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Anurans of a remnant forest in Urussanga, Santa Catarina, southern of Brazil

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Abstract: We provide a list of amphibians from a Submontane Forest remnant in Urussanga municipality, Santa Catarina, southern of Brazil. We sampling through visual and acoustic surveys in four distinct sites. Twenty-six species of anurans belonging to nine families were recorded, where nine species were rare, nine abundant, and eight common. Eleven reproductive modes were observed, with exotrophic tadpoles in still water (mode 1) being most frequent mode (38%). The period of highest vocalization activity occurred between October and January. Temperature, rainfall and air humidity were not correlated with the richness and abundance of calling males. Only photoperiod was positively correlated with the abundance of calling males and species richness.

Key words: amphibians; Atlantic Forest; biodiversity; reproductive modes; subtropical region

INTRODUCTION

Amphibian biodiversity has become increasingly threatened worldwide (Convention on Biological Diversity 2010). In Brazil, major threats to conservation are related to habitat destruction as a result of deforestation, expansion of agriculture, mining, burning, and development of urban infrastructure (Silvano & Segalla 2005).

Unlike its flora, the fauna of Santa Catarina is not well known (Cherem et al. 2004), despite the state's high biodiversity. In contrast, anuran composition in the states of Paraná and Rio Grande do Sul in southern Brazil is well-characterized, because a large number of studies have been conducted for several decades (Armstrong & Conte 2010; Bernarde & Anjos 1999; Both et al. 2008; Colombo et al. 2008; Conte & Machado 2005; Conte & Rossa-Feres 2007; Machado & Maltchik 2007; Santos et al. 2008; Zank et al. 2013). In Santa Catarina, little is known about species richness and geographical distribution of frogs due to the paucity of studies related to the subject (Garcia et al. 2008; Lucas 2008). Most previous research has been concentrated in the western part of the state (Bastiani et al. 2012; Bastiani & Lucas 2013; Lingnau 2009; Lucas & Fortes 2008; Lucas & Garcia 2011; Lucas & Marocco 2011) and near the central coast (Garcia 1996; Garcia & Vinciprova 1998; Garcia et al. 2003; Kwet 2006). A new species was recently described, as well, from the state (Bruschi et al. 2014).

Information regarding the temporal and spatial distribution of organisms is essential for understanding their ecological relationships with the environment (Ferreira et al. 2012) and species conservation (Eterovick et al. 2005). Information related to the abundance and species richness of amphibians in Santa Catarina is rare, but is of high important to rebuild the life history of these organisms and understand population fluctuations and the general trend of declines in amphibian populations (Lucas 2008). The objectives of the present study were: 1) to characterize species richness, constancy, and reproductive modes of anuran species in an area of the Atlantic Forest in southern Santa Catarina; 2) to verify the vocalization seasons of anuran males in four water bodies located in the study area; 3) to verify correlations among climatic predictors (temperature, precipitation and photoperiod) and species richness and male vocalization activity.

MATERIALS AND METHODS

Study site

The study was conducted on the premises of the Vale dos Figos Hotel, in the municipality of Urussanga, in southern Santa Catarina (28°28′53.19″ S, 049°18′38.07″ W, 195–222 m above sea level) (Figure 1). The vegetation comprises

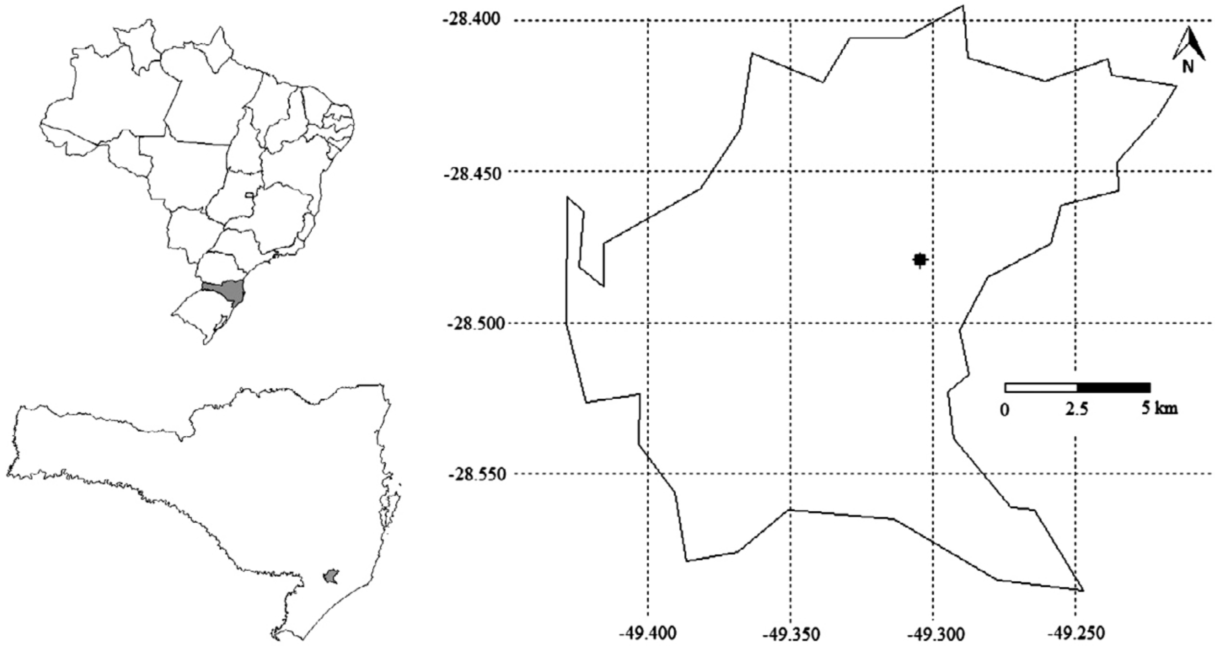

Figure 1. Map showing the study site in the state of Santa Catarina, Southern Brazil.

remnants of secondary submontane tropical rainforest (IBGE 2012) at different degrees of conservation and interspersed with exotic species and orchards. The climate, according to the Köeppen classification system (1948), is Cfa with average temperature ranging from 17.0–19.3°C and minimum and maximum averages ranging from 12.0–15.1°C and from 23.4–25.9°C, respectively. Annual precipitation ranges from 1,200–1,700 mm, with rain events distributed throughout the year (EPAGRI 2001). The area is drained by a tributary of the Urussanga River and is situated in the geomorphologic region of the coal outcrop.

Data collection

Field sampling was conducted monthly (n = 1 d/mo) from November 2010 to December 2011 by active search (Crump 1971) and visual and acoustic encounters (Zimmerman 1994) at four distinct sites: stream with sandy bottom (SSB); stream with pebbles (SP); marsh in open area (MOA); and marsh in forest remnant (MFR). Sites were chosen based on ease of access and potential to attract frogs. Reproductive modes of recorded frogs were classified according to the literature (Haddad & Prado 2005; Haddad et al. 2008, 2013).

Sampling was conducted between 15:00 and 00:00 h. Each site was visited three times on each sampling date, with equal amounts of time spent between different habitats within a site (45 minutes). All species seen or heard were recorded. Habitats were also visited ad libitum during the day, on separate dates from samplings, to record daytime activities. When required, specimens were collected and deposited in the Museu de Zoologia Prof[a]. Morgana Cirimbeli Gaidzinski (MUESC) at Universidade do Extremo Sul Catarinense, Criciúma, Santa Catarina, Brazil (permit SISBIO 29935-1). The individuals were manually captured, anesthetized, and sacrificed with a 5% lidocaine paste, then fixed in 10% formalin and preserved in 70% alcohol. The nomenclature adopted for this study followed Frost (2015).

Data analysis

Sampling efficiency was evaluated by a species accumulation curve, constructed from the matrix of monthly data collected on species presence/absence. Calculations were performed based on 1,000 randomizations using the nonparametric estimators, Bootstrap and Jacknife 1, based on presence–absence (incidence) of species, considering or not rare species, with the aid of the EstimateS 9.0 program (Cowell 2013). Each recorded species was classified according to the constancy of occurrence index (Dajoz 1983) and considered to be abundant (present in >50% of samples), common (present in 25%–50% of samples), or rare (present in <25% of samples).

The abundance of each species was determined based on the highest number of vocalizing males recorded during one of three passes through each site on a given sampling date, as suggested by Gottsberger & Gruber (2004). This procedure was adopted to avoid underestimating population abundance resulting from the use of average abundance between successive samplings (Conte & Rossa-Feres 2007). The diversity and evenness for each sampling site were evaluated by Shannon–Wiener's diversity index and Pielou's evenness index, respectively (Krebs 1999). Significant differences observed in specific diversity and evenness between the four sampling sites were evaluated using a Chi-square test with $p \leq 0.05$ (Zar 1999).

The influence of environmental variables (temperature, rainfall, relative humidity, and photoperiod) on species richness and abundance of vocalizing males was verified by applying Spearman's correlation coefficient (r_s) (Zar 1999). The month of September was excluded from this analysis because no species vocalization activity was recorded for that month.

Abiotic data (temperature, relative humidity, and rainfall) associated with sampling dates were obtained from the Experimental Station of EPAGRI at Urussanga (6 km from the study site). Data relating to photoperiod were obtained from the Brazilian National Observatory (http://euler.on.br/ephemeris/index.php). Temperature, rainfall, and humidity data were reported as averages of five days per month (four days before and on the day of sampling).

RESULTS

Twenty-six species distributed amongst nine families and 17 genera were recorded. Hylidae was the richest (n = 13 species), followed by Leptodactylidae (n = 5) and Bufonidae (n = 2). Six families contributed with only one species each (Table 1). The environments with the highest species richness were MOA (n = 15 species), followed by SP (n = 13 species), SSB (n = 11), and MFR (n = 8). The recorded variation in richness between environments was not statistically significant, as demonstrated by the Chi-square test (Table 1).

The general diversity index for the area was high (H = 3.037), although values for diversity and evenness were distinct among the sampling sites (H′ for SSB = 1.907^{ns}; SP = 2.078^{ns}; MOA = 2.062^{ns}; MFR = 1.094^{ns}), no significant differences were detected (p > 0.05) (Table 1). The species accumulation curve showed that the sampling effort was sufficient to register 86.66% of species potentially present in the study area. The difference between the estimated maximum number of species and the number registered was approximately four species (Figure 2).

Nine species were considered rare, nine were abundant, and eight were common species (Table 2). Vocalization

Table 1. Anurans amphibians recorded in four sampling sites in Urussanga, SC, between November 2010 and December 2011, where: SSB = stream with sandy bottom; SP = stream with pebbles; MOA = marsh in open area and MFR = marsh in forest remnant. *Species without vocalization activity.

		Sampling site				
Family	Species	SSB	SP	MOA	MFR	Voucher
Brachycephalidae	*Ischnocnema henselii* (Peters, 1870)	x	x		x	1248
Craugastoridae	*Haddadus binotatus* (Spix, 1824)*				x	Photo only
Bufonidae	*Rhinella abei* (Baldissera, Caramaschi & Haddad, 2004)			x		1249
	Rhinella icterica (Spix, 1824) *		x			Photo only
Centronelidae	*Vitreorana uranoscopa* (Müller, 1924)				x	Photo only
Hylidae	*Aplastodiscus ehrhardti* (Müller, 1924)	x	x			Photo only
	Aplastodiscus cochranae (Mertens, 1952)	x	x	x		Photo only
	Bokermannohyla hylax (Heyer, 1985)	x	x		x	1254
	Dendropsophus minutus (Peters, 1872)			x		Photo only
	Hypsiboas faber (Wied-Neuwied, 1821)	x	x	x	x	Photo only
	Hypsiboas bischoffi (Boulenger, 1887)	x	x	x	x	Photo only
	Ololygon catharinae (Boulenger 1888)	x	x			Photo only
	Scinax tymbamirim Nunes, Kwet & Pombal, 2012			x		Photo only
	Scinax fuscovarius (Lutz, 1925)		x	x		Photo only
	Scinax granulatus (Peters, 1871)*			x		Photo only
	Scinax perereca Pombal, Haddad & Kasahara, 1995	x	x	x		Photo only
	Trachycephalus mesophaeus (Hensel, 1867)				x	Photo only
Hylodidae	*Hylodes meridionalis* (Mertens, 1927)	x	x			1259
Leptodactylidae	*Adenomera araucaria* Kwet & Angulo, 2003			x		Photo only
	Leptodactylus gracilis (Duméril & Bibron, 1841)			x		1261
	Leptodactylus latrans (Steffen, 1815)			x		1262
	Physalaemus cuvieri Fitzinger, 1826.			x		Photo only
	Physalaemus nanus (Boulenger, 1888)	x	x		x	1260
Microhylidae	*Elachistocleis bicolor* (Valenciennes in Guérin-Menéville, 1838)			x		Photo only
Odontophrynidae	*Proceratophrys boiei* (Wied-Neuwied, 1824)	x	x			1252
Phyllomedusidae	*Phyllomedusa distincta* B. Lutz, 1950*			x		Photo only
Richness		11	13	15	8	
Diversity (H′)		1.907^{ns}	2.078^{ns}	2.062^{ns}	1.094^{ns}	
Equitability (e)		0.8283^{ns}	0.832^{ns}	0.8039^{ns}	0.6799^{ns}	
Diversity (H′) general for the area			3.037			

Figures 2. Amphibians recorded on the four sampling sites in Urussanga, SC, from November 2010 to December 2011: (**1**) *Ischnocnema henselii,* (**2**) *Haddadus binotatus,* (**3**) *Rhinella abei,* (**4**) *Rhinella icterica,* (**5**) *Vitreorana uranoscopa,* (**6**) *Proceratophrys boiei,* (**7**) *Aplastodiscus ehrhardti,* (**8**) *Aplastodiscus cochranae,* (**9**) *Bokermannohyla hylax,* (**10**) *Dendropsophus minutus,* (**11**) *Hypsiboas faber,* (**12**) *Hypsiboas bischoffi,* (**13**) *Ololygon catharinae,* (**14**) *Scinax tymbamirim,* (**15**) *Scinax granulatus,* (**16**) *Scinax perereca,* (**17**) *Phyllomedusa distincta,* (**18**) *Trachycephalus mesophaeus,* (**19**) *Hylodes meridionalis,* (**20**) *Leptodactylus gracilis,* (**21**) *Leptodactylus latrans,* (**22**) *Physalaemus cuvieri,* and (**23**) *Physalaemus nanus.* Photos by KC.

activity observed during the study indicated greater activity between October and January (Figure 1; Table 2). The period with the lowest number of vocalizing male species was in autumn (eight species), whereas the period with the highest number occurred in summer (18 species). Among inventoried species, *Vitreorana uranoscopa* vocalized only in February after a strong storm, *Rhinella abei*, *Aplastodiscus ehrhardti*, *Bokermannohyla hylax*, *Hypsiboas bischoffi*, and *Ololygon catharinae* were the only species recorded between April and July, and no species were recorded in September. Eleven reproductive modes were recorded for the study area (Table 2). Mode 1 (eggs and tadpoles in still water)

Table 2. Vocalization activity period, constancy of occurrence index and reproductive modes of amphibian species recorded in Urussanga, SC, between November 2010 and December 2011. Where: OF = occurrence frequency; CI = constancy index (Dajoz, 1983), C (Common species), A (abundant species) and R (rare species); RM = reproductive modes (sensu Haddad & Prado, 2005).

Taxon	OF (%)	CI	RM	Vocalization period													
				N	D	J	F	M	A	M	J	J	A	S	O	N	D
Brachycephalidae																	
Ischnocnema henselii	28.57	C	23		■								■				■
Craugastoridae																	
Haddadus binotatus	28.57	C	23	■													
Bufonidae																	
Rhinella abei	14.29	R	1							■			■				
Rhinella icterica	7.14	R	2														
Centronelidae																	
Vitreorana uranoscopa	7.14	R	25				■										
Cycloramphidae																	
Proceratophrys boiei	21.43	R	2		■												■
Hylidae																	
Aplastodiscus cochranae	42.86	C	5	■	■	■									■	■	■
Aplastodiscus ehrhardti	71.43	A	5	■	■				■	■		■	■		■	■	■
Bokermannohyla hylax	85.71	A	4	■	■	■	■	■		■		■	■		■	■	■
Dendropsophus minutus	71.43	A	1	■	■	■	■	■				■	■		■	■	■
Hypsiboas bischoffi	78.57	A	1	■	■	■		■	■	■	■	■	■		■	■	■
Hypsiboas faber	50.00	C	4	■	■	■	■								■	■	■
Ololygon catharinae	21.43	R	1								■		■				
Phyllomedusa distincta	7.14	R	24														
Scinax tymbamirim	64.29	A	1		■	■		■				■	■		■	■	■
Scinax fuscovarius	14.29	R	1		■										■		
Scinax granulatus	7.14	R	1														
Scinax perereca	57.14	A	1	■	■	■						■	■		■	■	■
Trachycephalus mesophaeus	28.57	C	1													■	
Hylodidade																	
Hylodes meridionalis	64.29	A	3		■	■		■					■		■	■	
Leptodactylidae																	
Physalaemus cuvieri	57.14	A	11	■	■	■	■					■			■	■	■
Physalaemus nanus	64.29	A	11	■	■	■	■	■					■		■	■	■
Adenomera araucaria	7.14	R	32										■				
Leptodactylus gracilis	42.86	C	30		■	■						■	■		■	■	
Leptodactylus latrans	35.71	C	11	■	■	■									■	■	■
Microhylidae																	
Elachistocleis bicolor	28.57	C	1			■	■										■
Richness				11	16	13	7	6	2	4	2	8	13	0	14	14	14

was the most frequent, being represented in 10 of the 26 species (38%).

Correlation analyses between monthly species richness, abundance of vocalizing males, and environmental variables (temperature, rainfall, relative humidity, and photoperiod) showed that species richness (r_s = 0.8, $p \leq 0.001$) and abundance of vocalizing males (r_s = 0.67, $p \leq 0.01$) were positively correlated only with variation in photoperiod (Figure 3A, 3B). The monthly species richness was not correlated to temperature (r_s = 0.46, $p \geq 0.001$), rainfall (r_s = −0.22, $p \geq 0.001$) nor relative humidity (r_s = −0.4, $p \geq 0.001$), as well as abundance of vocalizing males was not correlated to temperature (r_s = 0.18, $p \geq 0.001$), rainfall (r_s = −0.17, $p \geq 0.001$) nor relative humidity (r_s = −0.46, $p \geq 0.001$).

DISCUSSION

The 26 recorded species in the present study corresponded to 18% of 144 species listed for Santa Catarina (Lucas 2008) and about 4.9% of 529 recorded species in the Atlantic Forest (Haddad et al. 2013). The number of recorded species in this study was similar to those recorded in other studies conducted in Santa Catarina (e.g., Bastiani & Lucas 2013; Hartmann et al. 2008; Lingnau 2009; Lucas

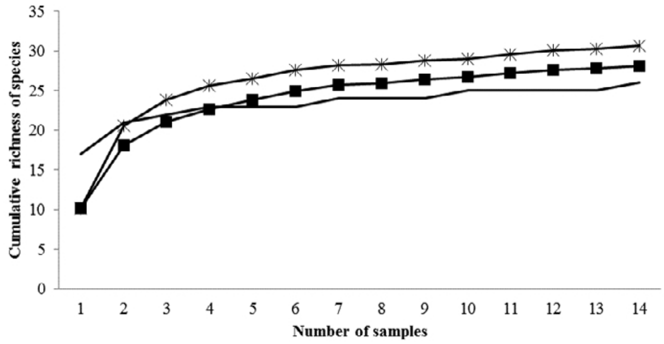

Figure 3. Curve of species accumulation, based on the monthly occurrence of anurans, recorded on the four sampling sites in Urussanga, SC, from November 2010 to December 2011. Legend: Solid black line with asterisk: Jacknife1, Solid black line with square: Bootstrap and Solid black line: Observed richness.

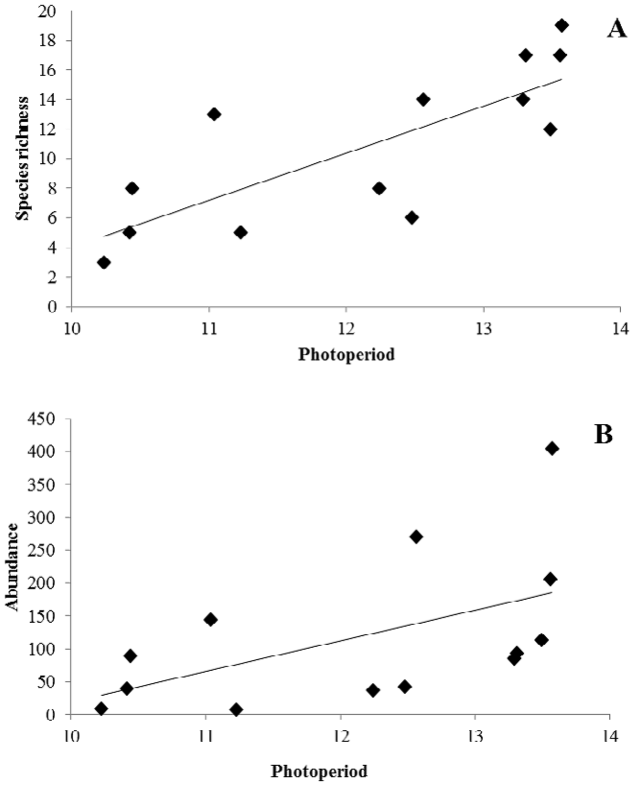

Figure 4. A. Graphic representing Spearman's correlation between photoperiod variation and monthly richness of species ($r_s = 0.8$ and $p \leq 0.001$) and, **B.** Graphic representing Spearman's correlation ($r_s = 0.67$ and $p \leq 0.001$) between photoperiod variation and abundance of vocalizing males, between November 2010 and December 2011.

& Fortes 2008; Lucas & Marocco 2011; Wachlevski & Rocha 2010). None of the species recorded in this study are cited on the Brazilian Official National List of Endangered Species of Wildlife (MMA 2014); however, three species are in the Vulnerable (VU) category for the state of Santa Catarina: Vitreorana uranoscopa, Aplastodiscus ehrhardti, and Aplastodiscus cochranae (CONSEMA 2011).

Temporary habitats (including the MOA site) tend to have less pressure from predators than permanent environments (Heyer et al. 1975), thereby allowing diversity and species richness (Skelly 1997). In contrast with permanent environments tend to be colonized by species with long reproductive periods, such as *Dendropsophus minutus* and *Hypsiboas faber* and species of the family Leptodactylidae (Maragno et al. 2013; Wells 1977). The abundance of rare species observed in this study may be due to occasional records while anurans were moving to breeding sites or to shelter areas, which were not the sampling sites themselves (e.g., *Phyllomedusa distincta*, *Scinax granulatus*, and *Scinax perereca*). Some species are explosive breeders (e.g., *Proceratophrys boiei* and *Vitreorana uranoscopa*) and appeared/vocalized during or after heavy rains (Duellman & Trueb 1994).

In subtropical regions, temperature and photoperiod are the most important factors regulating anuran vocalization activity (Canavero et al. 2009). In this study, vocalization activity was not correlated with temperature, relative humidity, or precipitation, but it may be associated with stability of variables during the seasons and year (EPAGRI 2001). Photoperiod was the only environmental variable that influenced variations in species richness and abundance of vocalizing males. Temperature is known to fluctuate directly with the photoperiod, and temperatures are highly variable throughout the year in southern Brazil (0–39°C; EPAGRI 2001). Anurans may use photoperiod as an indicator of suitable conditions for reproduction (Both et al. 2008; Duellman & Trueb 1994). In this study, most anuran species were found to reproduce throughout the year, with a decline from late summer (February) until winter (July), changing from higher to lower photoperiods.

The diversity of reproductive modes found in a coalfield in Urussanga municipality, was likely due to heterogeneity of the Atlantic Forest (e.g., presence of bromeliads, mountain streams, and moist leaf litter). Heterogeneity allows the occurrence of generalized reproductive strategies (direct development of terrestrial eggs [mode 23], foam nest floating on pond and exotrophic tadpoles in ponds [mode 11]) to specialist reproductive modes, as for *V. uranoscopa* and *H. meridionalis* that require more pristine environments (eggs from which exotrophic tadpoles hatch and drop into running water [mode 25] and eggs and tadpoles in streams [mode 3], respectively).

Faunal studies conducted in the state of Santa Catarina, especially in the far southern region, are important due the paucity and absence of temporal and spatial studies in an area that hosts the national critical area for pollution control and three areas of full protection (one state and two federal conservation areas). The present study demonstrates that even small and disturbed areas harbor important, threatened species (in both national and state lists), and may help to fill the knowledge gaps about the diversity in state.

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