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ACID WATER DRAGONFLIES IN EASTERN ENGLAND — THEIR DECLINE, ISOLATION AND CONSERVATION

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Ceriagrion tenellum, Orthetrum coerulescens and *Sympetrum danae* have declined in eastern England during the present century and are now confined to a few localities in this region. The declines are due to the cessation of peat digging and to agricultural improvement. Measurements of habitat and counts of territorial males showed that the surviving isolated populations of these species are very small — total populations are probably of the order of hundreds or thousands only. To test the dispersal powers of acid water dragonflies acid water ponds were constructed at Wood Walton Fen, in a region which has lacked acid water for many decades. No acid water dragonflies have colonised these ponds during the last twelve years, although *Aeshna juncea* has visited them. Varying numbers of *C. tenellum* from Dorset were introduced to these ponds in 1974, 1975, 1979 and 1980. Only one of the introductions was successful, producing progeny which emerged two years later.. Its descendants did not survive. Some general conclusions about the conservation of dragonflies are drawn from this work.

INTRODUCTION

In Britain eleven of the thirty-eight surviving breeding species of Odonata are virtually confined to acid waters. Three of these species occur in eastern England. They are *Ceriagrion tenellum* (de Villers) and *Orthetrum coerulescens* (Fabricius) which have a European distribution, and *Sympetrum danae* (Sulzer) which has a circumboreal one. Distribution maps compiled by the Biological Records Centre with the help of the British Dragonfly Society (CHELMICK, 1979; HAMMOND, 1983) provide evidence that these species have never been common in eastern England and that they have all declined there in recent decades (cf. Figs 1-3). The first part of this paper attempts to determine whether the three species are as rare in eastern England as they appear, and if so, to discover the causes of their recent declines.

Populations of rare species are becoming increasingly isolated under current conditions of land use. It is crucial for those concerned with their conservation to have quantified information about population sizes which can be related to viability. In the second part of the paper estimates are made of the surviving populations of the three species of dragonfly in eastern England.

Once populations reach low levels they are liable to succumb to accidental extinction if not to genetic deterioration, therefore it is desirable to create new habitats which will be colonised naturally or to which the threatened species can be introduced. The third part of this paper describes the creation of an acid water habitat in an area which has not had it for over fifty years, and an attempt to reintroduce *C. tenellum* to it.

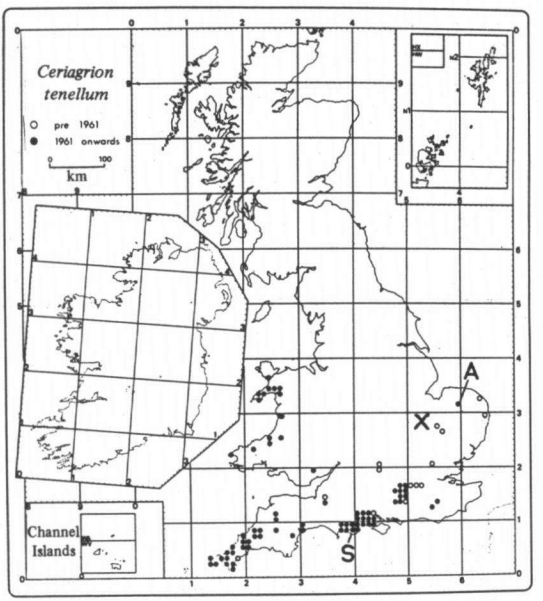

Fig. 1. Distribution of *Ceriagrion tenellum* in the British Isles (revised after CHELMICK, 1979 and HAMMOND, 1983). — A: Scarning Fen, Norfolk; — X: Wood Walton Fen, Cambridgeshire. The site of introduction experiments; the open circles nearby in the same square (52) show the position of Wicken and Chippenham Fens; the latter is the more easterly site; — S: Source of introduced insects in Dorset.

THE RARITY OF ACID WATER DRAGONFLIES IN EASTERN ENGLAND AND ITS CAUSES

Most of the soils of eastern England are derived from chalk, base rich clays and base rich glacial deposits, and so can never have supported acid waters. Therefore the three dragonflies must have always been local in this region. However, they appear to have undergone severe recent declines which require explanation. From 1974 I started a long-term study to confirm what was known about their distribution and to determine the causes of recent changes. As opportunities arose I visited as many of the sites of old records as possible, and looked for new ones by visiting as many as possible of the areas marked as rough land on Ordnance Survey maps. Most of these owed their survival to being commonland. To date (1986) I have looked at 40 sites but have failed to find any new locality of acid water dragonflies in eastern England.

Records made at sites which once supported acid water dragonflies and no longer do so, clearly indicate why the species have disappeared from most of them (see Tab. I). In about half the sites the cessation of peat digging for fuel has been the cause. In the other half the losses are due directly or

Table I

Probable causes of the disappearance of 17 acid water habitats in eastern England

Species	Instances of observed habitat change				
	Cessation of peat digging	Pond drained	Pond polluted	Seral change	Agricultural reclamation
C. tenellum	3				
O. coerulescens	3	1	2	1	1
S. danae	3	1		1	1?

indirectly to agricultural improvement. The lowering of watertables and subsequent seral changes may have also been caused partly by increased extraction of water. All the remaining localities of the three species were found to be threatened by the development of scrub in the absence of control by fire or grazing, and their survival today increasingly depends on deliberate conservation management.

It is concluded that the remaining populations of acid water dragonflies in eastern England are probably as isolated as indicated in Figures 1-3, and that the declines of the three species in the present century are due to the cessation of peat digging and to agricultural improvement.

THE SIZE OF THE REMAINING POPULATIONS OF ACID WATER DRAGONFLIES IN EASTERN ENGLAND AND THEIR DEGREE OF ISOLATION

Most of the surviving populations of acid water dragonflies in eastern England have apparently existed in their present condition for several decades. A possible exception is that of *O. coerulescens* in Harwood Dale. This colony was discovered by T. Graves in 1981. Other bogs exist on the North Yorks Moors and it is quite possible that other colonies will be found nearby in the future: the Harwood Dale colony may not be as isolated as it appears on Figure 2.

From the conservation point of view it is highly desirable to know the size of isolated, but apparently viable colonies. Unfortunately they are too vulnerable to be subjected to population studies based on capture/recapture methods involving marking. Accordingly I have used an index to indicate the order of magnitude of population sizes. I have counted the number of territorial males under optimal conditions of time and weather (MOORE, 1953). Since it was not possible to make many visits to the sites, I have supplemented the observations by measuring the amount of water body habitat on each site. Then, by using values of Highest Steady Density obtained in Dorset (MOORE, 1964), I have calculated the maximal number of territories which each site might possibly hold.

The numbers of adult dragonflies produced in any water body in one year depends on the number of eggs laid in it, the amount of food available, the amount of predation and on the area of suitable habitat in the water body. The number of territorial males at any particular water body depends on the intrinsic behavioural characteristics of the species concerned which determines territory

size, and also the size of the water body. Thus, the total population is related to the number of territorial males present but cannot be calculated accurately from the latter. Nevertheless published studies (e.g. PARR, 1973; BANKS & THOMPSON, 1985; MOORE, 1964) suggest that the number of dragonflies produced at any one water body rarely exceeds x100 the largest number of males present on any one day during the flying season. Future work may show this to be a false assumption, but at present it appears reasonable. Therefore, I suggest that the values obtained by observation and calculation in Table II indicate that all but one of the populations (that of *S. danae* at Sandringham Warren) consist of hundreds or thousands of individuals or less, rather than tens of thousands or hundreds of thousands.

The degree of isolation of these colonies is expressed in Table II by the distance of each population from the nearest one of the same species.

It is concluded that in eastern England the three acid water dragonfly species have survived in isolated populations for at least 40 years in what, entomologically speaking, are very small numbers.

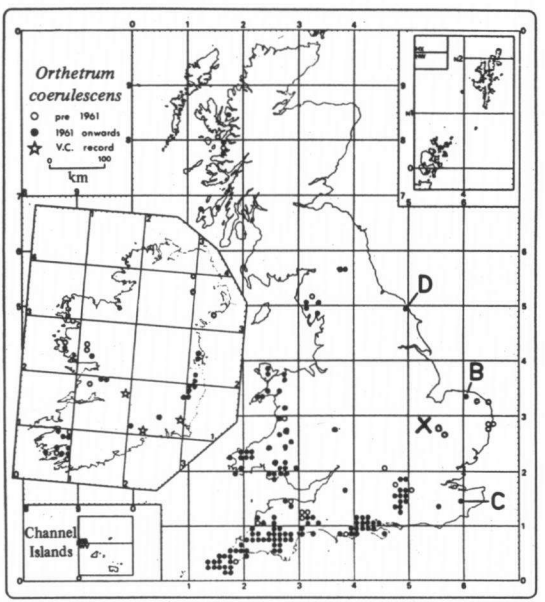

Fig. 2. Distribution of *Orthetrum coerulescens* in the British Isles (revised after CHELMICK, 1979 and HAMMOND, 1983). — B: Holt Lowes, Norfolk; — C: Hothfield Common, Kent; — D: Hardwood Dale, Yorkshire; — X: Wood Walton Fen, where new acid water ponds have not yet been colonised by this species; Holme Fen is in the same 10 km square.

ATTEMPTS TO RESTORE ACID WATER DRAGONFLIES TO THE FENS

Some of the low-lying, reclaimed land in eastern England, known as the Fens, was once covered by acid peat and supported populations of the acid water dragonflies described in this paper. By the time this study was started no permament acid waters remained. A small *Sphagnum* bog survived in the Holme Fen National Nature Reserve (NNR) (Fig. 3). However, it dried out too often to support dragonflies. Nearby at the Wood Walton Fen National Nature Reserve

Table II

The size and isolation of populations of acid water dragonflies in eastern England

Species	Locality (number of visits)	Distance from nearest locality (nearest 5 km)	Suitable habitat (water edge in m)	Largest number of territorial ♂ observed	Calculated maximal population of territorial ♂
C. tenellum	Scarning Fen (3)	185	20	6	29
O. coerulescens	Holt Lowes (5)	185	100	15	15
	Hothfield Common (2)	45	170	6	25
	Harwood Dale (1)	135	180	9	27
S. danae	Roydon Common (1)	80*	150	8	26
	Sandringham Warren (1)	80*	1,100	19	188

* This distance is from the nearest site in Lincolnshire. The two *S. danae* sites are 6 km apart. They are 40 km from Holt Lowes, where one individual *S. danae* was seen on 6. August 1984.

(see Figs 1-3) there was an area of acid fen supporting plants such as *Myrica gale, Calluna vulgaris* and *Erica tetralix,* but it contained no ponds. If a pond could be dug in this fen it would provide an acid water body which could be used to test the dispersal ability of the more robust acid water dragonflies (*O. coerulescens* and *S. danae*) and could be used as a site for reintroducing *C. tenellum,* which was most unlikely to get to the Fens unaided. The Wood Walton Fen Management Committee kindly gave me permission to carry out these experiments. The first pond (A) was dug by Mr Gordon Masøn MBE and his staff in 1974, and two more ponds (B&C) in 1980. Emergent plants (*Cladium, Juncus,* etc.) were planted round the edges of the ponds, and nearby birch (*Betula*) trees and bushes were cut down. The circumference of each pond was about 20 m and their pH ca 5.0.

When studying dragonflies on the Dorset heathlands in the 1950s I found that most of the ponds which supported *C. tenellum* contained *Sphagnum,* but not all of them. In 1979 I confirmed this finding by a further study of 35 acid water ponds in Dorset. *C. tenellum* was present at all the 14 ponds which contained *Sphagnum,* and on 14 of the 21 ponds which had no *Sphagnum.* Emergence of *C. tenellum* was observed from six of the ponds with *Sphagnum* and from two of the ponds without it. In one of the latter *Utricularia* was present, in the other a non-sphagnum moss. *Utricularia* developed naturally in pond A at Wood

Walton. *Sphagnum magellanicum* was introduced from a Dorset pond into ponds B & C at Wood Walton 1980. It survived for the length of the introduction experiment, but had died out by the end of 1983.

In 1974, 1975, 1979 and 1980 mature male and female *C. tenellum* were caught at a site in Dorset (see Fig. 1) where the species is extremely abundant. The insects were put in a darkened muslin cage and released on the day following capture at the edge of the Wood Walton ponds. The details of the releases and their results are shown in Table III.

It will be seen from Table III that pond A was quickly discovered by dragonflies, and within 5 years 14 species had appeared and half of them were proved to breed. However, none were acid water species. In 1980 and 1982 *Aeshna juncea* appeared on pond A, including a copulating pair. This is not a true acid water species, being found in water of a wide range of pH. Nevertheless in eastern England it seems to be virtually confined to acid waters. In East Anglia it has only been recorded from six 10 km squares in recent years (HAMMOND, 1983). Until recently its nearest locality to Wood Walton Fen was in the Breck country of Norfolk, about 110 km away. However, in 1972 the Nature Conservancy Council (NCC) began to excavate meres in the peat of the Holme Fen NNR, which is about 10 km from the Wood Walton Fen ponds, and *A. juncea* has been proved to breed there in recent years (BOSTON, 1984 and pers. comm.) The *A. juncea* observed at Wood Walton Fen probably originated from Holme Fen.

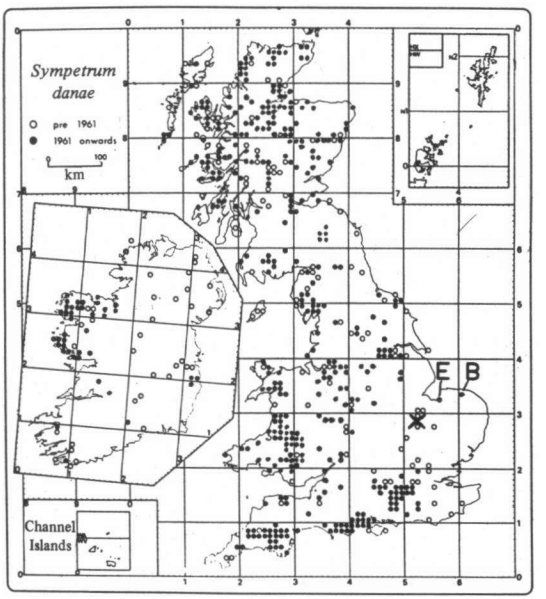

Fig. 3. Distribution of *Sympetrum danae* in the British Isles (revised after CHELMICK, 1979 and HAMMOND, 1983). — B: Holt Lowes, Norfolk (1 ♂ seen on 6 August 1984); — E: Sandringham Warren and Roydon Common, Norfolk; — X: Wood Walton Fen, where new acid water ponds have not yet been colonised by this species; Holme Fen is the same 10 km square.

In the twelve years that there has been acid water at Wood Walton Fen no *O. coerulescens* or *S. danae* have been observed there. This is not surprising conside-

Table III

New acid water ponds at Wood Walton Fen, their colonisation by Odonata and the introduction of *C. tenellum* to them

Date	Habitat changes	Cumulative totals of species observed (breeding) at pond A	Visits by acid water species	Numbers of *C. tenellum* introduced ♂	♀	Success and failure of introductions
1974	Pond A dug	7	—	6	7	+
1975		8(3)	—	39	40	—
1976	Pond A nearly dry	10(4)	—			
1977		14(6)	—			
1978		14(7)	—			
1979		14(7)	—	8	7	—
1980	Ponds B & C dug *Sphagnum* introduced	15(7)	A_j	35	18	—
1981	Reeds increased	15(7)	—			
1982		15(7)	A_j			
1983	*Sphagnum* last seen	15(7)	—			
1984	Reeds increased	15(7)	—			
1985	Reeds increased	15(7)	—			

A_j = *Aeshna juncea*. — The introductions in 1974, 1975 and 1979 were at pond A, those in 1980 were at ponds B and C. — See also Table IV.

ring the small size of their nearest populations and their distance away (see Figs 2 and 3). Nevertheless at least one *S. danae* has reached Holt Lowes (see Tab. II and Fig. 3) since 1979. Presumably it came from Roydon Heath or Sandringham Warren which are 40 km away.

C. tenellum takes two years to develop (CORBET, 1962) and so searches were made for adult insects two years after each introduction. The first (1974) introduction was successful: adult progeny from it were observed between 30.VI.76 and 11.VII.76. The largest number of males seen on one day was five: this was on 7.VII.76. Two females were seen on 10.VII.76 and oviposition was observed. On the other hand the other introductions to pond A in 1975 and 1979 were unsuccessful as were the two introductions to ponds B and C in 1980. The population emerging in 1976 left no progeny.

The failure of the 1975 introduction was probably due to the exceptional drought of 1976 which caused pond A to virtually dry out by the end of the summer. The reasons for the failure of the 1979 and 1980 introductions are not obvious. The insects travelled well and nearly all of them appeared healthy on release. The data in Table IV show that in 1980 (as in 1974 and 1975) some males took up territories effectively. The deterioration of habitat due to encroachment by reeds (*Phragmites*) was not significant until after the end of the experiment.

Table IV

The fate of adult *C. tenellum* introduced to new acid water ponds at Wood Walton Fen, 1974-1980

Introduced on	Number introduced	Numbers of individuals observed on days following introductions																									
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28* ... *44* ... *47th day*
19.VI.1974	6 ♂	3			0	1															2		2					0	
	7 ♀	0			0	0															0		0					0	
6.VII.1975	39 ♂			3												3													0
	40 ♀			1												2													0
10.VII.1979	8 ♂												0																
	7 ♀												0																
21.VI.1980	15 ♂											1									4						0		
	6 ♀											0									0						0		
19.VII.1980	20 ♂								7	10																		0	
	12 ♀								0	0																		0	

Once can only speculate on the cause of failure. Perhaps there was insufficient food for the larvae in the newly dug ponds B & C. Perhaps *C. tenellum* adapted to the mild climate of Dorset were unable to survive in the more rigorous climate of Cambridgeshire. Predation and competition patterns may have differed; certainly at the remaining eastern site at Scarning Fen *C. tenellum* appears not to share the habitat with any other dragonfly species.

DISCUSSION

What can be learnt from these tentative and incomplete studies? I believe they suggest an order of conservation priorities.

Priority 1: Maintain existing populations by effective habitat management.

Priority 2: Give support to existing populations by constructing new habitats nearby.

Priority 3: Construct new habitats in areas in which the species has become extinct, introducing individuals if necessary.

As regards acid water dragonflies in eastern England, operations under Priority 1 are already being carried out. The Norfolk Naturalist Trust controls the development of scrub on its reserves at Scarning Fen. When I observed the threat which scrub posed to the *O. coerulescens* population at Holt Lowes I got in touch with the Regional Office of the NCC, and thanks to them, the Norfolk Naturalist Trust and the Managers of the Holt Lowes Country Park, the threat to existing habitat has been greatly reduced and damaged habitats are being restored.

In Dorset both the NCC and the Royal Society for the Protection of Birds have constructed new ponds in reserves which already contain acid water habitats. These new ponds have been colonised by *C. tenellum, O. coerulescens* and *S. danae* among other species. It would not be difficult to make similar ponds on the heathland nature reserves managed by the Norfolk Naturalist Trust, and these would support existing populations nearby (see Priority 2).

The Fens are now so far from existing populations of acid water dragonflies that introductions are probably the only feasible means of restoring these species to the region. There is scope both at the National Trust's reserve at Wicken Fen

(see Fig. 1) and the NCC's NNR at Chippenham Fen (see Fig. 1) to make new peat diggings which could be sites for future introduction experiments. Proposals are currently under discussion. It may prove easier to reintroduce *C. tenellum* to these fens than to Wood Walton Fen. Meanwhile, the more we can learn about the biology of *C. tenellum* the more likely we are to succeed in re-establishing it in the Fens. There is nothing like trying to reintroduce a species into its old haunts to show how little we still known about its basic biology.

ACKNOWLEDGEMENTS

My thanks are due to the Nature Conservancy Concil for allowing me to carry out experiments at the Wood Walton Fen NNR, and to JOHN MASON for making some of the counts of *C. tenellum* at the Fen when I was unable to make them myself.

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