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Habitat choice of the salamander *Chioglossa lusitanica*: the effects of eucalypt plantations

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Abstract. Evidence is presented that golden-striped salamander *Chioglossa lusitanica* populations in eucalypt plantations may be subject to two influences. There is a low density of leaf litter invertebrates which are the preferred prey. Substrate choice experiments show that that the salamanders avoid eucalypt leaves as substrates for shelter. A long-term study of *Chioglossa* populations at two brooks in northern Portugal, however, showed that the numbers at one site did not change notably after plantation with eucalypts in comparison with the other, less altered, locality. *Chioglossa* is the most abundant amphibian species along water courses in the Spanish province of La Coruña, although eucalypts are planted along most of them.

Introduction

The first Australian eucalypts of the species *Eucalyptus globulus* were introduced into northwestern Iberia in the last century. *Eucalyptus*-forest have now been planted in northern Portugal, in the Galicia and Asturias regions of Spain, and elsewhere. Wood from these fast-growing trees is used in the cellulose industry. A summary of the known aspects of the environmental impact of both plantations and cellulose-factories is given by Varela (1990).

Planted *Eucalyptus* forests are usually monocultures, and they can have important effects on the indigenous flora and fauna. Few investigations have dealt with these effects in detail (Bongiorno, 1982; Bara et al., 1985; Varela, 1990; Bas and Sanandres, in press), and there are insufficient data to indicate whether a rational *Eucalyptus* management could at the same time provide cellulose to satisfy Europe's increasing paper demand and preserve the species diversity.

The golden-striped salamander, *Chioglossa lusitanica*, is the only recent representative of its genus. It is endemic in north-west Iberia and lives alongside brooks in mountainous areas. The goal of this study was to obtain more specific data about the influences of *Eucalyptus* on this species. Questions, which I tried to answer using several approaches, arose on several levels:

1. Is the general distribution of *Chioglossa* negatively or positively correlated with the major areas of eucalypt plantation?

2. Are brooks surrounded by eucalypts populated by *Chioglossa* less often than other habitats?

3. Will a eucalypt plantation result in a declining salamander population density in the long term?

4. Are there differences in diversity and density of potential salamander prey between eucalypt and deciduous forests?

5. Is eucalypt leaf litter accepted as sheltering substrate by salamanders?

The fieldwork component was made possible by a grant from the Societas Europaea Herpetologica.

Material and methods

A total of 104 water courses were visited during July and August of 1990 and 1991 in order to characterise the preferred habitat of *Chioglossa*. If no larvae or adults were found after searching for 30 minutes, it was asumed that none were present. Water courses in areas in which the salamanders appearently do not occur (see results on distribution) were not considered.

Vegetation along the water courses was recorded, and they were divided into six types:

A. Fast-running, small to medium sized brooks without submerged vegetation and mostly in hilly areas. The substrate is in most cases granitic sand. Stones and rocks consist of granite or sometimes slate. Only few mosses grow on the rocks, and there is a reduced humus and leaf litter at the brook borders. These brooks are sometimes surrounded by some trees (*Eucalyptus globulus*, *Pinus pinaster* or *Quercus robur*), but are often without vegetation of trees at all.

B. Fast running, small to large brooks, often without submerged vegetation. Mostly in hilly areas of deciduous forest. The substrate consists of medium sized gravel with large mossy slate or granitic stones. There is a thick humus and leaf liter layer at the brook borders.

C. Slow running brooks in areas of low inclination. The surrounding areas usually consist of meadows. These brooks are bordered by *Salix atrocinera* and *Alnus glutinosa* trees. They often have submerged vegetation. Borders with or without slate or granitic stones.

D. Very small brooks, with water flowing at a medium speed. Lack of stones at the borders and under water is typical. These (permanent) brooks often dry up after several hundred metres; they are not usually affluent to larger brooks.

E. Fast-flowing brooks in wich limestone rocks and stones are present under water and at the borders. They are mostly surrounded by deciduous forests and often pass through steep rocky slopes.

F. Slow or fast running brooks, mainly at high altitudes, surrounded by pastures with or without stones or rocks at the borders. Without any surrounding tree or shrub vegetation.

There were five springs which did not fit into any of these categories.

Systematic fieldwork has been carried out by Arntzen (1981) and Veenstra (1986) on two *Chioglossa*-populations from Valongo near Porto (N-Portugal), in 1977, 1978 and 1984. The surroundings of the brook Ribeiro do Inferno, where a first population lives, had not changed notably since 1977. Some eucalypts are scattered along the borders, other trees are rare. The year to year relative density of this population was estimated by counting the number of eggs deposited in two deserted mine galleries.

In a second population, salamanders live along the small brook Ribeira de Silverinha. In the early eighties, a dense *Eucalyptus* forest was planted around the Silverinha, leaving a free zone only a few meters wide around the brook. The size of this population was estimated by marking and recapturing. Recent data were sampled by Arntzen (unpublished).

A total of 50 pitfall traps (for ground-dwelling invertebrates) and 50 adhesive traps (for flying insects) were placed during June and December 1990 respectively for two week periods at two localities near Caaveiro Monastery in La Coruña province, Galicia. The first locality consists of a dense deciduous forest of *Castenea sativa* and *Quercus robur*; eucalypts of different ages have become dominant at the second, and only few other trees survive, although some *Ulex* shrubs grow between the trees. Both localities are crossed by small brooks which are populated by *Chioglossa*.

The pitfall traps were small plastic cups filled with vinegar. The adhesive traps were 15 × 10 cm plastic sheets covered on one side by adhesive glue, as often used to catch rats and mice. They were suspended from trees in a way that they could not be reached by vertebrates such as lizards or small mammals; pitfalls were small enough to allow even small lizards to jump out. In fact, no vertebrates were caught in the traps.

The number and size of invertebrates caught with each adhesive trap were recorded. Invertebrates caught with pitfall traps were recorded together for each locality.

To test substrate influences directly, salamanders in terraria were given the possibility to choose between deciduous leaves and another substrate with a comparable degree of humidity. The number of salamanders hiding under standarized shelters each morning on each substrate was recorded.

Results

Distribution

Reviews of the distribution of *C. lusitanica* have been published by Busack (1976) and Arntzen (1981). For the present compilation, data from Hartasanchez et al. (1981) and Bas (1980) were also considered. Localities where the distribution of the species is uncertain, such as the Sierra de Gredos, were ignored, as were some sites listed by Busack (1976) which were questioned by Arntzen (1984). R. Malkmus (Portugal), M.

Garcia-Paris (Galicia and Asturias) and P. Galan (Galicia) contributed many personal and partially unpublished observations.

Combining literature, personal communications and my own observations gives about 130 *Chioglossa* localities which are presently known. A personal communication from L. Yokochi indicates the presence of the species at the Serra de Sintra north of Lisboa, where it was probably introduced during the last century but was never found again.

There are some areas within the distribution limits which are not populated or where only few populations occur. These include the litoral between Porto and Coimbra (Malkmus, pers. comm.); the plain of Bergantiños, southwest of La Coruña; an extended zone east of Oviedo; and many parts of Lugo province.

Most records are concentrated in the west of Asturias, in La Coruña and Pontevedra, in northern Portugal at the latitude of Porto, and in the Serra de Lousa and the Serra do Geres (fig. 1).

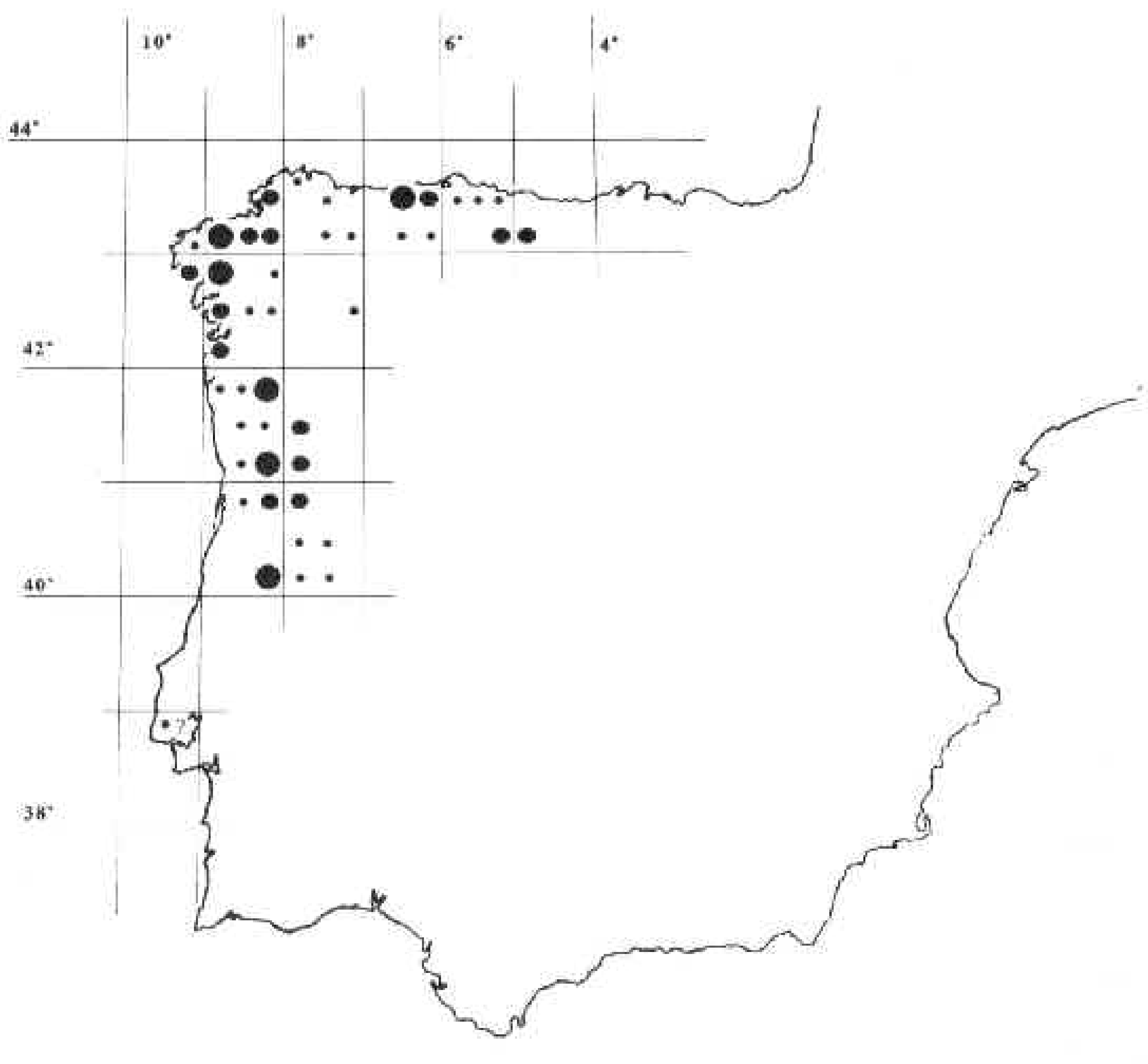

Figure 1. Distribution of *Chioglossa lusitanica*. Small circles: 1-2 records, medium-sized circles: 2-5 records, large circles: 6-12 records. The unconfirmed locality "Serra de Sintra", near Lisboa, is marked with a "?".

The area east of Porto and the Spanish provinces of La Coruña and Pontevedra are probably among the most densely populated regions. *Chioglossa* was the most common amphibian, occuring in 34 of the 46 brooks investigated in La Coruña (nearly 75%). Other amphibians such as *Triturus boscai* (10 records), *Salamandra salamandra* (9 records) or *Discoglossus galagnoi* (5 records) were much more difficult to find, although *Rana iberica* was also abundant (31 records). Arntzen (unpublished) found *Chioglossa* in 36 out of 78 (46%) investigated brooks in northern Portugal between 40° 20′ to 41° 40′ and to the west of 78° 30′. *Chioglossa* was less common in Asturias, occuring only in 50% of the brooks (difference significant at the 0.05 level). Veenstra (1982) found the species in only 2 out of 14 investigated brooks in eastern Asturias (14%). The relatively high numbers of records for this region shown in fig. 1 does probably not reflect a high degree of populated brooks but an intensive searching by Hartasanchez et al. (1981).

Generally, the areas densely populated by *Chioglossa* are also the main plantation zones for eucalypts. These trees have been and are being planted in the provinces of Pontevedra and La Coruña (to provide wood for the cellulose factory in Vigo and the planned factory in As Pontes) and near Porto. They can also be found in western Asturias. The protected Serra do Geres is — as far as known — the only densely populated *Chioglossa*-area which is mostly free from eucalypts.

Habitat

Brooks of types A and B turned out to be the largely preferred habitat; the presence of *Chioglossa* could be confirmed in nearly all of them (table 1). A lower percentage of brooks and streams of type C were populated. Some of these populations may have been due to drift, since all records of reproduction are from types A and B (Vences, 1990) and it is known that drift due to water currents can affect a high percentage of salamander larvae (Thiesmeier and Schuhmacher, 1990).

None of the 10 small brooks of type D was populated.

Table 1. Numbers of brooks of different types (A-F) examined in La Coruña and Oviedo provinces. Figures in parentheses show numbers of brooks populated by *Chioglossa*. For description of brook types see Material & Methods.

brook type	A	B	C	D	E	F
width and depth of brooks [cm]						
10 × 2 – 20 × 5	4(3)	0	0	6(0)	1(1)	0
50 × 2 – 100 × 5	9(9)	8(7)	4(4)	4(0)	0	0
100 × 10 – 200 × 5	8(8)	4(4)	10(7)	0	0	0
200 × 10 – 600 × 20	3(2)	7(7)	6(2)	0	3(0)	0
Total	24(22)	19(18)	20(13)	10(0)	4(1)	0

Chioglossa reach only a few kilometers into the limestone areas of Asturias; only one out of four brooks of type E was populated.

Since vegetation along the water courses turned out to be very heterogenous, a classification into vegetation types was not possible. However, at least some eucalypts were present along most A and B brooks.

All of the six brooks of type F were outside the distribution area of *Chioglossa*.

Population density

In the population Ribeiro do Inferno (no eucalypt plantation), egg numbers continuously increased in the lower mine since 1977. On the other hand, large irregular changes between egg numbers were observed in the upper mine (table 2). A continuous increase was noted in the total number of eggs in both mines. Within the mines, the main egg deposition places remained the same over the 14-year period. No differences could be found between many other parts of the mines and these sites, which consisted of single stones at the bottom of the mine and wet parts of the walls.

In the population Ribeira de Silverinha (dense eucalypt plantation), data from the literature and from Arntzen (unpublished) indicate an increase in the salamander population after the eucalypt plantation and a still high salamander density in 1991.

In general, densities of both populations performed parallel increases, between 1976 and 1991 which cannot easily be explained by metereological patterns. Veenstra (1986) presumed that the dry summers before 1977 may have resulted in a decrease of salamander densities. However, as in the years before 1976, precipation was very low in 1988 in NW Iberia, but a decline of the *Chioglossa* population at the Ribeiro do Inferno did not occur. At the Ribeira de Silverinha, the extreme drought was probably intensified by the draining effect of *Eucalyptus*. Survival of the *Chioglossa* population was not obstructed by this. Figure 2 shows that variance in population size and egg numbers at Valongo seems to be indepent of summer precipitation.

Table 2. Numbers of deposited eggs of *Chioglossa lusitanica*, observed in the mine galleries along the Ribeiro do Inferno (a) and estimated population size of *Chioglossa lusitanica* along the Ribeira da Silverinha (b) near Valongo (Porto, northern Portugal). Observations were made in 1976 and 1977 by J.W. Arntzen, in 1984 by G. Veenstra, in 1988, 1989 and 1991 by M. Vences, and in 1990 by J.W. Arntzen and M. Vences.

	1976	1977	1984	1988	1989	1990	1991
a Ribeiro do Inferno							
eggs upper mine	487	334	97	56	506	150	213
eggs lower mine	169	208	922	987	1200	1562	2043
eggs total	656	542	1019	1043	1706	1712	2256
b Ribeira de Silverinha							
Population size		1324	2234	–	–	2117	–
standard error		265	488	–	–	*	–

* not available due to method used.

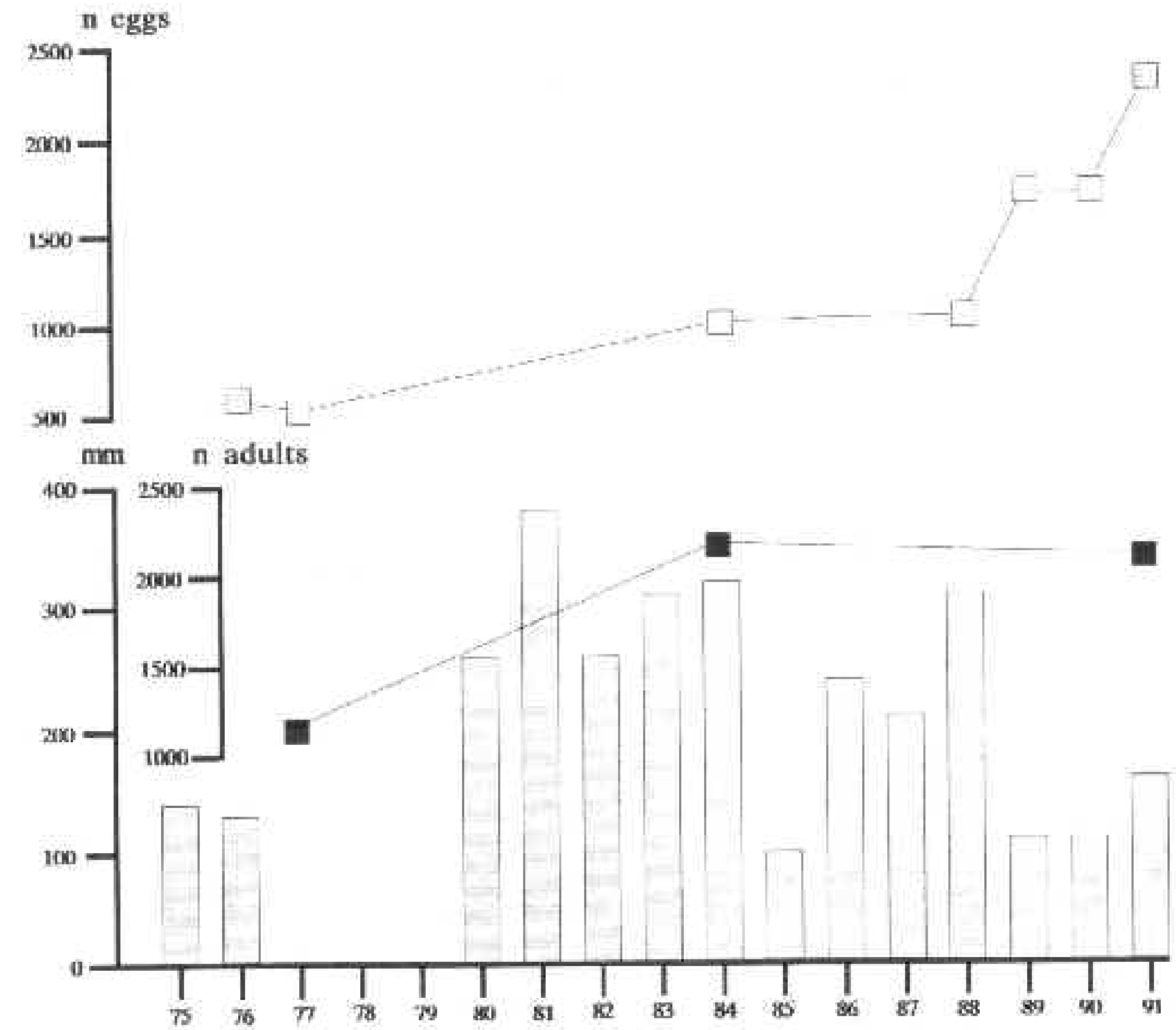

Figure 2. Number of eggs in the Valongo mines, population density estimates at the Ribeira de Silverinha and summer precipitations (months may to september, data from the Serra do Pilar observatory, Porto) in the years from 1975 to 1991.

Prey density

The number of flying insects, as caught with adhesive traps in summer (June), was significantly lower in deciduous forest when compared with eucalypts (t-test, table 3). Invertebrate species diversity was calculated using Simpson's (1949) niche amplitude formula. Species diversity was much lower in eucalypt forest due to the dominant occurence of one small species of dipteran (table 4).

In winter (December), a total of only four invertebrate (Diptera) species were caught with adhesive traps in both forest types. Together with this decrease in species diversity, an increase in the total number of specimens was observed. Differences between the two forests were not significant.

Table 3. Comparison of mean numbers of flying insects caught by adhesive and invertebrates caught with pitfall traps in a eucalypt and a deciduous forest at Caaveiro, given as mean number of specimens per trap. Differences between data pairs marked with stars are statistically significant. * P<0.05, t-test; ** P<0.001, Chi-square test.

	summer		winter	
	deciduous forest	eucalypt forest	deciduous forest	eucalypt forest
a adhesive traps				
number of invertebrates	57.0 (*)	84.2 (*)	250	262
number of invertebrates less than 1 cm in length	49.9	71.8	248	260
b pitfall traps				
number of invertebrates	12 (**)	4.8 (**)	3.3	1.3
number of invertebrates less than 1 cm in length	3.7	2.7	2.4	0.8
number of leaf litter invertebrates	3.1 (**)	1.3 (**)	0.9	0.5
number of *Carabus deyrollei*	5 (**)	0 (**)	0	0
number of *Carabus lateralis*	2.2 (**)	0.4 (**)	0	0
number of other carabids	0.4	0.3	0	0

Table 4. Invertebrate diversity in a eucalypt and a deciduous forest near Caaveiro (La Coruña, Spain) determined by flying insect specimens caught with adhesive traps and invertebrates caught with pitfall traps.

	summer		winter	
	deciduous forest	eucalypt forest	deciduous forest	eucalypt forest
a adhesive traps				
number of species	69	57	4	4
species diversity	13	3	–	–
number of species less than 1 cm in length	58	45	2	2
species diversity of species less than 1 cm in length		10.8	2.4	—
b pitfall traps				
number of species	17	24	14	7
species diversity	3.9	7.4	–	–
number of species less than 1 cm in length	7	12	6	5

Summarizing, the studied eucalypt site seemed not to be poorer in invertebrates as far as flying insects are concerned.

The number of invertebrates caught with pitfall traps in December was very low; this makes a reliable comparison between both sites for this season impossible. In June, many more invertebrates were caught in the deciduous forest than in the eucalypt forest.

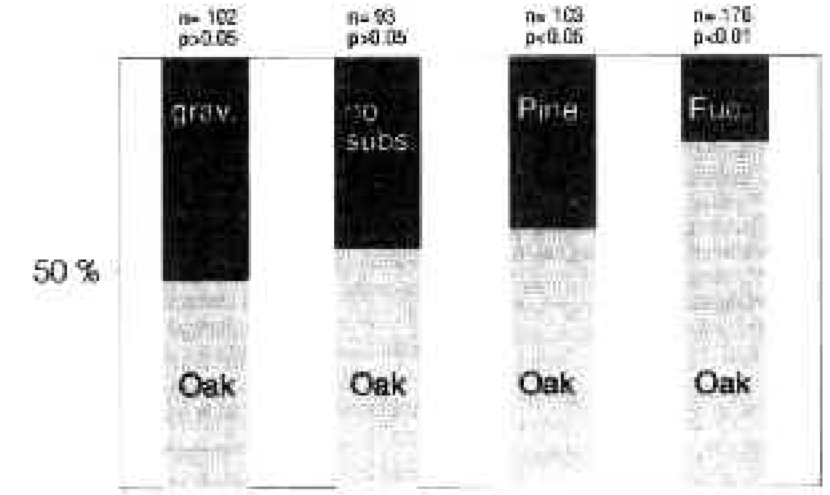

Figure 3. Substrate choice of *Chioglossa lusitanica* adults in terrarium experiments and significances of the deviation from a 50:50 distribution.

This difference is significant at a very high level as determined by a Chi-square test, and was mainly caused by the abundance of a carabid beetle, *Carabus* (*Eutelocarabus*) *deyrollei*, in the deciduous and its complete absence in the eucalypt forest. No significant difference was found after eliminating carabids and considering only species with body lengths of less than 1 cm, since many small flying insects (abundant also in the eucalypt forest, see previous section) appeared in the traps. However, densities of typical leaf litter invertebrates (Isopoda, Diplopoda, Chilopoda, Opiliones, Coleoptera larvae) were significantly lower in the eucalypt forest (table 3).

Substrate choice

Granitic gravel and glass surface without any additional substrate were not positively or negatively selected in the substrate choice experiments when compared with oak leaves. The deviation from a 50:50 selection was not significant in these two cases, nor were the selection differences between them.

A slightly significant (P<0.05, determined by a Chi-square test) negative selection of pine needles was found. The clearest avoidance was that of eucalypt leaves, which were used only by 20% of salamanders as sheltering substrates (P<0.01). This avoidance was also significant when compared with the selection of gravel and no substrate (P<0.005) and pine (P<0.05).

Combining the four results, substrates were chosen in the order: gravel, oak leaves, no substrate > pine needles > eucalypt leaves (fig. 3).

Discussion

Survival status of Chioglossa *and conservation measures*

Chioglossa lusitanica should be considered as a relatively rare species in some regions (e.g. eastern Asturias). In other regions (e.g. La Coruña) it is the most common brook dwelling amphibian species. The species does not yet seem endangered.

Since some biometric differences between norteastern and southwestern populations exist (Vences, 1990), attention should be focused on the easternmost and southernmost populations to preserve these gene pools. In addition, populations of endangered amphibian species at the distribution border are often the first to decline and finally to disappear (see Glaw and Vences, 1988, for the example of *Bufo viridis* in Germany). As reflected by the egg-deposition places within the Valongo mines, egg-depositing *Chioglossa* females seem to be highly faithful to single sites. Therefore border localities should be especially protected, since destruction of few small egg-deposition places might endanger whole *Chioglossa* populations.

Eucalypts and brook dwelling fauna and flora

The largest *Eucalyptus globulus* plantations are in the same areas where most records for *Chioglossa lusitanica* are concentrated. This is understandable since the climatic preferences of both species (high annual precipitation, absence of cold winters) are similar. Unlike the situation in the plantations near Valongo, many brooks in La Coruña province are immediately reached by eucalypt forests. *Chioglossa* commonly occur along these brooks. However, salamanders here are much more concentrated near the brooks and only after very heavy rain do they leave the immediate brook surroundings (Vences, 1990). Besides the draining effect of eucalypts, the major cause for this behaviour probably consists of a direct toxic effect of the substrate. Deciduous leaves were largely the preferred substrate in the choice experiments, indicating that behaviour as in the deciduous forests of Caaveiro, where salamanders spend from October to April within the forest at large distances from brooks and only gather along the brooks for mating, is normal for *Chioglossa*; a eucalypt substrate forces the animals to use only a restricted habitat at the immediate brook surroundings.

The high densities of flying insects in eucalypt forests can be explained by considering that flying insects are able to cover greater distances. In addition, they often spend their larval life in brooks, which are less affected by plantations than the humus layer.

Bara et al. (1985) studied invertebrate densities of eucalypt, pine and oak litter at eight sites in Galicia. Eucalypt litter appeared less populated than the other habitats in general, although in some cases density in eucalypt litter was higher. It should also be stressed that pines, with very high density of invertebrates, are not autochtonous in Galicia; it has been demonstrated that mammals (Bas, in press) and birds (Bongiorno, 1982) avoid pines.

Data on the food of various *Chioglossa* populations were published by Vences (1990). The most common food items in the deciduous forests of Caaveiro belong to the taxa Aranaea, Coleoptera and to leaf litter invertebrates such as Acari, Collembola, Diplopoda, Chilopoda. Flying insects were not consumed at all, although the trapping results presented above show that their density is not necessarily lower than in *Eucalyptus* forests. On the contrary, 40% of the prey in an *Eucalyptus*-habitat could be identified as flies (and fly larvae).

Food resources for salamanders in eucalypt substrates are not necessarily lower, but they are different from those in deciduous forest. Analyzing the data published by Vences (1990), the trophic niche of *Chioglossa* in deciduous forests (Simpson's index B = 8.1) appears to be wider than in eucalypt forests (B = 7.1). *Chioglossa* here are probably forced to feed on flying prey since leaf litter invertebrates are rare and the salamanders have to avoid the litter because of the toxic effects of the substrate.

In general, brook-dwelling species seem to be less affected by eucalypt plantations than other animals. Even those *Eucalyptus* forests bordering immediately on brooks do not have fatal effects on the brook fauna. Species such as the Spanish frog *Rana iberica* or the partially aquatic carabid *Carabus* (*Ctenocarabus*) *galicianus* were regularly found in brooks surrounded by eucalypts as well as *Chioglossa*. On the other hand, the species richness of non brook-dwelling mammals (Bas and Sanandres, in press), birds (Bongiorno, 1982), reptiles (Malkmus, pers. comm.) and plants (Bara et al., 1985; Varela, 1990) is much lower in eucalypt than in deciduous forests. Specialists such as the beetle *Carabus* (*Eutelocarabus*) *deyrollei* disappear completely after eucalypts have become the dominant trees (table 3). Doubtless, large eucalypt monocultures have strong impacts on NW Iberian ecosystems.

Traditional, small scale farming in combination with a minifundism hereditary system has fragmented Galicia into a large number of small parcels. This habitat diversity allows the survival of many animal and plant species in the cultivated countryside. Perhaps this patchwork-landscape could serve as an example for wood plantations of alternating eucalypt and oak parcels. A comparative study of the economic implications and environmental impact of such an alternating wood planting mode is urgently needed, since new plants of the cellulose industry propose the transform 4000 000 ha of Galicia into eucalypt monocultures, without providing the necessary studies of environmental impact (Varela, 1990).

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