TWM FOR CONSERVATION AND DEVELOPMENT IN THE HEADWATERS OF THE COCO, NICARAGUA AND HONDURAS

Sara K. Enders[1], Jordan Macknick[1], Shimon Anisfeld[1], Sean Johnson[1], Jairo Escalante,[2] Orlando Lagos[3]

[1]Yale School of Forestry & Environmental Studies, New Haven, USA
[2]Universidad del Norte de Nicaragua, Estelí, Nicaragua
[3]Banco Centroamericano de Integración Economica, Somoto, Nicaragua

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E-mail: sara.enders@aya.yale.edu

The mountainous border region between the departments of Choluteca, Honduras and Madriz, Nicaragua is an area rich in natural resources and home to an impoverished and growing human population. Point source and non-point source water pollution are among problems caused by unsustainable development here that threaten broad regional interests in addition to the health of local inhabitants. Ranching, agriculture, and foresting activities appear to have changed the hydrology of the forested watersheds which contain headwaters of rivers on both sides of the border, and poor land management is blamed for declining water resource availability and water quality problems in both countries. Because many water courses, including the two major rivers Río Coco and Río Negro, traverse the political boundary between the countries, conflicts between upstream and downstream users can become international disputes, as happened three years ago when Honduran farmers placed impoundments on the Río Comali and drastically cut inflows to the Río Coco, causing Nicaraguan officials to demand their removal.

A transboundary protected area has been proposed as a means to improve access to quality water resources on both sides of the Honduras/Nicaragua border in the catchments of the Coco and Negro, with increased access to alternative livelihoods, regulations and prohibitions on forest cutting and chemical use, and compensation for environmental services being some of the vehicles discussed (see abstract and presentation by Macknick et al., in this conference[1]). Data which document the impairment of waterways and which demonstrate a link between current land use activities and water conditions are necessary to justify imposing restrictions on livelihoods of local inhabitants, to determine where limited resources should be directed to maximally improve the situation, and to determine if compensation for environmental services is appropriate. This study makes use of remote and in-field land use and hydrologic mapping, water quality analyses involving bi-national simultaneous sample collection by community members, and interviews with land managers within the catchment area of the Río Coco to make recommendations for management intended to promote economic development and natural resource conservation in the region. At the time of submission of this abstract, data collection is ongoing.

Proper water resource monitoring and management are of obvious importance to the public health of watershed residents. Additionally, water chemistry monitored at a stream outlet is an indicator of activities such as soil erosion and nutrient uptake in the drainage area, which both are processes important to the management of watershed ecology and agricultural production. Finally, improvements in water quality and monitoring in this region will increase the viability of tourist attractions on which hopes for economic development have been placed such as the Cañon de Somoto.

The problem of identifying and regulating sources of non-point source pollution control is a significant challenge to water resource management and one which is receiving considerable attention worldwide. The approach to identifying diffuse contributors to water chemistry taken in this study follows the "snapshot"

[1] Macknick J. and Enders S. K. 2008. Bi-national water management for economic development in Nicaragua and Honduras. IV International Symposium on Transboundary Waters Management, Thessaloniki, Greece. 15-18 October 2008.

method of Grayson et al. (1997)[2], in which all major tributary junctions and discharge points are sampled during baseflow conditions to establish a longitudinal profile of water quality. This method gives a geographical view of water quality that permits relation to land use and allows for the identification of reaches over which water quality is worsened or bettered. A problem inherent to the application of this method over a large geographical area is the difficulty of sampling a large number of sites in a short enough period to keep atmospheric inputs constant during sample collection. To take the samples effectively simultaneously, the research team conducted recruitment and training of community members leading up to a coordinated collection of 90 water samples by 19 teams of two to four people within a four hour window on a single day. Channel width, depth, and velocity measurements were taken at each site to calculate discharge and determine analyte load. In addition to generating a dataset which the research team could not have produced working alone, this process capacitated the local community to continue monitoring beyond the period of this study. Such community monitoring would both fill a knowledge gap in a region in which very little water quality monitoring is done by the government, and increase awareness and empowerment of stakeholders with respect to their water resources.

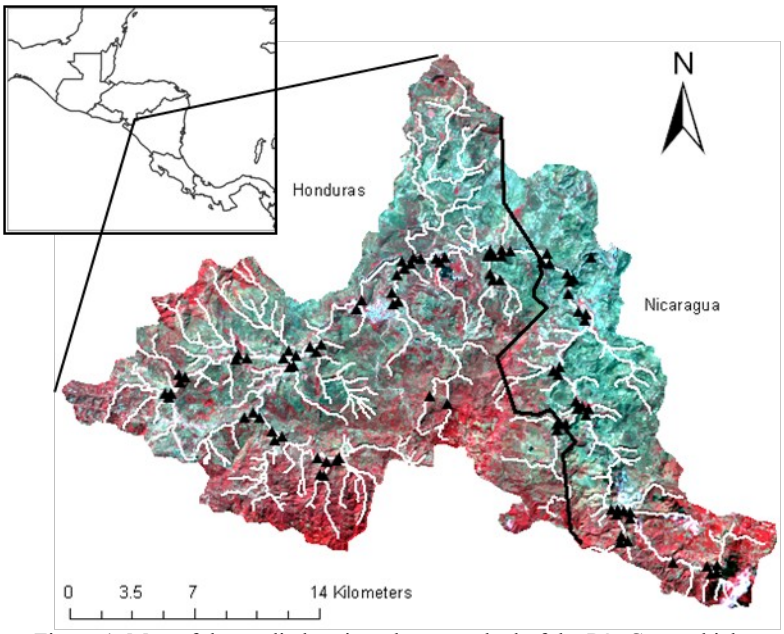

Figure 1. Map of the studied region, the watershed of the Río Coco which drains to the Cañon de Somoto. An ASTER satellite photo indicates summer (January) vegetation cover in red. The river network is depicted in white. The Honduras-Nicaraguan border is outlined in black. Sample site locations are indicated by black triangles.

Site Description—The study area is comprised of the catchment area which drains to the Río Coco where it exits the Cañon de Somoto, 12 km west of Somoto, Nicaragua at an elevation of about 600 m. This area includes the subwatersheds of the Río Comalí in the department of Choluteca, southern Honduras and the Río Tapacalí in Madriz, northern Nicaragua, which flow northward respectively 35 and 25 km from their sources in mountains of ~1700 m to reach the Cañon de Somoto.

Depending on elevation, average annual precipitation ranges from 700 mm to 1,700 mm, and average annual temperature ranges from 20°C to 27°C. Rainfall is heaviest during two wet seasons, from September to November and May to June. High elevations contain coniferous forest ecosystems dominated by *Pinus oocarpa*, and cloud forests are also present. The steep slopes in these high altitude regions are heavily cultivated for coffee production, and also sites of cattle ranching. Within this area lie the protected parks La Botija in Honduras and Tepesomoto-La Patasta in Nicaragua. The protections in this area include limitations on wood harvesting and the use of chemicals. In both parks, laws are weakly enforced due to bribes and a real (due to poverty and unemployment) and perceived (due to unawareness) lack of alternatives. Lower elevations contain more intensive agriculture, including farming of corn and beans for in-country consumption and horticulture (tomatoes, onions, and peppers) for a mix of consumption and export. It is here where irrigation is most intensive. Because export contracts incorporate measures of quality control absent from in-country sales of produce, management practices are found to differ considerably between crops growth for these two different markets. On both sides of the border, organic farming of coffee is increasing in incidence. In general, Choluteca is a greater agricultural exporter than is Madriz.

[2] Grayson R.B., C.J. Gippel, B. L. Finlayson and B. T. Hart. 1997. Catchment-wide impacts on water quality: The use of 'snapshot' sampling during stable flow. Journal of Hydrology 199: 1-2, 121-134.

Human populations on both sides of the border are overwhelmingly impoverished and experience high levels of unemployment, particularly in the "dog days" of summer (June through August), which is an agricultural growing season in which planting and harvesting work is unavailable. Artisan crafts are produced to a limited degree, and their production represents one of a very limited number of employment options for women. Both sides of the border are experiencing population growth and the phenomenon of rural to urban migration, driven by differential employment opportunities. Indigenous communities with limited autonomy are also components of the population.

Sample Collection Methodology and Preliminary Results—Water samples were collected on the morning of 16 July, 2008 and preserved in ice baths immediately upon collection for transport to the Estelí laboratory of Enacal, the Nicaraguan water utility. Samples for bacteria analysis were incubated within 8 hours of collection and analyzed for levels of Total coliform and *Escheria coli* using the Quanti-tray®/2000 method from IDEXX. Samples were also collected in duplicate and acidified after transport to the laboratory for subsequent flow analysis of base cations and macronutrients at Yale University in New Haven, CT. Spot testing for heavy metals and pesticide loading is also planned.

Preliminary *E. coli* results show a range of 4.1 to >2419 colony forming units (cfu) per 100 ml of water in the main reach of the Comali in Honduras, while the maximum concentration in the Tapacali is 1553.1 col/ 100 ml. Longitudinal variability along river reachs is considerable, and large changes are seen in stretches

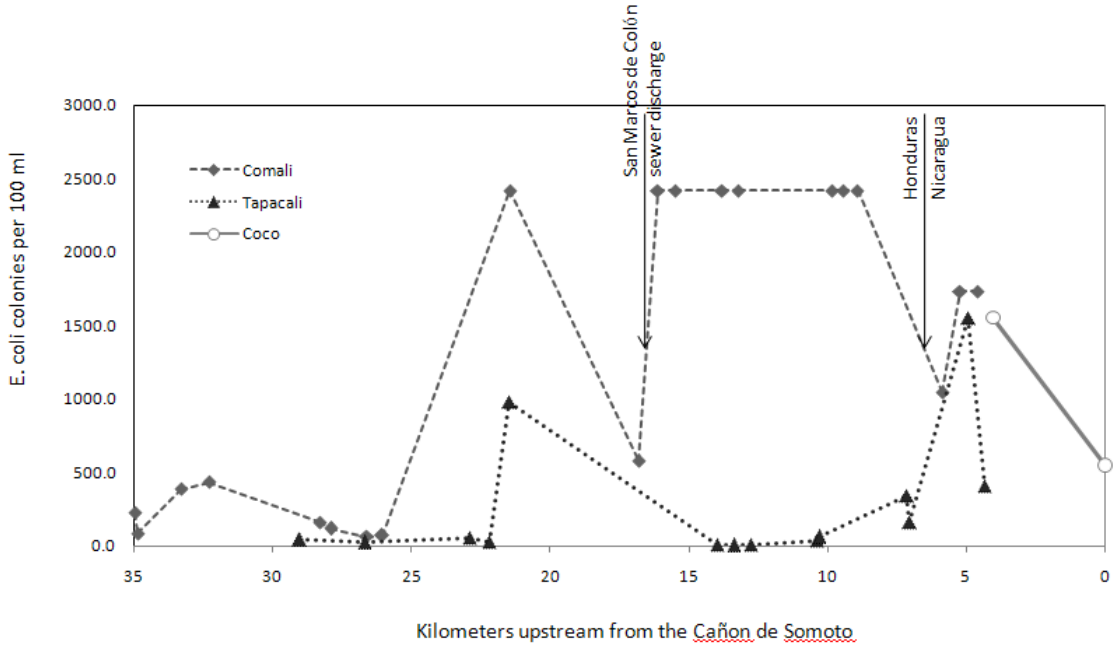

Figure 2. Preliminary *E. coli* results from the main stems of the Tapacali in Nicaragua and the Comali in Honduras and Nicaragua, sampled at major tributary junctions and discharge points, above the point where the two rivers join to form the Río Coco before entering the Canon de Somoto.

without a tributary junction, suggesting that localized processes, possibly including land use of riparian areas along the main channel, play an important role in determining bacteria levels. Further testing will explore the question of over what distance concentrations of bacteria and other pollutants attenuate in reaches of these rivers. A decrease in water quality at the point of discharge of sewage from the urban region of San Marcos de Colón into the Comali can be clearly seen. A useful water quality target for an international recreation site is the USEPA acceptable E coli standard for a single sample of 235 cfu/100 mL. The data strongly suggest that a bi-national effort to reduce E. coli levels in the Cañon de Somoto (represented by the two sample points along the Río Coco in figure 1) is appropriate.

Spatial analysis will be applied to maps of water quality and land use practices to investigate correlative relationships, such as the role of percent tree cover in determining a catchment's water quality. Populations

which would likely benefit from or bear the burden of restricting catchment activities that impair water resources will be identified.