Ecology of the Southern Damselfly

Coenagrion mercuriale

Conserving Natura 2000 Rivers

Ecology Series No. 8

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This document was produced with the support of the European Commission's LIFE Nature programme. It was published by **Life in UK Rivers**, a joint venture involving English Nature (EN), the Countryside Council for Wales (CCW), the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), and the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER).

ISBN 1 85716 714 7

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This document should be cited as: Thompson DJ, Rouquette JR & Purse BV (2003). *Ecology of the Southern Damselfly.* Conserving Natura 2000 Rivers Ecology Series No. 8. English Nature, Peterborough.

Technical Editor: Lynn Parr
Series Ecological Coordinator: Ann Skinner

Cover design: Coral Design Management, Peterborough.
Printed by Astron Document Services, Norwich, on Revive, 75% recycled post-consumer waste paper, Elemental Chlorine Free. 1M.

Cover photo: Peter Perfect/Woodfall Wild Images

Conserving Natura 2000 Rivers

This account of the ecology of the southern damselfly (*Coenagrion mercuriale*) has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of reports collating the best available information on the ecological requirements of each species and habitat, while a complementary series contains advice on monitoring and assessment techniques. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Life in UK Rivers is very much a demonstration project, and although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set 'conservation objectives' and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

As part of the project, conservation strategies have been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving favourable conservation status.

Understanding the ecological requirements of river plants and animals is a prerequisite for setting conservation objectives, and for generating conservation strategies for SAC rivers under Article 6.1 of the Habitats Directive. Thus, the questions these ecology reports try to answer include:

- What water quality does the species need to survive and reproduce successfully?
- Are there other physical conditions, such as substrate or flow, that favour these species or cause them to decline?
- What is the extent of interdependence with other species for food or breeding success?

For each of the 13 riverine species and for the *Ranunculus* habitat, the project has also published tables setting out what can be considered as 'favourable condition' for attributes such as water quality and nutrient levels, flow conditions, river channel and riparian habitat, substrate, access for migratory fish, and level of disturbance. 'Favourable condition' is taken to be the status required of Annex I habitats and Annex II species on each Natura 2000 site to contribute adequately to 'favourable conservation status' across their natural range.

Titles in the Conserving Natura 2000 Rivers ecology and monitoring series are listed inside the back cover of this report, and copies of these, together with other project publications, are available on the project website: www.riverlife.org.uk.

Introduction

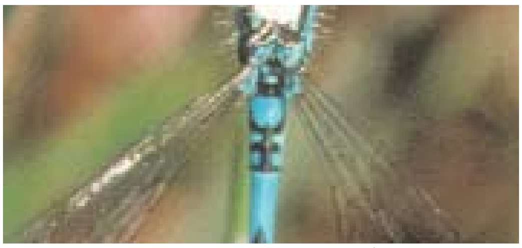
The southern damselfly (*Coenagrion mercuriale*) is one of Europe's rarest and most threatened damselflies. It is one of five members of the genus *Coenagrion* currently found in Britain. This genus, together with the common blue damselfly (*Enallagma cyathigerum*) and the white-legged damselfly (*Platycnemis pennipes*), constitutes the 'blue damselflies', which are all blue and black in coloration, and of which the southern damselfly is the smallest.

Males can usually be distinguished from other British blue damselflies by the 'mercury mark' on the second abdominal segment. However, this mark shows considerable variation within and between populations, such that the anal appendages and black spines along abdominal segments 3–5 constitute more reliable characters for identification (Askew 1988; Brooks & Lewington 2002; Hammond 1983).

Steve Cham

Rupert Perkins

Rupert Perkins



Dennis Bright/Environment Agency

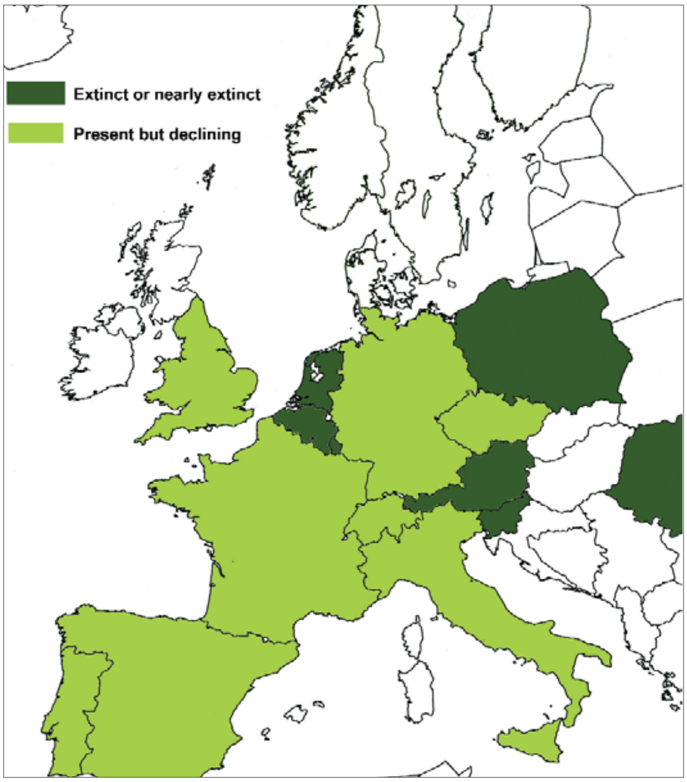
The blue damselflies look very similar from a distance, but a male *Coenagrion mercuriale* (top), can be distinguished from *Enallagma cyathigerum* (centre left) and *Platycnemis pennipes* (above) by a mercury mark on the second abdominal segment (left).

There are two female forms or morphs. The heterochrome (multi-coloured) form is olive green laterally with small pale marks anteriorly on segments 7–10. In the homeochrome (single-coloured) or andromorph (male-like) form, the pale colour is more extensive and the rest of the body is blue like the male's. The female may be distinguished from the azure damselfly (*Coenagrion puella*) and the common blue damselfly by the pale markings described above, and from *C. pulchellum* by the straight hind margin of the pronotum (the upper surface of the first thoracic segment) (Askew 1988; Brooks & Lewington 2002; Hammond 1983).

Additional characters for both sexes include a short, lozenge-shaped pterostigma (wing marking) and large, rounded spots behind the eyes (post-ocular spots). As with all coenagrionid damselflies studied to date, females are larger than males (mean left forewing length 16.5 mm for males, 18.2 mm for females; mean fresh body mass 21.6 mg for males, 26.4 mg for females) (Purse 2001).

Status and distribution

The southern damselfly is protected within Europe as a whole, and several European countries, including the UK, have taken complementary legislative measures for protection at a national or regional level (van Tol & Verdonk 1988; Grand 1996) (Table 1). It is the only resident British odonate to be listed in the Habitats Directive, and is listed on Schedule 5 of the UK Wildlife and Countryside Act 1981. It was added in 1998.



***C. mercuriale* has become increasingly rare or even extinct in many European countries. Consequently, it is now protected by international and regional legislation.**

The southern damselfly is restricted in distribution at both a global and national level. It is limited to the south and west of Europe and has populations of unknown status in northern Africa. Populations in Italy and northern Africa consist of different sub-species (*C. m. castellani* and *C. m. hermeticum* respectively) to other European populations (Askew 1988). It has disappeared from, or is on the edge of extinction in, seven European countries along the northern boundaries of its distribution (Austria, Belgium, Luxembourg, Netherlands, Poland, Romania and Slovenia) and is declining in three others (Britain, Germany and Switzerland) (Grand 1996).

UK distribution

Up to 25% of the global population of the southern damselfly is found in the UK. It is on the northern edge of its range in Britain and has a discontinuous distribution, restricted mainly to the south and west of the country. Major strongholds of populations are found on heathlands in

Table 1. Protection measures for the southern damselfly.

Legislation or convention	Level
Listed on the Bonn Convention for the conservation of Migratory Species of Wild Animals.	International
Listed on Appendix II of the Berne Convention on the Conservation of European Wildlife and Natural Habitats (1979), which outlaws the collection or possession of listed species.	International
Listed on Annex II of the European Community Habitat and Species Directive (1992), which requires the designation of Special Areas of Conservation (SACs) for animal and plant species of community interest.	Europe
Listed on Schedule 5 of the Wildlife and Countryside Act (1981), which protects against damage and killing of individuals, and damage or destruction of habitat, and protects biotopes in localities designated as Sites of Special Scientific Interest (SSSIs).	Britain
Listed as Rare (Category 3) in the British Red Data Book, and also features on the red lists of other European countries (Grand 1996).	Britain and Europe
Subject of the UK Biodiversity Action Plan (HMSO 1994).	Britain

the New Forest in Hampshire and the Preseli hills in Pembrokeshire, with scattered populations in Devon, Dorset and the Gower Peninsula, and single populations in Anglesey and Oxfordshire. There are also large centres of population in water meadow ditch systems surrounding the River Itchen and, to a lesser extent, the River Test in Hampshire. The UK distribution of the species is known very accurately because of sustained monitoring by the British Dragonfly Society.

The species has suffered a 30% decline in UK distribution since 1960. It has disappeared from Cornwall, has declined in Devon and Dorset, and has been lost from St. David's Peninsula in Pembrokeshire. The main factors influencing the decline are changes in grazing regimes, increasing habitat fragmentation, land drainage and water abstraction.

Although the two habitat types in which the southern damselfly is found in Britain (heathland streams/valley mires and water meadow ditch systems surrounding chalkstreams) seem different at first sight, there are actually many similarities for the ecological requirements of the species.

Life history

Emergence and immature period

Southern damselfly adults emerge from their final larval stage in mid-May until late July, depending on latitude and altitude. In 2002 there were mating pairs on at least two New Forest streams as early as May 19. On one of the Dartmoor sites, adults began emerging in the second week in June, and some were still appearing in the last week of July (DJ Thompson, unpublished).

The southern damselfly usually emerges in the morning in an upright position. Final instar larvae leave the water by ascending emergent vegetation, rather than by walking onto shore. There appears to be no consistent trend in plant species used by the southern damselfly. In southwest Germany, exuviae (cast skins) were found on rushes (*Schoenus* spp., *Juncus subnodulosus* and *J. alpinus*) and sedges (*Carex* spp.) (Buchwald 1989).

However, elsewhere in Europe, emergence perches for the southern damselfly include semi-emergent plants such as lesser water parsnip (*Berula erecta*), bittersweet (*Solanum dulcamara*), water mint (*Mentha aquatica*) and watercress (*Rorippa nasturtium-aquaticum*) (Sternberg *et al.* 1999). Purse & Thompson (2003a) concluded that the ideal emergence perches were plants with rigid stems that would not bend in the wind. The damselfly's wings and abdomen were less likely to be damaged if they did not touch surrounding vegetation during expansion and drying. In this study, such damage was a major cause of mortality at emergence, and deformed individuals that survived emergence rarely survived to sexual maturity.

Following emergence, adults leave the immediate vicinity of the water and move to feeding sites, where males acquire their mature coloration. The immature period of damselflies and dragonflies is poorly understood in terms of its length, where it is spent, and the behaviour of immature individuals. Banks & Thompson (1985) found that, in the azure damselfly, the immature period lasted for a mean of 13 days for males and 16 days for females, depending on prevailing weather conditions. In the southern damselfly, the immature period is less: Purse & Thompson (2003a) estimated that in good weather this stage lasted between five and eight days.

Dennis Bright/Environment Agency

The cast skins of *C. mercuriale* can be found on a variety of different emergent plants, as long as they have rigid stems.

Reproductive biology

The reproductive biology of the southern damselfly has recently been reviewed by Purse & Thompson (2003b). Following maturation, males visit the breeding sites almost every day of their mature adult lives unless there is bad weather. Reproductive activity is restricted largely to warm sunny days.

Females visit the breeding sites whenever they have a clutch of eggs to lay. It is not clear how frequently females can produce a clutch of eggs, as the situation for the southern damselfly at the northern margin of its range would appear to be more complex than for other damselflies studied at this latitude, which are not on the edge of their range. For example, both the azure damselfly and the large red damselfly (*Pyrrhosoma nymphula*) lay their entire clutch of eggs on each visit to their breeding sites (Banks & Thompson 1987, Gribbin & Thompson 1990). However, in the population of southern damselfly studied at the Crockford Stream in the New Forest, females did not lay their entire clutch of mature eggs before leaving the breeding site (BV Purse, unpublished) so that frequency of visits by females does not necessarily equate with frequency of mature clutches laid.

Males fly slowly and erratically over the breeding sites, but rarely for long distances. They often perch at vantage points to look for females. They are not territorial in the sense that they defend a particular length of stream, but they do tend to remain in the same area, sometimes throughout their entire adult lives, despite leaving each day to visit nearby roosting sites.

When females visit the breeding sites, males scramble to seize them. Copulation occurs in tussocks of vegetation in or beside the streams. The mean length of copulation in the study of Purse & Thompson (2003b) was 23.13 min (± 1.63 standard error). The structure of the penis indicates that males have access to almost the entirety of a female's sperm store. The threads at the apex of the penis, the cornua, are narrower and longer than the spermothecal duct, which leads to the sperm storage organs of the female, the bursa and the spermotheca. This is indicative in other odonates of a male's ability to remove rivals' sperm from those organs (Waage 1986, Robinson & Novak 1997).

Steve Cham

C. *mercuriale* pairs copulate on vegetation beside or in streams, remaining in contact with each other for about 70 minutes.

The presence of sperm on backward-pointing spines visible in scanning electron microscope photographs of the penis suggest that most of the time in copulation is spent by the male removing sperm from the sperm storage organs of the female, and insemination itself occurs only at the end of the copulation bout.

Pairs spend around 70 minutes together. As well as about 23 minutes spent in copulation, they spend around 30 minutes ovipositing and the remainder searching for suitable oviposition sites following copulation (Purse & Thompson 2003b). Copulations occur throughout the day, though there is a peak around midday.

The female oviposits in submerged plant stems. She lands on the plant substrate while the male either hovers upright on her prothorax (top part of the thorax, or upper body) while still attached to her. Typically, the male remains in contact with the female throughout the entire oviposition, a phenomenon known as contact guarding. On around 15% of occasions when the female submerges completely (BV Purse, unpublished), males break off contact and perch nearby (non-contact guarding) and usually leave before oviposition is complete. Females sometimes oviposit without the presence of males at the end of the day or at the end of the season.

Nigel Holmes

The southern damselfly prefers to oviposit in perennial plants with soft stems, such as watercress (above).

The eggs are laid into plant tissue. Pairs usually oviposit in several stems during an oviposition bout. Twenty-three plant species have been recorded as oviposition substrates used by the southern damselfly (Purse 2001). In the chalkstream water meadow ditches around the rivers Test and Itchen these include fool's watercress (*Apium nodiflorum*), lesser water parsnip, reed sweet-grass (*Glyceria maxima*), watercress, brooklime (*Veronica beccabunga*) and blue water-speedwell (*V. anagallis-aquatica*). BV Purse (unpublished) found that some plant species in the Crockford Stream, New Forest, were used more frequently than would be expected on the basis of their abundance. These preferred species were marsh St John's wort (*Hypericum elodes*), bog pondweed (*Potamogeton polygonifolius*) and jointed rush (*Juncus articulatus*).

It seems that the southern damselfly is largely opportunistic, but with a preference for oviposition in soft-stemmed plants, in which it is presumably easier to make the incision with the ovipositor before placing the egg. In addition to the physical properties of the preferred plant species, most share similar temporal properties. Most are perennial and at least semi-evergreen, providing some form of permanent cover for larval development. In the most suitable plants, southern damselfly females were able to deposit eggs at a rate of 14.66 eggs per minute (BV Purse, unpublished). This is amongst the highest deposition rates recorded for coenagrionid damselflies (Martens 1992). However, this rate is probably a reflection of the suitability of the plants in this study (marsh St John's wort and bog pondweed), as Martens (1999) found a much lower rate (3.66–5.08 eggs per minute) in a French population. Martens also noted that pairs of southern damselfly tended to aggregate during oviposition.

In Europe, oviposition occurred where water currents were between 0 and 5 cm s^{-1} (Sternberg *et al.* 1999), but in British chalk stream water meadow populations, oviposition required discernible flow of not less than 2.9 cm s^{-1} (Strange 1999).

BV Purse (unpublished) found 75% of eggs hatched within four weeks in stream conditions. A further 13% had begun to develop, but not beyond the appearance of eye spots. Since the eggs in this study came from single clutches, there is evidence of asynchronous emergence from a single clutch. Corbet (1955) found the hatch period to be a little shorter (three weeks), but his study was carried out in captivity.

Larval biology

The absence of a diapause (a period of suspended development found in some insects) in the egg stage means that egg hatch may occur from mid-June until late August. The southern damselfly exhibits semi-voltine development (a two-year life history) in Britain (Corbet 1957b; Purse & Thompson 2002) and in most mid-European populations (Sternberg *et al*. 1999).

Jim Rouquette

Late instar larva of *Coenagrion mercuriale*. Most southern damselfly larvae reach the final of 13 growth stages by their second winter.

Thielen (1992) reported a univoltine (single generation per year) life history at a German site subjected to increased temperatures due to water used in industrial cooling processes. Thus voltinism is a plastic trait and probably varies across the range of the species according to temperature and productivity. Growth occurs between March and October in Britain and most larvae reach the final (F), penultimate (F_1) or antepenultimate (F_2) stage by the second winter. The growth rate data provided by Purse & Thompson (2002) indicate a diapause (period of arrested development) in the penultimate larval instar in the autumn. There are 13 larval instar stages (Corbet 1955), though little is known about the first few.

This variation in larval growth, which begins at the egg stage, accounts for the lack of synchrony in adult emergence. One of the consequences of an asynchronous and semi-voltine life history is the possibility of interference competition between the two year-classes present at any one time. One way of avoiding this might be microhabitat separation between the senior and junior year-classes, as occurs with the emperor dragonfly (*Anax imperator*) (Corbet 1957a). However, neither Purse & Thompson (2002) nor Thielen (1992) were able to demonstrate such separation. It is possible that spatial separation may be achieved by small instars retreating further towards the base of submerged vegetation.

Food and feeding

Damselflies are general predators, both as larvae and adults. Coenagrionid damselfly larvae that develop over two years (like *C. mercuriale*) tend to be 'sit-and-wait' predators that attack any small moving animals that swim or crawl past their fishing sites. Studies of larval feeding ecology have invariably shown that prey are taken in accordance with their abundance in the environment (Thompson 1978 a, b). Harris (2000) analysed faecal pellets produced by southern damselfly larvae from the Glan-yr-afon Uchaf stream in Mynydd Preseli, Pembrokeshire. The principal prey items

Lynn Parr

***C. mercuriale* larvae prey on small invertebrates, such as freshwater shrimp.**

found were fly larvae, including blackflies (simuliids) and non-biting midges (chironomids), mayfly larvae (ephemeropterans), and small freshwater shrimp (gammarids). These groups were abundant in invertebrate samples taken from the same site (BV Purse, unpublished).

Relatively little is known about the feeding ecology of adult damselflies. Most feed on small flying invertebrates. Studies of the azure and large red damselflies revealed that females can virtually double their emergence weight by the time they appear at the breeding site to lay their first clutch of eggs (Banks & Thompson 1987, Gribbin & Thompson 1990). Thus females, at least, must have access to a good source of small flying invertebrates to realise their full reproductive potential.

Competitors and predators

The main competitors of southern damselfly larvae are likely to be any other small predators that share their habitat, and in particular any other damselfly or dragonfly larvae (odonates). Although many odonates are found on the same sites as the southern damselfly, relatively few species utilise the same stretches of stream as the larvae or have such highly specific habitat requirements. On heathland sites, the latter include the small red damselfly (*Ceriagrion tenellum*), the large red damselfly (*Pyrrhosoma nymphula*), the golden-ringed dragonfly (*Cordulegaster boltonii*), and the keeled skimmer (*Orthetrum caerulescens*). Indeed, the southern damselfly was only found at high densities at Waun Fawr in Pembrokeshire when these other species were absent or present in low densities (Evans 1989).

Lynn Parr

In the Test and Itchen valleys, larvae of demoiselles such as *Calopteryx* spp. are potential predators of *C. mercuriale* larvae.

In the Test and Itchen valleys the likely odonate competitors are slightly different. *Ceriagrion* and *Orthetrum* are absent, but other competitors include the banded demoiselle (*Calopteryx splendens*), the azure damselfly, the common blue damselfly, the blue-tailed damselfly (*Ischnura elegans*), and the common darter (*Sympetrum striolatum*).

Given current knowledge, predators of southern damselfly larvae can only be speculated upon. Some of the larger competitors, notably the golden-ringed dragonfly and the keeled skimmer, are potential predators. Other predators are likely to include fish. There are few data available on the prey of adult southern damselfly. However, there are some data on their predators. Purse & Thompson (2003a) found that mortality at emergence was low (5.1%) compared with other odonate studies, where estimates for mortality in the large red damselfly ranged from 3.3% (Bennett & Mill 1993) to 28% (Gribbin & Thompson 1991).

A significant proportion of the mortality in all of these studies was due to predation. In Purse & Thompson's study, the predators were mainly spiders. After emergence, BV Purse (unpublished) also found that 5% of observed ovipositions were disturbed by predation by spiders and water striders. Common lizards and stonechats have been observed to take adults, and many have been found stuck on sundew (*Drosera* spp.) at a range of heathland sites.

In keeping with most damselflies, adult southern damselflies often carry a considerable mite burden (*Arrenurus* spp.). Rehfeldt (1995), cited in Corbet (1999), found that mite-infested coenagrionid males made less frequent and briefer flights than mite-free males. They were also attacked by other individuals of the same species more often than those without mites, and were less likely to form mating tandems. Females were less likely to accept mite-infested males.

Adult *C. mercuriale* sometimes fall prey to the common lizard (top), while the larvae may be preyed upon by the larvae of *O. caerulescens* (top right) and *Cordulegaster boltonii* larave (bottom right). Larvae of *S. striolatum* (bottom left) may compete with *C. mercuriale* larvae, particularly in the Test and Itchen valleys.

All photos by Rupert Perkins

Genetics

Minimum viable population sizes have not been investigated for the southern damselfly but some generalisations can be made on the basis of work on other species. Brakefield (1991) states that if a management programme maintaining populations of a few hundred individuals failed, its failure would probably be due to variation in ecological conditions, rather than because of a loss of genetic variation. Most populations of the southern damselfly in Britain probably have small population sizes. But even if populations go through intermittent short bottlenecks, genetic variation is less likely to influence population persistence than variation in ecological conditions. The question then becomes just how small can population sizes become during bottlenecks, and the importance of replenishment of genetic material through dispersal.

Researchers at Liverpool University are currently exploring variation in microsatellite DNA (a region of DNA characterised by short [2–6 base pairs] sequence motifs [e.g. CA, GTT] that are repeated a huge number of times in tandem), within all the British the southern damselfly populations. A large number of polymorphic microsatellite loci (positions on chromosomes where different forms of microsatellite are located) have been identified and attempts are under way to relate genetic variation to population structure, population density, degree of isolation, habitat type and other variables. This study is due to report in 2005.

Population parameters

Mortality has been investigated at several stages in the life cycle of the southern damselfly (Purse 2001). At the egg stage, mortality during the hatch period was found to average 14% (but was highly variable), while at emergence it was found to be low (around 5%). It is probable that the maturation period is one in which much mortality occurs. Purse & Thompson (2003a) found that, at Crockford Stream, New Forest, only 22 of the 462 of individuals marked at emergence (4.8%) were recaptured after the maturation period.

In contrast, mortality in the mature adult stage, as estimated using sophisticated mark-release-recapture methods (Lebreton *et al*. 1992) was consistently low, with daily survival rates of between 0.8 and 0.9 for both males and females (Purse 2001). These fall well within the range typically found for odonates (Corbet 1999). Given that the larval stage makes up 95% of the lifespan of a semi-voltine species, the highest percentage mortality probably occurs in this stage, but is notoriously difficult to measure.

Although mortality rates have been well studied in individual populations of the southern damselfly, published population density estimates of the species in Britain are non-existent. There are two difficulties. The first is deciding which stage of the life cycle to count. Should the estimate be of egg numbers, the input into the population at a given site? Since the southern damselfly spends most of its life as a larva, habitat use by the larvae may most accurately reflect the habitat requirements of the majority of the life cycle.

However, the stage of the life cycle apparent to most people is the mature adult, so perhaps density estimates of this short-lived stage might be the most important. Indeed it is the adult stage that has attracted most attention. There are many estimates of numbers of individuals seen by observers on particular sites on certain dates (reviewed in Purse 2001). The most useful of these data are those that are repeated several times within a season and over many seasons. Such data, if collected in a standardised way, can provide important information of relative abundance of adults from one time period to the next and, indeed, from one year to the next.

The second difficulty is that these data cannot be used to estimate absolute population densities in terms of numbers of animals per square metre. In fact, there are no published estimates of the relationship between transect count numbers and population density – what does a count of, say, 27 males seen in a 100 m length of stream on one sunny afternoon mean in terms of population density? In Aylesbeare Common, Devon in 1998, 217 adults were observed over the 1998 field season, but the maximum daily count was 75, with an average daily count of 10 males (BV Purse, unpublished). At Upper Crockford in 1997, the maximum daily count was 269 (62 on average) but 3000 adults were marked through the season (BV Purse, unpublished). Thus annual population sizes could be at least 10 times larger than daily adult counts.

The most useful stage of the life cycle on which to obtain population estimates is the number of emerging adults. This, at least, gives an indication of the production of animals from a particular site and thus reflects the suitability of the habitat for the egg and larval stages. It can be obtained by counting exuviae. However, it is extremely labour intensive to obtain such data, given the length of the emergence period. Purse & Thompson (2003a) estimated, using emergence cages placed over the most suitable habitat in the Crockford Stream, New Forest, that the density of emerging adults of the southern damselfly was 52.2 per square metre ($\pm$ 10.8 s.e.). This is likely to be an estimate towards the upper end of its true population density in prime habitats.

Population density estimates of adults in terms of numbers per metre of stream can be obtained from mark-release-recapture (MRR) models, though almost all of those so far published for the southern damselfly have been used incorrectly, ignoring the underlying assumptions of simple models. MRR work carried out over periods longer than just a few days and the use of more sophisticated models, would be necessary to obtain worthwhile estimates of odonate population density (Lebreton *et al.* 1992).

One of the threats to the persistence of southern damselfly populations is increased fragmentation of its habitat, so dispersal ability is a key parameter for understanding population dynamics and population structure. Is its present distribution in Britain a series of isolated populations or does it occur in a metapopulation structure in at least some of its sites?

Purse *et al.* (2003) estimated dispersal in the Crockford Stream and in Glan-yr-afon Uchaf on Mynydd Preseli, Pembrokeshire. Figure 1 shows the net lifetime movement made by males and females at both sites. It is clear from these data that most individuals of both sexes at both sites moved very little during their mature adult lifespans, but also that some individuals were capable of relatively large dispersal distances, in one case in the Crockford study, over a kilometre.

A closer analysis of these data revealed that there was a significant difference between the two sites in the distribution of net lifetime movements. More dispersal of an intermediate distance occurred in Mynydd Preseli, probably due to greater availability of suitable habitat at intermediate distances. A much larger dataset from the Itchen valley is currently being analysed (JR Rouquette & DJ Thompson, unpublished).

The southern damselfly has traditionally been viewed as a particularly poor disperser, based partly on a combination of folklore, partly on watching individuals fly for short periods, and partly on small studies carried out over relatively short

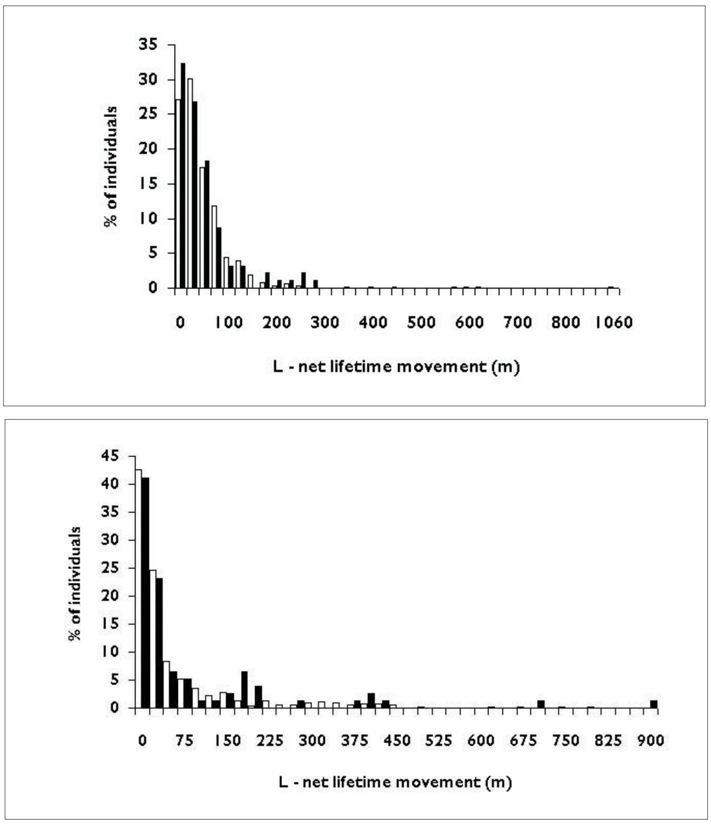


Figure 1. Percentage distribution of net lifetime movements (L) for male southern damselflies (open bars) and females (closed bars) in the New Forest (top left) and at Mynydd Preseli (bottom left). In both sites, most recaptured individuals dispersed over short distances but a few moved up to 1 km. The data are grouped in 25 m units, so that, for example, in the bottom figure, over 40% of males and females moved 25 m or less in their mature adult lifetimes (from Purse *et al.* 2003).

periods of time (Thompson & Purse 1999, Jenkins 2001). However, by comparison with the dispersal characteristics of the odonates studied by Conrad *et al*. (1999) it is clear that its dispersal potential is commensurate with its size – it is a small damselfly. Purse *et al*. (2003) were unable to detect any sex or size bias in their dispersal data.

Habitat requirements

Watercourse type

The data presented in this section represent a summary of those provided by Purse (2001). The southern damselfly requires base-rich, shallow streams with a constant slow-to-moderate flow and relatively high water temperature. In chalk stream water meadow systems, Strange (1999) found that adult populations were concentrated in channels where water velocities ranged from 7.5 to 20 cm s^{-1}. Flow rate in the larval habitats studied by Purse & Thompson (2002) in the Glan-yr-afon Uchaf, Pembrokeshire, ranged from 2 to 15 cm s^{-1}. Currents of around 10 cm s^{-1}(maximum of 35 cm s^{-1} allowing for a minimum concentration of 2.5–3.0 mg l^{-1} of oxygen, are important in determining the distribution of the southern damselfly in Baden Wurttemburg (Buchwald 1994).

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C. mercuriale **requires shallow, base-rich streams with a constant flow and relatively high temperature, such as such as the seepage that runs into the Latchmore Stream, New Forest (above) and the Peaked Hill Stream, a tributary of the Crockford Stream, New Forest (below).**

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Permanent conduction of water and proximity to springs or groundwater are cited as further important factors determining habitat suitability in Baden Wurttemburg. As well as assuring the permanence of water flow in shallow water bodies, springs maintain a higher than average temperature in winter (4–10°C in Baden Wurttemburg) (Buchwald 1989), and are more constant in temperature throughout the year, preventing freezing over or drying up. Similarly, chalk streams fed by groundwater or springs have a regular annual hydrograph. Since chalk is porous, the passage of water through rock is slow, so that the effects of irregularities in rainfall are smoothed and water temperature is stabilised at around 11°C all year (Berrie 1992).

Topography and geology

Although *C. mercuriale* may be found at altitudes up to 285 m above sea level (a.s.l.), in Britain it is mainly found at low altitudes. Eighty-two percent of sites occur below 90 m a.s.l. and the majority of these are found between 16 and 45 m a.s.l.. In France most sites occur below 400 m, though the species has been reported at one site at 1058 m. In Germany, most sites on meadow brooks and ditches were found between 400 and 500 m a.s.l., while those on alpine spring marshes were found between 500 and 920 m a.s.l.. The southern damselfly has been recorded at higher altitudes in Spain, up to 1500 m (Grand 1996), and above 1900 m in Morocco (Jacquemin 1994). The occurrence of the southern damselfly at high altitude in southern Europe, but at lower altitudes at the northern margins of its range, suggests specific thermal requirements.

Recently formed soft, calcareous deposits of clay, sandstone or limestone overlaid with acidic peat or gravel deposits feed most heathland streams occupied by the southern damselfly. Water meadow ditch systems are fed from chalk reserves. In both Germany and France limestone is found under those meadow streams and spring marshes occupied by the southern damselfly (Buchwald 1994; Grand 1996; Sternberg *et al*. 1999).

Plant species and communities associated with *C. mercuriale*

The southern damselfly is not associated with a particular plant species or plant community across its range, although bog St John's wort and bog pondweed (*Potamogeton polygonifolius*) are used by *C. mercuriale* in the majority of heathland sites, while reed sweet-grass, fool's watercress, and watercress occur in many chalk stream water meadow sites. In light of this, information on the prevalence of particular plant species is only useful when considering what these plants indicate about the chemical, hydrological and structural features of the habitat. Similarly, the southern damselfly is associated with a range of UK National Vegetation Community (NVC) types (see Table 2) showing a range of habitat preferences (Rodwell 1991, 1995).

Chemical parameters in watercourses occupied by the southern damselfly

A wide range of pH is found in watercourses on southern damselfly sites, although the majority of sites fall within the range 7.0–7.5. This is similar to the range found in the Upper Rhine valley (6.6–8.5) by Buchwald (1989). The main factor determining odonate distribution is seldom pH, however, and numerous species show a wide range of values (Corbet 1999).

Most sites have low conductivity values (less than 150 µS [microSiemans] cm s^{-1}), but those with the highest values were the Oxford and Anglesey fen sites, and the water meadow ditch systems of the Test and Itchen valleys, where levels typically reached around 550 µS cm s^{-1}. These high values presumably reflected the high input of calcareous water at these sites.

Phosphate concentration was less than 0.025 mg l^{-1} in most watercourses occupied by the southern damselfly, though there were some exceptions, most notably the Oxford fen site and parts of the Itchen valley, including the Itchen Valley Country Park. Most sites had low levels of nitrates (less than 0.2 mg l^{-1}) but there were more high nitrate than high phosphate values. These sites included those surrounded by improved and semi-improved grassland, as well as those surrounded by unimproved grassland or dry heath. It was not possible to relate nitrate or phosphate concentration to surrounding land use from these available data.

In monthly samples taken from the Glan-yr-afon Uchaf in Pembrokeshire, oxygen concentration ranged from 91–100% saturation (9.8 mg l^{-1} at 15°C at sea level). In Germany, on meadows in the Upper Rhine valley, the southern damselfly is found in well-oxygenated water with concentrations ranging from 2.5–30 mg l^{-1} (Buchwald 1989). The association of the southern damselfly with areas of high flow, high vegetation cover and proximity to springs may reflect its requirement for well-oxygenated water.

Table 2. Habitat types and NVC communities found on British southern damselfly sites.

Region	Habitat type	NVC communities
Oxford	Calcareous fenland including a flooded sand pit.	
Dorset	Wet heathland/valley mire in most sites, but one contains areas of poor fen. These sites are surrounded by dry heath, carr/scrub and unimproved grassland.	
Devon	Wet heathland/valley mire in both sites, with areas of basic flush surrounded by acid dry heath.	M14 found on and around streams.
Dartmoor	Wet heathland in both sites surrounded by carr/scrub and a mixture of acidic, improved and unimproved grassland. The habitat is sometimes described as Rhos pasture.	M16c and M25a were prevalent along streams with some M29 and M21a. M25a was again prevalent around streams.
New Forest	Most streams flow through valley mire and some through wet heathland. On four sites streams flow through burned mire. Most sites were surrounded by a type of heath – from the transition between wet heath and acid dry heath, but carr and acidic grassland were also present.	M21a and M29 were the most prevalent communities on streams, with some M14. Several communities were found around streams including S23, M9, S5, S4, S7, S14, MG8 and MG9.
Anglesey	Calcareous fenland with valley mire surrounded by moderately acidic grassland.	M13b and MG8 were found on the stream, surrounded by M24b.
Pembrokeshire	Wet heathland/soligenous valley mire with carr/scrub, acid, improved /semi-improved and unimproved grassland noted around streams.	M6c and M10 were found on streams, surrounded by M23.
Gower	Wet heathland/valley mire or boggy pasture surrounded by acid dry heath or unimproved grassland.	M15, M16c, M25a and H4 were found along stream sides.
Itchen and Test Valley	Water meadow ditch system on chalk streams where ditches flow through and are surrounded by improved, semi-improved and unimproved grassland. Carr/scrub surrounds half of the sites.	M9, MG11 and S23 were most prevalent on streams with some OV8, OV26, M22, S5 and S7. S23, S5, M9 were again prevalent around streams with some S4, MG8, MG9, S7 and S14.

Table 3 presents a summary of the main features required by the southern damselfly in Britain, and the possible ultimate factors governing selection of these features.

Potential threats

Fragmentation and population size

Areas of suitable habitat for *C. mercuriale* have become increasingly fragmented. Many British populations of the southern damselfly are isolated from other populations by tens of kilometres, well beyond the distance likely to be reached by individuals dispersing from other populations. Such isolated populations are thus more prone to extinction due to random environmental processes, as well as possible genetic effects. This problem is exacerbated by the relatively small size of some of the isolated populations.

Table 3. Summary of the main features required by the southern damselfly in Britain and the possible ultimate factors governing selection of these features.

Main features
Physical features
1. Low altitude, mostly < 90m a.s.l.
2. Gently sloping ground, < 10% slope
3. Water sources arising from soft deposits of sandstone, limestone and clay
4. Inorganic substrate overlaid with shallow organic peat or silt
5. Shallow narrow waterbodies on heathlands, small ditches on chalk streams
6. Slow to moderate but permanent water flow
7. Proximity to springs or groundwater
Vegetation features
8. Remoteness from intensive agriculture
9. Open and exposed watercourses (maintained by grazing, cutting, scrub removal and some channel clearance)
10. Medium to high cover of submergent and emergent stream vegetation (low to medium height)
11. Herbaceous, perennial stream vegetation
12. Shelter on bankside and sometimes within the stream (e.g. *Myrica gale*)
Chemical features
13. Dystrophic to oligotrophic conditions
14. Unpolluted water
15. High oxygen concentrations
Possible ultimate factors
Features 1, 4, 5, 7, 9, 11 ensure minimum stream temperature thresholds/regimes for larval development, oviposition and emergence.
Features 1 and 9 ensure minimum air temperatures for adult activity.
Feature 12 ensures availability of areas for roosting, maturation, feeding, displaying and basking.
Features 8, 9, 10, 11 and 13 ensure the provision of open stream areas with suitable substrates for oviposition and egg development, with no eutrophication and encroachment of invasive emergents and algae.
Features 2, 6, 7, 8, 10, 11 and 14 ensure sufficient oxygen for larval and egg development.
Feature 11 provides cover for the larval stage for feeding, and refuge from predators.
Feature 5 ensures relatively large rates of temperature increase when exposed.
(Adapted from Purse 2001)

Undergrazing

Undoubtedly, one of the main reasons for the decline of the southern damselfly in Britain over the last 40 years has been the change in grazing regimes on some sites (Evans 1989). The use of moderate grazing regimes should reduce the establishment of scrub and invading emergents on most sites. Grazing by heavier animals, such as cattle and horses, is preferred, as it causes some poaching of watercourse margins and creates the diversity of tussock structure preferred by the southern damselfly. Several populations have become extinct due to failed grazing regimes, including those at St David's Head, Venn Ottery Common and Waun Isaf. There are several other sites, notably in the New Forest, that are so densely covered with scrub, usually bog myrtle (*Myrica gale*), that mechanical removal is now required to give grazing animals access to the streams.

Channel silting up and management

Although ditches can support good colonies of the southern damselfly, they are more prone to silting up and encroachment by rank vegetation and scrub than are sites with a more natural hydrology. Consistent management efforts will be required to maintain colonies that occur in artificially ditched watercourses.

Overzealous clearance of channel vegetation can be almost as serious a threat if it is not undertaken with the life cycle of the southern damselfly in mind. Intermittent selective cutting by hand is recommended on heathland sites. Larger watercourses on chalk stream ditch systems may tolerate selective mechanical cutting. Strange (1999) recommends cutting aquatic vegetation in the central area of a ditch while retaining a broad fringe of emergent vegetation. Cutting should be performed yearly on a rotational basis on short, adjacent (not isolated) stream sections. The length of section, the timescales of rotation and the timing of the work will be different in different circumstances.

Water abstraction and water-level management

Water abstraction has been cited as an additional negative impact on some southern damselfly sites. Certainly, water abstraction from aquifers or springs feeding sites is quite frequent, particularly on the northern edge of the Mynydd Preseli. The movement of water through the water meadow systems of the Itchen Valley also requires close attention, since it is controlled by man-made sluices.

Eutrophication

Relatively few southern damselfly sites in Britain are directly threatened by nutrient runoff, but significantly, several of them are small, isolated populations (for example, Nant Isaf on Anglesey and Aylesbeare Common in Devon). Such sites are more vulnerable than larger, more buffered, sites.

Attainment of favourable condition

The attainment of favourable condition for southern damselfly sites will be achieved largely by avoiding the threats indicated above. Habitat attributes that relate to vegetation structure and physical features of watercourses are likely to constitute key attributes for the species. It is important to focus observational effort on features that can actually be influenced by management and those that can most easily be recorded by field workers.

The key habitat attributes that indicate favourable condition in the two main habitat types in which the southern damselfly occurs in Britain are shown in Table 4 (heathland streams) and Table 5 (chalk streams). Given the regional variation shown in some of these attributes (for example, plant species), a set of attributes based on these tables must be set up for each site designated for the species in the UK (Thompson *et al.* 2003).

Table 4. Key and subsidiary habitat attributes (with suggested upper and lower limits) that indicate favourable condition for *C. mercuriale* on heathland sites in Britain.

Key habitat attributes	Definition of upper and lower limits for favourable condition
1. Open, unshaded, shallow lengths of watercourse/mire with permanent discernible flow (approx. 10 cm s^{-1}).	*Upper limit of extent on site*: 100% of watercourse/mire. *Lower limit of extent on site*: Same % of watercourse/mire covered by such habitat in last survey or at least 50% of watercourse/mire.
2. Stream lengths with cover of submerged and semi-emergent, herbaceous macrophytes including some cover of *Hypericum elodes*, *Potamogeton polygonifolius*, or *Ranunculus flammula*, with some *Carex* spp. or *Juncus* spp.	*Lower and upper limit of cover*: 20–80%. *Upper limit of extent on site*: 100% of watercourse/mire. *Lower limit of extent on site*: Same % of watercourse/mire covered by such habitat in last survey or at least 50% of watercourse/mire.
3. Areas of adjacent bankside vegetation with medium heights of tussocks and/or medium height of emergents in stream.	*Lower and upper limit of height*: 0.2–0.6 m. *Upper limit of extent on site*: 100% of bankside, 50% of ditch. *Lower limit of extent on site*: Same % of watercourse/mire covered by such habitat in last survey or at least 30% of bankside. *Lower and upper limit of scrub or trees shading watercourse*: 0-40% cover.
4. Dystrophic to mesotrophic conditions indicated by a lack of areas of watercourse with encroachment of algae (except brown flocculent algae), bacterial film or invasive tall emergents such as *Juncus effusus*, *J. acutiflorus* and *Phragmites* spp.	*Upper limit of extent on site*: 25% of watercourse. *Lower limit of extent on site*: 0% of watercourse. *Lower and upper limit of scrub or trees shading watercourse*: 0–40% cover.
5. Some cover of peat or other organic substrate in watercourse/mire.	*Upper limit of extent on site*: 100% of mire or watercourse. *Lower limit of extent on site*: Same % of watercourse/mire covered by such habitat in last survey or at least 50% of watercourse/mire.
Subsidiary habitat attributes	**Definition of upper and lower limits**
6. Small areas of tall scrub or trees within 20 m of watercourse or mire but not on intervening habitat between two areas of population.	*Lower and upper limit of scrub or trees shading watercourse*: 0–40% cover.

From Purse 2001

Table 5. Key and subsidiary habitat attributes (with suggested upper and lower limits) that indicate favourable condition on chalkstream sites in Britain.

Key habitat attributes	**Definition of upper and lower limits**
1. Open, unshaded lengths of ditch with slow flow or with moderate (7.5–20 cm s^{-1}) flow in central channel and shallow slow-flowing areas at ditch edges.	*Upper limit of extent on site*: 100% of ditch/stream. *Lower limit of extent on site*: Same % of ditch/stream covered by such habitat in last survey or 50% of ditch/stream.
2. Ditch edges with broad fringe of herbaceous semi-emergent and submerged macrophytes including some cover of *Glyceria maxima*, *Mentha aquatica*, *Rorippa nasturtium-aquaticum*, *Ranunculus* spp. and *Veronica* spp.	*Lower and upper limit of cover*: 20–80% for both emergent and submergent portions. *Upper limit of extent on site*: 100% of ditch/stream, *Lower limit of extent on site*: Same % of ditch/stream covered by such habitat in last survey or 50% of ditch/stream.
3. Areas of adjacent bankside vegetation with medium height of tussocks and/or medium height of emergents in ditch/stream.	*Lower and upper limit of height*: 0.2–0.6 m. *Upper limit of extent on site*: 100% of bankside, 50% of ditch. *Lower limit of extent on site*: Same % of watercourse or mire covered by such habitat in last survey or at least 30% of bankside. *Lower and upper limit of scrub or trees shading ditch*: 0–40% cover.
4. Mesotrophic conditions indicated by a lack of areas of watercourse with encroachment of algae (except brown flocculent algae), bacterial film or invasive tall emergents such as *Phalaris arundinacea*, *Solidago canadensis*, *Filipendula ulmaria* and *Rubus* spp.	*Upper limit of extent on site*: 25% of watercourse. *Lower limit of extent on site*: 0% of watercourse. *Lower and upper limit of scrub or trees shading watercourse*: 0–40% cover.
5. Some cover of peat or other organic substrate in ditch/stream.	*Upper limit of extent on site*: 100% of ditch/stream. *Lower limit of extent on site*: Same % of watercourse/mire covered by such habitat in last survey or at least 50% of ditch/stream.
Subsidiary habitat attributes	**Definition of upper and lower limits**
6. Small areas of tall scrub or trees within 20 m of watercourse or mire but not on intervening habitat between two areas of population.	*Lower and upper limit of scrub or trees shading watercourse:* 0–40% cover.

From Purse 2001

Summary

The southern damselfly is the smallest of the blue damselflies found in the UK, where it is on the northern margin of its range. It has disappeared from, or is on the edge of extinction, in seven European countries along its northern boundaries, and is declining in three others, including Britain.

In Britain there are three main centres of population – the heathlands of Mynydd Preseli in Pembrokeshire and the New Forest, and the water meadow ditch systems of the Itchen and Test valleys. There are also small populations on the Dorset heaths, Dartmoor, East Devon pebble beds, Gower and two fens in Oxfordshire and Anglesey.

The species is sensitive to a number of habitat factors. A requirement for a thermally sensitive microclimate is reflected in broad-scale habitat use (for example, use of shallow, sun-exposed, permanently flowing water bodies indicated by perennial, herbaceous, aquatic vegetation), and in habitat use for oviposition and emergence.

The southern damselfly is semi-voltine in Britain, with a shorter larval growth period and flight period than in mainland European populations. Seasonal regulation is probably achieved by a facultative autumn diapause in the penultimate larval instar.

Dispersal distances are relatively poor, which means that the already highly fragmented British populations are likely to become even more fragmented, with implications for its conservation.

The main cause of the decline in the southern damselfly in Britain has been the use of unsympathetic grazing regimes in key habitats over long periods.

Research priorities

The main research priority for the conservation of the southern damselfly is concerned with genetic variation. It is important to learn whether the small population sizes seen in the southern damselfly in Britain are so low as to threaten long-term population persistence. Small populations are not only susceptible to extinction through random environmental processes, but also susceptible to processes that result in a loss of genetic variation.

Although extensive work is currently being undertaken by Liverpool University on dispersal by mature adults, it is not clear whether the mature adult stage or the immature adult stage is the most relevant for dispersal. Until some acceptable method can be found of marking adults individually at emergence that does not influence their maiden flight, this issue will not be resolved satisfactorily.

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Life in UK Rivers was established to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites.

Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

The southern damselfly is one of Europe's rarest damselflies. In the UK the species is on the northern edge of its range, and has declined by over 30% during the past 40 years.

The main causes of the southern damselfly's decline are loss and fragmentation of habitat due to scrub encroachment on riverbanks, abstraction and channel siltation.

This report describes the ecological requirements of the southern damselfly in a bid to assist the development of monitoring programmes and conservation strategies that are vital for its future.

Information on Conserving Natura 2000 Rivers and Life in UK Rivers can be found at
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This document was produced with the support of the European Commission's LIFE Nature programme and published by Life in UK Rivers – a joint venture involving English Nature, the Countryside Council for Wales, the Environment Agency, the Scottish Environment Protection Agency, Scottish Natural Heritage and the Scotland and Northern Ireland Forum for Environmental Research.