

Ecological linkages in a Caribbean estuary bay

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Supplement. Ecological linkages in a Caribbean estuary bay

The supplement contains the following items:

- **Text S1.** Retrieval and treatment of environmental data
- **Text S2.** Biological observations during research cruises
- **Text S3.** Collection of manatee data
- **Table S1.** Composition of landed species in Amatique Bay analyzed in this study
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Text S1. Collection and analysis of meteorological data

To study environmental variability we extracted time-series of precipitation, air temperature, sea surface temperature, chlorophyll *a* concentration and run-off from open internet sources as either historical records measured in the area or as satellite-derived data. Monthly precipitation (Pre, mm) from 1985 to 2010, monthly average air temperature (T_{air} , °C) from 1990 to 2010, wind direction from 2006-2010 and wind speed (Wind, km/h) from 1990-2010 and forecast tide data for the random years 2001, 2006 and 2008 were obtained from the national meteorological institute (INSIVUMEH 2012), using data from the Puerto Barrios, Izabal meteorological station, located near the Bay. Months of low wind stress, classified as "calm" or "variable" at the source, were not considered in calculation because the mean direction was not available. Average and dispersion of wind direction was calculated using Lund & Agostinelli (2014). Forecasted tide data were available as day maxima and minima (m). The tidal amplitude was calculated as the difference between daily maximum and minimum, and averaged on a monthly basis. Average monthly sea-surface temperature (SST, °C) from July 1985 to December 2009 and from 2003-2010 was derived from satellite imagery processed by NOAA/NASA's AVHRR Oceans Pathfinder global and MODIS/Aqua mission (Halpern et al. 2001). The former series was employed to study meteorological correlations as historical records span over a longer time period but limited to 2009. The later series was related to fish landing data in the period 2006-2010. Day length (sunlight duration, min) was calculated using NOAA's solar calculation algorithm for the Puerto Barrios geographical coordinates at 15° 44' N and 89° 33' (NOAA 2012).

Estimates of monthly run-off were derived by Burke & Sugg (2006) using a model for the Sarstún and Dulce rivers that accounts for the physical environment (elevation, slope, soils, precipitation, and land cover) in the drainage basin for the years 2003-2004.

Chlorophyll *a* concentration (Chl, mg m⁻³) from July 2002 to 2010 was obtained through NASA's Giovanni Ocean Color Radiometry data product visualization using SeaWiFS and MODIS databases. The temporal and spatial resolutions were 8 days and 4 Km respectively calculating averages for the polygon at latitudes (15.618, 15.984) and longitudes (-88.936, -88.437) inside the Bay. There is a lack of field data to ground truth satellite measurements in Amatique and this is of concern as remote chlorophyll *a* measurements can be biased (Dierssen 2010). Therefore, we attempted to compare and relate remote measurements of chlorophyll *a* in the bay with the turbidity measurements performed with a Secchi-disk and the concentrations of nutrients measured at the outlet of Lake Izabal by Quintana-Rizzo & Machuca (2008).

Text S2. Biological observations during research cruises

In 2008, four research cruises were performed by Ixquiac-Cabrera et al. (2008) in Amatique Bay to record prevailing oceanographic conditions and fish abundance. A 12 m fiberglass boat with a 150 Hp engine and a commercial trawl was employed. The trawl was 18 m long with a 14 m headline and mesh size of 1³/₄". The trawl was recovered by hand. Eleven stations were covered across the bay, with depths ranging between 5-25 m. The gear was towed for 30 min at a speed of 3 knots. All organisms were frozen for posterior identification in the lab. The swept area method was employed to estimate species abundances (Sparre & Venema 1998, Ixquiac-Cabrera et al. 2008). We employed data gathered in February and August to represent environmental conditions and species distributions during the dry and wet seasons respectively.

Text S3. Collection of manatee data

To estimate manatee abundance, aerial surveys were performed by Quintana-Rizzo & Machuca (2008) using the aerial survey replicate count methodology developed by Lefebvre & Kochman (1991). This method requires that after manatees have been spotted, the plane must be maneuvered back to the site of sighting, at a lower altitude and speed to confirm observations and perform recounts. An experienced primary observer (>100 hours) sat beside the pilot and a secondary observer (26 hours) sat behind allowing for continuous search on both sides of the plane. The aerial surveys were performed between 9 AM and 10 AM to maximize visibility and on a Beaufort wind force scale of 0-2. Average altitude ranged between 152-213 m and average speed was 160 km/h. The survey track was set about 500 m from the shoreline from Lake Izabal, to Punta de Manabique (Fig. 8 in the main article).

Table S1. List of fished species and birds analyzed in this study (and abbreviations). Sources: A. Estimates from dories and skiffs landings based on fishers anecdotal information in 1998 (Heyman & Graham 2000, Heyman & Granados-Dieseldorff 2012); B. Official shrimp trawler landings (DIPESCA, Guatemala); C. bottom-trawl research cruises (Ixquiac-Cabrera et al. 2008); D. Own data, E. Shorebird sightings (Eisermann 2009); F. manatee counts (Quintana-Rizzo & Machuca 2008). The last column suggest a preliminary classification of these species into functional groups based on results from Amatique.

Class	Common name or group of species analysed	Scientific name	Sources	Presumed functional group in Amatique
Malacostraca	"Shrimp" group (Shrp, main species)	<i>Litopenaeus schmitti</i> , <i>Farfantepenaeus notialis</i> <i>Xiphopenaeus kroyeri</i>	A, B, C	Estuarine dependent
Cephalopoda	Atlantic brief squid (Squid)	<i>Lolliguncula brevis</i>	B,C	Marine transient
Actinopterygii	Crevalle jack (Jack)	<i>Caranx hippos</i>	A	Marine transient
	Spanish mackerel (Mack)	<i>Scomberomorus maculatus</i>	A	Marine transient
	Common snook (Snook)	<i>Centropomus undecimalis</i>	A, D	Diadromous
	Tarpon (Tarpon)	<i>Melagops atlanticus</i>	A	Marine & fresh water
	Barracuda (Barra)	<i>Sphyraena picudilla</i>	A	Marine transient
	Goliath grouper (Group)	<i>Epinephelus itajara</i>	A	Marine transient
	Mutton snapper (Msnap)	<i>Lutjanus analis</i>	A	Marine transient
	Lane snapper (Lsnap)	<i>Lutjanus synagris</i>	A, B,C, D	Marine & estuarine
	Anchovies (Anch)	<i>Anchoa</i> spp <i>A.spinifer</i> , <i>A. cayorum</i> , <i>A. colonensis</i> and <i>Anchoviella elongata</i>	A C	Marine
	"Catfishes" (Bagre)			
	Gafftopsail catfish	<i>Bagre marinus</i>	A, B, D	Marine & estuarine
	Mayan catfish	<i>Ariopsis assimilis</i>	B, C	Marine

	"Mojarras" mixed group of Gerridae (Gerr)	Mainly <i>Diapterus rhombeus</i> and <i>Eugerres plumieri</i>	A	Estuarine & freshwater
	Caitipa mojarra	<i>Diapterus rhombeus</i>	C	Estuarine
	Striped mojarra	<i>Eugerres plumieri</i>	C	Freshwater-estuarine
	Blackbelt cichlid (Cich)	<i>Paraneetroplus maculicauda</i>	A	Freshwater transient
	"Cubera" snappers (Csnap)	Common misidentification		
	Cubera snapper	<i>Lutjanus cyanopterus</i>	A	Marine transient
	Grey snapper	<i>Lutjanus griseus</i>	A, D	Marine & estuarine
	"Corvina": Mixed group of Scianidae and Haemulidae	probably <i>Protosciaena bathytatos</i> and <i>Pomadasys corvinaeformis</i>	B,C	Probably marine
Aves	Black-bellied Plover (Pb)	<i>Pluvialis squatarola</i>	E	Group 1: Long migratory - short stopovers in Amatique during dry season
	Semipalmated Plover (Ps)	<i>Charadrius semipalmatus</i>	E	
	Spotted Sandpiper (Ss)	<i>Actitis macularius</i>	E	
	Whimbrel (Wh)	<i>Numenius phaeopus</i>	E	
	Least Sandpiper (Sl)	<i>Calidris minutilla</i>	E	Group 2: Long migratory with longer stopovers at late rainy season.
	Black-necked Stilt (Stb)	<i>Himantopus mexicanus</i>	E	
	Sanderling (S)	<i>Calidris alba</i>	E	
	Semipalmated Sandpiper (Sse)	<i>Calidris pusilla</i>	E	
	Collared Plover (Pc)	<i>Charadrius collaris</i>	E	Group 3: Migratory with longer stopovers at late rainy season. Pc breeds in Amatique
	Western Sandpiper (Sw)	<i>Calidris mauri</i>	E	
	White-rumped Sandpiper (Swr)	<i>Calidris fuscicollis</i>	E	
Mammalia	Manatee	<i>Trichechus manatus</i>	F	Freshwater migrations

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