EFFECTS OF CONVERSION OF PRIMARY FOREST TO PASTURE ON STREAM COMMUNITIES

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Abstract (G.G., A.M.)

This study looked at the ecological impact of deforestation on stream communities. In particular, we compared pools in streams flowing through pasture to those flowing through primary forest. Twelve orders of invertebrates were found among five sampling sites. Certain orders appeared to be exclusive to either pasture or forest stream sites. We found that pasture pools supported more diverse invertebrate populations. Large fish and surface insects were observed in greater abundances in pasture streams. Our results indicate deforestation has a definite impact on streams and the invertebrate communities they support, though further study is needed. In an age where deforestation has caused a widespread ecological dilemma, more studies like this one are needed in order to understand and compensate for undesirable effects of forest conversion.

Introduction (V.V.)

We studied the effects of conversion of primary forest to pasture land on stream communities. Due to increasing demands for beef for local consumption and export, a large percentage of the forests of Costa Rica have been converted into pasture land. Deforestation potentially has profound negative impacts on the physical and chemical properties as well as the biological communities in the deforested areas. As streams are largely influenced by their surrounding lands, we predicted that the conversion of primary forest to pasture would affect the streams going through the converted areas. These effects would be physical, chemical, and biological, influencing the abundance, diversity, and species composition of the stream bed. Streams are a water and fish source for Costa Rica, and influences on streams could influence local human populations as well.

We studied pools in three streams at the La Selva Biological Station, Costa Rica. We compared pool beds, benthic invertebrates, fish, and surface insects in pools in primary forest and pasture, and hypothesized that the abundance, diversity and species composition, and pool bed characteristics would differ between the two types of pools.

Methods (A.M.)

We chose five pools in two different streams on the La Selva Biological Reserve for our study: One pool in the Sura River passing through primary forest, two pools in the Sabalo River passing through pasture land and two pools in the Esquina River passing through primary forest. The Esquina River feeds into the Sabalo, therefore the primary forest sites on the Esquina are upstream from the Sabalo sites (Figure 1). A pool was defined as an area within the stream that was cut off from normal stream flow by fallen trees or small eddies along the streambed. When choosing each pool we minimized physical differences such as pool depth, width and length as well as the rate of current flow among sites. We sampled pools for benthic invertebrates by choosing a point in the downstream end of the pool which appeared to have a suitable substrate for invertebrates and filling a 500ml container with leaf litter and soil found in the streambed. Samples were emptied into labeled plastic bags and brought back to the lab where they were examined for invertebrates. Five rocks, greater than 10cm and less than 30cm in diameter were picked up at each sample interval. All invertebrates found on rocks were collected in sample jars and taken back to the lab for identification. These procedures were repeated at sampling sites 5 & 10 paces upstream along the same transect. At each site we estimated fish densities within the pool. Fish were defined in three size classes: small (0-5cm long), medium (5-15cm long) and large (15-30cm long), and the density of each size class within a pool was defined as either low (0-20 individuals), medium (20-50 individuals), or high (50-100 individuals). We also made estimates of surface insect densities for each pool. Density of surface insects was described as being either low (0-30 individuals), medium (30-60 individuals), or high (60-100 individuals) within each pool. In sites three and four we sampled fish populations by placing minnow traps in the deepest area of each pool. Each trap was left in the pool for eighteen hours, then fish caught within it were counted and removed. One individual of each species was brought back to the lab for identification.

When examining the diversity of organisms found among sample sites, we classified all invertebrates found in each pool in their orders and ecological guild and calculated the Shannon-Weiner diversity index for each site.

Site Descriptions (V.V.)

Site 1: Pool in Sura river, alongside trail marker SUR 200, 50m upstream from bridge to arboretum. Pool 15m long, 4m wide, 0-5m deep. Banks near vertical, 1-1.5m high. Primary forest on both sides. Many branches overhanging pool, with 70% estimated canopy cover. Pool bed clay-like, with thick layer of mud and large amounts of leaf litter and distributes. Few small rocks, minimal algae.

Site 2: Pool in Sabalo River, alongside trail marker SSE 1100. Pool 10m long, 5m wide, 0.5m deep. Banks near vertical, 1.5m high. Pasture on one side, fragmented secondary forest on other. Minimal branches overhanging pool, with 20% estimated canopy cover. Pool bed covered uniformly with gravel and small rocks. Leaf litter and detritus minimal, with few scattered leaf packs. Algae present on rocks.

Site 3: Pool in Sabalo River, between trail markers SSE 1500 and SSE 1550, 100 upstream from confluence of the Sabalo and Esquina Rivers. Pool 10m long, 4.5m wide, 1m deep. One bank near vertical, 1.5m high, other with gradual slope. Pasture on both sides. Minimal branches overhanging pool, with 30% estimated canopy cover. Pool bed covered uniformly with small rocks. Algae present, leaf litter minimal.

Site 4: Pool in Esquina River, along trail marker SSE 2100. Pool 12m long, 4m wide, 0.75m deep. Both banks with gradual slope. Primary forest on both sides. Few overhanging branches, with 60% estimated canopy cover. Pool bed uniformly covered with gravel and silt. Algae minimal, leaf litter substantial but patchy.

Site 5: Pool in Esquina River, alongside trail marker SSE 2300. Pool 10m long, 5m wide, 0.75m deep. Banks near vertical, 0.5m high. Primary forest on both sides. Many overhanging tree and shrub branches, with 80% estimated canopy cover. Pool bed uniformly covered with leaf litter, detritus and thick layer of mud. Minimal small rocks, no algae visible.

Results (G.G.)

We identified twelve taxa and a total of 265 individual invertebrates from all samples collected. Diptera were the most abundant invertebrates found - 95 individuals and were common to all five sites. Nematodes were the next most abundant invertebrates recorded - 87 individuals and were found in all stream pools but one (see Table 1).

Shannon-Wiener diversity indices calculated for each site indicated that pasture pools hosted more diverse invertebrate communities than two of the three forest pools (Appendix 1). Mann-Whitney U tests to compare the abundance of invertebrates in each of three feeding guilds (herbivore, predator, and deposit feeder) between pasture and forest pools failed to show significant differences.

We observed much higher quantities of visible filamentous algae in the pasture stream than in the forest stream which contained trace amounts or none at all.

We observed fish and surface insects to be more abundant in pasture pools than forest pools. In addition, large fish - > 30cm - were only found in pasture pools (Table 2) - all statistical tests run by G.G.

Discussion (T.Y.)

From the Shannon-Weiner diversity index, we found a higher diversity of taxa in the pasture stream. This can be explained as followed. The cultivation of land increases nutrient runoff into streams due to less root structures to retain leachates. In areas of deforestation, the streams contain trace amounts of leaf litter but more gravel and rocks on the stream bed. This is due to the fact that leaf fall decreases due to the removal of riparian vegetation. The streambed no longer contains a thick leaf layer, but contains rocks and gravel that are revealed after erosion of the stream bed. These exposed rocks hold more surface area and create a more permanent spot for algae and invertebrate to grow than does leaf litter. Hynes (1970) found that silt and clay substrates found in many primary forest habitats were less suitable for invertebrates than rocks that offered a firmer substrate (Burchame, 1985). Also if more leaf litter is present on the stream bed, it acts like a sponge and the flow rate of the stream would be decreased. A rocky streambed found in pasture would not impede flow rate. If the flow rate is higher, there would be a tendency to have a higher invertebrate immigration. This is due to a greater volume of water passing over the rocks over a given time. A future study comparing rocks vs. leaf litter and flow rates as a determinant of invertebrate abundance, would be helpful.

We found Dipterans to be the most abundant order. This can be attributed to the fact that Dipterans are the most variable in structure and habitat of all the insects (Pennak, 1978). In terms of individual orders of aquatic invertebrate, there were differences in abundance which can be attributed to different stream characteristics. Many more nematodes were found in the primary forest than in pasture land. This is probably due to the fact that nematodes feed on dead plant and animal material. The pasture stream does not have much dead plant material, and also does not have a protected area such as thick leaf litter for the dead material to collect on the bottom. Mayflies were found in more abundance in the pasture sites than the primary forest. This is probably due to the fact that mayflies are mostly found where there is high dissolved oxygen. Riffles which mix in nutrients and large quantities of oxygen to pools were found more frequently in stretches of pasture than forest. There is also more algae that produces O_2, and fewer detritovores which deplete O_2, in the pasture stream. The dragonfly larva was found in the forest stream and not in the pasture sites. This may be due to the fact that dragonflies are rare in polluted and torrential streams. The pasture stream may have dissolved pollutants from past banana plantations, and may be subject to torrential conditions during floods, whereas the primary forest offers a more pristine protected environment. Finally, water striders feed on high quantities of flying insects that accidentally hit the water. The high densities of water striders in the pasture areas may be due to the high abundances of aerial insects that we observed over the pasture stream. Pastures may attract flies and other aerial insects due to the presence of cows and cow pats, grasses, etc. The air space above the primary forest streams did not contain many aerial insects the streams did not contain high abundances of water striders.

Examinations of certain fish diets can explain their distributions in pools in pasture land or primary forest. Using the stomach content data and abundance data from Janet Burcham's study (Burcham, 1985), some correlations can be made. Neetroplus nematopus occurred thirty times more often in pastureland than in primary forest. This is probably due to its diet being primarily filamentous algae. Poecilia gilli is found only in pasture land. This is most probably due to the fact that it only eats diatoms which can only exist in sunny pools. Astyanax Fasciatus occurs in the pasture areas ten times more often than in forest streams. This is most probably due to the fact that Astyanax is an omnivore and eats aquatic insects, terrestrial insects, plants, algae, and diatoms. Its broad dietary needs would be more easily satisfied in the pasture stream. We did not get a large enough sample size to draw any conclusions, but we did catch Astyanax Fasciatus in the pasture. In another study of fish stomach contents between pasture sites and primary forest sites, the only sites that stomachs were empty, indicating hunger, were in the forest samples (J. Trexler). This leads us to our final point. The base of the food web in the stream community is from attached algae, aquatic macrophytes, diatoms, plant material from the surrounding environment, and small fish. The pasture stream seems to provide greater quantities of these bases than does the primary forest stream. The two streams can be viewed on inverted trophic pyramids. The pasture has a very high productivity in the first level of food supplies. This is due to more autotrophs that provide continual production. This plus a supply of invertebrates and smaller fish, allows a wide speciation and abundance of fish, and also allows for larger fish to exist at the top of the food chain, since the lower levels are well filled in. The primary forest may have similar numbers of invertebrates, but it has low autotrophic production. This decreases the overall productivity of the stream, and similarly narrows the walls of the trophic pyramid restricting abundance in higher trophic levels due to a more limited food base. Our fish density estimates match this model in that we found higher abundances of all size classes of fish in the pasture stream. We also only found very large fish > 30cm in the pasture stream.

There were limitations to our study. These were relatively small sample sizes, in exact fish counts, no analysis of stomach samples, lack of instruments to chemically analyze water and to precisely measure algae. Fish counts would have been improved

with seining nets or electroshock apparatus.

In conclusion, deforestation may lead to allowance for a larger food base, and thus a greater abundance of fish. The pasture stream was a well established stream. When deforestation first occurred, the original stream was probably destroyed in terms of organisms which were adapted to a primary forest habitat. The stream then rebuilt itself to its present status-for better or worse we can't say. Streams in plantations that are affected by insecticides would be worth studying in the future. We would predict their populations to be in much worse condition than in pasture or forest streams. Fish do seem to be a staple of the local people in Costa Rica, so from our findings, there are two valid arguments for and against deforestation and we cannot take a "moral stand".

Table 1 Benthic Invertebrate Samples - number of individuals found at each site at La Selva Biological Station, Rio Sura, Rio Sabalo, Rio Esquina, February, 1991

Order/Phylum	P,D,H		Site #1/PF	Site #2/PA	Site #3/PA	Site #4/PF	Site #5/PF
Coleoptera	P	larvae	10	1	–	–	2
Diptera	D	adults	12	9	16	19	5
		larvae					
Hemiptera	P	adults	6	1	3	–	–
Lepidoptera	H	larvae	1	–	–	1	–
Ephymoptera	H	adult					
		larvae	1	13	–	1	–
Trichoptera	H	larvae	1	1	2	–	1
Plecoptera	H	larvae	1	–	–	–	–
Odonta	P	adults	2	–	1	1	–
Neuroptera	P	adult	–	–	–	1	–
Annelida	D		10	5	–	–	–
Nematoda	H		–	3	16	1949	
Plathyhelmenthes	D		5	11	13	–	–

P,D,H: refers to foraging habits of the organisms
P-predator
D-deposit feeder
H-herbivore

Table 2 Fish species and abundance, surface insect density and additional pool characteristics of each site.

	Site #1/PF	Site #2/PA	Site #3/PA	Site #4/PF	Site #5/PF
Fish Sampling (only sites 3-4) species found			Alfaro cultratis Astyanax fasciatum	cichlosoma alfari Brycanamericus ricae Alfaro cultratus Priapichtys annectus	
Fish Abundance Estimates					
<5cm (small)	Medium	High	High	Medium	High
>5,<15cm(med.)	Low	Medium	Medium	Low	Low
>15 (large)	–	Low	Low	–	–
Surface insect density Low	High	High	Medium	Low	
Streambed substrate:	Leaf litter rocks	Gravel, rocks scattered leaves	rocks & silt	gravel, silt	leaf litter small logs
%canopy cover	70%	20%	30%	60%	80%
pool depth	.5m	.5m	1.0m	.75m	.75m
visible algae	None	Plentiful	Trace	Trace	None

Literature Cited

Burcham, Janet K., "Fish Communities and Environmental Characteristics of Two Lowland Streams in Costa Rica", 1985 Thesis Texas A&M University.

Trexler, J., "The Stomach Contents of Some Stream Fishes", 1983 OTS Coursebook.

Pennak, Robert, "Fresh Water Invertebrates", 1978

Figure 1 Sites chosen for stream sampling at La Selva Biological Station, Costa Rica.