The Impact of Tourism on the Herpetofauna of Tambopata, South-eastern Peru

Authors:

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Introduction

Unlike the large amount of attention that the mammal and avian fauna of South America have received, the reptiles and amphibians of the Amazon rainforest are largely unstudied (Vitt 1996). The first comprehensive study of a South American herpetofaunal community was an appended species list of Santa Cecilia, Ecuador (Duellman 1978). Subsequently, the herpetofaunal communities of Iquitos, Peru (Dixon & Soini 1986, Duellman & Mendelson 1995) and Manu National Park, Peru (Rodríguez & Cadle 1990, Morales & McDiarmid 1996) were studied, as well as the commencement of the Minimum Critical Size of Ecosystems Project near Manaus, Brazil (Zimmerman & Rodrigues 1990). In the Tambopata region of south-eastern Peru preliminary species lists of four sites were written (McDiarmid & Cocroft, unpubl., Duellman & Salas 1991, Sehgelmeble 1997, Salas 1995). All of the above studies were merely lists of species; Duellman (1990, see also Duellman & Koechlin 1991) summarised the knowledge of neotropical rainforest herpetofaunal communities, finding that much more research into the ecology of the species needed to be conducted.

The herpetofaunal component of TReeS-RAMOS Project Tambopata is the first study to analyse potential anthropogenic impacts on rainforest herpetofaunal communities. While studies have shown that some mammal and bird communities are altered by tourism (Griffiths & van Schaik 1993, Hidinger 1996, Yoon 1997), effects on herpetofauna are completely unknown. Reptiles and amphibians, many of which are nocturnal, arboreal, fossorial, or cryptozoic, come into contact with tourists less often than the larger, more visible mammal and bird species. Nevertheless, the presence of tourists and their trails may, indeed, impact the local herpetofauna.

For the herpetofaunal study, parcel locations were carefully chosen in order to match forest types (see Phillips 1993) and history of trail usage. As each lodge has a different complement of available forest types, one type was chosen per site in which to census. The older and higher forest types [Old Floodplain Forest (Type F) and Terra Firme Forest (Types G and H)] were preferred for the study to facilitate sampling. Due to the careful selection of forest types, many species known to be present at the lodge sites were not sampled. For example, many amphibians may only be found near lakes or rivers, but none of our surveys included these microhabitats. This study did not attempt to sample populations of all species; a smaller number of species is sufficient to demonstrate trends in tourist versus non-tourist areas.

The forest types used for herpetofaunal surveying at each lodge were:

- Cusco Amazónico (CAPH): Seasonally Flooded Swamp Forest/ Old Floodplain Forest transition (Type B/F).
- Explorers' Inn (EI): Terra Firme Sandy-Clay Forest (Type H).
- EcoAmazonía (ECO): Seasonally Flooded Swamp Forest (Type B).
- Sachavacayoc (SACHA): Old Floodplain Forest/ Terra Firme Clay Forest transition (Type F/G) with bamboo.
- Tambopata Research Center (TRC): Old Floodplain Forest/ Terra Firme Clay Forest transition (Type F/G) with bamboo

Methods

Each of the five sites was visited five times during the two-year study with the same amount of sampling days at each site during each visit. In order to assess the population levels of reptiles and amphibians in areas of current tourism and control areas free of tourism, two principle sampling methods were utilised: Quadrats and Visual Encounter Surveys (VES).

Quadrats

The quadrat method has been shown to be one of the most effective herpetofaunal sampling techniques (Jaeger & Inger 1994). Four observers intensively searched each quadrat, which measured 8 by 8 meters. Observers began at one of the four corners of each quadrat and moved at the same velocity in a clockwise direction. Each observer searched for one metre in width and moved one metre inward at each corner, until all four observers met in the centre of the quadrat. This synchronised movement prevented most of the individual reptiles and amphibians from exiting the quadrat before capture. The four observers consisted of two experienced co-ordinators (the authors) and two assistants. With four observers, quadrats were completed in an average of 11.33 minutes each during the daytime and 14.88 minutes each at night.

Observers searched for reptiles and amphibians through the leaf litter and on branches, trunks, and leaves up to 2 m in height. Each individual encountered was captured by hand, measured to the nearest 0.1 mm with callipers, weighed on a Pesola spring scale to the nearest 0.25 grams, marked, and immediately released at the point of capture. Also recorded were substrate and height at which individuals were encountered. Frogs and lizards were individually marked by toe clipping using the Twitty scheme (Twitty 1966, Donnelly et al. 1994). Snakes and caecilians were not marked because the likelihood of encountering them again is very small.

For each 8 by 8 m quadrat, environmental variables were also recorded. Air temperature was noted at the start of sampling. The percentage of cloud cover at the start of each quadrat was estimated. The diameter of all trees greater than 10 cm in diameter at breast height (dbh) was measured. Additionally, leaf litter depth was measured by penetrating the leaf litter with a metal wire and counting the number of leaves that the wire penetrated. This was done at four points on each side of the quadrat, for a total of 16 depth estimates. These environmental variables were recorded to account for variation among individual quadrats.

Quadrats were arranged in parcels measuring 80 by 70 metres. Each of the 56 quadrats per parcel was centred in a 10 by 10 m square with 2 m separating adjacent quadrats and 1 m between all quadrats and the borders of the plot. At each site two treatment quadrat plots were traversed by tourist trails. Also at each site, two control plots were located at least 200 m away from all tourist trails and treatment plots. A distance of two hundred metres was chosen after it was determined that the vast majority of the reptiles and amphibians captured during this study do not move more than 100 m in a lifetime.

Out of the 56 quadrats within each parcel, one half was sampled per site visit. The quadrats to be sampled were chosen randomly, using a random number table. During the two first visits of a site 14 of the 28 randomly chosen quadrats were surveyed during the morning and 14 at night. Beginning with the third site visit 22 quadrats were sampled at night and the remaining 6 during the morning. The reason for this change was that the capture rate for almost all species was much higher at night, therefore the change greatly increased the capture rate. In total, 112 quadrats were sampled per lodge visit.

Visual Encounter Survey (VES)

Two plots measuring one hectare each were demarcated, one for use as a treatment (tourist trail) parcel and one as a control parcel. Within each square plot, 24 straight-line transects of 100 m were marked with 4 metres separating adjacent transects. A small path was cut along each transect to facilitate walking and searching, and to prevent observers from straying into neighbouring transects while navigating with compasses at night. Each transect was walked twice per site visit, once during the morning and once at night. At least three days were allowed following parcel installation and maintenance before surveying began and at least two days between subsequent sampling of the same transect.

Transects were walked at an average pace of 25.71 minutes per 100 m transect during daylight and 39.63 minutes per transect at night. This slow pace enabled thorough examination of the vegetation by each observer. Relative to quadrats, effort expended while sampling was light, being confined to visual searching without disturbing the vegetation. Each team consisted of one co-ordinator, a second observer, and another assistant who processed all of the individuals caught. As with quadrats, all reptiles and amphibians were captured and processed as above, the only difference being that the transect where the individual was caught, the distance along that transect, and time of each individual capture were also recorded and tree diameter was not measured in the transect parcels.

Both quadrats and visual encounter surveys were used in this study because each targets different species. Faster moving lizards, most snakes, and arboreal frogs are more likely to be caught during VES, while frogs and small lizards that inhabit the leaf litter are more likely to be captured with quadrats (Crump and Scott 1994).

Analysis

Each lodge was sampled five times during the two-year study. Total person hours were calculated by summing the total number of quadrats and transects conducted during the two-year period (3,336 quadrats; 2,832 transects) and multiplying those numbers by the average length of the method (diurnal and nocturnal surveys separately) and the number of investigators present.

Four main categories of analysis were conducted. The first three types are analyses that were performed for each site separately. The last type also includes analyses among all the sites of Tambopata. The first analysis type compared the three treatment parcels (two quadrat, one transect) versus the control parcels to determine if there exist any direct effects on the abundance, species richness, or diversity of the herpetofaunal communities. The second tests effects on individual species. The third examined the effects of the tourist trails themselves on the herpetofaunal community. The fourth type of analysis examined the herpetofaunal community as a whole, considering abiotic factors. Each type of analysis will be examined in turn.

Treatment versus Control

Herpetofaunal diversity was calculated using the Shannon-Wiener Index (H') by lumping the three treatment parcels versus the three control parcels. Community similarity was broadly examined by using the Morisita and Percent Similarity indices. Two indices were used because they produce slightly different results; Krebs (1999) recommends Percent Similarity while Wolda (1981) recommends the Morisita Index as the best index available. The lumped treatment versus control abundances, by anuran and lizard species, were tested using the Wilcoxon Matched Pairs Sign Rank test. Snake abundances were not sufficiently high to perform this analysis.

Individual Species Parcel Abundance

Species abundances were tested by considering the six parcels individually, treatment versus control. All species present in Tambopata were not tested because many of the species do not have a sufficiently high abundance per parcel to produce valid results. Therefore, the eight most abundant anuran species of the region were chosen for analysis. Some species do not occur (or only marginally occur) at all sites; thus they were not analysed. In addition, the anuran species abundances per site were ranked and all the species within the top ten of each site (that were not included in the original eight) were also tested. One lizard species,*Anolis fuscoauratus*, was also tested at all sites; three other lizard species: *Gonatodes humeralis, Pseudogonatodes guianensis*, and *Prionodactylus eigenmanni*, were analysed at the two Río Madre de Dios sites (ECO and CAPH) where they were abundant. All species in this analysis were compared using the Mann-Whitney U Test. Snakes were not analysed.

Trail Effects

To determine if the tourist trail itself effects the abundance, species richness, or diversity of reptiles and amphibians, the quadrats that were in actual contact with the tourist trail (trail quadrats) were tested against a randomly chosen equal number of quadrats that did not touch the trail. Mann-Whitney U tests compared the species richness, diversity, and abundance of common species. The Percent Similarity and Morisita indices of similarity were also used to compare the trail and off-trail anuran and lizard communities. Snakes were omitted from all trail analyses because of their low occurrence.

To acquire an even finer view of potential trail effects, quadrats within each treatment parcel were grouped into units based on the distance from the trail to the quadrat. Five groupings were established as follows: trail quadrats, quadrats beginning no closer than five meters from the trail and no farther than ten meters from the trail, quadrat beginning 11-15 m from the trail, quadrats beginning 16-20 m from the trail, and quadrats more than 20 m from the trail. The quadrats that began less than five meters from the trail were excluded from the analysis. The number of quadrats in each grouping was determined by the number of quadrats available in every grouping, depending on the trail layout and parcel orientation. Some parcels did not have sufficient numbers of quadrats per grouping (e. g. parcels in which a circuitous trail filled most of the parcel) and were excluded from the analysis. The diversity of each trail grouping was regressed on the distance in meters from the trail to determine if distance from the trail directly causes differing levels of anuran diversity. Additionally, the anuran diversity and species abundance for the common species by trail grouping per site were tested using the Kruskal-Wallis Test.

Overall Effects of Tourism in Tambopata

The final analysis type examines potential trends throughout all the lodges sampled. Firstly, all of the quadrats in each trail grouping (see Trail Effects above) per site were combined and the diversity of the entire grouping per site was determined using the Shannon-Wiener Index of Diversity. Using the five sites as replicates, a Kruskal-Wallis test determined whether distance from the tourist trail affected anuran diversity as an overall trend throughout Tambopata.

Secondly, the treatment diversity (two quadrat parcels plus one transect parcel) of each site (see Table 4.2) was regressed on the average annual number of tourist visitors to each lodge (the log of tourist numbers was used to control heteroscedasticity). This regression was used to determine if the quantity of tourists (who walk upon the tourist trails of this study daily) affects the diversity of anurans and/or lizards of Tambopata.

Results

The intensive two-year herpetofaunal sampling of Project Tambopata yielded 6,012.92 person-hours, divided between diurnal and nocturnal surveys and transect and quadrat methodologies. The number of individuals caught for the entire study was 19,957, with 18,146 amphibians and 1,811 reptiles in total. When referring to species richness, 88 amphibian species and 55 reptile species were captured during sampling.

More specifically, there were 87 anuran species registered, one caecilian, one turtle species, 23 lizard species, and 32 snake species. Many additional species were recorded during non-sampling hours but those results will not be presented here. Figure 4.1 is a graphical depiction of the number of new species registered every month of the study. Figure 4.2 represents a graph of the accumulation of those species per month. It can be seen from this that the amphibian curve begins to flatten after the seventeenth month, signifying that a large percentage of all species were registered by the study; the portion of species that were not registered by that time represents an insignificant proportion of the total species actually occurring in Tambopata. The reptile curve, which begins to flatten at the fourteenth month, signifies that most species catchable with transect and quadrat methodologies had been caught by that time. Previous studies by other authors (e. g. McDiarmid and Cocroft, unpubl., Duellman and Salas 1991) registered many more species in Tambopata by sampling a wider diversity of forest types than was used in this study. The majority of reptiles not encountered were snakes, mostly arboreal and aquatic species.

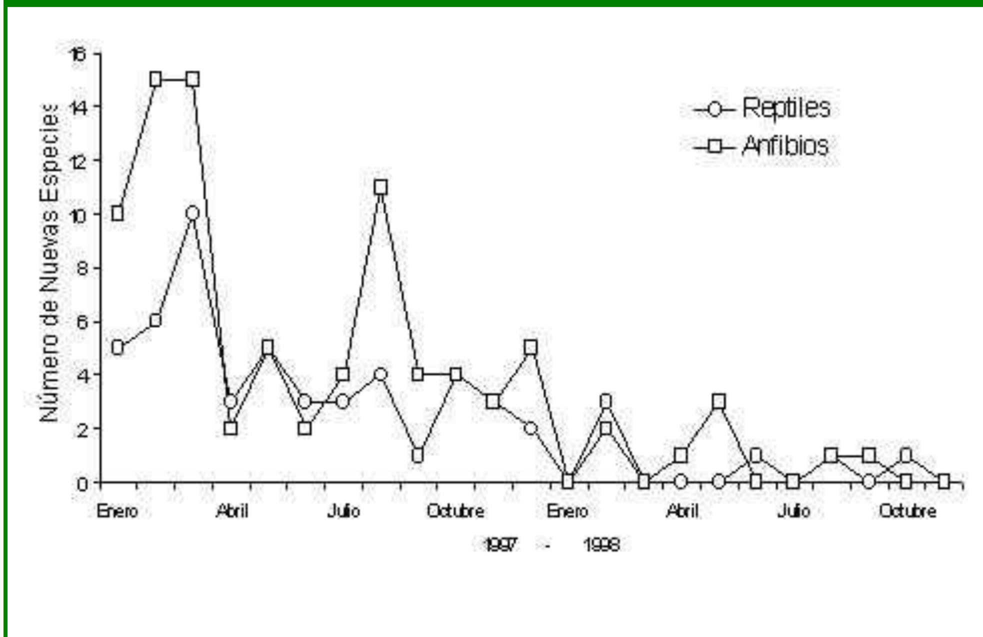

Figure 4.1. Number of new species encountered per month.

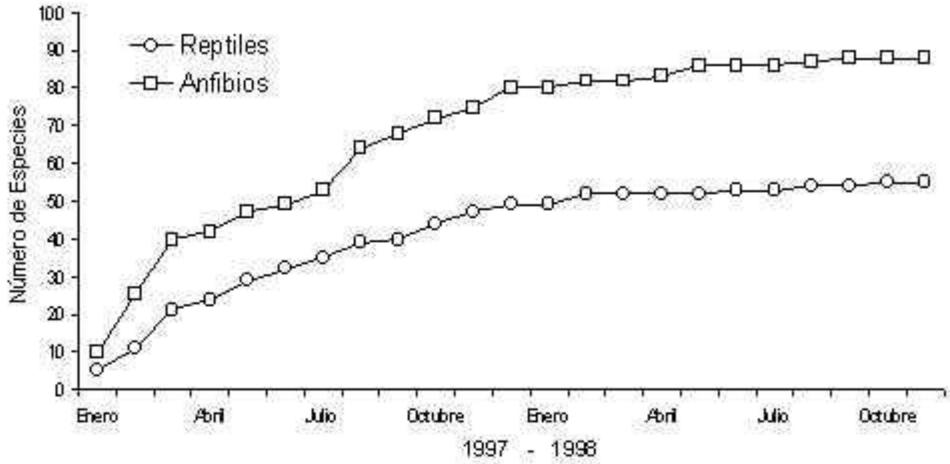

Figure 4.2. Species accumulation curves.

Treatment versus Control

The species richness of the treatment and control areas at each site is presented in Table 4.1. The Shannon-Wiener Index of Diversity for each site is shown in Table 4.2. The TRC has the highest overall amphibian diversity; EI has the lowest. While there is no test of significance for the Shannon-Wiener Diversity Index, it appears obvious that CAPH has strikingly higher amphibian diversity in its control areas while EI has much higher diversity in its treatment areas, and the other three sites have roughly the same diversity in both treatment and control. For reptiles, CAPH has the highest diversity while SACHA has the lowest. Both EI and SACHA have much higher diversity in the treatment areas than the control areas but the other three sites show similar diversities in both areas.

Table 4.1. Species richness sampled at 5 lodges.

Lodge	**T**	**T**	**T**	**C**	**C**	**C**
.	**Frogs**	**Lizards**	**Snakes**	**Frogs**	**Lizards**	**Snakes**
Cusco Amazónico	32	12	11	36	12	12
Explorers' Inn	39	4	11	27	5	6
EcoAmazonía	42	14	14	41	14	12
Sachavacayoc	38	10	15	36	7	9
Tambopata Research Center	43	10	9	44	8	13

Table 4.2. Diversity of amphibians and reptiles in Tambopata, Shannon-Wiener Index, Treatment vs. Control.

Lodge	**T**	**T**	**C**	**C**

.	Amphibians	Reptiles	Amphibians	Reptiles
Cusco Amazónico	0.833	1.001	1.076	1.005
Explorers' Inn	0.943	0.934	0.794	0.777
EcoAmazonía	1.062	0.896	1.004	0.934
Sachavacayoc	0.980	0.863	0.960	0.564
Tambopata Research Center	1.104	0.986	1.156	0.911

As a broad look at the overall results of the herpetofaunal study, community similarity indices were used. The results of the Percent Similarity and Morisita indices are shown in Table 4.3. According to each of the indices, the TRC appears to have the largest difference of anurans between treatment and control areas (i.e. tourism has affected the herpetofaunal community the most), while SACHA is the least affected. For reptiles the results were quite different; ECO is least affected while EI is most affected.

Table 4.3. Herpetofuana community similarity indices; Treatment vs. Control.

Lodge	% Similarity	.	Morisita	.
.	Amphibians	Reptiles	Amphibians	Reptiles
Cusco Amazónico	72.883	75.060	0.867	0.958
Explorers' Inn	74.236	62.973	0.921	0.951
EcoAmazonía	80.545	84.680	0.919	0.982
Sachavacayoc	86.616	73.622	0.971	0.967
Tambopata Research Center	62.793	68.109	0.742	0.983

When relative abundances of all species present per site were compared in treatment versus control, the Wilcoxon Test showed that only EI ($Z = -4.133$, $p = 0.000$) had significantly different anuran abundances over all species (see Table 4.4) with higher abundances in the treatment area. SACHA had significantly higher relative reptile abundances in the treatment areas but contrastingly, CAPH had higher reptile abundances in the control areas.

Table 4.4. Relative abundance, Wilcoxon probabilities, * $p < 0.05$, ** $P < 0.01$, *** $p < 0.001$, T = Treatment, C = Control.

Lodge	Anurans	Reptiles
Cusco Amazónico	0.896	0.030 *C
Explorers' Inn	0.000 ***T	0.138
EcoAmazonía	0.899	0.334
Sachavacayoc	0.153	0.001 ***T

Tambopata Research Center	0.628	0.861

Individual Species Parcel Abundance

The results of the Mann-Whitney U tests for parcel abundance by individual species are presented in Table 4.5. The numbers in the table are the calculated probability levels (p). None of the four lizard species tested produced significant results; some anuran species, however, had significantly higher abundances in either treatment or control areas.

Neither of the two Río Madre de Dios sites, ECO and CAPH, had any significant differences while each of the Río Tambopata sites had at least two significant results. EI had significantly higher abundance of the dendrobatid *Colostethus marchesianus,* the bufonid *Dendrophryniscus minutus,* and the leptodactylid *Physalaemus petersi* in the treatment parcels. SACHA had significantly higher abundance of the leptodactylid*Phyllonastes myrmecoides* and the microhylid *Ctenophryne geayi* in the treatment parcels. TRC had significantly higher abundance of the bufonid *Bufo cf. typhonius,* the microhylid *Chiasmocleis bassleri*, and*Physalaemus petersi* in the treatment parcels, while the dendrobatid *Epipedobates pictus* was significantly more abundant in the control area. For all of the other species tested, the null hypothesis of no relationship between tourism versus non-tourism parcels was accepted.

Trail Effects

When the potential effects of the actual tourist trail were considered no significant effect was found on the species richness of anurans at any site (Table 4.6). The diversity of anurans, however, was shown to differ significantly at SACHA ($U = 60.00$, $p = 0.029$) by having higher diversity in the trail quadrats, but at no other sites. On a species by species basis, only the microhylid, *Hamptophryne boliviana* was found significantly more often on the tourist trail than away from the trail (Table 4.7). In all cases of richness, diversity, and by species, lizard and snake abundances were too low to detect any trend. Similarity indices between the trail and off-trail groups for anurans showed high similarity with CAPH being the highest and TRC the lowest (Table 4.8). Reptile communities in the two treatments have low similarity, probably due to the large number of species with few individuals within each species. At finer scales, the linear regression of trail group diversity on quadrat distance from the tourist trail produced no significant results (Table 4.9). When actual distance from the tourist trail was considered, no patterns were detected in abundance of individual species (see Table 4.10).

Overall Effects in Tambopata

When trail groupings for all lodges were utilised to discover trends throughout the Tambopata area, no significant differences were detected (K-W = 1.935, $p = 0.748$). Regressions of treatment parcel diversity against annual tourist numbers also proved to be not significant, although the anuran regression suggests that a slight trend may be present ($F = 6.981$, $p = 0.078$), while lizard diversity showed no trend whatsoever ($F = 0.344$, $p = 0.599$).

Table 4.5. Results of the abundance per parcel, Mann-Whitney probabilities. IA = Insufficient Data to test; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, T = Treatment, C = Control.

.	.	.	.	Lodges	.	.
.	**The eight most abundant Anurans**	**CAPH**	**EI**	**ECO**	**SACHA**	**TRC**
1	*Adenomera andreae*	0.275	0.184	0.513	0.513	0.127

2	*Hamptophryne boliviana*	0.275	0.121	0.127	0.827	0.825
3	*Eleutherodactylus toftae*	0.376	IA	IA	0.827	0.275
4	*Chiasmocleis ventrimaculata*	0.827	IA	0.827	0.813	0.507
5	*Colostethus marchesianus*	0.513	0.050*T	0.513	IA	IA
6	*Eleutherodactylus peruvianus*	0.261	0.827	0.827	0.261	0.827
7	*Phyllonastes myrmecoides*	IA	0.121	IA	0.050*T	0.513
8	*Bufo cf. typhonius*	0.500	0.127	0.827	IA	0.050*T
.	**Other Abundant Anurans**	.	.	.	.	.
9	*Dendrophryniscus minutus*	.	0.050*T	.	.	.
10	*Epipedobates pictus*	.	.	0.184	.	0.050*C
11	*Hyla fasciata*	.	.	.	.	0.827
12	*Osteocephalus taurinus*	.	0.077	.	.	.
13	*Scarthyla ostinodactyla*	.	.	0.513	.	.
14	*Scinax cruentomma*	.	.	.	0.827	.
15	*Scinax garbei*	.	.	0.507	.	.
16	*Scinax icterica*	.	.	.	0.513	.
17	*Scinax pedromedinai*	0.268	.	0.513	.	.
18	*Scinax rubra*	.	.	.	0.513	.
19	*Eleutherodactylus skydmainos*	.	.	.	.	0.127
20	*Eleutherodactylus sp. 1*	.	0.077	.	.	.
21	*Leptodactylus mystaceus*	0.127	.	0.827	0.268	.
22	*Physalaemus petersi*	.	0.050*T	.	.	0.050*T
23	*Chiasmocleis bassleri*	.	.	.	.	0.046*T
24	*Ctenophryne geayi*	0.376	.	.	0.050*T	.
25	*Elachistocleis bicolor*	0.127	.	.	.	.
.	**Top Four Lizard Species**	.	.	.	.	.
1	*Anolis fuscoauratus*	0.268	0.658	0.376	0.268	0.513
2	*Prionodactylus eigenmanni*	0.827	.	0.827	.	.
3	*Gonatodes humeralis*	0.127	.	0.827	.	.
4	*Pseudogonatodes guianensis*	0.513	.	0.658	.	.

Table 4.6. Results of trail vs. non-trail for Anurans per lodge, Mann-Whitney probabilities; * p < 0.05, ** p < 0.01, *** p < 0.001, T = Treatment, C = Control.

Lodge	Species Richness	Species Diversity
Cusco Amazónico	0.563	0.659
Explorers' Inn	0.920	0.582
EcoAmazonía	0.126	0.286
Sachavacayoc	0.183	0.029*T
Tambopata Research Center	0.196	0.157

Table 4.7. Results per species for trail vs. non-trail per lodge, Kruskall-Wallis probabilities; * p < 0.05, ** p < 0.01, *** p < 0.001, T = Treatment, C = Control.

Species	CAPH	EI	ECO	SACHA	TRC
Adenomera andreae	0.600	0.885	.	0.786	.
Eleutherodactylus toftae	.	.	.	0.562	0.919
Physalaemus petersi	.	0.796	.	.	.
Chiasmocleis ventrimaculata	0.697	.	.	0.376	.
Hamptophryne boliviana	0.713	.	0.006**T	0.727	.

Table 4.8. Results of trail vs. non-trail indices of community similarity, IA = Insufficient Abundance to test.

Lodge	Percent Similarity		Morisita	
.	Amphibians	Reptiles	Amphibians	Reptiles
Cusco Amazónico	87.668	70.370	1.008	1.074
Explorers' Inn	81.715	75.000	0.991	1.875
EcoAmazonía	75.655	66.194	0.973	0.946
Sachavacayoc	80.967	40.000	0.953	0.908
Tambopata Research Center	69.423	IA	0.911	IA

Table 4.9. Regression results per lodge based on trail groups, F-test probabilities; * p < 0.05, ** p < 0.01, *** p < 0.001, T = Treatment, C = Control.

Lodge	Probability

Cusco Amazónico	0.324
Explorers' Inn	0.986
EcoAmazonía	0.545
Sachavacayoc	0.512
Tambopata Research Center	0.199

Table 4.10. Results of trail groups by species, Kruskall-Wallis probabilities, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Species	**CAPH**	**EI**	**ECO**	**SACHA**	**TRC**
Dendrophryniscus minutus	.	0.204	.	.	.
Scinax spp.	.	.	.	0.970	.
Adenomera andreae	0.746	0.850	.	0.168	.
Eleutherodactylus peruvianus	.	0.134	.	.	.
Eleutherodactylus toftae	.	.	.	0.146	0.975
Leptodactylus mystaceus	.	.	.	0.970	.
Phyllonastes myrmecoides	.	.	.	0.234	.
Physalaemus petersi	.	0.417	.	.	.
Chiasmocleis ventrimaculata	0.826	.	.	0.223	.
Ctenophryne geayi	.	.	.	0.975	.
Hamptophryne boliviana	0.646	.	0.212	.	.

Discussion

The herpetofaunal research team of TReeS-RAMOS Project Tambopata sampled an amazing array of species of reptiles and amphibians. Never before has a herpetofaunal study of this length and scale been performed in a rainforest habitat. Accordingly, with nearly 20,000 individuals censused, this study is uniquely able to discern trends of tourism impact on the local herpetofauna in Tambopata if such trends exist. The treatment versus control tests provide a wide variety of approaches that produce an equally large array of differing results. There are some important overall trends that may be gleaned from these results. EI has both higher diversity and relative abundance of anurans in the treatment areas. For reptiles, both EI and SACHA are more diverse in the treatment areas. Contrastingly, CAPH has higher diversity and relative abundance of both amphibians and reptiles in the control areas. No other sites have clear relationships of tourism and herpetofaunal diversity or relative abundance.

Anurans, indeed, are affected by the presence of tourism. This result is most obvious in CAPH where the diversity and relative abundance of amphibians is higher in the control areas after nearly twenty-five years of daily tourist pressure. When the trail vegetation becomes trampled and dies, it is likely that the absence of plant cover forces arthropods, the primary prey of anurans, to move away from the trails. Thus, the anurans have lost their local food source and must vacate the trail area to find their arthropod prey. In time, the anurans discover new food sources away from the trail area.

The effects at EI also support the alternative hypothesis that tourism affects the herpetological community, but in a different sense. Like CAPH, EI has been receiving tourists for nearly twenty-five years. But unlike CAPH, which has low, seasonally inundated forest, the Type H forest of the EI parcels never floods. The highly eroded trails at EI become flooded gullies during the rainy season which attract many species of frogs to the limited water source. The authors have observed oviposition by several anuran species in these trail pools (within the treatment parcels) at EI on various occasions. The temporary pools seemingly serve as suitable oviposition sites; however, when as many as forty tourists trample the area the next day, the survival rate of eggs and tadpoles is probably minimal. At EI anurans do not have the luxury of migrating to areas free of tourists because oviposition sites are limited in the non-flooding "high forests". They instead remain near these man-made bodies of water.

Accordingly, the reptile abundance at CAPH, and both the abundance and diversity at EI follow the anuran results. Where there are more amphibians, their snake and lizard predators are also more abundant and diverse. This pattern is easily explained by prey availability. The only site that cannot be explained thus far is SACHA. The reptile diversity and relative abundance of the treatment parcels are significantly higher than the control parcels, but without the concomitant amphibian pattern. The SACHA trends will be examined with the other analyses.

Besides the larger scale community results, some individual species are affected by tourism as well. For the most part the species that are affected by tourism have higher abundance in the treatment areas. Only*Epipedobates pictus* at the TRC was more abundant in the control areas. The EI species follow the previous treatment versus control results. Indeed, breeding congregations of *Physalaemus petersi* were seen calling and ovipositing in "Main Trail" at EI for several nights at the start of the rainy season. In other areas of EI trails, adult male *Colostethus marchesianus* deposit their tadpoles directly in the trail. Recently metamorphosed juveniles are occasionally seen emerging from the small pools on the trail, indicating that some tadpoles in the man-made pools do indeed survive past the tadpole stage, despite probable overall depressed developmental success.

At SACHA and TRC the microhylids *Ctenophryne geayi* and *Chiasmocleis bassleri* were significantly more abundant in the treatment areas. Additionally, *Dendrophryniscus minutus* and *Phyllonastes myrmecoides* were more abundant in treatment areas at EI and SACHA, respectively. A likely reason for their significant presence in the treatment areas is that all four of these species are ant specialists (Rodríguez and Duellman 1994) that prefer to live near tourist trails where ants of many species (e. g. *Atta* and *Echiton*) commonly utilise human-made trails (pers. obs.). Similarly, many bufonids prefer trails for their locomotion because of large body size; the *Bufo* cf. *typhonius* results agree with this notion.

The Tambopata species of the dendrobatid genus *Epipedobates* (*E. femoralis, pictus,* and *trivittatus*) all prefer the specific microhabitat of tree fall gaps (Duellman 1978, pers. obs.). When tourist trails are created tree fall gaps are usually avoided because the lodge owners and guides prefer to show the tourists what they consider "pristine" and uncluttered forest. By omitting the gap microhabitat, they are inadvertently avoiding areas where poison dart frogs are abundant, as shown at TRC where *Epipedobates pictus* is most abundant.

The trail analyses utilise a very different approach than the former analyses by examining tourism only using the treatment parcels and by searching for effects on the smaller scale of the parcel itself. No significant effects on anuran species richness were found, supporting Ludwig and Reynolds's (1988) statement that species richness is not an adequate measure of a community. SACHA was the only site to differ significantly in biodiversity between trail and off-trail quadrats. The similarity indices, however, result in a rather high similarity in the trail versus off-trail comparison at SACHA. Because similarity indices do not have statistical probability distributions associated with them (Krebs 1999) higher confidence should be placed in the Mann-Whitney U tests than the similarity indices. Therefore, the significant diversity difference at SACHA is an important result. No individual species, however, had significantly different abundances in the trail versus off-trail quadrats at this lodge.

The only species that had significantly different abundance between the trail quadrats and non-trail quadrats was the microhylid *Hamptophryne boliviana* at ECO. As the overall second most abundant frog species at ECO (behind *Adenomera andreae*) this is a very important result. As with the microhylid species mentioned above, it is likely that this ant specialist stays near open trails where many species of ants prefer to march.

The treatment versus control and trail versus off-trail similarity results may be directly compared to determine which tourism effect (i. e. large scale or small scale) is more important to the structuring of herpetofaunal communities in Tambopata (Tables 4.3 and 4.8). At three sites (CAPH, EI, and TRC) there is a larger treatment versus control effect while at ECO and SACHA effects are on the parcel scale of trail versus off-trail. Because of these dichotomous results no general statement of which effect is more important can be made at this time.

Neither the linear regressions on trail group distance nor the trail groups tests on individual species were statistically significant. This result may mean one of two possibilities: 1) the actual distance from the trail is not an important factor, or 2) the sampling was inadequate to determine such an effect. In the case of the trail groups analyses it is highly possible that the sampling was too thinly spread over the eligible parcels to contain enough individuals per species to amount to significant numbers for this type of analysis. As mentioned above, the trail systems of some sites meandered so much that they nearly filled the entire parcels, voiding them from the analysis. In other sites the habitat heterogeneity and trail system caused the parcel to contain too little of the trail to be used in the trail groups analysis. Because of the limited number of suitable parcels available no significant results were found. To attempt to counter the problem of sample size per trail grouping, all quadrats per trail grouping per site were combined into one data set. When sites were used as replicates, again, no significant result was found. Therefore, either the effects of distance from the trail are localised but not detected in these analyses or there is no effect of trail distance.

Annual tourist numbers may produce an effect on the diversity of the local herpetofauna. Although the regression was not significant ($p = 0.078$), a correlation of the same data shows a strong negative relationship (Pearson = -0.900) of annual tourists numbers and treatment diversity. As was concluded with the treatment versus control data, sites with long-standing high quantities of tourists (e. g. EI and CAPH) are most impacted by tourism pressure.

The fixed structure of current tourism programs at four of the lodges used in this study allows the tourist little opportunity to view reptiles and amphibians. Three lodges do offer a nocturnal boat trips to spot caimans, which occasionally gives the tourists views of one of the largest herpetofaunal species of the area. Sightings of frogs, lizards, and snakes are few and the general view of the lodge personnel and management is that tourists have little interest in seeing them. It must be mentioned, however, that one lodge, the TRC, does offer night-time hikes with the express purpose of searching for reptiles and amphibians. The herpetofauna questionnaire (see Chapter 6.0) provided some unexpected results that may be used to modify current tourism programs to include opportunities to view the more secretive herpetofauna. As can be seen from the results of this questionnaire, tourists do wish to see amphibians and reptiles and would participate in a night walk if it were offered. Additionally, a high percentage of tourists do not want the lodges to keep amphibians and reptiles as pets or capture caimans during the nocturnal boat trips. Both of these results acknowledge that most tourists are aware of conservation issues and understand that mistreating rainforest fauna is simply unacceptable. The questionnaire was also able to detect that tourists require more information about the wildlife they are likely to observe during their visit. A case in point is that four tourists claimed to have seen crocodiles during their stay although there are no crocodiles in Tambopata. Finally, seventy-three percent of the tourists sampled request more information about venomous snakes to be available at the lodge.

Conclusions

From the preceding Discussion it may be seen that tourism, in fact, does have an impact on the herpetofaunal communities of Tambopata, Perú. We may have great confidence in these conclusions because of the long length of the study, the rigorous methodologies, and extensive sampling. One important factor of tourism effects involves the intensity and length of tourism in an area. From TReeS-RAMOS Project Tambopata herpetological data we can see that, for amphibians, diversity decreases with time and high quantities of tourists. After a long period the amphibians either migrate to other areas that are not under tourism pressure or, in the case of the EI high forest, they remain in tourism areas but likely have very low reproductive fitness.

On the other hand, the presence of the actual tourist trail is not necessarily damaging to herpetofaunal communities. For many species the trail serves as a convenient area to hunt their prey, whether it be the ant prey of ant specialists or the amphibian prey of snakes and lizards. Additionally, trails facilitate movement of large species, including the bufonid toads and snakes.

In order to manage for high diversity of herpetofauna, the results of this study suggest several strategies that should be implemented by lodge owners and personnel. One possible strategy is to spread out the impact of tourists by having several different routes that different tourist groups can travel so that no one area of forest is impacted excessively. The current tourism programs at most of the tourist lodges in Tambopata utilise one route along which all tourists hike, thus concentrating the impact in one area. Providing more choices to the lodge guides may eliminate these "impact zones". A problem with this strategy is that, although it may benefit amphibians, numerous researchers (e. g. Mieczkowski 1995, Hunter and Green 1995) have shown that the most dramatic damage to vegetation occurs immediately after trail construction; creating many low-impact trails is more damaging to the forest than few high-impact trails. Another possibility, in lieu of cutting various trails, is to have one or two tourist routes with well-maintained raised platform trails. These trails may be wooden, metal, or any available material that may be made into a raised platform that may be easily walked by tourists. A raised platform does not cause erosion of the soil and the subsequent death of vegetation that may be the principle reason that amphibians flee areas of long-term tourist presence. The vegetation would not be altered and the herpetofaunal community would not be forced to emigrate to other areas.