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DRAGONFLIES AND NATURE CONSERVATION : AN ANALYSIS OF THE CURRENT SITUATION IN CENTRAL EUROPE *

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The main task of nature protection is to conserve the diversity of ecosystems and organisms. The targets of the effort in nature conservation are the plant and animal species, together with their specific habitats. However, such endeavour can only be successful if theory and practice complement each other in a significant way. In this connection some aspects of research and conservation measures concerning dragonflies are discussed. The needs of ecological research are outlined and some priorities for future work are suggested : surveys which are directly applicable by nature conservation institutions, basic investigations of habitat selection, dispersal, population dynamics, colonization of newly established ponds and revitalized running waters, succession, the impact of larva predation by fish on local fauna. Conservation of the various types of larval habitat, including the inconspicuous ones, is one of the main requirements of practical dragonfly protection. Furthermore, it is necessary to construct new water bodies which are suitable for endangered species (e.g. oligotrophic ponds differing in relief, soil, depth, water regime and vegetation structure). For the management of larval habitats various practical measures are suggested, including the "rotation model". Some arguments for dragonfly protection are provided and it is stressed that the European fauna cannot be successfully protected without the personal involvement of odonatologists.

INTRODUCTION

Nature protection is a socio-cultural task. Its main goal consists in conserving the evolved diversity of the landscape and the organisms. The

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* English version of the article entitled "Libellen und Naturschutz — Standortanalyse und programmatische Gedanken zu Theorie und Praxis im Libellenschutz" that appeared in *Libellula*, 1991, 10 (1/2) : 1-35.

targets of these efforts are plants and animals, together with their biotic communities, habitats and general living conditions. Among the classical targets of nature protection are orchids, birds and amphibians. Recently, further groups of plants and animals have been included, one of them being the dragonflies. The 80 or so Central European species also directly play an increasingly important role as objects of species conservation and as bioindicators.

Endeavours in nature conservation can only be successful if theory and practice complement each other meaningfully. Research and practice are the two fundamental pillars of nature protection. The latter, however, is by definition not a science, but a practically oriented idea that is mainly sustained by ethical motivations. Its essence is more to conserve particular values and not to gather new findings. Efforts in nature protection nowadays, however, can not be effective without scientific activities, as there are always diverse demands to use the biosphere in a complex way. Only by concerted investigations will it be possible to make available the theoretical basis necessary for carrying out potentially promising activities. Based on the example of the dragonflies, the following remarks should present an overview of biological research related to nature protection and the necessary practical measures to this end. The main focus is to show gaps in our present knowledge as well as to point out future directions in research and existing deficits in the practical activities of nature protection.

RESEARCH

Research oriented to aspects of nature protection should yield practicial knowledge. The data and findings obtained are an indispensable help for the practician's decisions. Clearly, much knowledge of the ecological basic research as well as the results obtained by investigations on the biology of the species can be used here. In addition to this, answers are needed to special questions on the conservation and promotion of particular species or groups of species.

Inventory of the status quo

The inventories in a particular landscape or region serve as the classical basis for the planning of measures in species protection : which dragonfly species occur where and how frequently ? The resulting regional or national distribution maps present an approximate description of the spatial distribution and occurrences of the respective species (Fig. 1, Schmidt, 1981b). Then the sampled data serve as a basis for making the Red Lists. To what extent the Red Data Books can be used for the practice of nature protection depends on the spatial accuracy and precision of the inventory. National or regional screen maps which exist for some parts of Central Europe (e.g. Maibach & Meier, 1987 ; Obenauer & Schanowski, 1989 ; Jödicke *et al.*, 1989)

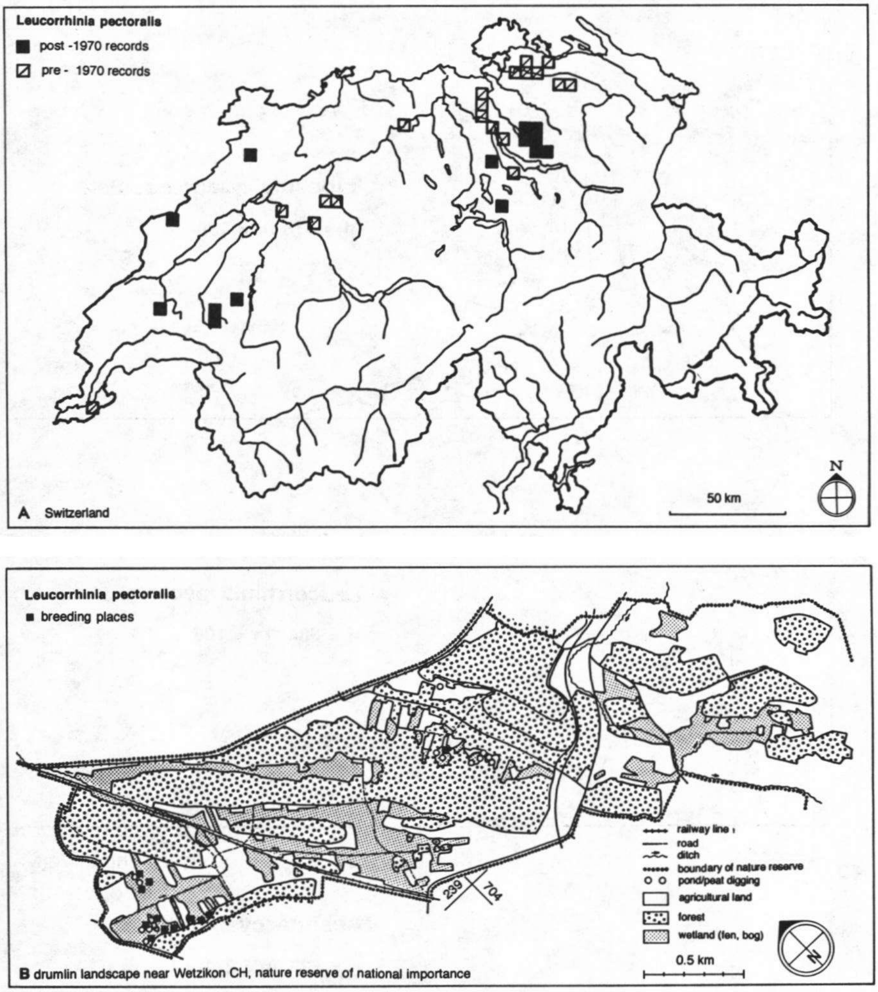

Fig. 1. Two extreme types of distribution maps. A : large-scale 5 km square distribution map without further details, therefore only of limited use for practical conservation. B : small-scale distribution map with precise indications of the localites where the species develops and emerges (ascertained by findings of exuviae). 239/704 : intersection of coordinates of Swiss National Grid Map (A from Maibach & Meier, 1987).

can easily be understood and compared and are compatible for computer and data processing. However, they are not able to meet all requirements of practical nature conservation. Measurements in protecting dragonfly species are only suitable together with the protection of the larval habitats, so data on their exact site, size and ecological situation are needed. Besides the data relating to the biology, some information on land tenure, political and

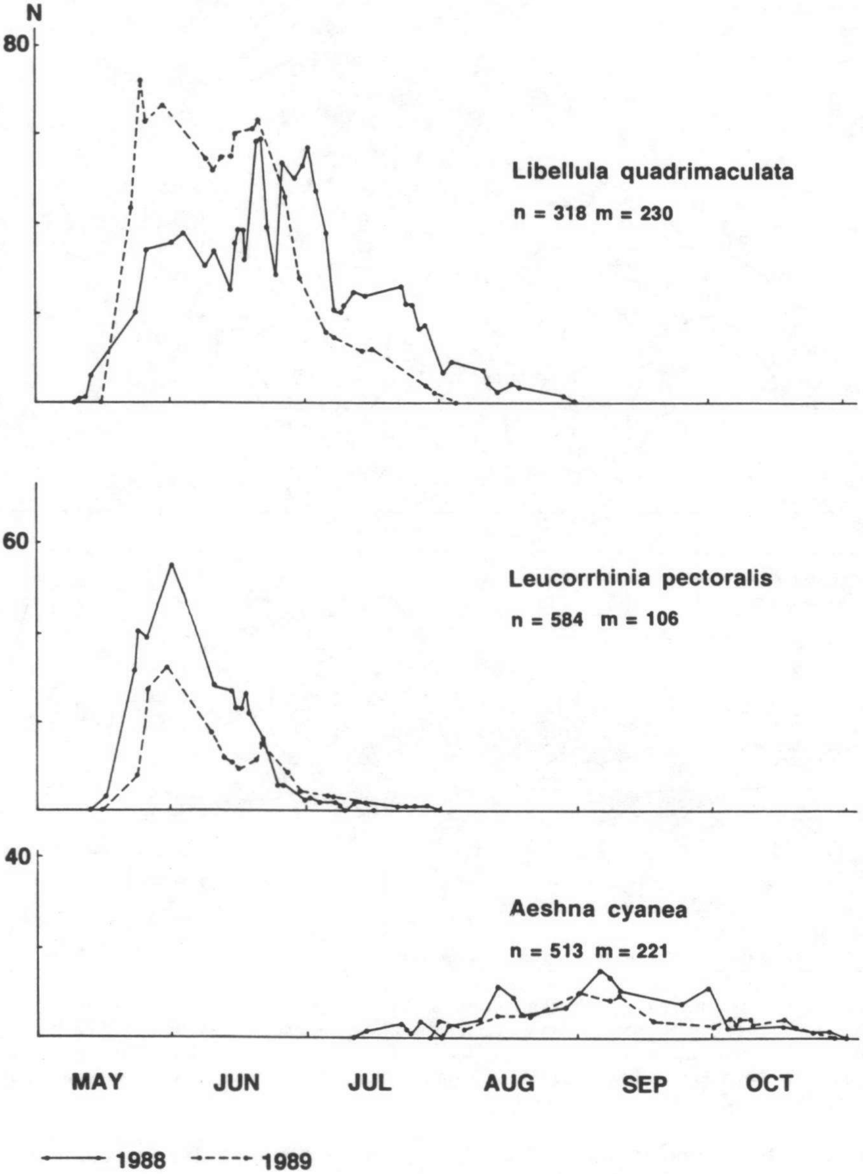

Fig. 2. Seasonal development of the imaginal population of three species of Anisoptera at a complex of peat ponds near Zürich. y-coordinate : number of male adults found during random sampling-counts at 18 ponds. The values only correspond to one part of the whole population, because all the animals can never be found at the breeding water at one time. n,m = number of adults emerged in 1988 (n) and 1989 (m) at the same ponds (finding of exuviae).

administrative affiliation and present use are also necessary. Furthermore, studies on damage in the habitat are useful, as well as proposals for possible measures in protection and maintenance. The data should be readily accessible in utilizable form for practical activities of nature conservation institutions at any time.

Again and again there is a temptation in the inventories to make extensive lists of species. If one strongly concentrates on the search for rarities (especially so-called guest species) the much more frequent species are too easily forgotten. For practical use, statements on sporadically appearing species are important, as well data on the reproduction of the local fauna, especially of indicator species. Findings of exuviae indicate a completed life cycle. The observation of larvae, tenerals or tandems and oviposition also provide valuable information.

Normally the terms "autochtonous" or "indigenous" are used in the context of dragonfly reproduction, though different opinions exist as to their meaning. JURZITZA (1989) stated that one can not conclude with certainty the autochthony of a dragonfly species at a particular water from the regular occurrence of larvae or emerging adults — an opinion, that raises many questions and shows that the criteria for autochthony of dragonflies must be reconsidered and the terms more clearly defined.

Data on the abundance of adults must be taken with reservation and viewed critically, as they are always the results of random sampling. In many cases they do not give clear information on the respective size of a population. This is illustrated by the counts taken over some years on the dragonflies of a brook and a complex of peat ponds near Zürich (Fig. 2). The results permit the following statements :

(1). The species-specific flight periods depend not only on the respective site with its climate ; at the same site they also vary from year to year as regards the beginning and length of the flight period. Besides the weather, the population size of a year has some influence on the flight period.

(2). The development of the adult populations during a flying-season is species-specific. In spring species (e.g. *Leucorrhinia pectoralis*) the curve rises steeply and has a narrow peak ; in summer species (e.g. *Aeshna cyanea*), however, it is flat and has a broad peak. For this reason one will get very different values for spring species within a short period if the random sample-inventory is carried out, even under the best weather conditions.

(3). Sometimes one can not correctly infer small larval populations from regularly observed small number of adults. So I counted up to 260 exuviae each year at a pond of 60 m^2, at which during the whole flight period at most 2 males of *A. cyanea* were present at the same time. KAISER (1984) points out after years' long observations on *A. cyanea*, that in species showing a pronounced migratory behaviour and a temporal separation of the mating sites, counts of adults do not give useful data on the population size. For the Anisoptera without migration and with spatial separation of the mating sites ("territorial species"), as well as for the less mobile Zygoptera, more reliable information can be expected. In any species normally only a certain proportion of the animals that have emerged in one season is present at the time of the random sample-inventory, probably no more than 10-20%. Furthermore, it should be noted that the population size changes continuously during the flight period, even in less mobile species like *Ceriagrion tenellum* (KRÜNER, 1984). As an additional difficulty in taking a quantitative inventory, there are species-specific temporal and spatial patterns of preferences at the breeding waters (DREYER, 1984).

(4). Even if adults of a species are regularly observed at a water, that does not necessarily mean that this species develops there. In the course of many years I regularly observed females of *Anax imperator* at the same pond ; yet exuviae were hardly ever found, and the species reproduces in great numbers at other waters of this region (WILDERMUTH & KREBS, 1983a).

(5). The most reliable information on the population sizes of special species at a breeding water are achieved by regular sampling of exuviae during the whole emerging period. This, however, is only possible and justifiable under certain circumstances, including a small water size, sharp and well passable shorelines, the accessibility of all emergence sites and, if necessary, permission to trespass the wetland. My own eight-year investigations gave the result that the number of adults that emerged at one breeding water, varied widely from year to year. Similar results were obtained by others for *Aeshna cyanea, Leucorrhinia dubia* and *L. rubicunda* (PAJUNEN, 1962 ; KAISER, 1964).

LOCAL STUDIES ON SPONTANEOUS COLONIZATION AND SUCCESSION AT NEWLY ESTABLISHED PONDS

In contrast to the many (often preliminary or limited) studies on regional distribution and the odonatological monographs, there exist only a few long-term local investigations which are satisfactory with respect to the inventory method used (e.g. MOORE, 1991). Examples, like the study on a garden pond by LÖHR (1986) and MAIER & WILDERMUTH (1991), show that in extensive studies with an appropriate method (i.e. the manner and frequency of data gathering) more can be achieved than just reliable statements on species composition and abundance, namely also qualitative and quantitative data on autochthony as well as on the periodicity of emergence, reproductive behaviour, population size and habitat preference. As in regional inventories, the sampling of exuviae also plays an important role in extensive local studies. The exuviae of many species can be determined with the help of the identification key on larvae already published (BELLMANN, 1987 ; CARCHINI,

Table I

Population dynamics of some Anisoptera species at a peat pond determined by the number of exuviae, based on 182 collecting trips in 1984-1989. The pond was constructed in 1972, and has an area of 60 m^2 and a maximal water depth of 80 cm

	1984	1985	1986	1987	1988	1989
Libellula quadrimaculata	48	60	4	12	76	63
Leucorrhinia pectoralis	2	3	3	1	233	40
Sympetrum sp. (sanguinem, striolatum, vulgatum)	49	108	–	15	21	1
Cordulia aenea	7	1	–	–	1	40
Somatochlora flavomaculata	–	–	–	–	1	7
Aeshna cyanea	68	175	13	259	19	11
Aeshna juncea	1	–	–	–	–	–
Aeshna grandis	–	–	–	–	–	1
Total *Anisoptera*	175	347	20	287	351	163

1983 ; FRANKE, 1979). Advice for practical work with exuviae is given by GERKEN (1984) and LANDMANN (1985).

To compensate for destroyed small ponds, many new ponds have been created for reasons of nature and species protection. When colonized spontaneously by Odonata, the ecological situation of the water and the potential of species occurring in surrounding waters play an important role, as do the species-specific ecological behaviour of the species and the time of pond construction. Various investigations have shown that at first certain pioneer species appear, which are later replaced by other species. The species composition is normally restricted to generalists (WILDERMUTH & KREBS, 1983a ; MARTENS, 1983, 1991 ; HEIDKAMP *et al.*, 1985 ; HÜBNER, 1988). We do not know very much yet about regularities and specifics important for nature protection, in considering the settlement of newly established waters. Only further investigations at different types of waters in various regions can give us more information on what has been successful and will have to be improved in establishing new ponds.

Quantitative long-term studies give the best information on the colonization and succession at newly established waters. An investigation started in 1984 at three new peat waters shows on the basis of the numbers of exuviae that they were settled from the beginning by *Libellula depressa, L. quadrimaculata* and *Aeshna cyanea* (example in Table II). *L. depressa* disappeared after the third year, while at this time *Leucorrhinia pectoralis* began to emerge. Exuviae of *Cordulia aenea* were found only after the fifth or sixth year, although the species had flown regularly from the beginning at all the ponds. Taking into account the data obtained so far as regards species composition and larval population size, particular parallels between the three apparently similar waters emerge, as well as clear differences.

Table II

Succession of 8 Anisoptera species at a pond constructed in October 1983 : number of exuviae determined in 223 collecting trips. Water surface 27 m^2, water depth maximally 50 cm

	1984	1985	1986	1987	1988	1989	1990
Sympetrum striolatum	128	22	61	28	6	1	–
Libellula quadrimaculata	–	26	42	97	103	60	132
Libellula depressa	–	5	9	–	–	–	–
Leucorrhinia pectoralis	–	–	1	29	139	31	147
Cordulia aenea	–	–	–	–	–	2	1
Aeshna imperator	–	1	–	–	–	–	1
Aeshna cyanea	–	–	17	74	11	6	22
Aeshna juncea	–	–	–	1	–	2	–
Total *Anisoptera*	128	54	130	229	259	102	303

Quantitative long-term studies are also worthwile at existing and older waters. They give information on the population dynamics of certain species as well as the temporal development of the species composition. Together with observations on the changes of a biotope (silting up, eutrophication, lowering of the groundwater level), important information results which can serve as a basis for necessary measures in nature protection.

Subsequent investigations after management measures at larval waters

Management measures are experiments with uncertain results as long as no predictions can be made about the ecological processes, due to the lack of knowledge. As such knowledge exists only to a small extent, more studies are needed about the effects of management measures at the larval habitats. Based on initial experience the consequences of certain management measures can be evaluated positively. Observations on *Lestes virens* and *Leucorrhinia pectoralis* at a peat mire changed by man demonstrated that the populations of both species grew after the regeneration of peat-diggings largely overgrown, and then they dispersed to newly established ponds nearby (Fig. 3). In a similar way weedcutting carefully made by hand, as well as the partial thinning out of riparian trees and bushes had a positive effect on the population size of *Calopteryx virgo* (Wildermuth, 1986b). Such studies should be continued at further waters and further species. In this connection the effects of the revitalization of running waters are particularly interesting.

Habitat selection and biotope binding

With regard to protection measures, knowledge on the species-specific relations of dragonflies to their larval waters is very important, especially to

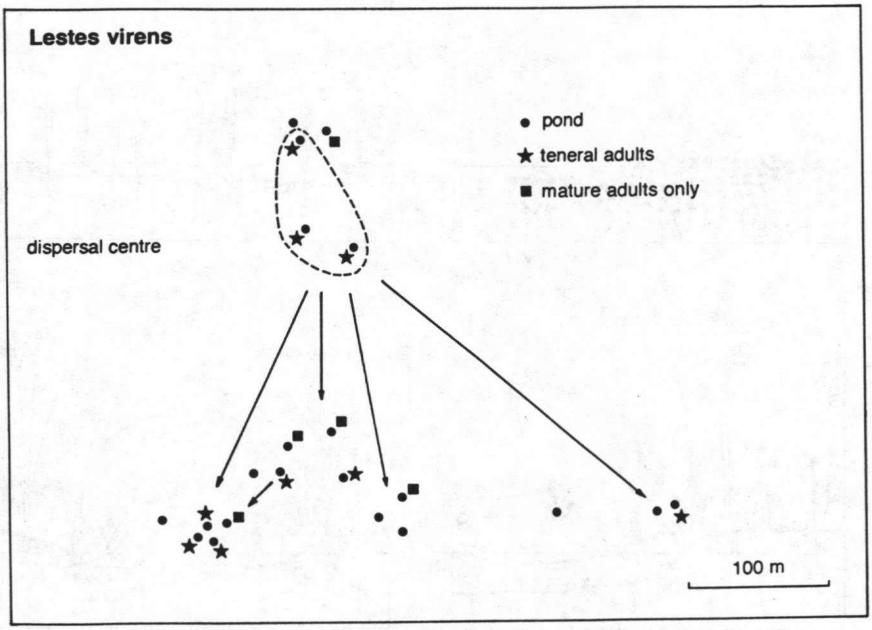

Fig. 3. Growth of the population and directed dispersal of *Lestes virens*, as a consequence of management in a former peat cutting area. The three circled ponds (center of dispersal) had already existed before the initiation of the measures, but had been strongly overgrown by vegetation. Since 1971 they were revitalized in several phases. All the other ponds are new. The observations of adults were made in 1984 ; the arrows show the supposed dispersal (from WILDERMUTH, 1986b). Circle = pond ; star = newly emerged adults ; square = mature adults only.

ecological specialists. Valuable information on this aspect can be attained in regional inventories if these are carried out by appropriate methods. Precise data on habitat requirements, however, can only be obtained by autecological research. In this connection the question arises as to the criteria by which the adults select the oviposition sites and how the larvae are bound to their habitats.

In a study on the habitat of *Somatochlora artica* I concluded that the adult animals recognize their oviposition sites by a pattern of sparkling reflections that emerge from vegetation at the water surface (WILDERMUTH, 1987). This hypothesis was verified only in part by field experiments with the help of dummies. The reflecting spots, however, are the releasing stimuli to a lesser extent than are large reflecting areas at the water surface (WILDERMUTH & SPINNER, 1991). Furthermore, studies at the larval waters showed that *S. arctica* develops not only in peat bogs, as can be read in the general literature. This point had already been made by RUDOLPH (1980) and ZIEBELL & KLINGER (1980). Among the decisive habitat factors are low water depth,

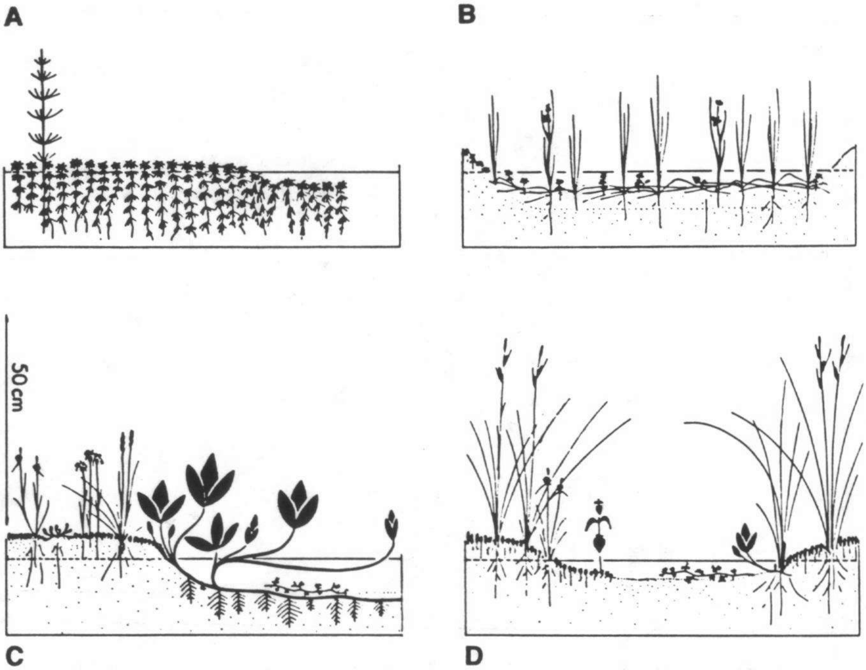

Fig. 4. Vegetation profiles through the larval habitats of *Somatochlora arctica*. A,B : "classical" habitats in *Sphagnum* bogs (A : floating stand of *Sphagnum*, B : puddle with *Sphagnum* and *Scheuchzeria* in a transition bog) ; C,D "atypical" habitats in fens (C Caricetum diandrae with *Menyanthes*, D Caricetum fuscae) ; from WILDERMUTH (1986).

particular vegetation structure (Fig. 4), high water temperatures, spatial separation from open, larger water surface areas and interspecific interactions which take place to small extent due to the spatial separation. The species is rather tolerant towards physical/chemical water parameters like pH, degree of hardness and content of electrolytes (WILDERMUTH, 1986). The same is true for other species characteristic of peat bogs (STERNBERG, 1985).

Generally, the appearance of the vegetation apparently plays a decisive role for habitat selection by dragonflies, as shown for *Nehalennia speciosa* (DEMARMELS & SCHIESS, 1977) and some species of slowly running waters (BUCHWALD, 1989). The same is true for *Leucorrhinia pectoralis* ; observations and experiments (manipulations of the vegetation, experiments with dummies) have proved that this species accepts peat ponds of particular succession phases as rendezvous and oviposition sites in the prealpine regions (WILDERMUTH, 1992). The few existing autecological studies show clearly that further investigations on habitat selection and biotope binding are needed for purposes of planning protection measures.

DISPERSAL

Due to the high mobility of most dragonfly species, genetic exchange between adjacent populations is possible, as well as the colonization of newly established larval waters. This mobility is generally known (MOORE 1954, 1960). There are, however, very few concrete data on the ability of a particular species to disperse. The results of marking experiments and different observations make it clear that the adults newly emerged at first leave the breeding water. Later, some or many of them return to that place, while the rest apparently disperse. The mature adults often stay at the same place for a longer time (Fig. 5A) or regularly visit the same group of oviposition sites (ZAHNER, 1960 ; PAJUNEN, 1962 ; HEYMER, 1973 ; KAISER, 1974). One has indications of dispersionn just from the observations of adult animals at sites at which they can not develop at all. The distances to the next known larval water of the respective species correspond with the minimal distance that was flown by the animals (Fig. 5B). In order to get more information on the dispersal

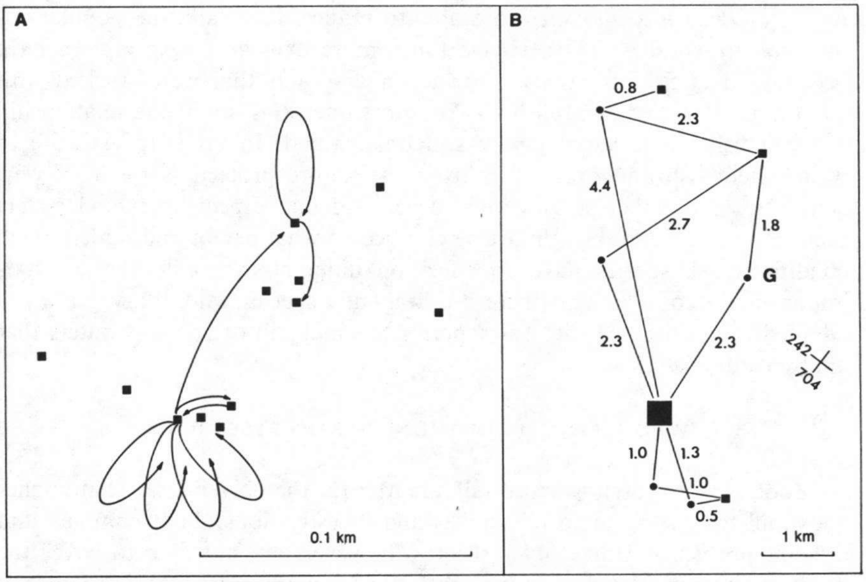

Fig. 5. Observations on the breeding site fidelity and dispersal of *Leucorrhinia pectoralis* in NE Switzerland. A diagram of the mobility of a mature, individually marked male that was observed at a complex of peat ponds on 9 days within a period of 2 weeks. B distances between larval waters (squares) and localites at which adults have been observed but not been able to develop (circles). Large square : large population with an annual emergence rate of 100-600 individuals. G : garden pond inside a larger village. 242/704 ; intersection of coordinates in the Swiss National Grid Map (Schweiz. Landeskarte).

abilities of endangered species, adults newly emerged in a group of waters should be marked, and their migration should be observed. This, however, is only possible if at least one large population exists there. Furthermore, for the various places several observers are needed. A concrete example of a planned pilot study on *Leucorrhinia pectoralis* is presented in figure 6.

DRAGONFLIES AND FISH

Various observations indicate that under certain circumstances the presence of fish has a negative impact on the populations of dragonflies (MACAN, 1966 ; CLAUSNITZER, 1983). It was proved by field experiments at a farm pond in North Carolina that the number of dragonfly species is reduced by the presence of fish (MORIN, 1984) Individual species are, however, not affected to the same extent. Among other causes, this is due to the fact that there are species-specific differences in the behaviour against predators. For example, an anti-predator behaviour seems to be completely absent in the larvae of *Leucorrhinia dubia* (HENRIKSON, 1988). As shown by quantitative studies on the Anisoptera of small peat waters in the canton of Zürich, even small fish species like the minnow (*Phoxinus phoxinus*) are able to reduce drastically the populations of larval dragonflies. Thus, twelve times more exuviae of Anisoptera have been found at fishless ponds than at similar ponds that were stocked with fish (WILDERMUTH, unpublished). Yet most questions about the relationship between fish and dragonflies are still unanswered. In order to estimate to what extent fish and dragonflies from the nature protecter's point of view can "coexist", further studies must be carried out, especially at still waters that are used by anglers. It must be clarified to what extent and under which conditions fish species have an effect on different dragonfly species. It is important to consider that there are dragonfly species whose larvae are not adapted to coexistence with fish (species of small still or running waters that are by nature fishless).

WHO TAKES CARE OF THE NECESSARY RESEARCH ?

Zoological research is first of all a matter for the universities. That applies above all to making intensive studies and investigations about complex and difficult problems. University institutes, however, are not able to cover the needs of research related to nature protection. In many cases there is no interest in universities about questions of applied ecology. Furthermore, there are studies — e.g. the inventories of dragonfly populations — that are not within the universities' field of duties. As there are only very few private or semi-state institutions which carry out ecological research on dragonflies, effective nature protection depends to a large extent on the collaboration of amateur

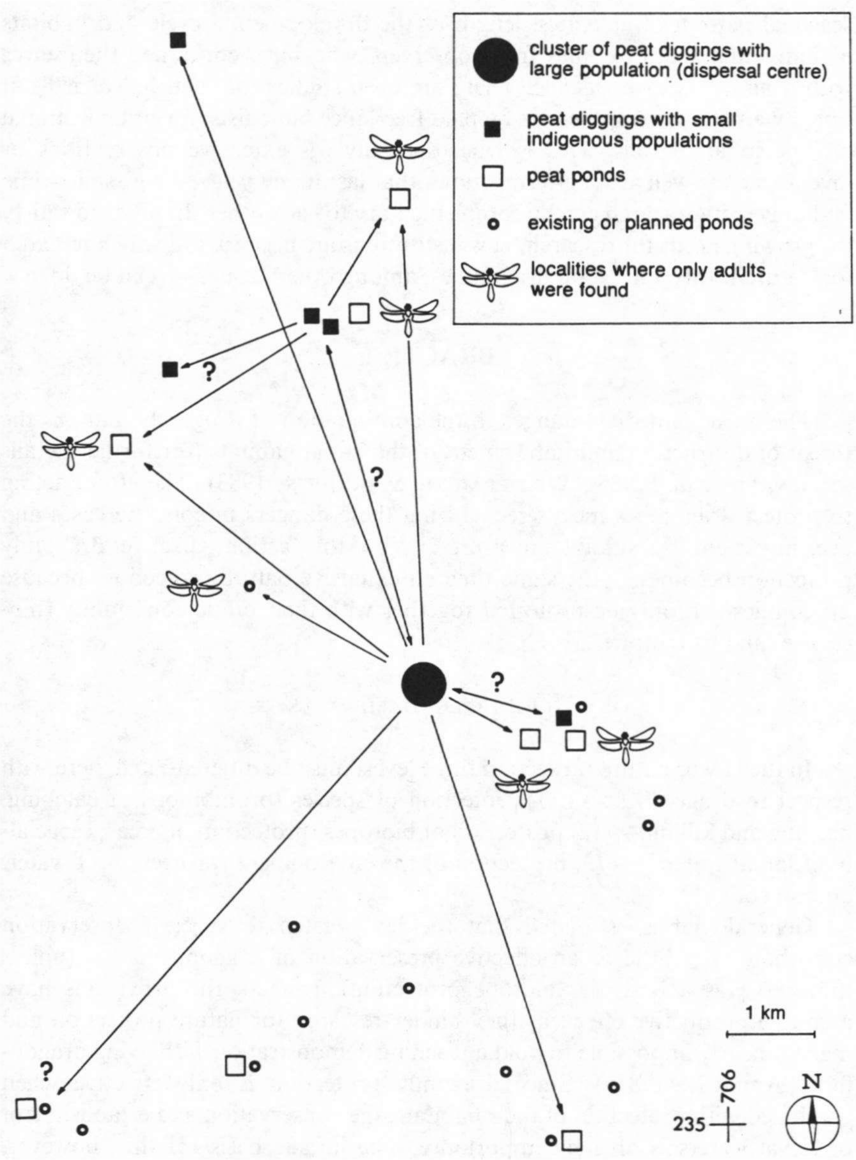

Fig. 6. Study project on the dispersal of *Leucorrhinia pectoralis* on an area of about 100 km² in the Zürich region (Switzerland). Newly emerged adults should be marked and studied as to whether they appear at suitable waters of the surroundings. Arrows : hypothetical lines of dispersal ; 235/706 : intersection of coordinates in the Swiss National Grid Map (Schweiz. Landeskarte).

researchers. The major part of our knowledge on the spatial distribution, seasonal pattern of activities, length of the developmental cycle and habitats of individual species comes from observers who have concerned themselves with dragonflies as a sideline. There are even studies that can be carried out only by amateur researchers or by paid free-lance biologists, for organizational and personal reasons. This is true especially for extensive observations or inventories, as well as long-term studies that last many years. Thus, spare-time and university research can be complementary to each other. In order to satisfy the growing needs for research, new institutions are necessary at which research for nature protection — on dragonflies, among other groups — can be done.

PRACTICE

The most immediate danger to the continuation of dragonfly fauna is the threat of destruction and impairment of the larval habitats (for further details see KNAPP *et al.*, 1983 ; WILDERMUTH & SCHIESS, 1983). Therefore, acting to protect dragonflies means recognizing these dangers in concrete cases and averting them by suitable measures. With this action effective dragonfly protection becomes at the same time an extensive nature protection, because dragonflies can only be protected together with their biotic community (biocenose) and its biotopes.

JURISTIC FUNDAMENTALS

In the law of nature protection three levels must be differentiated, here with respect to dragonflies : — (1) protection of species (prohibitions of catching, keeping and killing) — (2) protection of biotopes (protection of areas, especially of larval waters) — (3) protection of the environment (protection of water, air and soil).

Generally, it is estimated that the law related to species conservation contribute very little to an effective preservation of dragonfly fauna (unless they serve as a basis for biotope protection). Instead, the provisions have a counterproductive effect, as they hinder research for nature protection and make it nearly impossible to hold a teaching demonstration with living dragonflies (SCHMIDT, 1981a). Since dragonfly protection is only effective when combined with protection of their habitats, the conservation and establishment of larval waters is of great importance. The juristic basis for this, however, does not exist in every region, and there are great differences in its substance. For the canton of Zürich, for example, there exist rather extensive provisions. The fact that dragonfly waters are not sufficiently protected, despite this, is less due to the substance of the provisions than to a deficit in execution which has been observed again and again. By the way, experience has shown in recent years that protection of the biotopes alone does not suffice, as even protected larval waters are affected by the diffuse, widespread contamination of the water, air and soil (over-fertilization, toxification). This can only be prevented by effective legislation on environmental protection.

Conservation of the larval waters

A primary goal of nature protection involves the conservation of still existing biotopes. With respect to dragonflies, this applies for all the larval waters that can not be man-made or that need at least several decades for their development. Among these are remnants of the original landscape, e.g. the untouched or minimally impaired peat waters, as well as the flood plains of rivers and brooks, and the reed zone of lakes. But also man-made biotopes like gravel-pits, former fishponds and pead banks need a high priority in protection. Even small and less attractive larval waters such as spring rivulets, bog hollows and loam ponds must be included in the protection efforts. Often just these waters give possibilites for the development of endangered and specialzed species (Wildermuth & Krebs, 1987). A survey and description of the Central European types of biotopes relevant for dragonflies is given by Wildermuth & Schiess (1983). Detailed information on the habitat requirement of the endangered species are summarized in the programme for species protection by Schorr (1990).

Establishing substitute waters

As a substitute for the many destroyed larval habitats a lot of ponds have been newly established since 1970, the European Year of Nature Protection. As has been found since then, the standard types of ponds in private gardens, public parks and in the open landscape normally have a limited importance for the dragonflies because they offer only a possibility to develop for a few endangered species besides the generalists. When establishing new ponds, the specialists among the dragonfly species should be worthy of more attention than up to now. There are, for example, various possibilities to renaturalize areas of already fully exploited gravel-pits that have been turned over for nature protection (Wildermuth & Krebs, 1983b). In a gravel-pit situated in the canton of Thurgau (CH) differentially structured ponds and pools have been developed by carefully planned measures, as well as small rivulets on spring slopes, in which, among others, numerous exuviae of *Orthetrum brunneum* and few of *Cordulegaster bidentatus* were found. Altogether 35 species have been found there up to now, of which 20 are autochthonous (M. Hertzog, in litt.). Near Winterthur (canton of Zürich, CH) another new wetland area has come into being, and is developing promisingly. Here a large wasteland parcel situated in the midst of intensively exploited agricultural areas passed into the town's possession. A pond and some pools and rivulets were newly created over a clayish-gravelly soil, at the foot of a small inclined slope. One year after the construction 7 dragonfly species had already appeared — all of them pioneer species. Dozens of exuviae demonstrate the development of *Orthetrum brunneum* in the rivultes (WILDERMUTH & KREBS, 1987).

The revitalization of brooks and rivers corrected or put in drainage culverts resembles the construction of new ponds. Projects of this kind have been carried out in Switzerland (BOLLIGER, 1984) and Germany (GLITZ, 1991), and there is a good prospect for the realisation of further plans. To what extent the revitalized brooks are colonized by dragonflies will be shown by future accompanying investigations. Among other factors, it is important to consider from the beginning those structural elements that are necessary for the dragonflies of flowing waters.

REGENERATION AND MANAGEMENT

It has been discussed over and over whether biotopes should be managed or left on their own (e.g. WILDERMUTH, 1983, 1984 ; ZIMEN, 1985 ; PFLUG, 1987). The "field of tension between concerted interferences and natural development" (MAYERL, 1990) results from different ideas on nature protection and preservation of the landscape. That has to do with the fact that there is no universal philosophy of nature protection. However, there is no doubt that the situation of dragonfly fauna would be even worse without concerted management measures in certain larval waters. Besides the general decline of larval waters important for dragonflies, this is attributable to the lack of natural dynamics in today's landscape for the most part, especially at the flowing waters. Additionally many waters are stressed by excess nutrients. As a consequence, the ponds rapidly fill up with sediment, and the brooks are overgrown by water vegetation. It is observed that the dragonflies slowly vanish due to these changes of their larval waters, and on the other hand that certain management measures have a positive effect on many species (WILDERMUTH, 1986b) ; that means that interference is justified with respect to certain aims.

It is senseless to seek to work out detailed remedies for the regeneration of larval habitats. As each water is individual, the measures must be separately planned in every concrete case. On the other hand, there are some general recommendations that can be useful in practice, as presented in Table III. Among these guidelines is the rotation model, proposed for compexes of small waters (Fig. 7). In two cases known to me this model of management is being carried out (not systematically) and monitored with respect to its effects. In

Table III

Principles for management of dragonfly waters

- If possible take no measures on natural larval waters, except in case of changes caused by man (lowering of the groundwater level, washing in of fertilizers).
- Mechanical clearance of flowing waters by sectors, following one after another (i.e. the whole brook or ditch over some years); removal of the mud and weeds put out from the cleared-out sectors.
- Handwork maintenance of biologically valuable and sensitive sections of brooks and ditches, leaving structural elements as vegetation stands, blocks of stone or roots of riparian woody plants to a sufficient extent (as refuges from which cleared-out sections can be recolonized).
- Ditches should, at least in some sections, not run in a straight line and not only in the fall line, and they should not be constructed with rectangular standardized profile; structured diversity should be aimed for.
- In some sections brooks and ditches should be kept free of trees and bushes; solar illumination should be possible especially on those parts at which water flow is clearly visible.
- When revitalizing particular ponds, selected parts should be lef as resources for the re-colonization of the remaining parts.
- During weed-cutting in ponds, changes in their structure, if necessary should be carried out at the same time (e.g. construction of shallow riparian parts of sufficient size).
- For complexes of ponds a rotation model should be used, appropriate for the concrete case.

one case a group of peat ponds is involved, in the other some wasteland pools on sandy-loamy soil. At both complexes of waters succession proceeds rather rapidly. Based on the data present up to now, the model appears to be proving its worth. Thus in the loamy pools with scarce vegetation *Orthetrum albistylum* develops, among others, while *Sympetrum depressiusculum* prefers sites with rather dense vegetation (WILDERMUTH *et al.*, 1986). Surprisingly, at this locality a great number of *Hemianax ephippiger*-individuals succeeded in metamorphosing in 1989 (VONWIL & WILDERMUTH, 1990). The exuviae were found in pools that developed from the pioneer phase to the following phases. At the peat ponds *Leucorrhinia pectoralis*, in contrast to other species, avoided advanced succession phases. After the regeneration, however, it re-appeared (WILDERMUTH, 1992).

GLANDT (1989) criticized the rotation models, stating the fact that succession hardly ever goes in the same direction even in adjacent waters constructed on the same soil type, and hence, one condition for the applicability of the model is not fulfilled. Furthermore, the author remarks that flying animals like dragonflies, but not some other animal groups, are able to colonize one particular water from an adjacent one. Contrary to his opinion, it can be argued that models are always simplifications of the real situation therefore must be adapted to the concrete conditions. Furthermore, the differences between the habitats caused by succession may be greater than the differences between the individual waters referred to by GLANDT. In all, a (temporally

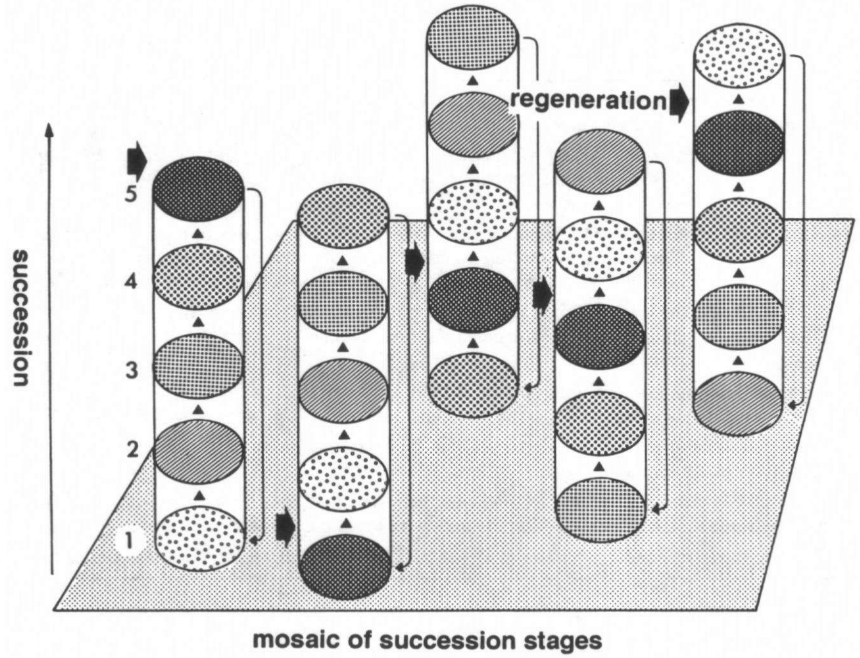

Fig. 7. Rotation model for the management of a complex of small waters. The columns show 5 small waters in 5 different succession phases (ordinate) on a rather small area ; the thick arrows mark the time of a measure that transfers the larval habitat back to the pioneer phase. By this kind of management all phases of succession exist at the same time abscissa : spatial mosaic of different phases). These phases rotate in the complex of waters in the course of time (from WILDERMUTH & SCHIESS, 1983).

and spatially) differentiated management modus promises more success than uniform measures or none at all. Incidentally, we ascertained that, besides the amphibians, pea-shells (*Pisidium*), water louses (*Asellus aquaticus*) and water mites (Acari) also immigrated into the newly created waters. The way in which this happened is not clear.

THE NETWORK OF DRAGONFLY HABITATS

Larval waters must be connected with each other so that a regular exchange of individuals can take place between isolated populations of one species. As the Anisoptera are able to fly over great distances, no great difficulties should be expected for this animal group. In the Zygoptera, however, there are some species that show a great breeding site fidelity (e.g. *Nehalennia speciosa*) or only fly over small distances. Therefore, a denser network of larval waters is necessary for them than for good fliers. Furthermore, specifically structured corridors for migration may be necessary for longer flying distances. Terrestrial biotopes such as sunny edges of the forest, waste-land, extensively cultivated meadows or dry water banks are often settled by dragonflies during the maturation period and for hunting. Although we do not know much about the significance of such terrestial biotopes for dragonflies, it is clear that they must be included in the areas to be protected. Accordingly, effective dragonfly conservation extends far beyond the conservation of single larval waters.

Dragonflies as indicator organisms in nature protection ?

With respect to the number of species, dragonflies represent about 0.2% of the Central European fauna. In view of this relation the question arises whether it is justified to set the dragonflies in the center of nature protection efforts. Generally it is wrong to follow nature protection from the view of one single group of organisms or just one species. Dragonflies always are parts of biocenoses that must be protected together with their biotope. This means in practice keeping the general view ; e.g. other plant or animal species also endangered must not be eliminated while protecting a particular species. On the other hand, the Order of the dragonflies or even one single species may be the center of efforts in nature conservation. That might be conceivable e.g. when trying to conserve specialist species of particular habitats. Moreover, it is generally justified to let the dragonflies have a special role : by their beauty and fame they are suited to be advertising agents, as are birds or butterflies — far better than rare flatworms or jumping plant lice. Finally, it must be pointed out that dragonflies can also be used as bioindicators, in order to judge the structural situation of a landscape or the water quality (Donath, 1984 ; Schmidt, 1989).

The difficult way from theory to practice

Despite some positive examples, the daily efforts in nature protection often are unsuccessful. One of the reasons is that the efforts in nature conservationists are very often exhausted by ineffective discussions and verbal demands. Some publications on dragonflies end with appeals, recommendations and advice. In the most cases it will rest there. Concrete projects are not carried out as there is resistance by the landowners or else economic interests are involved, or the authorities are too little committed, or money or labour are lacking. In many cases only purposefulness, perseverance and courageous activity achieve any success. Some concrete results depend on the activities of single persons. This is true also for odonatologists, whose personal efforts are needed.

On the difficult way from theory to practice one might ask why we protect dragonflies at all. There are various motives for this : — dragonflies are living creatures and merit respect (ethical motive) — dragonflies fascinate us by their colours, forms and the elegance in their movement (esthetical motive) — dragonflies are the object of the research biologist (intellectual motive) — dragonflies are the objects of juristic provisions related to their conservation (juristic motive).

In all these motives idealistic motives are involved. As the value of a dragonfly can not be defined by a certain sum of money, it is very difficult to assert the protection of nature against the protection of economic interest. Despite these difficulties, it is worth the efforts, because for many people the "treasures of our waters" are a source of enthusiasm and inner enrichment.

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