

GEOGRAPHICAL DISTRIBUTION OF THE ENDEMIC SARDINIAN BROOK SALAMANDER, *EUPROCTUS PLATYCEPHALUS*, AND IMPLICATIONS FOR ITS CONSERVATION

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The Sardinian brook salamander, *Euproctus platycephalus*, is a cryptically coloured urodele found in streams, springs and pools in the main mountain systems of Sardinia, and is classified as critically endangered by IUCN. General reviews of the mountainous range where salamanders occur are numerous, but very few field-based distribution studies exist on this endemic species. Through a field and questionnaire survey, conducted between 1999 and 2001, we report a first attempt to increase data on the present distribution of *E. platycephalus*. A total of 14 localities where Sardinian salamanders are represented by apparently stable and in some cases abundant populations have been identified, as well as 30 sites where species presence has been recorded after 1991. Some 11 historical sites were identified which are no longer inhabited by the species. The implications of this distributional study for the conservation of the species and for the realization of an updated atlas are discussed.

Key words: amphibian decline, island endemic, range, Sardinian mountain newt

INTRODUCTION

The genus *Euproctus* (Urodela, Amphibia) consists of three endemic species. The Corsican brook salamander *E. montanus* is found on the island of Corsica and the Pyrenean brook salamander *E. asper* lives in the Pyrenees between France and Spain. The Sardinian salamander *E. platycephalus* is a slender, cryptically coloured endemic that inhabits pools and streams in the mountains of Sardinia. The conservation status of the three *Euproctus* species is listed as 'strictly protected fauna species' within the Bern Convention (1998). *E. platycephalus* is classified by IUCN as critically endangered, on the basis of its endemism and of an estimated population reduction of 80% over the last 10 years (IUCN, 2000).

Habitat loss could be one of the main threats to Sardinian salamanders, due to a long period of drought over the island (which caused a water deficit of -46.6% compared to the island's water requirements in 2000: Regione Sardegna 2000), resulting in small rivers and streams being completely or partially dry during the summer months. Remaining salamander habitats have become fragmented and sometimes threatened by anthropogenic disturbance, pollution and eutrophication. Predation and/or competition due to the introduction of non-native species, such as *Salmo trutta*, which have been implicated as a threat to other salamanders (Read, 1998; Tyler *et al.*, 1998; Knapp & Matthews, 2000), are further contributing factors that threaten the long-term survival of the species.

This salamander is known to live in the eastern part of Sardinia, in the main mountain systems: Limbara in the north, Gennargentu in the centre, and Sette Fratelli, Gerrei and Sarrabus in the south (Colomo, 1999).

Alcher (1975) undertook a detailed field investigation listing a total of 45 sites where the species' presence was recorded, as adults or larvae. Puddu *et al.* (1988) published a general distribution map of the species in which its range basically overlaps with the mountainous areas of the island. Other distribution surveys and bibliographic sources do not add any information to the picture already described by these authors (Bruno, 1980; Rimpp, 1998).

Knowing the distribution of a particular species is a key issue in studies of theoretical and applied ecology, biodiversity and metapopulation biology (Cowley *et al.*, 2000). Besides being a fundamental goal in ecology, describing and explaining the distribution of endangered species has major significance for their conservation (Beebee, 1996). There is still little information concerning amphibian distributions and their relevance to the conservation management of threatened or declining populations. These field-based surveys should be combined with attempts to identify critical distribution determinants for a particular species.

Some widespread amphibians such as *Triturus* species, *Rana temporaria* and *Bufo calamita* in Britain, and endemics such as *Chioglossa lusitanica* in Portugal, have been extensively studied and their distribution documented with finely-scaled maps (Beebee, 1996; Teixeira *et al.*, 2001). Another example is given by Delaguerre & Cheylan (1992), who present a detailed atlas of the Corsican herpetofauna, in which *E. montanus* distribution is described. Although the distribution map is not confirmed by recent field survey, it gives fundamental information for further studies. Many other amphibian species, some of them rare or endangered (such as the Sardinian salamander), need similar high-resolution distribution studies.

This paper presents an assessment of the distribution of *E. platycephalus*, using data collected during a field

survey across the geographic range of the species over three years of research, conducted to identify locations that currently hold salamander populations. Reports of apparent population declines in the species are discussed, and information on its geographical distribution is used to assess potential threats to its persistence and long-term survival in various parts of its range.

METHODS

FIELDWORK SEASONS

Distribution data were collected during fieldwork seasons in 1999, 2000 and 2001. Fieldwork usually started in mid-April and finished in late July or August. This generally corresponded with the main breeding season of the species (Puddu *et al.*, 1988). Spring in Sardinia is usually mild and sunny with low precipitation (Delitala *et al.*, 2000). With summer approaching, water in the stream-beds diminishes gradually until most of the streams consist of a number of pools, either isolated or connected by very small water channels.

The 1999 field season focused on documenting the large scale distribution and typical habitat of the animals. At the end of it, six study sites were identified throughout the eastern part of the island (south, centre and north) and five sites surveyed in the south-west. During the 2000 field season, 14 sites were visited, including the six already known, and a questionnaire was distributed to forestry stations. In 2001, all known sites were re-visited, and 18 new sites (four in the south-west and 14 in the rest of the island) were surveyed, most of these suggested by replies to the Forestali questionnaire.

FORESTALI QUESTIONNAIRE

The Corpo Forestale e di Vigilanza Ambientale is a regional body in charge of controlling Sardinian territory, water courses and forests (equivalent to a forestry service). The island territory is divided into a number of districts, each one under the control of a forest station. The area is extensively patrolled by 'Forestali' workers, who usually have an excellent knowledge of the local

flora and fauna and are able to give accounts of salamander presence or absence. The questionnaire was distributed to 79 forest stations all over the island in July 2000, in order to collect records of salamander distribution (Table 1). A coloured photograph and a description of the species were supplied too. As there is only one other urodele found in Sardinia (the cave salamander *Speleomantes* sp.) which occupies a different habitat from *E. platycephalus*, forest station accounts were considered highly reliable.

SELECTION OF SURVEY SITES

The distribution survey was designed to identify streams supporting salamander populations at present, covering as evenly as possible the three areas of the eastern part of the island: south, centre and north. Survey sites were selected by combining three main sources of information: personal field trips to various sites during the fieldwork seasons following the suggestions of local people and exploration of the territory; the collection of replies to the *E. platycephalus* questionnaire; literature reviews (Alcher, 1975; Puddu *et al.*, 1988; Schenk *et al.*, 1995; Rimpp 1998). Out of 55 distribution survey sites, 51% were visited during the field seasons (with local collaborators and forest station workers, or on our own initiative) and the remaining 49% were obtained from the questionnaire replies and the distributional information existent at the beginning of this study.

SALAMANDER SURVEYS

The selected streams were surveyed for salamander presence at least once during each field season. The method used to assess *E. platycephalus* presence in a particular site was a careful observation of the chosen stream-bed at different altitudes, and in pools scattered along the water course. Searches took from 3-6 hrs, not considering the time necessary to reach the site. Approximately 1 km of the water course was walked by a team of three/four people going upstream. In most cases, salamander presence was immediately confirmed as

TABLE 1. Text in English of the questionnaire distributed to forest stations in July 2000.

QUESTIONNAIRE ON *EUPROCTUS PLATYCEPHALUS* 2000

Forest Station:

Villages and Districts included:

- According to the field experience of Forestali personnel and their knowledge of territory and local fauna, is the species present in this area?
- If yes, has it been observed recently?
- When (year and month)?
- Where (locality, stream, if possibile IGM coordinates)?
- If it has not been observed recently, was the species present in the past?
- When? When was its presence last assessed?
- What could be the reasons for decline or absence of the species in the area (water pollution, drought, anthropic presence, fishing, predators)?
- Other useful information (description of observed individuals, population density, personal notes).

TABLE 2. Environmental parameters collected during 1999, 2000 and 2001 field seasons in sites inhabited by *E. platycephalus*: minimum, maximum and mean values.

	Minimum			Maximum			Mean		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
Air temperature (°C)	20	16	13.5	28.5	30	27	23.4	25.7	23.6
Relative humidity (%)	48	45	40	79	85	75	63.9	59.4	55
Water temperature (°C)	12.5	11.7	12.7	24.5	24	21	17.9	17.2	16.2
Water pH	6.3	7	7	8.2	8.5	8.3	7	7.6	7.6
Water DO (mg/l)	—	6	3.4	—	10.6	12	—	8.1	7.7

soon as the first pools inhabited by the species were reached (these animals tend to aggregate in parts of the stream). The observation of one individual was also considered a sign of the presence of a salamander population. The observation could take longer in the case of absence of the animals, because a longer tract of the stream was surveyed before ruling out the presence of salamanders. In this case, rocks and stones underwater were turned and the bottom of pools disturbed using a stick, in order to see if any individual were hiding in the substrate.

STREAM TYPES AND CHARACTERISTICS

In each inhabited survey site, some environmental parameters were collected (air and water temperature, relative humidity, water pH and dissolved oxygen, Table 2).

Most of these survey sites were mountain or hill streams flowing through the typical Mediterranean macchia covering most of the island. This landscape is dominated by scrub plants such as heather (*Erica* sp.), myrtle (*Myrtus communis*), juniper (*Juniperus communis*), olive (*Olea europaea sylvestris*), *Cistus* sp., and *Pistacia lentiscus*, as well as holm and cork oak forests (*Quercus ilex* and *Q. suber*). A few sites did not conform to this broad habitat type. The pool at S. Nicolò Gerrei is a concrete water store located in a field dominated by grasses and brambles (*Rubus* sp.). The artificial lake (Laghetto) located near Tempio, also has a slightly different vegetation structure as the area surrounding the lake has been cleared. Funtana Urpis, between Isili and Villanovatulo, is an artificial pool built along a watercourse. Pischina Urtaddala is a natural lake (already

identified by Voosenek *et al.*, 1987) apparently isolated in a limestone locality, but it actually depends on the overflow of the Rio Flumineddu stream.

Streams and pools were completely open or canopy-covered, or partially protected by overhanging rocks or vegetation. There was one exception, where a very interesting hypogeous *E. platycephalus* population was found living in a stream flowing inside a cave (Is Angurtidorgiu, near Perdasdefogu).

RESULTS

DISTRIBUTION OF *E. PLATYCEPHALUS*

Sardinian salamanders have a naturally patchy distribution across the island, showing association with small and temporary streams, pools and small lakes, ponds and springs, at a wide range of altitudes (from 100 to 1200 m) and with preference for sites between 400 and 800 m (Fig. 1). The species was found at sites with water temperature ranging between 11.7 and 24.5°C, water pH between 6.3 and 8.5, and water dissolved oxygen ranging from 3.4 to 12 mg/l (Table 2).

At the completion of this study, eight sites in the north, 18 in the centre and 18 in the south of Sardinia were identified as localities currently and/or recently (after 1991) inhabited by the species. A total of four sites in the north, four in the centre and three in the south, constituting 20% of all sites considered, have apparently lost the species in the last two decades (Table 3). For a detailed list of all the sites where the presence of the species has been assessed in the three years of research or within the last 10 years, see Table 4.

DISTRIBUTION IN WESTERN SARDINIA

The present distribution study focused particularly on the eastern part of Sardinia, where the presence of *E. platycephalus* has always been confirmed in the past (Alcher, 1975; Puddu *et al.*, 1988) and which comprises the preferential habitat areas for these salamanders. The species is generally believed not to be present in most of the western areas, or its presence is questioned but not excluded (Alcher, 1975). There are very few records of observations on the west side of the island (forest station workers, pers. comm., Schenk *et al.*, 1995). Nevertheless, nine localities in the south-west of Sardinia (Table 5) have been visited at least twice over three years of re-

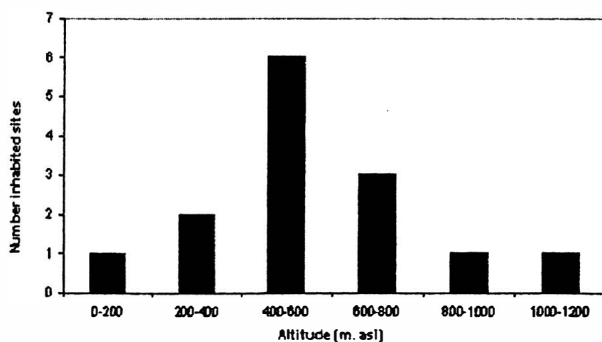


FIG. 1. Vertical distribution of sites inhabited by *E. platycephalus*.

TABLE 3. List of localities where *E. platycephalus* was present before 1991 (but where its presence was not confirmed more recently on the basis of the forestali station questionnaire) and source of information.

Locality	Mountain system	Year of observation	Source
Burcei (Rio Brabaisu)	Sette Fratelli	1990	Forest stn..obs.
Muravera (Rio Picocca)	Sette Fratelli	1975	Amphibiaweb
Tertenia	Ogliastra	1985	Local comm.
Benetutti	Goceano	1990	Forest. stn. obs.
Bolotana	Marghine	1990	Local comm.
Alà dei Sardi	Monti di Alà	1974	Alcher (1975)
Siniscola	Monti di Alà	1974	Alcher (1975)
Nuoro	Gennargentu	1974	Alcher (1975)
Orgosolo	Gennargentu	1974	Alcher (1975)
Arzana	Gennargentu	1974	Alcher (1975)
Gairo	Ogliastra	1974	Alcher (1975)

search. Salamanders were never observed. Fish presence (*Salmo trutta*) was recorded in four sites.

Combining past information and the results of the present distribution study, salamander presence in the south-west of the island cannot be completely ruled out. Undoubtedly, in these areas *E. platycephalus* is very rare, and possibly (considering comments and observations by Forestali workers and collaborators) in decline. Another mountainous area located in the north-west of the island, Marghine-Goceano, can also not be ruled out from the salamanders' range, as it has not been covered by this distribution survey. Few records exist on the past presence of the species (Schenk *et al.*, 1995).

FOREST STATION QUESTIONNAIRE

Responses on the presence/absence of the species were received from 60 of the 79 forest stations. Forty responses were negative, and 20 were positive. The negative responses contained some reports of the presence of the species in the past but not recently. The positive responses included photographs of salamanders, of study sites, and IGM (Istituto Geografico Militare) maps with the actual site where the species was seen indicated. Fig. 2 shows the distribution across Sardinia of the 60 Forestali districts that responded.

DISTRIBUTION MAPS

The general map (Fig. 3) shows the area where the species is present, combining historical and present data. Fig. 4 shows all the localities where species presence has been assessed during the three years of research and in the recent past (since 1991). The sites where it was known to be in the past (before 1991) but where it is no longer present (or at least can no longer be found) are also indicated. This map represents a first attempt to rectify the lack of field-based information on *E. platycephalus* distribution. It therefore provides a framework for further research on Sardinian salamander conservation.

DISCUSSION

Through a combination of field and questionnaire surveys, conducted between 1999 and 2001, we have attempted to collate information on the present distribution of the endangered endemic Sardinian brook salamander, *E. platycephalus*. As mentioned in the Results section, a total of 14 localities where Sardinian salamanders are present today have been identified, as well as numerous sites where species presence has been recorded since 1991. A number of historical sites appear no longer inhabited by the species and these should receive particular concern. Conservation efforts should focus on further detailed surveys and habitat protection of salamander-inhabited areas.

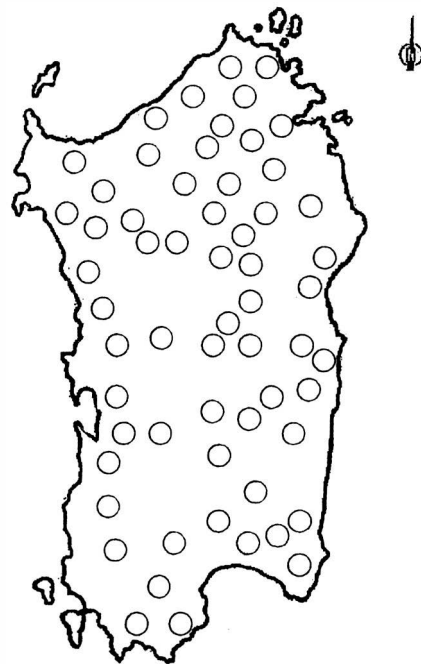


FIG. 2. Distribution in Sardinia of forestry districts (Uffici Forestali) which replied to the *Euproctus platycephalus* questionnaire in 2000.

TABLE 4. List of sites where *E. platycephalus* presence was confirmed by the authors between 1999 and 2001 (top), and (bottom): by forestry workers or local collaborators (Source) after 1991. Italics indicate sites visited by the authors in 2001 where newt presence was not confirmed on the day of survey.

Site	Mountain system	Year of observation	Notes
Rio S. Mannu	Sette Fratelli	1999	One individual
Rio Pressiu	Sette Fratelli	1999	One individual
Rio Gattu	Sette Fratelli	1999, 2000, 2001	High density
Rio Guventu	Sette Fratelli	2000, 2001	High density
Rio Melliana	Sette Fratelli	2000, 2001	Adults and larvae
Rio Angiulus	Sette Fratelli	2000, 2001	Adults and larvae
Rio Su Zurrù	Gerrei	2000, 2001	Adults and larvae
Is Angurtidorgiu	Quirra	2000, 2001	Hypogeous pop.
Roa Paolinu	Gennargentu	1999, 2000, 2001	High but declin.dens.
Rio Lardai	Gennargentu	2000, 2001	Adults and larvae
Funtana Urpis	Gennargentu	2000, 2001	One individual
Pischina	Supramonte	1999, 2000, 2001	High density
Rio Pisciaroni	Limbara	1999, 2000, 2001	High density
Loc. Letto di Fica	Gallura	1999	One larva
Site	Mountain system	Year of observation	Source
<i>Rio Acquacallenti</i>	<i>Sette Fratelli</i>	<i>1999</i>	<i>Forestali Q.</i>
Rio Baccusafigu	Sette Fratelli	1999	Forestali Q.
Rio Staulu Mannu	Sette Fratelli	1999	Forestali Q.
<i>Rio Pireddu</i>	<i>Parteolla-Gerrei</i>	<i>1998</i>	<i>Forestali Q.</i>
<i>Rio Baccu Onnai</i>	<i>Quirra</i>	<i>1999</i>	<i>Forestali Q.</i>
Rio Semida	Quirra	1999	Forestali Q.
<i>Rio Piras</i>	<i>Quirra</i>	<i>1993</i>	<i>Forestali Q.</i>
<i>Rio Bauporcus</i>	<i>Marganai</i>	<i>1998</i>	<i>Forestali Q.</i>
<i>Rio Maurreddu</i>	<i>Sulcis</i>	<i>1995</i>	<i>Forestali Q.</i>
Rio di Pula	Sulcis	1999	Local comm.
Rio Ermolinus	Gennargentu	1994	Forestali Q.
Rio S.Girolamo	Gennargentu	1994	Forestali Q.
Rio Longufresu	Gennargentu	1994	Forestali Q.
Rio Samunudolgiu	Gennargentu	1999	Forestali Q.
<i>Rio Pitzirimasa</i>	<i>Gennargentu</i>	<i>1999</i>	<i>Forestali Q.</i>
Rio Panargia	Gennargentu	1997	Forestali Q.
Rio Conca Sarui	Gennargentu	2000	Forestali Q.
<i>Rio Mannu</i>	<i>Gennargentu</i>	<i>1995</i>	<i>Forestali Q.</i>
Rio Araxisi	Gennargentu	1995	Forestali Q.
Rio Flumineddu	Gennargentu	1994	Forestali Q.
Rio Nesula	Gennargentu	1994	Forestali Q.
Loc. Oliena	Gennargentu	1992	Forestali Q.
<i>Rio Tedderi</i>	<i>Gennargentu</i>	<i>1996</i>	<i>Forestali Q.</i>
Su cunn'es'ebba	Supramonte	1995	Local comm.
Salto di Giosso	Monti di Alà	1998	Forestali Q.
<i>Sorg. Caltaroni</i>	<i>Limbara</i>	<i>2000</i>	<i>Forestali Q.</i>
<i>Rio Lo Frassu</i>	<i>Limbara</i>	<i>1999</i>	<i>Forestali Q.</i>
<i>Laghetto</i>	<i>Limbara</i>	<i>2000</i>	<i>Forestali Q.</i>
<i>Rio Sa Mela</i>	<i>Limbara</i>	<i>1995</i>	<i>Local comm.</i>
Rio ?(Berchidda)	Limbara	1992	Forestali Q.

TABLE 5. List of south-west sites surveyed by the authors (fieldwork seasons 1999-2001) for *E. platycephalus* distribution. Species presence, 1; absence, 0.

Site	Locality	Year of survey	Number of surveys	<i>E. platycephalus</i> presence	Fish presence
Rio Leni	Villacidro	1999	4	0	1
Rio Biddascema	Villacidro	1999	2	0	1
Sa spendula	Gonnosfanadiga	1999	2	0	0
Rio Bauporcus	Fluminimaggiore	2001	2	0	0
Rio Camboni	Uta	1999	2	0	1
Rio Guttureddu	Monte Arcosu	1999	3	0	0
Rio Gutturumannu	Santadi	2001	2	0	0
Rio AntoniPolla	Domus de Maria	2001	2	0	0
Rio Maurreddu	Pula	2001	2	0	1

SURVEY METHODS

As discussed by Beebee (1996), species distributions are usually assessed by field survey, and this procedure is subject to possible errors such as misidentification and recorder bias. Moreover, stream amphibians are challenging to sample because they are unevenly distributed, cryptically coloured, and often hidden in the substrate (Welsh *et al.*, 1997). On the other hand, as many species have low dispersal abilities, in amphibian

surveys the observation of a single individual usually means a population is present nearby (Beebee, 1996).

Using local people’s knowledge of sites has proved to be the best strategy to locate streams inhabited by

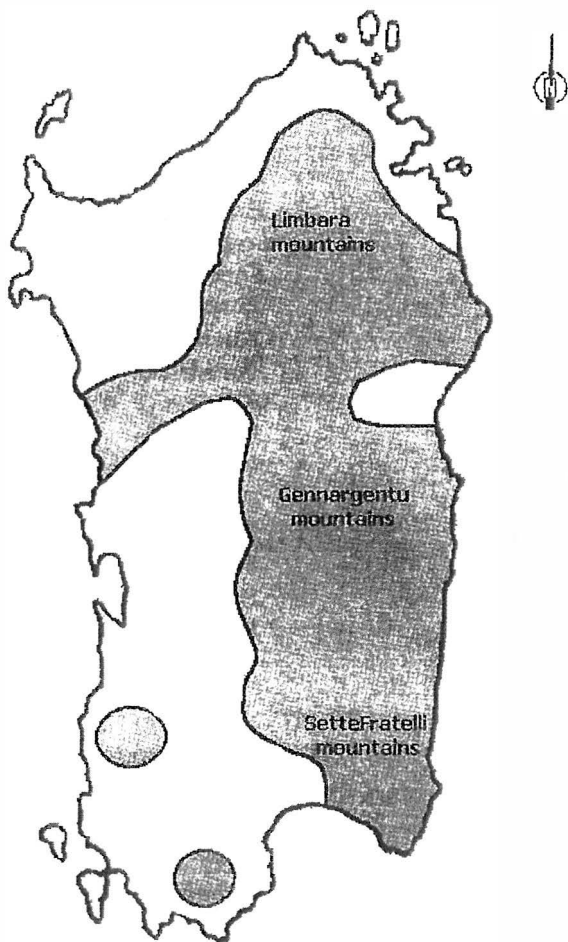


FIG. 3. Grey area: general historical distribution of *E. platycephalus* in Sardinia.

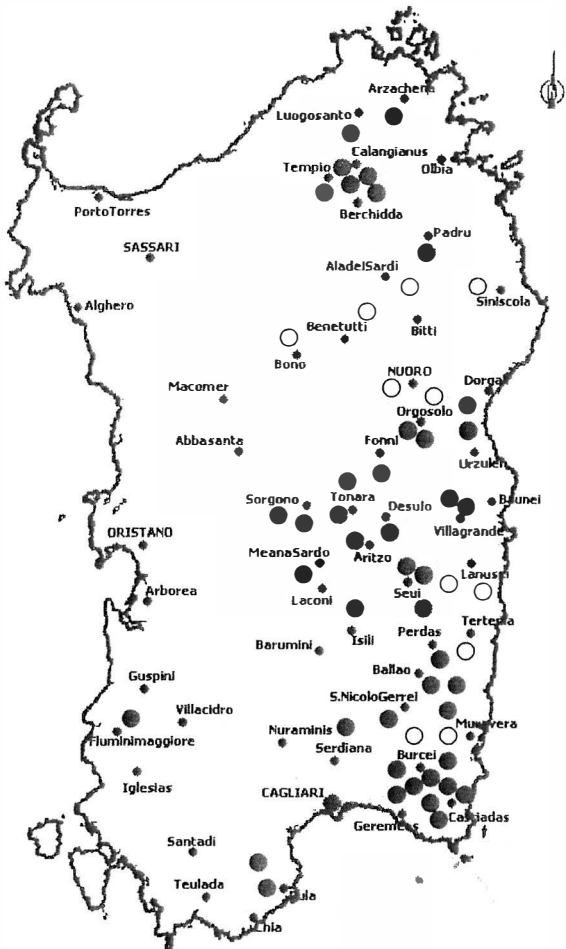


FIG. 4. Current distribution of *E. platycephalus* in Sardinia. Black spots: sites with *E. platycephalus* presence assessed, during 1999, 2000 and 2001 field work seasons (see Table 4). Grey spots: sites with species presence assessed (by forest station workers or local collaborators), after 1991 (see Table 4). White spots: sites with presence assessed in the past (before 1991), but not confirmed in the present, where the species could be locally extinct or have strongly declined (see Table 3).

salamander populations. Many of these are remote places, sometimes reachable only by knowing the territory very well and following concealed pathways through the Mediterranean *macchia*. Looking into pools and sections of a watercourse downstream – or relatively close to access paths or roads – is unlikely to reveal their presence as salamander populations often inhabit undisturbed parts of the watercourse. Only local fishermen or hunters sometimes visit these places. Some of the streams surveyed had long stretches that were dry during the summer months, so it was necessary to walk upstream for a while in order to find water (Rio Gattu, Rio Angiulus, Rio Mela).

Assessment of salamander presence was easier in the summer, when streams were drying up and isolated pools forming. Some sites where *E. platycephalus* was known to be present from previous observations did not give any clear information if visited too early in the season (April/early May), as the rapidly-flowing water did not permit the observation of salamanders in the stream. Salamanders are known to hibernate during the winter and sometimes aestivate in the summer (Puddu *et al.*, 1988). The difficult observation of individuals in very early spring in some sites could also be due to the fact that the animals were not actually active in the water before a certain time of the year. In some places, though, it was possible to observe a great number of animals active throughout the year (Pischina Urtaddala, pers. comm.).

Assessing the presence or absence of animals in a particular site was usually straightforward. In many streams, after the first salamander was observed, it was easy to spot tens of others, either in the same or in neighbouring pools. In some streams, both larvae and adults were observed (Rio Lardai, Rio Melliana, Rio Su Zurrù). A few sites had just a few or even one individual, and the presence of other specimens was impossible to confirm because of the particular characteristics of the study site (Funtana Urpis, an isolated artificial pool connected to a stream by underground water). The population inhabiting the Roa Paolinu stream (Gennargentu) appeared to decline in numbers over the three years. This could be due to a natural population fluctuation, or it could indicate that salamanders are declining in that area.

LITERATURE REVIEW

General and vague reviews of the mountainous range where salamanders occur are numerous, but very few field-based distribution studies exist on this endemic species.

In 1975, Alcher published a valuable attempt at mapping the distribution of *E. platycephalus*. Survey sites were described in terms of locality (the name of the closest village) and altitude, and cover eastern Sardinia, which was extensively visited over two summers (1973, 1974). It would be useful to repeat Alcher's survey today and obtain important information on the possible range contraction of the species. A detailed localization

of the survey sites, with locality, altitude but especially exact geographic position and name of the stream where larvae or adults were observed would be necessary. The lack of this information has prevented the use of this almost unique distribution study in a more extensive and quantitative way. Only six areas indicated by Alcher (1975) as inhabited by the species in the 1970s, but where salamanders are no longer present (on the basis of forest station questionnaire replies and communications), were included in the distribution survey (see Table 3).

DISTRIBUTION MAPS

As shown in Fig. 4, sites in black and grey are all considered recently inhabited by *E. platycephalus*. Black refers to the assessment of species presence through our field surveys (conducted between 1999 and 2001), and grey through the questionnaire survey and local communications (presence recorded after 1991).

Black sites can be considered confirmed inhabited locations, where salamander populations have been repeatedly observed over the last three years (Table 4, upper part). Grey sites are locations where *E. platycephalus* was found in the last 10 years, but its presence is not documented or unconfirmed today (Table 4, lower part). At a number of grey sites (14), indicated by Forestali collaborators and visited during the 2001 fieldwork season, salamanders were absent from the pools surveyed on the day of sampling (sites in *italics* in the lower part of Table 4).

As shown in Fig. 2, the distribution of forest stations (districts) which replied to the *E. platycephalus* questionnaire is widespread and uniform over Sardinia. On average, the questionnaire survey provided a good coverage of the island, based on reliable observations of forestry workers over the years (a number of replies were accompanied by photos, map details and oral communications ruling out false positive cases).

Some of the black sites, such as Letto di Fica (Gallura), Rio Suergiu Mannu and Rio Pressiu (Sette Fratelli), where – during the three years – only one individual was observed, are also considered sites inhabited by the species. The lack of information on the habitat use and metapopulation structure of Sardinian salamanders prevent us from excluding sites from the distribution maps solely on the basis of the number of individuals observed. Besides, in amphibian surveys, finding a specimen normally means that a population exists in the immediate vicinity (Beebee, 1996).

Particularly important from a conservation point of view are the pools where a high number of individuals have been always observed in each of the distribution surveys (1999, 2000 and 2001), such as Rio Gattu (Sette Fratelli), Pischina Urtaddala (Supramonte) and Rio Pisciaroni (Limbara). These sites, together with the streams and ecosystems associated, should be particularly protected and the areas managed in order to minimize factors that could be detrimental to salamander population viability.

LOCAL DECLINES

White sites in the distribution map indicate historical localities where salamander populations were observed before 1991, but species presence was not recorded after that time (see Table 3). They are therefore considered sites where the species is undergoing local extinctions or declines. However, these results should be taken cautiously and a long-term detailed field investigation should be conducted before considering the species extinct from an area. In particular, the area around Alà and Nuoro should be monitored more carefully, as well as the areas of Berchidda, Benetutti and Bitti, indicated as no longer inhabited by *E. platycephalus* (forest station questionnaires). The whole Ogliastra and the mountains around Tertenia, Lanusei and Gairo, should also be carefully monitored, although a strong decline in salamander presence is implicated by the data. Special concern should be given to the western areas of the island, Monte Linas and Sulcis in the south, and Marghine-Goceano in the north, where species presence or absence needs to be confirmed and updated.

AMPHIBIAN DECLINE

Comparing the present results with previous data (Alcher, 1975) suggests that the distribution of the species has changed little. However, the population sizes of *E. platycephalus* seem to have declined in the past few decades (Puddu *et al.*, 1988; Colomo, 1999; Rimpp & Thiesmeier, 1999), although this is not yet documented by an ecological census. Evidence could be found in some of the questionnaire replies, which report the presence of the species in a particular area in the past, but not today. This trend seems consistent with the global pattern of declining amphibian populations which was first described in 1990 (Blaustein & Wake, 1990) and then repeatedly documented over the last decade (Wake, 1998; Houlahan *et al.*, 2000). Simultaneous and widespread reported declines are causing concern especially because they often occur in pristine and apparently intact areas. Some population declines can be realistically evaluated by comparing the present species distribution with historical data. Unfortunately, many endangered and threatened amphibians have not been extensively studied and monitored, and still lack high-resolution distribution maps or informative atlases. Research is needed on the most recent historical aspects of amphibian distributions, as there might have been considerable fine-scale changes over relatively short time spans (Beebe, 1996). Especially endangered or declining species should be monitored and atlases with the present distribution of populations produced.

IMPLICATIONS FOR CONSERVATION

Many sites indicated in the distribution maps witness the disappearance of the Sardinian brook salamander from parts of its previous range. However, there are a number of streams and localities spread in the north,

centre and south of the island where the species is represented by stable and apparently abundant populations (Rio Pisciaroni in the north; Rio Lardai and Pischina Urtaddala in the centre; Rio Guventu, Rio Gattu, Rio Melliana, Rio Angiulus, Rio Su Zurrù and Is Angurtidorgiu in the south). The conservation of *E. platycephalus* should focus on these sites. Populations should be constantly monitored and further investigation should estimate population size and abundance. Associated habitats should be protected in order to keep the conditions that meet the ecological requirements of the species. Most of these streams flow through mountains and areas already designated as protected (Ente Foreste, Parchi Regionali). Nevertheless, the implementation of real conservation measures (such as fishing and tourism control), which would benefit not only endemic amphibians, but also many other organisms linked to the salamander habitat, has yet to be seen.

Some priorities for amphibian conservation and research in Sardinia are given here. The dissemination of information on *E. platycephalus* (and other endemic species) conservation status and distribution, and the creation (or implementation) of bioreserves and protected areas around the main stream and river systems are recommended. Freshwater ecosystems falling within the salamander's range should be given particular attention with respect to both study and conservation. Water pollution, expanding tourism and illegal fishing methods should be controlled, fish introduction stopped and possibly the removal of predatory fish from streams where they were not historically present attempted. A co-ordinated monitoring network (ideally with the aid of Forestali and Sardinian scientific institutions) for the island's whole herpetofauna should be created. This study provides the basis for future research on distribution changes, population expansions and declines of the endangered endemic Sardinian brook salamander. The most valuable application of these distribution data would be the improved management and conservation of the stream-related habitat in the Sardinian mountains and of the unique associated biodiversity.

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