

Quantifying mangrove deforestation in Ecuador's northern estuaries since the advent of commercial aquaculture

Background

Commercial aquaculture is undoubtedly responsible for much of the loss of Ecuador's mangrove forests (Bodero, 1993; Bodero & Robadue, 1997; Swedish Society for Nature Conservation, 2007; Spalding *et al.*, 2010). What remains unknown in Ecuador is an exact measure of mangrove deforestation since the advent of commercial aquaculture. It is noted that aquaculture in Ecuador now occupies more area than do mangrove forests (CLIRSEN, 2007). This paper addresses the loss of mangrove forests in four largest northern estuaries of Ecuador from the advent of commercial shrimp farming to the present and attempts to not only quantify mangrove loss but also expand upon the LULC (land use land cover) that has replaced the forests. This work is an expansion of research published in the *Journal of Land Use Science* in 2011 that examines some of the macro-forces driving mangrove deforestation (Hamilton & Stankwitz, 2011).

Material and Methods

This analysis focuses on the four largest estuaries in Ecuador's two most northern coastal provinces. The two largest estuaries in Esmeraldas Province are Cayapas-Mataje estuary on the Colombian international border at the northern end of the province, and Muisne estuary on the Manabi provincial border at the southern end of the province (Fig. 1). The two largest estuaries in Manabi Province are Cojimies estuary on the Esmeraldas provincial border at the northern end of the province, and Chone estuary located in central Manabi near the city of Bahia de Caraquez. These four estuaries are home to the majority of Ecuador's northern mangrove forests (Bodero, 1993).

A minimum of one longitudinal data point per decade for each of the four estuaries was selected based on data availability. The earliest longitudinal data-point was selected to be before or very close to the first arrival of commercial shrimp farming. The Muisne estuarine land use was established for 1971, 1986, 1998 and 2005. The first commercial shrimp ponds appeared after 1971 but before 1986 in Muisne. The Cayapas-Mataje estuarine land use was established for 1986, 1991, 1997, 2001 and 2008. The first shrimp farms appeared around 1986 in

Cayapas-Mataje. The Cojimies estuarine land use was established for 1971, 1986, 1998 and 2006. The first commercial shrimp ponds appeared after 1971 but before 1986 in Cojimies. The Chone estuarine land use was established for 1968, 1977, 1984, 1986, 1991, 1998, 2004 and 2006. The first shrimp farms appeared before 1977 and after 1968 in Chone estuary.



Fig. 1. Estuarine study sites in Esmeraldas and Manabi Provinces, Ecuador

The spatial extent of each estuary was determined from field survey and available topographic data. Once delineated, each estuary was then sub-divided in 30 m square pixels. Land use was then assigned to each pixel for each longitudinal data point by digitization of paper maps and remotely sensed data. Land use in each estuary, before 1980, was derived mainly from 1:25,000 topographic maps and from 1:60,000 aerial photographs. Land use from 1980 to 2000 was derived from Landsat 4 or 5. All land use after 2000 was derived from ASTER with the exception of 2005 in Muisne and 1991 in Chone when Landsat 7 was utilized. Each pixel in each estuary at each time-period was classified as mangrove forest, shrimp farming activity, or other. The other category usually consisted of water with other minor areas of mud, salt flats, and non-mangrove vegetation. Change rates and displacement of mangroves were calculated for each 30 m pixel.

Results and Discussion

The area of Cayapas-Mataje estuary was calculated to be 50714 ha. During the study period, mangrove decreased only slightly from 35118 ha pre-aquaculture to a low of 32344 ha in 2008 (Fig. 2). Shrimp farms increased from 27 ha in 1986 to a maximum area of 2800 ha in 2008. Cayapas-Mataje had the least mangrove loss and the least growth in shrimp farms among all estuaries during the study period. This is likely due to the preserved status of most of the area as a national park or mangrove reserve and RAMSAR site as well as other factors relating to political instability leading to a lack of foreign investment, the relative isolation of the region (roads only arrived in the last decade), and the local reliance on the mangrove forests for food and livelihood (Ocampo-Thomason, 2006; Veach, 1996). During a 2009 field trip to the region, all the shrimp farms in Cayapas-Mataje noted in this analysis had been abandoned.

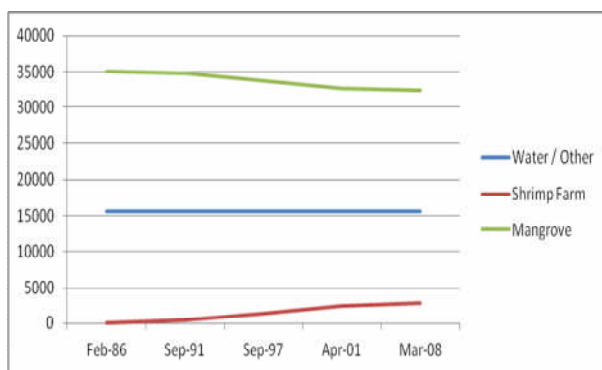


Fig. 2. Cayapas-Mataje estuarine LULC from February 1986 to March 2008

The area of Muisne estuary was calculated to be 6662 ha. During the study period, mangrove decreased from 3398 ha pre-aquaculture to a low of 999 ha in 1998 (Fig. 3). By 2005, mangrove had showed a slight increase from the lowest level to 1065 ha. Shrimp farms increased from zero area in 1971 to a maximum area of 3222 ha in 1998. By 2005, the growth of shrimp farms had ceased and a slight decline was occurring. At its maximum, shrimp farming in Muisne actually covered almost as much of the estuary as all other land uses combined. Mangrove cover was 29% of its pre-aquaculture level at its lowest point and had recovered to 31% of its pre-aquaculture total by 2005.

maximum, shrimp farming in Cojimies actually covered more of the estuary than all other land uses combined. Mangrove cover was 19% of its pre-aquaculture level at its lowest point and had recovered to 32% of its pre-aquaculture total by 2005.

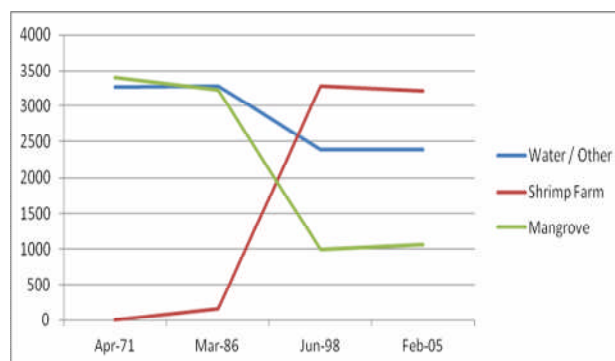


Fig. 3. Muisne estuarine LULC from April 1971 to February 2005

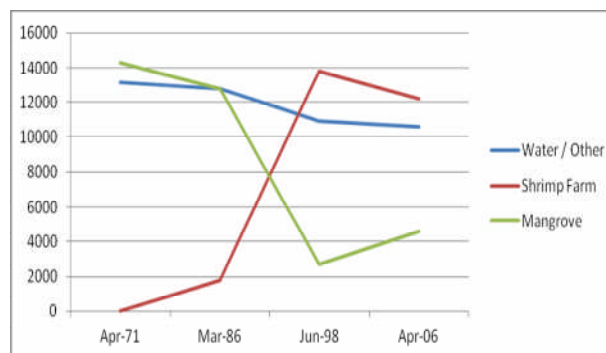


Fig. 4. Cojimies estuarine LULC from April 1971 to April 2006

The area of Chone estuary was calculated to be 8744 ha. During the study period, mangrove decreased from 4238 ha pre-aquaculture to a low of 1036 ha in 2001 (Fig. 5). By 2006, mangrove had showed a slight increase from the lowest level to 1464 ha. Shrimp farms increased from zero area in 1968 to a maximum area of 5192 ha in 2006. By 1998, the growth of shrimp farms had essentially ceased with only small fluctuations in area. At its maximum, shrimp farming in Chone actually covered more of the estuary than all other land uses combined. Mangrove cover was 24% of its pre-aquaculture level at its lowest point and had recovered to 35% of its pre-aquaculture total by 2006.

Conclusion

The area of Cojimies estuary was calculated to be 27410 ha. During the study period, mangrove decreased from 14269 ha pre-aquaculture to a low of 2679 ha in 1998 (Fig. 4). By 2008, mangrove had showed a slight increase from the lowest level to 4597 ha. Shrimp farms increased from zero area in 1971 to a maximum area of 13815 ha in 1998. By 2008, the growth of shrimp farms had ceased and a slight decline was occurring. At its

In total, the four major estuaries of Manabi and Esmeraldas provinces in northern Ecuador lost about 20950 ha of mangrove forests from the first arrival of aquaculture to the time of maximum deforestation, and about 17980 ha from the first arrival of aquaculture to the most current survey. This was a 37% decrease in mangrove cover to the point of maximum mangrove loss

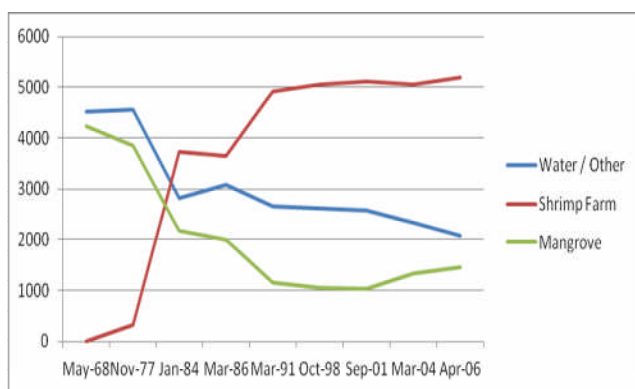


Fig. 5. Chone estuarine LULC from May 1968 to April 2006

and a 32% loss in mangrove cover to the most current data point. Excluding the ecological reserve of Cayapas-Mataje, mangrove loss in the three remaining estuaries actually totaled 83% to maximum loss around 2000, and 69% to the most current survey date. This resulted in only 17-31% of the original forest remaining in these estuaries. Commercial shrimp farms grew to a total of 71811 ha during the study period at all sites from a start point of close to zero. Shrimp farms did slightly diminish by the latest survey in each estuary but not enough to make a significant difference to any of the calculated values. Excluding the ecological reserve of Cayapas-Mataje, shrimp farms now occupy more estuarine area than all other uses combined including the surface area of water in estuaries of northern Ecuador. During the 2000s, mangrove forests appeared to be slowly re-growing in three of the four estuaries, and the losses in the fourth estuary have relatively stabilized. Considering the time required for a mangrove forest to reach maturity, another LULC survey will need to be conducted from 2015-2020 to establish that mangrove forests in these estuaries are truly recovering and are not merely a decadal anomaly.

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