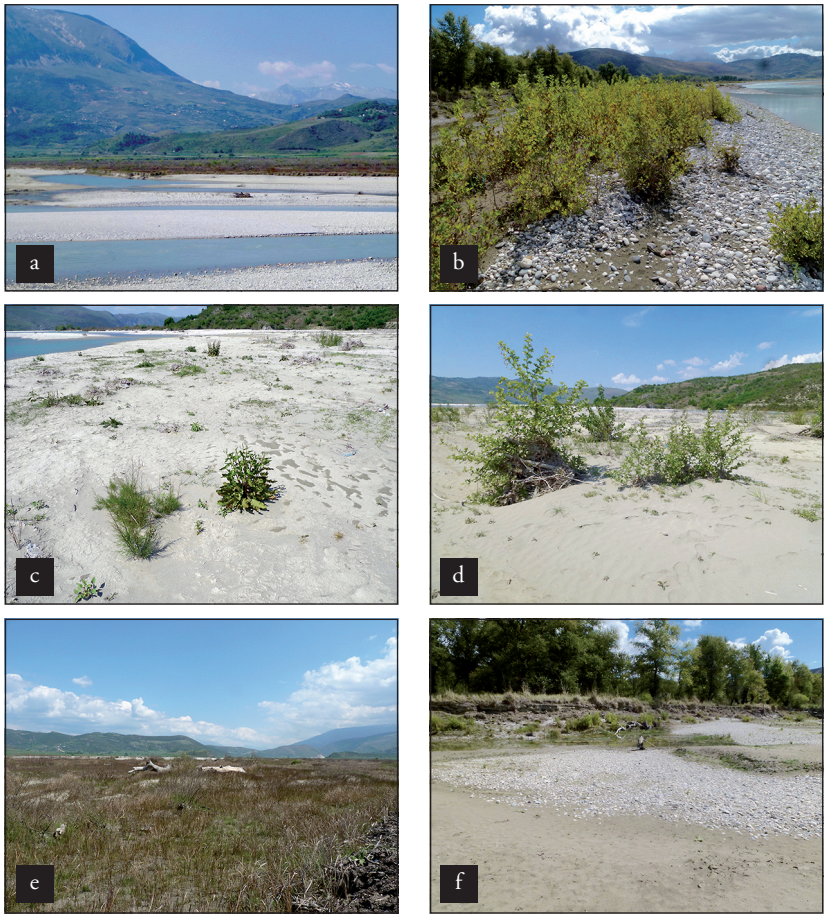


Fig. 13: Photo gallery of terrestrial habitat types: a) unvegetated gravel bars (B1) and pioneer vegetation on gravel bars (B2, Photo: Drescher), b) gravel bar, partly with sediment cover of coarse sand on the orographic right bank of Vjosa river NW of Poçemi. Scrub of 1–2 m height, dominated by *Platanus orientalis* mixed with *Populus nigra* and *Vitex agus-castis*. The herb layer is characterized by grasses (*Imperata cylindrica, Elymus* spec.*, Cynodon dactylon, Sacharum ravennae*) (B4, Photo: Drescher), c) sandy bank of a downstream connected side arm with scattered herb vegetation of *Dittrichia viscosa, Xanthium italicum* and *Imperata cylindrica*. The dead individuals of *Xanthium* help accumulate sand during flooding (C2, Photo: Drescher), d) scattered shrub vegetation of *Tamarix parviflora, Salix amplexicaulis, S. elaeagnos, Populus nigra* and herb species like *Chondrilla juncea, Dittrichia viscosa, Cynodon dactylon* a.o. Sediment bar with several dm sand cover and a scattered scrub with *Platanus orientalis* (C3, Photo: Drescher), e) meadow, degradation stage with regularily (yearly?) burned and partly heavily grazed forest, scarp, gravel, sand grassland dominated by *Imperata cylindrical* (D1, Photo: Schiemer), f) knee of the Vjosa river near Poçemi with a steep river bank. The elevated niveaus of the floodplain are pastured and covered with woodland of *Salix alba, Populus nigra* and *Populus alba* (D3, Photo: Drescher). – Abb. 13: Fotos terrestrischer Habitattypen: a) Schotterinseln ohne Vegetation (B1) bzw. schütterer Pioniervegetation (B2), b) Schotterbank, teilweise mit Sandanschüttungen, Pioniervegetation mit Sträuchern (B4), c) Sandbank an einem unterseitig angeschlossenen Nebenarm (A3) mit lockerer Pioniervegetation (C2), d) Gebüschvegetation auf einer Sandinsel innerhalb des „active channel" (C3), e) Überschwemmungsgebiet, intensiv als Weide genutzt und regelmäßig abgebrannt (D1, D2), f) kleine Flächen mit Auwald (D3).

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

rea, *Vitex agnus-castus, Populus alba, Platanus orientalis* a. o. (1–2 years old; 30–120 cm high) (Fig. 13d).

C4: Shrub stage on fine-grained sediment, bars and islands with dominating woody species (like *Salix alba, S. purpurea*, *Vitex agnus-castus, Populus alba, Platanus orientalis* and others, 2–5(8?) years old; 1–4 m high).

At elevated floodplain levels:

D1: Degradation stage: Regularily (yearly?) burned grassland, with dominant *Imperata cylindrica,* tussocks of *Saccharum ravennae* and scattered shrubs of *Vitex agnus-castus* and others (Fig. 13e).

D2: Early woodland succession phase, with *Platanus* orientalis*, Alnus glutinosa, Vitex agnus-castus, Rubus sanctus, Brachypodium sylvaticum* and others.

D3: Riparian woodland, with *Populus alba, P. nigra* and *Salix alba* – heavily grazed (Fig. 13f).

Landscape and habitat turnover

The physical disturbances and continued habitat rejuvenation due to high flow and floods are the main characteristics of riverine landscapes and the cue for understanding the biodiversity pattern and ecological functions (Ward et al. 1999a). River channel patterns are a consequence of geomorphic dynamics and the physical landscape characteristics (Schumm 1985, Benda et al. 2004, Rosgen 1994, Daja et al. 2018 this vol.).

The Vjosa has so far maintained its original geomorphic dynamics which is the most valuable asset from an ecological point of view. Our analysis of the river-floodplain relief (see above), in combination with the available flow data, allow a first approximation of the extensive transport of gravel and fine sediments. The terrestrial survey of three cross-sections was conducted using a Leica TC805 total station. The measurement of the bathymetry was applied for both (i) the active channel and (ii) the active floodplain in April 2017. High resolution point sampling was carried out using height-dependent criteria (h > 15 cm) for selecting terrain points. In a post-processing procedure, the cross sectional data (n = 3) was used for hydrodynamic-numerical (HN) modelling. For the analysis of hydromorphological parameters needed for the Nanson & Knighton (1996) classification (e.g. specific stream power), one-dimensional hydrodynamic-numerical models were applied (Bhallamudi & Chaudhury 1991, Correia et al., 1992, Niekerk et al. 1992). The modelling package HEC-RAS® was applied, which uses the 1D St.Venant equation to calculate open channel flow, based on a four-point implicit finite difference scheme allowing the modelling of larger time steps (Ligget & Cunge 1975). The model was chosen because of its capabilities for sub-/supercritical modelling (USACE 2002) and multifunctional parameter analysis for overbank- and main channel flow. More detailed analyses are presently being carried out and will be presented in the near future (Hauer et al. in prep.).

In order to determine grain size distributions (GSD) of bed surface material along gravel bars of the Vjosa, template measurements were carried out using a gravelometer (a thin aluminum plate containing square holes of different sizes). The holes usually correspond to

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

standard 0.5 f increment size sets, starting at 2 mm and reaching 256 mm (depending on the size of the template, Bunte & Abt 2001). Samples with grain size >256 mm were also included via the ruler application in order to consider possibly very coarse bed surface material of gravel bars. The calculation and graphical presentation of GSD curves was done by sampling at least 150 grains of gravel bar surface layer, with a minimum of 30 sediment particles around the mean diameter and neglecting grain sizes <2 mm (limited due to the gravelometer). Grain size distributions curves were determined and analyzed taking particle values as 'percent finer'.

Nanson & Knighton (1996) categorize the different types of multichannel river systems from alpine gravel-bed streams to lowland deltas. Based on (a) specific stream power (Wm^{-2}), (b) bed material size, (c) bank material size, (d) lateral migration rate, (e) vertical accretion rate, (f) channel sinuosity and (g) ratio island length/channel width. They proposed a classification of five different anabranching types. Within this framework, the Vjosa river can be classified as a laterally active gravel-bed river (Type 5 according to Nanson & Knighton 1996). Such gravel-dominated, laterally active, anabranching river systems are frequently found in cold climate regions with snowmelt and glacier runoff (e.g. Church 1983, Desloges & Church 1989, Kellerhals et al. 1972, Brierley & Hickin 1992, Nordseth 1973). The Vjosa, however, demonstrates these features in a Mediterranean climate.

The hydrodynamic-numerical modelling revealed a Q_{bf} (bankfull flow) of approx. 1000 m^3s^{-1} for all three sampled transects (Figs. 9–11). For this bankfull flow, the specific stream power was calculated to lie within the range of 22.8 W m^{-2}–39.8 Wm^{-2}. Moreover, pebble counting on the gravel bars of the Vjosa revealed a variability of d_{50} = 1.1 cm up to d_{50} =

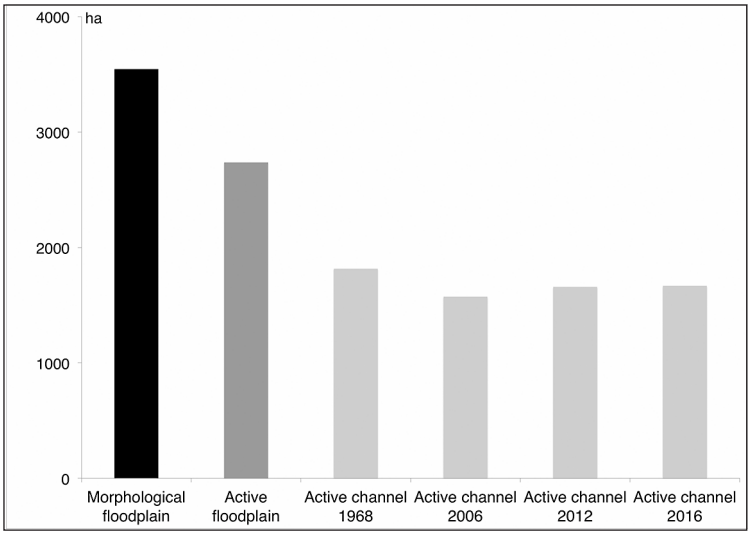


Fig. 14: Areal extent of the floodplains from Poçemi bridge to Memaliaj bridge over 35 km of river length, in the time from 1968 to 2016. The columns refer to the floodplain, which remain constant and the "active channel" which show some variability. – Abb. 14: Fläche des Überflutungsgebietes der 40 km Strecke von der Brücke in Poçemi bis zur Brücke in Memaliaj, in der Zeit von 1968–2016. Die Säulen zeigen die Größe des Überflutungsgebietes und die geringen Veränderungen in der Fläche des „active channels".

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

3.1 cm in the active channel, and gravel, sand and mud sediment deposits along the banks. Channel sinuosity as well as the ratio of island length/channel width (see Tab. 2) supported the classification of a laterally active gravel bed river.

Referring to Nanson & Knighton (1996) the modelled values of unit stream power are comparably small for a laterally-active gravel bed river. They are at the lower boundary for a type 5 channel type. The values are more transitory to a so-called "type 2, sand dominated anabranching river". Gravel-dominated laterally active channels are described as being transitional between meandering and braided (Desloges & Church 1989), which is the situation for the study site.

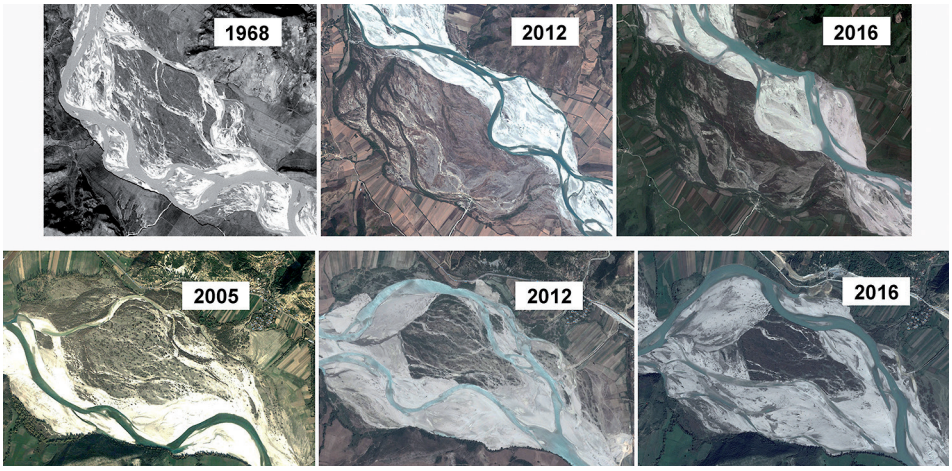


Fig. 15: Dynamics of the riverine landscape illustrated on the example of two satellite series showing the formation respectively erosion of major islands and the major shift in the location of the main river branches between 2005–2016 in the area of Kalivaçi and Poçemi. – Abb. 15: Dynamik der Flusslandschaft illustriert am Beispiel von 2 Serien von Satellitenaufnahmen von 2005 bis 2016 im Gebiet von Kalivaçi und Poçemi. Die Aufnahmen zeigen die weitgehende Verlagerung des Hauptarmes und die Bildung und Erosion großer Inseln in den erweiterten Bereichen des Inundationsgebietes.

Tab. 2: Comparison of the areal extent (in ha) of the active channel within the river-floodplain section of 6,6 km length at Poçemi, delineated in Fig. 7a. The data are derived from a series of satellite images: 22.12.1968, 1.9. 2006 (low water), 29.8. 2012 (low water), 29.5.2016 (mean water). The theoretical turnover rate per year is calculated from the shift in the geographic location of the active channel. The "Braiding index" was calculated as 2 x sum of Li/ Lr, where Li is the sum of the length of islands within a segment (Lr). The thalweg is given in km river length. – Tab. 2: Vergleich der Flächen (in ha) des "active channels" in dem 6,6 km langen Abschnitt bei Poçemi (siehe Abb. 7a). Die Werte wurden von Satellitenaufnahmen aus den Jahren 1968, 2006, 2012 und 2016 errechnet. Die theoretische Erneuerungszeit des "active channels " pro Jahr wurde aus dessen veränderter Position im Inundationsgebiet errechnet. Der "Braiding Index" als Maß der Fluss-Verzweigung errechnet sich als 2x die Summe der Inselängen (Li) in einem Flussabschnitt dividiert durch dessen Länge (Lr). Thalweg in km bezogen auf den Flussabschnitt.

	1968	2006	2012	2016
Active channel	591.9	511.3	567.7	594.4
Overlap in active channel	320.6	508.1	554.6	
% turnover per year	1.1	1.0	1.4	
Thalweg in km	10.5	9.4	9.7	9.4
Braiding Index	3.9 (2x17.4/8.9)			3.3 (2x13.5/8.1)

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

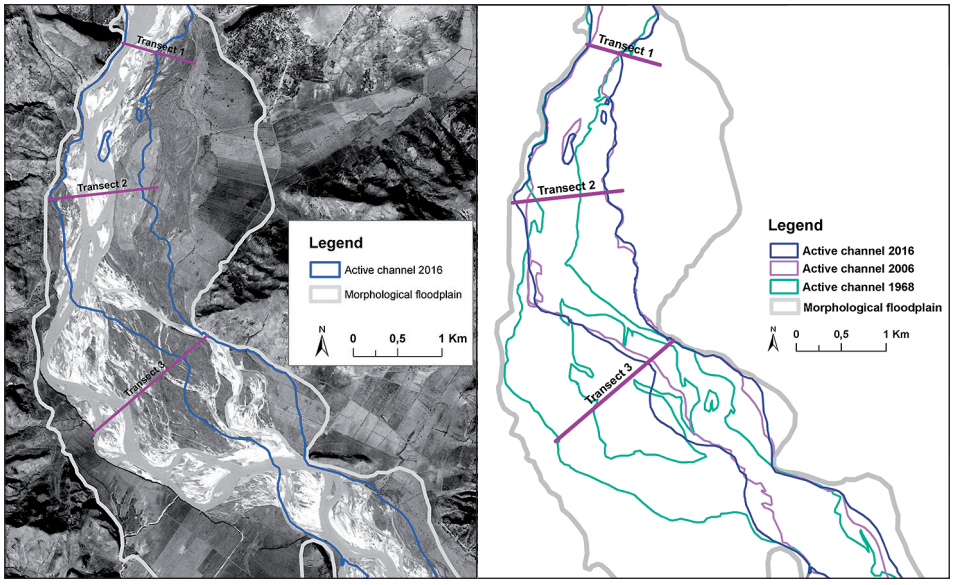


Fig. 16: a) Shift in the location of the active channel from 1968 to 2016. The satellite image from 1968 is overlaid by the position of the active channel in 2016. The outer borders of the morphological floodplains are marked. b) shift in the location of the active channel, its borders are marked for 1968, 2006 and 2016. – Abb. 16: a) Verlagerung des „active channels". In die Satellitenaufnahme von 1968 sind die Grenzen des AC 2016 eingetragen. b) äußere Grenzen des „active channels" 1969, 2006 und 2016.

The catchment of the Vjosa provides high sediment yields (bed load and suspended load) of up to 20–40 t. $ha^{-1}.year^{-1}$. A characteristic feature of braided and anabranching rivers is that bed load supply is higher than actual channel transport capacity. Reduction in bedload supply would lead to a more stable, single, sinuous but migrating channel (Carson 1984, Church 1983). Another criterion of the laterally active anabranching gravel beds are specific forms of avulsion at high flow rates, which incise into the existing floodplains (Nanson & Knighton 1996). Avulsion is the rapid abandonment of a river channel during mostly extreme flood events and the formation of a new river channel in former floodplains (Slingerland & Smith 2004). This is the case for the Vjosa, where the active channel is incised up to 3 m into the "active floodplain". Its gravel layers are frequently overtopped by overbank sands and silt, indicating the continued fluvial interaction in the geomorphic continuum of the river-floodplain system (see Brierley & Hickin 1992).

The landscape development over the past 50 years could be visualized from a series of satellite images from 1968 up to now. In the 36.5 km long river section from Poçemi to Memaliaj bridge – the area of the planned hydropower dams at Poçemi and Kalivaçi – the areal extent of the whole floodplain remained essentially constant (Fig. 14). However, the satellite images show the continuous shift in position of the active channel within the active floodplain. This dynamic displacement in the position of the main river arms and in the formation and erosion of major islands is exemplified in two time-series of satellite images illustrating the tremendous landscape dynamics of the area (Fig. 15).

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

This landscape dynamics is in the following exemplified in more detail for the 6.6 km long river-floodplain segment delineated in Figure 7a. Table 2 shows a variation in the areal extent (in ha) of the "active channel" of approximately 15 % from 1968 to 2016. Despite this relative constancy in area, the time series of satellite images illustrates the continued and drastic change in location of the active channel within the floodplain. This is expressed as overlap in the location of the AC during particular time intervals. The displacement is high, despite being constrained by the morphology of the valley which restrict the channel migration. Naturally, the displacement rates are strongly dependent on hydrology. Main translocations apparently occur due to channel avulsions at single extraordinary flood events. Keeping these caveats in mind, we arrive at average relocation rates of the active channel within the active floodplain in the order of 1–1.4 percent per year, which means a theoretical turnover time of less than 100 years. In this time frame the active river-floodplain system is completely restructured.

Figure 16 illustrates this lateral migration pattern of the AC within the floodplain over a period of nearly 50 years, exemplifying this enormous geomorphic dynamic.

At a more detailed scale the quantitative composition and turnover of habitat elements (as defined and indexed above), is analysed from a satellite series from 2006, 2012 and 2016 (Tab. 3). Some of these habitat types had to be combined, because they were either continuously interchanging with water level fluctuations (e.g. the riverine habitats A1–A4) or were not clearly discernable in the satellite images. Within the AC, the ratio between aquatic and terrestrial areas varied strongly with the water level at which the satellite images were taken. Higher water levels mean a larger extent of riverine habitats in comparison to the gravel and sand bars. At low and mean water levels, the river with its downstream connected or disconnected side-arms (A1–A4) represents approximately 10–15 % of the active channel. The areal extent of erosion pools (type A5) is very low, yet they are

Tab. 3: A comparison of the areal extent (in ha) of different types within the river-floodplain section delineated in Fig. 7a, according to the definitions and descriptions presented above. The values refer to the active channel and the active floodplain (below broken line). – Tab. 3: Vergleich der Flächen (in ha) der verschiedenen Habitattypen in dem 6,6 km langen Abschnitt bei Poçemi (siehe Abb. 7a). Definition und Beschreibung der Habitattypen siehe Text. Die Werte beziehen sich auf den „active channel" und den „active floodplain" (siehe Text).

	2006	2012	2016
Active channel (AC)			
River branches (A1–4)	93.2	97.7	141.9
Erosion pools (A5)	1.5	3.1	4.7
Gravel & sand bars, unvegetated (BC1)	183.9	327.4	313.3
Gravel & sandbars, early pioneers (BC2,3)	178.4	116.8	106.5
Gravel & sandbars, pioneers and shrubs (B4)	69.1	77.5	49.5
Active floodplain (AF)			
Grassland on elevated floodplain (D1)	293.5	282.6	237.1
Grassland with shrubs (D2)	227.3	165.7	218.4
Softwood forest (D3)	45.8	27.7	29.2
Wetlands (A6,7)	0.2	0.3	0.3
Arable land	24.1	18.0	16.0
Total area AC+ AF	1116.8	1116.8	1116.8
AC in % of AC+AF	47.1	55.7	55.1

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

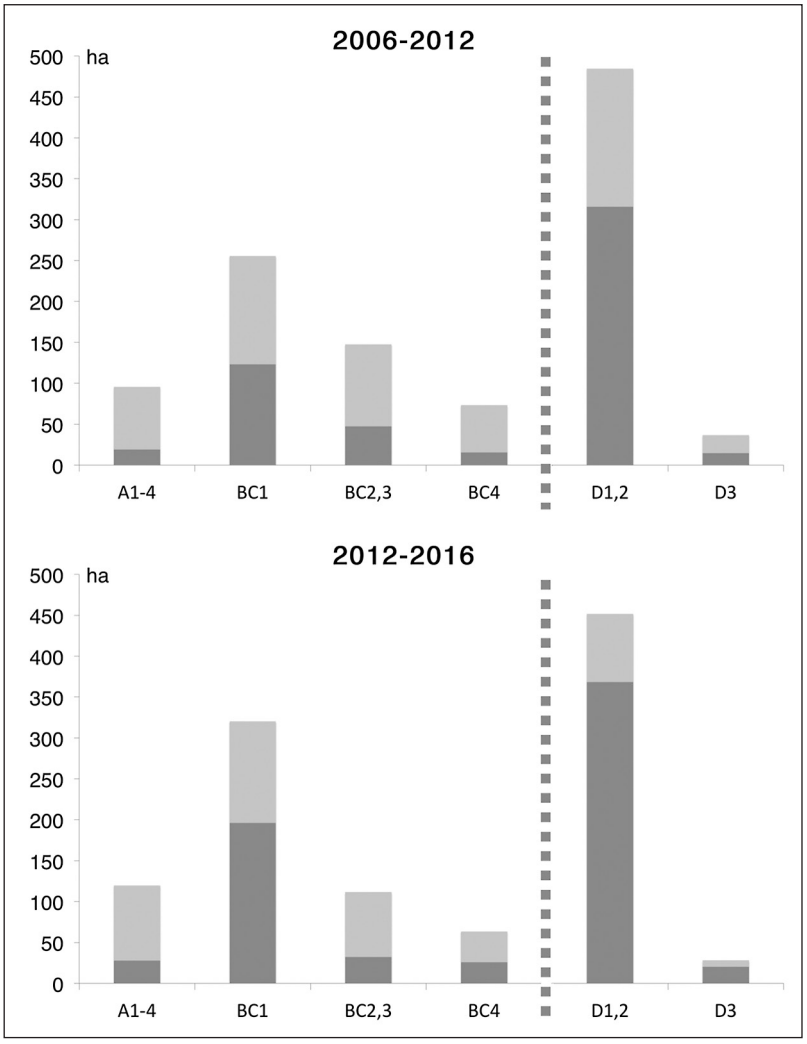


Fig. 17: A comparison of the composition habitat types in the Poçemi area (see text) based on values presented in Table 4. The total columns show the mean extent of the various habitat types in the period 2006–2012 and 2012–2016. The darker shaded parts show those areas which remained at the same positions. – Abb. 17: Zusammensetzung der Habitattypen in Fluss-Auenbereich von Poçemi, Zahlenangaben siehe Tabelle 4. Die Säulen geben die Gesamtfläche der einzelnen Habitattypen an. Der starker schattierte Teil der Säulen zeigt die ortskonstanten Anteile der Habitate.

very significant as habitat and refuge throughout the life cycle of many species. The unvegetated gravel and sand bars (B1/C1) cover the largest area (in the order of 35–53 % of the AC at low to mean water level). B4/C4, as advanced pioneer stages, occur within the active channel mainly on accreted islands.

Within the elevated active floodplain, grassland and grassland with shrubs are dominant (D1, D2) (also compare to Figs. 9–11). Softwood forests (D3) and wetlands (A7) have very

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

restricted occurrences and a low areal extent. The composition of grassland, grassland with shrubs and softwood forests at the elevated floodplains exhibits a higher stability. Apparent structural changes are to a large extent due to human activities by grazing and burning.

Figure 17 illustrates the average areal extent of the various habitat elements (in ha) over the periods 2006–2012 and 2012–2016 (total columns) and the proportion which within these time intervals remained in the same location (dark grey bar). The figure highlights two significant features: firstly, the proportion of habitat elements remains fairly constant over time, but, secondly, the continuous shift in the location of the various types indicates a fast turnover cycle, especially within the active channel.

In a further step of analysis, the shift in the location of habitat elements (area in ha) and their relocation within the floodplain was identified. Figure 18 summarizes these fluxes in the position of landscape elements between 2012 and 2016. The circles from left to right represent aquatic areas (A1–A4, the main branches, side-arms, etc.), unvegetated gravel and sand bars (BC1), bars with pioneer associations (BC2), bars with shrubs (BC3,4) and habitats on the elevated floodplain (D).

Figure 19 exemplifies the translocation of habitats from 2012 and 2016.

Combining this information on change in areal extent of the various habitat types and their shift in position over time, habitat renewal and turnover rates can be calculated (Tab. 4). Of course, the dynamic water level fluctuations complicate the calculation of turnover times, whose areal extent is strongly dependent on river stage. Nevertheless, the values give an approximation of the actual enormous dynamics. The position of the multichannel river changes rapidly, up to 20 % per year. For all the major habitat elements within the active channel, including smaller islands with a cover of pioneer vegetation and shrubs, the turnover times are in the order of 5–10 years. Isolated erosion pools within the active channel are specifically short-lived due to erosion and sedimentation, with a life-cycle of less than one year. Only larger erosion pools along the borders of the active channel can have slightly longer life times in the order of a few years. Especially within the active channel, the dynamics and turnover rates are particularly high, and changes occur at a short time scale.

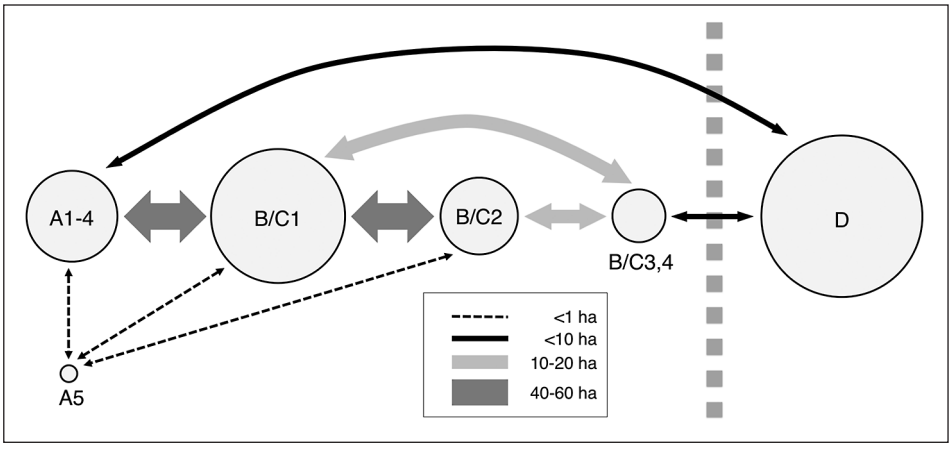


Fig. 18: Fluxes in the position of habitats in the Poçemi floodplain between 2012 and 2016. – Abb. 18: Flussdiagramm der Lokalisation von Habitatelementen zwischen 2012 und 2016.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

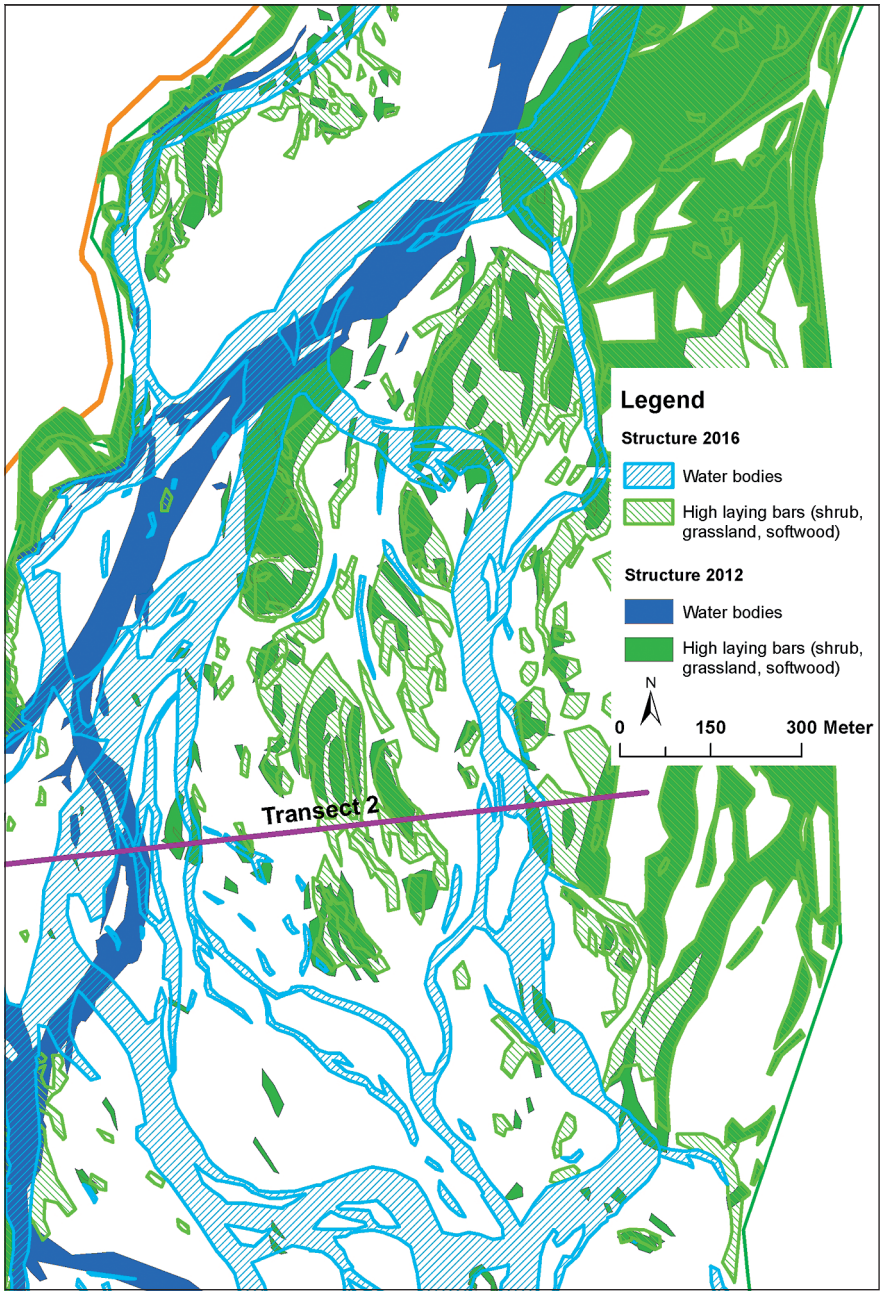


Fig. 19: Example of structural changes in the river – floodplain area of the Poçemi floodplain along Transect 2 between 2012 and 2016. The graph shows the change in position of the anabranching river system and of the higher laying bars and floodplain areas. – Abb. 19: Dynamik der Veränderung der Flusslandschaft am Beispiel eines Abschnittes bei Poçemi entlang Transekt 2. Die Abbildung zeigt die Veränderung in der Lage des Flusslaufes und der aquatischen Habitate und jener der höherliegenden Schotterinseln mit terrestrischer Vegetation.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Table 4: Habitat renewal rate (per year) within the active channel expressed in % of habitat area per year. – Tab. 4: Habitat-Erneuerungsraten pro Jahr innerhalb des „active channels“ in % des Flächenanteils des jeweiligen Habitat-Types.

	2006–2012		2012–2016	
River branches (A1–4)	76.4	13.4 %	91.5	19.2 %
Erosion pools (A5)	0	100 %	3.4	23.0 %
Gravel & sand bars, unvegetated (B1)	132.6	8.7 %	124.2	9.7 %
Gravel & sand bars, early pioneer (BC1–3)	100.7	11.4 %	79.5	17.8 %
Gravel & sand bars, pioneers and shrubs (B4)	60.1	13.7 %	21.7	14,8 %

The relative constancy of the quantitative composition of habitat elements on the one hand, and the high turnover rates on the other indicate that the whole river-floodplain system is in a state of dynamic equilibrium. Bormann & Likens (1979) coined such situations as a “shifting mosaic steady state” (see also Hohensinner et al., 2008).

A detailed study of the Tagliamento river in Italy initiated by the ETH Zürich, provides a good basis for a comparison with an alpine river system of similar size (Ward et al. 1999b, Tockner et al. 2000, Arscott et al. 2000, Edwards et al. 1999, Gurnell et al. 2001, Kollmann et al. 1999,). Van der Nat et al. 2003 analysed the relative change of aquatic and terrestrial habitats in the active corridor and found that within 2.5 years more than 59 % of the aquatic area and 29 % of vegetated islands were restructured. This is comparable with the high dynamics of the Vjosa river-floodplain system.

Figure 20 presents a summary of habitat composition and turnover cycles within the riverine landscape (a). It is apparent that especially the relationship between the riverine habitats A1–4 (see above) and B1/C1 – the unvegetated silt, sand and gravel bars – are continuously shifting with water level fluctuations. Microhabitat availability changes at a high rate within a yearly cycle.

Figure 20 summarizes information on vegetation patterns and successions, which are discussed in greater detail by Drescher (2018 this vol.). The different series of successions depend on sediment structure, soil-humidity and the frequency of disturbances by flooding and burning. For the active channel, the graph identifies successions on gravel (B series), on sand/ silt deposits (C series) and within short lived erosion pools (A5).

The succession on gravel deposits starts with herbs and grasses (B1) followed by seedlings of *Tamarix, Salix* spp. and *Populus nigra* (B2, B3). At the higher shrub phase (B4) *Populus nigra, Salix amplexicaulis* and *Salix alba* are the dominant woody species. Finally, a forest stage can develop, dominated by *Salix alba* and *Populus nigra*.

On silt and sand depositions, the pioneer stage (C2) consists of species which require higher soil moisture, like *Vitex agnus-castus* and *Platanus orientalis*. These species, together with *Salix* spp. and a wide variety of herbs, prevail as pioneers. At a later stage (C3, C4), woody species prevail, leading potentially to a forest stage of *Platanus orientalis, Salix alba and Populus alba*.

Erosion pools within the active channel (A5) initially develop a strong growth of filamentous algae. At longer periods of stagnancy, *Chara* sp. can occur, followed by species of a Nanocyperion-association. These successions are generally very short-lived and the turn-

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

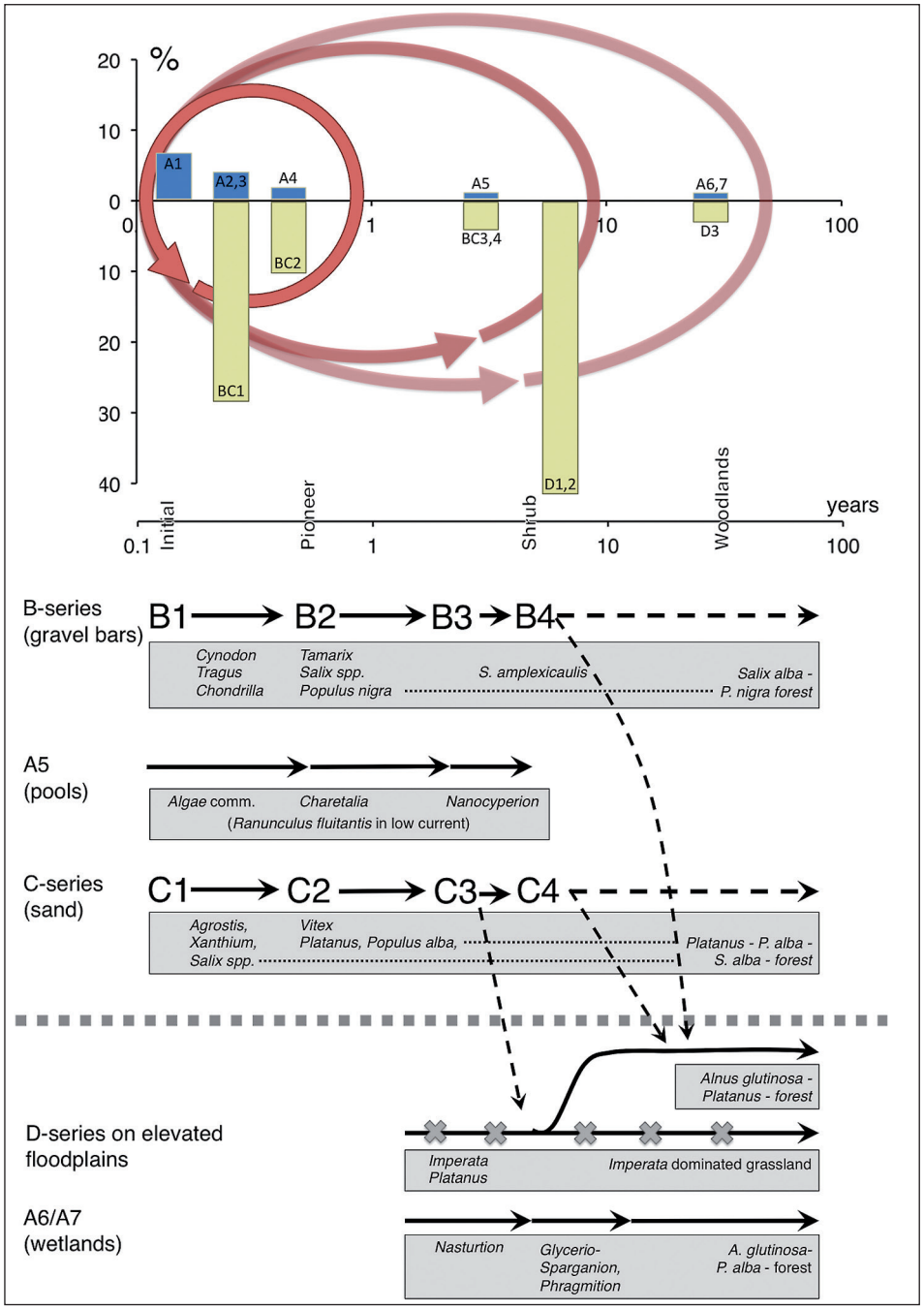


Fig. 20: A general scheme of habitat composition, turnover cycles and vegetation succession in the Vjosa floodplains. The "x"-marks in the D-series represent repeated burning.– Abb. 20: Ein allgemeines Schema der Habitatzusammensetzung, Landschaftsdynamik und Vegetations-Sukzession der Fluss-Auen der Vjosa.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

over is fast (see Fig. 13c). In pools with low flow and current, *Ranunculus aquatilis* agg. can develop.

A further succession series can be observed in former river beds within the floodplain away from the main channel, which receive water at higher floods or through groundwater (A6) or are fed by hillside brooklets (A7). A sequence of assemblages from Nasturtion, Glycerio-Sparganion and Phragmition alliances can develop, leading potentially to an *Alnus glutinosa-Populus alba* forest.

At the elevated floodplain and at higher locations ("islands" within the active channel), an *Imperata*-grassland interspersed with a variety of shrubs, e.g. *Tamarix* and *Platanus orientalis*, develops. Due to regular burning, most of these areas remain in an *Imperata*-dominated stage. In situations without regular burning or wherever burning has stopped, a tendency towards a *Platanus orientalis-Alnus glutinosa* forest was observed.

The relevance of fluvial dynamics for the maintenance of a high and specific biodiversity

The Balkan region is a hotspot of biodiversity with a very specific flora and fauna and a high degree of endemism (see Griffith et al. 2004, Shumka et al. 2018b this vol.). Within this geographic aspect (see Poff 1997), the species diversity encountered at the Vjosa depends on the ecological quality of its highly dynamic riparian zones. The fluvial dynamics create and maintain the heterogenic structure with a hierarchy of transition zones. Major floods cause the morphological restructuring of the river-floodplain landscape at a large scale (Junk et al. 1989, Tockner & Stanford 2002). The frequent smaller water level fluctuations ('flow pulses') are important for creating and maintaining habitat heterogeneity, especially within the active channel. They represent continuous disturbances (Pickett & White 1985), leading to a rejuvenation and turnover of habitat patches and biotic succession (Townsend et al. 1997, Ward & Tockner 2001, Schiemer 1999). The wide range of habitat types and ecotones in context with the dynamic water level fluctuations provide the conditions for the specific associations of well adapted species, with high levels of alpha, beta and gamma diversity (Ward et al. 1999a). Structural heterogeneity in such dynamic landscapes is significant to buffer physical disturbances and to maintain the species pool (Sedell et al. 1990). In addition, the longitudinal continuity in habitat availability is a significant requirement for maintaining the meta-community associations and the meta-population of characteristic species (e.g. Aldermatt et al. 2011, Funk et al. 2013).

Despite the limited time and the early season (April 2017) during which most of the material was collected, our findings confirm the biogeographic significance and the high conservation value of this riverine landscape. No doubt, longer-term studies are required to explore the enormous ecological and biogeographic wealth of the area. Within this study, over 90 taxa of aquatic invertebrates and nearly 400 taxa of terrestrial species were recorded. Many of them are endemic to the Balkan, a large proportion (over 40 %) has been documented for the first time for Albania. A few are described as new to science (e.g. *Isoperla vjosae* by Graf et al. 2018a, *Liocranoeca vjosensis by* Komnenov 2018 this vol.).

Major effort has been put into the assessment of the macrozoobenthos, (see Graf et al. 2018b this vol., Bauernfeind 2018 this vol., Shkembi et al. 2018 this vol.) which is an

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

important indicator group of the European Water Framework Directive (Hering et al. 2010). In large rivers, especially in zones of great geomorphological variability, the biodiversity levels are generally high (Nilsson et al. 1989). A variety of guilds occurs in the diverse aquatic habitats, ranging from the fast current main channel of the river to stagnant isolated pools and wetlands in the floodplains.

In the densely packed sediments of the fast runs of the Vjosa, the population densities and species diversity is comparatively low and the vertical dimension within the sediments is restricted. Higher densities of rheophilic species have been found in steep riffle sections with loose, less consolidated gravel and especially in situations in the main branches with large woody structures. The fauna contains typical elements that are characteristic of large, dynamic rivers and were once widely distributed across Europe and have now disappeared or lost large areas of their former distribution in Europe. The occurrence of plecopterans like *Marthamea vitripennis* or *Xanthoperla apicalis* and ephemeropterans like *Prosopistoma pennigerum* (Schletterer & Füreder 2009), pinpoints the outstanding conservation value of the river. Some of these potamal invertebrates belong to the most endangered aquatic species on an European scale.

The fish fauna is a further important indicator group for the ecological integrity of large river systems (Karr 1991, Schiemer 2000). A variety of guilds is characteristic of the different habitat types – from rheophilic to stagnophilic forms (Schiemer & Waidbacher 1992). The success of species guilds is determined by a complex array of ontogenetic and seasonal habitat requirements (Schlosser 1995). Rheophilic fish require a connected range of habitats from spawning sites, nurseries and feeding grounds, especially during the early phases of their life histories. The match-mismatch between ecological conditions and requirements is decisive for the survival of a population (Schiemer & Zalewski 1992, Schiemer et al. 2001). Only natural river systems with their structural heterogeneity and hydraulic interconnectivity of habitat patches provide such conditions.

The Vjosa is characterized by a large proportion of fish species that are endemic to the Balkans (see checklist, Shumka et al. 2018a this vol.). Our assessment using a set of techniques (backpack electrofishing, gill netting, longlining, beach seining) yielded a high density and diversity of species (Meulenbroek et al. 2018 this vol.). With few exceptions they belong to a rheophilic guild with a predominance of species of the genera *Squalius*, *Chondrostoma*, *Barbus* and *Alburnus*. In fast current riffle zones with loose, coarse gravel, *Oxynoemacheilus pindus* was abundant. The connected or recently disconnected areas of the anabranching system contained mainly juveniles of the rheophilic guild, indicating that under such dynamic situations a wide range of habitats is required to cover their multiple requirements in the course of the life cycle. The detailed assessment of Meulenbroek et al. (2018 this vol.) demonstrate the necessity to maintain the structural complexity of the riverine landscape for a diverse fish fauna. An interesting fish is also *Pelasgus thesproticus*, a stagnophilic form occurring regularly along the border of the active channel in isolated pools with macrophytic vegetation, or in wetlands and backwaters within the floodplain. Based on international experience, we can predict that the construction of hydropower dams will cause a massive decline and the disappearance of typical riverine species in the area (Schiemer & Waidbacher 1992).

As for the aquatic fauna our collections of terrestrial invertebrates, amphibians and reptiles illustrate the uniqueness and high conservation value of the area (see Frank 2018 this vol.,

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at







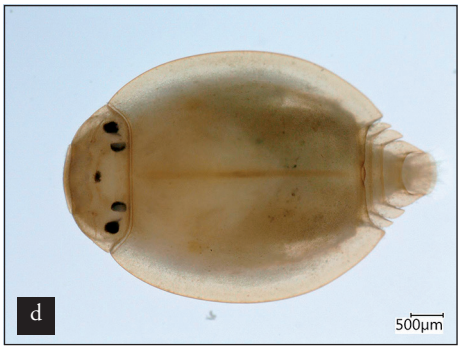






Fig. 21: A few example of species representative for the high conservation value of the Vjosa river-floodplain system (from above on the left to down on the right): a) *Typha minima,* Photo: Schiemer; b) *Pelasgus thesprotic-us;* Photo: Meulenbroek; c) *Perla marginata,* Photo: Graf; d) *Prosopistoma pennigerum,* Photo: Graf; e) *Xya variegata*, carabid beetle, Photo: W. Paill; f) *Poecilus striatopunctatus,* Photo: Kunz.– Abb. 21: Charakteristische Arten der Fluss-Auen der Vjosa, als Beispiel der hohen Schutzwürdigkeit des Gebietes.

Shumka et al. 2018b this vol.). Highly specific littoral communities with good colonizing and refuge capabilities are well represented on the bare ground and early pioneer habitats of rivers with high fluvial dynamics. These associations consist of carabid e.g. *Dyschirius spp.*, and staphylind beetles, spiders, some bugs (Saldidae) and orthopterans (e.g. *Xya variegata).* For a detailed account see Paill et al., Degasperi, Rabl & Kunz, Komnenov, Blick, Komposch, Wagner et al., Frank et al., all this volume).

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

In contrast to the biota of the dynamically changing habitats within the active channel, the terrestrial biodiversity of the elevated floodplain, both flora and fauna, are strongly affected by human interventions especially by large-scale fire clearances and intensive pasturing. A loss in biodiversity due to regular burning is clearly apparent by low species numbers and low population densities of species otherwise characteristic for floodplain meadows. Especially the less mobile insects of orthopterans, cicadas, and heteropterans, and gastropods are strongly affected by the intensive human activities (Duda et al., Rabitsch, Rabl & Kunz, all 2018 this volume).

The diversity of vascular plants in Albania is higher than that of Austria, despite its distinctly smaller size. Southern Albania is one of the biodiversity hotspots of vascular plants on the Balkan peninsula. The plant assemblages in the Vjosa floodplain are characterized by species formerly widespread in Europe, but nowadays almost extinct in large parts of its former area (e.g., *Typha minima*) (Drescher 2018 this vol., Rössler et al. 2018 this vol.).

In conclusion: the highly undisturbed river dynamics and the river-floodplain ecosystems along the Vjosa are in an excellent conservation status. All riverine habitats typical for the Vjosa are listed in the Annex 1 of European Union Habitats Directive, underpinning their importance for conservation at an European scale. They harbour viable communities of species that have largely or completely disappeared from other European rivers systems. Due to their specific demands, all of these species have almost entirely gone extinct in Central Europe.

We can predict that the majority of the specific biodiversity will disappear in the case of the planned dam constructions due to a loss of fluvial dynamics (Schiemer 2000).

In a report to the Bern Convention –on the Conservation of European Wildlife and Natural Habitats, species were listed which have been documented within the project area at Poçem These findings document and confirm the uniqueness and conservation status of the area (see Shumka et al. 2018b this vol.).

Summary: hazards of dam construction and the need for science in river management

In context of the planned hydropower dams at Poçemi and Kalivaçi along the Vjosa in Albania, decision makers and stakeholders should be aware of the profound and long-term environmental consequences and major environmental threats of dam constructions in alluvial zones. Today, the past over-regulation of rivers necessitates costly restoration measures for compensation in many industrialized countries (e.g. Karr 1991, Naiman et al., 2002, 2005, Poff et al. 2003, Tockner et al. 2008, Schiemer 2015).

With regard to the hydropower plans at the Vjosa, the environmental hazards refer to:

- the immediate endangerment of the high conservation value of the area and this national heritage by damming,
- a loss of groundwater resources in terms of quantity and quality,
- a deterioration of surface water quality (eutrophication processes at high water residence times can be expected to lead to toxic algal blooms),
- methane production as a result of anaerobic processes in the flooded areas,
- coastal erosion due to the reduction of sediment transport by the river,

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

– catastrophic floods especially considering the increase of flood risks due to global warming.

Besides these environmental issues, an array of environmental, socio-economic and legal concerns has not been addressed in the proposition of the hydropower plans and require clarification:

A major ambiguity is the high sediment load of the river which will reduce the efficiency in energy use within a period of a few decades due to dam-filling. For short-term economic considerations the uniqueness of the landscape and its cultural heritage is destroyed and options for their long-term sustainable economic use, e.g. in terms of development of tourism, are suppressed.

Finally there is an array of operational and legal concerns. Over the past 20 years, international water management has developed standardized operational procedures which should be adhered to. In EU countries, for example, river management must follow the European Water Framework Directive, EU Natura 2000 Directive, EU Birds and Habitats Directive and EU Flood Risk Directive. Regulations stipulate that projects have to be based on a detailed monitoring of environmental conditions and hazards and an assessment both of the socio-economy of river basin development and the reactions towards human interventions.

The environmental aspects must be addressed by a valid Environmental Impact Assessment. These EIA have to evaluate short-, medium-, and long-term impacts on nature and affected residents of a projected hydropower plant, and must consider alternative low-impact concepts (Moss 2008, Hering et al. 2010). They have to be based on detailed assessments of hydro-morphological processes, geomorphic and ecological structure and dynamics and predictions about the impacts on specific biodiversity. Prerequisites for such an approach are well defined, science based research programs principally with the goal of elucidating cause-effect relations at different spatio-temporal scales, in order to develop prognostic models for management (Surridge & Harris 2007, Vaughan et al. 2009, Arthington et al. 2010, Schiemer 2015). The apparent challenge is to follow the cause – effect chain between the governing factors hydrology and sediment load in order to gain a process-orientated understanding of river-floodplain systems and the resulting fluvial landscape dynamics and ecology. An interdisciplinary eco-hydrological approach must combine hydrology, sediment transport processes and ecology (Zalewski 2000, Wood et al. 2007).

In the EIA presented in the Pocem project plan, none of the apparent dangers have been seriously addressed and none of the potential long-term effects of the project were discussed. National and international consortia of scientists and experts have expressed their concerns about the poor quality of the EIA presented to the Albanian government and the EU. For the Kalivaci project, the EIA so far (July 2018) has not been made public.

Important water policy instruments such as the Water Framework Directive of the EU request action comprehensive catchment-wide planning process with clearly defined procedural steps.

A platform across the science-policy interface, were science can 'speak to' policymakers, authorities and other stakeholders, requires a clear participation and decision structure and a direct involvement of political decision makers in the discussion process (Simon & Schiemer 2015). Continued development of local expertise and expertise to communicate this to the public and decision makers.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

To achieve this goal, expert panels with long term mandates are required. Discussions with scientists and stakeholder should explore scenarios for the sustainable development of the river corridor, acknowledging the links between the integrity of the Vjosa ecosystem and economic, social and cultural aspects of human well-being. In order to contribute the scientific community in the Balkan countries is challenged to build up capacity and scientific foundations for regional water management. Albanian scientists – on the other hand – have to accept responsibility and help in decision making in landscape management.

Acknowledgments

We would like to thank Severin Hohensinner and Cercis Durmishi for critically reviewing the text, Wolfram Graf, Gernot Kunz, Wolfgang Paill, Gregor Subic for contributing fotos and Viola Winkler and Daniel Pucher for the computer graphics. We are grateful to Hubert Kraill for the chemical analysis of the water samples. We thank Klodian Skrame for his help in the bathymetric assessment of the landscape relief.

Literature

Aldermatt F., Schreiber S. & Holyoak M., 2011: Interactive effects of disturbance and dispersal directionality on species richness and composition in metacommunities. Ecology 92, 859–870.

Aliaj S., 2006: The Albanian orogeny: convergence zone between Eurasia and the Adria microplate. In: The Adria microplate: GPS Geodesy, Tectonics and Hazards, 133–149.

Amoros C., Rouy A.L., Reygrobellet J.L., Bravard J.P. & Pautou G., 1987: A method for applied ecological studies of fluvial hydrosystems. Regulated Rivers 1, 17–36.

Apostolakis A. & Simixhiu V., 2008: Mapping of protected areas in Vjosa river catchment. Greek Biotope/Wetland Centre (EKBY). Thermi.

Arscott D.B., Tockner K. & Ward J.V., 2000: Aquatic habitat diversity along the corridor of an alpine floodplain (Fiume Tagliamento, Italy). Arch. Hydrobiol. 149, 679–704.

Arthington A.H., Naiman R.J., McClain M.E. & Nilsson C., 2010: Preserving the biodiversity and ecological services of rivers: new challenges and research opportunities. Freshwater Biology 55, 1–16.

Bauernfeind E., 2018: Mayflies (Ephemeroptera) of the River Vjosa, Albania. Acta ZooBot Austria 155, this volume.

Benda L., Poff L., Miller D., Dunne T., Reeves G., Pess G. & Pollock M., 2004: The network dynamics hypothesis: how channel networks structure riverine habitats. BioScience 54, 413–427.

Bhallamudi S.M. & Chaudhury M.H., 1991: Numerical modelling of aggradation and degradation in alluvial channels. ASCE Journal of Hydraulic Engineering 119, 1145–1164. DOI/10.1061/(ASCE)0733-9429.

Blick T., 2018: A small collection of spiders (Arachnida: Araneae) from the Vjosa river, Albania – with an updated checklist for Albania. Acta ZooBot Austria 155, this volume.

Bormann F.H. & Likens G.E., 1979: Catastrophic disturbance and the steady state in northern hardwood forests: a new look at the role of disturbance in the development of forest ecosystems suggests important implications for land-use policies. American Scientist 67, 660–669.

Brierley G.J. & Hickin E.J., 1992: Channel planform as non-controlling factor in fluvial sedimentology: the case of the Squamish River, British Columbia. Geomorphology 4, 381–391.

Bunte K. & Abt S.R., 2001: Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

monitoring. RMRS-GTR-74, US Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Buijse A.D., Klijn F., Leuven R.S.E.W., Middelkoop H., Schiemer F., Thorp J.H. & Wolfert H.P., 2005: Rehabilitation of large rivers: references, achievements and integration into river management. Arch. Hydrobiol. Suppl. 115 (Large Rivers 15), 715–738.

Carbonneau P.E. & Piegay H., 2012: Fluvial Remote Sensing for Science and Management. Wiley-Blackwell, 440 pp.

Carson M.A., 1984: Observations on the meandering-braided river transition, the Canterbury Plains, New Zealand: Part two. New Zealand Geographer 40, 89–99.

Chatzinikolaou Y., Dakos V. & Lazaridou M., 2008: Assessing the ecological integrity of a major transboundary Mediterranean river based on environmental habitat variables and benthic macroinvertebrates (Aoos-Vjose River, Greece – Albania). Int. Rev. Hydrobiol. 93, 73–87.

Church M., 1983: Pattern of instability in a wandering gravel bed channel. In: Collinson J.D. & Lewin J. (Eds.) Modern and Ancient Alluvial Systems. International Association of Sedimentologists, Special Publication 6, 169–180.

Correia L.R.P., Krishnappan G. & Graf W.H. 1992: Fully coupled unsteady mobile boundary flow model. ASCE Journal of Hydraulic Engineering 118, 476–494. DOI/10.1061/(ASCE)0733-9429.

Daja, S., Xhemalaj X, Lipo, S. & Ago B., 2018: Stream Channel Characterization of Vjosa – a unique natural river. Acta ZooBot Austria 155, this volume.

Décamps H., 1996: The renewal of floodplain forests along rivers: a landscape perspective. Verh. Int. Ver. Limnol. 26, 35–59.

Décamps H., Pinay G., Naiman R.J., Petts, G.E., McClain M.E., Hillbricht-Ilkowska A., Hanley T.A., Holmes R.M., Quinn J., Gibert, J., Planty Tabacchi A.-M., Schiemer F., Tabacchi E. & Zalewski M., 2004: Riparian zones: where biogeochemistry meets biodiversity in management practice. Pol. J. Ecol. 52, 3–18.

Degasperi G., 2018: Glimpsing at the rove beetle fauna of Vjosa River, Albania (Coleoptera: Staphylinidae). Acta ZooBot Austria 155, this volume.

Desloges J.R. & Church M.A., 1989: Wandering gravel bed rivers. Canadian Geographer, 33, 360–364.

Drescher A., 2018: The Vjosa – the floodplains of an outstanding gravel bed river in southern Albania. Acta ZooBot Austria 155, this volume.

Duda M., Haring E. & Sattmann H., 2018: The mollusc fauna of the Vjosa river and its floodplains at Poçem, South Albania. Acta ZooBot Austria 155, this volume.

Durmishi C., Prifti I. & Nazaj S., 2014: Regional Geological Panorama. In: CBGA 2014 Field trip FT3 Geodynamic Evolution, Petroleum Geology, Potential Source Rocks, Reservoirs, Seals Carbonate Sedimentary Systems, Ionian and Sazani Zones, Albania, 3–16.

Durmishi C., Daja S., Ago B., Dindi E., Sinojmeria A., Nazaj S.J., Qorri A., Muçi R., 2018: Synthesis of geological, hydrogeological, sedimentological settings and geo-touristic features of the Vjosa Watershed. Acta ZooBot Austria 155, this volume.

Dynesius M. & Nilsson C., 1994: Fragmentation and flow regulation of river systems in the northern third of the world. Science 266, 753–762.

Edwards P.J., Kollmann J., Petts G.E., Gurnell A.M., Tockner K. & Ward J.V., 1999: A conceptual model of vegetation dynamics on gravel bars of a large Alpine river. Wetlands Ecology and Management 7, 141–153.

Frank T., 2018: Overview of the terrestrial animals of the Vjosa River, Albania. Acta ZooBot Austria 155, this volume.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Frank T., Saçdanaku E., Duda M & Bego F., 2018: Amphibian and reptile fauna of the Vjosa river, Albania. Acta ZooBot Austria 155, this volume.

Funk A., Schiemer F. & Reckendorfer W., 2013: Metacommunity structure of aquatic gastropods in a river floodplain: the role of niche breadth and drift propensity. Freshwater Biology 58, 2505–2516.

Graf W., Pauls S.U. & Vitecek S., 2018a: *Isoperla vjosae* sp. n., a new species of the *Isoperla tripartita* group from Albania (Plecoptera: Perlodidae). Zootaxa 4370 (2), 171–179.

Graf W., Grabowski M., Hess M., Heckes U., Rabitsch W. & Vitecek S., 2018b: Aquatic invertebrate fauna of the Vjosa in Albania. Acta ZooBot Austria 155, this volume.

Google Earth, 2018: Satellite Images Worldwide. Digital Globe, 2018, http:// www. earth.google.com.

Griffith H.I., Krystufek B. & Reed J.M., 2004: Balkan biodiversity: pattern and process in the European hotspot, Springer Netherlands, pp. 358.

Gurnell A.M., Petts G.E., Hannah D.M., Smith B.P.G., Edwards P.J., Kollmann J., Ward J.V. & Tockner K., 2001: Riparian vegetation and island formation along the gravel-bed Fiume Tagliamento, Italy. Earth Surf. Process. Landforms 26, 31–62.

Hering D., Borja A., Carstensen J., Carvalho L., Elliot M., Feld C.K., Heiskanen A.-S., Johnson R.K., Moe J., Pont D., Solheim A.L. & Van De Bund W., 2010: The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. Sci. Total Environ. 408, 4007–4029.

Hohensinner S., Herrnegger M., Blaschke A.P., Habereder C., Haidvogl G., Hein T., Jungwirth M. & Weiss M., 2008: Type-specific reference conditions of fluvial landscapes: a search in the past by 3D-reconstruction. Catena 75, 200–215.

Junk W.J., Bayley P.B. & Sparks R.E., 1989: The flood-pulse concept in river floodplain systems. In DODGE D.P. (Ed.), Proceedings of the International Large River Symposium, Canadian Special Publication of Fisheries and Aquatic Sciences 106, 110–127.

Karr J.R., 1991: Biological integrity: a long neglected aspect of water resource management. Ecological Applications 1, 66–84.

Kellerhals R., Neill C.R. & Bray I.D., 1972: Hydraulic and geomorphic characteristics of rivers in Alberta, Research Council of Alberta, River Engineering and Surface Hydrology Report, 72-1.

Kesh, Albanian Power Generation, 2009: Consultants'services for assessment of power generation potential of selected Albanian rivers. Appendix 1. Report for Vjosa system, 315 pp.

Kolaneci M., 2014: The hydrology of Vjosa River, after joining Drinos River. Tirana. (cit. in Rössler N., 2017).

Kollmann J., Vieli M., Edwards P.J., Tockner K. & Ward J.V., 1999: Interactions between vegetation development and island formation in the alpine river Tagliamento. Applied Vegetation Science, 2, 25–36.

Komnenov M., 2018: Spiders (Arachnida: Araneae) of the floodplains of the Vjosa river, South Albania. Acta ZooBot Austria 155, this volume.

Komposch C., 2018: Harvestmen (Arachnida: Opiliones) of the floodplains of the Vjosa river. Acta ZooBot Austria 155, this volume.

Lazaridou-Dimitriadou M., Chatzinikolaou Y., Vergoss S., BoboriD., Eleftheriadis N., Radea K., Gourvelou E., Dimalexis A., Statiri X., Sgouridis F., Dakos V., Pano N., Frasheri A. & Skqevit T., 2002: Program for the conservation, management and demonstration of the natural network between three different adjacent types of ecosystems: Narta lagoon, Aoos-Vjose river forest ecosystem, islands Zverneci and National Park Llogora. Final Report. Greek Ministry of Environment.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Liggett J.A. & Cunge J.A., 1975: Numerical methods of solution of the unsteady flow equations. In: Mahmood K. & Yevjevich V., (Eds.) Unsteady Flow in Open Channels. Vol. I, Water Resources: Fort Collins, Colorado, 89–179.

McClain M.E., Boyer E.W., Dent C.L., Gergel S.E., Grimm N.B., Groffman P.M., Hart, S.C., Harvey J.W., Johnston C.A., Mayorga E., McDowell W.H. & Pinay G., 2003: Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems. Ecosystems 6, 301–312.

Metivier F. & Barrier L., 2012: Alluvial landscape evolution: what do we know about metamorphosis of gravel bed meandering and braided streams, in: Gravel-bed Rivers: processes, tools, environments, chapter 34, edited by: Church M., Biron P., and Roy A., Wiley & Sons, Chichester, 474–501.

Meulenbroek P., Shumka S., Schiemer F., 2018: First reconnaissance of habitat partitioning and fish diversity in the alluvial zone of the river Vjosa, Albania. Acta ZooBot Austria 155, this volume.

Moss B., 2008: The Water Framework Directive: total environment or political compromise? Science of the Total Environment 400, 32–41.

Naiman R.J., Décamps H. & McClain M.E., 2005: Riparia: Ecology, Conservation and Management of Streamside Communities. Elsevier, 431 pp.

Naiman R.J., Bunn S.E., Nilsson C., Petts G.E., Pinay G. & Thompson L.C., 2002: Legitimizing fluvial ecosystems as users of water: an overview. Environmental Management 30, 455–467.

Nanson G.C. & Knighton A.D., 1996: Anabranching rivers: their cause, character and classification. Earth Surface Processes and Landforms 21, 217–239.

Nilsson C., Jansson R., Malmqvist B. & Naiman R.J., 2007: Restoring riverine landscapes: the challenge of identifying priorities, reference states and techniques. Ecol. Soc. 12, 1–6.

Niekirk A., Van Vogel K.R., Slingerland R.L. & Bridge J.S., 1992: Routing of heterogeneous size-density sediments over a movable stream bed: model development. ASCE Journal of Hydraulic Engineering 118, 246–263.

Nordseth K., 1973: Fluvial processes and adjustments on a braided river. The islands of Kopangsoyene on the River Glomma. Norsk Geografisk Tidsskrift 27, 77–108.

Paill W., Gunczy J. & Hristovski S., 2018: The Vjosa-floodplains in Albania as natural habitat for ground beetles: a hotspot of rare and stenotopic species (Coleoptera: Carabidae). Acta ZooBot Austria 155, this volume.

Pano N., 2008: Water sources of Albania. Albanian Academy of Sciences. Tirana.

Pano N. 2015: Pasurite ujore te Shqiperise [Water richness of Albania]. Academy of Sciences of Albania. Ed. "Kristalina-KH". 634 pp.

Pano N. & Avdyli B., 1984: Hydrology of the Albania. Monograph. In: Academy of Science, Institute of Hydrometeorology, 94–146.

Petts G.E. & Amoros E. (Eds.), 1996: Fluvial Hydrosystems. Chapman and Hall, London.

Petts G.E., Moller H. & Roux A.L. (Eds.), 1989: Historical Changes of Large Alluvial Rivers: Western Europe. Wiley, Chichester, 355 pp.

Pinay G., GumieroB., Tabacchi E., Gimenez O., Tabacchi -Planty A.M., Hefting M.M., Burt T.P., Black V.A., Nilsson C., Iordache V., Bureau F., Vought L., Petts G.E. & Décamps H., 2007: Patterns of denitrification rates in European alluvial soils under various hydrological regimes. Freshwater Biology 52, 252–266.

Pickett S.T.A. & White P.S., (Eds.) 1985: The ecology of natural disturbance and patch dynamics. Academic Press, Orlando, Florida.

Poff N.L., 1997: Landscape filters and species traits: toward mechanistic understanding and prediction in stream ecology. J. N. Am. Benthol. Soc. 16, 391–409.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Poff N.L., Allanj D., Palmer M.A., Hart D.D., Richter B.D., Arthington A.H., Rogers K.H., Meyer J.L. & Stanford J.A., 2003: River flows and water wars: emerging science for environmental decision making. Front. Ecol. Environ. 1, 298–306.

Puckridge J.T, Sheldon F., Walker K.F. & Boukton A.J., 1998: Flow variability and the ecology of large rivers. Marine and Freshwater Research 49, 55–72.

Rabitsch W., 2018: Snapshot of the terrestrial true bug fauna of the Pocem floodplains (Insecta: Hemiptera: Heteroptera). Acta ZooBot Austria 155, this volume.

Rabl D. & Kunz G., 2018: First insights in the grasshopper fauna (Insecta: Orthoptera: Saltatoria) of the river floodplain at Poçem (South Albania). Acta ZooBot Austria 155, this volume.

Rosgen D.L., 1994: A classification of natural rivers. Catena 22, 169–199.

Rössler N., 2017: Die Auenvegetation der Vjosa (Albanien) – einer der letzten wilden Flüsse Europas. Wissenschaftliche Abschlussarbeit Geographie, Karlsruher Institut für Technologie, Karlsruhe, 135 pp.

Rössler N., Egger G. & Drescher A., 2018: Riparian vegetation and fluvial processes of the Vjosa River (Albania). Acta ZooBot Austria 155, this volume.

Schiemer F., 1999: Conservation of biodiversity in floodplain rivers. Arch. Hydrobiol. Suppl. 115 (Large Rivers 15), 423–438.

Schiemer F., 2000: Fish as indicators for the assessment of the ecological integrity of large rivers. Hydrobiologia 422/423, 271–278.

Schiemer F., 2015: Building an eco-hydrological framework for the management of large river systems. Ecohydrology & Hydrobiology 16(1), 19–25.

Schiemer F., Keckeis H., Winkler G. & Flore L., 2001: Large rivers: the relevance of ecotonal structure and hydrological properties for the fish fauna. Archiv Hydrobiol. Suppl. 135 (Large Rivers 12), 487–508.

Schiemer F. & Waidbacher H., 1992: Strategies for conservation of a Danubian Fish Fauna. In: Boon P.J., Calow P. & Petts G.J. (Eds.), River Conservation and Management. Wiley & Sons, 363–382.

Schiemer F. & Zalewski M., 1992: The importance of riparian ecotones for diversity and productivity of riverine fish communities. Netherlands Journ. of Zoology 42, 323–335.

Schlosser I.J., 1995: Critical landscape attributes that influence fish population dynamics in headwater streams. Hydrobiologia 303, 71–81.

Schletterer M. & Füreder L., 2009: The family Prosopistomatidae (Ephemeroptera): a review on its ecology and distribution, with particular emphasis on the European species Prosopistoma pennigerum Müller, 1785. Aquatic Insects 31, Supplement 1, 603–620.

Schumm S.A., 1985: Patterns of alluvial rivers. Annual Review of Earth and Planetary Sciences 13, 5–27.

Sedell J.R., Reeves G.H., Hauer R., Stanford J.A. & Hawkins C.P., 1990: Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management 14, 711–724.

Seferlis M., Laco T. & Papadimos D., 2008: Identification of human pressures and impacts on the surface waters of Aoos/Vjosa watershed. The Goulandris Natural History Museum – Greek Biotope/Wetland Centre. Thermi, Greece. 70 pp.

Shumka S., Meulenbroek P., Schiemer F. & Šanda R., 2018a: Fishes of River Vjosa – An Annotated Checklist. Acta ZooBot Austria 155, this volume.

Shumka S., Bego F., Beqiraj S., Paparisto A., Kashta L., Miho A., Nika O., Marka J. & Shuka L., 2018b: The Vjosa catchment – a natural heritage. Acta ZooBot Austria 155, this volume.

Simon D. & Schiemer F., 2015: Crossing boundaries, complex systems, transdisciplinarity and applied system agendas. Curr. Opin. Environ. Sustain. 12, 6–11.

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Slingerland R. & Smith N.D. 2004: River avulsions and their deposits. Annual Review of Earth and Planetary Sciences 32, 257–285.

Surridge B. & Harris B., 2007: Science-driven integrated river basin management: a mirage? Int. Sci. Rev. 32, 298–312.

Thorp J.H., Thoms M.C. & Delong M.D., 2006: A model of biocomplexity in river networks across space and time. River Res. Applic. 22, 123–147.

Tockner K., Bunn S.E., Gordon C., Naiman R.J., Quinn G.P. & Stanford J.A., 2008: Flood plains: critically threatened ecosystems. In: N.V.C. Polunin (Ed.), Aquatic ecosystems: trends and global prospects, Cambridge University Press, 45–61.

Tockner K. & Stanford J.A., 2002: Riverine floodplains: present state and future trends. Env. Cons. 29, 308–330.

Tockner K., Ward J.V., Arscott D.B., Edwards P.J., Kollmann J., Gurnell A.M., Petts G.E. & Maioloni B., 2000: The Tagliamento River: a model ecosystem for alpine gravel-bed rivers. In: Plachter H. & Reich M. (Eds.), Ecology and conservation on gravel bed rivers and alluvial floodplains in the Alps. Springer, Berlin.

Townsend C.R., Scarsbrook M.R. & Doledec S., 1997: The intermediate disturbance hypothesis, refugia, and biodiversity in streams. Limnol. Oceanogr. 42, 938–949.

USACE, 2002: HEC – RAS User manual 3.1.1. U.S. Corps of Engineers.

Van Der Nat D., Tockner K., Edwards P.J., Ward J.V. & Gurnell A.M., 2003: Habitat change in braided flood plains (Tagliamento, NE-Italy). Freshwater Biology 48, 1799–1812.

Vaughan I.P., Diamond, M., Gurnell A.M., Hall K.A., Jenkins A., Milner N.J., Naylor.A., Sear D.A., Woodward G. & Ormerod S.J., 2009: Integrating ecology with hydromorphology: a priority for river science and management. Aquatic Conservation: Marine and Freshwater Ecosystems 19, 113–125.

Wagner H.C., Seifert B., Borovsky R. & Paill W., 2018: First insight into the ant diversity of the Vjosa valley, Albania (Hymenoptera: Formicidae). Acta ZooBot Austria 155, this volume.

Ward J.V. & Tockner K., 2001: Biodiversity: towards a unifying theme for river ecology. Freshwater Biology 46, 807–819.

Ward J.V. & Tockner K. & Schiemer F., 1999a: Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regulated Rivers Research & Management 15, 125–139.

Ward J.V. & Tockner K., Edwards P.J., Kollmann J., Bretschko G., Gurnell A.M., Petts G.E. & Rossaro B., 1999b: A reference river system for the Alps: the "Fiume Tagliamento". Regulated Rivers Research & Management 15, 63–75.

Winemiller K.O., Flecker A.S. & Hoeinghaus D.J., 2010: Patch dynamics and environmental heterogeneity in lotic ecosystems. J. N. Am. Benthol. Soc. 29, 84–99.

Wood P.J., Hannah D.M. & Sadler J.P. (Eds.), 2007: Hydroecology and Ecohydrology – Past, Present, Future. Wiley.

Zalewski M., 2000: Ecohydrology – the scientific background to use ecosystem properties as management tools toward sustainability of water resources. Ecol. Eng. 16, 1–8.

Received: 2018 06 04

Addresses:

Univ.-Prof. Dr. Fritz Schiemer, Department of Limnology and Oceanography, University of Vienna, Althanstr.14, A1090 Vienna, Austria. E-mail: friedrich.schiemer@univie.ac.at

Mag. Dr. Anton Drescher, University of Graz, Division of Plant Sciences, Holteigasse 6, A8010 Graz, Austria. E-mail: anton.drescher@uni-graz.at

© Zool.-Bot. Ges. Österreich, Austria; download unter www.zobodat.at

Univ.-Prof. Dipl.Ing. Dr. Christoph Hauer, Institute of Hydrology, University of Natural Resources and Life Sciences, Muthgasse 18, A1190 Vienna, Austria.
E-mail: christoph.hauer@boku.ac.at

Dr. Ulrich Schwarz, Fluvius: Floodplain Ecology and River Basin Management, Hetzgasse 22, A1030 Vienna, Austria. E-mail: office@fluvius.com

ZOBODAT - www.zobodat.at

Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien. Frueher: Verh.des Zoologisch-Botanischen Vereins in Wien. seit 2014 "Acta ZooBot Austria"

Jahr/Year: 2018

Band/Volume: 155_1

Autor(en)/Author(s): Schiemer Fritz, Drescher Anton, Hauer Christoph, Schwarz Ulrich

Artikel/Article: The Vjosa River corridor: a riverine ecosystem of European significance 1-40