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Monitoring the effects of conservation actions in agricultural and urbanized landscapes – also useful for assessing climate change?

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Abstract

Various methods for measuring the success of conservation actions and for evaluating aquatic habitats are outlined, based on quantified dragonfly monitoring. They are discussed with respect to their practicability and information value, counts of adult males and especially of exuviae yielding the most valuable results. These are presented by actual examples of mire ponds, streams, ditches and rivers from central Europe, making allowance for the dynamics of the habitats and their dragonfly community. Records of detailed data, if repeated subsequently at the same localities with the same methods, are considered a useful basis for preparation of distribution maps and for comparison of the fauna over the time. Fauna shifts in horizontal and vertical distribution over the time should be judged critically with respect to climate change as they could also be caused by anthropogenic habitat changes.

Keywords

measuring conservation effects, species conservation, monitoring, dragonflies, Odonata

Introduction

The results of any efforts toward conservation and promotion of species become apparent in the development of species richness and population size of plants and animals. This does not only apply to the protection of more or less undisturbed ecosystems but is especially true for constructional measures in nature reserves aiming at the promotion of species diversity. On principle, there are two ways to measure the effect of

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conservation actions: (1) to survey the number and diversity of species and (2) to follow up the long-term development of the local populations by counting individuals. In practice it will always be necessary to focus on selected groups of organisms or even on single species. Thereby, the choice of the focus organisms depends on the type and size of biotopes. For rather small oligotrophic grassland communities, orchids, grasshoppers or butterflies will be suitable, whereas for large marshes birds and amphibians would be a reasonable choice. Dragonflies (Odonata) have proved to be suited for many types of water bodies as the larval stage is spent under water. After completion of their development they emerge as imagines above water, mostly on riparian substrates, leaving the larval skins (exuviae) that can be collected for identification and census. Furthermore, reproductive activities of the adults occur at the breeding sites thus allowing easy determination of the species' variety. Since it is possible to carry out quantified odonatological field studies, dragonflies can be used for measuring the success or failure of conservation activities in wetland habitats. Here, a short account is given, mainly based on the author's experience, on methods, collection of data, analysis, and conclusions with respect to the development of dragonfly communities following wetland management mostly in nature reserves within agricultural and urban landscapes of central Europe.

What can be counted?

Quantitative studies require counts of species and individuals. Besides mature imagines these may comprise various developmental and maturation stadia, possibly combined with records of reproductive activities. A combination of various data will supply the best information, as they provide different evidence for the assessment of species richness, indigeneity, and population size. In this context the following single variables are of different importance:

Number of species. The number alone is little informative. It should be combined with the listed names of the species, possibly supplemented by indication of those belonging to respective regional Red Lists. Unless the list of species is based on a minimum of repeated counts scattered over the flying season and critically annotated with respect to the specific habitat requirements of the rare spp., it is of only limited informational value. There is no point in assigning numerical values to the different spp. in order to assess the effects of conservation actions or the importance of a biotope. This should be done by qualitative argumentation.

Number of individuals (mature imagines). Because of the male biased operational sex ratio at the breeding sites, counts of mature males yield a better basis than those of females for the estimate of the size of a breeding population at a certain locality. However, in territorial species that competitively space out conspecifics or temporally share a breeding site as in many Libellulidae, Corduliidae or Aeshnidae, the population size may be strongly underestimated. The number of recorded individuals at a specific site can also be indicated by abundance classes. In Baden-Württemberg/Germany the following classes are used (cf. Sternberg & Buchwald 1999: 183): I = 1 individual, II = 2-5, III = 6-10, IV = 11-20, V = 21-50, VI = <50 individuals. Another method for measuring the colonization of a habitat is to determine the weekly or seasonal largest number of adult males at small ponds (Moore 2002) or the mean highest steady density of males per 100 m shore or bank stretch of large water bodies (Moore 1991). In any case, adults should be counted systematically, i.e. as often as possible or at least at regular intervals at about the same time, on sunny days with little or no wind, and between two hours before and past solar noon. Moore and Corbet (1990) even recommend counts within one or at most two hours of solar noon. The results yield a reasonable but rather unprecise idea of the real population size. A much better approach would be using capture-recapture. However, this requires marking of tenerals or adults and the application of mathemathical models. As for this method rather great expenditure is needed it is not practicable for surveys.

Presence throughout the flying season. Alternatively or in addition to counting the individuals simply the presence of the species may be noted on each visit. The sum of days with their presence – the frequency sum (FS) – can then be compared with that of the syntopic species. Consequently, the absolute and relative frequency sum (FS_a and FS_r [%]) may give a quantitative idea of the actual colonization of a water body (for more information and examples see below). In addition, the data may be used for computations applying simple or more sophisticated mathematical models.

Exuviae. They are the best evidence for successful breeding and the value of larval cases for semi-quantitative ecological studies cannot be overestimated. Thanks to the keys available for nearly all European species (e.g. Gerken and Sternberg 1999; Heidemann and Seidenbusch 2002), the identification is possible with certainty up to species level even for most Zygoptera. Exuviae of many species are found on plants emerging from a water body or on vegetation near its edge, while others cling to stones, sand, rocks, concrete walls, tree trunks, roots or posts. Larvae ready for emergence may walk ten metres or more over land and even climb on trees. However, most of them emerge near the water's edge. In *Somatochlora alpestris*, e.g., 91% of the exuviae were collected within a strip of one metre on each side of the water line (Knaus 2000). The total number of exuviae collected at a site throughout one emergence season, designated emergence sum (ES), should be indicated for every year separately. Generally, counts in Anisoptera are easily practicable. However, the exuviae of Zygoptera are small, delicate and often hidden among vegetation to an extent that it will be very difficult to detect relevant numbers. Although larval skins may persist for months under dense sedge vegetation or other sheltered places like rocks or parts of buildings like bridges or boathouses, they should be collected throughout the entire emergence period and as often as possible, especially before inclement weather, because rain or wind may displace or destroy them. Small and easily accessible ponds with well defined edges and emergent vegetation confined to a narrow riparian belt are most suited for quantitative exuviae collecting. On the other hand, at water bodies with large areas or wide zones of emergent vegetation it is most difficult or even impossible to come close to the effective seasonal emergence sum. Therefore, at more or less homogeneous breeding waters, counts must be restricted to selected riparian sections or areas of largely overgrown water bodies and the total emergence number has to be assessed by projection. Some lake shores and river banks may only be accessible by raft or canoe. In large rivers with low water temperatures swimming with protective neoprene diving suit provided a most successful method for collecting exuviae of Gomphidae (Osterwalder 2004, 2007).

Larvae. They give also strong evidence for successful breeding of the respective species at certain sites. However, compared with exuviae, there are several disadvantages. Quantitative sampling of larvae requires special equipment and experience (e.g. Suhling and Müller 1997: 152–154). Furthermore, the sampling technique in dense submerged vegetation is completely different from that on sand or gravel ground. In addition, the larvae of many species, especially damselflies, are only identifiable under the miscroscope and for practical reasons they often have to be preserved in ethanol unless they are identified quickly and taken back to their habitat. Finally, stadia younger than F-0 or F-1 of many European species cannot be identified with the keys so far available. Even if all the larvae of a water body could be determined, the sum would not represent the reproductive population as only a small part of the larvae will survive.

Tenerals. A census of freshly emerged imagines, featured by pale colours and their bodies and wings still being soft, is especially recommended for Zygoptera as they are easier to find and to count than exuviae (Moore and Corbet 1990). Their presence indicate successful development at the place where they have been found with high probability. However, in some cases it may be difficult to identify the species in the field, especially in females of Coenagrionidae. Furthermore, many individuals are only present at water for a short time after emergence and subsequently disperse in the hinterland (e.g. Lestidae). Nevertheless, counting teneral Anisoptera (e.g. *Sympetrum striolatum*) may be an adequate method for estimating the size of mass emergence, provided the right moment – before the maiden flight – is chosen.

Additional indications for reproduction: For practical reasons it is not always possible to provide evidence for reproduction success of certain species by exuviae findings or observation of tenerals. Indications for reproduction at a water body, although weaker than those mentioned, are records of territorial males, tandems, copulation wheels, and ovipositing females. According to Höppner (1999), observed copulation or oviposition combined with the presence of minimal 2–5 adults may indicate indegeneity in many species.

Short-term and long-term studies at small stagnant water bodies

In order to assess the success of conservation measures and the future needs for management, as much information as possible is desirable on the dragonfly community of a site. Thorough short-term studies provide appropriate data on the actual state of species diversity and population size, and may be sufficient for immediate decisions of small operations or corrections in the habitats. However, biotopes and their biocenoses are dynamic systems to be considered in medium and long-term management planning. Therefore, besides data on the actual situation of a local dragonfly fauna, there is need for information on the development of their diversity and population size as pointed out in the following examples of small moorland ponds.

The water bodies are situated in the nature reserve 'Drumlinlandschaft Zürcher Oberland' on the Swiss plateau near Zurich (47°19'N, 08°48'E), ca. 500 m above sea level. The area is characterized by a number of small shallow valleys running parallel on turf ground between rolling, oblong and largely wooded hills (Wildermuth et al. 2001). In this region peat had been exploited extensively during three centuries. Around 1950 peat cutting, having been practised throughout extensively, was abandoned and subsequently the water filled peat holes and drainage ditches that functioned as secondary habitats for aquatic organisms for a long time became widely overgrown. Hence, the diversity and population sizes of dragonflies declined. From 1970, in the frame of conservation actions, about 30 peat diggings were successively restored or freshly created and maintained according to the rotational principle (Wildermuth and Schiess 1983; Wildermuth 2001). Monitoring of the dragonfly fauna also started in 1970 and has been continued up to the present with varied intensity according to the aims and the time available (Wildermuth 1980, 2005, 2008).

In 2005 an intensive short-term survey was carried out at 11 ponds varying in succession stage and in size between ca 10 and 80 m^2, situated within about 5 hectares moorland with fen and bog vegetation of the 'Böndlerried/Ambitzgi'. The site was visited on 63 days throughout the emergence and flying season, following approximately the same transect, but sometimes extended to some additional water bodies like ditches and puddles. Exuviae were collected systematically merely at 6 selected ponds, and of Anisoptera only. One of the ponds, no. 6d, was in the pioneer stage with bare peat at shallow edges, and so were two shallow ditches and a large puddle on turf ground. In total 35 dragonfly species were recorded (Table 1), i.e. 71% of the 49 spp. found between 1970 and 2005 within the entire nature reserve. As shown in Fig. 1 the cumulative number of species raised continuously during the flying season until its end. Only 30 of the 35 spp. frequented the 11 ponds (Table 2), the other 5 were mainly encountered at fresh ditches or puddles. The highest relative frequency sum was recorded in *Coenagrion puella*, followed by *Lestes sponsa* and *Libellula quadrimaculata*, with *C. puella* probably constituting the largest population. Out of the 30 spp. at least 16 are considered indigenous according to exuviae findings or the observation of tenerals, copulating pairs or ovipositing females. Two spp., *Lestes virens* and *Leucorrhinia pectoralis*, both indigenous in the sampling area, deserve special interest as they are critically endangered in Switzerland (Gonseth and Monnerat 2002) and threatened in most parts of Central Europe (e.g. Ott and Piper 1998). The relatively high frequency sum in *L. pectoralis* (FS_r = 8.6%) and the finding of more than 100 exuviae indicate the conservational importance of the site. This is underlined by the regular occurrence of *Somatochlora flavomaculata*, *Orthetrum coerulescens* and other spp. that are nationally rare (Wildermuth et al. 2005). Most spp. are not confined to moorland ponds. In some of them a large FS may not conclusively signify high reproductive success and vice versa as shown at pond no. 7d for two aeshnids, with FS_a = 7 and ES = 0 in *Anax imperator*

Table 1. Presence of adults of dragonflies on the ‚Böndlerried/Ambitzgi' during the flying season 2005. (Orig.)

date 2005 →	02.5.	12.5.	13.5	17.5.	19.5.	20.5.	24.5.	26.5.	29.5.	01.6.	03.6.	08.6.	09.6.	10.6.	11.6.	13.6.	16.6.	17.6.	18.6.	21.6.	22.6.	23.6.	24.6.	27.6.	28.6.
Calopteryx splendens																									
Calopteryx virgo									●					●	●					●	●				
Lestes sponsa															●			●		●	●	●	●	●	●
Lestes virens																									
Lestes viridis																									
Sympecma fusca	●							●																	
Platycnemis pennipes																									
Pyrrhosoma nymphula	●	●			●	●	●	●	●	●	●		●	●	●	●	●		●	●	●		●	●	●
Coenagrion puella		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Coenagrion pulchellum					●	●	●							●											
Enallagma cyathigerum								●												●		●	●		
Ischnura elegans																									
Ischnura pumilio								●																	
Aeshna cyanea																									
Aeshna grandis																									
Aeschna isoceles										●								●							
Aeshna juncea																								●	●
Aeshna mixta																									
Anax imperator									●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
Anax parthenope																									
Cordulegaster boltonii																									
Cordulia aenea		●	●		●	●	●	●	●		●			●	●		●								
S. flavomaculata										●	●			●	●	●	●	●	●	●	●	●	●	●	●
Somatochlora metallica																									
Leucorrhinia pectoralis			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Libellula depressa		●			●		●	●	●	●	●			●				●	●	●		●	●	●	●
L. quadrimaculata	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Orthetrum brunneum																●		●	●					●	●
Orthetrum cancellatum																		●							
O. coerulescens																									
Sympetrum danae																									
Sympetrum flaveolum																									
S. sanguineum																				●		●	●	●	●
Sympetrum striolatum																									
Sympetrum vulgatum																									

29.6.	03.7.	04.7.	09.7.	12.7.	13.7.	14.7.	15.7.	20.7.	22.7.	23.7.	25.7.	27.7.	28.7.	04.8.	05.8.	08.8.	09.8.	10.8.	11.8.	18.8.	19.8.	24.8.	29.8.	30.8.	31.8.	01.9.	03.9.	04.9.	05.9.	07.9.	15.9.	22.9.
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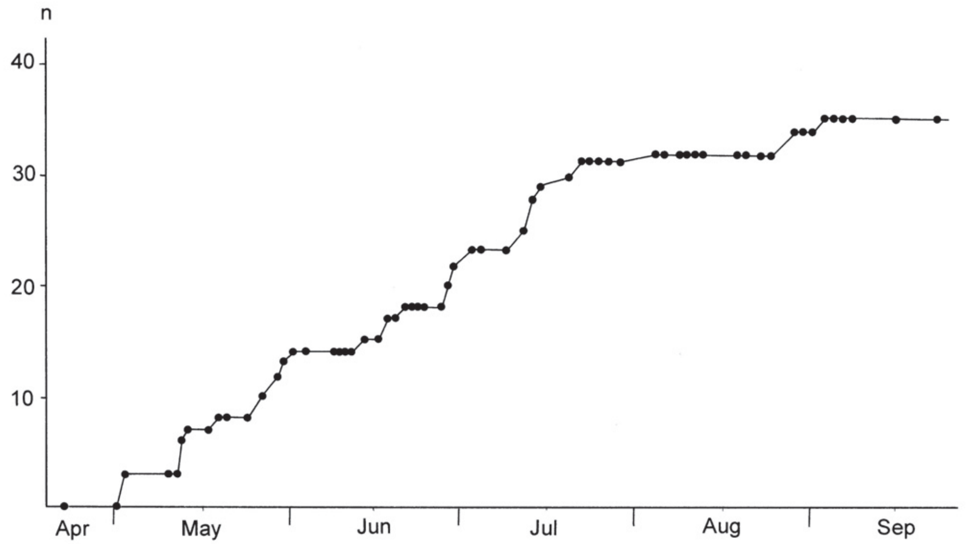

Figure 1. Development of the cumulative number of dragonfly species in the course of 63 visits during the flying period at 'Böndlerried/Ambitzgi'. (Orig.).

and FS_a = 4 and ES = 43 in *Aeshna cyanea*. Similar observations had been made in earlier years. *Libellula depressa* and *Orthetrum brunneum* as pioneer spp. typically colonized pond no. 6d where mating and oviposition were repeatedly recorded. *Calopteryx splendens*, *C. virgo* and *Cordulegaster boltonii* bred in a small brook some hundred metres away from the pond area and regularly visited the stagnant waters. Therefore, they do not belong to the fauna of the ponds of the survey area. The same holds true for *Enallagma cyathigerum* that is regionally common but needs larger and deeper ponds with only little overgrown water surface. It will disappear as soon as the succession is proceeded. For a number of spp. that generally are not rare, e.g. *Ischnura elegans*, *Platycnemis pennipes*, and *Aeshna grandis*, the mire ponds seem to be unsuited. They are considered guest species as are *A. isoceles*, *Somatochlora metallica*, and *Sympetrum flaveolum*. This is in contrast to *Coenagrion pulchellum*, another sp. with very low FS. It has declined much in the area for unknown reasons but is still breeding in small numbers.

Small ponds and their dragonfly community may change in short time, especially in the early succession stages of a habitat. This is shown in a two years-study at the 'Oberhöflerried', at a different area of the same nature reserve as described above. Four new ponds, ca 50-125 m^2 in size and up to 1 m deep, were created within 1.5 hectares of fenland in autumn 2003. The late summer species *Sympetrum striolatum* and *Aeshna cyanea* oviposited immediately after the water holes were finished and their eggs overwintered. Monitoring was performed rather intensively in 2004 (23 visits) and in 2005 (34 visits). In both years 28 spp. were recorded but with different species composition. The list comprised 34 spp. for 2004 and 2005 in total and its composition resembeled that of the 'Böndlerried/Ambitzgi'. On the other hand, there were striking differences not only

Table 2. Presence of adults of the dragonfly spp. encountered at 11 ponds of the ‚Böndlerried/Ambitzgi' in 2005. The figures indicate the number of days with presence of the spp. on 63 visits throughout the flying season. FS_a and FS_r = absolute and relative frequency sum (see text). * = evidence for reproduction (exuviae, tenerals) (Orig.).

	2a	2b	3	4	6	6a	6b	6c	6d	7d	8a	FS_a	FS_r
Calopteryx splendens	1									8	1	10	0.6
Calopteryx virgo			3						1	2		3	0.2
Lestes sponsa	15	9	19	14	26	35	22	32	27	37	25	261*	16.5
Lestes virens	1	3	3	6		6		2	3	5	4	33*	2.1
Lestes viridis	2		1		6	1	1	2	3	5	3	24*	1.5
Sympecma fusca						1		3				4	0.3
Platycnemis pennipes										1		1	0.1
Pyrrhosoma nymphula	4	1	1	2	8	2	2	2		2	8	32*	2.0
Coenagrion puella	42	41	41	33	25	34	27	32	35	38	34	382*	24.2
Coenagrion pulchellum					1	3						4	0.3
Enallagma cyathigerum									13			13	0.8
Ischnura elegans									1			1	0.1
Ischnura pumilio									1			1	0.1
Aeshna cyanea		2	2	1	1	2			1	4	3	16*	1.0
Aeshna grandis			2			1				1		4	0.3
Aeshna isoceles		1										1	0.1
Aeshna juncea	2	2	2	1	1	8			1	7	1	25	1.6
Anax imperator	5	15	16	1	2	3		3	21	7	1	75*?	4.7
Cordulegaster boltonii						1				2		3	0.2
Cordulia aenea	5	4	3						1	5		18*	1.1
Somatochlora flavomaculata	6	4	3		5	4	7	2	1	12	3	47*	3.0
Leucorrhinia pectoralis	24	19	10	7	9	11	7	14	14	15	6	136*	8.6
Libellula depressa			4						18	1		19	1.2
Libellula quadrimaculata	23	30	20	22	15	17	19	24	36	28	14	248*	15.7
Orthetrum brunneum									8			8	0.5
Orthetrum cancellatum								1	11	1		13	0.8
Sympetrum danae				1			1	1		2		5	0.3
Sympetrum striolatum	7	5	3	2	9	7	5	5	8	15	12	88*	5.6
Sympetrum vulgatum						1	1		1	1		4	0.3
Sympetrum sanguineum	10	6	1	2	7	8	6	13	5	18	28	104*	6.6

in the species composition but also in the FS. Exactly these features changed impressively from the first year to the second, demonstrating the vivid dynamics of habitats and their dragonfly community throughout the pioneer stages of the ponds (Table 3). During the first year besides exclusive pioneer spp. such as *Libellula depressa* several other spp. that typically breed in advanced succession stages arrived in numbers: *Coenagrion puella*, *Enallagma cyathigerum*, *Ischnura elegans*, *Anax imperator*, *Libellula quadrimaculata*, and *Sympetrum striolatum*. All three *Lestes* spp. of the region were already present: They probably immigrated from the 'Böndlerried/Ambitzgi' that was situated 1.5 km

Table 3. Presence of adults of the dragonfly spp. in two subsequent years at 4 ponds that were created in autumn 2003 at the ‚Oberhöflerried'. The figures indicate the number of days with presence of the spp. on 23 and 34 visits, respectively, throughout the flying seasons in 2004 and 2005. FS_a and FS_r = absolute and relative frequency sum (see text). * = evidence for reproduction (exuviae, tenerals) (Orig.).

	2004 (n = 23)						2005 (n = 34)					
	O1	**O2**	**O3**	**O4**	**FS_a**	**FS_r**	**O1**	**O2**	**O3**	**O4**	**FS_a**	**FS_r**
Calopteryx splendens	1	1			2	0.5	1				1	0.2
Calopteryx virgo	2	1		1	4	1.0	1	1		1	3	0.6
Sympecma fusca					0	0	13	6	2		21*	4.0
Lestes sponsa	2	3	2	1	8	2.0	2	7	1		10	1.9
Lestes virens	1				1	0.3			2		2	0.4
Lestes viridis	5	6	3	5	19	4.9	2	2	3	6	13	2.5
Platycnemis pennipes	1	1	2	3	7	1.8					0	0
Pyrrhosoma nymphula	3		3	1	7	1.8	9	6	8	5	28*	5.4
Coenagrion puella	10	10	14	15	49	12.6	17	28	18	15	78*	15.0
Enallagma cyathigerum	15	14	12	5	46	11.8	28	31	23	4	86*	16.5
Erythromma viridulum				4	4	1.0					0	0
Ischnura elegans	11	7	6	2	26	6.7	17	20	4		41*	7.9
Ischnura pumilio	2	1			3	0.8	1				1	0.2
Aeshna cyanea	2			3	5	1.3	4	3	2	1	10*	1.9
Aeshna grandis	1				1	0.3					0	0
Aeshna juncea	1			1	2	0.5	1	7	2	1	11	2.1
Aeshna mixta				1	1	0.3	2	1			3	0.6
Anax imperator	8	10	8	6	32	8.2	15	11	10	5	41*	7.9
Brachytron pratense					0	0	1			1	2	0.4
Cordulia aenea	3	5	2	3	13	3.3	11	7	6	2	26	5.0
Somatochlora flavomaculata				1	1	0.3	2	1		2	5	1.0
Somatochlora metallica					0	0			1		1	0.2
Libellula depressa	7	7	10	2	26	6.7			1	3	4	0.8
Libellula fulva					0	0			1		1	0.2
Libellula quadrimaculata	13	11	9	7	40	10.3	13	17	16	10	56*	10.8
Orthetrum brunneum			4	2	6	1.5		1	1		2	0.4
Orthetrum cancellatum	4	1	4		9	2.3	5	6	4		15	2.9
Orthetrum coerulescens	1		3		4	1.0					0	0
Crocothemis erythraea					0	0	2	4	1		7	1.3
Sympetrum danae	7	8	1		16	4.1					0	0
Sympetrum striolatum	11	13	9	10	43*	11.0	10	10	10	7	37*	7.1
Sympetrum vulgatum	2		1		3	0.8					0	0
Sympetrum sanguineum	7	3	2	3	15	3.8	1		1	1	3	0.6
Leucorrhinia pectoralis					0	0	6	4	1		11	2.1

away in the northwest. *Platycnemis pennipes*, *Erythromma viridulum*, *Ischnura elegans* and *Orthetrum cancellatum* presumably originated from a large pond 1.5 km apart in the southeast, *Calopteryx virgo* and *C. splendens* as guests from a nearby ditch with slowly running water. *Sympetrum striolatum* already emerged in the summer of the first year: Many exuviae and tenerals were found at three of four ponds, and *Aeshna cyanea* was recorded in the larval stage. Other spp. like *Pyrrhosoma nymphula* and *Orthetrum coerule-*

scens had already bred in the vicinity, but only the former sp. will establish at the ponds while the latter will remain an accidental visitor. *Aeshna mixta*, *A. grandis* and *Libellula fulva* are also considered guests as long as aquatic vegetation has not developed yet.

Looking back to the records of continuation and changes in the dragonfly community in the course of the first two years, some tendencies emerged. *C. puella*, *E. cyathigerum*, *I. elegans*, *A. imperator*, *L. quadrimaculata* and *S. striolatum* – all are at least partly univoltine spp. in this region – were expected to establish definitely breeding populations. *Sympecma fusca* arrived in spring of the second year, and immediately produced a new generation that emerged during late summer in numbers. For the reserve it was a new breeding sp. that is expected to colonize the ponds for many years to come. Others as *C. aenea*, *S. flavomaculata* and *O. cancellatum* will follow, while the pioneer spp. *I. pumilio*, *L. depressa* and *O. brunneum* will soon disappear. *Leucorrhinia pectoralis* was of special interest. As several males appeared at three of the four new ponds, *L. pectoralis* can be expected to become a breeding sp. here, hence the management actions are considered successful. Finally, from the species list it could be inferred that the species richness and the composition of the dragonfly community largely depends on the potential of the regional fauna.

Long-term monitoring (35 years) in the entire reserve yielded the following results:

- In total 49 dragonfly spp. were recorded, about half of them considered indigenous. The populations of most spp. could be maintained or promoted by appropriate management of the water bodies. Two breeding spp. became extinct, at least one sp. is considered a new permanent colonizer.
- Newly created ponds were immediately colonized by a relatively large number of spp. Some of them bred only in the pioneer stage of their habitat and disappeared already in the second or third year (e.g. *Libellula depressa*), while others established stable populations during the subsequent succession (e.g. *L. quadrimaculata*).
- The first univoltine pioneer species to colonize a newly created water body depended on the seasonal time of construction. In spring it typically was *Libellula depressa*, in autumn *Sympetrum striolatum*.
- In any species the seasonal number of emerging individuals varied enormously between different ponds and years up to a factor of >100 as shown for *Leucorrhinia pectoralis* in Table 4.
- *Leucorrhinia pectoralis* colonized only fishless water bodies on turf ground in medium succession stages, i.e. when the water surface was partly overgrown. Pioneer and late stages were avoided (Wildermuth 1992, 1994). The local population was promoted by rotational management of the breeding ponds (Wildermuth 2001, 2005).
- Some spp. emerged only four or five years after the construction of a water body, although adults were regularly present in the pioneer stage (*Cordulia aenea*, *Somatochlora flavomaculata*).
- Some spp. had to be considered as guests. They only appeared sporadically as individuals and never bred (e.g. *Aeshna affinis*, *Anax parthenope*, *Crocothemis erythraea*, *Sympetrum flaveolum*).

Table 4. Emergence sum (ES, number of exuviae) of *Leucorrhinia pectoralis* from 1984–2005 at six selected mire ponds (no. 2a-8a) in the 'Böndlerried/Ambitzgi'. (From Wildermuth 2005, completed).

	2a	4	6	6b	7d	8a
1984		78	39			
1985		28	11			
1986	1	5	6		1	
1987	42	2	2		29	30
1988	84		21	3	139	93
1989	9		13	3	31	8
1990	3	41	18	6	147	152
1991	18	102		20	1	2
1992	19	15		25	6	
1993	105	24		2	1	26
1994	177	6		30		3
1995	15	12		85	13	13
1996		15	1	7		1
1997		61		35	13	1
1998	521	40		64		
1999	66	9		1	10	
2000	50	17			5	
2001	59	101		13	17	
2002	6	31	6		5	
2003	23	50	18	8	11	
2004		1	4		7	
2005	3	2	3	3	55	
Total	1198	638	139	302	436	309

– A few spp. reproduced only temporarily with merely small numbers of offspring, the larvae mostly confined to a single water body (*Aeshna grandis*, *Aeshna mixta*, *Brachytron pratense*, *Somatochlora arctica*).
– The populations of at least two spp. declined, possibly due to climatic change (*Aeshna juncea*, *Sympetrum danae*).
– *Nehalennia speciosa* became extinct in the course of the study period, most probably due to desiccation and overgrowth of the habitat (Wildermuth 2004). *Coenagrion hastulatum* vanished before habitat management in the reserve had begun, possibly due to the loss of open water in the peat diggings.

Census at linear biotopes: ditches, brooks and rivers

Monitoring the dragonfly populations of small draining ditches and brooks is little problematic because the habitats are easy to survey, provided their banks are open and unhinderedly accessible. If their structure varies in different sections the suitability as habitat for the dragonfly fauna can be checked simultaneously by regular collection of exuviae and counts of teneral and mature adults along the water course.

The results of simple counts of *Orthetrum coerulescens* at small draining ditches in a fen on a stretch of ca. 150 m are summarized in Fig. 2. There is strong evidence for reproduction at the site, and the annual population size may be assessed by the highest recorded number of males. In addition the seasonal development of the adult population can be followed up. The population exists for many years and had been established by restoration of ditches and fenland that was completely overgrown with shrubs. By subsequent maintainance of the ditches, always performed in spacial and temporal sections, the population increased. The highest daily number ever recorded during a five year period amounted 33 territorial males.

The second example concerns *Calopteryx virgo* that typically inhabits small and well oxygenated streams characterised by open running water, sunny patches, perches for territorial males, and water plants or rootlet felts as oviposition substrates. The species was monitored at a ditch-like water course 1 km in length running between a forest edge and a railway line, along a fen and through agricultural land. For hydraulic reasons, i.e. to enable the drain-off in periods with high precipitation, the river-bed was cleared sporadically. In order to preserve the benthic fauna, the works were carried out in sections and spread over a few years. As it was unknown if the method would prove successful, the effects on the aquatic biocoenosis was examined by a survey of the *Calopteryx virgo* population (Wildermuth 1986). A census of adult males and females was conducted on nine days during the flying season. The results from 1986 are represented in Fig. 3. They clearly show that some sections of the stream were more densely populated than others, obviously due to differences in habitat quality. Males and females concentrated mainly on sections III and IV where the creek was bordered by open fenland. However, from mid-July the number of individuals declined rapidly, especially at section III, probably because the water surface became covered with lush riparian vegetation and therefore was no longer visible for the dragonflies.

At rivers Gomphidae, typical inhabitants of large running waters, are suited for assessing the naturalness of the biotopes and the effects of restoration. The investigation methods may comprise mapping of adults and exuviae from the bank or by canoe and plotting the results in squares of 1 km^2 (e.g. Schlumprecht et al. 2004). The most accurate method in deep, fast running and cold rivers is certainly the collection of exuviae at the bank from the water side by swimming in a diving suit (Osterwalder 2004). This was also successful at newly created alluvial habitats like oxbows and cut-off meanders on the Swiss plateau (Osterwalder 2005, 2007). In the 'Foort'-example near Bremgarten (CH) the works were carried out in winter 2003/04 and 2004/05, respectively, and the survey of Gomphidae started in June 2005. Exuviae were collected at three new side branches as well as at two adjacent river sections upstream and downstream. Three Gomphidae spp. were recorded at the stretches in different numbers, surprisingly all of them also at the new habitats and in some cases in numbers (Table 5). It is assumed that the larvae were drifted from the main river bed into the new side branches where they found a suitable habitat for completing their development and emergence.

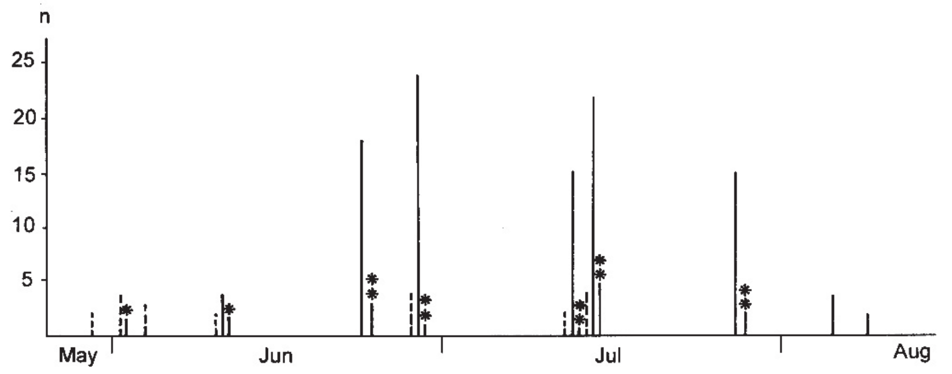

Figure 2. Development of a small population of *Orthetrum coerulescens* at 'Oberhöflerried' in 2005. Bars: adult males, broken bars: tenerals, * = exuviae, ** = copulae. (Orig.).

Summary, conclusions and outlook on faunal distribution shifts with respect to climate change

From the experience of survey and monitoring procedures the following conclusions are drawn:

(1) Dragonflies (Odonata) are suitable organisms for quantitative studies to measure the effects of conservation actions and to rate the value of aquatic habitats: They are conspicuous and attractive insects, restricted in species number, relatively easy to identify and to count, and they colonize a great variety of water bodies. Many species are habitat specialists.

(2) For the evaluation of biotopes all dragonfly species should be considered, not only those of the Red Lists. Regional common spp. may have a flagship role or they are important bioindicators, e.g. *Calopteryx virgo* for streams in urban landscapes, *Libellula depressa* for stagnant waters in pioneer stages, *Leucorrhinia dubia* for mire habitats, and *Cordulegaster bidentata* for seepage springs and headstreams.

(3) Methods of monitoring comprise counts of the number of species and individuals: larvae, exuviae, tenerals and mature adults. The latter can be indicated by the abundance classes, the weekly or seasonally largest number of adult males, the mean highest steady density, or by the frequency sum. Best method is the semi-quantitative collection of exuviae and the determination of the emergence sum. Additional indications for reproduction at a water body are obtained by records of territorial males, tandems, copulation wheels, and ovipositing females.

(4) Monitoring should consider the dynamics of biotopes and dragonfly communities, because species richness and its composition may change rapidly according to succession, especially in the early stages. Therefore, both short-term and-long term-studies are needed. Although the latter are uneconomic and require persistence they are of invaluable importance.

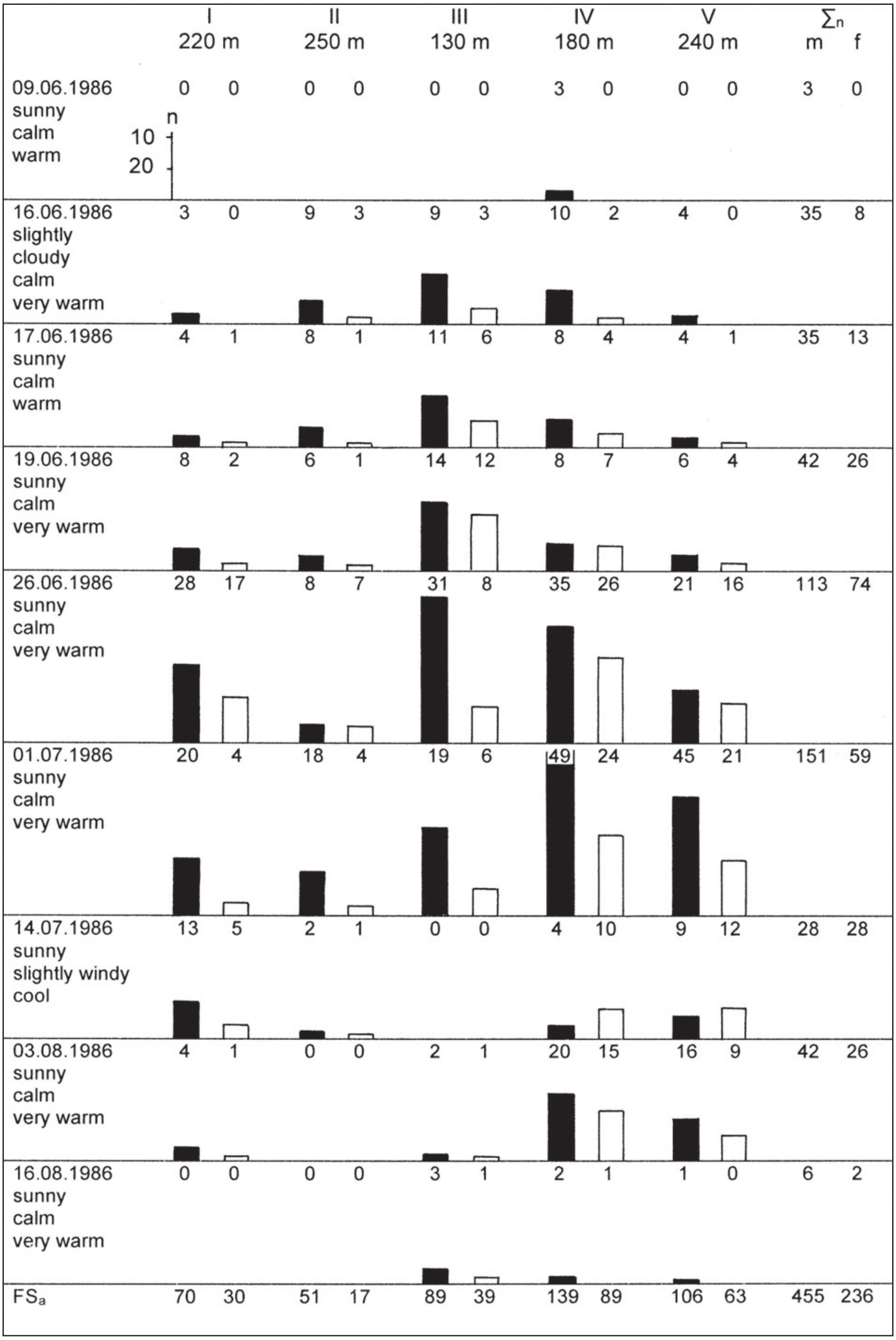

Figure 3. Development of a population of *Calopteryx virgo* in 5 sections (I-V) of a 1 km-stretch of a small brook near Wetzikon (CH) in 1986. Bars: number of adults per 100 m, black: males, white: females. The absolute number of recorded individuals is given above each column. $\sum_n$ = total number of recorded males (m) and females (f) per count, FS_a = absolute frequency sum. (Orig.).

Table 5. Number of exuviae findings of three Gomphidae species at two sections of the river Reuss at ‚Foort' near Bremgarten (CH) and three adjacent side branches that had been created in winter 2003/04 and 2004/05. Numbers in each column: left *Onychogomphus forcipatus forcipatus*, middle *Gomphus vulgatissimus*, right *Ophiogomphus cecilia*. (Osterwalder 2007).

date of census	river Reuss section 1.331 1 × 1250 m			new side branch 1.348 2 × 475 m			new side branch 1.349 2 × 495 m			new side branch 1.350 2 × 140 m			river Reuss section 1.332 1 × 1250 m		
01.06.2005	0	31	0	0	94	0	0	16	0	0	64	1	0	1	0
23.06.2005	9	0	39	1	9	29	15	3	38	5	1	30	5	0	9

(5) Provided high quality and corresponding comprehensiveness, the monitoring data can be used as basis for distribution maps. The records with as much details as possible (see point (3), including those on geographical situation, altitude, date, weather, type of habitat) should be stored in central data banks.

(6) Dragonflies may serve as indicators for climate change. This can be assessed by comparison of data over the time. However, this method requires exact data on the species community of many localities, including abundance of species, geographical position, altitude, and habitat quality. Because exact historical data are usually not available, it is necessary to ascertain the present state of local faunas for future comparison. Yet the results of comparison between actual and former data should be interpreted with caution and refer to the complete regional fauna, i.e. not remain restricted to one or two species. Furthermore, it should be considered that changes in the dragonfly fauna may also be caused by biogeographic fluctuations for unknown reasons or by habitat alterations.

For central Europe, is expected that climate change will be become manifest in higher temperatures, increase of winter precipitation and decrease of summer rainfall. This will result not only in horizontal and vertical shift of many faunal elements but also in habitat changes. Shallow and tiny water bodies in moorlands, e.g., may dry up regularely in summer and therefore become unsuitable for larval development of habitat specialists. Furthermore, the periodically formed astatic habitats in prealpine alluvions filled up by melting water during the spring months could completely disappear due to the lack of high waters. The same may happen in gravel pits, ditches and other secondary habitats in the vicinity of river courses. On the other hand, lowering of the water table could also be caused by extraction of ground water for human requirements. Therefore, while assessing the effects of climate change on the dragonfly fauna, it is important to distinguish between climatic factors and other reasons affecting or improving the larval habitats. On this account, faunal surveys should always be paralleled by records of the local habitat conditions. So far only few regional long-term investigations complying with these requirements are available, an exceptional example being the studies by Vonwil and Osterwalder (1994, 2007). The more important it is to imply ecological data in future census studies.

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References

Gerken B, Sternberg K (1999) The exuviae of European dragonflies. Arnika & Eisvogel, Höxter and Jena, 354 pp.

Gonseth Y, Monnerat C (2002) Rote Liste der gefährdeten Libellen der Schweiz. CSCF, Neuchâtel & BUWAL, Bern. Vollzug Umwelt, 46 pp.

Heidemann H Seidenbusch R (2002) Larves et exuvies des libellules de France et d'Allemagne (sauf de Corse). Société française d'odonatologie, 416 pp.

Knaus P (2000) Emergenzstudien an *Somatochlora alpestris* in den Zentralalpen (Odonata: Corduliidae). Libellula 19: 117–142.

Moore NW (1991) The development of dragonfly communities and the consequences of territorial behaviour: a 27 year study on small ponds at Woodwalton Fen, Cambridgeshire, United Kingdom. Odonatologica 20: 203–231.

Moore NW (2001) Changes in the dragonfly communities at the twenty ponds at Woodwalton Fen, Cambridgeshire, United Kingdom, since the study of 1962–1988: Odonatologica 30: 289–298.

Moore NW, Corbet PS (1990) Guidelines for monitoring dragonfly populations. J. Br. Dragonfly Soc. 6: 21–23.

Osterwalder R (2004) Gomphidennachweise an Fliegewässern im Kanton Aargau (Schweiz) und angrenzenden Gebieten. Mercuriale 4: 6–16.

Osterwalder R (2005) Gomphiden-Exuvienfunde an neu angelegten Seitenarmen und renaturierten Uferabschnitten von Reuss und Aare im Kanton Aargau. Tagungsband GdO-Tagung in Essen.

Osterwalder R (2007) Gomphiden-Exuvienfunde an neu angelegten Seitenarmen und renaturierten Uferabschnitten von Reuss und Aare im Kanton Aargau, Schweiz (Odonata: Gomphidae). Libellula 26 (in press).

Ott J, Piper W (1998) Rote Liste der Libellen (Odonata). In: Binot M, Bless R, Boye P, Gruttke H, Pretscher P (Eds) Rote Liste gefährdeter Tiere Deutschlands: 260–263. Bundesamt für Naturschutz, Bonn-Bad Godesberg, 260–263.

Schlumprecht H, Strätz C, Potrykus W, Frobel, K (2004) Libellenverbreitung und wasserwirtschaftliche Renaturierungsmaßnahmen im oberen Maintal. Nat.schutz Landsch. plan., 36: 277–281.

Sternberg K, Buchwald R (1999) Die Libellen Baden-Württembergs, vol. 1. Ulmer, Stuttgart. 468 pp.

Vonwil G, Osterwalder R (1994) Kontrollprogramm NLS. Libellenfauna Reusstal 1988–1992. Grundlagen und Berichte zum Naturschutz 7. Baudepartement Aargau, Aarau, 1–82.

Vonwil G, Osterwalder R (2006) Kontrollprogramm Natur und Landschaft. Die Libellen im Kanton Aargau. Sondernummer 23 Umwelt Aargau, Departement Bau, Verkehr und Umwelt, Abteilung Landschaft und Gewässer: 1–96.

Wildermuth H (1980) Die Libellen der Drumlinlandschaft im Zürcher Oberland. Vierteljahrsschr. Nat.forsch. Ges. Zürich 125: 201–237.

Wildermuth H (1986) Die Auswirkungen naturschutzorientierter Pflegemassnahmen auf die gefährdeten Libellen eines anthropogenen Moorkomplexes. Nat. Landsch. 61: 51–55.

Wildermuth H (1992) Habitate und Habitatwahl der Großen Moosjungfer (*Leucorrhinia pectoralis*) Charp. 1825 (Odonata, Libellulidae). Z. Ökol. Nat. schutz 1: 3–22.

Wildermuth H (1994) Populationsdynamik der Großen Moosjungfer, *Leucorrhinia pectoralis* Charpentier, 1825. (Odonata: Libellulidae). Z. Ökol. Nat. schutz 3: 25–39.

Wildermuth H (2001) Das Rotationsmodell zur Pflege kleiner Moorgewässer. Nat. schutz Landsch. plan. 33: 269–273.

Wildermuth H (2004) *Nehalennia speciosa* in der Schweiz: ein Nachruf (Odonata: Coenagrionidae). Libellula 23: 99–113.

Wildermuth H (2005) Kleingewässer-Management zur Förderung der aquatischen Biodiversität in Naturschutzgebieten der Agrar- und Urbanlandschaft. Nat. schutz Landsch. plan. 37: 193–201.

Wildermuth H (2008) Konstanz und Dynamik der Libellenfauna in der Drumlinlandschaft Zürcher Oberland Rückblick auf 35 Jahre Monitoring. Vierteljahrsschr. Nat. forsch. Ges. Zürich 153: 57–66.

Wildermuth H, Schiess H (1983) Die Bedeutung praktischer Naturschutzmassnahmen für die Erhaltung der libellen in Mitteleuropa. Odonatologica 12: 345–366.

Wildermuth H, Zollinger J, Flöss I (2001) Die Drumlinlandschaft Zürcher Oberland. In: Nievergelt B, Wildermuth H (Eds) Eine Landschaft und ihr Leben: das Zürcher Oberland. vdf, Hochschulverlag AG an der ETH, Zürich,145–166.

Wildermuth H, Gonseth Y, Maibach A (Eds) (2005) Odonata - Die Libellen der Schweiz. - Fauna Helvetica 12, CSCF/SEG, Neuchâtel. 400 pp.