The

HERPETOLOGICAL BULLETIN

Number 88 – Summer 2004

PUBLISHED BY THE

BRITISH HERPETOLOGICAL SOCIETY

THE HERPETOLOGICAL BULLETIN

The **Herpetological Bulletin** is produced quarterly and publishes, in English, a range of articles concerned with herpetology. These include full-length papers of mostly a semi-technical nature, book reviews, letters from readers, society news, and other items of general herpetological interest. Emphasis is placed on natural history, conservation, captive breeding and husbandry, veterinary and behavioural aspects. Articles reporting the results of experimental research, descriptions of new taxa, or taxonomic revisions should be submitted to The Herpetological Journal (see inside back cover for Editor's address).

ISSN 1473-0928

Printed by Metloc Printers Limited, Old Station Road, Loughton, Essex.

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Information for contributing authors is available at: http://www.thebhs.org

Front cover illustration. Rio Magdalena Poison-dart Frog, *Dendrobates truncatus*. Photograph © Chris Mattison. See article on page 11.

The British Herpetological Society

THE HERPETOLOGICAL CONSERVATION TRUST

Joint Scientific Meeting:

Herpetofauna ecology & conservation

"Targeting research where it's needed"

Saturday 4 December 2004
Berrill Lecture Theatre, Berrill Building, The Open University, Milton Keynes

This one-day seminar will present current biological and ecological research on herpetofauna that addresses conservation problems and knowledge gaps. In doing so, it aims to encourage greater communication between academic researchers, conservationists, consultants, NGOs, statutory agencies, land managers and decision-makers in determining where research is needed most.

0930-1000 Registration
1000-1005 Welcome address

Session 1:

1005-1030 Trevor Beebee – "Inbreeding effects in natterjack toad populations"
1030-1055 David Sewell & Richard Griffiths – "Population dynamics of great crested newts at metapopulation and landscape levels: an eight year study"
1055-1120 Tim Halliday – "Does the amphibian decline phenomenon have any relevance to the UK?"

1120-1145 Coffee

Session 2:

1150-1215 Jim Foster – "Researching the return of the pool frog"
1215-1240 Daniel Pickford – "Toads in a hole? Ecotoxicological research on UK amphibians"

1240-1340 Lunch (provided)

Session 3:

1345-1435 Brendan Godley – "Marine turtle conservation in the UK Overseas Territories"
1435-1500 Jonathan Houghton – "Leatherback turtles in the Irish Sea: addressing the knowledge gaps"
1500-1515 Tony Sainsbury – "Disease risk assessment for herpetofauna translocations"

1520-1540 Coffee

Session 4:

1545-1610 Oskar Kindvall – "Population viability analysis on relict sand lizard populations"
1610-1635 Ina Blanke – "Evaluating sand lizard conservation status & management success"
1635-1655 Nick Smith & Calista Bebbington – "Evaluating the relative effectiveness of ACO materials"
1655-1725 Discussion: "Is research addressing current needs?"
1725-1730 Closing remarks

Registration is £20 including lunch (£10 to students/concessions, £5 to BHS & ARG members). Send cheques payable to "The Herpetological Conservation Trust", 655a Christchurch Road, Boscombe, Bournemouth, BH1 4AP, UK. Contact Chris Gleed-Owen for further information (chris.go@herpconstrust.org.uk). Free shuttle minibus from Milton Keynes Central train station. Accommodation available at the Campanile Hotel, Fenny Stratford, Milton Keynes (3 miles), twin/double rooms for £43.95 (tel. 01908 649819). A social gathering is anticipated on the Friday evening for those staying overnight. University location and campus maps are available online and as pdf's from http://www.open.ac.uk/maps/.

New East Lothian sites for the Adder (*Vipera berus*) found from 19th century records

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RECORDS of Adders in the vicinity of Edinburgh are scarce, though old, unofficial accounts of their presence do exist at Whitadder Reservoir in the Lammermuir Hills, in East Lothian. The Lammermuirs are a range of hills running south-west from six miles south of Dunbar. Partially cultivated and gently sloping, they look unimpressive reptile habitats to those of us accustomed to Highland Adder sites. BHS member Charles Montgomery, a member of the Lothian Amphibian and Reptile Group, researched other old records of Adders mentioned in William Evans's paper to the Royal Physical Society in 1894, entitled *'The Reptiles and Batrachians of the Edinburgh District'*. Members of the group decided to investigate, and a preliminary visit to Whitadder Reservoir in the spring of 2002 proved positive. On 26th April, 2003 several members of the LARG visited Whitadder Reservoir and saw five male and two female adult Adders, together with a male and female Slow-worm (*Anguis fragilis*) and one Common Lizard (*Zootoca vivipara*).

Evans (1894) mentions killing (!) two Adders further up the Whitadder Water at Johnscleugh. The group visited the site on the morning of 10th May 2003, and saw two adult females, and one adult male. In the afternoon we drove further east, to a site called Crichness. Here we found two baby Adders and one very unusual bluish male. This year, on 22nd April, we visited a site only 15 miles east south-east of Edinburgh, Lammerloch Reservoir, a much smaller water body than Whitadder, and two adjacent ponds. We saw two mature males, two mature females and two immature animals whose sex was disputed. A month later we again visited Whitadder Reservoir, but only saw one Adder, a male. We saw no Slow-worms but several Common Lizards, including a very interesting lime green female. In the

Waterbody adjacent to the Lammerloch Reservoir, site of the new East Lothian Adder records. Photograph © C. Montgomery.

Male Adder from area of Lammerloch Reservoir. Photograph © C. Montgomery.

afternoon of the same day we drove down along the boundary river with Borders Region, stopping to visit a marshy wooded area in Monynut Forest where we saw a large male Adder. Presumably animals had moved down from the higher well-drained uplands to the marshy hunting grounds. We assumed that the popularity of the banks of the reservoirs and lochs was because of the abundance of rodents as well as baby lizards for the young snakes to feed upon.

Apart from their intrinsic value, these survey trips serve to highlight the worth of even fairly old records. Information collated by a Victorian naturalist has made it possible for modern herpetologists to reconfirm many sites and has nudged us in the direction of some 'new' ones. A lot of work remains to be done but the heartening news is that, over 100 years later, all these populations are still there and appear to be thriving.

N.B. Strangely enough, Whitadder in old Scots means 'white water', not 'white adder'.

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Green Lizards and Wall Lizards on Bournemouth cliffs

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AS well as Britain's six native reptile species, there are a handful of exotic species dotted around the country, which have almost all clearly originated from deliberate or accidental releases. Wall Lizards, Italian Wall Lizards, Green Lizards, Aesculapian Snakes, Dice Snakes, garter snakes of various kinds, European Pond Terrapins, and Red-eared Terrapins are among those that have been reported over the last century (Arnold, 1995; Beebee & Griffiths, 2000; Fitter, 1959). Some populations have not persisted, but others appear to be surviving quite well, particularly in southern English counties where the summers are warmer. On the whole, these naturalised species are confined to isolated locations and they do not appear to be spreading. Nevertheless, we know so little about most of them that we cannot say how well they are doing. The Wall Lizard certainly occurs most widely, and clearly has no problems breeding in our climate. On the south coast, there are known Wall Lizard populations on Portland, the Purbeck coast, Poole Bay cliffs, Shoreham and throughout the town of Ventnor on the Isle of Wight. Green Lizards have historically been released in several south coast locations, with limited success, but a thriving population was recently discovered on Bournemouth's cliffs and appears to have no problems breeding and persisting in the south coast's sunny climate.

During July 2002, I was walking eastwards from Boscombe Pier to Hengistbury Head, alternating between the clifftop paths and the promenade below. About late morning, I traversed the cliff via a zig-zag path and thought I saw a female Wall Lizard. I 'knew' the nearest population was a few miles to the west, but I wrote a hesitant entry in my notebook. Then, to my amazement, I saw what was quite clearly a male Green Lizard. It was vivid green with fine black speckles, about 30 cm total length, and with a dark tail that looked regrown. I didn't notice a blue throat but I was pretty certain it was a male. I immediately made some phone calls to relay the news and check if anyone at The HCT knew about this, but no-one did. As I continued along the zigzag, checking walls as I went, I did see some Wall Lizards, the males tending to be bright green mottled black. So it appeared that in one visit I had 'discovered' new populations of two species of lizard. Within a week or so, a local naturalist visited our office and said that he too had recently seen Wall Lizards and a single Green Lizard at the same location. He had been visiting the location for years and had never seen either species before, except for a possible Wall Lizard sighting about 1995. We began to wonder how long these species had been there. Were they recently introduced or long established?

Bournemouth and Poole Bay cliffs provide a wide variety of habitats, from bare sand, dune grasses, native herbs and shrubs, to countless introduced plants and trees. Hottentot fig is a severe problem, smothering and displacing everything; elsewhere Pampas grass, Holm oak, bamboo, yucca, garden privet, and sycamore are locally abundant. Sand Lizards are confined largely to marram areas from Boscombe Pier to Sandbanks, and do not appear to exist east of Boscombe Pier, despite there being suitable habitat. Common Lizards are fairly ubiquitous on the cliffs and clifftops, Slow-worms are remarkably uncommon, and snakes are virtually or actually absent. The 'new' Wall Lizard and Green Lizard area has a diversity of native and exotic scrub, seaside daisies, sand and gravel exposures, dune grasses, and a series of walls, mostly pointed. An added benefit of the cliffs is their southerly aspect and shelter provided by the chines (enabling breeding in Clouded Yellow Butterflies as well as exotic lizards; M. Skelton, pers. comm.).

Wanting to know more about the extent and origin of these lizards, I embarked on a regime of regular visits throughout the summer and autumn of 2002, and regularly saw Wall Lizards (sometimes over 30 animals), including numerous juveniles. They weren't confined to walls either; bare sand slopes, grass and shrubs seemed to be equally suitable. They were not too fussy about the weather, and amazingly a few juveniles and the odd adult could be seen right through the winter in temperatures as low as 4 or 5°C. I got a couple more glimpses of Green Lizards that year, including a second smaller animal, but always on the same zigzag path. However, Michael Skelton, a local naturalist, saw them elsewhere within 100m of the zig-zag and photographed one at the clifftop on a lump of concrete where I'd seen only Wall Lizards before. At that point, I still thought there may only have been a handful of animals. It wasn't until April 2003 that there suddenly seemed to be a boom in Green Lizard sightings. It's difficult to know whether this is just because we weren't looking closely before, or whether there has been a sudden influx of lizards. (Obviously the latter explanation raises more awkward questions than it answers). We began to search more widely along clifftop areas, especially when Michael saw a juvenile Green Lizard, and found Green Lizards several hundred metres further along the cliff. We even discovered a dwarfed oak bush close to the clifftop but surrounded by mown grass, that is regularly used by up to four Green Lizards of varying ages!

In the spring of 2003, juveniles clearly from 2002 were already as large as adult Common Lizards; a pale fawny green-brown colour with two pale lime green/white dorsolateral stripes and two lateral stripes. As the weeks progressed the young developed black blotches too. In the absence of contrary advice from others more familiar with both species, it is this even number of stripes that leads me to believe that these Green Lizards are *Lacerta bilineata* rather than *Lacerta viridis* (or any other species). The western race, present across the Channel in France and Jersey, is *L. bilineata*. We saw female adults about 20cm long during 2003, and later in the year Michael saw neonates. In summer 2003, I began to look further west and saw Green Lizards and Wall Lizards about 1 km away from the original zig-zag. Together with another confirmed third-party Green Lizard sighting further along the Southbourne cliffs, this means that the Green Lizards now extend along at least 3 km of cliffs. The questions of population size, age and origin became more perplexing, particularly given that this had remained virtually unknown to the wider herpetological community. (The fact that it was virtually on The HCT's doorstep caused amusement too!). Wall Lizards have been seen

Typical marram habitat on cliffs at Bournemouth. Photograph © Chris Gleed-Owen.

First-clutch (?) 2003 juvenile Green Lizard, 7th May 2004. Photograph © Jonathan McGowan.

sporadically further afield than the zig-zag path site, but they do not appear to be distributed as extensively as the Green Lizards; perhaps a function of their size and habitat preferences.

Some new data have come to light in 2004, thanks to Jonathan McGowan from the Bournemouth Natural Science Society who has been visiting the zig-zag site for a number of

Immature male Green Lizard, 16th May 2004. Photograph © Chris Gleed-Owen.

Second-clutch (?) 2003 juvenile Green Lizard, 4th May 2004. Photograph © Jonathan McGowan.

Male Wall Lizard, April 2004. Photograph © Chris Gleed-Owen.

years. He first saw Green Lizards there in 1999 – a new earliest confirmed record – but he has a reliable third-party sighting of a large dead Green Lizard from a footpath there in 1994. Jonathan regularly sees Green Lizards of all ages, including males up to 50 cm total length. His first sighting of 2004 was a large male on 16th March, which is as early as Sand Lizards appear in Dorset, and earlier than I had imagined the Green Lizards were emerging. More intriguing still, in early May 2004 he photographed juvenile Green Lizards that were clearly from different cohorts. Not including five or six months of hibernation, the older one had obviously been growing for several months, but the younger one appeared to be only a couple of weeks old. This suggested a very late hatching in 2003. I now believe that, much like the Sand Lizards and Wall Lizards in the Bournemouth area, at least some of the Green Lizards are double-clutching. Up until now, all the records have still been east of Boscombe Pier, the approach road to which should form a reasonably good barrier to dispersal. However, Jonathan has seen an adult male Green Lizard at the base of the cliffs west of Boscombe Pier, towards Bournemouth Pier. This is much further west than any previous sighting, and is worrying because it transgresses perhaps the only barrier to dispersal westwards into Sand Lizard territory. If there is any conflict between the Green Lizards and Sand Lizards, then we should be concerned. It may be coincidental that there are no Sand Lizards on the cliffs east of Boscombe Pier, all the way to Hengistbury Head, despite the habitat being present, but it is slightly suspicious.

So, how did these exotic lizard populations come about? I suspect they originated as captive animals that were released, deliberately or accidentally, some time in the last 20 years, but I don't know where or when. There are extensive areas of scrub and dune grass along most of the cliffs, providing good Green Lizard habitat in the majority of places. If the current distribution dispersed from one release, then I would have thought it would take 20 years to reach their current density and extend up to 2 km (or possibly 3km) in each direction. Fitter (1959) noted that a single Green Lizard was seen on the Isle of Wight in 1934, several miles away from where 100 had been released in 1899. On Bournemouth cliffs, given the numbers of sightings within fairly small areas, I would guess there are upward of 500 animals along the cliffs from Boscombe to Southbourne, possibly even 1000. If there were multiple releases, then it would explain a wide distribution in a shorter time, and allow for a smaller population altogether. Multiple releases would also explain why there were virtually no sightings earlier than about five years ago. Beach hut owners at the bottom of the zigzag tell me the Wall Lizards only appeared in about 1999. I was initially sceptical of this being a reliable fact as most holidaymakers and dog-walkers still don't see any lizards today. However, it seems that sightings from the other sources seem to begin around the mid- to late-1990s. If a nucleic population became established around that time, it would take a few years to become established and large enough to be obvious. Michael Skelton's first probable record was in 1995, Jonathan McGowan's records start in 1999 (or possibly 1994), and Dave Bird tells me Wall Lizards appeared at another Poole Bay cliff site around the same time in the late 1990s.

I'm trying to glean more information from people who know about these Green Lizard and Wall Lizard populations; unfortunately it's not easy. I am slightly concerned that the releases may still be going on, mainly because they could have detrimental effects on the Sand Lizards. Sand Lizards are present west of Boscombe Pier, but are absent from the whole 5 km of cliffs east of Boscombe Pier where the Green Lizards are present. It is tempting to draw an obvious conclusion. Either way, a systematic study is needed in order to investigate the effects of exotic lizard populations on native reptiles – a risk assessment of sorts. It would also be useful to confirm the origins of these populations, lest the folklore gets out of hand. I don't believe they swam the Channel as suggested by every journalist who contacted me last year. I also don't think they could have arrived in prehistory and persisted naturally, although I am not absolutely convinced that all the south coast Wall Lizards are introduced. Until someone funds a genetic study of all known populations, and a phylogeographic comparison with European mainland populations, I will still harbour a slight suspicion that perhaps one could be native. The Ventnor population may be the strongest candidate; it's conceivable that 'Green Lizards' released there a century ago were in fact Wall Lizards but Fitter (1959) seems convinced otherwise. Today the Wall Lizard population is distributed widely throughout the town and adjacent areas, including the Botanic Gardens car park, and is well known to the locals. As for Green Lizards, a release in Torbay in Devon in 1937 (Fitter, 1959) may still survive, and there are reported sightings of Green Lizards near Dawlish (Keith Corbett, pers. comm.). Also, a Plymouth resident who was familiar with a population thought to be Italian Wall Lizards in Plymouth in the 1950s, recently rediscovered them alive and well (D. Coles, pers. comm.).

At The HCT, we hold the national database of records for the rare amphibians and reptiles, but also exotic species data. We're recording and gathering records on the Wall Lizard, Green Lizard, and other exotics. A quick extract of my own sightings from 2002 and 2003 shows a total of 40 visits to the zig-zag, resulting in 348 Wall Lizard sightings, 22 Green Lizard, and 58 Common Lizard sightings. These visits were in various weather conditions (which we record and encourage others to record), and with 'sightings rates' of up to 32 Wall Lizards per hour. Common Lizards don't seem to be very common where there are lots of Wall Lizards, and as already pointed out, Sand Lizards are non-existent. This year, on one brief walk with Hampshire Amphibian and Reptile Group in poor conditions, we saw seven Green Lizards, all immature or juvenile, and only three Common Lizards. The HCT is providing advice to Bournemouth Borough Council on the management of the cliff and clifftop habitats for reptiles. Others are providing botanical and entomological advice. The aims are to improve the wildlife value of the cliffs and clifftops as natural and semi-natural habitat. Invasives will be dealt with first; in particular, Hottentot fig which will be sprayed and removed *en masse* when dead. What was 'amenity grassland' on the clifftops will be left to grow rank, and gorse blocks will be reduced to manageable mosaics and cut back from path edges to alleviate the fire risk. Some signage is planned to explain to change of management. A watching brief will need to be kept on the exotic lizards and their interactions with the native species. A student from Sparsholt College is currently mapping the distributions of each species (Steve Scammell).

All in all, it is tempting to view the exotic newcomers to Bournemouth's cliffs as an interesting addition to Britain's reptile fauna, but we have to keep an eye on how they might be impacting on the native lizards. The Wall Lizards aren't confined to walls; they live throughout the vegetation and bare ground, albeit in lower numbers. The dune grass and scrubby habitats are perfect for Green Lizards. Both species are breeding, and both are evidently laying two clutches. The south coast climate is amenable to both; the Green Lizards seem to be active from March to October, the Wall Lizards even longer. The Wall Lizards' active season is presumably so long because most live within cracks in walls that heat up quickly. It doesn't take more than 10 minutes of sun before they're out, and I've seen them basking when there's frost on the ground in an adjacent shadow. I have also seen juveniles feeding in the middle of winter. The notion of a long hibernation does not seem to apply to this species in Britain. I suspect that they have a distinctly different physiology to the native lacertid lizards, more akin to North American species. If they can feed on a winter's day, then retreat to their refuge overnight in sub-zero temperatures, and then come out again the next day, they must be pretty hardy. You could even say that they're beating the native species at their own game.

ACKNOWLEDGEMENTS

Thank you for all the helpful information received from Dave Bird, David Coles, Keith Corbett, Jonathan McGowan, Martin Noble and Michael Skelton. Thank you also to Stuart Clarke and Bournemouth Borough Council for involving The HCT and others in consultation over management of the reptile habitats on Bournemouth cliffs.

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The care and captive breeding of the caecilian *Typhlonectes natans*

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CAECILIANS (Apoda) are the often overlooked third order of amphibians and are not thought to be closely-related to either Anurans or Urodelans. Despite the existence of over 160 species occurring throughout the tropics (excluding Australasia and Madagascar), relatively little is known about them. The earliest known fossil caecilian is *Eocaecilia micropodia*, which is dated to the early Jurassic Period approximately 240 million years ago. *Eocaecilia micropodia* still possessed small but well developed legs like modern amphiumas and sirens. The worm-like appearance and generally subterranean habits of caecilians has often led to their dismissal as primitive and uninteresting. This view-point is erroneous. Far from being primitive, caecilians are highly adapted to their lifestyle. *Typhlonectes natans* are minimalist organisms having dispensed with tail, limbs, one lung and functioning eyes. Animals which live in underground burrows or the turbid depths of South American rivers, however, have no use for these organs.

Instead of sight, caecilians have a pair of organs known as the tentacles situated in pits between the eye and nostril. The tentacles are connected to both the optic nerves (and muscles) and the olfactory system. How this hybrid sense (sight, taste and smell combined) functions is unknown. That this sense does function is undeniable. I can testify from personal observation how rapidly caecilians locate and consume food. The research of Himstedt & Simon (1995) clearly demonstrates how efficient caecilians are at foraging for food using the tentacle organ by locating food items faster than newts in experiments. They are the only vertebrate animals known to possess motile sub-ocular tentacles. Caecilians have poor hearing but, like other amphibians and fish, have a well developed lateral line system.

Many caecilians have no larval stage and, while some lay eggs, many including *Typhlonectes natans* give birth to live young after a long pregnancy. Unlike any other amphibian (or reptile) this is a true pregnancy in which the membranous gills of the embryo functions like the placenta in mammals, so that the mother can supply the embryo with oxygen. The embryo consumes nutrients secreted by the uterine walls using specialized teeth for the purpose.

Captive Care

In March 1995 I acquired ten specimens of the aquatic caecilian *Typhlonectes natans* (identified by cloacae denticulation after Wilkinson, 1996) which had been imported from Guyana. I immediately lost two as a result of an ill-fitting aquarium lid. Another died after only six days as a result of a severe bacterial infection which did not respond to antibiotic treatment. The remaining seven, however, thrived. They ranged from 25 cm to 35 cm in length and were on average 1–2 cm in diameter.

I established them in a 180 cm x 61 cm x 46 cm (6 ft x 2 ft x 1.5 ft) tank with a substrate of river sand (from a local unpolluted stream) 10 cm deep, and a water depth of 30 cm (later raised to 40 cm) of soft acid water (pH 5–6 & dH 3), at 74°C with external filtration. The tank was furnished with plenty of bogwood and extensive non-rooting plants (Java Fern, Java Moss and Rigid Hornwort) as I anticipated extensive burrowing.

The caecilians do burrow but not as much as I expected. They are active equally by day and night and appear oblivious to bright light even when shone directly on them. Their tastes are catholic and they seem to do well on frozen bloodworm, chopped mussels, prawns and chopped sprats (later I stopped using sprats because of the mess and potential for fouling of the water; as a codicil, if feeding with non-live food remember to feed freshwater animals with marine fish/prawns – this reduces the risk of disease transmission). They grew well and by 1997 the largest individual measured 3 cm in diameter and approximately 55 cm in length.

Initially, I was reluctant to introduce fish to the aquarium, fearing that they would be eaten or even attack the caecilians. I experimented with small tetras and, when these remained unscathed, gradually introduced a full community of Amazonian fish. To this date no living fish has ever been harmed – even small loaches resting amongst the inactive caecilians under the bogwood. Similarly, the large cichlids ignore the caecilians even when their breeding territories are violated. When a fish dies, however, it is consumed immediately leading me to speculate that carrion forms a significant part of wild caecilians diets. This is backed up by the relative abundance of *Typhlonectes* sp. near riverside fishing villages in northern South America, where they have been observed eating the entrails of gutted fish (Hofer, 2000).

Breeding

In July 1997 I lowered the water level in the tank to 18 cm and allowed the pH to drop well below 5 and the organic content of the water (especially nitrates) to rise considerably. This was a deliberate attempt to simulate dry season conditions when the flooded river basins of the Amazon shrink to shallow pools. To my surprise, on 13th July the caecilians began to mate. The smaller males entwined themselves around the two much larger females. With their lower bodies entwined and positioned vent to vent, the males inseminated the females (the sexual organ – phallodeum – was large and obvious). This process often lasted for several hours, with initial frenzied activity subsiding into stillness so profound that on more than one occasion I believed that both animals had drowned. Periodic mating continued until 18th July 1997.

After mating had clearly finished, I returned the water conditions to their original state (pH 5/6, dH 3 and 40 cm deep). After that things went on as they had before and it was many months before I realized that one of the females was indeed pregnant. This was the largest of the females approximately 55 cm long (22 inches). Her girth gradually increased, over the months the diameter of her body reaching more than 6 cm at its greatest. The birth finally took place on the night of 10/11th June 1998, ten months and three weeks after mating had ceased. Unfortunately, the births took place during the hours of darkness so I didn't observe the process. Six young were born. One was unfortunately stillborn but the rest are alive at the time of writing (March 2004). The young varied from 10–15 cm in length and approximately 5 mm in diameter. Some still retained external gills which were lost within hours. The young were weak and feeble initially and I immediately dropped the water level to help them get to the surface to breath. The mother did appear to push some of the youngsters towards the surface on occasion although this may have been coincidental rather than a deliberate act. The young began to feed after a few days, initially on frozen bloodworm and later on finely-chopped adult food. They quickly gained strength and were able to swim rapidly within a week but grew very slowly. At two years old, most of the five young had not quite reached 30 cm in length and had a body diameter of about 1 cm. Currently (March 2004), aged more than five years, they are about 45 cm in length with a body diameter of 1.5–2.5 cm.

All but one of the original adults gradually died between 1998 and 2000. The surviving adult remains active and healthy. I had originally supposed that this was a small male but, in the intervening years, it has matured into a large 60 cm long) female much larger than any of the younger animals. I have had this animal for nine years now and, judging by the growth rate of the others, it was at least two years old when I obtained it. The five-year old young have only now achieved the size and maturity exhibited by the original animals when they bred. This implies that *Typhlonectes natans* is a long lived species which reaches maturity at a fairly advanced age.

Conclusions

My hypothesis is that *Typhlonectes natans* is a dry season breeder mating mid-dry season one year and giving birth early in the dry season in the following year. This would confer a number of advantages. The first being that the feeble new-born young would be less liable to drown as would almost certainly happen in the flooded forests during the wet season. The second advantage is that food is plentiful and concentrated into small areas during the dry season, particularly for scavengers. The disadvantage is that the stress on the mother of such a long pregnancy (the mother in this case died four months after giving birth despite extensive care and treatment) makes it improbable that breeding would take place every year in the wild. Every second year seems more likely (it may be possible that a well fed captive female caecilian might regain breeding condition faster). Females of a relative of *T. natans*, *Dermophis mexicanus* are known to have a biennial sexual cycle while the males breed annually (Jared et al., 1999). This would mean that the reproductive rate of *Typhlonectes natans* is very low. It therefore follows that the mortality rate of wild caecilians must also be low or they would long-since have become extinct (rather than persisting as a group for over 200 million years).

Why then, since *Typhlonectes natans* appears to take no steps whatever to avoid predation, does it not get decimated by the wide array of predators present in its habitat (fish, turtles, otters, snakes, cormorants, freshwater dolphins, herons & egrets to name a few)? There is good evidence for the toxicity of many caecilians, particularly members of the genera *Ichthyophis* and *Dermophis*, although the extent of toxicity in *Typhlonetes* species is less clear. References have been made to the toxic effects of *Typhlonectes compressicauda* on the predatory Wolf Fish, *Hoplias malabaricus* (Miller, 2003). My supposition is that, in common with many other amphibians, *Typhlonectes natans* is either unpalatable or positively toxic. I have, however, kept my caecilians with fish for eight years now and none have suffered any ill effects. I would therefore assume that, in common with bufonid toads, it is necessary to either eat the caecilian or agitate it very severely before any toxins are exuded. I have not tried this and advise others not to do so, on both safety and humanitarian grounds. This supposition would be best proved/disproved at autopsy by a pathologist.

The majority of amphibians have rapid reproductive rates, laying large numbers of eggs with little or no parental care (there are of course exceptions such as Darwin's Frog, midwife toads, *Pipa* spp. and others) these are essentially 'r' selected species. It would appear that *Typhlonectes natans* represents the opposite extreme: a 'K' selected species, characterized by a long life span, late maturity, and a very low rate of reproduction with extensive parental care (in this case a pregnancy lasting approximately 11 months). This is more commonly associated with animals like whales and elephants. For an amphibian this extreme example of 'k' selection is exceptional. In general 'K' selected species require stable habitats with constant environmental conditions in order to thrive. They are very vulnerable to sudden environmental changes and recover very slowly, if at all, from population declines. A further complication is that the long life spans and low reproductive rates of such organisms make it very difficult to detect long-term breeding failures which may lead to population crashes. Concerns have been expressed because of large-scale global declines in amphibian populations. This led to the establishment of the Declining Amphibian Population Task Force (DAPTF) by the IUCN in order to monitor amphibian populations, and to use such declines as an environmental and ecological barometer. The unusual life history of *Typhlonectes* species makes them even more vulnerable to environmental change than the majority of amphibians and, although current populations do not appear to be undergoing significant declines, this should be carefully monitored.

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Dendrobates truncatus: an often overlooked poison-dart frog

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DENDROBATES truncatus (Cope, 1861), or the Rio Magdalena Poison-dart Frog, hails from the tropical forests of the Magdalena river valley of Colombia. It is apparently closely-related to the more popular *D. auratus*, a species often kept for its hardiness and ease of breeding.

Keeping

The species should be maintained as for other poison-dart frogs. A suitable setup would be a large glass vivarium maintained at 20–24°C (I used an external proprietary heat-pad, controlled by a thermostat) and sprayed regularly (or with running water – others have described how this can be achieved in the vivarium) to keep the humidity levels high. I used 75 x 30 cm vivaria (actually aquaria) to maintain two breeding pairs and did not experience excessive territoriality. If taller vivaria are used, the species co-exists happily with other species which occupy a different spatial niche (i.e. higher up in the vivarium) such as *D. ventrimaculatus*.

Vivaria 'roofs' were custom-made by me from clear perspex. Ventilation is very important in such a warm, humid environment. An effective method of achieving this is to site a ventilation panel (mesh or a series of carefully-drilled holes) above the vivarium's light-source. All light-sources emit some heat and this causes air from inside the setup to rise out through the holes. A second ventilation panel situated at the opposite side of the vivarium allows fresher air to be drawn inside. Aquarium-style UV tubes were always used for lighting (ca. 12 hours a day), although this was mainly for the benefit of the plants.

I experienced better success with this species and 'happier', healthier frogs if the back and sides of vivaria were well-planted. *Philodendron* species are a good group of plants to use and I highly recommend *Scindapsus* (Devil's Ivy) as it grows well under most conditions (in fact, in the vivarium, it will need to be regularly cut back!). Bogwood furnishings or other decoration, as well as bromeliads, for hiding paces are appreciated and help to make the setup an attractive display. With this aspect of frog-keeping your imagination and pocket depth are the only limits! Growing plants also help to remove waste products from the substrate (but are not a substitute for cleaning and removing debris!) as well as providing micro-climates of differing humidity through transpiration.

D. truncatus is not a fussy eater and will take hatchling crickets and fruit-flies from metamorphosis onwards. These should be dusted with a proprietary vitamin/calcium supplement designed for amphibians and reptiles. Also suitable as food are various aphids as and when these are available (so long as their host plants have not been sprayed with any chemicals). Elderberry bushes are often a good place to find thousands of blackfly!

Breeding

Under the above conditions, breeding may occur spontaneously. An increase in spraying, however, and therefore humidity, at the latter end of summer is sometimes needed to persuade frogs unwilling to reproduce. Readiness is signalled by a low, buzzing call (which is so quiet, your partner/parents/housemates are unlikely to object!) from the males. *D. truncatus* seems to respond to a slight drop in ambient temperature which occurs naturally at the end of our northern summer. It seems that this, plus higher humidity, simulates the onset of the southern hemisphere's rainy season (although I have not properly tested this). Male frogs are slightly smaller than females and noticeably slimmer. They can, with practice, also be differentiated by their larger toe-pads (though these are not very obvious in this species).

If a male is successful in attracting a female, eggs (4–20 in my experience) will be laid in a suitable refuge. The typical half-coconut "igloo" on a petri dish is fine, but I used old plastic fishfood tubs, inverted and with a 2 cm hole cut in one side. Some frogs will care for their own eggs and in due course carry the emergent tadpoles to a water dish. I found it more satisfactory to remove the dish or lid on which the eggs were laid to a humidity box for more successful hatching. Such a box consists of a plastic ice-cream tub (or similar box), which must have some holes to let air circulate, floating in a larger container containing a few inches of water at about 20°C. The eggs are sprayed lightly every day but must not be allowed to submerge as they will die. I also added a few drops of aquarium fungicide to the spray water in order to help prevent infection (often happens without this measure and can run riot!). Spraying keeps the eggs moist but also agitates them slightly and mimics the effects of care from their parents. This seems to be beneficial.

It is generally obvious when the tadpoles have wriggled free of their jelly covering and at this stage they can be transferred to a water container (at a similar temperature) for rearing. Several tadpoles can be maintained together in a 5 litre container; being fed on fish flakes and/or thawed frozen spinach. Metamorphosis takes around 16 weeks. Tadpoles reared much faster than this may suffer developmental problems.

Metamorphs are very large for poison-dart frogs (often above 1 cm) and take small fruit-flies and hatchling crickets immediately. They can be maintained in the same way as the adults and will live happily with their parents when they are big enough not to be bullied, so long as there is room in your vivarium.

Afterthoughts

This is a fascinating and rewarding frog to keep in the vivarium and I am often surprised that more hobbyists do not breed this species. I put this down to their relative obscurity in the dart-frog world. There was a serious pollution incident in the Rio Magdalena a few years ago (so serious that the Catholic Church in Colombia issued instructions for their adherents to NOT eat fish on Fridays!) and the area is suffering widespread environmental degradation (overfishing, overcultivation etc.) which has unknown and potentially lasting effects on the wildlife dependent on the river valley and its associated estuary (a Ramsar site). Chemical pollution of the river by local industry also continues.

If you are interested in keeping and breeding dendrobatids and have the opportunity to obtain some *D. truncatus* from a reliable (= legal and reputable) source, why not give them a try? The opportunity to encounter them in the wild seems an increasingly unlikely possibility....

Notes

The frog in the photograph is one of a pair (male) in my collection which produced many healthy tadpoles over a period of about five years. It was photographed using an old (Pentax) SLR camera and extension tubes at close-range. This requires much patience, good lighting, phlegmatic frogs and the assistance of a 'frog-wrangler' to retrieve escaping subjects.

If anyone knows or hears of new measures to protect the Rio Magdalena valley area I would be interested in hearing from them at the above e-mail.

RESEARCH ARTICLES

Population declines of Common Toads (*Bufo bufo*): the contribution of road traffic and monitoring value of casualty counts

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ABSTRACT — Routine counts of Common Toads (*Bufo bufo*) killed by road traffic were used to demonstrate synchronous population declines since the late 1980s at three breeding sites in Cambridgeshire. All factors that might have contributed to the declines were considered in turn. It was concluded that road mortality of adult toads played a significant part at each site, although other factors were also implicated, especially habitat modifications. The level of local traffic flow was likely to have resulted in unsustainable losses, and counts decreased more rapidly on the busier roads. The use of counts of dead toads as a monitoring technique is discussed and suggestions made. A data-set of casualty counts needs careful interrogation, with analysis concentrating particularly on counts in the recent past.

SINCE Blaustein & Wake (1990) drew attention to the decline of many amphibian species in different parts of the world, this subject has generated considerable debate and concern. In Britain, we have been aware of amphibian population decreases for rather longer, the Common Toad (*Bufo bufo*) being one of the species for which regional declines occurred in the first half of the twentieth century. Declines of the toad began during the early 1940s when the war effort demanded more effective agricultural operations, and populations suddenly decreased in intensively farmed areas such as the East Anglian Fens (Cooke & Ferguson, 1976). After the Second World War, agricultural intensification continued and this, together with loss of habitat in and around towns, led to widespread population declines of the toad in the 1950s and 1960s (Cooke, 1972). These decreases slowed in the 1970s, with the continual erosion of suitable habitat being partially offset by the creation of garden ponds, particularly in England (Cooke & Scorgie, 1983). However, in the 1980s there were signs of further declines in parts of central and southern England (Hilton-Brown & Oldham, 1991). By this time, conservationists were showing increasing interest in toads, in particular by attempting to reduce mortality by carrying toads across roads (Langton, 1989). In the mid 1990s, a survey of these volunteer patrols revealed that a high proportion believed their local toad populations to be declining (Foster, 1996). Following on from this observation, Carrier & Beebee (2003) undertook a postal enquiry and found for the period 1985-2000 that there had been significant declines in Common Toad populations in central, eastern and south eastern England. Underlying reasons for these population decreases were unclear, but they occurred for populations outside gardens and parks, and the Common Frog (*Rana temporaria*) remained relatively unaffected (Carrier & Beebee, 2003).

This paper examines in detail one particular area in Cambridgeshire to determine whether recent declines occurred in Common Toad populations and, if they did, to attempt to unravel the factors responsible. While the situation may or may not be typical of those highlighted as of concern by Carrier & Beebee (2003), its recorded history up to 1980 broadly reflected that described

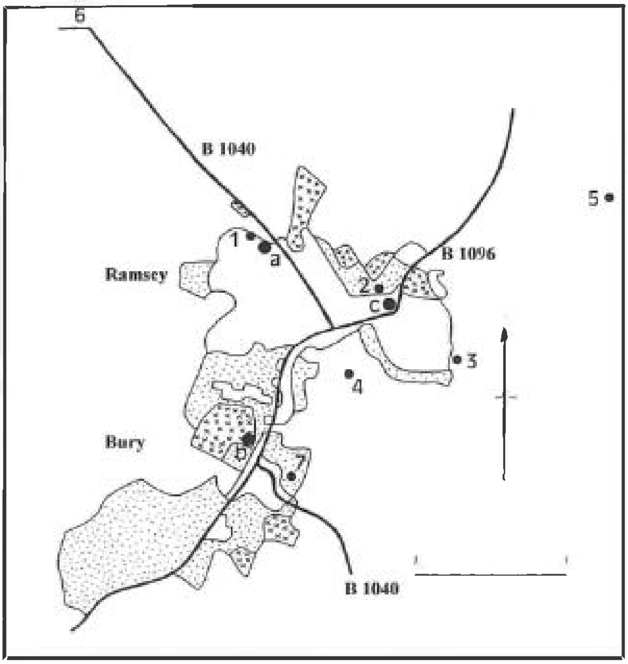

Figure 1. Sketch map of the area of Ramsey and Bury showing the main roads (thick lines) and the extent of development up to about 1950 (unshaded), 1975 (stippled) and 2000 (small crosses). The main toad breeding sites are marked by large black dots: (a) Field Road Pond, (b) Bury Pond and (c) Horse Pond. Other sites are numbered 1–7, as listed in Table 4; these are indicated by smaller dots, apart from no.6, which is a length of river beside the B 1040. The scale bar is 1 km.

above. Thus Common Toad populations decreased in this part of the country from the early 1940s through to the 1960s, before stabilising in the 1970s (Cooke & Ferguson, 1974, 1975; Cooke & Scorgie, 1983). This location is also in the centre of that part of the England where the recent declines have occurred (Carrier & Beebee, 2003).

The study utilises routine counting of road casualties as a method for monitoring population declines, so it is necessary to discuss what information such counting might provide.

WHAT CAN MONITORING NUMBERS OF ROAD CASUALTIES TELL US ABOUT POPULATION CHANGE?

In Britain, the recommended method for surveying populations of Common Toads is to count heads at night during the height of the breeding season (Griffiths & Inns, 1998). However, toads often breed in large, deep, turbid bodies of water that present logistical or safety problems for a surveyor, particularly at night. The possibility has been explored of utilising more readily achievable types of counts, including counts of road casualties (Cooke, 2000 and unpublished). At one of the sites examined in this paper, numbers of toad casualties counted on the roads over a period of 10 years or more were positively related to counts of live toads in the breeding site and to spawn production.

Hels & Buchwald (2001) modelled the probability of survival of an individual toad crossing a road, arguing that its chances depended on the number of vehicles passing per unit time, the killing width of the wheels, the velocity of the toad and its angle of crossing. Whether a casualty is recorded by an observer depends on how soon the count is made and on carcass persistence, which is related to the activity of scavengers and to weather conditions (Hels & Buchwald, 2001; Slater, 1994). A single count will detect only a (small) proportion of toads killed during migration, but systematic annual counts of casualties should reflect changes in the toad population if all the above factors remain unchanged. At most sites in this country, it is probable that frequency of road traffic has increased over time; and average tyre width is also likely to have increased. Therefore, if the number of adults breeding at a site does not change significantly from year to year, and neither do the other factors listed, then numbers killed by traffic should increase. If traffic levels continue to rise, toad losses may become unsustainable and the population will begin to decline. As a result, number of casualties recorded annually will level out, then progressively decrease.

This means that a situation where casualty counts increase over several years, although worrying for conservationists, indicates a stable or even an increasing toad population if the other factors apart from traffic remain constant. On the other hand, decreasing numbers of road casualties may indicate a declining population. While such a population reduction may have been caused by the road traffic, it may instead have occurred for other unrelated reasons, such as a reduced carrying capacity of the local environment, and simply be mirrored by the numbers killed on the roads.

SITE DESCRIPTIONS

Ramsey is a market town in Cambridgeshire at the south western edge of the Fens. The human population of the parish of Ramsey was 8080 in 2001, an increase of 37% over that of 1981 (Cambridgeshire County Council Research Group statistics). The nearby village of Bury was separate from Ramsey up to 1950, but expansion of both means there is no longer any clear separation (Figure 1). The human population of the parish of Bury was 1760 in 2001, an increase of 81% when compared with 1981. The large area developed to the south west of the centre of Bury during 1950–1975 (Figure 1) was primarily housing and other buildings constructed for the Royal Air Force.

Within the Ramsey/Bury area in recent decades, there have been three principal breeding sites for Common Toads (Figure 1a, b and c):

Field Road Pond. This pond (grid reference TL 283856) was created as a ballast pit in 1864 when Ramsey's northern railway station was built. The station and track were dismantled in the early 1970s. The pond is beside Field Road, one of the busier domestic roads of the town and is about 100 m from the B 1040, the main road out of Ramsey to the north west (Figure 1). The surface of the pond measures about 45 x 30 m, and it has a terrestrial margin of about 5 m, much of it covered by scrub and trees. Restricted access to the banks and the often turbid nature of the water has made systematic counting of breeding toads impossible.

Bury Pond. Washing lagoons were created behind a vegetable processing plant (TL 282843) in the 1950s. Toads evidently did not colonise immediately, but were common by the early 1980s. The site was progressively surrounded by housing during the 1970s and 1980s, and the plant itself was pulled down in 1988 to make way for new houses. One modified pond was retained specifically as a toad breeding site and is now managed by the Cambridgeshire Wildlife Trust. The dimensions of the pond are about 25 x 15 m, with a terrestrial margin of about 5 m. The pond is about 100 m from the main Ramsey-Huntingdon road, the B 1040. A traffic count on this road in 2002 was 6679 vehicles in 12 hours, an increase of 11% over 1992 (Cambridgeshire County Council, 2002). Because there has been ready access to most of the pond's edge and the water is usually clear, it has been possible to make regular counts of breeding toads and to monitor amounts of spawn by means of an index (Cooke, 2000). Bury Pond is 1.3 km in a straight line from Field Road Pond.

Horse Pond. Horse Pond is beside the B 1096 (at TL 292852). It has a hard sloping bottom, so that passing horses could be watered, and has been a feature of the town for centuries. It measures roughly 25 x 45 m with grassy margins varying between 1 and 6 m. Since the 1980s, a resident population of up to 40 semi-domesticated Mallards (*Anas platyrhynchos*) has made the pond very turbid, thereby precluding routine counting of breeding toads. Horse Pond is 1.3 km from Bury Pond and 0.9 km from Field Road Pond.

TOAD CASUALTY COUNTS

Each of these three sites has minimal terrestrial habitat in which toads might live, and animals evidently migrate over considerable distances to breed. Elsewhere toads often migrate >1 km (eg Sinsch, 1989). Because of the spacing of the breeding ponds in Ramsey and Bury, toads occur throughout the area depicted in Figure 1. In spring, dead toads may be found on roads anywhere in the area, but tend to be concentrated close to the three breeding sites. Casualties were counted on about 1.3 km of roads near Field Road Pond each year 1974–2003. Near Bury Pond, casualties were counted from 1990 to 2003 on a road circuit around the pond of 1.6 km (including

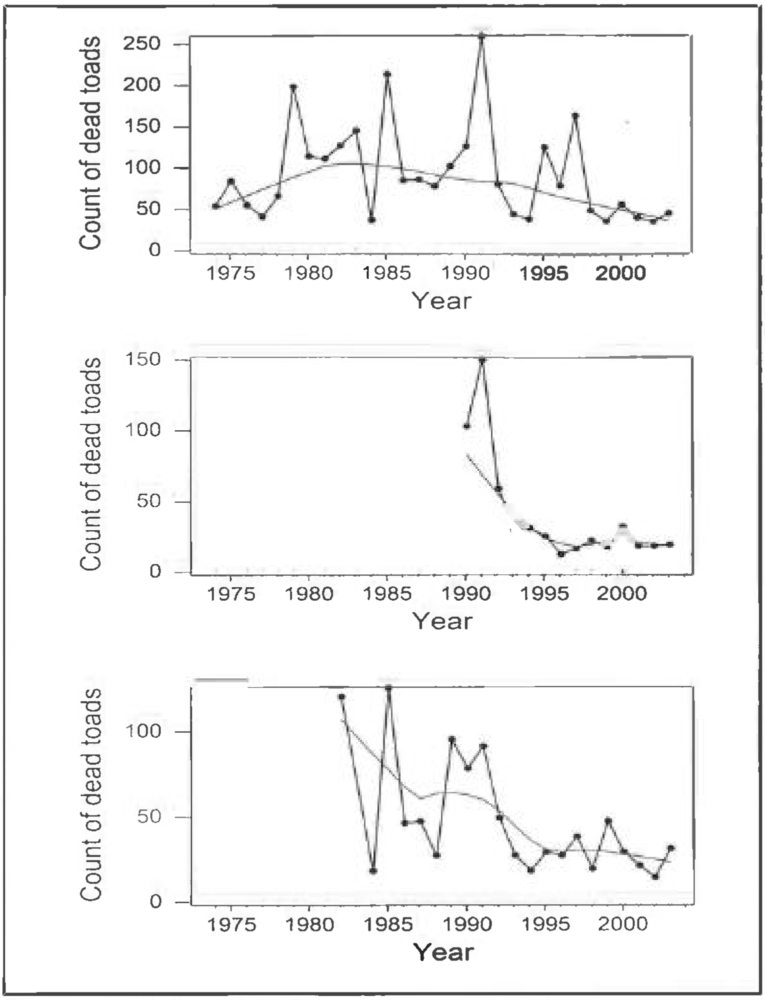

Figure 2. Annual peak casualty counts at the three toad breeding sites. A distance weighted (LOWESS) line indicates the underlying trends. a (top): Field Road; b (centre): Bury; c (bottom): Horse Pond. Note the different vertical scales.

a 500 m stretch of the B 1040). At Horse Pond, dead toads were counted along a 250 m length of the B 1096 in 1982 and from 1984 to 2003. During the toad breeding season, brief checks were made on most days to ascertain when peak numbers of casualties appeared to occur. When this happened, casualty counts were made on foot during daylight. If further appreciable mortality was noted in the same breeding season, counts were repeated as necessary and the highest figure used for that year. Earlier counts at Bury and Field Road Ponds are given in Cooke (1995 and 2000).

Casualty counts are shown for the three breeding sites in Figure 2. Regression coefficients are given in Appendices 1–3 for log_e(count + 1) against year for all periods of at least 10 years, with significant ones being emboldened. No adjustment was made for significance in the large number of comparisons in order to retain meaningful patterns in the significant coefficients. Focusing first on the Field Road data (Figure 2a and Appendix 1), the earlier coefficients for successive data-sets, 1974-year x, tended to be positive and the later ones negative. Only the earliest positive analysis, for 1974–1983, was statistically significant, whereas many of the later negative ones were significant. Thus, had only part of this 30 year period been recorded, any conclusion would have been dependent on the years covered. A distance weighted (LOWESS) line has been superimposed in Figure 2a to indicate the underlying trend; numbers increased to a peak in the early 1980s, then decreased to 2003. Data for Bury Pond showed negative coefficients for all periods of at least 10 years, with most being significant (Appendix 2). Smoothing the transformed data suggested a rapid decrease from 1990 to about 1997 (Figure 2b). At Horse Pond, a few early coefficients were positive, but the great majority were negative, with many of the later ones being significant (Appendix 3). Smoothing the transformed data indicated an overall decrease (Figure 2c).

Comparing transformed casualty counts between the three sites showed positive and significant relationships: Field Road Pond vs Horse Pond, Pearson correlation coefficient = 0.773 ($P < 0.001$); Field Road Pond vs Bury Pond, 0.540 ($P < 0.05$); Horse Pond vs Bury Pond, 0.689 ($P < 0.01$). This pointed to synchronous declines in counts at the three sites. By monitoring events in the Bury Pond, it is known that the breeding population has decreased significantly since 1990 (Cooke 2000 and unpublished), and the evidence based on casualty counts therefore indicated similar population changes at the other two sites. Examination of the regression relationships for count data during 1985-2003 and 1990–2003 suggested that the greatest rate of decline occurred at Bury Pond (Table 1). The start date of 1985 was selected because Carrier & Beebee (2003) chose the time period of 1985–2000 for their enquiry; and the start date of 1990 was the year that casualty counting began on the road circuit around Bury Pond. Regression coefficients were consistently more negative for 1990–2003 than for 1985–2003 (Table 1).

Site	1985–2003		1990-2003	
	Coefficient ±SE	Proportional annual loss	Coefficient ±SE	Proportional annual loss
Field Rd Pond				
All roads	-0.075 ± 0.023**	0.07	-0.105 ± 0.039*	0.10
Field Road	-0.125 ± 0.026***	0.12	-0.162 ± 0.044**	0.15
Star Lane	-0.037 ± 0.028	0.04	-0.069 ± 0.044	0.07
Bury Pond				
All roads	-	-	-0.145 ± 0.039**	0.13
B 1040	-	-	-0.215 ± 0.043***	0.19
Estate roads	-	-	-0.131 ± 0.052*	0.12
Horse Pond				
B1096	-0.077 ± 0.022**	0.07	-0.086 ± 0.033*	0.08

Table 1. Regression coefficients and proportional annual loss for log_e(casualty counts + 1) at the three sites, 1985–2003 and 1990–2003. *significant relationship $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

REASONS FOR POPULATION DECREASES

Potential reasons for changes in population size are listed in Table 2. It is also necessary to consider factors that might modify casualty counts (Table 3). While the main focus is on identification of reasons for population declines between 1985 or 1990 and 2003, it is recognised that factors responsible may have started to influence toad numbers prior to 1985. Potentially important factors, both for population decreases and for modifying counts, are italicised in the Tables and discussed below.

Reduction in the surface area of the breeding site. At Bury, the three ponds that existed up to 1988 were reduced to a single pond, with a decrease in surface area of about 75%. This may have limited recent reproductive potential.

Reduction in breeding site depth. In the autumn of 1992, Cambridgeshire Police drained the Field Road Pond when searching unsuccessfully for a missing person. The water surface never returned to its previous level and remained about 50 cm lower than before, perhaps affecting reproductive output.

Amount of vegetation. High densities of aquatic vegetation may may decrease tadpole survival, but little marginal vegetation may reduce toadlet survival (Young & Beebee, 2002). Since the 1980s, Horse Pond has had impoverished aquatic and marginal plant communities because of the presence of large numbers of ducks.

Failure to produce toadlets. At Bury, metamorphic success was visually assessed as poor, moderate or good each year from 1987 until 1998. During five of the first six years, 1987–1992, metamorphosis was good, whereas during 1993–1998 it was good in only one year. Areas of open water have persisted at this site, and increasing density of aquatic vegetation (Young & Beebee, 2002) seems unlikely to have reduced tadpole survival. Reading & Clarke (1999) suggested that when toads spawn earlier in warmer springs the resulting tadpoles might suffer higher

Factor	Bury Pond	Field Road Pond	Horse Pond
Breeding site			
Surface area	*Large reduction late 1980s*	No change	No change
Depth	No change	*Reduction in 1990s*	No change
Amounts of aquatic and marginal vegetation	Usually balanced amounts	Impoverished throughout study period	*Generally poor for aquatic higher plants and marginals since 1980s*
Point source pollution	No evidence of any pollution incidents	No evidence	No evidence
Breeding season			
Failure to spawn	No	Not studied	Not studied
Spawn loss	Nothing unusual seen	Not studied	Not studied
Failure to produce toadlets	*General failure 1993-8*	Not studied	Not studied
Waterfowl	Sporadic presence	Low numbers present	*Unusually high numbers since 1980s*
Competition from frogs	*Frogs increased greatly and mixed pairs seen*	No frogs seen	*Frogs increased*
Human predation or collection	No evidence	*Traditional site for collection by children*	No evidence
Terrestrial habitat			
Surrounding land developed	*Large change in recent decades*	*Some change*	*Some change*
Migration impeded	*Greatly impeded by fences and walls*	*Impeded to a more limited extent*	*As at Field Road*
Increase in traffic on existing roads	*Yes*	*Yes*	*Yes*
Extra roads	*Yes*	No	Not recently
Change in behaviour			
Move to garden ponds	*Some reports*	*Some reports*	*Some reports*
Move to other sites	No evidence	*Increases noted in 1990s*	*Increases noted in 1980s and 1990s*
Miscellaneous			
Disease	No evidence of incidents	No evidence	No evidence
Diffuse pollution	Not studied	Not studied	Not studied
Climate change	*Warmer springs may help to increase chance of frog/toad mixed pairs*	Unknown	As at Bury

Table 2. Evidence for factors that might have contributed to the recent observed declines in toad populations. Potentially important factors are in italics.

mortality, but no relationship was found at Bury Pond between the date of the casualty count and metamorphic success.

Presence of waterfowl. Since the 1980s, Horse Pond has had a large resident population of Mallard, and these have been regularly fed by local people. This has led to permanently turbid conditions with a reduced diversity of aquatic plants; and the ducks may also feed on spawn and tadpoles. However, in experiments with caged tadpoles elsewhere in this area, larval growth and development rate have been good in enriched sites (Cooke, 1981), and the waterfowl may not, on balance, be detrimental to toads.

Competition from frogs. Common Frogs increased in Ramsey and Bury during the study period, spawn production peaking at 283 clumps in 2002 in Bury Pond and 44 clumps in 2001 in Horse Pond. At Bury Pond, mixed pairs, consisting of a frog and a toad, have been occasionally seen since 1990. If a male frog mates with a female toad, the toad's reproductive output will be lost for that year. Inter-specific mating may have become progressively more serious for the survival of the Bury toads as they have become rarer and male frogs more abundant. However, this seems an unlikely mechanism to have caused the toad declines of the early 1990s. Another recent threat to the toad population in Bury Pond is that the hundreds of thousands of frog tadpoles that hatch each year may outcompete the toad tadpoles or inhibit their development.

Human predation or collection. Field Road Pond has always attracted children during the toad breeding season. Numbers of adults, spawn and tadpoles have been regularly removed from the site over the last 30 years. Such losses in the 1970s and early 1980s were apparently not associated with population decreases, but may be more significant now that the toads are rarer.

Changes in the surrounding land. Brown- and green-field land close to the breeding ponds has been developed in recent decades, mainly for housing (Figure 1). An exception to the trend was the dismantling of the station and track of the railway station beside Field Road Pond in the early 1970s. Approximately 40% of the land within 250 m of Bury Pond has been converted to relatively high density housing since 1975, while the figure for both Field Road Pond and Horse Pond is about 10%. Although gardens will provide terrestrial habitat for toads, the overall carrying capacity may not be as high as previously with roads and buildings now covering much of the land.

Barriers to migration. Another consequence of the building programmes may have been to render migration more difficult with the construction of walls, fences and the houses themselves. Dispersal may have been affected, resulting in

Table 3. Evidence for factors that might have affected the frequency with which casualties occurred and were counted in any particular year. Potentially important factors are in italics.

Factor	Bury Pond	Field Road Pond	Horse Pond
Toad behaviour			
Direction of migration changed	*Some modification*	*Significant modification*	No obvious change
Distance migrated changed	No obvious change	No obvious change	No obvious change
Angle of crossing roads changed	Not directly studied but no obvious change in migration pattern	As for Bury Pond	As for Bury Pond
Velocity of crossing roads changed	Not studied	Not studied	Not studied
Miscellaneous			
Changes in weather	No clear changes in spring rainfall	As for Bury Pond	As for Bury Pond
Activity of scavengers	Bird scavengers rare throughout	As for Bury Pond	As for Bury Pond
Activity of conservationists	*Toad lifting primarily 1988-1994*	*Toad lifting 1987-1994*	*Toad lifting 1988-1989*

Site number and grid ref.	Description	Toad status
1. TL 282857	Pond in field by mill.	Good population in 1950s, but few bred by 1970s. Pond destroyed 1979/1980.
2. TL 291853	Overgrown pond in pasture.	Small population 1950s, declining to non-breeding refuge by late 1980s. Pond destroyed 1999.
3. TL 296848	Pond in school playing field.	Breeding site since 1970s at least, but numbers usually low.
4. TL 288847	Pond on golf course.	Breeding site since 1960s at least. Pond became silted and marshy but part dredged 2002/3.
5. TL 305860	Farm reservoir.	Site created 1950s. Built up to large population in 1995, but since declined. Sporadic presence in nearby farm ponds.
6. TL 271872	Fen river, extending 1.5 km to west.	In 1990s, significant numbers noticed for first time on adjacent road - maximum kill in 1995. Also seen beside river in late 1990s at TL 307881 and further east.
7. TL 284841	Field pond incorporated into garden.	Pond renovated 1990s. Small breeding population of toads, with many frogs.

Table 4. Other sites in the area where Common Toads have bred. Locations are indicated by the numbers in Figure 1.

toads being over-crowded in suboptimal habitat. Isolation of the colonies will have increased and genetic diversity reduced (Hitchings & Beebee, 1998).

Increase in road traffic on existing roads. As an example of the increase in traffic on existing roads: an increase of 11% in the number of vehicles using the B 1040 to the south of Bury was recorded between 1992 and 2002 (Cambridgeshire County Council, 2002). Greater traffic flow will increase mortality of toadlets, juveniles and adults, which may subsequently affect population size (Hels & Buchwald, 2001).

Construction of new roads. Near Bury Pond, a number of new roads were constructed during the late 1970s and the 1980s. Mortality of the terrestrial stages is likely to have been increased because of encountering traffic where none occurred before. Difficulty with migration, as mentioned above, may have resulted in adult toads walking along roads rather than across them. Not only will this have exacerbated road mortality, but there were instances of toads following curbs and falling into new drainage gulley pots.

Movement to garden ponds. Toads generally do not form large breeding aggregations in garden ponds (Cooke, 1975) and the vogue for creating garden ponds has benefited the Common Frog much more than the Common Toad (e.g. Cooke & Scorgie, 1983). Nevertheless, there have been increasing numbers of reports of toads in local garden ponds. This fact does not necessarily point to toads colonising garden ponds rather than their traditional sites, as it is often not clear whether the toads were breeding or simply using the ponds as refuges. Even those breeding in gardens may have been doing so because migration routes to their usual sites were blocked.

Movement to rivers, reservoirs and other sites. The occurrence of toads at other local sites is summarised in Table 4. During the 1990s, the toad population seemed more widely dispersed than formerly. Populations in several locations were high in 1995 (eg site 5). Dead toads seen on the B 1040 beside the old course of the River Nene (site 6, Figure 1) were at least 2 km from the breeding site at Field Road. As the casualty count was high at Field Road in 1995, it is possible that good emergence there in the early 1990s produced an exceptionally large cohort of young toads that dispersed unusually widely. Dead toads were also encountered along the B 1040 between site 6 and Ramsey. Wider dispersal, though, cannot account for the losses observed at the three traditional sites. In this context, it is worth mentioning a possible immigration event at Field Road, as opposed to emigration. Less than 200 m to the north west of Field Road Pond, there was another pond used by much smaller numbers of toads during the 1970s (site 1, Figure 1). This pond was destroyed during the winter of 1979/1980, so it is likely that toads that formerly bred there then swelled the numbers breeding at Field Road in the early 1980s. However, there were no roads between the two ponds, and any appreciable effect on numbers killed by traffic was unlikely.

Climate change. It is possible that warmer springs may decrease the interval between local spawning dates of Common Toads and Common Frogs, if toads show a greater response (Cooke, 2000, 2003), and render mixed pairs more likely (see above). The advantages and disadvantages of climate change were fully discussed by Reading & Clarke (1999).

Changes to direction of migration. To determine whether direction of migration had been modified over time at Field Road Pond, counts were compared between Field Road to the south east of the pond and Star Lane to the south west. Field Road is a busy suburban road, whereas Star Lane is a quiet side street which was a dead-end until the 1980s when it was modified, together with a neighbouring street, to form a crescent off Field Road. Field Road showed a steeper decline in casualty counts in recent years than Star Lane (Table 1), the difference in the slopes of the regression lines being significant ($P < 0.05$). At Bury, casualty counts were examined for 1990–2003 for the B 1040 to the east of the pond and for the two principal estate roads to the west, which were constructed in the late 1970s and 1980s. Counts showed a steeper decrease on the B 1040 where traffic was likely to be heavier (Table 1), although the slopes of the regression lines were not significantly different. Such comparisons were not possible at Horse Pond where toads were counted on a single road only. Observations around Bury and Field Road Ponds suggested that a progressively smaller proportion of toads migrated each year over the busier roads. Total annual casualty counts might have been rather higher in the 1990s had migration patterns not been modified.

Activity of conservationists. The local Wildlife Trust first organised conservationists to help toads across roads in 1987. Prior to that date, little effort had been made to reduce numbers of toads killed. The years of 1988 and 1989 witnessed the most activity, and Trust helpers and other individuals reported moving totals of >700 and >600 respectively. Official toad warning signs were erected in 1993 at Field Road and close to Horse Pond. However, numbers of toads found in the early 1990s declined and interest waned, and by the mid 1990s, only one or two individuals bothered to look for toads. The impact of helping toads is difficult to estimate quantitatively: a proportion of the toads carried across the roads would otherwise have been killed. Therefore, without such conservation action, numbers killed would have been higher, especially in 1988 and 1989. The trend at all three sites for casualty counts to show a significant decline from the late 1980s occurred despite this bias. Had the conservation action not happened, these trends would probably have been even more marked, especially at Field Road where helpers were most active.

Assessment of contributing factors. It is worthwhile considering Horse Pond first because fewer reasons for change were identified there (Table 2). The presence of frogs and waterfowl were probably relatively unimportant, which left: a certain amount of habitat change, an increase in traffic and some movement to other sites. All of these factors were also identified at Bury and Field Road. At Bury Pond, movement to other sites was rated as comparatively unimportant, but the major landscape changes of recent decades could help explain the more dramatic reduction in the toad population. These changes included a reduction in pond area, a probable reduction in carrying capacity of the terrestrial environment, impeded migration and higher mortality on the roads. The general failure to produce toadlets at Bury Pond during 1993–1998 remained unexplained. Casualties have been counted for longest at Field Road, where the pattern over the last 30 years of an increase followed by a decline was consistent with increasing road traffic having a progressive impact which eventually became unsustainable. While this pattern might instead reflect changes caused by other factors, the observation that declines in casualty counts in recent years were steeper on the busier roads lends support to traffic mortality being the main reason for the observed decline. Individual toads have a propensity to migrate in a certain direction (eg Oldham, 1999), which could explain why the pattern of direction of migration was modified to favour the less lethal routes. In the equation of Hels & Buchwald (2001), survival probability decreased exponentially with increasing road traffic, so a situation might quickly change from traffic deaths being sustainable to being unsustainable. In 2002, during a 12 hour daytime period observing traffic use, 6679 vehicles were counted on the B 1040 south of Ramsey and Bury (Cambridgeshire County Council, 2002). A toad crossing a road with this amount of traffic during a whole day would have a probability of being killed of 0.67, when taking into account the diurnal variations in traffic intensity and toad activity in the Danish study of Hels & Buchwald (2001).

DISCUSSION

Casualty counts showed synchronised declines at the three sites, 1990–2003. At Bury Pond, the population declined during this period with casualty counts being significantly related to counts of toads in the breeding site and to a spawn string index (Cooke, 2000 and unpublished). It is reasonable to conclude that (1) toad populations have decreased at all three sites and (2) these declines may have common causes. While other factors will have contributed (particularly various habitat modifications at Bury), road traffic mortality appears to be implicated. At a site in the Netherlands, the mortality of female toads was estimated at 29% during a single breeding season on a road carrying less than one twentieth of the traffic on the B 1040 at Bury in 2002 (van Gelder, 1973). Using the model and data of Hels & Buchwald (2001), the amount of traffic on the B 1040 was sufficient to kill at least 67% of toads trying to cross. While it is not possible to state what the threshold of sustainability might be, such a level is surely unsustainable (see Langton, 2002). The pattern of counts around the Field Road site, 1974–2003, was consistent with road mortality becoming unsustainable in the 1980s. Although only circumstantial evidence, this is supported by counts on Field Road itself showing a greater decrease than on a much quieter side road. Fahrig et al. (1995) reported from Canada that locations with high traffic intensity had smaller toad populations and fewer road casualties per km of road. Results from this study in Ramsey and Bury appear to show the progress of this effect from year to year.

It is not clear how typical these sites might be with regard to those sites with declining populations reported by Carrier & Beebee (2003). In Britain, toad populations face many other types of threat. Factors listed in Table 2 might provide a convenient framework for considering reasons for toad declines elsewhere, perhaps with other local factors being incorporated. There is nothing particularly remarkable about Ramsey or Bury. Each of the three main breeding sites is not more than 100 m from a B class road. The same is true of three of the seven sites listed in Table 4; the remaining four populations would be expected to have lower mortality because of traffic. Carrier & Beebee (2003) ruled out road mortality as a significant cause of the reported population decreases because replies from road patrol volunteers about changes in status did not differ from those of other rural correspondents. However, toads at the non-patrol sites may still cross roads and the patrols' actions may exert a compensatory effect. Young & Beebee (2002) followed up a sub-set of replies from the correspondents of Carrier & Beebee (2003) and reported widespread concern about increasing road traffic. In an earlier enquiry by Froglife, patrol volunteers considered that an increase in traffic was the main reason for the population declines they reported (Foster, 1996).

If road mortality is implicated in toad declines more widely, this could help to explain the lack of a similar impact on frog populations (Carrier & Beebee, 2003). Common Frogs are far less prone to be killed on the road, presumably because they neither migrate so far as toads nor tend to cross such relatively open and dry habitats. Also frogs are faster when crossing roads (Hels & Buchwald, 2001). In recent years, casualty counts of frogs near to Bury Pond or Horse Pond have always been <10. Frogs in this area are increasing by colonising garden ponds (eg Cooke, 2003) and other sites such as Bury Pond (Cooke, 2000).

Long term decreases in casualty counts have proved of value in this study by indicating population declines for the local toad colonies. It should be stressed again that if counts increase in a typical situation of increasing traffic flow, then it is likely to be impossible to interpret this as a population change without much more detailed knowledge. The question then arises as to how useful shorter term monitoring might be, especially as inter-year counts may vary by up to an order of magnitude (Figure 2)? Regression analysis is not the answer. Based on the counts at Field Road from 1974 to 1994, there was no evidence of any major long term trend (Cooke, 1995); at this point in time, the regression coefficient was +0.006 (Appendix 1), but there had been decreases for three successive years (Figure 2a). Although counts temporarily increased again in the mid 1990s, this conclusion was reached at a time when the long term decrease had already begun. A data-smoothing technique may help to understand trends. The LOWESS line for Field Road revealed a slow decline in counts from the early 1980s, but this was distance weighted and based on the whole data-set. Calculating a three year moving mean would have raised a minor concern in 1993 and then a permanent concern from 1999. Even looking out for decreases over three consecutive years could prove of value. One further word of caution about casualty counts – Slater (1994) concluded that daytime counts of toads might grossly underestimate true mortality or completely fail to detect it because of the scavenging activity of corvids. In Ramsey and Bury, corvids were rare around the breeding sites, and were never seen feeding on dead toads. However, in other locations, Carrion Crows (*Corvus corone*) and Magpies (*Pica pica*) will be common, and their potential impact should be considered.

It is not the purpose of this paper to discuss in detail what might be done when a population decline is suggested because of road traffic. There has been concern about toad mortality on roads since the 1980s and many techniques are available involving carrying toads across roads; installing warning signs, constructing tunnels, using barriers to steer them away from danger or to render them easier to collect and carry to the pond; or even moving the colony to a safer location (eg Langton, 1989, 2002; Schlupp & Podloucky, 1994; Highways Agency, 2001). Translocation or installation of barriers or tunnels are probably impractical in the majority of situations. Although carrying toads across the roads failed in Ramsey and Bury to prevent or arrest population declines, it remains the most practical and popular method. If more conservationists appreciate that road mortality is a real, rather than a hypothetical, risk to their local toads, then even more people may participate. It would be far better to use casualty monitoring as a device for checking the success of conservation action, rather than waiting until a population decline was indicated and then attempting to rectify the problem. Knowing that you are preventing population declines that would otherwise occur should provide more of a stimulus for continuing. If toad numbers start to decline, conservation effort should be intensified, not allowed to slacken, as in Ramsey and Bury. Once we have a greater ability to understand and quantify risk, it should be possible to target volunteer effort more effectively, as well as provide objective input to local planning issues.

ACKNOWLEDGEMENTS

We are grateful to G. Dean, R. Edwards, P. Fearn, Mrs P. Peacock, E. Pearce and J. Stott for information on sites and on toad patrols, and to Prof T. Beebee and T. Langton for helpful comments on an earlier draft of the paper.

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Appendix 1. Regression coefficients for log transformed casualty counts at Field Road Pond for runs of ten or more years. Start years are given along the top of the table and end years down the side. Positive coefficients are in italics, and significant relationships are emboldened.

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1983	*0.131*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
1984	*0.052*	*0.039*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
1985	*0.080*	*0.074*	*0.092*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
1986	*0.062*	*0.054*	*0.065*	*0.048*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
1987	*0.049*	*0.040*	*0.047*	*0.031*	-0.024	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
1988	*0.037*	*0.027*	*0.032*	*0.015*	-0.033	-0.076	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
1989	*0.034*	*0.026*	*0.029*	*0.015*	-0.025	-0.059	-0.034	•	•	•	•	•	•	•	•	•	•	•	•	•	
1990	*0.036*	*0.029*	*0.033*	*0.021*	-0.012	-0.038	-0.014	-0.011	•	•	•	•	•	•	•	•	•	•	•	•	
1991	*0.050*	*0.046*	*0.051*	*0.043*	*0.018*	*0.001*	*0.027*	*0.037*	*0.051*	•	•	•	•	•	•	•	•	•	•	•	
1992	*0.040*	*0.035*	*0.038*	*0.029*	*0.006*	-0.011	*0.010*	*0.015*	*0.022*	*0.043*	•	•	•	•	•	•	•	•	•	•	
1993	*0.022*	*0.015*	*0.016*	*0.006*	-0.018	-0.035	-0.021	-0.021	-0.021	-0.013	*0.013*	•	•	•	•	•	•	•	•	•	
1994	*0.006*	-0.002	-0.003	-0.014	-0.037	-0.055	-0.045	-0.049	-0.053	-0.051	-0.038	-0.115	•	•	•	•	•	•	•	•	
1995	*0.010*	*0.003*	*0.003*	-0.007	-0.026	-0.041	-0.030	-0.031	-0.033	-0.028	-0.013	-0.071	-0.038	•	•	•	•	•	•	•	
1996	*0.007*	*0.001*	*0.000*	-0.008	-0.026	-0.039	-0.029	-0.030	-0.031	-0.027	-0.014	-0.063	-0.034	-0.047	•	•	•	•	•	•	
1997	*0.013*	*0.008*	*0.008*	*0.001*	-0.014	-0.024	-0.014	-0.013	-0.012	-0.006	*0.008*	-0.030	*0.000*	-0.005	-0.012	•	•	•	•	•	
1998	*0.005*	*0.000*	-0.001	-0.008	-0.022	-0.032	-0.025	-0.025	-0.025	-0.021	-0.011	-0.046	-0.024	-0.031	-0.042	-0.064	•	•	•	•	
1999	-0.004	-0.010	-0.011	-0.019	-0.033	-0.043	-0.037	-0.038	-0.040	-0.038	-0.032	-0.065	-0.049	-0.059	-0.072	-0.096	-0.111	•	•	•	
2000	-0.007	-0.013	-0.014	-0.022	-0.035	**-0.044**	-0.039	-0.040	-0.042	-0.041	-0.035	-0.065	-0.050	-0.059	-0.071	-0.090	-0.102	-0.100	•	•	
2001	-0.013	-0.018	-0.020	-0.027	**-0.040**	-0.049	**-0.044**	**-0.046**	-0.048	-0.048	-0.044	-0.071	-0.059	**-0.068**	-0.079	-0.097	**-0.108**	**-0.107**	-0.048	•	
2002	-0.018	-0.024	-0.026	-0.033	**-0.045**	**-0.054**	**-0.050**	**-0.052**	**-0.055**	**-0.055**	-0.052	**-0.077**	**-0.067**	**-0.076**	**-0.087**	**-0.103**	**-0.113**	**-0.114**	-0.067	-0.065	
2003	-0.021	-0.026	-0.028	**-0.035**	**-0.046**	**-0.054**	**-0.051**	**-0.053**	**-0.055**	**-0.055**	**-0.053**	**-0.075**	**-0.066**	**-0.074**	**-0.083**	**-0.097**	**-0.105**	**-0.104**	-0.063	-0.061	-0.099

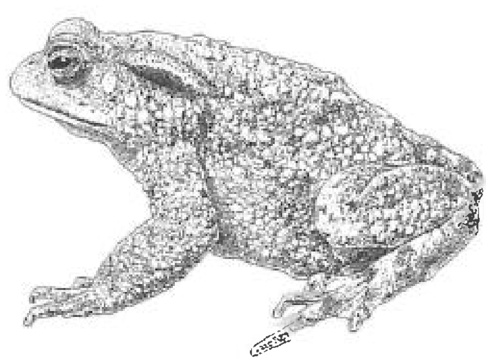
Appendix 2

Regression coefficients for log transformed casualty counts at Bury Pond for runs of ten or more years. Start years are given along the top of the table and end years down the side. Positive coefficients are in italics, and significant relationships are emboldened.

	1986	1987	1988	1989	1990	1991	1992	1993	1994
1995	-0.107	*	*	*	*	*	*	*	*
1996	**-0.182**	**-0.188**	*	*	*	*	*	*	*
1997	**-0.202**	**-0.211**	**-0.251**	*	*	*	*	*	*
1998	**-0.221**	**-0.232**	**-0.268**	**-0.364**	*	*	*	*	*
1999	**-0.200**	**-0.206**	**-0.233**	**-0.304**	**-0.295**	*	*	*	*
2000	**-0.174**	**-0.175**	**-0.192**	**-0.245**	**-0.227**	**-0.220**	*	*	*
2001	**-0.195**	**-0.199**	**-0.217**	**-0.266**	**-0.254**	**-0.253**	**-0.235**	*	*
2002	**-0.205**	**-0.210**	**-0.228**	**-0.271**	**-0.262**	**-0.263**	**-0.250**	**-0.215**	*
2003	**-0.190**	**-0.192**	**-0.205**	**-0.240**	**-0.228**	**-0.223**	**-0.206**	**-0.170**	-0.158

Appendix 3. Regression coefficients for log transformed casualty counts at Horse Pond for runs of ten or more years. Start years are given along the top of the table and end years down the side. Positive coefficients are in italics, and significant relationships are emboldened.

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1991	*0.026*	*	*	*	*	*	*	*	*	*	*	*	*
1992	*0.009*	*0.089*	*	*	*	*	*	*	*	*	*	*	*
1993	-0.028	*0.024*	*0.024*	*	*	*	*	*	*	*	*	*	*
1994	-0.066	-0.034	-0.034	-0.115	*	*	*	*	*	*	*	*	*
1995	-0.071	-0.045	-0.045	-0.114	-0.085	*	*	*	*	*	*	*	*
1996	-0.074	-0.053	-0.053	**-0.111**	-0.087	-0.109	*	*	*	*	*	*	*
1997	-0.065	-0.046	-0.046	**-0.094**	-0.071	-0.086	-0.105	*	*	*	*	*	*
1998	**-0.074**	-0.059	-0.059	**-0.103**	-0.085	-0.099	-0.117	**-0.180**	*	*	*	*	*
1999	-0.060	-0.045	-0.045	**-0.080**	-0.062	-0.071	-0.081	**-0.126**	-0.106	*	*	*	*
2000	-0.058	-0.044	-0.044	**-0.075**	-0.059	-0.066	-0.073	**-0.110**	-0.091	-0.066	*	*	*
2001	**-0.061**	-0.050	-0.050	**-0.078**	**-0.063**	**-0.070**	**-0.077**	**-0.109**	**-0.093**	-0.072	-0.022	*	*
2002	**-0.070**	**-0.061**	**-0.061**	**-0.087**	**-0.075**	**-0.082**	**-0.090**	**-0.119**	**-0.107**	**-0.093**	-0.055	-0.029	*
2003	**-0.063**	**-0.054**	**-0.054**	**-0.077**	**-0.065**	**-0.071**	**-0.076**	**-0.099**	**-0.086**	-0.071	-0.036	-0.011	-0.010



Common Toad, *Bufo bufo*. Drawing reproduced from *Amphibians and Reptiles of Surrey* (Surrey Wildlife Trust), with kind permission of the artist, Paul Veenvliet. (www.studiocinqo.com/p_veenvliet)

The California Red-legged Frog, *Rana aurora draytonii*, along the Arroyo Santo Domingo, northern Baja California, Mexico

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HISTORICALLY, the California Red-legged Frog occurred from northern California (Shasta County) to Northern Baja California, Mexico at elevations below 2440 metres (Stebbins, 2003). In California, the species was originally found in 46 counties but now occurs in only 22 (U.S. Fish and Wildlife Service, 2002). Remaining isolated populations of California Red-legged Frogs are found in the Sierra Nevada, northern Coast, northern Transverse Ranges of California, and Northern Baja California (Stebbins, 2003). In the Central Coast of California populations are common (U.S. Fish and Wildlife Service, 2002).

In the United States, the California Red-legged Frog is listed as a federally threatened species (since 1996) through the Endangered Species Act (USFWS 1996). In the state of California, within which most of its range is contained, it is designated a California Species of Special Concern (CDFG, 2003). In Mexico, there is no special protection for this species (Grismer, 2002). However, Mexican laws protect all wildlife but the protection is rather illusive. Under its red-list of threatened species the World Conservation Union does not include the California Red-legged Frog (IUCN, 2003).

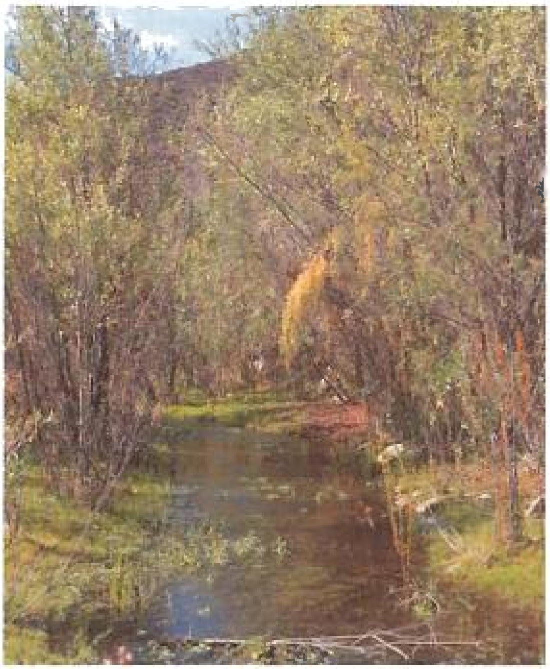
California Red-legged Frogs live in a Mediterranean climate where aquatic breeding habitats are diverse and subject to significant temporal and spatial changes (Jennings & Hayes, 1994). They use streams, pools in or next to streams, marshlands, springs, large reservoirs, natural and artificial ponds, sand and gravel pits containing water, wells, and lagoons (Storer, 1925; Wright & Wright, 1949; Stebbins, 1951, Hayes & Jennings, 1988; and Jennings, 1988). During periods of wet weather, frogs may disperse and use upland riparian habitat (distances up to 3 km), and use summer habitat when water is not available at their normal breeding areas (Rathbun et al., 1997). The use of seasonal habitat can be also associated with foraging activities. California Red-legged Frogs lay 2,000 to 5,000 eggs from late November to late April. Eggs hatch in 6 to 14 days and tadpoles require 11 to 20 weeks to metamorphose (Storer, 1925). Over-wintering tadpoles have been observed in the central coastal area of California (Fellers at al., 2001). Sexual maturity is reached at about 2 years for males and 3 years for females (Jennings & Hayes, 1985). The diet of California Red-legged Frogs is mainly composed of invertebrates, and for the larger adults vertebrates. However, tadpoles are phytograzers.

Environmental Setting

The Arroyo Santo Domingo is located 250 km south of the US-Mexican border within the Northern Baja California Province. It extends for a distance of approximately 80 km from the San Pedro Mártir Mountains to the Pacific Ocean. The Santo Domingo Drainage traverses the California phytogeographic region (Grismer, 1994), a region characterised by mesophytic vegetation communities dominated by Pacific coastal shrubland and foothill chaparral. The climate is cooler and wetter than in the rest of Baja California. The temperature of western Baja California is regulated by the Pacific Ocean influence, which creates a coastal advection fog keeping the air temperature cool (Grismer, 1994). Most precipitation occurs during winter storms.

METHODS

Our objective was to collect data on the distribution of the California Red-legged Frog along the Santo



Arroyo Santo Domingo; elevation 860 metres. Photograph © Pierre Fidenci.

California Red-legged Frog, *Rana aurora draytonii*, from El Arroyo Santo Domingo. Photograph © Pierre Fidenci.

California Red-legged Frog, *Rana aurora draytonii*, from El Arroyo Santo Domingo. Photograph © Pierre Fidenci.

Domingo drainage, which represents the southernmost known location reported for this species (Welsh, 1976; Grismer, 2002). We surveyed three stretches of the Arroyo Santo Domingo during the spring of 2002 and 2003. The first stretch of approximately 1.5 km was located downstream east from Missión Santo Domingo at about 60 m elevation. We surveyed this site on May 25th, 2002 and May 20th, 2003. The second site was located north of Valledares at about 500 m elevation. We surveyed this site on May 24th, 2002. The third site, called El Potrero, was at about 860 m elevation. We surveyed this site on May 26th, 2002, and May 21st and 22nd, 2003.

Field surveys consisted of day-time and night-time surveys. Day-time surveys were conducted by visually scanning banks with binoculars between 09:30 and 16:00 hrs. Night-time surveys were conducted between 21:00 and 23:00 hrs using binoculars and a 6-volt flashlight. Both visual and auditory methods were used to detect frogs. In cases where frogs were obscured from view, the vegetation was parted where possible to uncover hidden pools.

RESULTS AND DISCUSSION

We observed California Red-legged Frogs at both our lower and higher elevation sites, and although we did not conduct surveys above 900 m, it is likely that the species is to be found at higher elevations along the Arroyo Santo Domingo. Indeed, Welsh (1976) encountered California Red-legged Frogs in the Sierra San Pedro Martír at 2200 m. We did not observe any signs of the species at 500 m elevation, and local farmers confirmed that they had not seen frogs in that section of the creek either. It appears that the California Red-legged Frog is not distributed continuously along El Arroyo Santo Domingo, but could use these uninhabited stretches during dispersal (Rathbun et al., 1997). As noted by Welsh (1976), California Red-legged Frogs are present at a wide range of elevations (60-2200 m) among different microhabitat types along the Arroyo Santo Domingo.

At the lower elevation site, we observed *Rana aurora drayonii* tadpoles (about 4 weeks old) by in their hundreds with the apparent absence of adults. However, we did not find any tadpoles or egg masses at the higher elevation sites, despite the numerous adults observed. The lack of tadpoles is curious since we conducted surveys after the breeding season when tadpoles are most likely to be found (Jennings & Hayes, 1994). Additionally, the occurrence of tadpoles at the lower part of the Rio Santo Domingo confirmed that we conducted surveys in concordance with the timing of tadpole presence. The absence of tadpoles could be attributed to different causes (e.g., use of other parts of the creek for breeding where we did not conducted surveys) but remains unknown.

An average of ten adult *R. aurora draytonii* were observed at El Protero during day-time spring surveys. Frogs were found less than 20 cm from water in shady areas. No tadpoles were found. The largest frog had a snout-vent length of 83.8 cm. Frogs were mostly found outside water, near small and large pools, and used the main channel and backwater pools. Most backwater pools appeared to lack fish, and all the frogs observed were of a sufficiently large size to avoid predation from fish such as trout (*Oncorhynchus sp.*). Most pools also had submerged aquatic vegetation providing the opportunity for refuge. The largest frog was found basking in a shady area next to a boulder, where aquatic vegetation was absent. This pool was part of the main creek at the site of a small cascading waterfall, and was relatively deep (0.8 m) with a sandy bed. Frogs appeared to use the numerous small granite crevices for thermal and physical refuge, where temperatures are cooler and less subject to diel variation. Most of the frogs did not show any escape behaviour until approached within 0.2 m. At other sites in California, California Red-legged Frogs jump usually within 1 m of human presence (pers. obs.). This geographic difference in the timing of escape responses could be explained by the low predation rate along the Rio Santo Domingo.

An average of five frogs were observed during the night-time surveys, most of them found during the early evening. Frogs seen on land during the day were usually found at the same location at night.

Potential Threats and Conservation

In general, California Red-legged Frogs along the Arroyo Santo Domingo appear to be protected from any significant impacts that could threaten their survival, at least in the short term. However, I identified two potential threats that could become important in the future due to population growth: habitat loss and alteration due to recreation, and agriculture.

Habitat loss and alteration appears to represent the most significant impact on the Arroyo Santo Domingo. It occurs primarily at the lower section where a dirt access road allows recreation activities along the creek. The creek is used actively by humans for fishing and swimming. Negative impacts include vehicles crossing and illegal garbage disposal along the creek.

Agriculture and livestock grazing also appear to have a negative impact on the Arroyo Santo Domingo. Water diversion was observed at various localities along the Arroyo Santo Domingo below 860 m. Alteration in the hydrology of free-flowing creeks caused by the construction of dams and other similar projects may be expected to have serious effects on stream-dwelling amphibians (Lind et al., 1996). Water is pumped directly from the creek, mostly in its lower sections. Some water is also diverted at El Portrero (860 m) and La Mission (600 m) where two farms are present. The amount of water used by these two farms seems negligible due to their small agriculture practices. At El Portrero, water is diverted into artificial, shallow seasonal pools. They are devoid of emergent vegetation and allow watering of fruit trees and seasonal crops. For a few days after these temporary pools are filled with water, California Red-legged Frogs can be readily observed

(Martorell pers. comm., 2002), and thus appear to be beneficial in providing additional suitable habitat. The owner of this property has also created a permanent pond at about 300 m from the Arroyo Santo Domingo, which could provide additional breeding habitat for frogs since water would be present for more than five months of the year.

As noted by Grismer (2002), illegal reptile collecting for commercial use in the United States poses an important threat to local, endemic, and insular herpetofauna of Baja California. According to local people, however, California Red-legged Frogs are not captured for food or the pet trade along the Arroyo Santo Domingo. These frogs were collected for human consumption in California until the mid 1950s, and therafter replaced by the introduced larger Bullfrog (*Rana castebeiana*) from the East Coast of the United States (Jennings & Hayes, 1985). Fortunately, local people of Baja California do not consider this species as a food resource.

California Red-legged Frogs in the El Arroyo Santo Domingo deserve special attention since they might constitute the largest remaining population at the extent of the species' distribution. Our 2002 and 2003 field surveys can be regarded as a preliminary step in assessing its current range and population status in Mexico. The difficulty in accessing sites that have never been previously surveyed or visited by any biologists should be considered a priority in any future surveying effort, and may lead to possible extensions to its range.

ACKNOWLEDGEMENTS

I thank Angela Pasillas and Efrain Martorell for their generous hospitality in Baja California, and Renée Sittman and James Buskirk, who participated in the fieldwork. Finally, I am grateful to John Garcia of Garcia and Associates for the use of the GPS unit.

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NATURAL HISTORY NOTES

NATRIX N. HELVETICA **(Grass Snake): CLUTCH SIZE AND FEMALE REPRODUCTIVE BEHAVIOUR.** On July 13th 2004 during weekly reptile surveying a dead female Grass Snake was found in riverine woodland to the north of the New Forest village of Brockenhurst. The remains were complete, but the front half of the body was decomposed and reduced to skin and bone. The rear half of the body remained intact and it was obvious that the female was gravid. The remains were recovered. The snake was 76.5 cm long in total with an estimated snout-vent length (SVL) of 62 cm. Body weight could not be determined due to partial decomposition; however, records from a similarly sized gravid female at the same site indicate a probable weight of approximately 150 g. Five intact and fully developed eggs were removed from the oviduct. Each was approximately 32 mm in length and 17 mm in diameter. The combined weight of the eggs was 22 g. Two eggs were yellow and discoloured. The other three appeared in good condition, however it was apparent by the following day that none were viable. Opening of each egg revealed part addled albumen and a disc of blood cells approximately 5mm in diameter, but no trace of embryos. The female was found in the middle of a grassy animal track. The track passes through a woodland glade that attracts many Grass Snakes each year to deposit their eggs. The site is centred on a substantial wind blown beech that has become heavily overgrown by bramble and bracken. Tracks create basking opportunities for the females, which typically mosaic bask, positioning themselves immediately behind the vegetation frontage. On favourable days half a dozen or so females can be encountered in as many metres. Females arrive in June and remain for much of the month. Whilst here they slough their skins and deposit their eggs before dispersing in late June or early to mid July. Repeat captures over the last three years demonstrate that not only do some females habitually use this location for egg deposition, but that they select this site in preference to other woodland glades in the area that

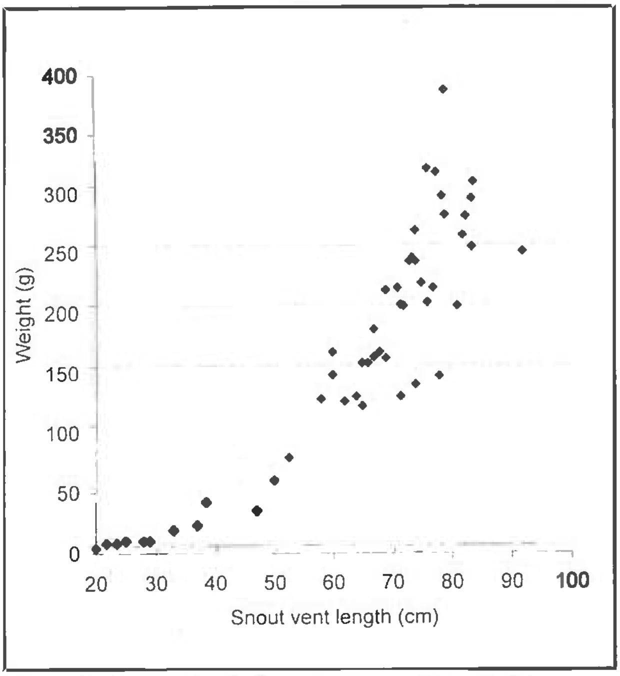

Figure 1. Relationship between body weight and SVL for female Grass Snakes.

are apparently equally suitable for egg-laying in terms of their vegetation structure and illumination. The female was amongst the smallest gravid individuals measured at this egg-laying site (mean total length of all females 87cm, range 76–99.5cm, $n = 20$, mean SVL 72cm, range 58–82.5cm; mean body weight 218 g, range 148–385 g, $n = 12$) and provided the first direct evidence for reproductive output of grass snakes at this site. The clutch size is similar to that of Swedish (Madsen, 1983) and Italian (Luiselli et al., 1997) Grass Snakes of similar size. Plotting the relationship between SVL and body weight for 50 females recorded in this area suggests that they commence breeding when they attain a SVL of approximately 60cm because the variation in recorded weights of Grass Snakes for a given length increases markedly at SVL's in excess of 55–60cm (Figure 1). Using the growth-age relationships described by Madsen (1983) suggests that this corresponds to an age of approximately four years which also similar to that of Swedish Grass Snakes, but younger than that described for Grass Snakes from montane populations in Italy (Luiselli et al., 1997). The cause of death could not be determined. Predation appears unlikely because the body was not consumed. Animal trampling is possible as is killing by humans, however even under the poor weather conditions that existed during the early part of July the Grass Snakes at this site remained extremely alert and proved very difficult to catch for recording purposes. The dimensions of the eggs at 32x17mm is slightly larger than the 25x15mm reported for newly deposited Grass Snake eggs in Beebee & Griffiths (2000); however, the membrane of the oviduct remained intact and there was no apparent damage to the surrounding tissues, thus egg binding does not appear to have been a problem. Regardless of the cause, this individual provided a small but important piece of information about the Grass Snake population at this site. Grass Snakes remain the Cinderella of the British snakes, attracting less attention then either the Adder or Smooth Snake, despite the fact that they are probably the snake that is most familiar to the public. There is much scope for further study of this species, indeed the persistence of the Grass Snake as a common species may ultimately depend upon it.

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