EFFECTS OF SUCCESSIONAL FOREST STAGE ON ARTHROPOD AND BAT COMMUNITIES

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Abstract: Humans have had a large impact on forest structure in recent history. Practices in logging and conversion of forest to agricultural land have led to significant changes, especially in the age structure of forests, and it is consequently important to understand how these changes affect faunal communities. Because many arthropods feed on forest vegetation, and insectivorous bats feed on the arthropods, we hypothesized that the difference in vegetation between successional stages of the forest would affect these communities. We measured arthropod morphotype richness, abundance, and size, as well as bat richness and foraging time in early and late successional forest stages. There were arthropod morphotypes that overlapped between forest stages, but many were unique to one or the other. Bat morphotypes were completely unique to successional stage. However, we found that arthropod richness, abundance, and size did not differ between successional forest stages. Also, bat richness and foraging use was not significantly different between successional forest stages. It seems that the types of resources offered to the faunal communities vary across successional stages, and that species composition may depend of different varieties of resources.

Key words: bat foraging, forest structure, Petterson D240X

INTRODUCTION

In recent history humans have been changing tropical forest characteristics through such activities as logging and clearing land for agriculture. In particular, forest structure (e.g., successional stage) has been affected, and may be influencing the faunal communities within. We chose to study the tropical communities of arthropods and insectivorous bats. Many arthropods feed upon forest vegetation, therefore a change in vegetation may alter the arthropod community. As well, the insectivorous bat community might change in response to the arthropod community. We hypothesized that successional stage of a forest would affect the composition, abundance, and richness of the arthropod community, as well as the composition, foraging use, and richness of the insectivorous bat community.

There are many possibilities of how successional change in the forest could affect these communities. Vegetative types differ between successional forest stages, which may cause arthropod herbivory specialization and therefore community composition changes. Because early successional, pioneer plant species tend to be fast-growing and therefore poorly defended, it could be expected that the richness and/or abundance of arthropods in the early successional forest would be greater than in the early successional forest. Alternatively, it may be that successional stage has no affect on composition, richness, or abundance of the arthropod community.

Insectivorous bats may show a response to trends of composition, richness, and abundance in the arthropod community. If bats specialize on certain arthropod species, the bat community composition may change in response to the suite of arthropod species present in each forest stage. If arthropod abundance or richness is greater in early successional forests, it may follow that bat use or richness is also greater if there is more abundant prey. It is also possible that if there are other overriding factors than prey type and abundance, bat community composition, richness, and use between successional stages in forests may not differ or may not be congruent with patterns of arthropod

composition, richness, and abundance.

METHODS

We sampled the arthropod and bat communities in early and late successional growth 1 km north of the biological station in La Selva, Costa Rica on 16 - 17 February 2004. We sampled two older successional plots (at marker 850 on trail SOR and marker 350 on trail CCL) and two early successional plots (20 m from SOR on path between stages 0 - 1 year and 1 - 2 years, and 10 m from SOR on path between stages 3 - 4 years and 4 - 5 years). To sample the night arthropod community we hung three sticky traps (at 1 m, 2 m, and 3 m above ground) at each plot from ca. 1730 to 0630 each sampling day. Each arthropod was identified to morphotype and measured for length. Morphotype data were used to calculate arthropod richness and abundance.

To sample the bat community we used a Petterson D240X ultrasound detector, set at a listening frequency of 45 kHz, to record search-phase insectivorous bat calls. We sampled each plot once for 20 min during dusk (ca. 1730 to 1930) and during pre-dawn (ca. 0400 to 0600) when bat activity is likely to be highest. We recorded the total bat foraging time in our sampling area (10 m radius of ultrasonic detection) by noting the length of time we heard clicks through the detector in order to determine foraging minutes/sample. We also tried to record a sample of each call (Appendix 1). Call samples were analyzed using Sonobat 2.0, and sorted according to their duration, bandwidth, slope, and high and low frequencies. Species richness was determined by differentiating between distinct sonotypes.

All data were analyzed comparing early vs. late successional stages. Difference in insect richness was analyzed with an ANOVA model that included successional stage, day, plot nested within successional stage, and stage*night. Differences in insect abundance and insect length were analyzed with ANOVA models that included successional stage, day, height of the trap, plot nested within successional stage, stage*height, stage*night, and night*height. Differences in bat richness and foraging minutes/sample were analyzed with an ANOVA model that included day, time of day, successional stage, plot nested within successional stage, night*time of day, night*stage, and time*stage.

RESULTS

There were 27 arthropod morphotypes that occurred only early successional forest, ten that occurred only in late successional forest, and 14 that occurred in both (Fig. 1a). There were six bat morphotypes that occurred only in early successional forest, four that occurred only in late successional forest, and none that occ-

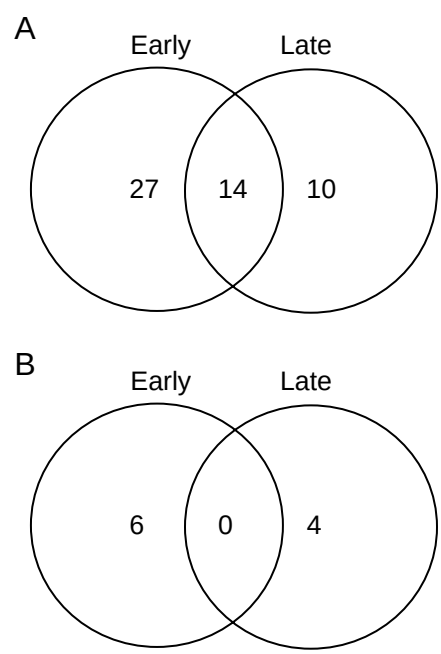


Figure 1. Number of morphotypes found in early and late successional forests; overlapping area indicates morphotypes found in both successional stages. A: Arthropod morphotypes. B: Bat morphotypes.

urred in both (Fig. 1b).

On average, arthropod richness and abundance per plot, and abundance per plot of arthropods ≥ 2 mm in length, were greater in early successional forest than in late successional forest (Fig. 2a, Fig. 2b, and Fig. 2c, respectively). However, none of the models were significant ($F_{5,7}$ = 2.23, P = 0.34; $F_{11,23}$ = 2.24, P = 0.09; and $F_{11,23}$ = 0.93, P = 0.55 for richness per plot, abundance per plot, and abundance per plot of arthropods ≥ 2 mm in length, respectively). Mean length of insects (mm) did not differ between successional stages of forest (mean ± SE = 3.05 ± 0.4 and 2.74 ± 0.40 for early and late successional forest respectively; $F_{11,23}$ = 0.40, P = 0.93). Average number of bat morphotypes per plot was not significantly different between early successional forest and late successional forest ($F_{8,14}$ = 0.64, P = 0.73 for the model; Fig 3a). Bat use, in foraging minutes/sample, did not differ between early and late successional forest ($F_{8,14}$ = 1.21, P = 0.42 for the model; Fig. 3b).

Discussion

We found that successional stage does affect arthropod and insectivorous bat communities. Bat composition was completely different between successional stages; there was overlap in insect species composition, but the majority of species were unique to their successional stage. Surprisingly arthropod abundance, richness, and length, as well as bat richness and foraging minutes/sample, did not change significantly with successional stage, although there were trends of increasing arthropod abundance and richness with early successional stages.

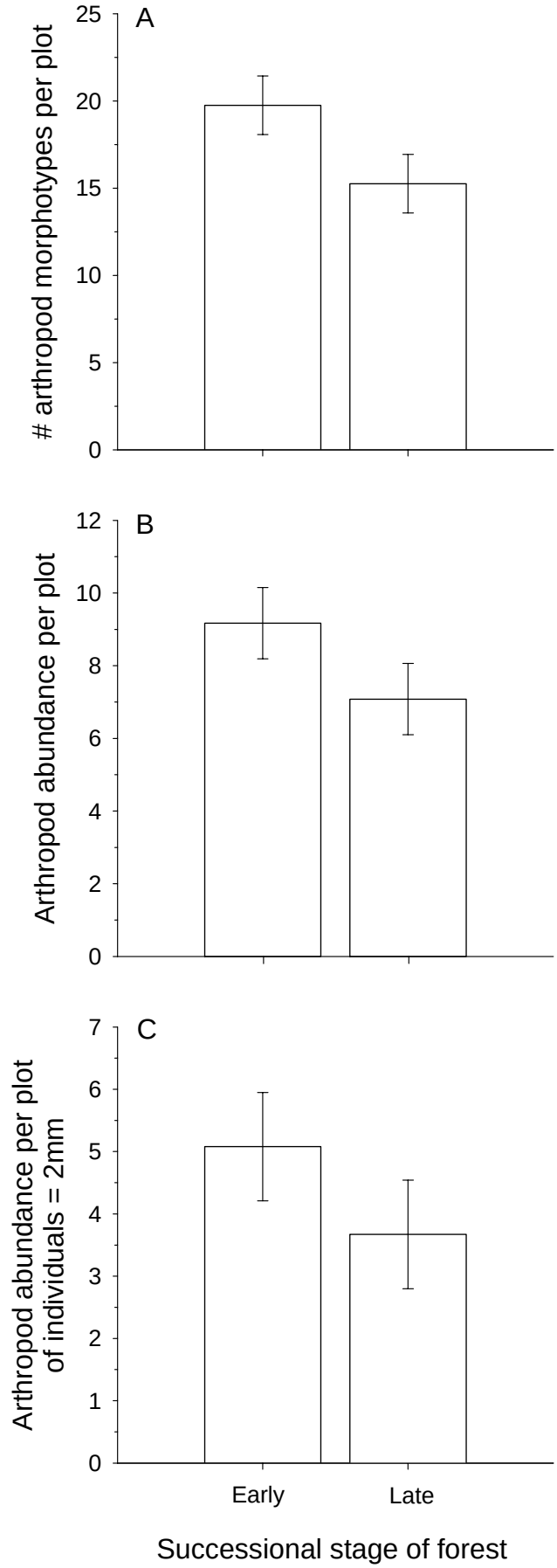


Figure 2. The effect of forest successional stage on the arthropod community. Means ± SE are reported for (A) arthropod richness per plot, (B) arthropod abundance per plot and (C) arthropod abundance per plot of individuals ≥ 2 mm in length.

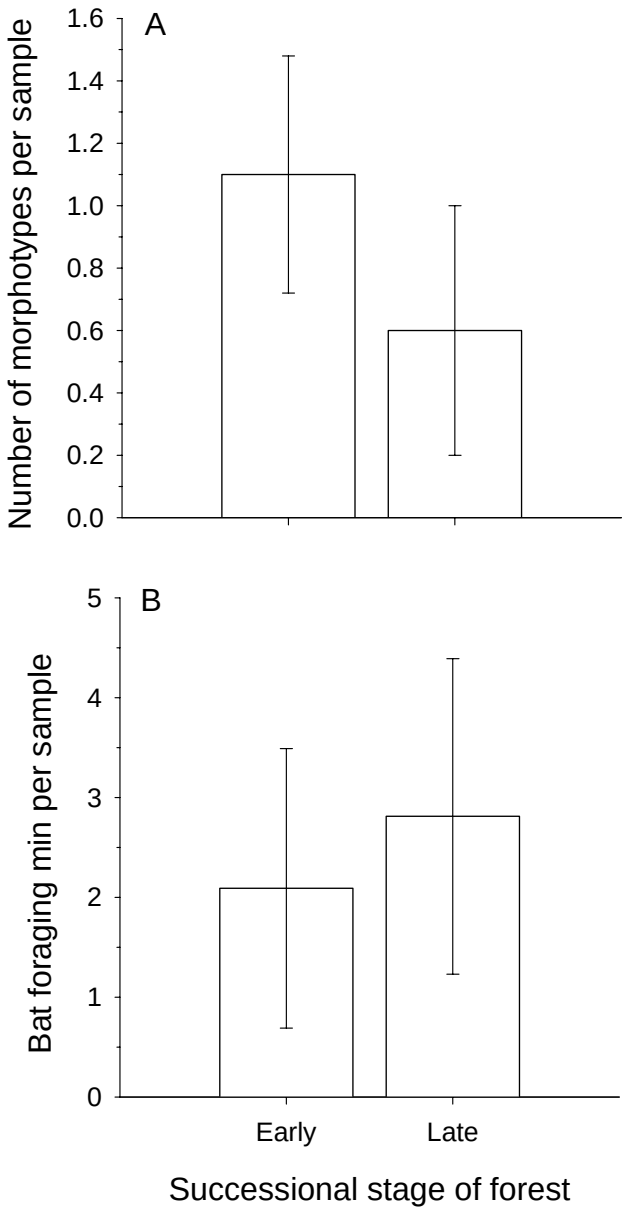


Figure 3. The effect of successional stage on the bat community: means ± SE are reported for (A) bat richness per sample and (B) bat use of plot in foraging minutes per sample.

The high instance of unique bat and arthropod morphotypes per successional stage may be explained by the differing range of available niches in forests of different ages. This shift of niches may be a result of forest structure changes through time. Arthropods, generally limited in mobility, depend on their immediate environment for resources to grow and reproduce. Arthropod species may show high preference for food type, and thus may be unique to specific areas where this food type is found. Insectivorous bats may prefer certain types of insects, and thus they may be unique to areas where those insects are supported. We speculated that different bats may prefer larger or smaller prey items, and that difference in arthropod size between the successional stages may help explain differences in bat community composition. There was no change in average arthropod size between stages, and so arthropod size difference likely is not a factor that affects bat community composition. However, our methods of collection may have only sampled a small sized subset of the arthropod community; such things as large moths, which may be an important food source for some bats, would not have been caught by a small sticky trap. Future studies should use a variety of collection methods to better sample the night aerial insect community.

It may also be that the forest structure affects bat foraging; dense and low early growth may be more difficult to fly through that higher and more open older growth. It would be interesting to determine how arthropod type and bat foraging success affect spatial preferences of feeding bats. Future studies could perhaps determine this by analyzing bat flight patterns, as well as stomach contents to determine prey preferences.

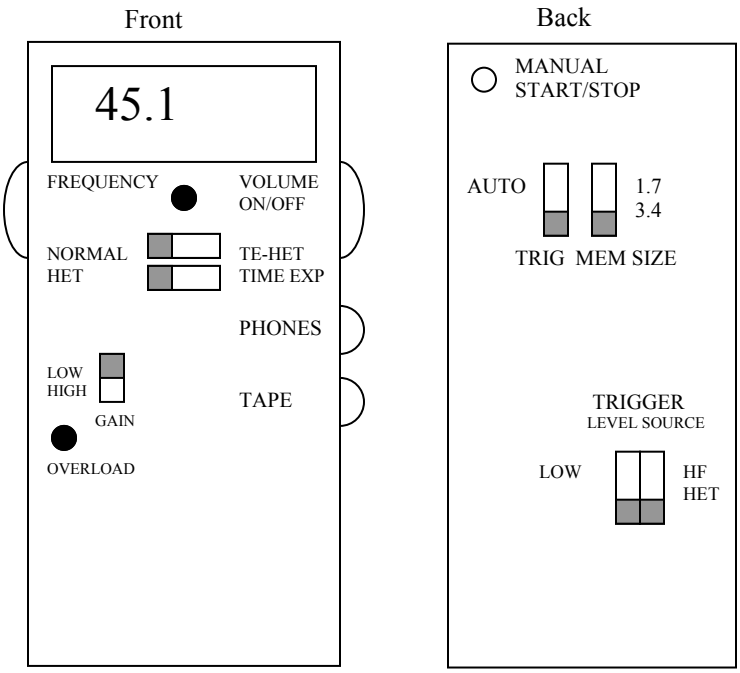
It has been thought that the fast-growing plants that characterize young successional plots are generally more edible, due to decreased secondary metabolites, which may explain the trends of increasing arthropod richness and abundance in early successional plots. However, this should be determined by a more thorough examination of the arthropod community. We only observed aerial insects, which may be more mobile than others, so perhaps other insect communities would show more distinctive trends in abundance and richness. Also, since there is much more height to the forest structure of late successional growth we may

not have sampled the entire arthropod community. Future studies could sample at a wider range of levels in the different successional stages, to see how insect abundance and richness varies with height.

Since bat richness did not change with successional stage, it seems that forests of different types support the same overall richness, even though individual species may differ. The lack of a difference in insect abundance between successional stages may explain the lack of change in bat foraging minutes/sample. There are also other factors that may have influenced our measurements of bat foraging; the range with the Petterson D240X ultrasound detector is limited to a 10 m radius, and perhaps bat activity is high up in the forest canopy, but we could not sample it. Additionally, we experienced scattered periods of rainfall throughout our sampling effort. Rain seemed to diminish the insect activity, which may have thus influenced bat feeding activity. Future studies could examine how weather influences bat and insect activity by observing feeding activity through a variety of weather patterns.

Differences in successional stage do influence the composition of faunal communities. Therefore the increasing rate of human-influenced change of forest structure and age may likely also increase the rate of change of resident species. Richness and abundance may not be influenced, but the alterations in species composition should be taken into consideration as humans alter land use and continuously diminish old forest growth.

Appendix 1.



The directions on how to use the Sonobat 2.0 program are excellent in explaining how to analyze recordings of bat calls on a computer. Their directions on using the Petterson ultrasonic recorder, however, are somewhat lacking. The diagram above shows the settings we used to record bat calls.

What you hear:

When the detector is turned on, bat calls sounds like clicks that change in volume and speed as bats fly and hunt. These clicks are changed into tonal chirps by the computer.

Modes:

There are two modes to this detector: **AUTO** and **MAN**ual. In **AUTO** mode the machine is supposed to be able to be triggered by the presence of a bat call, and automatically record calls continuously to the computer. We were unable to get this mode to work, as bat calls never actually triggered recording. A less finicky mode is **MAN**ual, which makes use of the **MANUAL START/STOP** button on the back.

*How to setup **MAN**ual mode:*

When the back TRIG is on **MAN**, the detector is in manual mode. In order to continuously hear any bat clicks, keep the front switch on **NORMAL.** In **TE-HET** the detector records in a way that we cannot hear, making it difficult to determine when a bat was actually present. More work should be done to determine exactly what happens in **TE-HET** mode, but keeping it on **NORMAL** works fine. The switch below, with **HET** and **TIME-EXP,** is interesting. You can listen in **TIME-EXP** (time expansion) to bat calls that are lengthened as they would be on the computer, so actual tones can be heard. However, we were unable to obtain recordings this way, nor could we tell how long bats were in our detection area. Therefore we kept the switch on **HET**.

*How to record calls in **MAN**ual mode:*

When turned on the detector immediately starts playing picked up sounds through the speaker. When the **START/STOP** button on back is pressed, the red light should turn on. This means that the detector is continuously re-

cording. When the button is pressed again, the light turns off and the machine replays the last 3.4 sec (or 1.7, depending on which **MEM SIZE** is preferred) onto the computer (which records at a slower speed for analysis, so at 10x speed it takes 34 sec to get the entire replay). At the same time, the speaker plays all current sounds. Therefore you can record a call and still note whether bats are in the area.

Some issues:

Cicadas, breaking sticks, and water can also be picked up by the detector, which may hinder recording. Interference can be minimized by switching the **GAIN** to **HIGH**. Quieter bat calls will not be recorded this way, but it prevents cicadas from overloading the recorder (indicated when the red **OVERLOAD** light is on). We're also not sure what the **TRIGGER LEVEL SOURCE** switches do on the back, but the settings shown worked.

Frequency setting:

We listened and recorded at a **FREQUENCY** of 45kHz because other studies determined that many bat calls are picked up +/- 5kHz of this level. However, bats have a range of calls that can reach up to and above 100kHz, so it may be beneficial to experiment with recording at different ranges.

Final thoughts:

Whenever the red light next to **FREQUENCY** is lit, the detector is recording, and whenever the red light is unlit it is replaying. Any experimentation with switch combinations should be done with this in mind. It was unwieldy to need a computer in order to record calls in the field. It is possible to record calls from the detector onto a tape recorder that can then be dumped on a computer later. This should be looked into.