A SUSTAINABLE SHRIMP MARICULTURE INDUSTRY FOR ECUADOR

Edited by Stephen Olsen and Luis Arriaga

International Coastal Resources Management Project

The University of Rhode Island

Status of Coastal Water Quality in Ecuador

Estado de la Calidad del Agua Costera en el Ecuador.

Lucía Solórzano

Resumen

El desarrollo industrial y técnico en el Ecuador ha causado la contaminación de algunos sectores de la costa ecuatoriana. Según algunos estudios, las áreas más afectadas son el Río Guayas, el Estero Salado, el Río Esmeraldas y los lugares próximos a las industrias pesqueras.

En el río Guayas, los niveles en la superficie de oxígeno disuelto y DBO fluctúan entre 2,7 a 4,5 mg O_2/l y entre 0,65 a 2,88 mg O_2/1, respectivamente. Los valores de fosfato, nitrato y nitrógeno orgánico disuelto en superficie (1 m profundidad) tienen los siguientes rangos: 2,0 a 6,0 ug-at PO_4P/l; 10 a 50 ug-at NO_3N/l; y, 40,0 a 60,0 ug-at NO_3N/l, respectivamente. El cobre está entre 38,92 y 94,52 ug/l; el hierro entre 131,85 y 414,80 ug/l; y, el cadmio entre 1,0 y 14,5 ug/kg. Las investigaciones de mercurio en los sedimentos indica valores entre 1.532 y 3.250 ug/kg, peso seco. Los niveles de hidrocarburos de petróleo son menores que 2 ug/l.

En el Estero Salado, los niveles de oxígeno superficial fluctúan entre 3,0 y 4,7 mg O^2/l. Los valores superficiales (1 m) de fosfato, nitrato y amonio están entre 2,8 y 33,4 ug-at PO_4-P/l; 3,8 y 18,5 ug-at NO_3N/l; y, 5,2 y 114,2 ug-at NH_4-N/l, respectivamente. Los valores de cobre, cadmio, hierro y mercurio en los sedimentos varían entre 65,0 y 799,5 mg/kg (peso seco), o,5 y 3,2 ug/kg (peso seco), 0,56 y 2,93 g/kg (peso seco), y 190 y 4.900 ug/kg (peso seco), respectivamente. Los niveles hidrocarburos de petróleo en la superficie (1 m) son similares a los del río Guayas, excepto en los lugares donde se los suministra a los buques comerciales. En un proyecto futuro se efectuarán determinaciones de niveles de cobre, cadmio y mercurio, de las fuentes para las masas de agua y de la vías de reducción.

Las masas de agua mencionadas anteriormente son eutróficas. Las concentraciones de cobre y cadmio están sobre los límites considerados inócuos para los organismos acuáticos. No hay contaminación significativa por hidrocarburos de petróleo.

Summary

The industrial and technical development of Ecuador has caused the contamination of some sections of the Ecuadorian coastal sea. According to some studies, the more affected areas are the Guayas River, the Estero Salado, Esmeraldas River and the sections near the fishing industries.

In the Guayas River, the surface levels of dissolved oxygen and biochemical oxygen demand (BOD) fluctuate between 2.7 to 4.7 mg 0_2/l and 0.65 to 2.88 mg 0_2/l, respectively. The surface (1m depth) phosphate, nitrate and dissolved organic nitrogen values range between 2.0 to 4.0 µg-at PO_4 P/1, 10 to 50 µg-at NO_3 N/l and 40.0 to 60.0 µg-at DON N/l, respectively. Surface water concentrations of copper range between 36.92 and 94.52 µg/l, iron between 131.85 and 515.80 µg/l and cadmium between 0.1 and 14.5 µg/l. The research on mercury in the sediment has yielded values between 1.53 and 3.25 µg/kg of dry weight. Petroleum hydrocarbon levels are lower than 2 µg/l.

In the Estero Salado, the surface levels of oxygen fluctuate between 3.0 and 4.7mg 0_2/1. The surface (1m) values of phosphate, nitrate and dissolved organic nitrogen are between 2.8 to 33.4 µg-at. PO4-P/l, 5 to 10 µg-at, NO3-N/1, and 6.7 to 72.7 µg-at. DON-N/1, respectively. The copper, cadmium, iron and mercury values in the sediment vary between 65.0 and 799.5 mg/kg (dry weight), 0.5 and 3.2 µg/kg (dry weight), 0.56-2.93 g/kg (dry weight) and 190 and 4,900 µg/kg (dry weight), respectively. The levels of petroleum hydrocarbon in the surface (lm) are similar to those in the Guayas River, except in the places where the commercial ships are supplied. Determining copper, cadmium and mercury levels and sources in the water masses, and means of reduction will be undertaken in a future research project.

The water masses mentioned above are eutrophic. The concentrations of copper and cadmium are over the limit considered as innocuous for aquatic organisms. There is no significant contamination by petroleum hydrocarbons.

Introduction

The economic growth of Ecuador between 1970 and 1980, together with industrial and technological development and rapid population increase produced serious ecological effects, particularly in some sections of the costal sea. The application of detergents for domestic use, heavy metals in industry, insecticides in agriculture and petroleum hydrocarbons for transportation and other uses, greatly increased. The effects of these substances on the environment prompted the scientific community to investigate the levels of these materials in the water bodies that receive domestic and industrial waste from the largest population centers of the country. The Ecuadorian government, responding to requests from the institutions conducting the marine contamination studies, partially financed some of the research projects. The scientific findings clearly justify the need to maintain permanent environmental monitoring programs in at least some of the areas where there are conflicting uses of resources.

Background

Geography

Ecuador straddles the equator and has an area of 283,562 km^2. It has a population of roughly 8 million people (1982 census).

The Ecuadorian coastal region is located between the shoreline and the external slopes of the occidental mountains that extend to a height of 1800 meters. This coastal area is generally 100 to 200 km wide, except in the adjacent part of the Guayaquil Gulf, where it is only from 20 to 30 km (Vinueza, 1984). The coastline is 1,300 km long, including all its irregularities, and 560 km in a straight line. In this region there are river basins that are the main recipients of the domestic and industrial discharges from the towns located there.

The areas below are the most affected by contaminating agents from various sources. These areas are classified (Solorzano, 1981) according to degree of contamination:

Area	Classification	Comments
Guayas River	severe	domestic and industrial debris, discharges from Guayaquil and towns nearby located in the basin; agrochemical residues from Guayas River effluents
Estero Salado	serious	domestic and industrial debris; discharges from the city of Guayaquil and oil terminal
Esmeraldas River	moderate	effluents mainly from refinery and carried by Tiaone River
Sectors adjacent to fisheries, beaches, etc.	moderate	industrial discharge on beaches, etc.

Other areas that require special attention, like the mangrove zone, particularly on the Gulf of Guayaquil, Manta (port, fishing industries, etc.) port areas including oil terminals like La Libertad and Puerto Bolivar, etc., are not listed because there is not enough information about the contamination levels.

In this work we will only refer to water bodies that surround the city of Guayaquil.

The Guayas River

The Guayas River travels a distance of 50 km before reaching the Gulf of Guayaquil. It is formed by the Daule and Babahoyo Rivers. Like its tributaries, the Guayas River is affected by the tide. The Babahoyo has four main tributaries: Vinces, Catarama-Zapotal, San Raulo and Yaguachi. These rivers are located in the northeast and southeast sectors of the lower basin. The Yaguachi River is the most meridional of the Babahoyo River tributaries. It is formed by the Chanchan and Chimbo Rivers, and also receives the water of the Milagro River. It is the Yaguachi River that shows the most significant changes in water quality of all the rivers that form the Guayas Basin. The Vinces River, that changes its name to Baba in its upper course, has its origins near the city of Santo Domingo. This river has numerous tributaries. The Daule River is the second most important tributary of the Guayas River and drains the western part of the basin (Vinueza, 1981). Its main tributaries in that margin are the Pedro Carbo, Colimes, Puca and Congo Rivers (Figure 1).

Sanitary Sewage System of Guayaquil

The city of Guayaquil is located along the Guayas River. It has approximately 1.2 million inhabitants (Dicc, Larouse, 1986) with a projected growth of 4.5 percent for the period of 1981 to 1990. In the year of 1990 Guayaquil's population will be approximately 1.75 million, and 2.72 million by the year 2000.

The total area of the city is 34,700 hectares (ha), of which only 6,100 ha have an adequate sewage system. The existing service reaches only 58 percent of the population. In 1979, 450,000 people in Guayaquil did not have sewers and every year 21,000 more people are added to this number. A large percentage of the non-serviced area is occupied by marginal urban developments and by industries (Empresa Municipal de Alcantarillado de Guayaquil, EMAG, 1980). The city's contaminated waters are emptied, without treatment, into the Guayas River, Daule River and Estero Salado.

Guayaquil has two separate classes of sewers: sanitary and pluvial. The sanitary sewage has a northern and southern division, both of which discharge the waste waters into the El Progreso and Guasmo plants. The main collector of the northern systems is 10.5 km long and serves 2,500 ha with an approximate population of 250,000 inhabitants. This collector starts in the Prosperina Section of Guayaquil and continues to the preliminary treatment at the Progreso plant, then empties into the Daule

River near the juncture of the Babahoyo River. The main collector of the southern systems is 7.5 km long and serves 1,300 ha, with an approximate population of 250,000 inhabitants. The southern collector ends in the treatment station of El Guasmo and the sewer water is discharged later through sub-aquatic piping in the Guayas River (Figure 2).

Water Quality in the Guayas River

The population explosion, as well as the rapid industrial growth of Guayaquil have increased the volume of residual waters far beyond the capacity of existing infrastructure services, thereby altering the chemical-physical conditions of the water bodies that receive them. These alterations are shown in some of the parameters detailed below.

Salinity

The salinity at the surface (1m) of the Guayas River varies continuously, but higher salinity values are always in the river outlet due to the exchange with the waters of the Gulf of Guayaquil. The salinity range is within 1 percent in the Daule River to 30 percent near the Gulf. During the rainy season, the surface salinity (1m) decreases along the river.

Dissolved Oxygen

According to Valencia (1980), the dissolved oxygen values are between 2.7 and 4.7 mg 0_2/l oxygen, with the higher values found in the area adjacent to the Babahoyo River, far from the influence of populated areas. On the other hand, in the Daule River where the debris of Guayaquil is discharged, the oxygen levels decrease to less than 2.7 mg O_2/1.

Biochemical Demand of Oxygen

The analyses performed by EMAG (1979) shows values of biochemical oxygen demand (BOD) from 0.65 and 2.88 mg/l, reaching higher levels in places where domestic waste discharges occur.

Bacteria

The domestic and industrial waste waters of Guayaquil discharged into the Daule and Guayas Rivers produce high levels of bacterial contamination, resulting in a decrease in the rivers' oxygen content, high BOD and increased concentrations of inorganic and organic nutrients that have direct effects on the ecosystems of both rivers.

Fortunately, after treatment at La Toma treatment facilities, the drinking water supplied to the Guayaquil population is of excellent quality, according to the Sanitary Microbiology Department of the National Institute of Hygiene and Tropical Medicine "Leopoldo Izquieta Perez" of Guayaquil (Table 1).

Nutrients

The distribution of surface (1 m) nutrients in the Guayas River is irregular, depending upon tides and the volume of debris discharged into the river. Valencia (1980) found that surface phosphate values fluctuated between 2.0 to 4.0 ug-at PO_4-P/1, except that in the area adjacent to the Progreso station, the concentration of phosphate increased by up to 50 percent. The author also reported similar distributions of nitrate. The levels of this nutrient were quite high, fluctuating between 10.0 and 50.0 µg-at. NO_3-N/1, with the lowest levels detected in the southern part of Guayaquil and off Santay Island, and the highest values measured near the Progreso Station, where the sewage water is discharged (Figure 2). Dissolved organic nitrogen levels (DON) were measured at 40.0 and 60.0 µg-at. NO_3-N/1, and were similarly distributed.

Metals

According to Perez (work in preparation) the quantities of copper, iron and cadmium on the surface (1m) of the Babahoyo, Daule and Guayas Rivers are variable, fluctuating between 36.92-94.52 µg/1, 131.85-515.80µg/l, and 0.05-14.5 µg/l, respectively. In the Guayas River, copper as well as iron tend to decrease inversely to salinity. In Babahoyo River, the levels of both metals are slightly higher than those of the Guayas River. Cadmium is found in almost all sampling sites of the Guayas River, with concentrations between a minimum value of 1.9 µg/l and a maximum of 10.4 µg/l. In the Daule River, cadmium levels are under 1 µg/l, except in those samples taken in the vicinity of the domestic sewage effluent, (Progreso Station), where values of 11.4 and 14.5 µg/l have been recorded.

Mercury

Mercury levels in the sediment of the Guayas River vary from 1.53 to 3.257 µg/kg of dry weight, (Chalen de Padilla, 1986). Similar results were obtained by the same author in the Jambeli Channel located in the inner estuary of the Gulf of Guayaquil.

Petroleum Hydrocarbons

The amount of dissolved hydrocarbons and/or coloids found by the author (1986) in the lower courses of the Babahoyo, Daule and Guayas Rivers varied between 0.10 µg/l and 2.80 µg/l. The highest value was recorded in a sample taken in the Guayas River after an oil spill from a commercial vessel.

Pesticides

Pesticide research has recently been conducted in some of the rivers that form the basin of the Guayas River. The pesticides investigated were DDT, Aldrin, Chlordane, Mirex, Lindane, Opade OP, Dieldrin and Heptachlore. Traces of the pesticides were detected only at the beginning of the rainy season (information provided by Agricultural Health Laboratories, Ministry of Agriculture, Ecuador).

Estero Salado

Estero Salado is a sea inlet that reaches from Canal del Morro on the south, to Guayaquil on the north. Its depth varies from 5 to 10 meters. The daily tides are approximately 3m high in Canal del Morro, 3.5m in Puerto Nuevo in Guayaquil, and 4m in the vicinity of the State University of Guayaquil. The current of the tides reach a speed higher than 100m/sec (Murray, Siripong and Santoro, 1973), and the accumulation of sediments is scarce, except in small sections of Estero Salado that are protected by mangroves. The tide currents also cause strong vertical and horizontal mixing that tends to homogenize the physical and chemical properties of the waters.

Water Quality in the Estero Salado

According to Arriaga (1976), the sewage effluents enter Estero Salado at a rate of approximately 100 l/sec, which is equivalent to 81,640 m^3 in 24 hours. If we take into account the bacteria, inorganic nutrients and soluble organic nutrients, metals, petroleum hydrocarbons, and other organic components that are present in waste water, we will better understand the alteration that occurs to the physical/chemical properties of the Estero.

Salinity

The salinity of the Estero varies between 22 and 31 percent (Pesantes, 1975). During almost all the year, the Estero has greater than 25 percent salinity, with only slight changes observed between Canal del Morro and near to Guayaquil. In areas adjacent to this city, the salinity is influenced by the domestic effluents, and especially by precipitation. These changes can be significant from one year to the other, depending on the intensity of the rains during the rainy season.

Dissolved Oxygen

The domestic discharge of 400,000 inhabitants of Guayaquil deposited into the Estero Salado is equivalent to a biochemical oxygen demand of 10,000 m.t./year, which greatly affects the concentration of dissolved oxygen. From Canal del Morro to nearby places of Guayaquil, the surface levels of oxygen fluctuate between 3.0 and 4.7 mg 0_2/l.

The concentration at the surface tends to be slightly higher than at 1 meter above the bottom. The author and Viteri (in press) found surface levels (1m) of 3.13 ml 0_2/l and bottom values of 1.79 to 2.33 mg 0_2/l, in two stations adjacent to the city of Guayaquil.

Bacteria

Research by Reyes (personal communication, 1976) indicates that, water contamination of the Estero was quite low. In contrast, microbiological analysis by Guzman (personal communication) showed the increase of contamination that occurred during the following decade.

Nutrients

In the section of Estero Salado that surrounds the city of Guayaquil, Ayarza (in press) found surface phosphate values that varied between 4.9 and 33.4 µg-at P-PO/1 and ammonia levels of 5.2 to 114.2 µg-at NH_4-N/1 (Table 2). The section that showed the highest levels corresponded to the area adjacent to two residential areas of the city of Guayaquil (Urdesa and Miraflores).

Valencia (1980) found phosphate levels higher than 4.0 µg-at PO_4-P/1 in waters near the gate at the Guayas River-Estero Salado (Figure 3), and in waters near the main avenues of Guayaquil. Ormaza in 1986 (work in preparation) found phosphate levels that fluctuated between 1.6 and 2.85 µg-at. PO_4-P/1 along the Estero Salado from Guayaquil to Canal del Morro.

Valencia (1980) reports surface values of nitrate from 5.0 to 10.0 µg-at. NO_3-N/1 in waters adjacent to the gate at the Guayas River-Estero Salado (see Figure 3). Levels lower than 5.0 µg-at. NO_3-

N/1 in other stations located between 5 de Junio Bridge and Portete Bridge were found by the author and Viteri (in press). Ormaza (work in preparation) recorded nitrate values between 8.4 and 18.5 µg/l in the area between Canal del Morro and Guayaquil. The highest value was found at buoy 50, near some shrimp farms. The values of soluble organic phosphate and soluble organic nitrogen found by the author were between 0.05 and 1.09 µg-at. PO_4-P/1 and 6.7 and 72.7 µg-at. NO_3-N/1, respectively.

Metals

The sediment of one section of Estero Salado, located between Portete and 5 de Junio Bridge, was analyzed for copper, cadmium and iron content. The results obtained show a copper range between 65.0 and 799.5 mg/kg (dry weight), cadmium between 0.5 and 3.2 u/kg (dry weight), and iron between 0.56 and 2.93 g/kg (dry weight). The higher levels of copper and iron were found in the vicinity of industries, while the maximum cadmium value was found near the center of the city.

Mercury

According to Chalen de Padilla (1986) the sediment of Estero Salado showed mercury values between 190 and 4,900 µg/kg of dry weight, but Ayarza (1987) reports that in some sections of the Estero near the city their samples gave negative results for this metal (Table 3). The author (1986) also found that some samples of bivalves from the same section showed lower levels of mercury than the permissible limit accepted by the FDA of the United States (Table 4).

Petroleum Hydrocarbons

Levels of petroleum hydrocarbons soluble and/or coloids were relatively low in samples taken in the Estero Salado near Guayaquil. In fact, samples taken throughout the Estero Salado showed values lower than 2 µg/l, except in those taken near oil spillages from commercial vessels (Solorzano, 1986). However, there are found extremely high values in Estero del Muerto, a section of the Estero Salado where commercial vessels take on oil (Valencia, 1986).

Conclusions

The ecology of the aquatic systems that surround the city of Guayaquil has been affected by domestic as well as industrial discharges. Current research indicates that contamination is caused predominantly by domestic waste. The eutrophication observed in the Guayas River, as well as in the Estero Salado, indicates that the growing city has a great impact on the marine environment. The circulatory processes in both the Guayas River and the Estero Salado mix the waters vertically and horizontally so that the chemical and physical parameters of the surface and the bottom are similar and there is less change to anoxic conditions in deep waters. The nutrient levels in the section adjacent to Guayaquil, are higher than in the rest of the Estero Salado, while in the Guayas River, the higher levels of nutrients are observed near the sewage outfalls.

Heavy metals are also of concern, particularly copper, cadmium and mercury. The copper concentration in the aquatic systems studied has a relative importance and is over the limit of 10 µg/l considered innocuous for aquatic species (Ketchum, 1975), though part of this copper may be merged to organic material present in the water, inhibiting its toxicity to marine organisms. Research with this contaminant is part of a project to be developed in the near future in the Contamination Laboratories of Institute Nacional de Pesca. Presently, the origin of such high levels of copper is unknown, but the possibility that such levels could be the results of continental erosion processes has not been rejected.

Cadmium levels throughout almost all places sampled, in Estero Salado as well as Guayas River, are variable, but higher levels are associated with the city of Guayaquil. The level considered innocuous to aquatic species is 10 µg/l (Ketchum, 1975), and some values recorded in the water masses that surround

Guayaquil justify a more detailed study of cadmium distribution and concentration to determine its source and develop ways of controlling its discharge.

The sediment of the inner estuary of the Gulf of Guayaquil, including the sediment of the Guayas River, lower courses of the Babahoyo and Daule Rivers and of all the Estero Salado, showed significant mercury contamination, the exact source of which is unknown. However, gold extraction industries in the coastal section near the Jambeli Channel use approximately two tons of mercury per year, and could be contaminating the small rivers that empty into the channel. This would explain the absence of mercury in sediment samples and organisms taken in other sections near Guayaquil (Solorzano, 1986). Non-published data produced by Chalen de Padilla from migratory fish, including tuna and shark specimens captured in Ecuadorian coastal waters also show low levels of mercury.

Both dissolved petroleum hydrocarbons and/or coloids of the Guayas River, as well as those of the Estero Salado, were found at levels lower than 2 μg/l, which suggests the absence of contamination due to petroleum hydrocarbons.

Table 1
Treated and non-treated waters from La Toma treatment station in 1984

	Untreated water			Treated water		
Month	Plate Count	Coliforms NMP per 100 ML		Plate Count	Membrane filtered bacterial coliform colonies per 100 ML	
		Total	Fecal		Total	Fecal
January	13,000	1,300	790	10	0	0
February	150,000	3,400	2,700	0	0	0
March	190,000	3,500	700	0	0	0
April	40,000	200	90	5	0	0
May	80,000	330	170	10	0	0
June	20,000	1,100	700	30	0	0
July	30,000	2,100	950	5	0	0
August	20,000	2,400	790	20	0	0
September	20,000	140	80	0	0	0
October	25,000	490	230	10	0	0
November	30,000	1,100	790	0	0	0
December	20,000	330	130	10	0	0

Source: Teresa de Guzman, Departamento de Microbiologia , National Institute of Hygiene and Tropical Medicine.Unpublished data.

Table 2
Nutrients in Estero Salado, section adjacent to Guayaquil between 5 de Junio and Portete Bridges.

Sampling site		NH4-N ug-at/l	PO_4-P ug-at/l
5 de Junio	1m	26.7	14.46
	10m	24.2	8.80
Empacadora	1m	21.4	24.80
	8m	16.8	7.01
San Eduardo	1m	9.6	9.41
	6m	16.6	6.06
Pte. Portete	1m	1.8	7.28
	10m	5.2	4.48
Salitral	1m	4.0	6.18
	10m	6.2	4.57
Fertisa	1m	10.2	4.92
	10m	7.2	5.11
C.C.Q.Q.	1m	26.8	15.10
Pte. Urdesa	1m	26.3	15.02
	4m	39.8	9.94
Pte. Alban Borja	Surface	30.2	25.96
Policentro	Surface	16.4	24.76
Parque Urde sa Norte.	Surface	81.2	20.46
Pte. Miraflo res	Surface	114.2	33.40
Frente Si Cafe	Surface	32.8	24.62

Source: Ayarza, in press.

Table 3
Mercury in the sediment of the stations sampled in the secion of Estero Salado adjacent to Guayaquil between 5 de Junio and Portete Bridges

Site	mg/kg dry weight
Pte. 5 de Junio	313
San Eduardo	481
Empacadora	Negative
Puente Portete	685
Salitral	Negative
Fertisa	1,680
Facul.CC.QQ.	Negative
Puente Urdesa	2,980
Puente Alban Borja	376
Puente Miraflores	128
Frenta a "Si Cafe"	1,290

Source: Ayarza, in press.

Table 4
Mercury content in aquatic organisms of Estero Salado, near the city of Guayaquil

Organisms	Weight (grams) with shell	Weight (grams) without shell	Length (mm)	% Moisture
Mytella strigata	0.13	0.46	11.42	76.3
Tagelus (Tagelus) affinis	1.74	1.00	30.70	86.0
	4.24	2.27	33.70	78.9
	2.16	1.33	33.90	78.1
	2.36	1.38	37.60	71.8
	3.09	1.86	39.70	75.4
	3.52	2.14	43.80	74.3
	11.16	6.19	48.20	24.9
	13.80	6.68	50.00	80.9
	8.22	5.02	55.75	82.1
	14.44	8.60	61.40	76.3
	12.91	7.87	67.80	81.4
Mytella guayanensis	0.20	0.10	11.85	61.0
	2.64	0.84	35.3	82.1
	6.25	0.84	48.6	76.8
	8.28	2.43	50.0	79.7
	8.08	2.25	55.1	83.8
	10.43	2.94	61.3	75.8
	12.78	3.35	67.1	84.0
Ostrea calumbiensis	9.53	1.6370	41.5	
	13.98	2.237	47.2	87.2
	15.70	3.478	49.2	88.4
	24.53	2.96	53.7	83.9
	14.39	1.99	55.2	84.8
	16.40	1.36	56.7	96.9
	13.90	2.87	57.2	80.4

Source: Solorzano, 1986.

Figure 1. Scheme of the River Guayas basin.

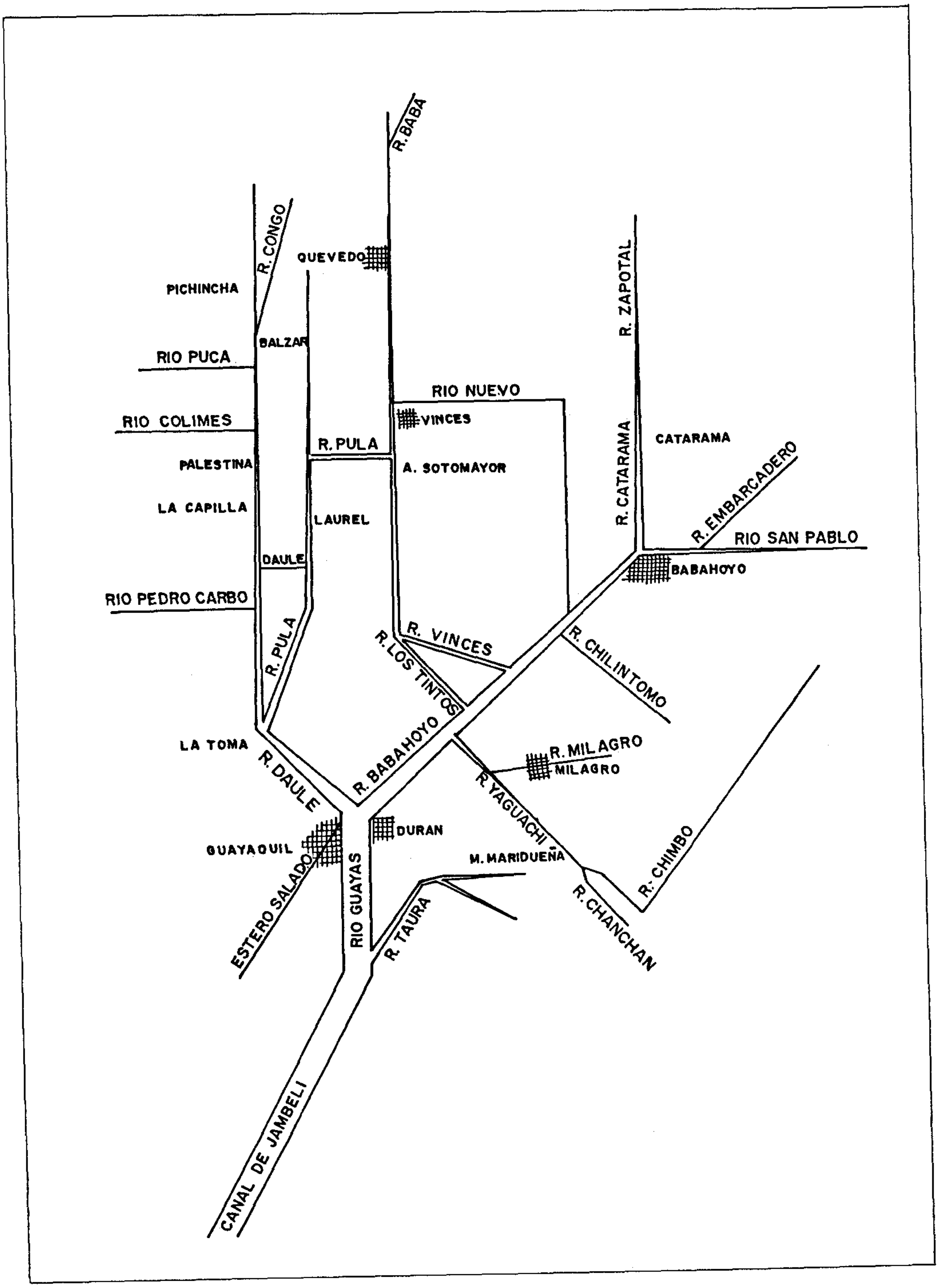


Figure 2. Infrastructure of the basic sewage system of Guayaquil, according to EMAG, 1980.

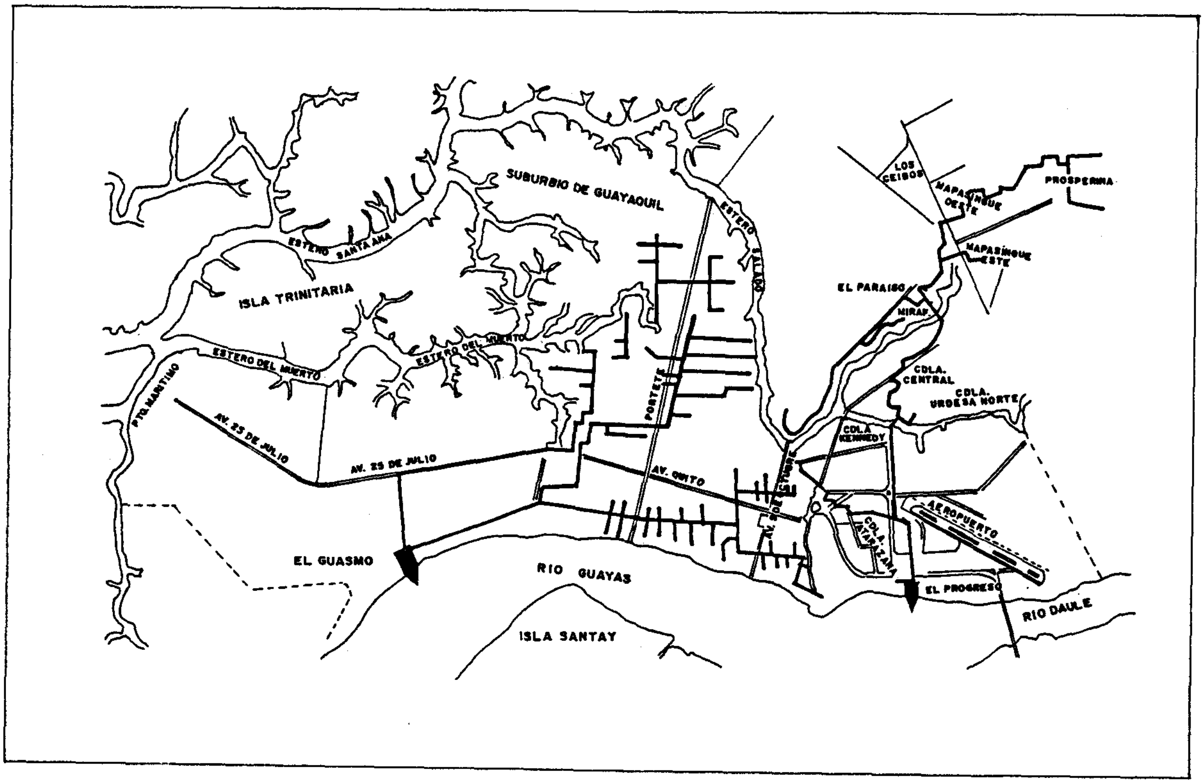
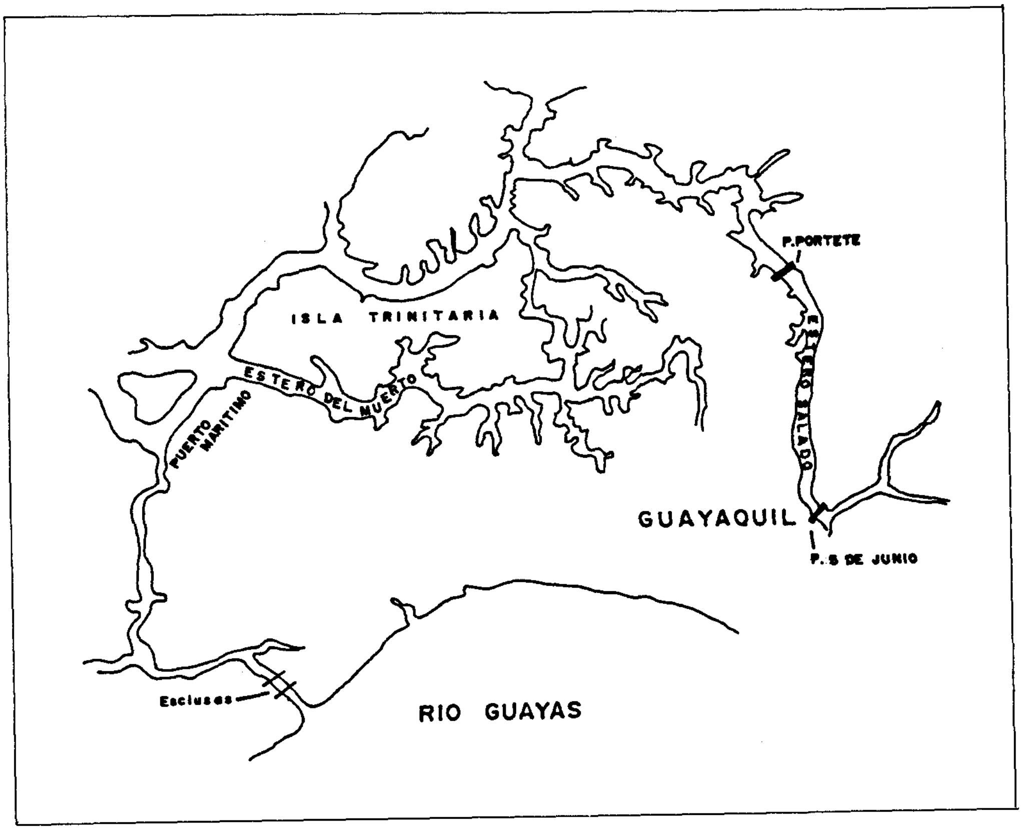


Figure 3. Urban section of the Estero Salado.



References

Arriaga, M. Luis. 1976. "Contaminacion en el Oceano Pacifico Sur-Oriental (Ecuador-Peru-Chile) Rev. Com. Perm." Pacifico Sur 5:3062.

Ayarza, W., S. Coello, N. Chalen de Padilla, P. Garces, L. Garcia, M.L. Garcia de Retamales, F. Ormaza, E. Perez, F. Pesantes y L. Solorzano. "Estudios Biogeoquimicos de una Seccion del Estero Salado." En prensa.

Chalen de Padilla, N. 1986. "Investigacion de mercurio en el sedimento del Estuario interior del Golfo de Guayaquil, incluyendo el rio Guayas, curos inferiores de los rios Daule y Babahoyo y el Estero Salado." Reporte II del Proyecto de Contaminacion del INP-CPPS-PNUMA. 1-5pp.

Diccionario Enciclopedico LAROUSSE. 1986. "Editado por Planeta Colombia Editorial, S.A." Fasciculo 42, tomo3. 793-813.

Empresa Municipal de Alcantarillado de Guayaquil (EMAG). 1979. "Datos fisicos y quimicos del Rio Guayas." Guayaquil: 1-130.

Empresa Municipal de Alcantarillado de Guayaquil (EMAG). 1980. "Resumen de estudios y programas de EMAG para la recuperacion del Estero Salado." Guayaquil: 1-20 pp.

Junta Nacional de Planificacion, Censo. 1982. "Datos poblacionales del Censo Nacional de 1982." Oficinas de los Censos Nacionales-INP, Quito, Ecuador

Ketchum, B.H. 1975. "Problems in aquatic ecosystems with special reference to heavy metal pollution of the marine environment." Ecological Toxicology Research (A.D. Mc.Intyre and C.F. Mills, eds). New York: Plenum Press 76-81.

Murray, S.D., A. Siripong and J. Santoro. 1973. "Circulationand Salinity distribution in the Rio Guayas Estuary, Ecuador;" Coastal Studies Institute, L.S.U. 1-23.

Pesantes, V.F. 1975. "Distribucion de las propiedades fisicas y quimicas del Golfo de Guayaquil." Rev. Com. Perm. Pacifico Sur, 3:21-37.

Rendon, M., N. Chalen de Padilla y E. Perez. 1983. "Estudio preliminar de los rios de la region del Litoral. Ecuador." Rev. Cienc. del Mar y Limnologia. Vol. 2, No. 1.179-221.

Solorzano, L. 1981. "Fuentes, niveles y efectos de la contaminacion marina en el Pacifico Sudeste." CPPS Serie Seminario y Estudios. 2, 173-241.

Solorzano, L. 1981. "Reporte I del Proyecto de Contaminacion." INP-CPPS-PNUMA. 1-17.

Solorzano, L. and G. Viteri. "Investigacion quimica de una seccion del Estero Salado. Revista de Ciencias del Mar y Limnologia del Instituto Nacional de Pesca." In press.

Valencia, Manuel. 1980. "Contaminacion quimica y bacteriana del rio Guayas para la Seccion Nacional del Instituto Panamericano de Geografia e Historia." Instituto Oceanografico de la Armada. Guayaquil, Ecuador: 1-24.

Valencia, M. 1986. "Analysis de la problematica de la contaminacion por hidrocarburos del petroleo y otros parametros quimicos del Estero del Muerto, Guayaquil 1985." Doc. Div. Quimica Oceanografica, INOCAR. Taller regional CPPS-PNUMA-CEPAL sobre evaluacion del Impacto ambiental producido por un desarrollo portuario, caso de estudio en Ecuador: Guayaquil. November 24-28, 1986. In press.

Vinueza, J. 1984. "Problemas Geoeconomicos y Politicos del Ecuador." 1-125.