Monitoring of Tropical Shallow-water Fish Communities around the EcoEléctrica Liquefied Natural Gas Import Terminal and Co-generation Plant in Guayanilla Bay, Puerto Rico

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ABSTRACT

One of the permit conditions for the operation of the EcoElectrica co-generation plant at Guayanilla Bay Puerto Rico requires a monitoring program to assess the long–term impacts of the Intake and Discharge waters of its cogeneration plant to marine communities surrounding the area. Among the principal goals of the EcoElectrica's biological monitoring program plan was to ensure that thermal effluents produced by the EcoElectrica Discharge Station are not creating an impact to marine organisms on nearby locations. Thus, the aim of this study is to determine if there is any environmental impact on the fish fauna near the Discharge Station by comparing fish species composition, diversity, abundance and health condition between the Intake and Discharge Stations of EcoElectrica cogeneration plant.

Fish communities from the Intake and Discharge Stations at the EcoElectrica LNG terminal pier were sampled in October/December 2001, February/ March 2002, September 2002, and February 2003. Reef fish assemblages were recorded using three complementary sampling methods: stationary point count method, fish traps, and beach seine net. Results from multivariate tests at different sampling periods showed significantly distinct fish communities among stations with little variation among sampling periods. The Discharge Station had a higher abundance of fish and number of species per point count than the Intake Station. The families Pomacentridae, Haemulidae, and Gerreidae accounted for most of all families observed on all methods combined within the Intake Station whereas in the Discharge Station the families Haemulidae, Lutjanidae, Chaetodontidae, and Gerreidae were the most abundant families recorded.

The dusky damselfish, *Stegastes fuscus*, the french grunt *Hamulon flavolineatum* and the silver jenny, *Eucinostomus gula* were among the most abundant species. No gross external morphological symptoms (e.g. presence of ulcers tumors color aberrations) were found on fish caught within stations. The preliminary results of this study indicate that apparently no potential

environmental hazards have been found to affect fish populations near the Discharge Station.

KEY WORDS: Fish assemblages, recruitment, disturbance

Monitoreo de las Comunidades de Peces Tropicales en Áreas Someras Alrededor de la Planta Ecoeléctrica de Licuado y del Terminal de la Importación del Gas Natural y de la Planta de la Cogeneración en la Bahía de Guayanilla, Puerto Rico

Una de las condiciones del permiso NPDES para operar el terminal de importación de gas natural licuado y la planta de cogeneración de EcoEléctrica, situada en la bahía de Guayanilla, Puerto Rico, requiere un programa de monitoreo biológico para evaluar los impactos a largo plazo de las aguas provenientes de las estaciones de la descarga (Discharge Station) y de la toma de agua (Intake Station) a las comunidades marinas cercanas al área. Uno de los objetivos principales del plan del programa de monitoreo biológico de EcoEléctrica es asegurar que los efluentes termales producidos por la zona de descarga no están creando un impacto adverso a los organismos marinos en las localidades cercanas a la planta. El propósito de este estudio es determinar si hay algún impacto ambiental en las comunidades de peces aledañas a la zona de la descarga, comparando la abundancia, diversidad, condición y composición de especies de peces de arrecife entre las estaciones de descarga y de toma de agua de EcoEléctrica.

Las comunidades de peces de las estaciones de la toma de agua y de la descarga de EcoEléctrica fueron monitoreadas en Octubre/Diciembre 2001, Febrero/Marzo 2002, Septiembre 2002 y Febrero 2003 mediante el uso de censos visuales de puntos estacionarios, nasas y chinchorro de arrastre. Los resultados de las pruebas multivariadas muestran que las comunidades de peces son significantemente distintas entre estaciones, pero con poca variación entre periodos de muestreo. La estación de descarga tuvo significantemente una mayor diversidad y abundancia de peces que la estación de la toma de agua. Las familias Pomacentridae,Gerreidae y Haemulidae componen la mayoría de las familias de peces observadas por todos los métodos de muestreo combinados en la estación de la toma de agua mientras que la comunidad de peces en la estación de la descarga está compuesta en su mayoría de las familias Haemulidae Lutjanidae y Chaetodontidae.

La damisela obscura *Stegastes fuscus*, el ronco amarillo *Haemulon flavolineatum* y la mojarra pequeña *Eucinostomus gula* fueron de las especies más abundantes. No se encontraron lesiones físicas (presencia de ulceras tumores, manchas etc.) en las especies capturadas en las zonas de estudio. Los resultados preliminares del estudio indican que aparentemente no se ha encontrado ningun problema ambiental que haya afectado las poblaciones de peces cerca de la descarga.

PALABRAS CLAVES: Las comunidades de peces, problema ambiental, terminal de importación de gas natural licuado

INTRODUCTION

During the last 30 years, Puerto Rico has experienced a rapid industrialization and subsequent increase in demand for electrical power (Lopez 1979). This demand has led to the construction of several fossil fuel and thermoelectric power plants, all of which were located in coastal areas and used seawater for associated cooling processes. During the cooling process, cooling water temperatures become elevated and the water is subsequently discharged back into the sea. However, concerns for the thermal impact of heated effluents on surrounding environments fostered several studies on the effects of thermal pollution on marine organisms (Lopez 1979). Extensive bibliographies concerning the effects of temperature on fish and other organisms have been published by Coutant (1971, 1974). However, these studies have largely concerned themselves with temperate or subtropical fish communities while few have examined tropical fish communities.

A benthic finfish-monitoring program was initiated on October 2001 as a complementary study to the EcoElectrica's Biological Monitoring Program Plan (BMPP). One of the permit conditions for the operation of the EcoElectrica co-generation plant requires a monitoring program to assess the long–term impacts of the Intake and Discharge waters of its cogeneration plant to marine communities surrounding the area. Among the principal goals of the study was to ensure that thermal effluents produced by the EcoElectrica Discharge Station (Sta.) are not creating an impact to marine organisms on nearby locations. Thus, the aim of this study is to determine if fish species composition, diversity, abundance and health condition differs between the Intake and Discharge Sta. of EcoElectrica cogeneration plant. The program will produce technical data that should prove very useful in designing and constructing other land development proposals. In addition, the program should, provide guidance in setting mitigation policy and designing mitigation requirements.

METHODS

Sampling

The fish communities around the Intake and Discharge Sta. (Figure 1) at the EcoElectrica LNG terminal pier were sampled using visual census, fish seine nets, and fish traps from October 2001 to December 2001, from February 2002 to March 2002, September 2002 and February 2003. For each station, a 5 x 5 m grid pattern was produced over a habitat map provided by Vicente & Associates. This numbered grid was the basis for selecting point count and trap survey sites.

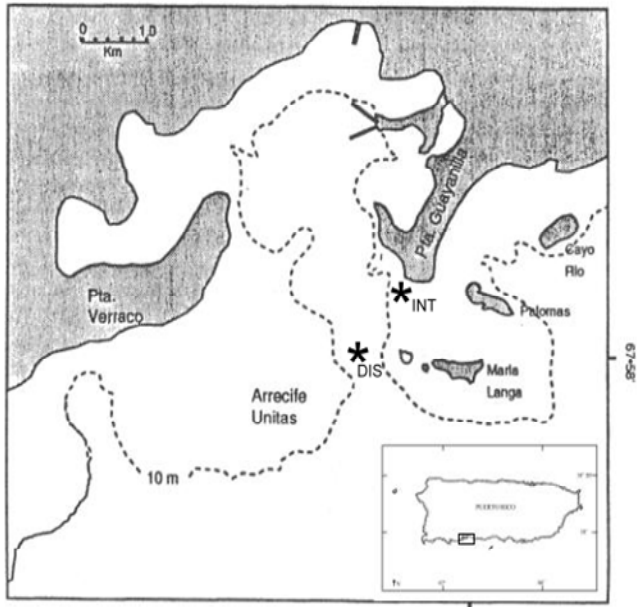

Figure 1. Location of Intake and Discharge Sta. in Guayanilla Bay, PR.

At each of the ten points randomly selected in each station, one diver using the Stationary Point Count Visual Census (Bohnsack and Bannerot 1986) recorded major habitat category type, fish species in that habitat category, number of fish present for each species, and size categories of fish observed to the nearest 5 cm. For each station, five fish traps hauling sites were also randomly selected. Fish traps used in this study were chevron-shape (91cm x 45.72 cm) with 3.8 cm bar mesh. Traps were unbaited and fished for 24 hours. Finally, three beach seine hauls were conducted at each station. The beach seine net measured 9.14 m x 1.2 m, had weights and floats attached. The net mesh size was 1.3 cm stretch mesh. All fish caught in the fish traps and in the seine net were identified, enumerated, and measured (SL) to the nearest millimeter, and released at the point of capture. The general conditions of the fish sampled were determined based on gross external morphological symptoms (i.e. presence of ulcers tumors, color aberrations).

Data from visual census were analyzed using cluster analyses and non-metric multi-dimensional scaling statistical techniques to describe the variation between species abundance and composition at each location and at each period. Abundance and presence/absence data from each location and at each period were analyzed using the Bray-Curtis similarity measure. One-way analyses of similarity (ANOSIM) tests were used to test the hypothesis that fish assemblages from the two locations and three periods were similar. Variations of abundance, number of species per census, diversity and evenness index between stations were examined by Mann-Whitney test (Sokal and Rohlf 1981).

RESULTS

Stationary Point Count Visual Census

Thirty visual census point counts were made at the Intake Sta. intercepts and at the Discharge Sta. intercepts (Figure 1). For the Intake Sta., 303 fishes were observed representing 20 species and 11 families (see Table 1a). The dusky damselfish *Stegastes fuscus* accounted for 72 % of fish observed. The most frequently observed fish at all Intake fish point counts was the dusky damselfish *Stegastes fuscus (*97 %). The families Pomacentridae and Haemulidae accounted for 78 % and 13 % of all families observed in the Intake Sta. fish.

Table 1a. Abundance of species per family recorded by visual census at Intake Station

Species	Family	Abundance	Percent	Frequency of occurrence
Stegastes fuscus	Pomacentridae	217	71.6	97.5
Haemulon flavolineatum	Haemulidae	22	7.3	7.5
Anisostremus virginicus	Haemulidae	12	4.0	10.0
Total Number of Fish		303		
Total Number of Species		20		

Only species with >4% of abundance.

For the Discharge Sta., (Table 1b) 287 fishes were observed representing 43 species and 18 families. The french grunt, *Haemulon flavolineatum* accounted for 15 % of fish observed. The most frequently observed fish in all Discharge fish point counts were the dusky damselfish, *Stegastes fuscus* (47 %). The families Haemulidae and Lutjanidae accounted for 23 % and 19 % of all families observed in the Discharge Sta.

Table 1b. Abundance of species per family recorded by visual census at Discharge Station

Species	Family	Abundance	Percent	Frequency of occurrence
Haemulon flavolineatum	Haemulidae	61	15.4	17.5
Stegastes fuscus	Pomacentridae	44	11.1	47.5
Lutjanus griseus	Lutjanidae	28	7.1	10.0
Thalassoma bifasciatum	Labridae	27	6.8	17.5
Lutjanus apodus	Lutjanidae	26	6.6	20.0
Acanthurus bahianus	Acanthuridae	20	5.1	20.0
Myripristis jacobus	Holocentridae	20	5.1	25
Stegastes partitus	Pomacentridae	18	4.5	30.0
Total Number of Fish		396		
Total Number of Species		43		

Only species with >4% of abundance.

The Discharge Sta. had higher number of fish and number of species per point count than the Intake Sta. (Figures 2 and 3). Species diversity (H') (Figure 4) and evenness (Figure 5) was also higher in the Discharge Sta. Mann-Whitney rank sum test showed that the mean number of species and the diversity index (H') were significantly higher ($p < 0.001$) in the Discharge Sta. Results of the percentage similarity of species composition and fish densities between stations indicated a low similarity in species composition (32 %). There were only 16 species shared between stations. Average linkages clustering of mean abundance of species among stations and sampling periods showed two distinct groups with little variation among sampling dates (Figure 6). This pattern was confirmed by multidimensional scaling analyses and produced a low Kruskall stress value 0.01 indicating that the data was a good fit for the model (Figure 7). Two-way ANOSIM test confirmed that differences among stations were significant ($p < 0.003$) but there were no differences among sampling periods ($p > 0.05$).

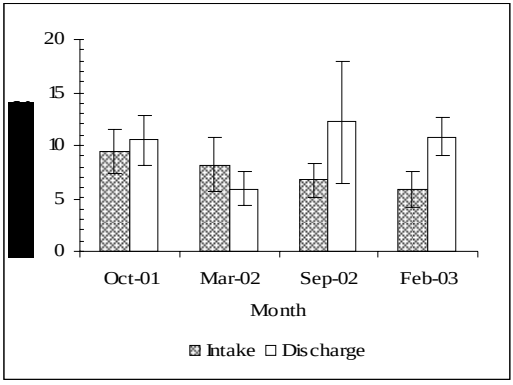

Figure 2. Mean number of fish per point count by site and sampling month.

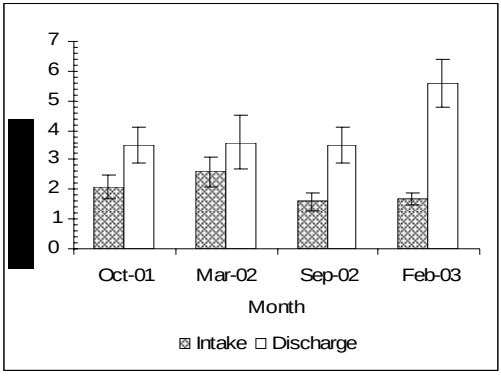

Figure 3. Mean number of species / point count by site and sampling month.

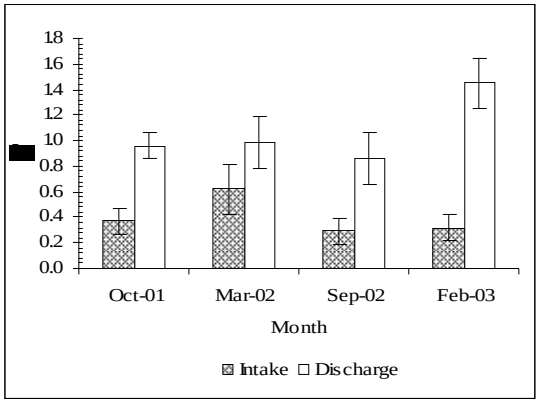

Figure 4. Mean Shannon-Weaver Diversity Index per point count by site and sampling month.

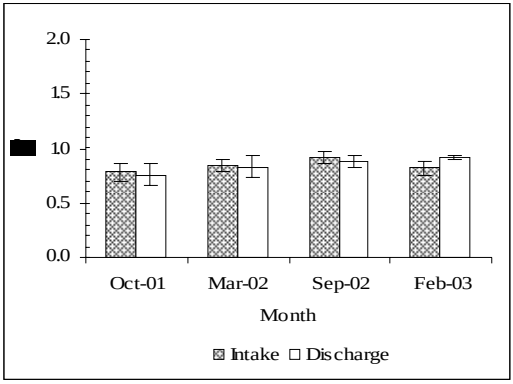

Figure 5. Mean Pielou Evenness Index per point count by site and sampling month.

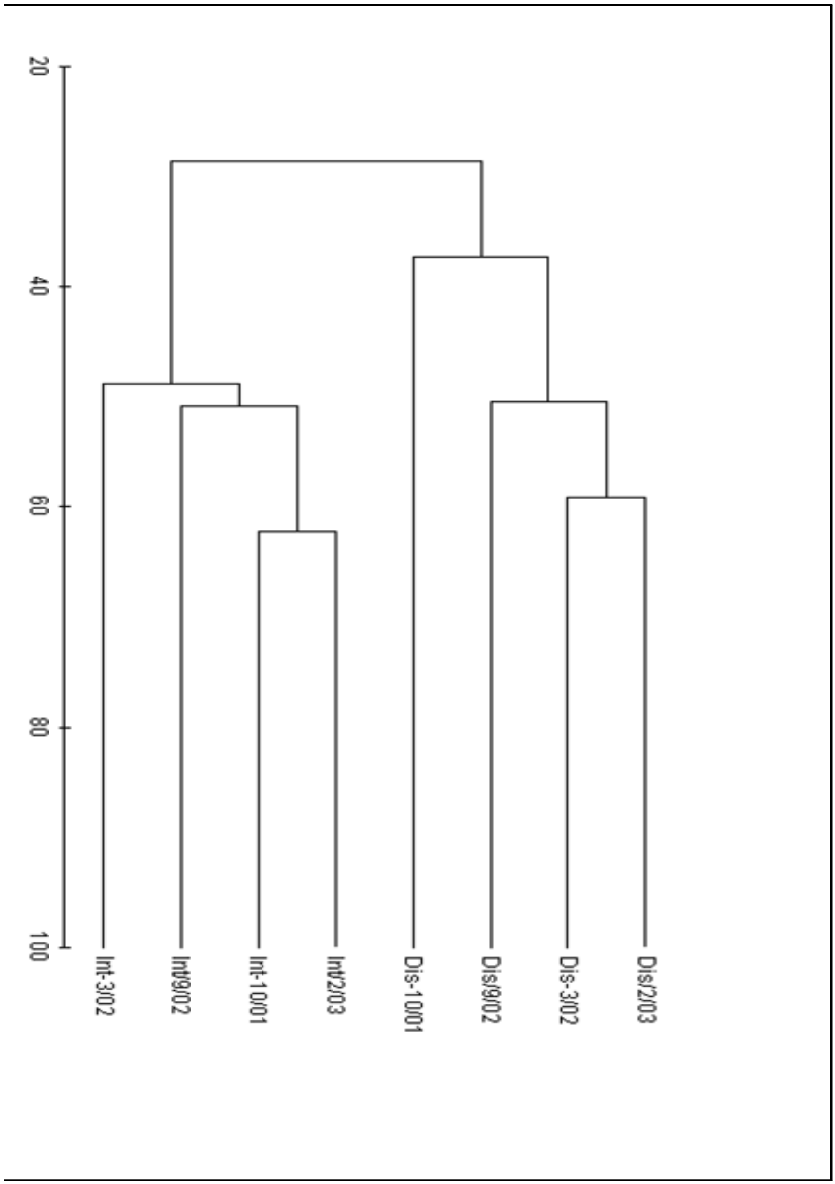

Figure 6. Cluster analysis of similarities of fish fauna among stations per date.

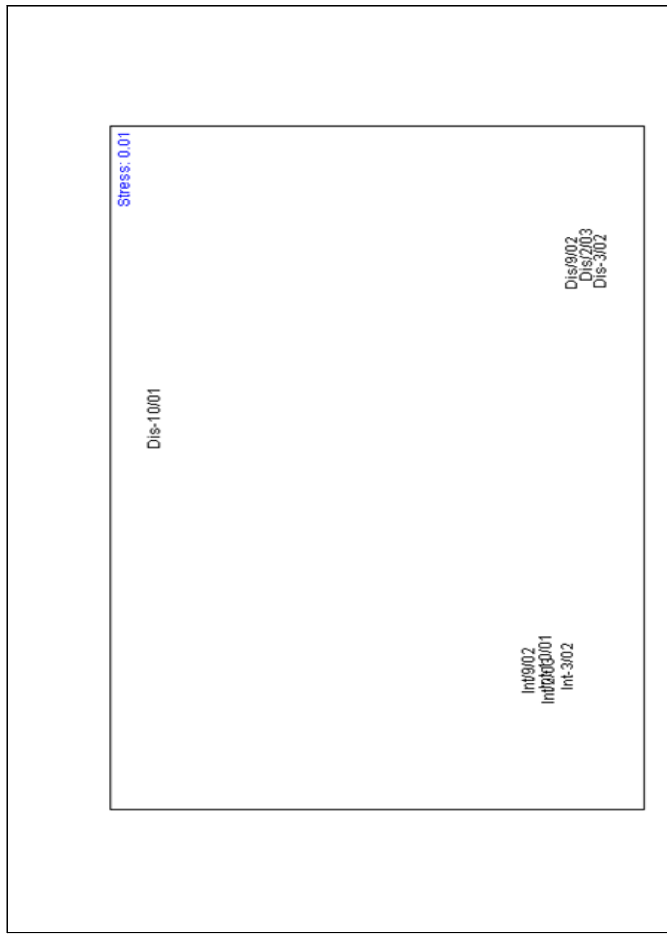

Figure 7. MDS ordination of fish fauna among station per date.

Length frequencies for economically important species within stations are shown in Figures 8, 9, 10, and 11. *Haemulon flavolineatum, H. plumieri, Ocyurus chrysurus* recruit (< 5cm TL) densities were highest on the Discharge Sta. while larger individuals (> 15cm TL) were rare on both stations during these sampling periods.

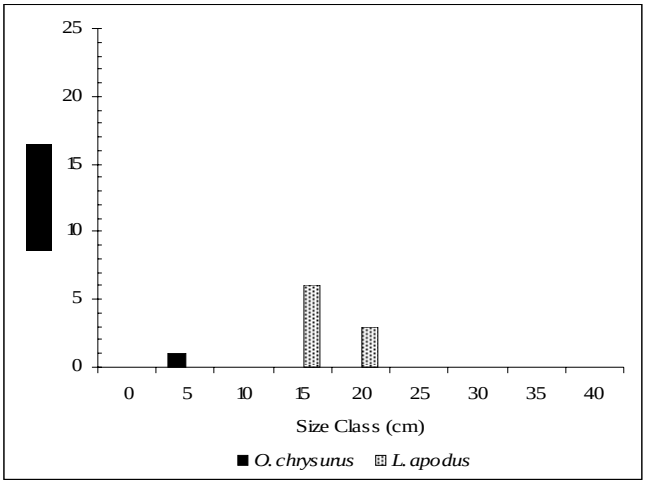

Figure 8. Size class distribution of lutjanid species observed on visual census in the Intake Station.

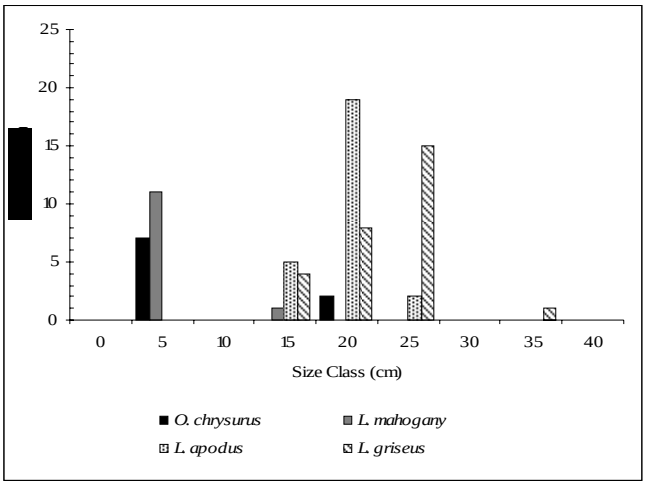

Figure 9. Size class distribution of lutjanid species observed on visual census in the Discharge Station.

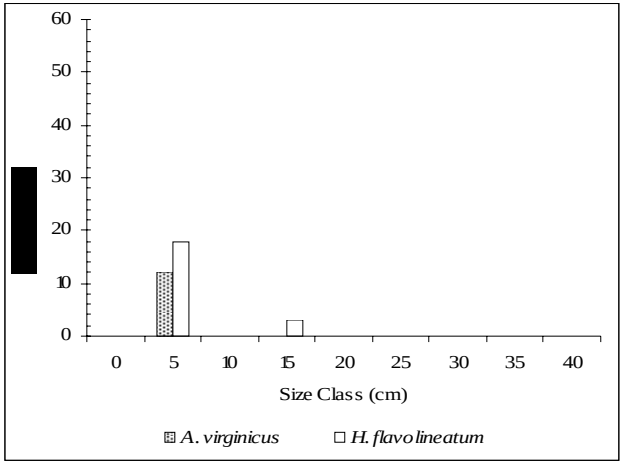

Figure 10. Size class distribution of haemulid species observed on visual census in the Intake Station

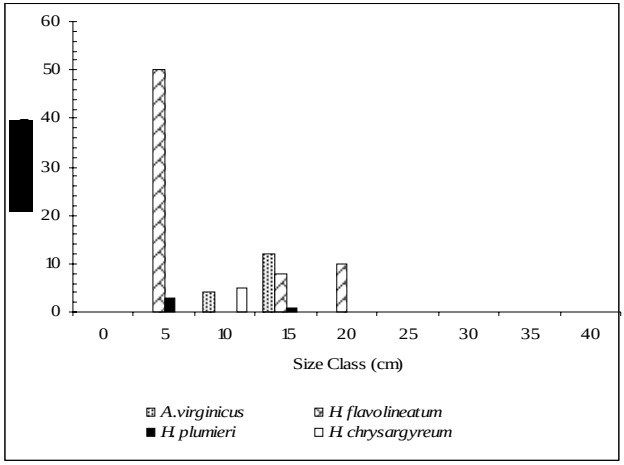

Figure 11. Size class distribution of haemulid species observed on visual census in the Discharge Station

Fish Traps

In the Intake Sta., the most abundant fish was the banded butterflyfish *Chaetodon striatus* (Table 2a). At the Discharge Sta. (Table 2b), the banded butterflyfish *Chaetodon striatus*, and the squirrelfish *Holocentrus adcencionis*, accounted for 52 % of the total catch. The Discharge Sta. had higher number of fish and species caught per trap-haul than the Intake Sta. (Figures 12 and 13). Mean standard lengths and mean fish sizes at sexual maturity are shown in Table 2a and 2b. Results suggest that in general, *Haemulon album*, *Sparisoma chrysopterum*, and *Lutjanus apod*us caught on traps were smaller than their mean size at sexual maturity. No gross external morphological symptoms (e.g. presence of ulcers tumors color aberrations) were found.

Table 2a. Abundance and mean standard lengths (mm) of species caught by fish trap hauls at Intake Sta.

Species	Abundance	Percent	Mean Length (SE)	Maturity	Reference
Chaetodon striatus	2	50.0	147.2(21.6)	132	Aiken (1983)
H. aurolineatum	1	25.0	215.0	130	Billings & Munro (1974)
H. plumieri	1	25.0	195.0	165-210	Roman Cordero (1991)
Total No. of Spp.	3				
Total No. of Fish	4				

Table 2b. Abundance and mean standard lengths (mm) of species caught by fish trap hauls at Discharge Sta.

Species	Abundance	Percent	Mean Length (SE)	Maturity	Reference
Chaetodon striatus	14	35.0	114.5(1.5)	132	Aiken (1983)
Holocentrus adcencionis	6	17.6	222.6(10.1)	145	Wyatt (1983)
Haemulon plumieri	5	14.7	215.0(5.3)	165-210	Roman Cordero (1991)
Chaetodon capistratus	4	11.8	103.5(5.3)	88.0	Aiken (1983)
Chaetodon ocellatus	3	8.8	133(8.3)	139	Aiken (1983)
Lutjanus apodus	3	8.8	223(11.1)	250	Thompson & Munro (1983)
Acanthurus bahianus	2	5.9	179.5(0.5)	111.0	Reeson (1983)
Sparisoma chrysopterum	2	5.9	215.0	235	Figuerola et al. (1998)
Total No. of Spp.	9				
Total No. of Fish	40				

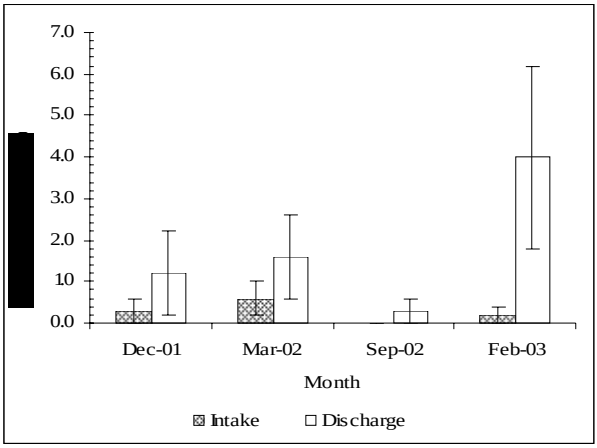

Figure 12. Mean number of fish caught by traps at Intake and Discharge Sta.

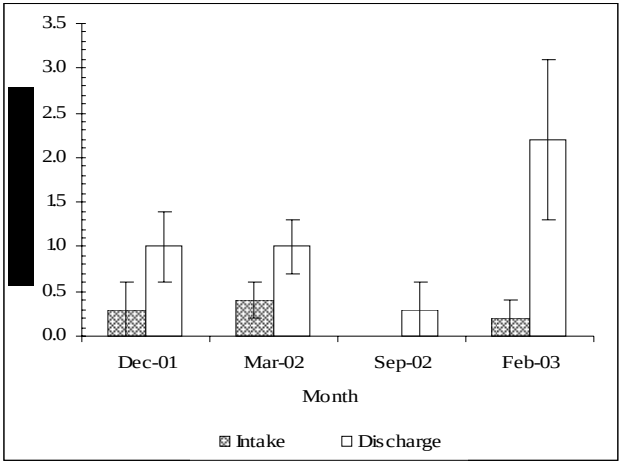

Figure 13. Mean number of species caught by traps at Intake and Discharge Sta.

Beach Seine

In the Punta Guayanilla Sta., the white sprat, *Harengula clupeola*, accounted for 19 % of seine catches (Table 3a). In the Maria Langa Sta. the silver jenny *Eucinostomus gula*, accounted for 43 % of the catches (Table 3b). Mean standard lengths and mean fish sizes at sexual maturity (length at which 50 % of the population become mature for the first time) are shown in Table 3a. The mean catch per seine haul for Punta Guayanilla within all sampling dates ranged from 5 to 23 fish per seine haul whereas for Maria Langa it ranged from 4.3 to 30.3 fish per seine haul (Figure 14). Mean number of species caught per seine haul for Punta Guayanilla within all sampling dates ranged from 1.3 to 6 species per seine haul whereas for Maria Langa it ranged from 2.3 to 2.6 species per seine haul (Figure 15). Results here suggest that, in general, most species of snappers, grunts as well as other fishes such as the permit *Trachinotus falcatus* and the doctorfish *Acanthurus chirurgus*, caught on seine nets were smaller than their mean size at sexual maturity. No gross external morphological symptoms were found.

Table 3a. Abundance of species per family by seine net-hauls at Pta. Guayanilla.

Species	Abundance	Percent	Mean Length (SE)	Maturity	Reference
Eucinostomus gula	30	18.99	71.3 (4.2)	N/A	N/A
Harengula clupeola	27	17.09	81 (1.6)	N/A	N/A
Trachinotus falcatus	19	12.03	40.5 (1.8)	486	Crabtree et al. (2002)
Anchoa lyolepis	18	11.39	54 (2.1)	N/A	N/A
Acanthurus bahianus	11	6.96	50.3 (2.4)	155	Reeson (1983)
Pseudupeneus maculatus	10	6.33	62.6 (1.7)	185	Munro (1983)
Total No. of Spp.	21				
Total No. of Fish	158				

Only species with >4% of abundance.

Table 3b. Abundance and mean standard lengths (mm) of species caught by seine net-hauls at Maria Langa.

Species	Abundance	Percent	Mean Length (SE)	Maturity	Reference
Haemulon flavolineatum	83	41.92	57.9 (1.0)	160	Billings & Munro (1974)
	46	23.23	60.6 (4.2)	N/A	N/A
Eucinostomus gula					
Ocyurus chrysurus	28	14.14	80.7 (2.3)	248	Figuerola et al (1998)
Haemulon sciurus	14	7.07	41.56 (2.75)	200	Billings & Munro (1974)
Total No. of Spp.	16				
Total No. of Fish	198				

Only species with >4% of abundance.

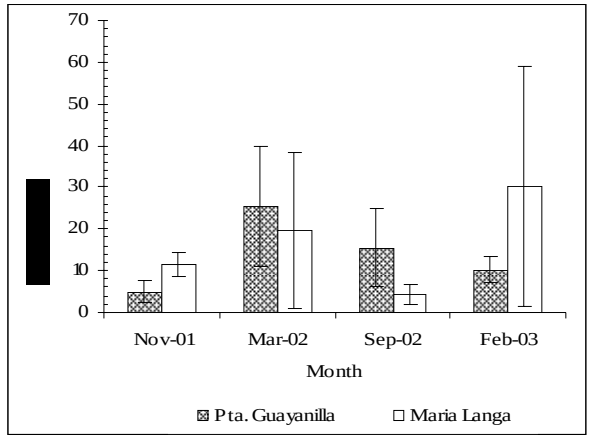

Figure 14. Mean number of fish caught by seine nets at Pta. Guayanilla and Maria Langa Sta.

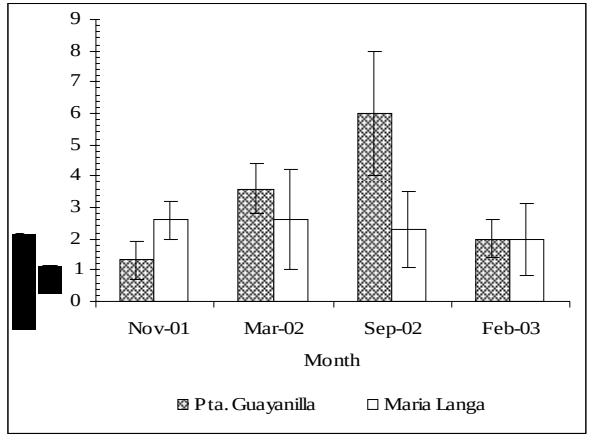

Figure 15. Mean number of fish caught by seine nets at Pta. Guayanilla and Maria Langa Sta.

DISCUSSION

Fish communities from the Intake and Discharge Stations around the EcoElectrica LNG Plant differed in community structure. Our results from the Stationary Point Counts Visual Census show that the fish fauna had a very low index of similarity (32 %). Both stations have few species in common. Almost all the fish species composition on the Intake Sta. were dominated by one or two species of damselfishes. This lowered the diversity and the evenness indexes for the Intake Sta. In contrast, species richness values on the Discharge Sta. doubled the ones on the Intake Sta. Furthermore, species composition on the Discharge Sta. was more evenly distributed between Lutjanids, Labrids, and Haemulids. Results from the multivariate tests at different sampling periods also showed distinct fish communities among stations with little variation among sampling periods.

The differences in fish among stations may be attributed to interacting factors such as increased sedimentation, abundance of food resources, and structural heterogeneity in habitats. Several studies have found significant positive correlations between living coral cover, coral species diversity, and abundance of reef fishes (Gladfelter and Gladfelter 1978, Galzin et al. 1994). Furthermore, other studies found that fish biomass increased with structural heterogeneity of reef substratum (Carpenter et al. 1981). Previous benthic studies at the Discharge and the Intake Sta. found higher vertical relief, species diversity and live coral cover in the discharge than in the Intake Station (Castro and Garcia 1996). It is likely that the higher structure complexity in the Discharge Station offers more shelter to many reef fish near the discharge area.

Light availability may be an important component of feeding success, thus influencing on the habitat quality for nearshore fishes (McFarland 1991). Previous work on the effects of turbidity (with associated changes in light intensity) indicated that reductions in prey contrast, foraging efficiency, reactive distance, and visual range, reduce feeding success (McFarland 1991, Duffy- Anderson and Able 1999). Poor light conditions in areas under heavy sedimentation may have similar effects especially if fishes rely on vision to acquire food. The use of vision as the principal means of capturing prey is common and available evidence suggest that planktivorous fishes, such as grunts, are visual feeders (McFarland 1991). Data on sedimentation levels on the Intake and Discharge Sta. suggest that in general the Intake Sta. receives more heavy sedimentation than the Discharge Sta. (Vicente & Associates unpublished data). Therefore, light conditions may give a possible explanation on fish distribution among areas. However, while it seems likely that visually feeding fishes would be unable to feed in darkened under pier environments around heavy sedimentation, we cannot exclude the possibility that there was less food available on the Intake Sta. It may be that juvenile fishes around the Intake are able to successfully consume prey in darkened habitats but that food availability was too low to support good growth rates. Evidence of higher potential prey food availability around the Discharge Sta. comes from the higher abundance of zooplankton around this area, thus supporting complex trophic food webs on this station (Garcia 2002).

Although availability of food may be a factor in habitat selection, evidence

suggests that predator avoidance may be important for juvenile fishes. One interesting finding was that the recruit phase of certain economically important reef fishes, such as the yellowtail snapper *Ocyurus chrysurus* and mahogany snapper *Lutjanus mahogany*, were found on algal patches, small patch reefs, and limited rubble areas surrounded by mud habitats in the Discharge Sta.; recruits of the french grunt *Haemulon flavolineatum* were found on isolated small patch reefs near the Intake Sta. It appears that these species use these nearshore sites as nursery areas as a refuge from predators in spite of the influence of natural gas plant effluents.

Comparisons of our field data with previous studies are complicated by differences in sampling gear, precise location of collection, and historical changes in habitat. In general, however, it appears that many of the same fishes have continued to dominate Guayanilla Bay nearshore habitats over the last 25 to 30 years. For example, Martin and Patus (1973), and Kimmel (1979) reported mojarras (Gerreidae), jacks (Carangidae), and the sea bream *Archosargus rhomboidalis* (Sparidae) as very common in their gill net collections. About 20 years later during the environmental studies preceding the construction and operation of a liquid natural gas thermoelectric power plant in Guayanilla Bay, these same fish families predominated at all seine collections whereas butterflyfish, grunts and the sea bream *A. rhomboidalis* dominated the fishtrap catches (EcoElectrica 1999). Finally, comparing our visual census results with previous fish censuses at the Intake and Discharge Sta. during the preoperational phase of the LNG thermoelectric power plant (Castro and Garcia 1996) we found similar fish faunas at both stations with minor differences in their species relative abundance.

The three methods used to sample nearshore habitats yield satisfactorily although somewhat different results due to biases inherent in each method. Fish traps tended to under represent certain species (such as *Stegastes fuscus*) that apparently avoided traps or were small enough to pass through the trap mesh and not to be caught. However, traps allowed accurate standard length measurements of the most abundant species. Baitfish such as the silver jenny, and small snooks were more abundant in seine net catches than in transects and fish traps. However, seines were limited to areas adjacent to the shore without rocky and hard bottom substrates. The visual census method can provide a list of species in an area. It is also possible to collect some length frequency information based on visual estimates of fish size. However, visual estimates are not as accurate as actually measuring each fish. Nevertheless, by utilizing these three methods at the same time, a more complete view of the finfish community can be achieved than from any one method alone. Results here also document the importance of these nearshore habitats for juvenile fishes. Most fish sampled by beach seine nets were smaller in size then their mean size at sexual maturity (for beach seine catches see Tables 3a, 3b) suggesting that seagrass beds around Punta Guayanilla and Maria Langa have an important nursery value for many reef fish inhabitating these nearshore areas.

This report is a product of a preliminary baseline study initiated to determine our state-of-knowledge about the impacts of Discharge/Intake effluents of EcoElectrica LNG Plant. It has demonstrated that there are some statistically significant differences between fish assemblages at Intake and

Discharge Sta. at the community level. The collection of data to explain the mechanisms for increased abundance of fish at the Discharge Sta. was beyond the scope of this study, however, we suggest that a number of mechanisms including reduced siltation, increased food abundance, and structural complexity, may be responsible for differences in fish fauna among stations. Identifying the level of current knowledge, areas of uncertainty, and future research needs could provide a more consistent review and evaluation of development proposals, and decrease potential impacts to threatened marine communities if the information is utilized in the course of permit review and assimilated into regulations.

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