

# GOING BEYOND THE EXPLOITATION ECOSYSTEM HYPOTHESIS FOR ALGAE IN RÍO CLARO

ALANNA H. PURDY AND DYLAN D. THOMAS

Faculty editor: Matthew P. Ayres

*Abstract:* Algae account for most of the primary production of some riparian systems. In the Río Claro of Corcovado, Costa Rica, most of the algal biomass is found in a filamentous and very fragile morphology in a small part of the intertidal zone. Previous studies suggested that trophic cascades limit the algae upstream, but have not examined the full spectrum of abiotic and biotic possibilities which could limit its distribution and abundance. Trophic cascades appeared to be affected by the tide as predicted by the Exploitation Ecosystem Hypothesis (EEH), but there was also evidence for abiotic effects, especially from depth and water velocity. Apparently, the standing biomass of primary producers in the Río Claro, chiefly one species of alga, depends on several factors, many of which are associated with the tide.

*Key Words:* *autochthonous, competition, conductance, salinity, substrate, transplants*

## INTRODUCTION

The energy flux within ecosystems is limited by the primary productivity, which in rivers is commonly based upon algae. However, the pool size of primary producers can be quite variable depending on a variety of local conditions that influence plant productivity and the rate at which plant matter is consumed by herbivores. In rivers of the Osa Peninsula, Costa Rica, there tends to be relatively little standing algal biomass (Winemiller 1983), but it is not clear why. The foodweb of the Río Claro, near Sirena Biological Station, is strongly based on algae (Winemiller 1983), chiefly a blue-green algae, which attains conspicuously high biomass (in a

filamentous morphology) within a band of the intertidal zone (Figure 1).

The lower reaches of the river change dramatically with ebbing tides because the river lacks an extensive floodplain or estuary. The factors that influence why algae are much less abundant near the mouth of the river and above the intertidal zone are poorly understood. Carreras et al. (2006) suggested the possibility that tidal-induced trophic shifts influence the intensity of herbivory on algae, and reported some results that were consistent with this hypothesis. However, they were unable to sample at high tide and only assessed the impact of one family (Gobiidae) of primary consumers.

In general, algal morphology and abundance may be limited by 1)

abiotic factors such as salinity, depth, current, and substrate; 2) biotic factors such as herbivory or interspecific competition; 3) a combination of biotic and abiotic factors, acting in conjunction or separately at either end of the tidal zone. To distinguish between these, we sampled water depth, conductance, substrate type, algal cover, and the bird and fish communities along the intertidal zone of Río Claro, and transplanted algae upriver and downriver.

## METHODS

We sampled the intertidal zone of Río Claro (river mouth: N 08.46417°, W 083.59298°; Table 1) in Playa Sirena, Corcovado National Park, Costa Rica from 8 - 10 Feb 2008. We divided our study area into eleven transects spaced approximately 60 m apart, each 2 m wide and spanning the width of the river. Within each transect, we randomly sampled four 2 x 2 m sites at low and high tide.

TABLE 1. GPS coordinates on the eleven study transects along the Río Claro of Corcovado, Costa Rica.

Transec	
t	UTM
1	17 P 214494 936565
2	17 P 214626 936676
3	17 P 214721 936669
4	17 P 214765 936693
5	17 P 214883 936802
6	17 P 214906 936821
7	17 P 214977 936816
8	17 P 215110 936761
9	17 P 215170 936843
10	17 P 215268 936809
11	17 P 215294 936793

For each plot, we estimated the depth, percent algal cover, and substrate composition: i.e., percentage of silt (fine particulate matter), sand, gravel (0-1 cm), cobble (1-10 cm), boulder (>10 cm), and leaves. We performed a principal components analysis to condense the six substrate types into two principal axes. We also measured the conductance ( $\mu$ Siemens / cm) of a water sample from each transect.

For six plots along the study area, we spent two minutes estimating the number and size of fish within the plot, and the number and species of birds within 100 m of the plot. We estimated fish biomass by calculating length\*number of fish.

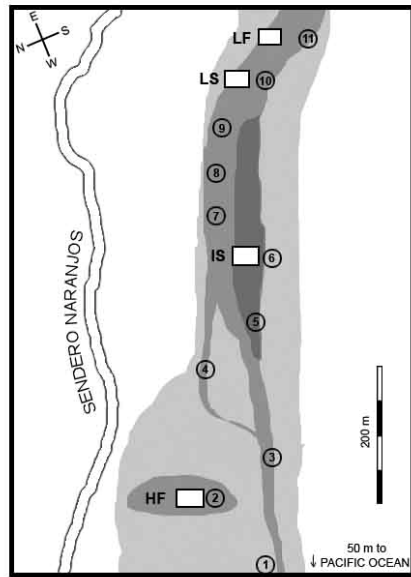


FIGURE 1. Map of the intertidal zone of the Río Claro, Corcovado National Park, Costa Rica. The river roughly doubles in width at high tide (light grey) from low tide levels (medium grey). Algae were present throughout, but the filamentous morphology was only abundant on the south side of the river along the central stretch of the intertidal zone (dark grey). Algae-covered rocks were transplanted from the site of Treatment IS to the other indicated treatments to assess the affect of water velocity, herbivory and salinity on algal survival. Numbers indicate location of transects.

We collected a total of 40 rocks covered by the long, filamentous algae from the middle of the river (Treatment IS, Fig. 1) and transplanted the rocks to four areas along the river: high salinity and fast water (HF), intermediate salinity and slow water velocity (IS), low salinity and high water velocity (LF) and low salinity and low water velocity (LL) at how tide. Rocks from Treatment IS were handled and replaced to serve as a control. Each treatment consisted of 10 transplanted rocks, five of which were bagged to protect

against herbivory and mechanical stress. After two days, we examined and photographed the rocks from each treatment.

## RESULTS

After the river depth peaked at high tide, the width of the river dramatically shrunk. Conductance at low tide decreased non-linearly with increasing distance upriver, with the greatest change occurring at the river mouth. For transects 3 and above, the water was relatively fresh (conductance < 500  $\mu\text{S}/\text{cm}$ , corresponding to salinities < 2 parts per thousand). We were unable to obtain conductances at high tide due to water damage to the conductance meter. Water turbidity and time constraints prevented accurate species identification and abundance estimation of fish at high tide.

Average algal cover was very low on the edge of the study area (Transects 1, 2, and 11) and was highest at transect 4 (Figure 3). The depth of the river at low tide did not significantly affect algal cover ( $F = 0.74$ ,  $df = 1, 42$ ,  $P = 0.39$ ). However, the difference in water depth between high and low tide was positively related to algal cover for upstream transects ( $r^2 = 0.25$ ,  $df = 26$ ,  $P = 0.0065$ , Figure 4).

Treatment IS (control) revealed that even slight handling of the algae significantly reduced its abundance and biomass. For all of

transplants, most of the long strands were broken, and only the algae that remained firmly attached to the rocks were compared (Figure 2).



FIGURE 2. Rocks from Río Claro, Corcovado, Costa Rica, covered in filamentous algae (top) from a bagged treatment and devoid of long filaments (bottom) from an unbagged treatment.

Bagging the treatments reduced the mechanical stress of fast currents. Unbagged algae in Treatments HF and LS both were subjected to fast currents and lost >90% of their long filaments, whereas bagged algae in both treatments were longer and more intact. Algae seemed to suffer in salty marine water, since algae in Treatment LS remained green while

algae in Treatment HF started to become brown within 48 h after being moved. In the slow water current transects (Treatments IS and LF), there were no clear physical differences between the bagged and unbagged treatments.

Unbagged algae in Treatment IS (fast current) was greatly reduced, while unbagged algae in Treatment LF (slow current) retained much of its long filaments, supporting the result that fast currents decrease algal biomass.

Most substrate types showed no clear relationship with algal cover. There was no linear relationship between algal cover and PC1 ( $F = 0.11$ ,  $df = 1, 42$ ,  $P = 0.11$ ; PC1 was positively correlated with sand and leaves ( $r = 0.60$  and  $0.44$ , respectively), and negatively related to cobble ( $r = -0.54$ ). Plots with abundant boulders were significantly more likely to have high algal cover, since PC2 (which was negatively correlated with gravel,  $r = -0.76$ ) was negatively related to algal cover ( $F = 28.1$ ,  $df = 1, 42$ ,  $P < 0.0001$ ). In contrast, the fish community was clearly affected by substrate. PC1 was positively and linearly related to fish biomass ( $F = 9.49$ ,  $df = 1, 22$ ,  $P = 0.0055$ ).

Small shrimp (Palaemonidae) were observed in most transects throughout the study area, but were most abundant in the dense, filamentous algae mats (transects 5 - 8). There was a positive, linear

relationship with depth at low tide ( $F = 8.98$ ,  $df = 1,4$ ,  $P = 0.04$ ). The distribution and abundance of fish are summarized in Table 2.

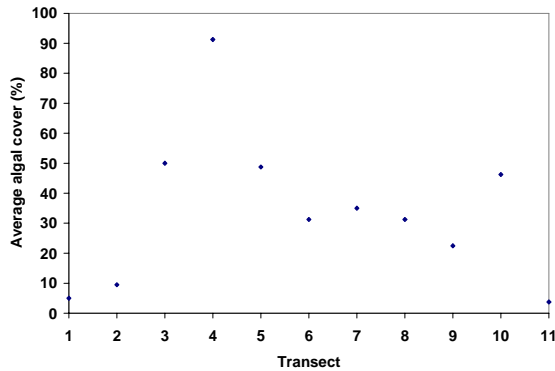


FIGURE 3. Average algal cover within eleven transects separated by 50 meters (transect 1 – 11 goes upriver) in the Río Claro of Corcovado National Park, Costa Rica

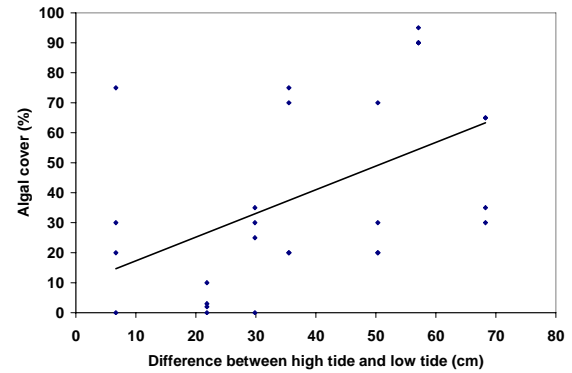


FIGURE 4. Relationship between tidal difference in depth between high tide and low tide (cm) and algal cover (%) in Río Claro, Costa Rica.

TABLE 2. Locality, abundance and description of each fish species sampled at low tide in the Río Claro of Corcovado National Park, 9 and 10 Feb, 2008.

Species	Common name	Description	Diet	Localities	Greatest # individual s observed among 3 sampled plots	Average length (cm)
<i>Eucinostomus currani</i>	Pacific flagfin mojarra	Black-tipped spinous dorsal fin, silvery coloration	Vegetable matter, microinvertebrates , detritus (Bussing 1998)	6, 10	15, 14	2
<i>Awaous transandeanus</i>	River goby	Tan coloration, dark dappling along body, fins transparent	Detritus, filamentous algae, chironomids, microbivalves (Bussing 1998)	8	5	5
<i>Lutjanus Colorado</i>	Colorado snapper	Red anal, caudal and pectoral fins, darker dorsal coloration	Fish, shrimp (Winemiller 1983)	8	5	25
<i>Lutjanus argentiventris</i>	Yellowtail snapper	Head pink, anterior half of body salmon color, posterior yellow-orange, fins yellow-orange	Fish, shrimp (Bussing 1998)	8	15	20
<i>Lutjanus novemfasciatus</i>	Pacific dog	Tan coloration with darker	Fish, shrimp (Winemiller 1983)	8	10	8

s	snapper	bands along body, reddish pectoral fins, dark ridge along edge of caudal and dorsal fins				
<i>Gobionellus sagittula</i>	Long tail goby	Tan-brown coloration, darker dappling along body and caudal fin	Benthic microalgae (personal observation)	10	1, 5	2.5
<i>Sphoeroides annulatus</i>	Bullseye Pufferfish, Cuchusapo	Grey dappling interrupted by yellow-tan oblong circles on dorsal half of body, unmistakable	Benthic crustaceans, snails (Winemiller 1983)	8	1	7
Unknown	-	Large minnow, sandy coloration, schooling	?	3, 10	1, 1	6
Unknown	-	Small minnow, sandy coloration, schooling	Hiding in algae	3, 4, 6, 8	50, 15, 1, 1	2

## DISCUSSION

Most of the algal biomass of Río Claro occurs in a filamentous form within a zone of relatively shallow, sunny, and calm water about 200 m upstream from the river mouth. Transplant studies showed that there was no suitable habitat for algae near the ocean (likely due to high salinity), nor upriver (likely due to herbivory), and that fast currents rapidly decreased algal biomass.

Algal abundance was not related to substrate, and substrate availability was not the factor limiting algae upstream. We also

doubt that interspecific competition influences algal abundance here because there appeared to be only one common species of algae in the system.

All the shallow, calm regions of the intertidal zone supported large algal biomass, thus it seemed that suitable algal habitat was largely determined by water velocity, depth, and the presence of piscivores. Our data supported the hypothesis that neither biotic nor abiotic factors alone, but rather a combination the two (high salinities downstream and lack of a third trophic level

upstream) determine the distribution of the algae.

Piscivorous fish come in with the tide, which might effectively add an additional trophic level to the system. Theory from community ecology predicts that changes from even to odd numbers of trophic levels will produce alternations in the abundance of plants due to alternations in the pattern of top-down effects (exploitation ecosystem hypothesis; Oksanen et al. 1981). Thus changes in the number of trophic levels from the incursions of marine fish at high tides could theoretically explain the high algal abundance in the middle reaches of the river. Presumably our study transects with the largest tidal fluxes also experience the most large fish at high tide, which could be why they contained more algae. We were unable to do a thorough sampling of the aquatic communities at each transect, but our results were consistent with the exploitation ecosystem hypothesis, in that we observed more algae where larger fish were found, and less algae and more herbivorous fish (gobies) above the intertidal zone. We also recorded the abundance of piscivorous birds (herons and kingfishers), but less than ten birds were observed feeding, so we doubt that birds significantly affect the lower trophic levels of this system. If the exploitation ecosystems hypothesis is at work, and herbivores are indeed

exhibiting top down control of algae upstream in Río Claro, then more complete surveys from the intertidal zone all up way upriver should confirm that algal abundances are highest in regions where there is an odd total number of trophic levels.

#### LITERATURE CITED

- Bussing, W.A. 1998. Peces: freshwater fishes of Costa Rica. San José, C.R.: Editorial de la Universidad de Costa Rica.
- Carreras, A.R., B.D. Bates and P.R. Wright. 2006. Evaluating the Exploitation Ecosystems Hypothesis in a marine-influenced river community. Dartmouth College, Hanover, NH. Pp. 82-85.
- Oksanen, L., S.D. Fretwell, J. Arruda, P. Niemelä. 1981. Exploitation ecosystems in gradients of primary productivity. *The American Naturalist* 118:240-261.
- Winemiller, K.O. 1983. An Introduction to the freshwater fish communities of Corcovado National Park, Costa Rica. *Brenesia (Costa Rica)* 21: 47-66.