Ecologically-sustainable tree monocultures contribute to conservation of an Araucaria Forest endemic frog

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Abstract
Tree monocultures frequently have a negative impact on biodiversity; however, the adoption of ecologically-sustainable management practices can produce a different outcome. In this study we evaluate how the replacement of Araucaria Forest by ecologically-sustainable monocultures affects the abundance, age structure, sex ratio, and diet of the endemic frog Physalaemus lisei Braun and Braun (1977) (Leiuperidae). From October 2003 to April 2005, population samples were taken with pit-fall traps in three 1 ha sites for each of the following habitats: Araucaria Forest, and old monocultures of Araucaria angustifolia, Pinus, and Eucalyptus. The number of individuals captured in Araucaria Forest was similar to that of the monocultures. Population recruitment was higher in the exotic monocultures. Captured individuals were female-biased, the sex ratio being similar for all habitats. Physalaemus lisei was slightly more generalist on the monocultures. These results suggest that the forestry industry, by adopting ecologically-sustainable management practices, can contribute to the conservation of threatened and endemic species.

Keywords: Araucaria Forest, endemism, habitat replacement, Pinus, Eucalyptus, frog, Physalaemus lisei

Introduction
The replacement of natural environments by man-made habitats is one of the major causes of changes in population and community structure of amphibians around the world (Alford and Richards 1999; Young et al. 2001; Green 2003; Cushman 2006). In the Brazilian Atlantic Forest more than 250 endemic amphibian species are potentially endangered due to negative effects of deforestation and habitat fragmentation (Brooks et al. 2002). In this environmental context, the quality of the anthropogenic matrix is essential to ensure the success of amphibian populations.

Human-induced impacts can influence amphibian populations by modifying the physical structure of the habitat, the frequency and distribution of reproductive sites, such as streams, lakes and temporary ponds (Knutson et al. 1999, 2004; Laan and Verboom 1999;
Metts et al. 2001), the availability of food resources, and the density of predators and parasites (Lafferty and Kuris 1999; Gibbs and Stanton 2001; Dauber and Wolters 2004). The response of amphibians to habitat changes, however, can be quite variable since it depends on the life history of each species (Marsh and Pearman 1997; Gascon et al. 1999; Tocher et al. 2001; Ficetola and De Bernardi 2004).

*Physalaemus lisei* Braun and Braun (1977) (Leiuperidae) is an endemic species restricted to the *Araucaria* plateau of southern Brazil (Braun and Braun 1980; Duellman 1999; Kwet and Di-Bernardo 1999; Frost 2000; IUCN et al. 2004). Although it is highly endemic, *Physalaemus lisei* is locally abundant, being frequently found foraging in leaf-litter during the day (Kwet and Di-Bernardo 1999). Its reproductive period extends from August to February, during which time females lay eggs mostly in temporary ponds but also in foam nests attached to the vegetation surrounding shallow streams (Braun and Braun 1977; Garcia 1998; Kwet and Di-Bernardo 1999).

From the 20 million ha previously occupied by Araucaria Forest, it is estimated that less than 5% remains. In the last century, logging, fire, and cattle were the main forces altering the landscape (Gantzel 1982; Teixeira et al. 1986; Dutra and Stranz 2003; Behling et al. 2004). In this same area, large stands of economically-driven tree monocultures of exotic species, such as *Pinus* and *Eucalyptus*, are being established. Since the rotation period is extremely short, tree density is high and the understorey is extremely simplified. This type of monoculture is frequently seen as a “green desert”.

In a few National Forests, however, ecologically-sustainable management practices have been adopted (Fonseca et al. forthcoming). The management designs of these areas are those of environmental mosaics, composed of remnants of Araucaria Forest mixed with monocultures of both exotic and native species. The stands are relatively small with sparsely distributed trees, giving a chance for the development of a complex understorey. Also, managers have adopted longer rotation periods, allowing ecological succession to occur. All these measures are making the monocultures more suitable for biodiversity.

In this study we evaluate how the replacement of Araucaria Forest by ecologically-sustainable tree monocultures affects the abundance, age structure, sex ratio, and diet of the endemic species *Physalaemus lisei*.

**Material and methods**

**Study area**

This study was carried out in the São Francisco de Paula National Forest (29°23′–29°27′S, 50°23′–50°25′W), southern Brazil. The reserve encompasses 1606.70 ha and is located on a plateau with elevation ranging from 650 to 920 m above sea level (Stranz 2003). The area is cut by small streams and shallow depressions favour the formation of temporary ponds. The climate is temperate and the average monthly temperature varies between 9.9°C in July and 20.3°C in February (Backes 1999). Precipitation is distributed fairly evenly over the year (>100 mm per month) with mean annual rainfall of 2252 mm (Backes 1999).

The landscape was originally dominated by Araucaria Forest and natural grasslands (Rambo 2000). However, before the National Forest was established, part of the area was used for agriculture and cattle ranching. At the end of the 1940s, a portion of the disturbed area was replanted with the native species *Araucaria angustifolia* (Bertol.) Kuntze (1898) (hereafter, plantation of *Araucaria angustifolia*—PA). At the end of the 1960s, two exotic species of *Pinus* were introduced, the loblolly pine *Pinus taeda* Elliott (1824) and the slash
pine *Pinus elliottii* Engelm (1880) (plantation of *Pinus*—PP). Plantations of a hybrid variety of *Eucalyptus* began around the 1970s (plantation of *Eucalyptus*—PE). Currently, the main landscape element in the National Forest is Araucaria Forest (44.4%), followed by monocultures of *Araucaria angustifolia* (23.5%), *Pinus* (16.8%), and *Eucalyptus* (0.4%). Other land uses such as grass fields, roads, lakes and buildings accounts for 14.1%.

In the study area, the leaf-litter amphibian community comprises seven species, the most frequently recorded being *Chaunus ictericus* Spix (1824) (51%), *Physalaemus lisei* (37%), and *Physalaemus cuvieri* Fitzinger (1826) (7%). *Leptodactylus plaumanni* Ahl (1936), *Leptodactylus ocellatus* Linnaeus (1758), *Physalaemus cf. gracilis* Boulenger (1883), and *Eleutherodactylus guentheri* Steindachner (1864) represent together only 5% of the records.

Population size and structure

We tested for differential habitat use by *P. lisei* among four distinct habitats: Araucaria Forest, and plantations of *Araucaria*, *Pinus*, and *Eucalyptus*. For each habitat, we randomly selected three sites as replicates. At each site, we established a 1 ha grid divided into quadrats of 25 × 25 m. Then, we randomly selected five quadrats and placed a pitfall trap in each, allowing a minimum distance of 25 m between traps. The pitfall trap was made of a plastic bucket (diameter: 33 cm; height: 48 cm) associated with four orthogonal drift fences made of plastic (length: 3 m; height: 50 cm above and 10 cm below the surface). The fences were centred on the bucket and aligned with the cardinal points (adapted from Halliday 1996). Since the understorey vegetation structure was similar among the four habitats, we presume equal catchability among the four forest habitats. Cartographic maps from the Instituto Brasileiro de Geografia e Estatística (IBGE) were used to measure the distance between each sample site and the nearest stream.

Frog sampling was carried out bimonthly from October 2003 to April 2005. The traps remained opened for three full days and were visited daily. The total sampling effort was, therefore, 1800 traps·day. All sampled individuals were sexed, measured, weighed, marked, and released. Males of *P. lisei* can be recognized by the short and robust forelimbs with strong fingers (Braun and Braun 1977) and by the presence of a yellowish coloration on their throat (Kwet and Di-Bernardo 1999). Females can be distinguished by the forelimbs with slim fingers and by the white or light yellow throat (Braun and Braun 1977; Kwet and Di-Bernardo 1999). Individuals weighing less than 1 g had no sexual dimorphism and were classified as juveniles (Braun and Braun 1977). The frogs were weighed to the nearest 0.1 g with a portable balance and marked using a toe-clipping system (Halliday 1996).

Daily rainfall (mm) was recorded from a pluviometer installed next to the National Forest office building.

Diet

Sixty individuals of *P. lisei* were collected from October to December of 2003, at the beginning of the reproductive period, in sites far from the pitfall sampling areas. A total of 15 specimens was collected in each of the four habitats to determine their diet. The collection was performed by visual search during the day. Collected individuals were classified by sex, measured, weighed, numbered, anaesthetized, and killed. Then, a 10% formalin solution was injected into the stomachs to stop digestion and the material was preserved in a 70% alcohol solution. In the laboratory, the stomach contents were classified at the Order level.
The availability of food resources, constituted by ground invertebrates, was assessed in March 2004. In each 1 ha area, three randomly located sites were sampled with a set of five pitfall traps that remained in the field for eight consecutive days. Each set of five traps constituted one sample. The pitfalls were transparent plastic cups 10.5 cm high and 7.5 cm diameter at the top, protected from directly incident rain by a 15 cm diameter round plastic plate suspended 10 cm above the trap. The pitfalls contained 70% ethanol to preserve the specimens, and detergent to break the water surface tension and prevent the invertebrates from escaping. The samples were preserved in ethanol for later classification. The insects and myriapods were classified in Orders and other invertebrates were classified as Oligochaeta, Hirudinea, Gastropoda. The immature forms were not considered.

Statistical analysis

Pearson correlations were used to assess the relationship between the number of captures per site and the proximity of each sampling site to the nearest stream (Zar 1999). Correlations were also used to test the relationship of the number of captures per census with the rainfall of the previous two months (60 days) and the rainfall of the sampling period (3 days). One-way ANOVA was performed to compare the number of captures between habitats (Zar 1999). Kruskal–Wallis rank tests were used to evaluate age structure through time and between habitats (Zar 1999). To detect sex ratio biases, G tests for goodness of fit were employed (Sokal and Rohlf 2000). One-way ANOVA was used to compare the number of food items and the number of taxonomic orders between habitats (Zar 1999), rarefaction curves being utilized to standardize the sampling effort across habitats (Gotteli and Entsminger 2004). One-way ANOVA was used to evaluate the availability of ground invertebrates between habitats. For the comparisons among food availability and the diet of *Physalaemus lisei*, G tests were conducted (Sokal and Rohlf 2000). Manly preference index (x) was used to evaluate feeding preferences according to the availability of different invertebrate taxonomic groups in the study site (Krebs 1999).

Results

Population abundance

The number of captures of *Physalaemus lisei* was quite high in October 2003 and reached its peak in December 2003, during the southern hemisphere summer. From February to October 2004 the number of captures decreased consistently and increased again from December 2004 to February 2005 (Figure 1A). The number of individuals of *Physalaemus lisei* collected bimonthly was significantly correlated with the rainfall recorded during the 3-day sampling period ($r=0.665$, df=8, $P=0.036$). However, rainfall is fairly constant throughout the year, thus a non-significant correlation was found ($r=0.270$, df=8, $P>0.05$). Captures per site were also not correlated with proximity of streams ($r=0.020$, df=10, $P>0.05$).

Only one individual was recaptured among censuses. A female first captured in a *Pinus* site in April 2003 was caught 50 m from the initial point in April 2004. During this year, it gained 0.3 g from an initial weight of 1.4 g.

*Physalaemus lisei* was caught in all habitats and at all study sites. The number of captures of *P. lisei* in Araucaria Forest was not significantly different from that recorded in monocultures of *Araucaria angustifolia*, *Pinus*, and *Eucalyptus* ($F_{3,8}=0.411$, $P>0.05$, Figure 1B).
Population structure

The body mass of *P. lisei* varied from 0.1 g for juveniles to 3.0 g for reproductive adults (median of 1.8 g). The difference in median body mass for females (1.90 g) and males (1.75 g) was not significant (*U=554.5, P>0.05*). The weight distribution of captured frogs

Figure 1. Number of individuals of *Physalaemus lisei* captured in the São Francisco de Paula National Forest, southern Brazil. (A) Temporal dynamic between October 2003 and April 2005; (B) among-habitat variation in the mean (±SE) number of captures. FO, Araucaria Forest; PA, *Araucaria angustifolia* plantation; PP, *Pinus* plantation; PE, *Eucalyptus* plantation.
changed significantly through the 18 months of the study \( (U=32.474, \text{df}=8, P<0.001) \) (Figure 2A). In October and December 2003, most individuals were adults, exhibiting around 2 g of body mass, and only three juveniles were recorded. In contrast, in February 2004 most individuals were juveniles of less than 1 g, indicating a strong recruitment. In February 2004 only three adults were recorded and no adult was recorded in April or June, suggesting hibernation or even a massive mortality rate after the reproductive period.
February to December 2004 the median body mass grew continuously, reaching around 2 g. In February 2005 a new recruitment event started.

The median body mass of *P. lisei* varied significantly among habitats (*U*=13.888, df=3, *P*=0.003) (Figure 2B). Considering all sites of Araucaria Forest and *Araucaria angustifolia* monocultures, only three of the 41 recorded individuals were juveniles. In contrast, nine and 10 juveniles were recorded in *Pinus* and *Eucalyptus* sites, respectively.

**Sex ratio**

Sixty-nine females and 13 males were recorded, giving a female-biased sex ratio of 84.1%, significantly different from 1:1 (*G*=37.54, df=1, *P*<0.001). Along the 10 sampling periods, the female-biased sex ratio remained unaltered (*G*$_{het}$=7.08, df=9, *P*>0.05). Furthermore, female sex ratio was similar between Araucaria Forest and the tree monocultures (*G*$_{het}$=2.46, df=3, *P*>0.05; Table I).

**Diet and feeding preference**

The diet of *P. lisei* comprised 18 invertebrate taxa (*N*=193 food items), including insects, arachnids, crustaceans, and myriapods (Figure 3). The most important Order was Hymenoptera (34% of the food items), followed by Coleoptera (16.9%), Araneae (16.3%), Isopoda (7.1%), Blattoidea (4.4%), Hemiptera (3.8%), and Psocoptera (2.7%). These seven orders together represented more than 80% of the classified items (nine items could not be identified). In the leaf-litter pitfall traps, 30 invertebrate taxa were present (*N*=35,953 records); the most frequent taxon was Collembola (39% of arthropods recorded), followed by Hymenoptera (17%), Coleoptera (16%), and Diptera (10%). These four orders together represented more than 80% of the records (Figure 3).

The diet of *P. lisei* was quite different from that expected from the availability of food resources in the study site (*G*=128.33, df=29, *P*<0.001; Figure 3). Clearly, *P. lisei* did not include as many Collembola in its diet as could be expected by its high availability in the leaf-litter. When Collembola is excluded from the analysis, *P. lisei* still exhibited a non-random diet (*G*=94.19, df=28, *P*<0.001). Although Hymenoptera was the most frequent food item on the diet of *P. lisei*, this was due to the high density of ants in the leaf-litter. Considering the seven most important taxonomic orders in the feeding niche of *Physalaemus lisei*, Manly preference index indicated feeding preference for Blattoidea (*a*=0.41), Araneae (*a*=0.18), and Isopoda (*a*=0.16) (Critical *a*=0.143). The taxa avoided

| Table I. Number of males and females sampled in four habitats of the São Francisco de Paula National Forest, Brazil. |
|-----------------|----------------|----------------|-----------------|----------------|
| Habitat         | Female | Male | Total | df     | G        |
| Araucaria Forest| 22     | 5    | 27    | 1      | 10.63*** |
| Araucaria plantation | 13     | 0    | 13    | 1      | 13.45*** |
| Pinus plantation | 17     | 5    | 22    | 1      | 6.28**  |
| Eucalyptus plantation | 17     | 3    | 20    | 1      | 9.64*** |
| Total           | 69     | 13   | Total 4 | 39.99*** |
|                  |        |      | Pooled 1 | 37.54*** |
|                  |        |      | Heterogeneity 3 | 2.46 |

*G* tests were used to compare observed sex ratios with the expected ratio of 1:1. One was added to every observed cell to meet the test assumptions. **P<0.01, ***P<0.001.
by *P. lisei* were Collembola, Diptera, and Acarina. Furthermore, *P. lisei* seems to eat fewer beetles than expected from their availability.

The total number of diet items recorded in Araucaria Forest (*N* = 21) was smaller than the number recorded in monocultures of *Araucaria angustifolia* (*N* = 61), *Pinus* sp. (*N* = 59), and *Eucalyptus* sp. (*N* = 43). More frogs were captured in Araucaria Forest with empty stomachs than in the other habitats. Also, frogs in Araucaria Forest had fewer items per stomach (1.4 ± 0.4) than sites of *Araucaria angustifolia* (4.1 ± 0.5), *Pinus* (3.9 ± 1.2), and *Eucalyptus* (2.9 ± 0.6) plantations, this difference being marginally significant (*F*[3,56] = 2.750, *P* = 0.051; Figure 4). These results contrast with the higher abundance of invertebrates found in Araucaria Forest (3946.33 ± 375.08) and *Araucaria angustifolia* plantations (3559 ± 997.57) when compared to the exotic plantations of *Pinus* (2708.33 ± 128.55) and *Eucalyptus* (1770 ± 306.60) (*F*[3,8] = 4.307, *P* < 0.05).

The mean number of Orders found per individual varied significantly between habitats (*F*[3,56] = 6.344, *P* = 0.001). When standardizing the sample size, rarefaction analysis indicated that *P. lisei* has higher taxonomic richness in its diet in plantations of *Araucaria angustifolia*, at 95% confidence interval (Figure 5). Individuals collected in Araucaria Forest had 1.0 ± 0.2 invertebrate orders per stomach, which was significantly lower than individuals captured in *Pinus* sp. (2.4 ± 0.4) and *Araucaria angustifolia* plantations (2.7 ± 0.3).

**Discussion**

The replacement of natural vegetation by tree monocultures generally has a negative impact on amphibian species (Heinen 1992; Waldick et al. 1999; Pineda and Halffter 2004; Parris and Lindenmayer 2004; Krishna et al. 2005). In India, many species suffered with the substitution of their native habitat by coffee plantations (Krishna et al. 2005). The negative impact of coffee plantations was also observed in aquatic-breeding species of...
Mexican cloud forest, where many amphibians were recorded only at native forest sites (Pineda and Hallfter 2004). In Australia, the substitutions of natural habitats by Pinus radiata plantations caused serious impacts on the population structure of frogs (Parris and Lindenmayer 2004). In Canada, amphibians were more abundant in natural forest than in Black Spruce Picea mariana (Mill.) Briton et al. (1888) plantations of any age (Waldick et al. 1999).

In contrast to this general pattern and to what one could expect from its high endemism, P. lisei seems to cope adequately with the level and type of habitat disturbance occurring in
the São Francisco de Paula National Forest. The abundance of *P. lisei* in Araucaria Forest, a species-rich native habitat, was not significantly different from the old monocultures of *Araucaria angustifolia*, and even more surprisingly, was very similar to that found in monocultures of exotic *Pinus* and *Eucalyptus*.

The explanation for such a population pattern lies in the management regime adopted by the National Forest, that differs strongly from the one adopted by the economically-driven monocultures of the region. In fact, it has been argued that the management regime of the National Forest is reasonably close to what one could call “the best scenario” in terms of biodiversity conservation (Fonseca et al. forthcoming). The total planted area is not large (<600 ha), being structured as a forest mosaic which allows high connectivity with Araucaria Forest patches. The stands are relatively small and vary in form and size. The terrain preparation did not use heavy machinery. Agrochemicals (e.g. pesticides, herbicides, and fertilizers), frequently implicated in the population decline of pond- and stream-breeding amphibians (Hayes et al. 2002; Boone et al. 2004; Relyea 2005), were infrequently used. The rotation periods of the plantations are quite long, contrasting with the short period of local commercial monocultures (7–10 years). In 2005, the studied stands of *Araucaria angustifolia*, *Pinus*, and *Eucalyptus* were 46–58, 33–40 and 11–33 years old, respectively. Logged areas are not uniformly distributed across the landscape. There is no harvesting on plantations and the space between the trees is quite large, allowing the establishment of a dense understorey. In the National Forest, the use of native species in the monocultures also differs from the private enterprises, based exclusively on exotic species that, due to high invasive potential, have been demonstrated to represent a serious threat to natural environments (Richardson and Higgins 1998).

Some studies support the view that different management regimes in monocultures can produce different outcomes in the amphibian community. For instance, newer and recently managed monocultures of Cacao had fewer species of leaf-litter amphibians than older monocultures, where there is low management (Heinen 1992). Renken et al. (2004) found that two clearcut management levels in small and highly-connected plantation patches of Missouri Osark Forest affected amphibians at a small spatial scale, but at a larger spatial scale they did not detect significant effects of these managements. Besides habitat substitution per se, intensively managed plantations affect the amphibians through alterations to litter, water quality (due to agrochemicals), and microhabitat architecture/temperature (Betts et al. 2005).

**Life cycle and recruitment**

*Physalaemus lisei* apparently has a one-year life cycle. Adults of *P. lisei* initiate their activities at the end of the southern hemisphere winter, beginning to call in August (Garcia 1998). In early September, females deposit their eggs in male-produced foam nests (Solé 2000) that have been demonstrated to protect the eggs and tadpoles against desiccation (Heyer 1969; Duellman and Trueb 1986) and predators (Downie 1990; Menin and Giaretta 2003). In October, the first individuals complete their metamorphosis. In December, the population reaches its peak with the overlap of the early generation with the recently born juveniles. The highest number of young individuals occurs in February and the adult cohort seems to diminish and finally disappear in April. At that time, juveniles have already grown substantially, and gained about 1 g in 2 months. We found no evidence that the life cycle was affected in the ecologically-sustainable monocultures.
The geographic distribution of *P. lisei* is restricted to rainy areas of high altitude. Since rainfall is quite high, achieving more than 100 mm every month, reproductive sites seem to be available throughout the year. Therefore, it is the low winter temperatures, with the minimum average temperature reaching less than 10°C (Backes 1999), that seems to control the reproductive cycle of *P. lisei*. The lack of relationship between population size and stream proximity reinforces the view that temporary ponds are the primary reproductive sites for *P. lisei*. The age structure of *P. lisei* revealed that population recruitment was stronger in *Pinus* and *Eucalyptus* than in both the native forest and the monocultures of *Araucaria angustifolia*. A possible explanation for such a pattern is the modification of the physical properties of the soils by the exotic species, facilitating the creation of a higher density of temporary ponds.

**Biased sex ratio**

In general, natural populations are expected to exhibit a sex ratio of 1:1 (Fisher 1930; Williams 1975). When sex ratio bias is detected either the sex ratio of the population as a whole is biased or sex differences in habitat preference or activity intensity are in place. Many studies have described biased sex ratios in the genus *Physalaemus*. Giaretta and Menin (2004) described male bias of *Physalaemus fuscomaculatus* Steindachner (1864) in a pitfall trap sampling, and attributed this pattern to differences of mobility between sexes. They inferred that males could be more mobile than females when searching for temporary ponds, especially at the beginning of the rainy season. In contrast, females, being aurally orientated, were inferred to follow shorter ways to the calling (spawning). Bokermann (1962), however, found a male-biased sex ratio for *Physalaemus cuvieri* despite the fact that he had indications that females were more active than males. Yet in this study individuals were actively collected near ponds, probably not offering equal catchability of the sexes.

The sex ratio of *P. lisei* was consistently female-biased, independently of season and habitat. One possibility is that indeed population sex ratio is female-biased due to an unknown evolutionary process. However, we favour another explanation. Since most randomly located pitfall traps were placed relatively far from reproductive sites, they were unable to sample reproductive males, since they tended to be aggregated around adequate reproductive sites for vocalization. In contrast, the pitfalls were efficient in trapping females which seem to travel more freely on the forest floor. Despite this, the results suggest that sex ratio do not differ between Araucaria Forest and ecologically-sustainable monocultures.

**Feeding niche**

*Physalaemus lisei* can be considered a generalist species, since at least 18 invertebrate taxonomic orders are included in its diet. Few organisms in its diet were considered to be exclusively aquatic (e.g. Hyalellidae), indicating that they forage preferably on the leaf-litter. The dominance of Hymenoptera in the diet is directly linked to the great relative abundance of ants in the study site. However, *P. lisei* clearly exhibit feeding preferences. Since Collembola was the most abundant taxon in the litter but occurred in very low frequency in the diet, this suggests that for *P. lisei* the capture effort of these small-sized organisms is not energetically rewarding. When removing Collembola from the analyses, *P. lisei* showed significant preference for Blattoidea, Aranae, and Isopoda, and apparently does not like Diptera and Acarina. It is interesting to note that *Physalaemus cuvieri* and *Physalaemus cf. fuscomaculatus*, two co-generic species, have termites as their main prey.
(Bokermann 1962; Giaretta and Menin 2004), while *P. lisei* did not include Isoptera in its diet, probably due to the very low availability of this taxon in the study site.

The wide feeding niche of *Physalaemus lisei* seems to enable it to obtain food in the ecologically-sustainable monocultures. In fact, individuals captured in Araucaria Forest sites had fewer items per stomach than those captured in the monocultures, many of them being captured with empty stomachs. This was so despite the fact that Araucaria Forest was the habitat with the highest availability of ground invertebrates. Rarefaction curves suggested that individuals in Araucaria Forest were somewhat more specialist than those living in monocultures. This, however, seems to be a small price to pay for such an important habitat shift.

**Conservation implications**

Araucaria Forests are vanishing from Brazil, reducing the geographic range of the associated biodiversity. The original habitat has been drastically replaced by cattle ranch, agricultural fields and, particularly, by tree monocultures of extremely short cutting cycles. While ecologically-managed tree plantations clearly are not equivalent to native forests, our results suggest that they can contribute positively to the conservation of *Physalaemus lisei*, an Araucaria Forest endemic species. Further studies are needed to verify whether these findings can be extended to other species of the Araucaria Forest amphibian community.

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