The assessment of the dragonfly fauna (Insecta: Odonata) as a tool for the detailed typological characterisation of running waters

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Odonata play an increasing role as indicators in the assessment of the ecological status of running water systems in modern water management. In this connection, the application of the Rhithron-Potamon Concept dealing with the longitudinal distribution patterns of aquatic communities along biocoenotic regions has proven to be a sound approach. Central aspect of the assessment procedure is the comparison of the odonatological status quo with a river type-specific reference state, which focuses on the potential dragonfly community at the (near-)pristine character of the water body investigated. A more detailed method of defining reference species is required particularly with regard to special river types, as the exclusive assignment of the biocoenotic region may cause misleading results. This present paper deals with one of the last near-natural hyporhithron river sections in Austria, the lower course of the Antiesen. Taking into account the Antiesen's canyon-like geologic features with reduced availability of different habitat types for dragonflies in the riparian ecotones, the predetermined spectrum of hyporhithron reference Odonata species was adapted by discussing autecological requirements and river-morphology and revealed two river type-specific core reference species (*Calopteryx virgo* and *Onychogomphus forcipatus*) and five river type-specific accompanying reference species. The comparison of these reference species with the results of a comprehensive field study carried out in 2020 at the Antiesen confirmed the unique features of this river type and the dominating hyporhithron characteristics. It also revealed, however, a slight epipotamon influence indicated by the high abundance of *Calopteryx splendens*, one of the river type-specific accompanying reference species, probably due to increased water temperatures.

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Die Bedeutung von libellenkundlichen Erhebungen zur Bewertung des ökologischen Zustandes von Fließgewässern nimmt in der modernen Wasserwirtschaft stetig zu. Das Rhithron-Potamon-Konzept, das die längenzonalen Verteilungsmuster (biozönotische Regionen) der aquatischen Lebensgemeinschaften zum Inhalt hat, stellt hierbei eine sensitive methodische Grundlage dar. Zentraler Aspekt der Beurteilung des ökologischen Zustandes ist der Vergleich eines gewässertyp-spezifischen Referenzzustandes mit dem Status quo. Insbesondere im Fall der speziellen Ausprägungen von Gewässertypen, z. B. Schluchtstrecken, kommt der Festlegung der Referenzbedingungen ein besonderer Stellenwert zu. Die ausschließliche Anwendung der biozönotischen Region mit den jeweiligen Referenzzönosen kann zu irreführenden Ergebnissen führen. Die vorliegende Studie behandelt eine der letzten naturnahen hyporhithralen Flussabschnitte in Österreich, den Unterlauf der Antiesen in Oberösterreich. Unter Berücksichtigung der schluchtartigen morphologischen Ausprägung des Gewässerabschnittes mit der stark herabgesetzten Verfügbarkeit von – aus libellenkundlicher Sicht – relevanten Habitaten in den litoralen Ökotonen war das gewässertyp-spezifische libellenkundliche Leitbild entsprechend zu adaptieren. Eine umfangreiche odonatologische Untersuchung der Antiesen im Jahr 2020 unterstreicht insbesondere durch die Nachweise der Leitarten *Calopteryx virgo* und *Onychogomphus forcipatus* die ökologische Wertigkeit des Gewässerabschnittes. Hohe Abundanzen von *Calopteryx splendens*, einer gewässertyp-spezifischen Begleitart, deuten auf einen leichten epipotamalen Einfluss, wahrscheinlich in Folge von erhöhten Wassertemperaturen, hin.

Keywords: river type, canyon, Rhithron-Potamon Concept, reference state, ecological status, Water Framework Directive, reference species.

Introduction

Since the implementation of the EU Water Framework Directive 2000/60/EC (WFD; European Community 2000), the assessment of the ecological status of surface waters in Europe is based upon a comparison between a near-pristine reference condition and the present-day status of water bodies. Already before the WFD, several studies stressed the importance of dragonfly communities as indicators for evaluating the ecological integrity of riverine systems in a type-specific approach (Schorr & Götz 1996, Laister 1998). Reference conditions are defined as surface water types with nearly undisturbed characteristic morphological and hydrological properties as well as with type-specific aquatic communities. In the case of running waters, this previous natural state is either known or assumed to have existed prior to large-scale channel regulations, approximately until the mid-19th century. Deviations from this benchmark (which corresponds to the "high ecological status" according to WFD) are expressed within an evaluation system comprising the following classes: "good ecological status", "moderate ecological status", "poor ecological status", and "bad ecological status".

A comprehensive abiotic and biotic typology of surface waters hence constitutes the essential basis for assessing their ecological status (Moog & Wimmer 1990, Ehlert et al. 2002). Determining running water reference conditions primarily depends on the search for existing near-natural river stretches with almost undisturbed typological morphological and hydrological characteristics. For many running water types, however, such river stretches no longer exist: In Austria, for example, the ecological status of only 15 % of the running waters with a catchment area >10 km^2 is classified as "high" (BMLFUW 2017). For many river types reference conditions are not available anymore, particularly in the case of large rivers and running waters situated in populated valleys. The reasons behind this development are manifold and include deficits in river morphology, longitudinal and lateral connectivity as well as hydrology due to flood control, energy production and agricultural hydraulic engineering (BMLFUW 2017, Chovanec 2018a). If nearly undisturbed river stretches no longer exist, historical maps and reports (e.g. fisheries data of monasteries) as well as old paintings may provide useful information for professional judgement and/or as input data in models (Chovanec & Waringer 2001, Wiesbauer 2019). In some instances, aerial photographs make palaeochannels visible and therefore provide information useful for deriving former channel morphologies (Wiesbauer & Denner 2013).

In order to implement the stipulations of the WFD, running water typology in Austria is based on the definition of 15 spatial units ("bioregions") as well as on the designation of "large rivers". Bioregions are ecologically and geographically defined areas and subunits of the ecoregions, which – for Europe –were delineated by Illies (1978; see also Hughes 1995, Bryce & Clarke 1996, Omernik 1996, Fink et al. 2000, Chovanec 2018a, Moog et al. 2004). Large rivers are defined as running waters with a stream order >7 and/or a catchment area >2500 km^2 and/or a mean discharge >50 m^3/s. For each river type, hydromorphological reference conditions have been defined by Wimmer et al. (2012).

Within the spatial framework of bioregions, stream zonation patterns according to the longitudinal distribution of riverine organisms along biocoenotic regions represent one of the most important parameters for the characterisation of running waters. This so called rhithron–potamon concept (Illies 1961, Illies & Botosaneanu 1963) was developed from the subdivision of rivers into fish regions (Thienemann 1925) and describes longitudinal changes of community structures from the spring-fed headwaters (crenon) through the cooler and shaded upland sections of a river (rhithron) to the warmer and less steep streams of the lowlands (Potamon; Chovanec 2018a). The knowledge on riverine distribution patterns of aquatic species has been used to establish bioindication systems, particularly in order to assess measures of hydraulic engineering as well as hydrological alterations (Moog & Chovanec 2000).

Odonata belong to the group of macroinvertebrates that represent one of the four biological quality elements stipulated in the WFD in order to monitor the ecological status of running waters. Considering their unique ecological characteristics, Odonata have become model organisms for the characterisation of water bodies as well as for environmental assessment procedures. Important aspects of their role as indicators include their wide distribution in the aquatic ecosystems and the presence of eurytopic species which are more resilient to environmental changes, and stenotopic species, which are able to adapt only to a small range of environmental disturbance (Waringer 1989, Chovanec & Waringer 2001, Chovanec et al. 2015, Cezário et al. 2021). Several studies carried out in Austria set forth how the concept of biocoenotic regions could be applied not only to macroinvertebrates, but also to dragonflies alone. Such investigations focus on the rivertype-specific evaluation of river rehabilitation (e. g. Chovanec 2018a, b, 2019a, b) and demonstrate the benefit of a reliable and sound ecological concept as well as the various advantages of utilising dragonflies as bioindicators.

This study expands on the characteristic zonational distribution patterns of dragonfly species (Chovanec et al. 2017) and employs it for a detailed typological characterisation of the near-natural section in the lower course of the Antiesen, a river in Upper Austria (Chovanec 2020a). Thus, the investigation at hand aims at a sharp definition of this special river type and, thus, of the reference state, the "high ecological status", of this river section. The part of the Antiesen under scrutiny is one of the last downstream sections in Austria with large segments free of measures of hydrological engineering (Barth & Gumpinger 2009, BMLFUW 2017). This investigation should be exemplary in using Odonata in order to sharply define the typological character of near-pristine running water sections with special regard to the concept of biocoenotic regions.

Methods

General approach

The detailed typological characterisation of the lower course of the Antiesen developed in this study comprises four steps:

- abiotic classification of the river section and definition of the river type in accordance with the methodology used in Austria in order to implement the WFD (Fink et al. 2000, Wimmer et al. 2000, Wimmer & Wintersberger 2009, Wimmer et al. 2012);
- definition of reference species for this river type based on the longitudinal zonation patterns of Odonata (Chovanec et al. 2017), on zoogeographical aspects (Holzinger et al. 2015), and on detailed species-specific ecological requirements;

- comparison of the reference species with the inventory of autochthonous species recorded in the field and additional discussion of the total species spectrum;
- detailed definition of the river type based on the odonatological findings (CHOVANEC 2020a).

Study area and abiotic classification of the Antiesen's lower section

Six river stretches (A–F) with a length of 100 m each were chosen to cover the main morphological features of the near-pristine sections of the Antiesen's lower course (Figs. 1–9). The stretches A (A: 48.33814°N, 13.41289°E) and B were situated in the largest meander about 7 km before the mouth of the Antiesen into the River Inn, the stretches C–F (F: 48.35517°N, 13.40667°E) in sum covered a smaller meander about 3.5 km before the mouth.

The Antiesen, a 4th order stream (WIMMER & MOOG 1994), springs at an altitude of 655 m above sea level and flows for 42 km in a north-western direction. Its mouth into the River Inn is at 320 m above sea level. The mean discharge at this point is about 5 m^3s^{-1}. The catchment area of the Antiesen with a size of 286 km^2 is located in the landscape unit Innviertler- und Hausruckviertler Hügelland (FINK et al. 2000) which is part of the bioregion Bavarian-Austrian Foothills of the Alps. This bioregion belongs to the ecoregion Central Highlands (ILLIES 1978) and – in an administrative context – to Upper Austria, one of the nine Austrian provinces. With a length of 10 km, the river's lower course shows meanders deeply incised into the tertiary rocks of the molasse zone typical of the geology of the catchment area. In this river section, the canyon-like walls of marine siltstone ("Schlier") reach vertical heights in excess of 20 m (Figs. 5 – 9). The width of the river varies between 12 and 20 m, the slope is about 0.3 % (Figs. 2, 3, 4, 7). In some places, the riverbed shows natural widenings up to 40 m width (Figs. 5, 8). The substrate is dominated by microlithal (grain size range >2 cm to 6 cm) and mesolithal (>6 cm to 20 cm; ÖSTERREICHISCHES NORMUNGSINSTITUT 1996; Figs. 5, 9). Choriotopes characterised by akal (> 0.2 cm to 2 cm) can be found in areas near the riverbanks with reduced flow velocities (Fig. 4, 6). Current velocities at mean water level measured in the investigated stretches range between few cm s^{-1} up to 1 m s^{-1}. The most frequent plants of bank vegetation are *Urtica dioica* and *Phalaris arundinacea* as well as neophytic plants (*Fallopia* sp., *Impatiens glandulifera*, and to a lesser extent *Heracleum mantegazzianum*).

Odonatological classification of the Antiesen

To describe stream zonation patterns for the Austrian benthic invertebrate fauna, a 10 point system was used (MOOG & HARTMANN 2017). The number of points allotted to the individual biocoenotic regions indicates the Odonate species´ preferences for the respective stream zones. Those species with at least one point for the hyporhithron provided the basis for the definition of the reference species inventory of the Antiesen. This list was processed and adapted with special regard to zoogeographical aspects, detailed species-specific ecological requirements, and the specific typological features of the river section investigated. This classification of Odonata has been carried out by CHOVANEC et al. (2017).

Field methods

Field work was performed according to the methodological guidelines of CHOVANEC (2019a; see also SCHMIDT 1985). In order to cover all phenological groups, five field excursions were carried out in 2020: 21/22 May, 11/12/13 June, 3/4/5 July, 20/21 July und 9/10 August. At the six 100 m stretches tenerals and adults were counted, the sampling of exuviae as well as the observation of reproduction behaviour completed the surveys. The numbers of imagines recorded were transferred into a five-class abundance system in which dragonfly family-specific spatial requirements were taken into account (Table 1). The species-specific abundance class shown in the summarising presentation of the results was determined by the largest number of specimens per species recorded during the field trips. The detailed results for each stretch at each excursion are presented in Chovanec (2020a).

Tab. 1: Allocation of numbers of individuals/100 m to abundance classes. – Tab. 1: Zuteilung von Individuenzahlen/100 m zu Abundanzklassen (Chovanec 2018a, 2019b).

	1 Single	**2 Rare**	**3 Frequent**	**4 Abundant**	**5 Extremely abundant**
Zygoptera without Calopterygidae	1	2–10	11–25	26–50	>50
Calopterygidae and Libellulidae	1	2–5	6–10	11–25	>25
Anisoptera without Libellulidae	1	2	3–5	6–10	>11

The dragonfly-based river characterisation presented in this study was carried out on the basis of those species using the water body as reproduction habitat (i.e. autochthonous or resident species). According to the scheme of Chovanec (2019a) the following criteria were considered to determine certain, probable, or possible autochthony of species at one of the six river stretches investigated (see also Bried et al. 2015):

- certain autochthony at one stretch: records of tenerals and/or exuviae
- probable autochthony at one stretch: observations of reproductive behaviour (such as copula, tandem, or egg deposition) and/or imagines in abundance class ≥3
- possible autochthony at one stretch: records of imagines in abundance class 1 or 2 at least at two surveys.

To determine if species are certainly, probably or possibly autochthonous at the whole river section (the near pristine parts of the Antiesen´s lower course) the following criteria were applied:

- certain, probable or possible autochthony at the whole section: species certainly, probably or possibly autochthonous at least at one stretch according to the criteria listed above (the highest degree of autochthony at on stretch is responsible for the section´s degree)
- possible autochthony at the whole section: a species also is classified as probably autochthonous at the whole section if it is recorded in abundance class 1 or 2 at two or more stretches. In particular, classifications of species into the category “possible autochthony” have to be scrutinised in detail if their ecological requirements are opposed to this classification: Limnophilous aeshnid species, for example, often use the airspace above rivers for hunting without using the running waters for reproduction (Chovanec 2019a).

Results

Abiotic classification

Taking into account both the sound river typology scheme developed by Huet (1949) based on slope and river width and the formation of deeply incised meanders, the lower course of the Antiesen has been classified as a particular specification of a large hyporhithron zone: "canyon-like large hyporhithron of the bioregion Bavarian-Austrian Foothills of the Alps" (Chovanec 2020a). The term "large" was introduced in this definition, because hyporhithron waters with a mean discharge of >2 m^3s^{-1} and a river bed width of at least >5 m are classified as "large hyporhithron" according to BMLFUW (2017).

River type-specific reference species

Table 2 shows all Odonate species occurring in Austria with at least one point for the hyporhithron zone (Chovanec et al. 2017). The following species are not included in the reference species inventory for the lower course of the Antiesen: *Chalcolestes parvidens*, *Coenagrion mercuriale*, *Coenagrion ornatum*, *Cordulegaster heros* and *Somatochlora meridionalis* are not occurring in Upper Austria (Holzinger et al. 2015). *Cordulegaster boltonii* and *Orthetrum coerulescens* prefer significantly smaller running waters (Laister 1996; Sternberg & Buchwald 2000, Sternberg et al. 2000, Wildermuth & Martens 2019). *Ophiogomphus cecilia* was not considered as reference species due to its preference for sandy/gravelly substrate as larval habitat (Schwarz et al. 2007, Wildermuth & Martens 2019) which is not typical of the lower course of the Antiesen. Due to the canyon-like character of the river section investigated, rhithron-species usually colonising water bodies of different successional stages situated in the riparian zones or floodplain areas were not considered in the reference species list for the lower course of the Antiesen (Table 2): *Chalcolestes viridis*, *Pyrrhosoma nymphula*, *Anax imperator*. As shown in Table 2, the reference species spectrum of the lower Antiesen therefore comprises the following Odonata: *Calopteryx*

Tab. 2: Deduction of the Odonata reference species for the river type "canyon-like large hyporhithron of the bioregion Bavarian-Austrian Foothills of the Alps"; blue: river type-specific core reference species; green: first-degree river type-specific accompanying reference species; yellow: second-degree river type-specific accompanying reference species. – Tab. 2: Ableitung der Referenzarten für den Gewässertyp "schluchtartiges großes Hyporhithral der Bioregion Bayerisch-Österreichisches Alpenvorland"; blau: gewässertyp-spezifische Leitarten, grün: gewässertyp-spezifische Begleitart erster Ordnung, gelb: gewässertyp-spezifische Begleitarten zweiter Ordnung.

Rhithron Odonata occurring in Austria	Valency points	Not included as river type-specific reference species due to		
		distribution	species-specific ecological requirements	special character of the river type
Chalcolestes parvidens (Artobolevskij, 1929)	1	x		
Chalcolestes viridis (Vander Linden, 1825)	1			x
Calopteryx splendens (Harris, 1780)	1			
Calopteryx virgo (Linnaeus, 1758)	6			
Platycnemis pennipes (Pallas, 1771)	1			
Ischnura elegans (Vander Linden, 1820)	1			
Coenagrion mercuriale (Charpentier, 1840)	2	x		
Coenagrion ornatum (Selys, 1850)	3	x		

Rhithron Odonata occurring in Austria	Valency points	Not included as river type-specific reference species due to		
		distribution	species-specific ecological requirements	special character of the river type
Pyrrhosoma nymphula (Sulzer, 1776)	1			x
Anax imperator Leach, 1815	1			x
Gomphus vulgatissimus (Linnaeus, 1758)	2			
Ophiogomphus cecilia (Geoffroy in Fourcroy, 1785)	2		x	
Onychogomphus forcipatus (Linnaeus, 1758)	3			
Cordulegaster boltonii (Donovan, 1807)	2		x	
Cordulegaster heros Theischinger, 1979	3	x		
Somatochlora meridionalis Nielsen, 1935	2	x		
Orthetrum brunneum (Fonscolombe, 1837)	1			
Orthetrum coerulescens (Fabricius, 1798)	1		x	

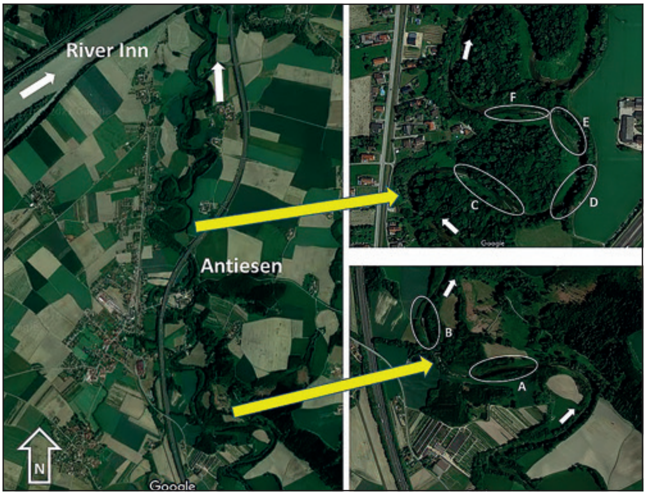

Fig. 1: Location of the study area and of the stretches A–F. White arrows indicate the flow direction. – Abb. 1: Lage des Untersuchungsgebietes und der Untersuchungsstrecken A–F. Weiße Pfeile zeigen die Fließrichtung an. Quelle: Google maps.

Fig. 2: Stretch A in the lower course of the Antiesen (Upper Austria) with a gravel bank. – Abb. 2: Strecke A im Unterlauf der Antiesen (Oberösterreich) mit Kiesbank. Foto: A. Chovanec, 12.06.2020.

Fig. 3: Stretch B in the lower course of the Antiesen (Upper Austria) with reduced flow velocity. – Abb. 3: Strecke B im Unterlauf der Antiesen (Oberösterreich) mit herabgesetzter Strömungsgeschwindigkeit. Foto: A. CHOVANEC, 21.05.2020.

Fig. 4: Upstream part of stretch C in the lower course of the Antiesen (Upper Austria) with reduced flow velocity, fine substrate and densely vegetated banks. – Abb. 4: Oberstromiger Teil von Strecke C im Unterlauf der Antiesen (Oberösterreich) mit herabgesetzter Strömungsgeschwindigkeit, feinem Substrat und dichter Ufervegetation. Foto: A. CHOVANEC, 21.07.2020.

Fig. 5: Canyon-like downstream part of stretch C in the lower course of the Antiesen (Upper Austria) with high flow velocities and coarse substrate banks. – Abb. 5: Schluchtartiger unterstromiger Teil von Strecke C im Unterlauf der Antiesen (Oberösterreich) mit hoher Strömungsgeschwindigkeit und grobem Substrat. Foto: A. CHOVANEC, 21.07.2020.

Fig. 6: Upstream part of stretch D – a canyon-like section in the lower course of the Antiesen (Upper Austria) with low flow velocities. – Abb. 6: Schluchtartiger oberstromiger Teil von Strecke D im Unterlauf der Antiesen (Oberösterreich) mit geringer Strömungsgeschwindigkeit. Foto: A. Chovanec, 21.05.2020.

Fig. 7: Downstream part of stretch D – a narrow, canyon-like section in the lower course of the Antiesen (Upper Austria) with high flow velocities. – Abb. 7: Unterstromiger Teil von Strecke D – ein enger, schluchtartiger Abschnitt im Unterlauf der Antiesen (Oberösterreich) mit hohen Strömungsgeschwindigkeiten. Foto: A. Chovanec, 21.05.2020.

Fig. 8: Stretch E – river widening in the canyon-like section in the lower course of the Antiesen (Upper Austria) with a large gravel island. – Abb. 8: Strecke E – Aufweitung in einem schluchtartigen Abschnitt im Unterlauf der Antiesen (Oberösterreich) mit einer großen Kiesinsel. Foto: A. Chovanec, 21.05.2020.

Fig. 9: Stretch F – a canyon-like section in the lower course of the Antiesen (Upper Austria) with gravel banks and high flow velocities. – Abb. 9: Strecke F – ein schluchtartiger Abschnitt mit Kiesbänken und hohen Strömungsgeschwindigkeiten. Foto: A. Chovanec, 11.06.2020.

splendens, *Calopteryx virgo*, *Platycnemis pennipes*, *Ischnura elegans*, *Gomphus vulgatissimus*, *Onychogomphus forcipatus*, and *Orthetrum brunneum*.

The sum of the seven reference species´ valency points is 15, the mean value is 2.1. Following the calculation scheme of Chovanec (2019a), river type-specific core reference species are defined as stenoecious species with species-specific valency points exceeding the mean value (*C. virgo* with 6 valency points and *O. forcipatus* with 3 VP). First-degree river type-specific accompanying reference species are characterised by valency points equal to the mean value (*G. vulgatissimus* with 2 VP), species with one VP are defined as second-degree river type-specific accompanying reference species (*C. splendens*, *P. pennipes*, *I. elegans*, and *O. brunneum*).

Fig. 10: Copula of *Calopteryx virgo* at stretch A at the Antiesen (Upper Austria). The four wings of the male are asymmetrically held behind the abdomen, away from the sun, to reflect radiation onto the abdomen (see also Brockhaus et al. 2020). – Abb. 10: Kopula von *Calopteryx virgo* an Strecke A an der Antiesen (Oberösterreich). Die vier Flügel des Männchens sind asymmetrisch auf der sonnenabgewandten Seite des Abdomens positioniert, um das Aufwärmen des Hinterleibes zu optimieren (siehe dazu Brockhaus et al. 2020). Foto: A. Chovanec, 06.07.2020.

Fig. 11: Female *Onychogomphus forcipatus*, newly emerged at stretch A at the Antiesen (Upper Austria). – Abb. 11: An Strecke A der Antiesen (Oberösterreich) frisch emergiertes Weibchen von *Onychogomphus forcipatus*. Foto: A. Chovanec, 12.06.2020.

Fig. 12: Male *Onychogomphus forcipatus* at stretch E at the Antiesen (Upper Austria). – Abb. 12: Männchen von *Onychogomphus forcipatus* an Strecke E der Antiesen (Oberösterreich). Foto: A. Chovanec, 21.07.2020.

Tab. 3: Dragonfly species recorded at the six stretches of the Antiesen (A–F). 1–5: abundance classes (see Tab. 1); Aut. Autochthony, * possibly autochthonous; ** probably autochthonous; *** certainly autochthonous; *(*) possible autochthony is unlikely at this site due to species-specific habitat requirement;* blue: river type-specific core reference species; green: first-degree river type-specific accompanying reference species; yellow: second-degree river type-specific accompanying reference species. – Tab. 3: An den Strecken A–F der Antiesen nachgewiesene Libellenarten. 1–5: Abundanzklassen (siehe Tab. 1); Aut. Bodenständigkeit, * möglicherweise bodenständig; ** wahrscheinlich bodenständig; *** sicher bodenständig; *(*) mögliche Bodenständigkeit ist an diesem Standort aufgrund der artspezifischen Habitatansprüche auszuschließen;* blau: gewässertyp-spezifische Leitarten, grün: gewässertyp-spezifische Begleitart erster Ordnung, gelb: gewässertyp-spezifische Begleitarten zweiter Ordnung.

	A	B	C	D	E	F	Aut.
Calopteryx splendens (Harris, 1780)	3***	2*	5***	2**	3***	4**	***
Calopteryx virgo (Linnaeus, 1758)	4***	4***	5***	2***	3**	2***	***
Platycnemis pennipes (Pallas, 1771)	5***	4***	3***	1	2***	2***	***

Ischnura elegans (Vander Linden, 1820)	1	1	2***	1***	1*	2*	***
Aeshna cyanea (Müller, 1764)			1				
Aeshna grandis (Linnaeus, 1758)	1		1(*)	1	1(*)	1	(*)
Aeshna mixta Latreille, 1805	1		1		1		(*)
Anax parthenope (Selys, 1839)			1				
Gomphus vulgatissimus (Linnaeus, 1758)		1***				1***	***
Onychogomphus forcipatus (Linnaeus, 1758)	1***	4***	3**	1	1*	1	***
Somatochlora flavomaculata (Vander Linden, 1825)					1		
Orthetrum cancellatum (Linnaeus, 1758)					1		

Field study

Table 3 provides an overview of the results regarding species inventories, maximum abundance classes, and classification of autochthony. The whole river section comprised a species inventory of four Zygoptera and eight Anisoptera. Six species were classified as certainly autochthonous due to the records of tenerals and/or exuviae: *C. splendens*, *C. virgo*, *P. pennipes*, *I. elegans*, *G. vulgatissimus*, and *O. forcipatus*. Both river type-specific core reference species, *C. virgo* and *O. forcipatus*, were found at each stretch. *Calopteryx virgo* was classified as autochthonous at each stretch and reached abundance classes ≥3 at four stretches, *O. forcipatus* was certainly, probably and possibly autochthonous at four stretches and reached abundance classes ≥3 at two (Figs. 10–12).

Only two freshly emerged specimens of *G. vulgatissimus*, the only first-degree river type-specific accompanying reference species, were found. Three of the four second-degree river type-specific accompanying reference species (*C. splendens*, *P. pennipes*, and *I. elegans*) occurred at each stretch and were autochthounous at – at least – four stretches (Table 3). Numbers of *I. elegans*-individuals were continuously low; *Platycnemis pennipes* reached abundance classes ≥3 at three stretches, but only at the excursion in the beginning of July. *Calopteryx splendens* occurred at each stretch autochthonously, at four of them in abundance classes ≥3. *Aeshna grandis* and *Aeshna mixta* were observed hunting above the water surface at several stretches and excursions; *Aeshna cyanea*, *Somatochlora flavomaculata*, and *Orthetrum cancellatum* were also sighted, but only once.

Discussion

Abiotic classification

The typological classification of the lower course of the Antiesen with special regard to the biocoenotic region is not consistent in literature. According to the Water Information System Austria (BMLFUW 2017) which represents the basis for water management activities in Austria, the lower reach of this river is characterised as a "medium size epipotamon zone" (see also GUMPINGER & SILIGATO 2007, BARTH & GUMPINGER 2009). Applying the typology scheme developed by HUET (1949), the Antiesen section investigated, would have to be classified as hyporhithron. The detailed river typology by WIMMER & WINTERSBERGER (2009) established for Upper Austria also follows this approach (see also SILIGATO & GUMPINGER 2005). The hyporhithron character of the investigated section is confirmed by ornithological records of *Cinclus cinclus* and *Motacilla cinerea* (Chovanec 2020a; see also Roché & Frochot 1993). According to Wimmer et al. (2012) canyons are, such as cascades and anastomosing running water sections, "special river types". In these cases, particular focus has to be placed on the definition of reference communities.

River type-specific reference species

The canyon-like character of the Antiesen´s lower course is coined by several features which have a significant influence on the habitat availability for Odonates:

- the river corridor is defined by the streambed itself,
- the lateral mobility of the channel is constrained,
- floodplains are lacking,
- riparian ecotones are restricted to a very narrow strip of streambank vegetation (Verry et al. 2004).

All the aquatic and semi aquatic habitat types along a gradient of *lateral connectivity* are thus not existent at the examined river type (Gregory et al. 1991, Naiman & Décamps 1997, Ward & Stanford 1995, Ward et al. 1999, Chovanec & Waringer 2001, Cunningham-Minnick et al. 2019). Geomorphic processes and disturbances are restricted to the formation of in-bed structures, such as gravel bars and islands (Figs. 2, 5, 8, 9; see also Steiger et al. 2005).

The sum of the numbers of river type-specific core reference species and of first- and second-degree river type-specific accompanying reference species for the Mattig, a "regular" hyporhithron water body with no canyon-like characteristics, situated in the same bioregion as the Antiesen, makes up twelve (Chovanec 2019a). Due to the specific morphological properties of the lower section of the Antiesen with its constrained river corridor, the number of the type-specific species is reduced to seven. However, according to the increase in the number of Odonata species along a river continuum from the source to the lower course, the inventory of reference species typical of hyporhithron sections is limited compared to potamon rivers (e. g. Hawking & New 1999, Chovanec 2019b).

Field study

The field study at this near-pristine river section confirmed the predetermined reference species deducted from abiotic characteristics of the canyon-like hyporhithron water body: the inventory of autochthonous species recorded at the river nearly completely corresponds to the list of reference species; only one of the second- degree river type-specific accompanying reference species, *O. brunneum*, did not occur at the Antiesen. Poorly vegetated shallow areas with low currency highly exposed to the sun are not available to a sufficient degree to fulfil the ecological requirements of this species (Weihrauch 2015, Chovanec 2018b). The records of the resident river type-specific core reference species in mainly high abundances underline the dominating hyporhithron character of the river section (see for example Schorr 1990, Suhling & Müller 1996, Martens 2001, Petrovičová & David 2013, Wildermuth & Martens 2019).

In undisturbed aquatic communities, accompanying species usually occur in reduced frequencies and abundances compared to core reference species. In the present study, this fact is particularly reflected by the records of *G. vulgatissimus* and *I. elegans*. *Calopteryx splendens* usually plays no or only a minor role in rhithron dragonfly communities (Chovanec

2018a, b, 2020b). Sunny riparian zones with dense vegetation and reduced flow velocities (e. g. Fig. 4) favour the occurrence of this species, but not necessarily in upstream sections. Like *G. vulgatissimus*, *C. splendens* is typical of potamon rivers (CHOVANEC 2019b). In 2019 and 2020 water temperatures of the Antiesen ranged between 2 and 22° C. *Calopteryx splendens* prefers running waters with summer water temperatures between 18 and 24° C (SCHORR 1996). An amplitude of temperatures of ≥20° C is typical of epipotamon waters (MOOG & WIMMER 1990, 1994). The occurrence of *C. splendens* hence indicates a slight temperature-based epipotamon influence.

The canyon walls as well as canopy density due to the forests situated at the narrow riparian zone and at the top of the terraces (Figs. 2, 3, 6–9) lead to a reduced solar loading into the river channel (FORNEY et al. 2013). This is why aeshnids tolerating shaded conditions were observed hunting at several stretches and excursions (*A. grandis*, *A. mixta*; STERNBERG & HÖPPNER 2000, STERNBERG & SCHMIDT 2000, WILDERMUTH & MARTENS 2019). On the other hand, *Anax imperator* did not occur at the Antiesen, although favourable habitats of this species are situated only few kilometres away. At other sunny river sections investigated in this bioregion, *A. imperator* was a regular guest (e. g. CHOVANEC 2018a, b, 2019 a, b, 2020b, c).

Conclusion

The network of rivers with a catchment size > 10 km^2 situated in the bioregion Bavarian-Austrian Foothills of the Alps has a length of 3,626 km. The hydro-morphological component of the ecological status is classified as "high" only for 280 km. Only 18 km of this number, for example, account for the bioregion "large hyporhithron". Odonatological investigations of near-pristine river sections contribute to the knowledge on autecological requirements and are the key support in defining river type-specific reference communities (CHOVANEC 2020b). This is of special importance for special river types, such as canyon-like rivers, where data concerning aquatic communities are not abundant. Reference sites with their biotic and abiotic features are not only the prerequisite for a sound river type-specific assessment. They are also useful for evaluating long-term changes in ecological integrity, for example caused by climate change, and for the definition of rehabilitation targets concerning disturbed river sections of the same type (HUGHES et al. 1986, GRAMBOW et al. 2020).

The study at hand illustrates the necessity of focusing on a detailed typological characterisation of special river types, such as canyon-like sections, by applying an odonatological approach. The near-natural condition of this part of the Antiesen allows for a sound definition of an Odonate reference community for a large hyporhithron section, incorporating a complex array of geomorphological and river typological properties as well as for an improved knowledge on species-specific habitat needs. The application of the assessment scheme for "normal", non-canyon-like hyporhithron zones of this bioregion with twelve reference species (CHOVANEC, 2019a) to the near-pristine Antiesen section would reveal only a "good dragonfly-based ecological status". The field study carried out at this river section provided a spectrum of resident species, which nearly perfectly corresponds to the reference list set up for this special river type and indicates a "high dragonfly-based ecological status". Additional ubiquitous and/or limnophilous species indicating potamalization effects due to hydraulic engineering were not detected (CHOVANEC 2018a, 2019b).

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